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MAJOR WINTER AND NONWINTER FLOODS IN SELECTED BASINS IN NEW YORK AND PENNSYLVANIA

BY

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ABSTRACT

The scientific design of flood-control works is based on an evaluation of the hydrologic factors basic to flood events, particularly how rainfall and snow runoff, soil conditions, and channel influences can combine to produce greater or lesser floods. For this purpose an analysis of the pertinent hydrologic data is needed. The methods of analysis adopted should conform as closely as possible to those already in use and must be adapted to the quality of the available information.

Maximum floods in 8 basins in New York and Pennsylvania during the winter and nonwinter months were studied, a total of 21 floods.

The most outstanding winter flood of record in the North Atlantic region was that of March 1936. Rainfall plus snow melt in the basins studied ranged between 3.04 and 6.87 inches, and associated volumes of direct runoff from 1.88 to 5.63 inches. Winter floods have a common characteristic in their relation to freezing temperature. The antecedent periods, representing a period of snow accumulation and frost penetration, are below freezing, and the flood itself is contemporaneous with a period of above-freezing temperatures, usually associated with rain, during which the previously accumulated snow is melted. A second common characteristic of major winter floods is their tendency to be associated with widespread causal meteorologic conditions. There was a more complete conversion of rainfall and snow melt into runoff during the winter storms studied than during the wettest nonwinter flood. Snow melt during winter floods ranged from 0.04 to 0.07 inch per degree-day above 32° F.

The depth of mean areal rainfall produced by the nonwinter storms studied ranged from 3.05 to 4.96 inches. The maximum 24-hour quantity at single stations was 14 inches, which was measured during the storm of July 1935 in New York. The volume of direct runoff ranged between 1.39 and 3.41 inches. The portion of rainfall that was converted into runoff varied in accordance with the rate of antecedent base flow, expressed in second-feet per square mile, and emphasized the influence of antecedent conditions.

The average volume of direct runoff during winter floods was 4.24 inches, and the average during nonwinter floods was 2.44 inches. The latter, however, were more concentrated as to time, tending to compensate for large volume of runoff in winter, so that the crest rates of direct runoff averaged 0.056 inches per hour during the winter and 0.051 inches during the nonwinter period.

INTRODUCTION

UTILITY OF FLOOD-CONTROL DATA

In recent years nearly all parts of the country have experienced record-breaking floods that have caused much damage and suffering, yet this damage has not discouraged the continued occupancy and use of lands so situated as to be almost predestined to recurrence of flooding. Instead, demands have been made that the floods be controlled, so that damages in the future can be avoided or at least mitigated. The scientific design of public works for the control of floods is based on the study and evaluation of the hydrologic factors basic to floods, such as rate and amount of rainfall and snow melt, soil conditions, and channel influences. The first step in such an evaluation is the marshaling of all available climatologic and stream-flow data in an orderly array, convenient and accessible for thorough investigation. The United States Geological Survey in several recent reports on floods has presented comprehensive data in considerable detail. These essential data are not, however, in a form suitable for direct application to flood-control problems. For such purposes there is need for the computation of basic rates, volumes, and interrelations and for explanation of the processes involved in the correlation of rainfall and runoff. This report is directed to that end; it presents results of computations and analyses of basic data in publications and files of the Geological Survey and the Weather Bureau.

A further objective is the presentation of tested procedure for the analysis of flood data. The section on Methods of analysis outlines techniques that are of wide utility. The application of computed results to practical problems is dependent to a large extent on the method by which they were derived, as results derived by one procedure are not necessarily comparable with those derived by another. The advantages of uniform procedure are many. This report, therefore, explains in more detail than heretofore the methods used by the Geological Survey for evaluating the basic rates and volumes needed in considering water problems. The computations are presented in form suitable for use in other similar studies.

SCOPE OF THE PRESENT REPORT

The work presented in this report had its inception in a project for "Surveys of floods and droughts" for which funds were provided by the Federal Emergency Administration of Public Works. The compilation of basic data on major winter and nonwinter floods according to outlines prepared by the senior author was assigned to the district offices of the Geological Survey at Albany, N. Y., and Harrisburg, Pa. The work at Albany was performed by H. W. Fear, assisted by L. A. Wiard, G. E. Cook, D. Myers, and J. McGrath, under the direction of A. W. Harrington, district engineer; and that at Harrisburg by Geo. Weber, assisted by M. I. Rorabaugh and T. H. Hake, under the direction of J. W. Mangan, district engineer. The coordination of the work and the preparation of this report were conducted by W. B. Langbein, division of water utilization, under the direction of R. W. Davenport, chief.

Early hydrologic analysis in the United States was directed largely toward the study of the annual yield of rivers and the relations between this yield and such climatic factors as annual precipitation and temperature. General conclusions reached by such men as Rafter, Vermeule, and others who carried on these early studies still find wide application and utility.

As the demands for water for power, irrigation, and municipal use increased, the irregularly varying rates of flow of rivers became of greater economic consequence, and it was desirable to ascertain the nature of stream flow during short periods of time. Thus, Mead[1] in 1908 and Meyer[2] in 1915 discussed certain principles underlying the relations between monthly climatic conditions and associated runoff and showed that such analysis required the maintenance of a distinction between surface and ground-water runoff and the study of their relation to soil moisture.

Analysis of the March 1913 flood in Ohio by the Miami Conservancy District and the subsequent design and construction of a system of detention reservoirs in the Miami River Basin served to emphasize that much of the yield of many streams occurs as flood flow associated with identifiable heavy rainfall. Intensive studies of the nature of stream flow in times of flood for use in the design of protective or control works are now directed, among other things, toward answering the question of how much runoff will result from a given storm and what will be its time distribution.

The conclusion has generally been reached that stream flow is the integrated result of the many separate but generally identifiable meteorologic factors and the indirectly related but important soil, geologic, and biologic factors. Search is in progress for methods for evaluating the runoff in a given area in terms of the associated edaphic and physiographic conditions. Records of stream flow have been collected by the Geological Survey at some places for over 40 years. These include many floods, representing many different combinations of meteorologic and hydrologic conditions. Such records, in conjunction with the climatologic records of the Weather Bureau, provide a basis for solution of the rainfall-runoff equation.

The present report is essentially a presentation of basic hydrologic conditions underlying major winter and nonwinter floods of record in selected areas in New York and Pennsylvania, followed by derivation of certain fundamental factors. In its preparation search has been made for all existent information on rainfall, snow cover, and temperature

[1] Mead, D. W., Water-power engineering, pp. 111–197, New York, McGraw Publishing Co., 1908.

[2] Meyer, A. F., Computing runoff from rainfall and other physical data: Am. Soc. Civil Eng. Trans., vol. 79, pp. 1056–1224, 1915.

not generally available in regularly published reports of the Weather Bureau or the Geological Survey. Data heretofore published are not included in this report, except where deemed necessary for completeness or for explanation. Acknowledgment is made to the Weather Bureau for furnishing results of measurements and observations of rainfall and temperature, and to other persons and agencies, as indicated in the appropriate places, who have furnished helpful information.

Besides these basic data, the report presents mean areal storm precipitation; mean areal precipitation during short periods of time; snow cover and snow melt; mean areal temperature; volume of direct and groundwater runoff; and retention, infiltration index, and time interval between the occurrence of rainfall plus snow melt and the associated direct runoff, as derived by computation. Methods of deriving these results are explained in the following section.

METHODS OF ANALYSIS

The analytical methods followed in this report are, in general, those already described in other flood reports of the Geological Survey. They conform as closely as practicable to standard procedures already in use and described in other published works. Some departures seemed to be required by the quality of the available information and the time available for its compilation. In order that the adequacy of the computed results may be evaluated, the methods actually employed are described below.

Rainfall.—Thorough search was made for rainfall records in published reports and files of the Weather Bureau and other organizations. All data so compiled for areas in or near the respective basins were used to compute the mean areal precipitation.

The mean areal precipitation during the storms studied was computed by the Thiessen[3] method, the lines being drawn by the use of perpendicular bisectors, as described by Horton.[4] This method assumes that the precipitation at any point in the basin during a given interval is the same as that recorded at the nearest rain gage. The ratio between the area so assigned to a given rain gage and the total basin area is its Thiessen weight. The recorded total storm precipitation at each rain gage was multiplied by its Thiessen weight. The sum of the products equals the mean areal precipitation. In order to show the areal distribution of total storm rainfall, isohyetal maps also have been prepared. In general, these maps have not been used for determining mean areal precipitation, tests having demonstrated that in the areas under consideration the Thiessen method was adequate for the purpose. The Thiessen weights were convenient

[3] Thiessen, A. H., Precipitation average for large areas: Monthly Weather Rev., Vol. 39, p. 1083, July 1911.

[4] Horton, R. E., Rational study of rainfall data: Eng. News-Record, pp. 211–213, Aug. 2, 1917.

also for use in determining mean areal precipitation during selected portions of the storm, as described below.

Besides the total amount of storm rainfall, information as to its time distribution is of interest, as well, particularly with respect to computation of infiltration rates and detailed time comparisons of rainfall and runoff. For this purpose the mean areal precipitation was computed for specified intervals of time throughout the storm period. The length of the interval was chosen on the basis of the accuracy of the available records and the size of the particular basin. Thus, 6-hour intervals were chosen for the Sacandaga River Basin above Hope, N. Y., with an area of 491 square miles, and 24-hour intervals for the basin of West Branch of Susquehanna River above Williamsport, Pa., area 5,682 square miles. The longest interval used was 24 hours.

Most of the rain gages available for this purpose were read only once daily, either in the morning or in the evening, but two or more recording gages also were available within the storm areas and within or near the basins studied.

The records of hourly rainfall at the automatic rain gages were used to establish a rainfall distribution pattern for the given basin. Allowance was made for the estimated time of travel of the storm between the point of observation and the basin or the group of rain gages. Time of travel was estimated by comparison of the times of rainfall at the available automatic rain gages and inspection of the weather map. Measurements of the daily catch at each nonautomatic rain gage were then distributed over the 24-hour period preceding the time of observation so as to conform to the pattern established by the automatic rain gages.

In this manner the precipitation between selected clock hours was computed at each rain gage, regardless of the time of reading. These computed amounts are shown in the tables accompanying the account of each flood. The contemporaneous amounts at the several rain gages were averaged in accordance with the Thiessen method to obtain the mean areal precipitation during the respective periods of time, and the mean areal amounts are given in the tables.

Snow cover.—Extensive search was made for information regarding snowfall and antecedent snow cover. With respect to the flood of March 1936, this phase was, in general, satisfactorily covered by the data given in Geological Survey Water-Supply Papers 798, 799, and 800[5]. Additional information is included in this report. The available data on snow cover, however, were inadequate to account for the behavior of streams. These data, therefore, were supplemented by an approximation of the water content of the initial snow cover, obtained by subtracting the

[5] The floods of March 1936, pt. 1, New England rivers; pt. 2, Hudson River to Susquehanna River region; pt. 3, Potomac, James, and upper Ohio Rivers: U. S. Geol. Survey Water-Supply Papers 798, 799, and 800, 1937.

runoff from the precipitation during that part of the winter or subfreezing season preceding the flood and considering the difference as an indication of the maximum amount of water on the ground in the form of snow just before the thaw. There were indications that some snow remained in parts of the basins after the flood period. Estimates of water content of this snow were made by computing the difference between direct runoff and precipitation during a thawing period immediately following the flood, and using the results, where positive, as an indication of the minimum contribution to runoff during the subsequent thawing period from snow left on the ground after the main flood period. These differences between total precipitation and observed runoff during the flood periods described gave information that was useful in supplementing and interpreting measurements of snow cover and in making estimates of the probable snow cover preceding the flood and that remaining on the ground after the flood and from these to compute the amount of snow melt contributed to the flood. The computations for each flood are described in appropriate detail as a part of the discussion of that flood.

Direct runoff.—Computations of the amount of direct runoff during the several floods were made by the methods described in other flood reports of the Geological Survey, particularly Water-Supply Paper 867.[6] In brief, the method used is as follows: Hydrographs of discharge during the flood period, as well as during a substantial period preceding and following the flood were plotted, as shown, for example, on figure 8, page 20, which applies to Sacandaga River near Hope, N. Y., during the flood of March 1936.

Fluctuations in stream flow suggest two classifications as to time: direct and base runoff. Direct runoff is that runoff which is directly associated as to time with causative rainfall or melting of snow. It forms the bulk of the hydrograph and is responsible for the destructive flood flows. Base runoff on the other hand is represented by the sustained or fair-weather flow, and in the basins studied in this report, may be considered as composed largely of ground-water effluent. Direct runoff in these basins may be considered to include superficial wash or sheet flow and such shallow perched-water effluent—wet-weather seeps and springs—that reaches the streams during and promptly after the occurrence of rainfall or the melting of snow.

The total area under the hydrograph on figure 8 represents the runoff that reached the streams from both surface and ground-water sources resulting from the storms of March 1936 plus the flow that would have been maintained if there had been no increment of supply after March 10. On figure 8 a graph has been drawn representing the estimated discharge

[6] Hurricane floods of September 1938: U. S. Geol. Survey Water-Supply Paper 867, pp. 421–423, 1940.

from ground-water sources. The area enclosed within the hydrograph and above the estimated base-flow line is equivalent to the direct runoff associated with the flood. This area has been further subdivided, where necessary to determine the portion of the direct runoff attributable to discrete or separate periods of precipitation. The method of making this subdivision is also shown on figure 8. Table 8, page 25, shows the steps used in computing the volume of direct runoff of Sacandaga River near Hope, N. Y., associated with the precipitation period, March 8-14, 1936.

The mean river discharge during successive equal intervals of time are tabulated through the flood rise, following the estimated recession shown on figure 8, for March 16-19, when the normal recession from the first flood rise was interrupted by succeeding rainfall and snow melt. The estimated base runoff (including any direct runoff remaining from a preceding flood that had not drained from the channel system before the beginning of the flood in question) as read from figure 8 is then tabulated for corresponding intervals and subtracted from the mean discharge previously listed. The differences represent the direct runoff during the selected intervals. The sum of the differences, converted into inches over the drainage area, represents the total direct runoff associated with the indicated flood.

Ground-water runoff and recharge.—The approximate amount of ground-water runoff and net recharge to ground water may also be computed from the hydrograph and the estimated graph of base flow. The method of computation used is as follows: Again referring to figure 8 showing a hydrograph of discharge of Sacandaga River near Hope, N. Y., during March 1936, it was estimated that as a result of the climatologic events of March 9-21, ground-water discharge rose from 300 second-feet on March 9 to about 1,750 second-feet on March 28. During this time the total discharge from ground-water sources was estimated as 22,500 second-foot-days. Studies of hydrographs of Sacandaga River during fair-weather periods, when river flow is assumed to consist entirely of ground-water discharge, indicate that the normal rate of depletion of this discharge is as shown on figure 1. This depletion hydrograph was then integrated to determine the volume of flow remaining in the ground-water body that is available for runoff in relation to the rate of ground-water discharge. The ground-water storage curve, as the result of the integration is known, is shown on figure 2. Since the depletion curve shown on figure 1 does not extend below 0.09 second-foot per square mile, the volumes of storage shown in figure 2 refer to the volume of 0.09 second-foot per square mile as an origin.[7] As previously stated, the estimated ground-water flow between March 9-28 was about 22,500 second-foot-days. On the last-mentioned day there was an esti-

[7] Report of cooperative hydrologic investigations: Pennsylvania Dept. Forests and Water, pp. 59–64, processed report, August 1939.

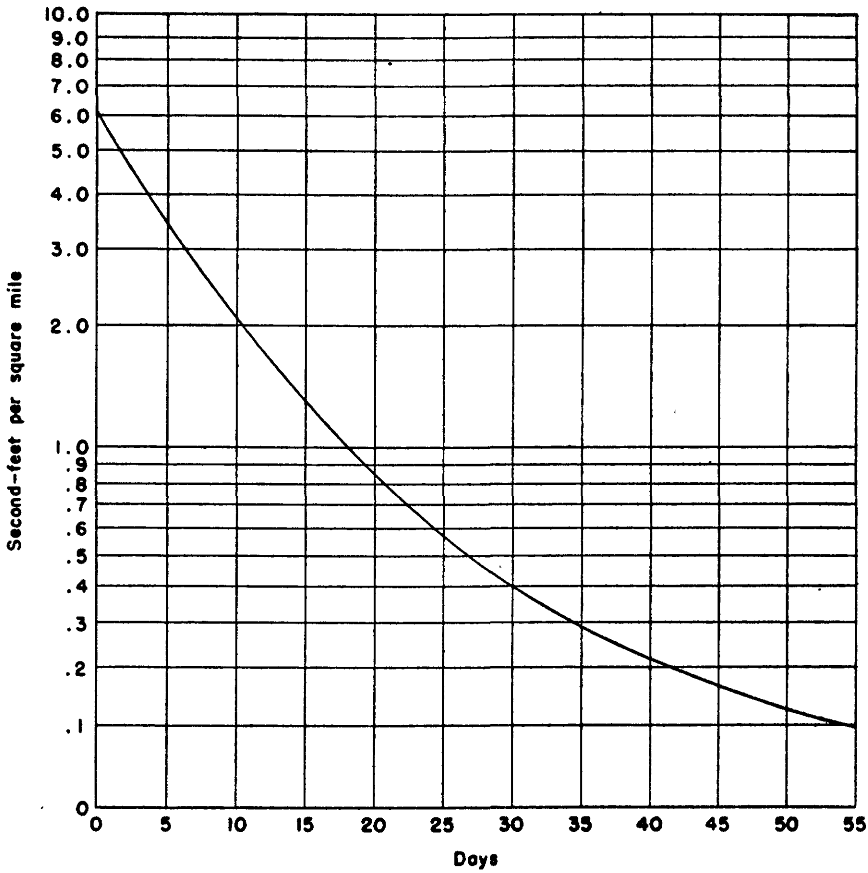

FIGURE 1.—Average ground-water depletion curve, Sacandaga River near Hope, N. Y.

mated rate of discharge of 1,750 second-feet (3.56 second-feet per square mile), which, according to figure 2, indicated that the volume in storage to be yielded to the streams regardless of whether there is any additional rainfall or not was 20,000 second-foot-days. The total flow and potential flow was therefore 42,500 second-foot-days. But on March 9 there was a flow of 300 second-feet (0.61 second-foot per square mile), which indicated, according to figure 2, that 4,000 second-foot-days would be delivered as stream flow after that date in addition to that produced by subsequent events; accordingly, of the total of 42,500 second-foot-days, 4,000 must be subtracted as being attributable to events prior to March 9. The ground-water runoff produced solely by the events of March 8-21 is therefore 37,500 second-foot-days or 2.8 inches over the 491 square miles.

Separate determinations of the ground-water runoff associated with each of the two separate flood rises between March 9-22, 1936, were not made due to the uncertainties of determining the ground-water storage at the end of the first storm while the streams continued in flood.

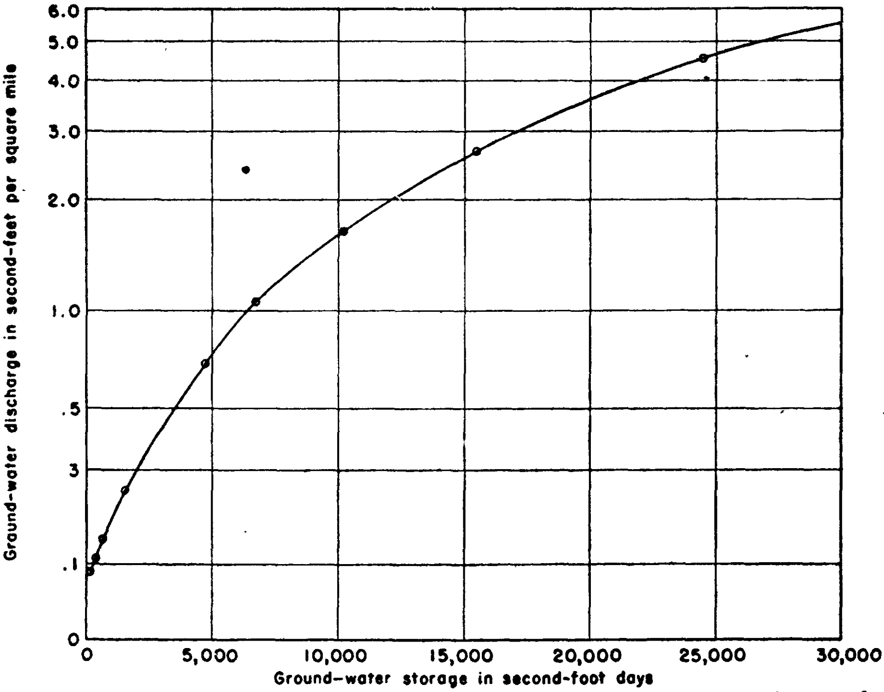

FIGURE 2.—Relation between the rate of ground-water discharge and volume of available ground-water storage, Sacandaga River near Hope, N. Y.

Lag interval.—Recent writers[8] have pointed out that the time difference between supply and the associated direct runoff bears a general relation to the shape of the unit hydrographs. This time difference, called the lag interval, is defined herein as the time interval between the center of mass of supply—rain and snow melt—effective in producing runoff and the center of mass of direct runoff. As described by Langbein,[9] the lag interval as so defined not only is inversely proportional to the ordinates of maximum discharge hydrographs of equal volume but also is equal to the slope of the discharge-storage curve applicable to the basin, and so provides two useful measures.

Computations have been made of the lag interval for each of the floods studied in this report, and comparisons have been made between the lag intervals thus computed for different floods in a given basin, and in a section. Rates of flood discharge comparisons are made between concentration of rainfall and runoff during the floods studied in the several basins in terms of their lag intervals.

[8] Hoyt, W. G., and others, Studies of rainfall and runoff in the United States: Geol. Survey Water-Supply Paper 772, pp. 209–210, 1936. Snyder, F. F., Synthetic unit graphs: Am. Geophys. Union Trans., 19th Ann. Meeting, pp. 447–454, 1938. Langbein, W. B., Some channel-storage and unit-hydrograph studies: Am. Geophys. Union Trans. 21st Ann. Meeting, pp. 620–627, 1940.

[9] Langbein, W. B., op. cit.

In the computation of the lag interval as defined above, the graph of effective supply is not generally available, particularly with respect to snow melt. Estimates based on available meteorologic data are therefore necessary. The basins studied in this report are large and have relatively long lag intervals and therefore errors of a few hours in the estimates of the time of net supply are not important. However, the volume of net supply, being equal to the volume of direct runoff, is known.

Table 9, on page 25, illustrates the method employed to determine the time of center of mass of net supply as applied to the flood of March 8-14, 1936, on the Sacandaga River near Hope, N. Y. The second column lists the mean areal precipitation as taken from table 3 during the 12-hour periods indicated in the first column. The third column lists the estimated snow melt during the indicated periods. These estimates were made by distributing the known total snow-melt during the flood period proportionately on the basis of the thawing temperatures during the selected periods. The total snow melting, determined by the difference between the initial and final snow cover, as previously discussed, plus the water content of any additional snowfall during the storm, as indicated by Weather Bureau observations, and supplemented by reference to temperature readings, was divided by the total degree-days above 32° F. during the storm period. The ratio so derived was multiplied by the degree-days above 32° F. during each interval, and the product reported as the melting during that interval. During some of the intervals, the indicated snowfall exceeded the snow melt so computed. Such conditions are indicated by a minus sign in column 3.

The total supply, as reported in the fourth column of table 9, is the sum of the precipitation plus the snow melt. This supply was then diminished by amounts sufficient to account for the infiltration or other retention of water by the ground, so that the total net supply equaled the measured direct runoff. The total retention (total supply minus total direct runoff) was distributed among the several periods as follows: One-half of the retention of 1.16 inches in the example used for illustration was distributed uniformly with respect to time among the several periods and the remaining portion was distributed proportionately on the basis of amount of total supply. These amounts of retention were then readjusted so that the retention during any interval did not exceed the supply during that interval and so that net supply did not begin until the stream flow at the gaging station had begun to rise. In general, the amount by which the net supply was reduced at the beginning of the storm period to allow for the latter adjustment was added to the net supply in the latter part of the storm period, since the portion of supply converted into runoff, other things being the same, tends to increase as the storm continues. The seventh column of table 9 lists the time lever (time from origin) of the indicated masses of net supply from the selected origin, 6 p.m. of March 8; and the last (eighth) column lists the product of the separate amounts of net supply and their corresponding time levers. The quotient of the sums of the last column and the sixth column (net supply) equals the time corresponding to the center of mass of volume of supply with reference to the origin. The final computations are made below the table, with appropriate explanation.

Infiltration index.—The progress of precipitation into infiltration and runoff is a complex process not clearly apparent. It is quite likely that some of the precipitation becomes runoff at the surface of the ground, and that as the remaining infiltrated water encounters more impervious soil horizons, additional volumes are induced to flow laterally through the upper stratum of greater permeability by relatively short routes to the stream channels, and so also become part of the direct runoff. There may be a wide zone of gradation between distinct surface runoff and distinct ground-water runoff. In the absence of definite information as to the relative amounts of the surface and subsurface flow that combine to make up the flood hydrograph, it is convenient to classify their sum as direct runoff. Similarly, it is convenient to use a single measure of the retentive capacity of the ground regardless of the differing rates of infiltration or percolation existing at different places in the basin or at different soil horizons.

It might be conceived that the rates at which water can pass below the ground surface and through lower strata are limited by the given soil, vegetal, and moisture conditions and that the supply in excess of these rates becomes direct runoff. Consequently a measure of these resultant rates might be defined by the average rate of rainfall such that the volume of rainfall at greater rates equals the total direct runoff and the volume at lesser rates equals the volume of retention. This average rate has been termed the infiltration index and does not necessarily refer to the rate of infiltration at the ground surface or the rate of percolation of water through subsurface strata.

The infiltration index for a given storm was determined by the following method: Tabulations were prepared of the volume of rainfall that fell in excess of trial infiltration indices of 0.01, 0.05, 0.10, 0.20, and 0.30 inch per hour at each available recording rain gage. Graphs were then prepared showing the computed rainfall excess for each gage against the total storm rainfall at the particular gage, in terms of the infiltration index, and lines of equal infiltration index were drawn so as to conform to the plotted points. Figure 3 shows the results of these computations for the East Branch of Delaware River Basin above Fishs Eddy, N. Y., applicable to the storm of August 20-25, 1933. Four recording rain gages were available as follows: Scranton, Pa., Binghamton, N. Y., Kingston, N. Y., and Voorheesville, N. Y. Although none of these were in the basin, they were well enough arranged around it to indicate the storm characteristics. The points plot close enough to the trend lines shown to justify the assumption that the rainfall distribution at any point in the area is related to the total precipitation. The maximum precipitation at any of the recording rain gages was 4.72 inches at Scranton, Pa., and since the mean precipitation over the basin is 6.22 inches extrapolation was needed. The precipitation in the basin during the storm varied between a maximum and a minimum of about 12.0 inches and 4.4 inches, respectively, but the curves of equal infiltration index within this range were considered as straight lines and the mean areal precipitation as adequately indicating the mean infiltration index. Figure 3 was based on rainfall records at individual rainfall stations and the rainfall distribution indicated for the mean areal precipitation

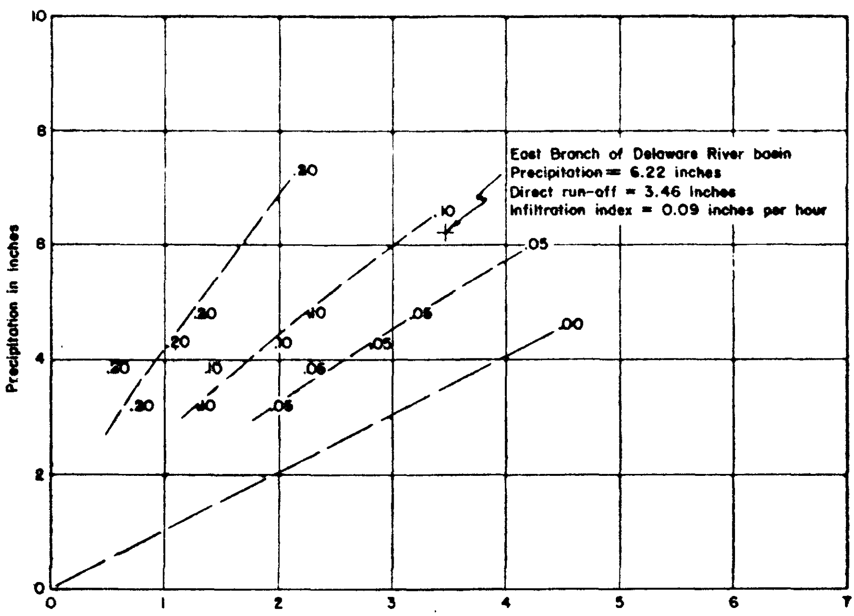

FIGURE 3.—Graph showing relation between rainfall and rainfall excess, in terms of infiltration index, at recording rain gage near East Branch of Delaware River basin, storm of August 20–25, 1933.

is that for a station having precipitation equal to the mean areal precipitation and does not indicate the distribution of rainfall of a graph showing contemporaneous hourly values of mean areal precipitation. However, the generation of runoff is considered a local event and is therefore determined by the local or unit-area rainfall distribution rather than by the mean of the contemporaneous rainfall over a whole basin, although the resultant discharge at the gaging station is the integration of the runoff as generated from the several localized areas composing the basin. On this basis, the mean areal infiltration index, according to figure 3, corresponding to mean areal precipitation of 6.22 inches and direct runoff of 3.46 inches, is 0.09 inch per hour. The value of the index so computed is intended to serve as a measure of the hydrologic conditions affecting the generation of runoff from rainfall that is independent of the effects of amount and time distribution of rainfall. The index does not necessarily represent a rate of infiltration or retention that existed for any appreciable length of time or over any appreciable area.

Difficulties with respect to rate and distribution of snow melt are such as to prohibit the computation of infiltration index during winter storms.

WINTER FLOODS

The most outstanding winter flood of record in the North Atlantic region occurred as a result of the widespread extratropical storm and thaw of March 9-22, 1936. Records of river discharge and flood heights of the March 1936 floods, as well as studies of the basic hydrologic conditions, are presented in a series of three volumes published by the Geological Survey.[10] In all but one of the basins studied in this report, the March 1936 flood was the greatest winter flood of record. The present study has for its purpose a more detailed inquiry into the hydrologic background and features of these events than was given in the earlier reports and a comparison of these winter floods with the major nonwinter floods in the same basins, which have not hitherto been undertaken.

Major winter floods have a common characteristic in their relation to freezing temperatures. Thus, each of the floods summarized in table 1 was preceded by a 30-day period during which the average temperature was well below freezing, but each was contemporaneously associated with temperatures markedly above freezing. At the termination of the subfreezing periods the ground surface was covered with an accumulated snow cover and the ground was frozen to a depth dependent on the opportunity for frost penetration, which may be influenced by the presence of snow cover. Rising temperature releases this snow mantle at a rate dependent on the intensity and duration of the thawing temperature, and the snow melt almost invariably finds its absorption by the ground impaired by the presence of frost. The snow melt contributed to each of the major floods listed in table 1 was augmented by contemporaneous rainfall which, as during the March 1936 flood, generally exceeded the amount of antecedent snow cover.

Possibly a second common characteristic of major winter floods is their tendency to be associated with the widespread extent of the causal meteorological conditions. Thus, during March 1936, record-breaking floods occurred as a result of two widespread storms, each of which

[10] The floods of March 1936, pt. 1, 2, and 3: U. S. Geol. Survey Water-Supply Papers 798, 799, and 800, 1937.

extended over nearly all of New England, New York, Pennsylvania, and New Jersey, and parts of Maryland and Virginia. The storms occurred over ground covered by snow, which was melted by a general rise in temperature contemporaneous with the storm rainfall. Winter floods, unless caused by an ice jam are definitely not a local condition, because they depend largely on temperature, which tends to be uniform over wide areas. Another common characteristic, as illustrated by the data in table 1, is the tendency of floods throughout the area covered by this report to occur most frequently during March and April, the spring "break-up" months, which mark the termination of the winter's accumulation of snow and the beginning of the thaw. The season's accumulation of snow represents the integration of many different snowstorms of various intensity and areal extent; it therefore tends to be uniform over wide areas, but is affected by local altitude and exposure. The flood-producing potentialities of the snow cover, however, depend not only upon its depth but also upon how rapidly and to what extent the temperature rises above the freezing point. During the outstanding floods listed herein, the rise was abrupt and very marked.

Figure 19 included in the section on nonwinter floods, presents the results of a study of the relation between rainfall plus snow melt and the associated total runoff for the various storms listed in tables 1 and 63. The winter floods lay close to the line indicating 100 percent runoff, and generally there was a more complete conversion of supply into runoff than took place during the wettest nonwinter flood studied.

Table 1 summarizes selected hydrologic data with respect to the winter floods. In the following pages there is presented more detailed information concerning each of the major winter floods in the basins studied, with appropriate discussion. The volumes of snow cover, rainfall, and runoff for the floods of March 1936 given in this report, being based on more detailed analysis, may differ in some respects from those given for the same basins in Water-Supply Papers 798 and 799.

FLOODS OF MARCH 1936

SACANDAGA RIVER NEAR HOPE, N. Y.

During the winter of 1935-36 there were prolonged periods of subfreezing temperature with heavy snowfall. Records of the depth of snow on the ground at points in and near this basin just prior to the beginning of the storm of March 1936 were probably the most adequate of any section of the State, since there were a number of well-distributed stations at which snow surveys were made regularly. These stations were generally at elevations between 800 and 2,000 feet in second-growth woodlands, typical of a great part of this mountainous drainage basin. Measurements made early in February showed an average snow depth

TABLE 1.—*Summary of rainfall and runoff data for winter floods*

Drainage basin	Drainage area (sq. mi.)	Precipitation period	Total precipitation (inches)	Water content of snow at beginning of flood period (inches)	Estimated net snow melt during flood (inches)	Approximate duration of measurable rainfall (hours)	Maximum precipitation in 24 hours (inches)	Maximum rate of discharge		Volume of direct runoff (inches)	Difference between precipitation plus snow melt and direct runoff (inches)	Approximate ground-water runoff (inches)	Temperature during storm period (°F)	Temperature during 30-day antecedent period (°F)	Precipitation during 30-day antecedent period (inches)	Ratio of maximum 24-hour runoff to total direct runoff (percent)	Time interval from center of mass of net supply to—	
								Second-feet	Inches per hour								Center of mass of direct runoff (hours)	Time of peak discharge (hours)
Sacandaga River near Hope, N. Y.	491	Mar. 8–14, 1936	1.86	7.35	1.18	54	[a] 1.23	10,200	0.032	1.88	1.16	2.8	35	16	2.30	35	52	25
		Mar. 15–22, 1936	3.37	6.17	2.07	96	[b] 1.30	23,900	.075	5.23	.21		39	---	---	27	45	2
East Branch Delaware River at Fishs Eddy, N. Y.	783	Mar. 9–15, 1936	1.87	4.7	2.55	42	[c] 3.00	33,900	.066	3.08	1.34	2.1	40	20	1.20	43	34	14
		Mar. 15–21, 1936	4.36	2.15	2.15	96	[d] 2.86	46,000	.091	5.45	1.06		46	---	---	32	36	12
Chemung River at Chemung, N. Y.	2,530	Mar. 9–14, 1936	1.89	2.85	2.05	45	[e] 1.70	92,300	.058	2.39	1.55	1.80	37	22	1.13	49	33	32
		Mar. 15–21, 1936	4.71	.8	.0	80	[f] 2.25	83,000	.051	4.00	.71		36	---	---	27	30	21
Susquehanna River at Wilkes-Barre, Pa.	9,960	Mar. 9–15, 1936	1.51	3.0	2.1	---	[e] 1.70	186,000	.029	2.83	.78	1.25	39	22	1.50	23	67	40
		Mar. 16–21, 1936	4.15	.9	.45	---	[f] 2.25	232,000	.036	4.38	.22		40	23	1.85	17	70	43
Susquehanna River at Harrisburg, Pa.	24,100	Mar. 9–14, 1936	1.74	3.2	2.0	---	---	436,000	.028	2.92	.82	1.5	40	23	1.70	20	86	39
		Mar. 16–21, 1936	4.69	1.2	.8	---	---	740,000	.048	4.53	.96		41	28	2.27	21	83	32
West Branch Susquehanna River at Williamsport, Pa.	5,682	Mar. 9–15, 1936	1.99	3.8	2.3	39	[g] 2.10	165,000	.045	3.10	1.19	2.0	39	24	1.30	32	49	27
		Mar. 16–21, 1936	6.02	1.5	.85	55	[h] 4.47	264,000	.072	5.63	1.24		39	29	2.50	27	50	19
Genesee River at St. Helena, N. Y.	1,017	Mar. 10–14, 1920	.88	3.0	2.2	24	[i] .80	39,600	.060	2.08	1.00	.80	36	19	1.10	55	32	26

[a] Recorded at Speculator, N. Y., at 8 a.m. March 12, for preceding 24 hours.
[b] Recorded at Speculator, N. Y., at about 8 a.m. March 18, for preceding 24 hours.
[c] Recorded at Slide Mountain, N. Y., at 8 a.m. March 12, for preceding 24 hours.
[d] Recorded at Slide Mountain, N. Y., at 8 a.m. March 18, for preceding 24 hours.
[e] Recorded at Burdett, N. Y., at 8 a.m. March 12, for preceding 24 hours.
[f] Recorded at Elmira, N. Y., at midnight March 17, for preceding 24 hours.
[g] Recorded at Weikert, Pa., in the afternoon of March 11, for preceding 24 hours.
[h] Recorded at Kylertown, Pa., at midnight March 17, for preceding 24 hours.
[i] Recorded at Bolivar, N. Y., during late afternoon of March 12, for preceding 24 hours.

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of at least 21 inches, with a water content of about 4.3 inches. By March 1, the snow cover had increased to an average of approximately 27 inches, with a water content of over 6 inches, and by March 8, as indicated in table 2, to nearly 30 inches, with an average water content of about 7.35 inches. The distribution of the snow cover on March 8 is shown in figure 4. The snow blanket on that day represented potential runoff of considerable magnitude.

Measurements made during the storm are given in table 2 and shown graphically on figures 5 and 6. The measurements indicate a water content of 6.17 inches over the basin on March 15, or a net melting of 1.18 inches during the first storm period. Measurements of snow cover in the period March 22-25 indicate a mean areal depth of 4.1 inches water content, or a total snow runoff during the storm of 3.25 inches.

Precipitation during the storm at 12-hour intervals at five rainfall stations in and near the basin is given in table 3. Precipitation occurred on every day, the greatest amount being on March 17. The total storm precipitation over the basin, shown graphically on figure 7, was 5.23 inches, of which 1.86 inches fell during the first period, March 8-14, and 3.37 inches fell during the second period, March 15-22.

Daily mean precipitation is given in table 4, with daily maximum, minimum, and average temperatures. The temperature averaged 4° F.

TABLE 2.—*Observations of snow cover, Sacandaga River near Hope, N. Y., March 1936*

["T" indicates a trace; "P" indicates patches of snow]

Place of observation (New York)	Altitude (feet)	Prior to storm period [a]		March 15–17		March 22–25	
		Snow depth (inches)	Water content (inches)	Snow depth (inches)	Water content (inches)	Snow depth (inches)	Water content (inches)
Arietta	1,700	----	----	----	----	[b] 12	[b] 3.2
Barton Mines	----	27.0	[c] 6.21	12.0	3.0	----	----
Batchellerville	800	----	----	----	----	T	----
Benson Center	----	23.0	5.75	18.5	4.65	1.0	[d] .25
Broadalbin	800	----	----	----	----	P	----
Edinburg Hill	1,100	25.8	5.84	18.5	5.36	T	----
Elm Lake	1,700	34.2	8.43	23.3	6.67	15	5.4
Griffin	1,300	25.3	5.80	13.0	4.67	----	----
Harrisburg Lake	----	25.0	[d] 6.25	14.0	[d] 3.5	10	2.5
Hoffmeister	1,860	38.0	[d] 9.5	31.0	[d] 7.75	25	[d] 6.2
Hope	900	25.2	5.27	14.3	5.50	8.7	3.4
Hope Falls	----	----	----	14.3	3.6	----	----
Indian Lake	1,650	34.0	[d] 8.5	27.0	[d] 6.75	15	[d] 3.75
Lake Pleasant	1,800	33.3	8.20	24.0	8.20	12	4.8
Morgan Mills	1,700	33.3	8.17	23.7	7.50	----	----
Peters Corners	1,500	----	----	----	----	[e] 10	[e] .34
Piseco	1,700	31.2	7.77	28.8	9.50	17	6.2
Sacandaga Park	800	24.0	5.23	16.0	4.90	----	----
Saratoga County Sanatorium	----	34.5	[d] 8.6	19.5	4.9	3	[d] .75
Speculator	----	----	----	12.0	[d] 3.0	----	----
Wells	1,000	25.8	5.40	14.3	5.80	----	----
West Day	800	25.0	6.28	17.9	5.58	----	----

[a] Based on snow surveys between Feb. 28 and Mar. 2, 1936, and other measurements prior to March 9.
[b] 80 percent of ground covered.
[c] Computed from observations at nearby points.
[d] On basis of estimated 25 percent water density.
[e] 10 percent of ground covered.

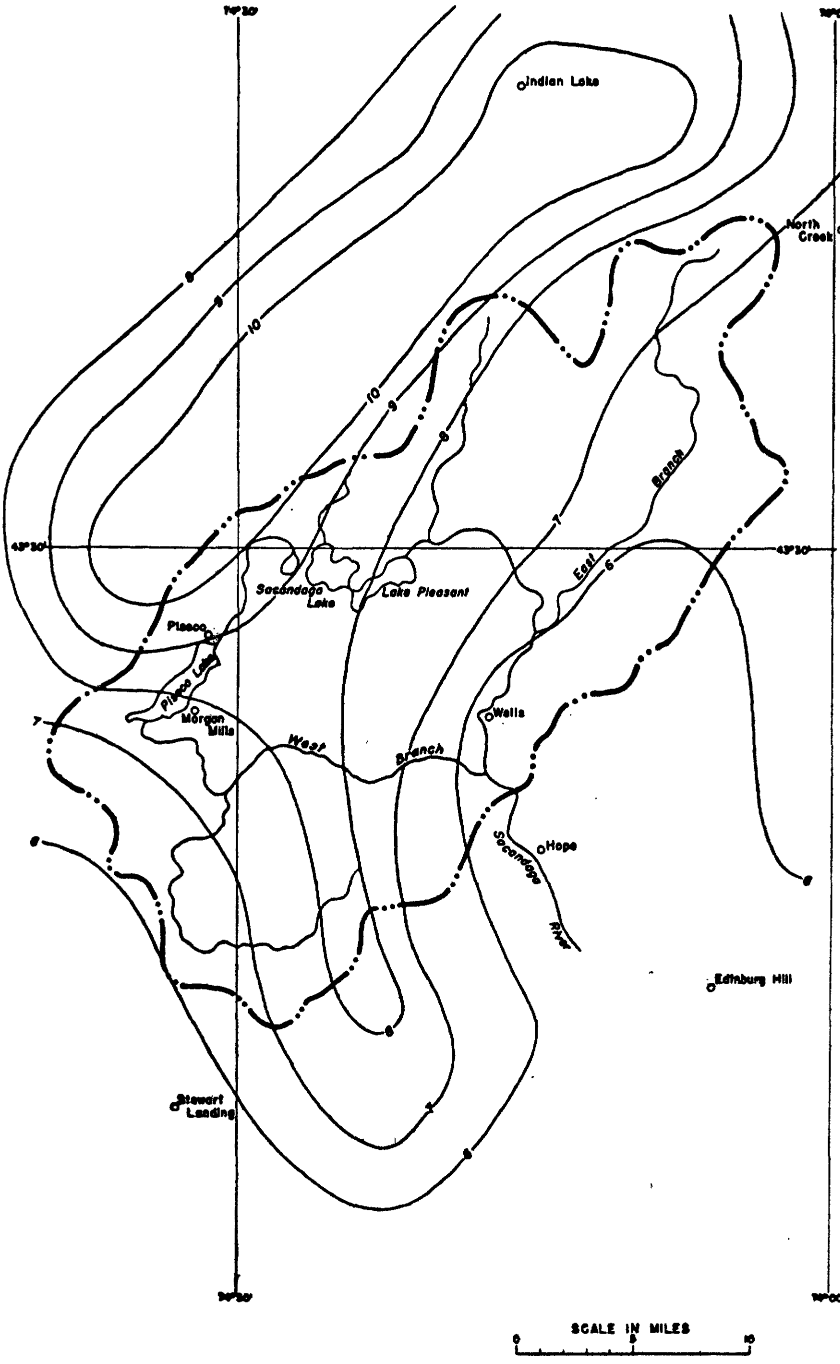

FIGURE 4.—Map of Sacandaga River basin above Hope, N. Y., showing depth, in inches, of water content of snow on the ground, March 8, 1936.

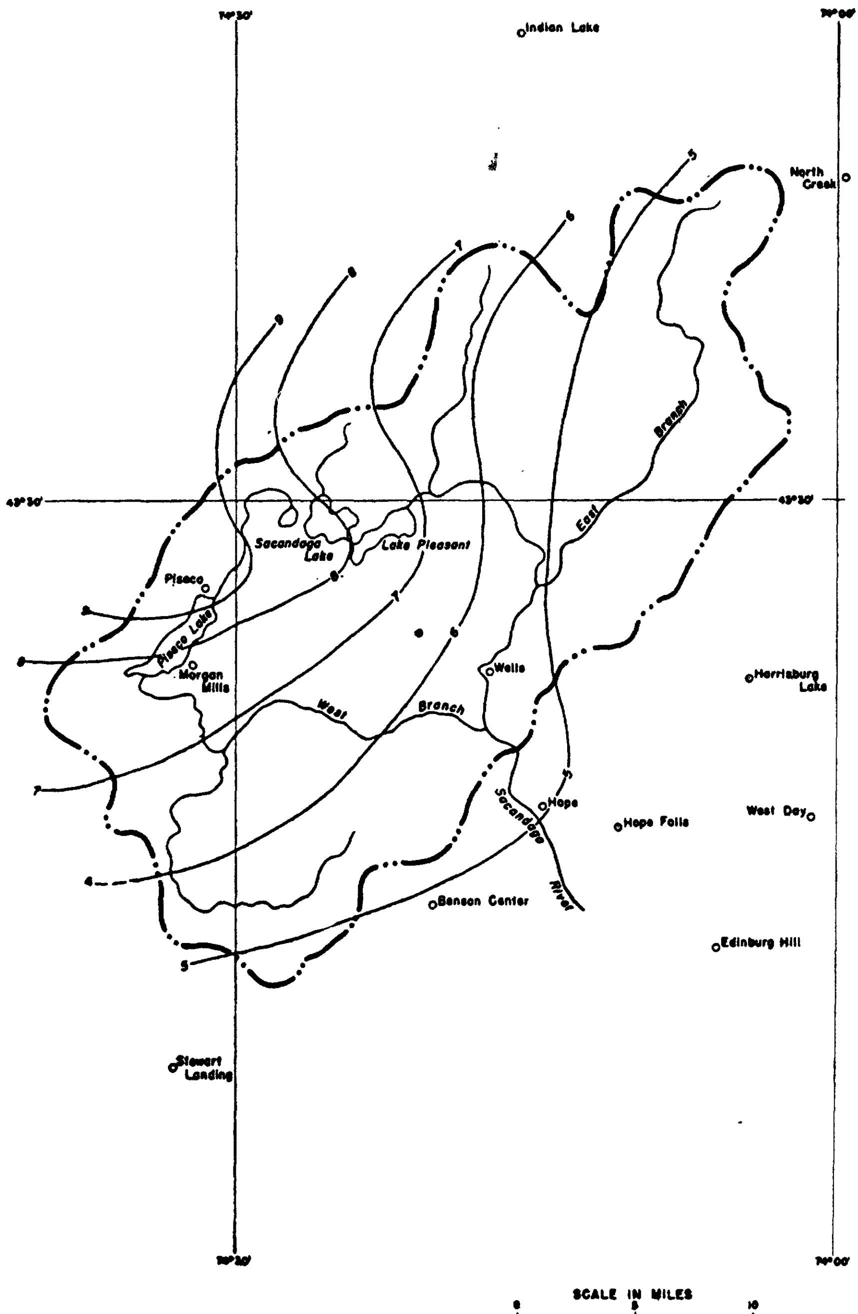

FIGURE 5.—Map of Sacandaga River basin showing depth, in inches, of water content of snow on the ground, March 15–16, 1936.

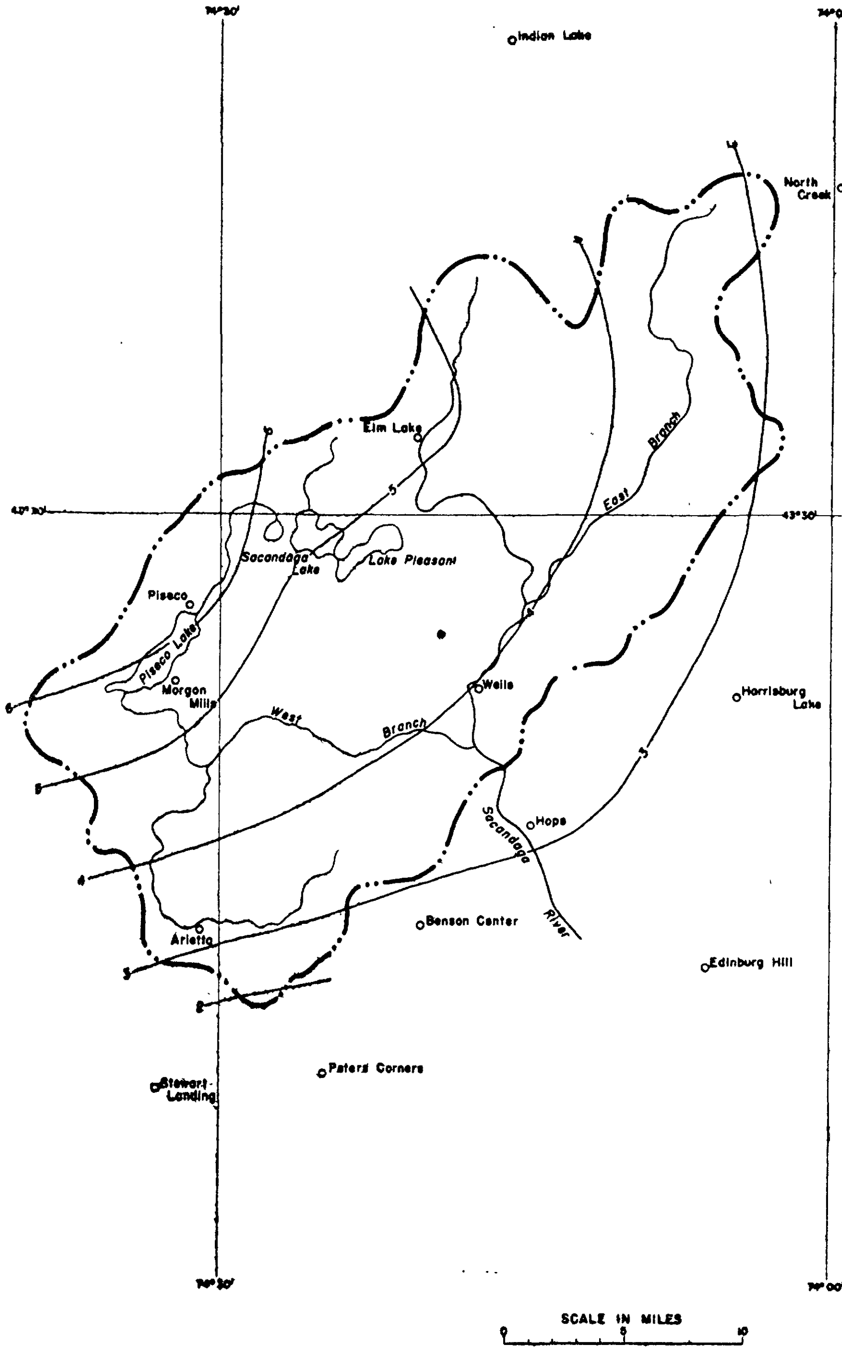

FIGURE 6.—Map of Sacandaga River basin showing depth, in inches, of water content of snow on the ground, March 22, 1936.

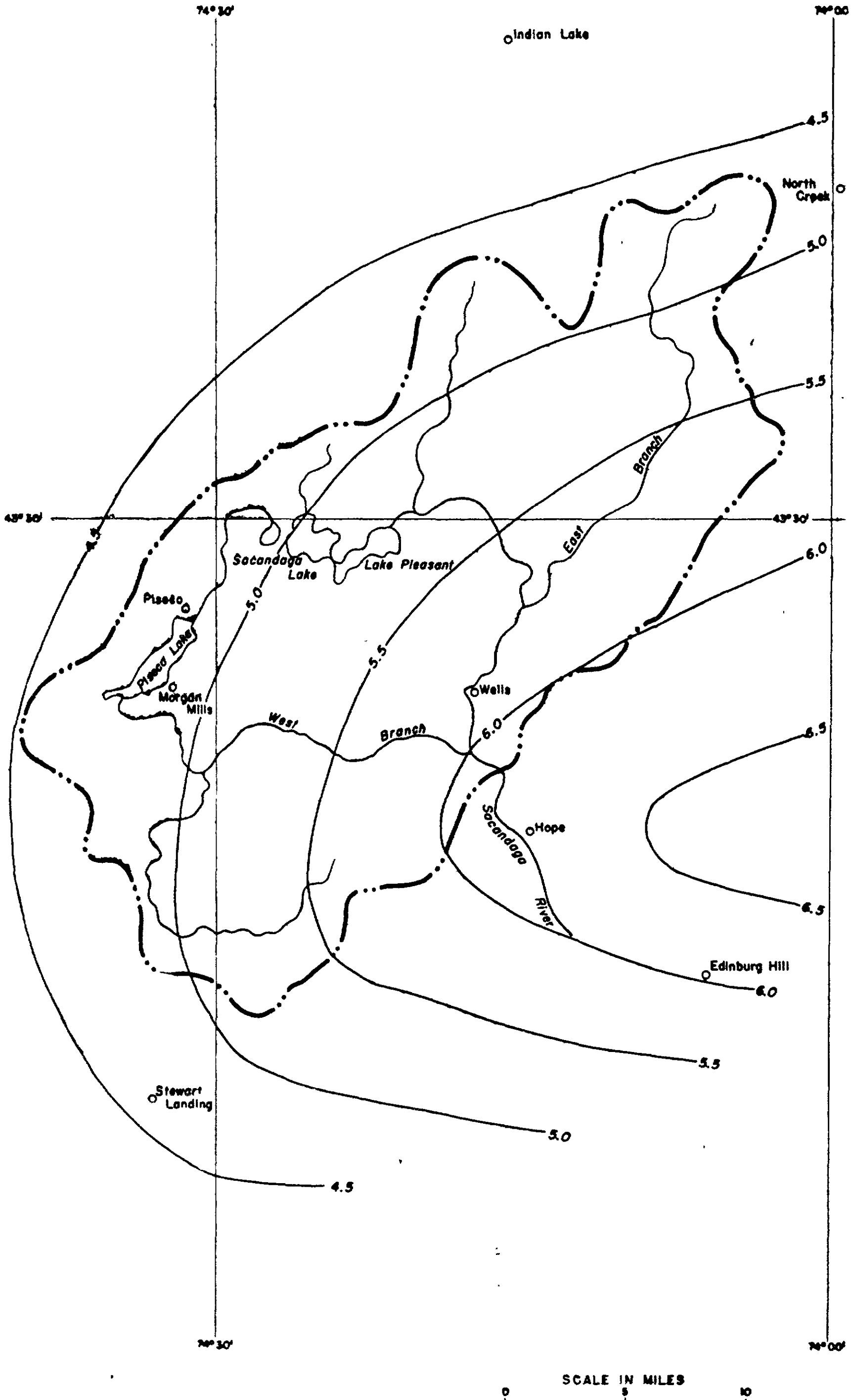

FIGURE 7.—Map of Sacandaga River basin above Hope, N. Y., showing lines of equal precipitation, March 8-22, 1936.

above freezing during the period, and there was some effective thawing temperature on each day. Table 5 gives a record of observations at Wanakena, N. Y., of air and soil temperatures and precipitation during the month of March. Although Wanakena is not in the basin, the record is of interest for its completeness and for illustrating the march of events during this month in the Adirondack Mountains. The record indicates that frost was present until March 15 at 6-inch depth, but that there was no frost during the month at 24-inch depth.

Daily mean temperatures during the 30-day antecedent period, February 8 to March 8, are given in table 6. The average for 30 days was 16° F., and on only 2 days was the average above freezing. Active thawing did not begin until March 9.

Discharge from the basin is given in table 7, and variations in discharge in graphic form are shown on figure 8. Direct runoff during the first period as delineated on figure 8 and as computed in table 8 was 1.88 inches. The lag interval between the rainfall and snow runoff and the direct runoff (table 9) was 52 hours. The flood peak followed the center of mass of net supply by 25 hours.

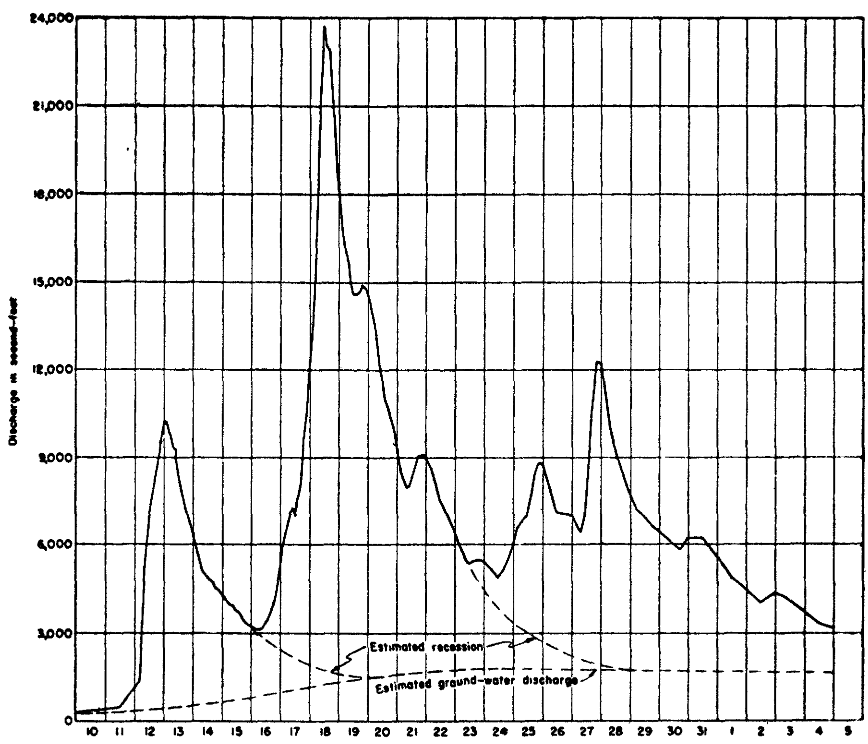

FIGURE 8.—Hydrograph of Sacandaga River near Hope, N. Y., showing discharge, March 1936.

TABLE 3.—*Precipitation, in inches, for 12-hour periods, at stations in and near Sacandaga River Basin near Hope, N. Y., March 8–22, 1936*

Station (New York)	Altitude (feet)	Weight (per-cent)	12-hour period ending	March 8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Hoffmeister	1,860	11.4	12 m.	0.08	0.06	0	0.18	0.28	0.19	0.10	0.11	0.30	0.38	0.21	0.04	0.10	0.07	0.02
			12 p.m.	.16	0	0	.38	.18	.20	0	.22	.38	.38	.04	.03	.16	0	.04
Hope	900	17.8	12 m.	0	.17	.55	0	.56	.10	.13	.02	.05	.55	.51	.20	.11	.06	.15
			12 p.m.	.08	.36	.28	.28	.34	.11	.09	.03	.30	.53	.36	.14	.09	.09	.08
North Creek	1,020	11.2	12 m.	.02	.02	0	.20	.27	.10	.03	.03	.28	.51	.39	.22	.11	.13	.11
			12 p.m.	.04	0	0	.40	.15	.05	0	.06	.51	.50	.28	.16	.04	.23	0
Speculator	1,770	51.3	12 m.	0	0	0	.31	.30	.08	.08	.05	.37	.64	.43	.11	.12	.13	0
			12 p.m.	0	0	0	.62	0	.16	0	.11	.62	.65	.21	0	.25	0	0
Stewart Landing	1,550	8.3	12 m.	.17	.23	.07	.09	.18	.16	.09	.06	.34	.38	.21	.17	.06	.07	.05
			12 p.m.	.34	.14	0	.18	.16	.16	.06	.10	.57	.18	.22	.10	.05	.09	0
Average or total			12 m.	0.02	0.06	0.11	0.21	0.33	0.10	0.09	0.05	0.29	0.56	0.40	0.14	0.11	0.11	0.04
		100.0	12 p.m.	.07	.07	.05	.47	.11	.15	.02	.10	.52	.54	.22	.05	.17	.05	.02

TABLE 4.—*Daily mean areal precipitation and temperatures, Sacandaga River near Hope, N. Y., March 7-22, 1936*

March	Mean areal precipitation (inches)	Temperature		
		Maximum [a] (°F.)	Minimum [a] (°F.)	Mean [b] (°F.)
7	....	30	....	....
8	0.09	36	—2	17
9	.13	38	22	30
10	.16	42	30	36
11	.68	43	32	38
12	.44	48	36	42
13	.25	42	26	34
14	.11	40	21	30
15	.15	43	18	30
16	.81	45	32	38
17	1.10	48	31	40
18	.62	53	37	45
19	.19	52	38	45
20	.28	51	30	40
21	.16	45	32	38
22	.06	44	29	36
8–22	5.23	45	27	36

[a] Average of readings at Gloversville and Indian Lake, N. Y.
[b] Average of maximum and minimum.

TABLE 5.—*Hydrologic data[a] observed at Wanakena, N. Y., March 1936*

[In this table "T" indicates a trace, "B" shows blown snow, and "P" indicates patches of snow]

March	Time of observation (a.m.)	Air temp. (°F.)			Soil temperature in °F. at depth of				Precipitation (inches)		
		Observed	Maximnm	Minimum	1 inch	6 inches	12 inches	24 inches	Rain	Snow	Snow on ground
1	9:50	11	21	—12	31.0	31.4	31.5	32.0	0.11	1.0	14.5
2	9:35	20	38	—21	22.0	24.4	31.5	32.0	------	------	13.5
3	9:40	30	43	20	30.0	30.0	32.0	32.0	.04	.4	12.5
4	9:10	41	52	20	30.0	30.2	32.0	32.0	T	------	12.5
5	9:15	22	30	7	27.0	28.4	32.5	32.0	------	------	10.5
6	9:15	6	14	2.5	27.5	29.0	31.5	31.5	T	.4	10.0
7	9:15	13	29	—15	20.5	24.2	31.5	32.0	------	------	10.0
8	9:15	21	44	—8	21.5	24.6	31.5	32.0	------	------	10.0
9	9:25	37	44	21	31.5	31.0	31.5	32.0	.18	1.5	10.5
10	9:15	42	60	27	31.5	31.4	31.5	32.0	------	------	9.5
11	9:15	49	52	32	32.0	31.8	32.0	32.5	------	------	6.0
12	9:30	43	44	41	32.5	31.8	32.0	32.0	.10	------	P
13	10:05	29	32	24	32.0	32.0	31.5	32.0	.37	4.5	5.5
14	10:20	21	39	16	32.0	32.2	32.0	32.0	.20	4.0	9.5
15	9:30	38	56	14	32.0	31.8	32.0	32.5	T	------	5.5
16	9:25	35	47	29	32.0	32.0	32.0	32.0	.16	------	1.5
17	9:40	46	57.5	30	32.0	32.2	32.5	32.5	.52	1.0	2.5
18	9:15	33.5	55	31	37.0	32.6	32.0	32.5	.22	------	P
19	9:15	51.5	56	31	47.5	35.8	33.0	33.0	.04	------	P
20	9:20	32	41	29	32.0	32.2	32.0	32.0	.09	T	P
21	9:15	36	42	27	32.0	32.2	32.5	32.5	.24	------	P
22	9:55	29.5	38	27	32.0	32.2	32.0	32.0	.30	B	6.5
23	9:50	36	52	10	32.0	32.2	32.5	32.5	T	------	4.5
24	9:15	51	66	34	47.0	35.4	33.0	33.0	------	------	1.0
25	9:15	49	57	43	50.5	42.6	33.0	33.0	.09	------	
26	9:15	39	55	22	33.0	32.6	32.5	32.5	------	------	P
27	9:15	44	55.5	23	40.0	36.4	32.5	32.5	T	------	P
28	9:15	35	48	30	42.0	34.6	32.5	32.5	.39	------	P
29	9:15	47	63.5	22	32.5	32.8	33.0	33.0	------	------	P
30	9:15	44	60	26	52.5	39.4	33.5	34.0	.04	------	P
31	9:15	29.5	31	29	37.5	39.2	34.5	36.0	.32	------	P

[a] Data furnished by the State Rangers School, central-station record.

TABLE 6.—*Daily mean temperature*[1], *Sacandaga River near Hope, N. Y., February 8 to March 8, 1936*

	Mean temperature (°F.)		Mean temperature (°F.)
Feb.		*Feb.*	
8	6	23	8
9	12	24	13
10	12	25	32
11	5	26	34
12	5	27	34
13	7	28	26
14	15	29	14
15	26	*Mar.*	
16	16	1	15
17	29	2	8
18	18	3	28
19	4	4	27
20	3	5	32
21	4	6	20
22	3	7	11
		8	17
Mean			16

[1]Average of recorded daily maximum and minimum temperatures at Indian Lake and Gloversville, N. Y.

Direct runoff associated with the second period, as computed in table 10, was 5.23 inches. There was an elapsed time interval of 45 hours between the centers of mass of supply and direct runoff.

The direct runoff totaled 7.11 inches. Total precipitation was 5.23 inches and snow melt was 3.25 inches making a total supply of 8.48 inches, indicating a retention of 1.37 inches. However, ground-water runoff approximated 2.8 inches, pointing to an underestimation of the gross areal supply of at least 1.43 inches.

At a point some 30 miles below the gaging station, the flow of the Sacandaga River was impounded in the Sacandaga Reservoir, the level of which rose over 20 feet during the storm period. The storage of this large volume of water materially diminished the flood damage created by the Hudson River below Hadley, N. Y., and saved the city of Albany from destruction like that wrought by the flood of March 1913.

EAST BRANCH OF DELAWARE RIVER AT FISHS EDDY, N. Y.

The snow cover in this basin seemed to become depleted more rapidly than it did in any of the other basins studied herein. The initial quantity estimated at 4.7 inches water content, entirely disappeared during the storm period. This rapid melting probably resulted from the higher temperatures prevailing over the area, the average during the storm being 42.5° F., with an average below freezing on only one day.

The above estimate of snow cover is an average between that of 4.8 inches given in Water-Supply Paper 799, and 4.6 inches derived as follows: Precipitation between December 1, 1935, and March 8, 1936, was about 8.8 inches, while associated runoff totaled 4.2 inches leaving an indicated retention of 4.6 inches, mostly as snow. Runoff associated

TABLE 7.—*Gage height and discharge of the Sacandaga River near Hope, N. Y., during flood of March 1936*

MEAN DISCHARGE, IN SECOND-FEET, 1936

Day	Feb.	Mar.	Apr.	Day	Feb.	Mar.	Apr.	Day	Feb.	Mar.	Apr.
1	260	300	4,970	11	220	460	3,340	21	180	8,720	2,170
2	260	260	4,200	12	200	6,000	3,500	22	180	7,690	2,190
3	240	260	4,080	13	200	8,420	3,270	23	170	5,620	1,960
4	240	280	3,340	14	200	5,000	2,960	24	170	5,250	1,780
5	260	340	2,920	15	240	3,720	2,960	25	160	7,470	1,600
6	240	420	8,020	16	220	3,550	3,150	26	220	7,480	1,500
7	240	360	7,630	17	200	7,840	3,060	27	300	8,960	1,400
8	240	320	5,300	18	200	19,400	2,670	28	380	9,620	1,300
9	220	300	4,080	19	190	15,400	2,380	29	340	6,930	1,260
10	220	340	3,480	20	190	11,800	2,110	30	--------	6,120	1,400
								31	--------	6,120	-------
Mean monthly discharge, in second-feet									227	5,315	3,133
Runoff, in inches									0.50	12.47	7.12

GAGE HEIGHT[a], IN FEET, AND DISCHARGE, IN SECOND-FEET, AT INDICATED TIME, 1936

Hour	Feet	Sec.-ft.	Feet	Sec.-ft.	Feet	Sec.-ft.	Feet	Sec.-ft.	Feet	Sec.-ft.	Feet	Sec.-ft.
	March 8		March 9		March 10		March 11		March 12		March 13	
2	-----	-------	-----	-------	-----	-------	-----	-------	-----	-------	6.67	10,200
4	-----	-------	-----	-------	-----	-------	-----	-------	5.11	1,870	6.60	9,900
6	3.56	-------	-----	-------	-----	-------	-----	-------	-----	-------	6.57	9,790
8	-----	-------	-----	-------	-----	-------	-----	-------	5.20	5,250	6.45	9,330
10	-----	-------	-----	-------	-----	-------	-----	-------	-----	-------	6.32	8,850
12 m	3.73	[b] 320	3.81	[b] 300	3.96	[b] 340	4.07	[b] 460	5.86	6,990	6.19	8,380
2	-----	-------	-----	-------	-----	-------	-----	-------	-----	-------	6.05	7,900
4	-----	-------	-----	-------	-----	-------	-----	-------	6.20	8,180	5.96	7,580
6	3.81	-------	-----	-------	-----	-------	-----	-------	-----	-------	5.84	7,180
8	-----	-------	-----	-------	-----	-------	-----	-------	6.39	9,100	5.76	6,920
10	-----	-------	-----	-------	-----	-------	-----	-------	-----	-------	5.66	6,610
12 p. m.	-----	-------	-----	-------	-----	-------	4.30	819	6.68	10,200	5.59	6,390
	March 14		March 15		March 16		March 17		March 18		March 19	
2	5.47	6,030	4.79	4,180	4.32	3,190	5.42	5,880	7.39	13,100	8.29	17,400
4	5.36	5,700	4.76	4,110	4.29	3,130	5.58	6,360	7.69	14,400	8.13	16,600
6	5.24	5,360	4.71	3,990	4.29	3,130	5.72	6,790	8.10	16,500	8.00	16,000
8	5.15	5,110	4.69	3,950	4.29	3,130	5.82	7,120	8.70	19,700	7.91	15,600
10	5.11	5,000	4.62	3,790	4.32	3,190	5.87	7,280	9.53	22,100	7.80	15,000
12 m	5.06	4,860	4.60	3,750	4.39	3,320	5.78	6,990	9.38	23,800	7.72	14,600
2	5.04	4,810	4.56	3,670	4.48	3,500	5.95	7,550	9.27	23,100	7.72	14,600
4	4.98	4,650	4.48	3,500	4.58	3,710	6.05	7,900	9.23	22,900	7.73	14,600
6	4.94	4,540	4.42	3,380	4.66	3,880	6.25	8,600	9.07	21,900	7.74	14,700
8	4.91	4,470	4.40	3,340	4.78	4,150	6.53	9,520	8.85	20,600	7.78	14,900
10	4.87	4,370	4.38	3,300	4.90	4,440	6.79	10,700	8.66	19,500	7.77	14,800
12 p. m.	4.83	4,270	4.36	3,260	5.12	5,030	7.10	11,900	8.45	18,200	7.73	14,600
	March 20		March 21		March 22		March 23		March 24		March 25	
2	7.66	14,300	6.33	8,890	6.33	8,890	-----	-------	-----	-------	5.59	6,390
4	7.58	13,900	6.22	8,490	6.27	8,670	5.45	5,970	5.20	5,250	5.68	6,670
6	7.47	13,400	6.15	8,240	6.20	8,420	-----	-------	-----	-------	5.72	6,790
8	7.32	12,800	6.07	7,960	6.12	8,140	5.30	5,530	5.14	5,080	5.76	6,920
10	7.16	12,100	6.08	8,000	6.01	7,760	-----	-------	-----	-------	5.77	6,950
12 m	7.02	11,600	6.14	8,210	5.95	7,550	5.24	5,360	5.07	4,890	5.79	7,020
2	6.88	11,000	6.23	8,530	5.90	7,380	-----	-------	-----	-------	5.89	7,350
4	6.80	10,700	6.32	8,850	5.84	7,180	5.28	5,470	5.16	5,140	6.03	7,820
6	6.73	10,400	6.37	9,030	5.80	7,050	-----	-------	-----	-------	6.20	8,420
8	6.66	10,100	6.39	9,100	5.73	6,830	5.29	5,500	5.30	5,530	6.28	8,710
10	6.57	9,790	6.39	9,100	5.67	6,640	-----	-------	-----	-------	6.32	8,850
12 p. m.	6.45	9,330	6.37	9,030	5.60	6,420	5.26	5,420	5.45	5,970	6.30	8,780

[a]Supplemental records:—Mar. 12, 5 a.m., 10.08 ft. (backwater from ice); 6:50 a.m., 8.74 ft. (backwater from ice); 6:20 p.m., 7.40 ft. (backwater from ice); Mar. 18, 12:30 p.m., 9.40 ft., 23,900 sec.-ft.

[b]Mean for the day.

LOCATION.—Water-stage recorder, lat. 43°21'10", long. 74°16'15", 1½ miles below junction of East and West Branches of Sacandaga River and 4½ miles above Hope, Hamilton County.

DRAINAGE AREA.—491 square miles.

REMARKS.—Records published in Geol. Survey Water-Supply Paper 799.

TABLE 8.—*Computation of volume of direct runoff associated with precipitation period March 8-14, 1936, Sacandaga River near Hope, N. Y.*

March	12-hour period ending—	Daily mean discharge (second-feet)	Estimated recession from preceding storm and base runoff (second-feet)	Direct runoff (second-feet)
10	12 p.m.	350	350	0
11	12 m.	410	370	40
	12 p.m.	510	390	120
12	12 m.	3,610	410	3,200
	12 p.m.	8,700	430	8,270
13	12 m	9,620	480	9,140
	12 p.m.	7,220	530	6,690
14	12 m.	5,580	580	5,000
	12 p.m.	4,500	630	3,870
15	12 m.	3,930	700	3,230
	12 p.m.	3,520	770	2,750
16	12 m.	[a]3,000	840	2,160
	12 p.m.	[a]2,600	920	1,680
17	12 m.	[a]2,300	1,000	1,300
	12 p.m.	[a]2,050	1,090	960
18	12 m.	[a]1,850	1,180	670
	12 p.m.	[a]1,650	1,270	380
19	12 m.	[a]1,550	1,360	190
	12 p.m.	[a]1,450	1,450	0
Total				
Sec.-ft.-½ days		64,400	14,750	49,650
Sec.-ft.-days		32,200	7,375	24,825 (= 1.88 inches)

[a]Estimated recession under subsequent rise.

TABLE 9.—*Computation of time of center of mass of net supply, and lag intervals, Sacandaga River near Hope, N. Y., March 8-14, 1936*

March	12-hour period ending	Mean areal precipitation (inches)	Estimated snow melt (inches)	Precipitation plus snow melt (inches)	Net supply (inches)	Time from origin (days)	Product (inch-days)
8	12 m.	0.02	[a]—0.02	0	0	....	....
	12 p.m.	.07	[a].0	.07	0	0	0
9	12 m.	.06	[a]—.04	.02	0	.5	0
	12 p.m.	.07	.07	.14	.05	1	.05
10	12 m.	.11	.07	.18	.10	1.5	.15
	12 p.m.	.05	.15	.20	.11	2	.22
11	12 m.	.21	.11	.32	.20	2.5	.50
	12 p.m.	.47	.24	.71	.50	3	1.50
12	12 m.	.33	.14	.47	.32	3.5	1.12
	12 p.m.	.11	.38	.49	.34	4	1.36
13	12 m.	.10	[a]—.05	.05	.02	4.5	.09
	12 p.m.	.15	.15	.30	.21	5	1.05
14	12 m.	.09	[a]—.07	.02	0	5.5	0
	12 p.m.	.02	.05	.07	.03	6	.18
Total		1.86	1.18	3.04	1.88	....	6.22

[a]Estimated result of snowfall and thawing.

Center of mass of net supply occurred $\frac{6.22}{1.88} = 3.31$ days after 6 p.m. of March 8 = March 12.06 (=8.75 + 3.31).

Time of center of mass of direct runoff was at March 14.21 or 2.15 days (52 hours) after center of mass of net supply.

Peak discharge occurred at 1 a.m. March 13 or 1.05 days (25 hours) after center of mass net supply.

TABLE 10.—*Computation of volume of direct runoff associated with precipitation period March 15-22, 1936, Sacandaga River near Hope, N. Y.*

March	Daily mean discharge (second-feet)	Estimated recession from preceding storm and base runoff (second-feet)	Direct runoff (second-feet)
16	3,150	3,000	150
	3,950	2,600	1,350
17	6,670	2,300	4,370
	9,010	2,050	6,960
18	17,200	1,850	15,250
	21,600	1,650	19,950
19	16,100	1,550	14,550
	14,700	1,450	13,250
20	13,200	1,500	11,700
	10,400	1,550	8,850
21	8,390	1,600	6,790
	8,880	1,600	7,280
22	8,390	1,650	6,740
	6,990	1,700	5,290
23	5,760	1,750	4,010
	[a]4,700	1,800	2,900
24	[a]4,050	1,800	2,250
	[a]3,550	1,800	1,750
25	[a]3,200	1,800	1,400
	[a]2,900	1,800	1,100
26	[a]2,600	1,750	850
	[a]2,350	1,750	600
27	[a]2,150	1,750	400
	[a]2,000	1,750	250
28	[a]1,850	1,750	100
	[a]1,750	1,750	0
29			
Total:			
Sec.-ft.-½ days	185,490	47,300	138,190
Sec.-ft.-days	92,745	23,650	69,095 (= 5.23 inches)

[a]Estimated recession under subsequent rise.

TABLE 11.—*Computation of time of center of mass of net supply, and lag intervals, Sacandaga River near Hope, N. Y., March 15-22, 1936*

March	12-hour period ending	Mean areal precipitation (inches)	Estimated snow-melt (inches)	Precipitation plus snow-melt (inches)	Net supply (inches)	Time from origin (days)	Product (inch-days)
15	12 m.	0.05	0.00	0.05	0.05	0	0
	12 p.m.	.10	.05	.15	.15	.5	.08
16	12 m.	.29	.08	.37	.36	1.0	.36
	12 p.m.	.52	.16	.68	.65	1.5	.98
17	12 m.	.56	.04	.60	.59	2.0	1.18
	12 p.m.	.54	.21	.75	.72	2.5	1.80
18	12 m.	.40	.18	.58	.55	3.0	1.65
	12 p.m.	.22	.31	.53	.51	3.5	1.78
19	12 m.	.14	.16	.30	.29	4.0	1.16
	12 p.m.	.05	.28	.33	.32	4.5	1.44
20	12 m.	.11	.08	.19	.18	5.0	.90
	12 p.m.	.17	.18	.35	.34	5.5	1.87
21	12 m.	.11	.07	.18	.18	6.0	1.08
	12 p.m.	.05	.14	.19	.18	6.5	1.17
22	12 m.	.04	.04	.08	.08	7.0	.56
	12 p.m.	.02	.09	.11	.10	7.5	.75
15–22	....	3.37	2.07	5.44	5.25	....	16.76

Center of mass of net supply occurred $\frac{16.76}{5.25}$ = 3.20 days after 6 a.m. of March 15 = March 18.45.

Time of center of mass of direct runoff was at March 20.23 or 1.88 days (45 hours) after center of mass of net supply.

Peak discharge occurred at 12:30 p.m. March 18 or 2 hours after center of mass of net supply.

with meteorologic events of March 26-31, after the flood period, was less than precipitation, indicating little, if any, contribution from melting snow.

There was a total rainfall of 6.23 inches over the basin distributed geographically as shown in figure 9 and distributed with respect to time

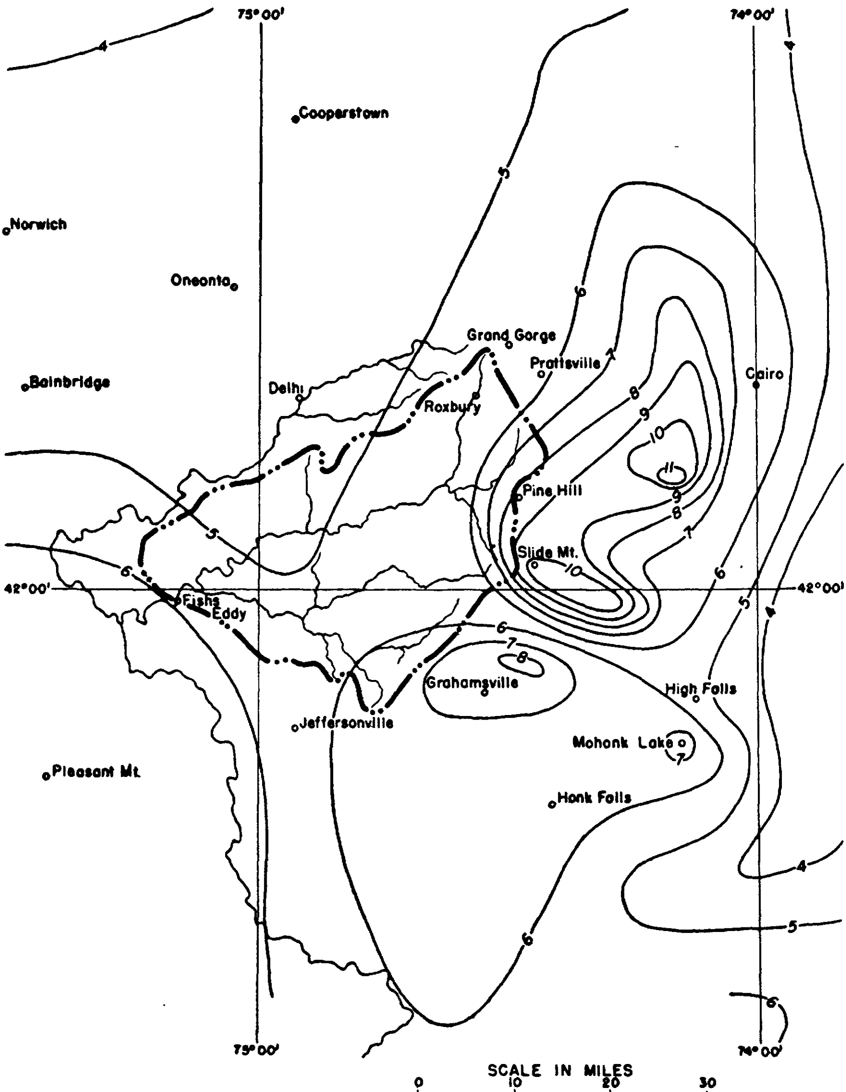

FIGURE 9.—Map of basin of East Branch of Delaware River above Fishs Eddy N. Y., showing lines of equal precipitation, March 9-22, 1936.

as shown in table 12, which gives precipitation in 6-hour intervals at the indicated rain gages. Daily mean areal precipitation is given in table 14 together with daily maximum, minimum, and mean temperatures. Daily mean temperatures during the 30-day antecedent period are given in table 13. The average temperature was 20° F., with an average above freezing on only 6 days.

Discharge at Fishs Eddy is given in table 15 and shown graphically on figure 10. The volume of direct runoff associated with the first flood period, as computed in table 16, was 3.08 inches. The total supply in the form of precipitation and melted snow was 4.42 inches leaving a retention of 1.34 inches. During the second flood period, the direct runoff was

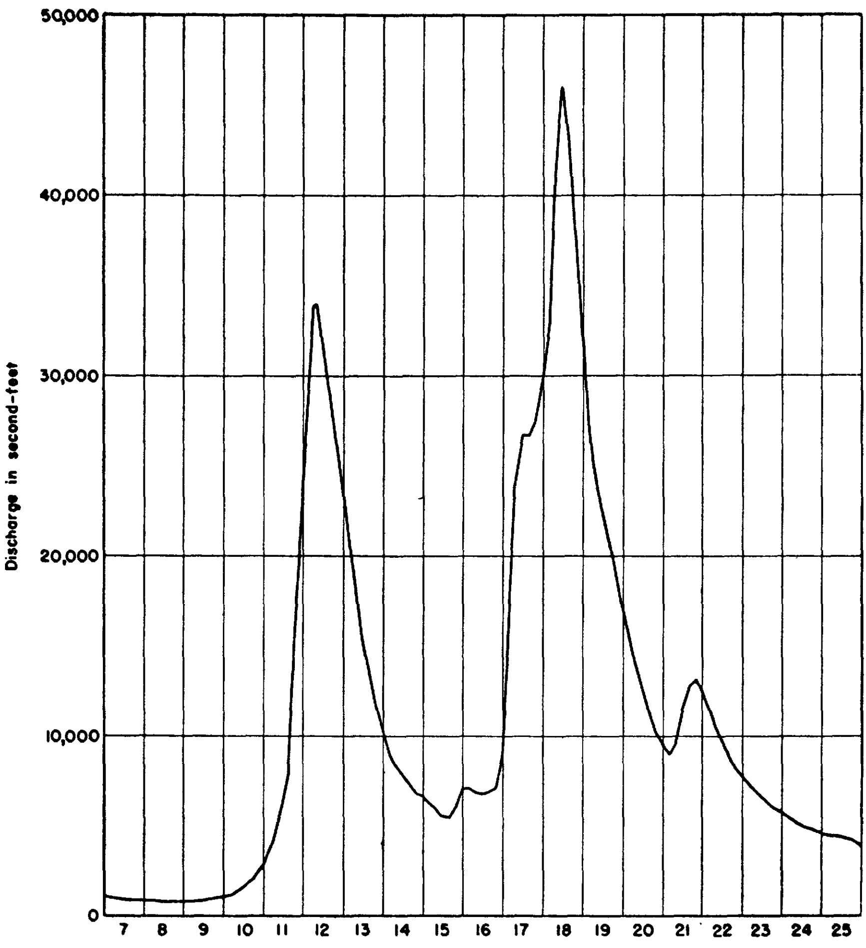

FIGURE 10.—Hydrograph of East Branch of Delaware River at Fishs Eddy, N. Y., showing discharge, March 1936.

5.45 inches from a total supply of precipitation, and estimated snow melt was 6.51 inches, leaving a retention of 1.06 inches. The total flood retention was therefore 2.40 inches. Ground-water runoff associated with the flood period, as computed by methods previously explained, was 2.1 inches, indicating net field-moisture increment and evaporation losses of only 0.3 inch, which is very low in view of the total quantity of water,

TABLE 12.—*Precipitation, in inches, for 6-hour periods, at stations in and near East Branch of Delaware River at Fishs Eddy, N. Y., March 1936*

Station (New York)	Weight (per-cent)	6-hour period ending	March 8	9	10	11	12	13	14	15	16	17	18	19	20	21
Bainbridge	0.6	6 a.m.	0.00	0.00	0.02	0.00	0.13	0.05	0.06	0.01	0.02	0.13	0.56	0.11	0.00	0.34
		12 m.	.00	.11	.00	.01	.07	.00	.00	.02	.17	.02	.12	.08	.00	.09
		6 p.m.	.00	.19	.00	.05	.26	.00	.02	.02	.24	.07	.03	.18	.00	.12
		12 p.m.	.13	.11	.00	.06	.13	.06	.02	.02	.38	.21	.05	.05	.03	.02
Delhi	25.8	6 a.m.	.00	.00	.02	.00	.21	.08	.00	.00	.00	.20	.46	.09	.00	.20
		12 m.	.00	.08	.00	.00	.04	.00	.00	.00	.16	.05	.21	.03	.00	.10
		6 p.m.	.00	.15	.00	.00	.16	.00	.00	.00	.22	.14	.06	.07	.00	.14
		12 p.m.	.02	.05	.00	.11	.20	.00	.00	.00	.61	.17	.05	.06	.02	.03
Grahamsville	8.3	6 a.m.	.00	.00	.01	.03	1.09	.00	.02	.10	.00	.05	1.48	.21	.00	.74
		12 m.	.00	.05	.02	.13	.00	.00	.00	.00	.08	.07	.26	.07	.00	.10
		6 p.m.	.00	.08	.03	.48	.02	.00	.09	.00	.11	.17	.08	.16	.00	.14
		12 p.m.	.08	.05	.02	.57	.01	.01	.09	.00	.17	.54	.13	.05	.06	.03
Grand Gorge	0.4	6 a.m.	.00	.00	.00	.02	.26	.02	.10	.00	.03	.18	1.06	.13	.00	.54
		12 m.	.00	.02	.01	.03	.03	.00	.00	.02	.24	.05	.15	.00	.00	.03
		6 p.m.	.00	.03	.01	.11	.11	.00	.00	.02	.35	.12	.04	.01	.00	.05
		12 p.m.	.16	.02	.01	.13	.05	.10	.00	.02	.54	.39	.07	.00	.00	.01
Jeffersonville	26.0	6 a.m.	.00	.01	.00	.00	.29	.04	.00	.00	.00	.28	.73	.32	.00	.34
		12 m.	.00	.03	.00	.05	.05	.00	.00	.00	.03	.08	.33	.11	.00	.18
		6 p.m.	.00	.04	.00	.16	.23	.00	.00	.00	.04	.18	.09	.25	.00	.23
		12 p.m.	.01	.00	.00	.14	.06	.00	.00	.00	.83	.27	.19	.07	.03	.00
Pine Hill	18.4	6 a.m.	.00	.00	.00	.05	1.01	.05	.02	.02	.00	.19	1.21	.21	.00	.73
		12 m.	.00	.01	.06	.12	.06	.00	.00	.00	.26	.05	.25	.02	.00	.08
		6 p.m.	.00	.01	.06	.44	.26	.00	.02	.00	.38	.14	.07	.06	.00	.11
		12 p.m.	.04	.00	.05	.53	.13	.01	.02	.00	.59	.44	.12	.02	.05	.02
Prattsville	0.5	6 a.m.	.00	.00	.00	.01	.33	.03	.01	.02	.01	.22	1.22	.12	.00	.66
		12 m.	.00	.00	.01	.04	.04	.00	.00	.01	.29	.05	.15	.02	.00	.05
		6 p.m.	.00	.01	.00	.15	.16	.00	.01	.01	.41	.14	.04	.05	.00	.07
		12 p.m.	.12	.00	.01	.18	.08	.00	.01	.01	.64	.44	.07	.01	.05	.02
Roxbury	12.4	6 a.m.	.00	.00	.00	.00	.24	.08	.04	.01	.00	.30	.72	.10	.00	.28
		12 m.	.00	.07	.00	.09	.04	.00	.00	.00	.12	.07	.34	.03	.00	.15
		6 p.m.	.00	.10	.00	.31	.19	.00	.02	.00	.18	.19	.09	.07	.00	.20
		12 p.m.	.01	.00	.00	.12	.17	.04	.01	.00	.89	.27	.05	.05	.02	.15
Slide Mountain	7.6	6 a.m.	.00	.00	.00	.07	1.45	.04	.04	.01	.00	.14	1.87	.27	.00	.90
		12 m.	.00	.01	.06	.17	.04	.00	.00	.00	.20	.08	.33	.10	.00	.07
		6 p.m.	.00	.01	.06	.63	.18	.00	.00	.00	.29	.22	.10	.22	.00	.09
		12 p.m.	.09	.01	.06	.75	.09	.04	.00	.00	.45	.69	.16	.06	.07	.02
Average or total	100.00	6 a.m.	0.00	0.00	0.01	0.02	0.55	0.05	0.02	0.02	0.00	0.21	0.90	0.20	0.00	0.45
		12 m.	.00	.05	.02	.07	.04	.00	.00	.00	.13	.07	.28	.05	.00	.11
		6 p.m.	.00	.07	.02	.25	.19	.00	.01	.00	.20	.16	.08	.14	.00	.16
		12 p.m.	.03	.01	.01	.28	.13	.01	.01	.00	.65	.33	.11	.05	.04	.04

10.93 inches, involved. The following is an inventory of the rainfall and runoff during the winter season of 1935-36 in this basin:

Period	Rainfall and runoff (inches)		
	Precipitation	Runoff	Difference
December 1, 1935 to March 8, 1936	8.8	4.2	4.6
March 9-22	6.2	10.6	—4.4
March 23-31	1.6	1.4	.2
Total	16.6	16.2	0.4

Although the above inventory shows a positive balance to allow for evaporation losses and soil-moisture accretion, it seems too low to be

TABLE 13.—*Daily mean temperature[a], East Branch of Delaware River at Fishs Eddy, N. Y., February 8 to March 8, 1936*

Day	Mean temperature (°F.)	Day	Mean temperature (°F.)
Feb.		*Feb.*	
8	8	23	8
9	17	24	18
10	7	25	39
11	9	26	38
12	14	27	40
13	7	28	29
14	24	29	22
15	30	*Mar.*	
16	20	1	24
17	33	2	16
18	19	3	31
19	2	4	36
20	3	5	36
21	7	6	20
22	8	7	20
		8	22
Mean			20

[a]Average of recorded daily maximum and minimum temperatures at Delhi, Jeffersonville, and Roxbury, N. Y.

TABLE 14.—*Daily mean areal precipitation and temperatures, East Branch of Delaware River at Fishs Eddy, N. Y., March 8-22, 1936*

March	Mean areal precipitation (inches)	Temperature		
		Maximum[a] (°F.)	Minimum[a] (°F.)	Mean[b] (°F.)
8	0.03	40	4	22
9	.13	47	31	39
10	.06	59	31	45
11	.62	51	35	43
12	.91	52	32	42
13	.06	34	25	29
14	.04	44	25	35
15	.02	60	30	45
16	.98	55	38	46
17	.77	62	36	49
18	1.37	58	45	51
19	.44	55	39	47
20	.04	57	33	45
21	.76	49	37	43
22	0	46	31	38
	6.23	51	31	41

[a]Average of readings at Delhi, Jeffersonville, and Roxbury, N. Y.
[b]Average of maximum and minimum.

TABLE 15.—*Gage height and discharge of the East Branch of Delaware River at Fishs Eddy, N. Y., during flood of March 1936*

MEAN DISCHARGE, IN SECOND-FEET, 1936

Day	Feb.	Mar.	Apr.	Day	Feb.	Mar.	Apr.	Day	Feb.	Mar.	Apr.
1	550	1,100	3,570	11	460	9,000	4,220	21	460	11,100	2,850
2	500	1,000	3,500	12	440	29,000	4,240	22	440	9,740	3,310
3	500	900	3,970	13	440	15,800	5,880	23	440	6,600	2,660
4	500	900	3,500	14	460	7,890	6,490	24	440	5,100	2,410
5	480	1,100	3,240	15	500	6,020	6,270	25	460	4,350	2,210
6	480	1,300	7,930	16	550	7,090	5,650	26	550	3,660	2,050
7	460	1,000	8,110	17	550	23,200	4,820	27	850	3,950	1,890
8	460	800	5,870	18	550	38,600	4,050	28	1,100	6,300	1,690
9	460	850	4,570	19	500	23,100	3,520	29	1,200	5,090	1,590
10	460	1,700	4,300	20	480	12,800	3,030	30	-------	4,350	1,480
								31	-------	3,970	-------
Mean monthly discharge, in second-feet									542	7,979	3,962
Runoff, in inches									0.75	11.75	5.64

GAGE HEIGHT[a], IN FEET, AND DISCHARGE, IN SECOND-FEET, AT INDICATED TIME, 1936

Hour	Feet	Sec.-ft.	Feet	Sec.-ft.	Feet	Sec.-ft.	Feet	Sec.-ft.	Feet	Sec.-ft.	Feet	Sec.-ft.
	March 8		March 9		March 10		March 11		March 12		March 13	
2	-------	-------	-------	-------	-------	-------	8.16	3,310	14.89	27,100	-------	-------
4	-------	-------	-------	-------	-------	-------	8.67	3,770	15.90	31,100	13.01	20,400
6	-------	-------	-------	-------	6.82	1,220	8.92	4,260	16.59	33,900	-------	-------
8	-------	-------	-------	-------	-------	-------	9.18	4,890	16.61	33,900	12.20	18,000
10	-------	-------	-------	-------	-------	-------	9.89	5,520	16.46	33,300	-------	-------
12 m.	[b]6.53	[b]800	[b]6.54	[b]850	7.10	1,550	14.30	6,270	16.01	31,500	11.31	15,300
2	-------	-------	-------	-------	-------	-------	16.25	7,420	15.57	29,800	-------	-------
4	-------	-------	-------	-------	-------	-------	9.98	8,790	15.13	28,000	10.59	13,100
6	-------	-------	-------	-------	7.43	2,090	11.37	13,400	14.86	26,900	-------	-------
8	-------	-------	-------	-------	-------	-------	13.64	18,300	14.63	26,100	10.00	11,500
10	-------	-------	-------	-------	-------	-------	13.60	21,600	14.31	24,900	-------	-------
12 p.m.	-------	-------	-------	-------	7.96	2,920	13.94	23,600	13.90	23,500	9.49	10,200
	March 14		March 15		March 16		March 17		March 18		March 19	
2	-------	-------	-------	-------	-------	-------	9.76	10,900	15.88	31,000	-------	-------
4	9.04	9,140	7.54	6,240	8.01	7,090	11.40	15,600	16.31	32,700	14.90	27,100
6	-------	-------	-------	-------	-------	-------	12.94	20,200	17.17	36,300	-------	-------
8	8.67	8,340	7.37	5,940	7.92	6,930	14.04	24,000	18.13	40,600	14.28	24,800
10	-------	-------	-------	-------	-------	-------	14.59	25,900	18.84	44,200	-------	-------
12 m.	8.37	7,750	7.18	5,620	7.85	6,800	14.83	26,800	19.19	46,000	13.65	22,600
2	-------	-------	-------	-------	-------	-------	14.85	26,900	19.07	45,400	-------	-------
4	[a]8.07	7,200	7.13	5,530	7.88	6,850	14.79	26,700	18.61	43,000	13.12	20,800
6	-------	-------	-------	-------	-------	-------	14.78	26,600	18.10	40,500	-------	-------
8	7.86	6,820	7.48	6,130	8.01	7,090	14.98	27,400	17.51	37,800	12.53	19,000
10	-------	-------	-------	-------	8.32	7,660	15.28	28,600	16.86	34,900	-------	-------
12 p.m.	7.71	6,550	7.96	7,000	8.82	8,650	15.55	29,700	16.13	32,000	11.96	17,200
	March 20		March 21		March 22		March 23		March 24		March 25	
2	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
4	11.40	15,600	8.97	8,980	9.96	11,400	-------	-------	-------	-------	-------	-------
6	-------	-------	-------	-------	-------	-------	8.01	7,090	7.03	5,360	6.46	4,440
8	10.84	13,900	9.26	9,660	9.57	10,400	-------	-------	-------	-------	-------	-------
10	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
12 m.	10.32	12,300	10.04	11,600	9.24	9,620	7.72	6,570	6.86	5,080	6.41	4,360
2	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
4	9.87	11,200	10.45	12,700	8.91	8,850	-------	-------	-------	-------	-------	-------
6	-------	-------	-------	-------	-------	-------	7.46	6,100	6.68	4,790	6.31	4,220
8	9.50	10,200	10.62	13,200	8.60	8,200	-------	-------	-------	-------	-------	-------
10	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
12 p.m.	9.16	9,420	10.36	12,400	8.36	7,730	7.23	5,700	6.55	4,580	6.15	3,980

[a] Supplemental records: Mar. 11, 3 p.m., 16.61 ft., 8,090 sec.-ft.; 5 p.m., 9.44 ft., 10,100 sec.-ft.; 7 p.m., 14.96 ft., 16,300 sec.-ft. Mar. 12, 7:30 a.m., 16.62 ft., 34,000 sec.-ft. Mar. 15 3 p.m., 7.11 ft., 5,5 0 sec.-ft. Mar. 18, 12:30 p.m., 19.21 ft., 46,000 sec.-ft.

[b] Mean for the day.

LOCATION.—Water-stage recorder, lat. 41°58′00″, long. 75°10′50″, at railroad bridge in Fishs Eddy, Delaware County, 4½ miles below mouth of Beaver Kill. Zero of gage is 950.84 feet above mean sea level.

DRAINAGE AREA.—783 square miles.

REMARKS.—Records published in Geol. Survey Water-Supply Paper 799.

TABLE 16.—*Computation of volume of direct runoff associated with precipitation period March 8-15, 1936, East Branch of Delaware River at Fishs Eddy, N. Y.*

March	12-hour period ending	Daily mean discharge (second-feet)	Estimated recession from preceding storm and base runoff (second-feet)	Direct runoff (second-feet)
8	12 m.	800	800	0
	12 p.m.	800	800	0
9	12 m.	825	800	25
	12 p.m.	875	800	75
10	12 m.	1,225	825	400
	12 p.m.	2,162	850	1,312
11	12 m.	4,390	900	3,490
	12 p.m.	14,070	1,100	12,970
12	12 m.	31,140	1,200	29,940
	12 p.m.	27,200	1,300	25,900
13	12 m.	19,270	1,350	17,920
	12 p.m.	12,450	1,400	11,050
14	12 m.	8,818	1,600	7,218
	12 p.m.	7,057	1,650	5,407
15	12 m.	6,088	1,700	4,388
	12 p.m.	[a]5,200	1,800	3,400
16	12 m.	[a]4,500	1,900	2,600
	12 p.m.	[a]3,800	2,100	1,700
17	12 m.	[a]3,300	2,200	1,100
	12 p.m.	[a]3,000	2,300	700
18	12 m.	[a]2,700	2,400	300
	12 p.m.	[a]2,500	2,500	0
Total				
Sec.-ft.-½ days		162,170	32,275	129,890
Sec.-ft.-days		81,085	16,138	64,945 = 3.08 inches

[a]Estimated recession under subsequent rise.

TABLE 17.—*Computation of time of center of mass of net supply, and lag intervals, East Branch of Delaware River at Fishs Eddy, N. Y., March 8-15, 1936*

March	6-hour period ending	Mean areal precipitation (inches)	Estimated snow melt (inches)	Precipitation plus snow melt (inches)	Net supply (inches)	Time from origin (days)	Product (inch-days)
8	6 p.m.	0.00	0.00	0.00	0.00	0.00	0.000
	12 p.m.	.03	.05	.08	.00	.25	.000
9	6 a.m.	.00	.04	.04	.00	.50	.000
	12 m.	.05	.09	.14	.04	.75	.030
	6 p.m.	.07	.13	.20	.06	1.00	.060
	12 p.m.	.01	.10	.11	.04	1.25	.050
10	6 a.m.	.01	.08	.09	.05	1.50	.075
	12 m.	.02	.21	.23	.17	1.75	.298
	6 p.m.	.02	.35	.37	.30	2.00	.600
	12 p.m.	.01	.21	.22	.16	2.25	.360
11	6 a.m.	.02	.10	.12	.08	2.50	.200
	12 m.	.07	.16	.23	.17	2.75	.468
	6 p.m.	.25	.22	.47	.38	3.00	1.140
	12 p.m.	.28	.17	.45	.37	3.25	1.203
12	6 a.m.	.55	.08	.63	.53	3.50	1.855
	12 m.	.04	.14	.18	.13	3.75	.488
	6 p.m.	.19	.20	.39	.30	4.00	1.200
	12 p.m.	.13	.08	.21	.17	4.25	.722
13	6 a.m.	.05	.00	.05	.02	4.50	.090
	12 m.	.00	.00	.00	.00	4.75	.000
	6 p.m.	.00	.00	.00	.00	5.00	.000
	12 p.m.	.01	[a].01	.00	.00	5.25	.000
14	6 a.m.	.02	[a].02	.00	.00	5.50	.000
	12 m.	.00	.03	.03	.00	5.75	.000
	6 p.m.	.01	.09	.10	.07	6.00	.420
	12 p.m.	.01	.05	.06	.04	6.25	.250
15	6 a.m.	.02	.00	.02	.00	6.50	.000
		1.87	2.55	4.42	3.08	......	9.509

[a]Estimated result of thawing and snowfall.

Center of mass of net supply occurred $\frac{9.509}{3.08}$ = 3.09 days after 3 p.m. March 8 = March 11.72.

Time of center of mass of direct runoff was at March 13.15 or 1.43 days (34 hours) after center of mass of net supply.

Peak discharge occurred at 7:30 a.m. March 12 or 0.59 day (14 hours) after center of mass of net supply.

acceptable. There is some indication here that rainfall data during this flood in the mountainous region drained by the East Branch of the Delaware River were inadequate and that the gross water supply was probably greater than was indicated by available records.

Tables 17 and 19 give mean areal precipitation at 6-hour intervals and the estimated snow melt during concurrent intervals. The estimates of snow melt were made by distributing the total amount through the flood period on the basis of temperature, reducing the rate somewhat as the snow cover diminished. Snow was assumed to have been entirely gone by March 21. The total supply listed in tables 17 and 19 was converted into net supply by the methods previously explained, and the time of center of mass computed for each flood period. The lag interval between the center of mass of net supply and center of mass of direct runoff for each flood period as computed in tables 17 and 19 was 34 hours and 36 hours for the first and second periods, respectively. The lag interval from the center of mass of net supply to the flood peak was 14 hours and 12 hours for the first and second periods, respectively.

TABLE 18.—*Computation of volume of direct runoff associated with precipitation period March 15-21, 1936, East Branch of Delaware River at Fishs Eddy, N. Y.*

March	12-hour period ending	Daily mean discharge (second-feet)	Estimated recession from preceding storm and base runoff (second-feet)	Direct runoff (second-feet)
15	12 m.	6,088	6,088	0
	12 p.m.	5,970	5,200	770
16	12 m.	6,970	4,500	2,470
	12 p.m.	7,185	3,800	3,385
17	12 m.	19,050	3,300	15,750
	12 p.m.	27,400	3,000	24,400
18	12 m.	37,100	2,700	34,410
	12 p.m.	40,100	2,500	37,600
19	12 m.	26,400	2,500	23,900
	12 p.m.	19,730	2,500	17,230
20	12 m.	14,750	2,400	12,350
	12 p.m.	10,750	2,400	8,350
21	12 m.	9,715	2,400	7,315
	12 p.m.	12,630	2,400	10,230
22	12 m.	10,940	2,300	8,640
	12 p.m.	8,575	2,300	6,275
23	12 m.	7,120	2,300	4,820
	12 p.m.	6,120	2,300	3,820
24	12 m.	[a]5,100	2,200	2,900
	12 p.m.	[a]4,350	2,200	2,150
25	12 m.	[a]3,610	2,200	1,410
	12 p.m.	[a]3,000	2,200	800
26	12 m.	[a]2,550	2,100	450
	12 p.m.	[a]2,300	2,100	200
27	12 m.	[a]2,100	2,100	0
Total				
Sec.-ft.-½ days		299,613	69,988	229,645
Sec.-ft.-days		149,806	34,994	114,822 = 5.45 inches

[a]Estimated recession under subsequent rise.

TABLE 19.—*Computation of time of center of mass of net supply, and lag intervals, East Branch of Delaware River at Fishs Eddy, N. Y., March 15–22, 1936*

March	6-hour period ending	Mean areal precipitation (inches)	Estimated snow melt (inches)	Precipitation plus snow melt (inches)	Net supply (inches)	Time from origin (days)	Product (inch-days)
15........	12 m.	0	0.11	0.11	0.07	0	0
	6 p.m.	0	.20	.20	.15	.25	.038
	12 p.m.	0	.14	.14	.10	.50	.050
16........	6 a.m.	0	.09	.09	.06	.75	.045
	12 m.	.13	.15	.28	.23	1.00	.230
	6 p.m.	.20	.22	.42	.37	1.25	.362
	12 p.m.	.65	.13	.78	.70	1.50	1.050
17........	6 a.m.	.21	.05	.26	.22	1.75	.385
	12 m.	.07	.12	.19	.16	2.00	.320
	6 p.m.	.16	.19	.35	.30	2.25	.675
	12 p.m.	.33	.14	.47	.42	2.50	1.050
18........	6 a.m.	.90	.09	.99	.90	2.75	2.480
	12 m.	.28	.11	.39	.35	3.00	1.050
	6 p.m.	.08	.13	.21	.18	3.25	.585
	12 p.m.	.11	.07	.18	.15	3.50	.525
19........	6 a.m.	.20	.03	.23	.18	3.75	.679
	12 m.	.05	.04	.09	.06	4.00	.240
	6 p.m.	.14	.05	.19	.15	4.25	.637
	12 p.m.	.05	.03	.08	.05	4.50	.225
20........	6 a.m.	.00	.00	.00	.00	4.75	.000
	12 m.	.00	.02	.02	.00	5.00	.000
	6 p.m.	.00	.02	.02	.00	5.25	.000
	12 p.m.	.04	.02	.06	.02	5.50	.110
21........	6 a.m.	.45	....	.45	.40	5.75	2.300
	12 m.	.11	....	.11	.08	6.00	.480
	6 p.m.	.16	....	.16	.13	6.25	.812
	12 p.m.	.04	....	.04	.02	6.50	.130
22........	6 a.m.	.00	....	.00	.00	6.75	.000
		4.36	2.15	6.51	5.45	....	14.458

Center of mass of net supply occurred $\frac{14.458}{5.45}$ = 2.65 days after 9 a.m. of March 15 = March 18.03.

Time of center of mass of direct runoff was at March 19.52 or 1.49 days (36 hours) after center of mass of net supply.

Peak discharge occurred at March 18.52 or 0.49 day (12 hours) after center of mass of net supply.

TABLE 20.—*Hourly precipitation, in inches, at recording gages in and near Susquehanna River basin, March 9-22, 1936*

[In this table, "a" indicates no record, "T" indicates a trace of precipitation, "leaders" indicate zero precipitation, and an asterisk (*) shows that the data have been included in the following measurement.]

Station	Day	a.m.												p.m.												Total	Estimated amount precipitation reported as snow (inches)
		1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12		
Arnot Forest, N. Y. U. S. Soil Conservation Service.	9	...	...	...	...	...	...	...	...	...	...	0.02	0.02	0.02	0.02	0.02	0.01	...	0.01	0.02	0.01	...	...	...	...	0.15	a
	10	...	...	0.01	0.01	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	.02	a
	11	...	...	...	...	...	...	...	...	0.02	0.02	.02	.02	.02	.02	.02	.02	0.11	.13	.13	.13	0.32	0.06	0.09	0.10	1.23	a
	12	0.03	0.03	.03	.03	0.01	...	...	...	...	...	...	...	.03	.10	.08	.03	.03	.02	.03	.03	.02	.03	.03	.03	.59	a
	13	.03	.03	.02	...	...	...	...	...	...	.01	...	...	...	...	.04	.04	.03	.04	.04	.03	.04	.04	.03	.01	.43	a
	14	...	...	.01	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	.02	...	...	...	...	...	.03	a
	15	...	...	.01	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	.01	a
	16	...	...	.08	.12	.06	0.06	0.06	0.08	.04	.15	.07	.06	...	...	...	.06	.13	.13	.07	...	...	.04	.04	.04	1.29	a
	17	.04	.04	.04	.03	.04	.04	.04	.03	...	.01	.03	.03	.03	...	...	...	...	.36	.01	.01	.08	.08	.20	.33	1.47	a
	18	.26	.18	.15	.02	...	...	...	...	...	...	...	.01	...	...	...	...	...	...	...	...	...	...	...	...	.62	a
	19	.05	.11	.18	.06	.23	.23	.08	.04	...	...	...	...	...	...	...	...	...	.02	.02	.02	.02	.02	.02	.02	1.12	a
	20	.02	.02	.02	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	.06	a
	21	...	...	...	.06	.15	.22	.10	.10	.10	.04	.01	.01	.01	.03	.03	.03	.03	.03	.04	.03	.03	.03	.03	.03	1.14	a
	22	.03	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	.03	a
Binghamton, N. Y. U. S. Weather Bureau.	9	.01	T	T	...	...	...	...	T	.01	.02	.03	.03	T	T	.01	.03	.04	.05	.03	.02	.01	T	.02	.03	.34	...
	10	.02	T	.01	T	T	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	.03	...
	11	...	...	...	...	...	T	T	T	.02	T	T	.01	.01	T	T	T	T	.04	T	T	.01	.05	.01	.02	.17	...
	12	.06	.06	.01	.01	T	...	...	...	...	T	.01	.01	.01	.02	.05	.03	.04	.05	*	.04	*	*	*	.08	.48	0.29
	13	*	*	.02	...	...	...	...	...	...	...	...	...	T	T	...	...	...	*	*	.02	T	T	...	T	.04	.04
	14	*	*	.01	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	T	.01	T	...	...	...	.02	.01
	15	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	16	...	...	...	...	.01	T	.04	.05	.14	.16	.04	T	.01	.05	.01	.09	.08	.01	.06	.24	.06	.02	.02	.04	1.13	...
	17	.01	.02	.02	.07	T	T	.01	.01	T	.02	.01	T	...	...	...	...	.02	T	.03	.04	T	T	.01	.13	.40	...
	18	.20	.47	.32	.13	.12	.08	.03	T	T	...	...	...	...	...	...	...	...	...	...	...	...	T	.01	.02	1.38	...
	19	.06	.12	.13	.17	.07	T	...	...	...	...	T	.04	.05	.06	.04	.05	.04	.03	.03	.02	.02	.01	.01	...	.95	.25
	20	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	21	...	T	.09	.06	.12	.14	.08	.01	.02	T	...	...	...	...	.02	.02	.02	.01	.02	.02	T	T	T	T	.63	.11
	22	T	T	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	T	...
China, N. Y. U. S. Geological Survey.	9	...	...	...	...	...	...	.01	.01	.05	.04	.05	.04	.01	.01	...	...	.01	.01	.02	.03	.02	.01	.02	.02	.36	a
	10	.01	.01	.02	...	...	...	...	...	...	...	.01	...	.01	.01	...	...	...	...	...	...	...	...	...	...	.07	a
	11	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	.01	.01	...	...	.01	.03	.06	a
	12	.01	.04	.07	.08	.04	.02	...	...	...	.01	...	.01	.01	...	.02	.01	.07	.03	.01	.02	.06	.03	.11	.05	.70	a
	13	...	.01	...	.03	...	...	...	...	...	...	...	.01	...	...	...	...	...	...	...	...	...	...	.01	...	.06	a
	14	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	a
	15	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	a
	16	...	...	.01	...	...	...	.04	.02	.05	.10	.07	...	.01	...	...	.02	...	...	.01	.07	.20	.06	.02	.06	.74	a

TABLE 20.—*Hourly precipitation, in inches, at recording gages in and near Susquehanna River basin, March 9-22, 1936*—*Continued*

Station	Day	a.m.												p.m.												Total	Estimated amount precipitation reported as snow (inches)
		1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12		
China, N. Y. (Con.)	17	.04	.06	.02	.04	.03	.02	.02	.03	.02	.02									.06	.04	.04	.01		.02	.47	a
	18	.05	.09	.08	.19	.20	.18	.09	.03	.05	.03	.01		.01												1.01	a
	19		.05	.07	.02	.02	.01				.01	.07	.11	.02			.01	.01		.01		.02	.01			.44	a
	20								.04	.01	.01															.06	a
	21			.06	.03	.13	.14	.12	.05	.01		.01	.01	.01	.11	.16	.20	.05	.01	.04	.02	.02				1.18	a
	22								.01	.01	.01	.01	.01													.05	a
Clarion, Pa. (Piney) Pennsylvania Electric Co.	9	.01		.01	.01			.01		.02	.01		.01			.01			.01				.01			.11	a
	10							.01																		.01	a
	11							.02	.01	.01		.02	.05	.03	.04	.05	.02	.05	.12	.20	.04		.01			.67	a
	12	.02	.02	.03		.01				.01		.04		.01			.01	.01	.01		.02					.19	a
	13				.01	.02		.01				.01	.01	.02	.02				.01				.01			.12	a
	14					.01										.11	.07	.02	.03		.01				.01	.26	a
	15						.01			.01	.09	.01				.01		.04								.17	a
	16	.06	.14	.16	.04	.05	.06	.05	.03	.01	.02	.05	.02	.06	.02	.02				.01			.01	.01	.05	.87	a
	17	.10	.20	.25	.21	.14	.26	.26	.17	.23	.26	.14	.27	.36	.10	.11	.10	.09	.08	.06	.06	.07	.06	.07	.06	3.71	a
	18	.05	.06	.04	.04	.06	.06	.07	.07	.08	.10	.13	.11	.12	.07	.03				.01		.08	.01		.01	1.20	a
	19	.08	.01		.01			.02	.02		.01			.01	.01		.01								.01	.19	a
	20																					.01			.02	.03	a
	21	.01		.03	.05	.05	.03	.04	.03	.03	.03	.05	.05	.06	.01		.01									.48	a
	22																										a
Hammondsport, N. Y. U. S. Soil Conservation Service.	9	.02		.01	.01	.01	.02																			.07	a
	10																										a
	11												.01	.02	.06	.02	.01	.07	.07	.06	.04	.08	.10	.03	.03	.60	a
	12	.04	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	.46	.50	a
	13																			.01	.04	.01	.01			.07	a
	14																			.07						.07	a
	15																										a
	16			.03	.13	.07	.02	.02	.01		.01	.01	.02	.02	.01		.02	.09	.06	.04	.01		.03	.03	.02	.65	a
	17		.01	.05	.07	.02	.12	.29		.01	.06	.04	.15	.10	.11	.10	.01				.06	.08	.07	.21	.08	1.64	a
	18	.08	.02	.04	.05			.01																.01	.01	.22	a
	19	.03	.05	.13	.10	.16	.18	.20	.02		.04	.04						.01	.03	.07	.02	.02		.01		1.11	a
	20																										a
	21				.02	.06	.14	.19	.06		.04	.01		.01							.01	.01	.02	.02		.59	a
	22																										a
Harrisburg, Pa. U. S. Weather Bureau.	9							T	T																	T	
	10				T	T	T	T	T	T								T		.11	T					.11	
	11	.02	T	.01	.01	.01	.01	.02	.01	.01	.04	.08	.14	.12	.28	.10	.03	.09	.12	.04	.04	.17	.18	.09	.03	1.65	
	12	.01									.01	.13	.10	.10	.10	.08	.05	.01	T				T			.59	.41
	13						T																			T	T
	14																			T	T					T	

	15	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
	16	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	T	T	.12	T	---	---	.17	T	.29	---
	17	---	.14	.03	.18	.01	T	.01	.02	T	T	T	---	---	T	T	T	T	.01	.02	.18	.30	.14	.10	.10	1.24	---
	18	T	---	---	---	---	---	---	---	---	---	---	---	T	T	.18	.04	.01	.02	.07	T	.01	---	---	---	.33	---
	19	---	---	.02	T	.08	.11	.08	T	---	---	---	T	T	.05	.05	.06	.07	.01	---	---	---	---	---	---	.53	---
	20	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	.03	.15	.18	---
	21	.09	.04	.09	.01	.01	.02	.01	.07	.10	.01	.01	.01	T	T	.01	T	---	---	---	T	T	---	---	---	.48	---
	22	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Rochester, N. Y. U. S. Weather Bureau.	9	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
	10	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
	11	---	---	---	---	---	---	---	---	---	---	T	.01	.05	.02	.06	.08	.03	.06	.05	.07	.17	.16	.09	.07	.92	---
	12	.05	.01	.01	T	T	T	.01	T	.01	---	T	T	.01	.05	.06	.07	.06	.06	.04	.04	.02	.01	T	.01	.52	0.43
	13	T	.01	T	---	---	---	---	---	---	T	T	T	T	.01	.02	.02	.02	.03	.03	.03	.02	.02	.01	.01	.23	.23
	14	T	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	T	.01	---	---	---	---	.01	.01
	15	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
	16	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
	17	.04	.06	.06	.06	.05	.09	.10	.07	.05	.03	.02	.02	.03	.04	.04	.05	.04	.04	.05	.03	.04	.05	.05	.04	1.15	.30
	18	.05	.05	.05	.06	.05	.04	.04	.02	.01	T	T	---	---	---	---	---	---	---	---	---	---	T	T	T	.37	---
	19	T	.02	.07	.08	.09	.10	.10	.12	.11	.01	.01	T	T	.01	T	.01	.05	.06	.05	.03	.02	.01	T	.01	.96	.23
	20	T	T	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	T	T
	21	---	---	---	---	---	---	.01	.04	.10	.06	.05	.04	.06	.06	.06	.05	.05	.02	.02	.03	.04	.04	.03	.01	.77	.77
	22	---	T	T	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	T	T
Scranton, Pa. U. S. Weather Bureau.	9	---	---	---	---	---	---	---	T	T	---	---	T	---	---	---	---	T	T	---	---	T	.01	T	T	.01	
	10	T	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	T	---
	11	---	---	---	---	T	T	T	T	T	.01	T	T	T	T	T	.03	.02	.03	T	.06	.03	.03	T	.05	.26	---
	12	.08	.06	T	.01	T	---	---	---	---	---	---	T	.02	.03	.06	.04	*	*	*	.06	*	*	*	.04	.40	.06
	13	*	*	.02	---	---	---	---	---	---	---	---	T	T	T	T	---	---	*	*	.01	*	*	*	.02	.05	.05
	14	T	T	T	T	---	---	---	---	---	---	---	---	---	---	---	---	---	---	*	.02	*	*	*	.03	.05	T
	15	T	T	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	T	
	16	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	.06	.18	.08	.01	.04	.13	.08	.08	.66	---
	17	.08	.01	T	.01	T	T	.03	.04	.03	T	---	---	---	---	.01	.02	.09	.03	.03	.05	.02	.02	.13	.14	.74	---
	18	.08	.09	.17	.11	.12	.07	.02	.01	T	---	---	---	---	T	---	---	---	---	---	---	T	T	T	.08	.75	---
	19	.13	.09	.10	.08	T	---	---	---	---	---	.01	.07	.04	T	.02	.02	.03	.01	.01	.02	*	*	*	.02	.65	T
	20	T	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	T	---
	21	T	.05	.10	.09	.10	.03	T	.01	T	---	---	---	T	.06	.15	.14	.05	*	*	.13	T	T	T	T	.91	.10
	22	T	T	T	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	T	---
South New Berlin, N. Y. U. S. Geological Survey.	9	.01	.03	.02	.05	.03	.02	.03	---	.05	.05	.05	.04	.08	.07	.04	.06	.06	.01	.02	.01	.01	---	---	---	.74	a
	10	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	a
	11	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	.01	.01	.04	.10	.16	a
	12	.10	.02	.01	.02	---	---	---	.01	.01	---	---	.02	.01	.03	.04	.01	.01	.03	.04	.01	.03	---	---	.01	.41	a
	13	---	---	.01	.02	.02	.01	.01	.01	---	---	---	---	---	---	---	.01	.02	.01	.01	.08	.01	.01	.02	.01	.26	a
	14	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	.02	---	---	---	---	.02	a
	15	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	.01	.07	---	---	---	.08	a
	16	---	---	---	.02	.05	.05	.10	.05	.21	.31	.04	---	---	.07	.01	.09	.09	.02	.06	.21	.12	---	---	.03	1.53	a
	17	.01	---	.04	.02	---	.03	.02	---	.01	---	---	---	---	---	---	---	---	---	.02	---	.01	---	---	---	.16	a
	18	.03	.03	.07	.20	.10	.09	.06	.04	.04	.03	.02	.02	.01	---	---	---	---	---	---	---	---	---	---	---	.74	a
	19	---	.02	.01	.01	.02	---	---	---	---	.01	.10	.02	.04	.01	---	---	---	---	---	---	---	---	---	---	.24	a
	20	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	a
	21	---	.01	.01	.02	.04	.04	.02	.02	---	.01	.01	.01	---	---	---	---	.07	.01	---	.01	.01	---	---	---	.29	a
	22	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	a

TABLE 20.—*Hourly precipitation, in inches, at recording gages in and near Susquehanna River basin, March 9-22, 1936*—*Continued*

Station	Day	a.m.												p.m.												Total	Estimated amount precipitation reported as snow (inches)
		1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12		
Syracuse, N. Y.	9				*	*	.09				T	T														.09	
U. S. Weather Bureau.	10																										
	11										T	T	*	*	.03		T	T	T	*	.04	*	*	*	.10	.17	
	12	*	*	.12			*	*	.08	*	*	.01	*	*	*	*	.12	*	*	*	.24	*	*	*	.14	.71	.44
	13	*	*	*	.10			T	T				*	*	*	*	*	*	*	*	.14	*	*	*	.07	.31	.31
	14	*	*	.01																	T	*	.03			.04	.01
	15																				T					T	
	16			*	*	*	.25					*	.01	*	*	.05	*	*	*	*	.20	*	*	*	.20	.71	.40
	17	*	*	*	*	*	*	*	.22	T	T	T	T				*	*	*	*	.17	*	*	*	.30	.69	.10
	18	*	*	*	*	*	*	*	.60	*	*	*	.19	T												.79	
	19	*	*	*	*	*	*	*	.24	T	T			*	*	*	.18	*	*	*	.01	*	*	*	T	.43	T
	20	*	*	*	.01																					.01	.01
	21						*	*	.27	*	*	.10			*	*	*	*	*	*	.16	*	*	*	.05	.58	T
	22	*	*	*	.04																					.04	T
Truxton, N. Y.	9		.05	.03					.02	.03																.13	a
U. S. Geological Survey.	10																										a
	11										.02	.01		.01					.02	.10	.01		.03	.03	.03	.26	a
	12	.08	.10	.07	.01					.01					.04	.03	.06	.07	.02	.01	.04	.02	.07	.05	.02	.70	a
	13	.02	.01	.01							.02							.02	.03	.02	.05	.03	.03	.01	.03	.28	a
	14	.02																			.05	.04				.11	a
	15																										a
	16				.11	.11	.09	.07	.07	.03	.03	.04	.02		.03	.03		.06	.10	.04	.05	.04	.01	.01	.01	.95	a
	17	.03		.01	.03	.02			.13	.11	.02	.01							.04	.02	.11	.05	.02	.01		.61	a
	18	.09	.18	.16	.16	.18	.06	.12	.08	.05	.04	.05	.03													1.20	a
	19		.01	.03	.09	.06	.12	.04	.02	.01					.05	.08	.05					.01	.01			.58	a
	20	.01	.01								.01															.03	a
	21						.09	.09	.09	.04	.05	.04	.01					.01		.10	.04	.03	.02	.03		.64	a
	22	.01	.01	.01	.02	.03																				.08	a

TABLE 21.—*Reported snowfall, in inches, at selected cooperative Weather Bureau stations, Susquehanna River basin, March 9-22, 1936*

[In this table "T" indicates a trace]

Station	March													
	9	10	11	12	13	14	15	16	17	18	19	20	21	22
New York:														
Alfred	----	----	----	8	4	1	----	1	5	4	1.5	1	3.5	----
Angelica	----	----	----	6	3	T	----	----	4	3	2	2	4	T
Cohocton	----	----	----	2	5	----	----	----	----	----	3	----	2	----
Cooperstown	----	----	----	----	2	1	----	----	----	----	----	----	----	----
Cortland	----	----	----	----	3.5	2	----	----	2	----	2	----	1	----
Elmira	----	----	----	3.5	2	----	----	1	----	----	T	----	3	----
Franklin	T	----	----	4	----	2	----	----	----	----	T	----	1	----
Hammondsport	----	----	----	----	5.5	2	----	----	2	----	----	2.5	5	T
Woodhull	----	----	----	8	2	2	----	3	2	----	4	1	3	----
Pennsylvania:														
Altoona	----	----	----	1	2.5	----	----	----	----	----	----	----	1	----
Bellefonte	----	----	----	3	----	----	----	----	----	----	----	----	----	----
Clearfield	----	----	----	1	6	----	----	----	----	----	----	----	4	----
Ebensburg	----	----	----	4	3	----	----	----	----	----	T	----	6	----
Hanover	----	----	----	----	0.5	----	----	----	----	----	----	----	----	----
Kylertown	----	----	----	6	2	----	----	----	----	----	T	----	4	----
Lawrenceville	----	----	----	3	2	1	----	T	T	T	T	2	3	----
Montrose	----	----	1.5	2	----	----	----	----	----	----	2	----	.5	----
Morris Run	----	----	----	4.5	4	----	----	----	----	----	1	1	5	----
Muncy Valley	----	----	----	T	3	T	----	----	----	----	----	----	T	----
Wellsboro	----	----	----	5.5	1.5	T	----	T	----	----	.5	.5	4	T

CHEMUNG RIVER AT CHEMUNG, N. Y.

Table 22 lists the computed calendar-day precipitation at all rain gages in and near the Chemung River Basin, for the period March 8-21, 1936. The indicated calendar-day amounts at the nonrecording rain gages were computed by the methods previously explained on the basis of time distribution of rainfall registered at the autographic rain gages, as published in table 20. The daily mean areal precipitation was computed by averaging the precipitation at the several rain gages on the basis of the indicated weights, of which the rain gage at Woodhull, N. Y., has the greatest, controlling 560 square miles of the total basin area of 2,530 square miles. In table 22 are listed 11 rain gages, an average of 230 square miles per rain gage. The areal distribution of the total precipitation is shown by the isohyetal map in figure 11.

The computed calendar-day precipitation is also listed in table 24 together with the maximum, minimum, and average temperatures. These temperatures were computed on the basis of observations at Alfred, N. Y., Elmira, N. Y., Woodhull, N. Y., and Lawrenceville, Pa. Maximum daily temperatures were above freezing during the entire period and averaged below freezing only during 3 days. Daily mean temperatures during the 30-day period preceding the March 1936 floods are given in table 23. With the exception of those on 5 days, the temperatures were consistently below freezing.

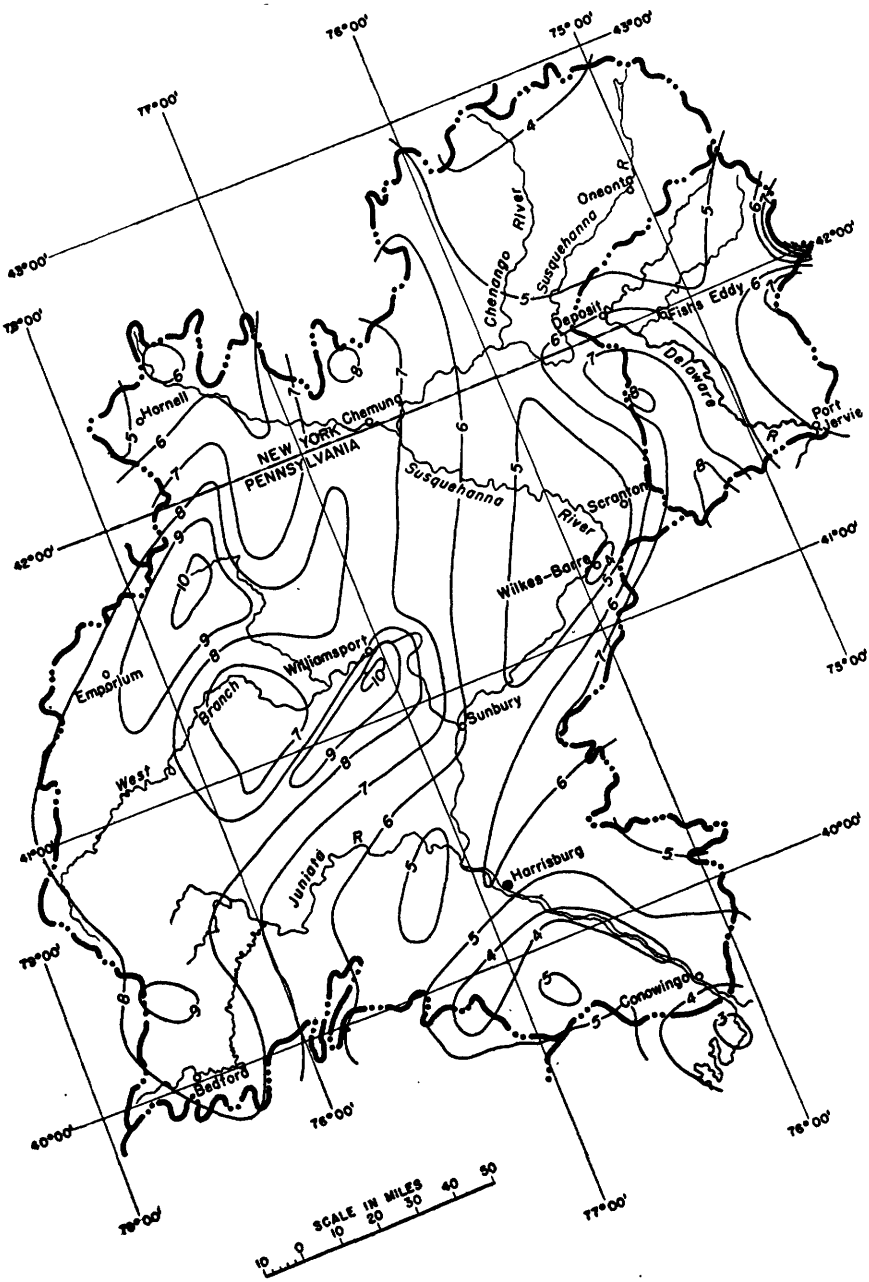

FIGURE 11.—Map of Susquehanna and upper Delaware River basins showing lines of equal precipitation, March 9-22, 1936.

Estimates of snow cover on March 9 and that remaining on March 25 were based on observations given in Water-Supply Paper 799 supplemented by inventories of the total precipitation and runoff during the winter season of 1935-36. Temperatures from December 1935 through February 1936, were substantially below freezing. During this period precipitation over the basin averaged about 5.9 inches, and runoff to March 8 totaled 2.2 inches, leaving a retention of 3.7 inches, which represents the maximum possible snow cover on March 9. Records of snow depths from March 9-12, 1936, at places in and near the basin, as reported in Water-Supply Paper 799, ranged from a trace at Lawrenceville, Pa., to 30 inches measured at C. C. C. Camp 155, 13 miles west of Wellsboro, Pa. The available measurements are inadequate in number and distribution to give accurate indications of the snow cover, but if supplemented by an assumed water content of 25 percent they indicate a mean areal snow cover equivalent to about 2 inches water content. This estimate, which is unduly influenced by measurements made in towns where the cover is not representative, tends to be low and is probably near the minimum possible snow cover. The actual amount was probably within the range of 2.0 inches so determined and 3.7 inches determined as the maximum from an inventory of the precipitation and runoff during the preceding subfreezing season. For the purpose of this analysis the snow cover has been estimated as the average of these two determinations, or 2.85 inches.

The estimate of the amount remaining on March 23 at the conclusion of the flood precipitation period was similarly made. Temperatures after the flood averaged above freezing. During the period March 23 to April 2 the precipitation totaled about 0.3 inch whereas the runoff associated with events of that period totaled 1.45 inches pointing to a contribution of 1.15 inches from snow remaining on March 23. Many observations at Weather Bureau stations, as reported in Water-Supply Paper 799, indicate negligible snow after March 23; snow 2 inches deep was reported at Morris Run, Pa., on March 22. At various Civilian Conservation Corps camps outside the basin, heavier snow cover was reported. Based on this evidence, a net snow cover of 0.8 inch water content on March 23 was estimated. Following is a summary of the precipitation and runoff during the winter season of 1935-36:

Period	Rainfall and runoff (inches)		
	Precipitation	Runoff	Difference
Dec. 1, 1935 to Mar. 6, 1936	5.9	2.2	3.7
Mar. 9-22	6.6	8.2	—1.6
Mar. 23 to Apr. 2	.3	1.45	—1.15
Total	12.8	11.85	0.95

In the first period listed there was substantial snow accumulation, while in the last two the snow cover was depleted. Although some of the

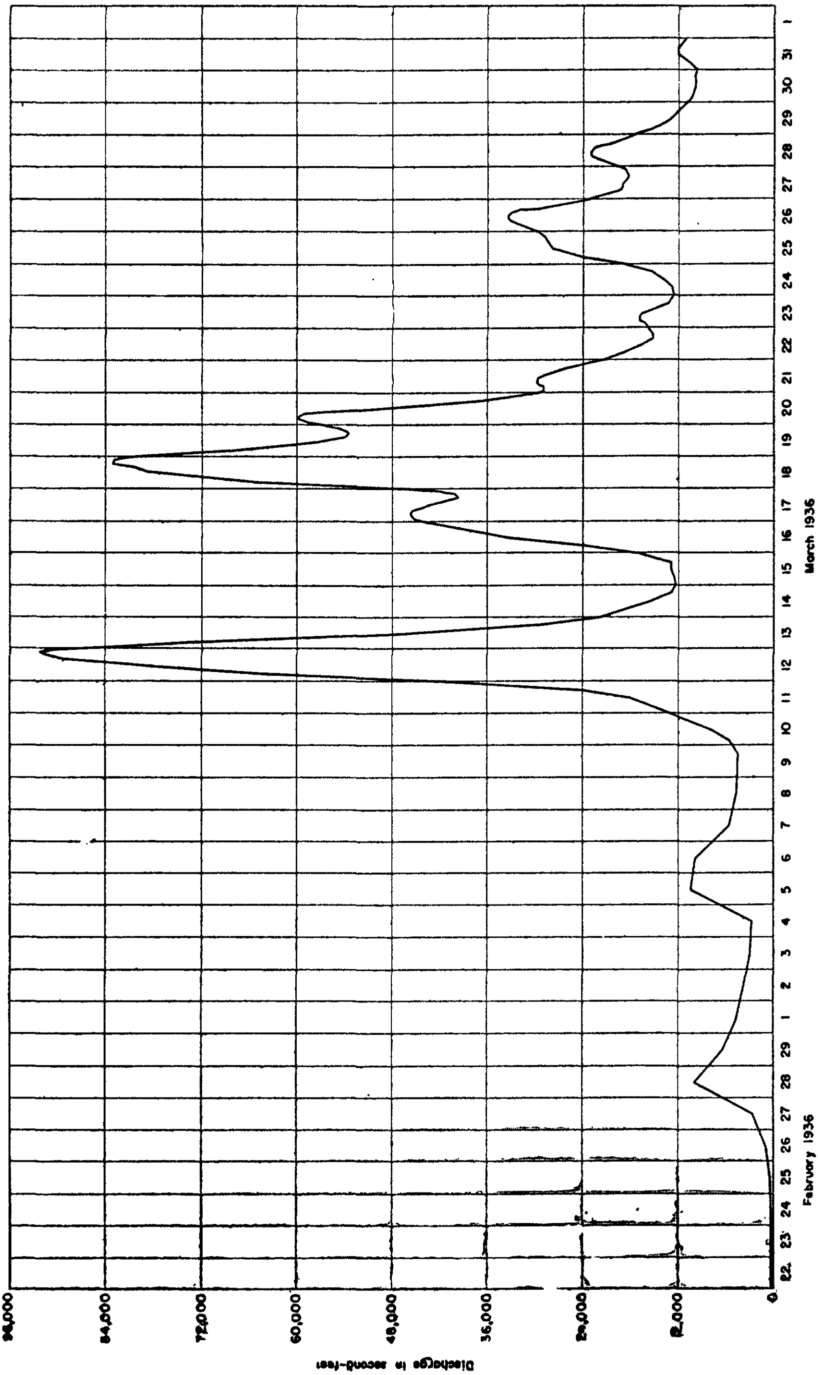

FIGURE 12.—Hydrograph of Chemung River at Chemung, N. Y., showing discharge, March 1936.

precipitation of March 9-22 fell as snow, there was an apparent minimum net thawing of 1.6 inches. The total snow runoff during the flood period reported in table 27 is 2.05 (2.85 −0.8) inches, which allows 0.45 inch of the total seasonal retention of 0.95 inch for soil-moisture accretion and evaporation losses during the flood period—only a small portion of the total amount of water involved.

Discharge at Chemung, N. Y., during the floods of March 1936, is given in table 25 and shown as a hydrograph in figure 12. The amount of direct runoff associated with the first part of the flood period (precipitation period March 9-14, 1936) has been computed as shown in table 26 based on the discharge records in table 25. The total direct runoff was 2.39 inches in comparison with 1.89 inches of precipitation and an estimated snow melt of 1.9 inches, leaving 1.40 inches available for infiltration, ground-water recharge, and evaporation losses. Ground-water runoff during this separate period has not been computed. In contrast to most other parts of the Susquehanna River Basin in March 1936, the Chemung River reached its highest stage during the first storm period, and its peak discharge on March 12 was the highest during the entire record.

The lag interval from center of mass of net supply to the peak discharge and to the center of mass of direct runoff has been computed as shown in table 27. Mean areal precipitation is for the calendar day and is taken from table 24. Estimated daily snow melt has been computed by distributing the total net amount for the flood (2.05 inches) on the basis of the daily excess in temperature above freezing. On certain days temperature and records, as shown in table 21, indicate that some of the precipitation fell as snow and remained as such at midnight of that day. This snowfall has been indicated in table 27 as minus snow melt, as previously explained. On March 13 the snowfall exceeded the thawing but on the following day the reverse was true. The net supply has been estimated on the basis of the total precipitation plus estimated snow melt. The computed lag intervals are 33 hours to the center of mass of direct runoff and 32 hours to the flood peak.

Direct runoff associated with the second precipitation period, March 15-21, as computed in table 28, was 4.00 inches over the basin. This runoff was the result of 4.71 inches of precipitation, some of which fell as snow, and snow melt during the period. Most of the precipitation on March 17, 18, and 19 was in the form of snow because of the localized drop in temperature on those days. By the consequent alleviation of flood stages, this drop in temperature was a saving feature in many areas.

The lag intervals during the second period computed on table 29 were 30 hours to the center of mass of direct runoff and 21 hours to the flood peak. The lag interval to the center of mass of direct runoff agrees closely with that computed for the first part of the flood.

TABLE 22.—*Daily precipitation, in inches, at rain gages in and near Chemung River basin above Chemung, N. Y., March 8-21, 1936*

Station	Altitude (feet)	Weight (percent)[a]	March 8	9	10	11	12	13	14	Total 9–14	15	16	17	18	19	20	21	Total 15–21
New York:																		
Alfred	1,840	0.082	0	0.12	0.01	0.26	0.42	0.22	0.03	1.06	0.02	0.72	1.14	0.60	0.26	0.04	0.39	3.17
Arnot [b]	1,920	.017	0	.17	.01	1.33	.63	.22	.04	2.42	.45	.75	.85	1.25	.77	0	.76	4.83
Burdett	1,030	.021	.10	.03	.23	1.36	.94	.12	0	2.78	.20	.86	.51	.67	.26	0	.65	4.15
Cohocton	1,290	.055	.08	0	0	1.35	.78	.20	.10	2.51	.15	.59	.59	.84	1.22	0	.49	3.88
Elmira	863	.146	0	.22	0	1.05	.50	.37	0	2.14	0	.80	2.25	1.03	.04	0	1.31	5.43
Hammondsport [b]	----------	.055	.05	.07	0	.60	.50	.07	.07	1.36	0	.65	1.64	.22	1.10	0	.60	4.21
Hammondsport	1,300	.055	.10	0	.09	.66	.63	.15	.06	1.75	.21	.76	.67	.86	1.10	.21	.10	3.91
Haskinville	1,620	.079	0	.12	0	.17	.50	.30	.08	1.17	.04	1.04	1.23	.80	.84	0	.33	4.28
Woodhull	1,825	.223	0	.12	.03	1.06	.81	.34	0	2.36	0	1.57	1.15	.81	1.25	0	.26	5.04
Pennsylvania:																		
Lawrenceville	1,000	.177	0	0	.01	.46	.77	.08	.02	1.34	.04	1.26	1.30	.97	.75	0	.45	4.77
Morris Run	1,700	.090	0	.12	.04	1.19	1.06	.05	0	2.46	.04	1.54	1.45	1.49	.55	.02	.64	5.73
Average or total	----------	1.000	0.02	0.09	0.02	0.83	0.71	0.21	0.01	1.89	0.06	1.17	1.19	0.94	0.81	0.03	0.51	4.71

[a] Percent of total Chemung River drainage area, determined by Thiessen method.
[b] Recording gage.

TABLE 23.—*Daily mean temperature*[a], *Chemung River at Chemung, N. Y., February 8 to March 8, 1936*

Day	Mean temperature (°F.)	Day	Mean temperature (°F.)
Feb.		*Feb.*	
8	15	23	12
9	22	24	26
10	8	25	44
11	9	26	38
12	13	27	38
13	15	28	25
14	27	29	26
15	27	*Mar.*	
16	22	1	21
17	23	2	19
18	12	3	31
19	1	4	40
20	6	5	33
21	9	6	19
22	9	7	24
		8	28
Mean			23

[a] Average of recorded daily maximum and minimum temperatures at Alfred and Elmira, N. Y., and Lawrenceville, Pa.

TABLE 24.—*Daily mean areal precipitation and temperatures, Chemung River basin, March 8-22, 1936*

March	Mean areal precipitation [a] (inches)	Temperature: Maximum [b] (°F.)	Minimum [b] (°F.)	Mean [c] (°F.)
8	0.02	39	16	28
9	.09	42	34	38
10	.02	50	32	41
11	.83	48	38	43
12	.71	45	32	38
13	.21	34	22	28
14	.01	44	24	34
15	.06	56	28	42
16	1.17	49	33	41
17	1.19	34	29	31
18	.94	36	30	33
19	.81	37	30	34
20	.03	50	25	37
21	.51	42	30	36
22	0	44	29	36
	6.60	43	29	36

[a] Midnight to midnight.
[b] Average of readings at Alfred, Elmira, and Woodhull, N. Y., and Lawrenceville, Pa.
[c] Average of maximum and minimum.

TABLE 25.—*Gage height and discharge of the Chemung River at Chemung, N. Y., during flood of March 1936*

MEAN DISCHARGE, IN SECOND-FEET, 1936

Day	Feb.	Mar.	Apr.	Day	Feb.	Mar.	Apr.	Day	Feb.	Mar.	Apr.
1	440	4,660	8,930	11	380	19,400	5,830	21	320	27,400	3,140
2	440	3,800	8,130	12	380	74,900	7,580	22	320	17,200	3,420
3	420	2,970	9,710	13	360	51,200	10,700	23	300	15,200	3,140
4	420	2,830	6,290	14	360	15,700	8,930	24	300	14,200	2,560
5	440	10,500	5,070	15	360	13,300	7,630	25	400	26,000	2,200
6	420	10,000	6,000	16	380	32,000	6,390	26	950	30,500	2,000
7	420	5,570	9,580	17	380	43,200	5,070	27	2,600	19,400	1,860
8	400	4,560	6,550	18	380	72,200	4,360	28	10,000	21,100	1,680
9	380	4,560	5,490	19	380	61,900	3,890	29	6,360	13,400	1,680
10	380	7,740	5,280	20	340	48,100	3,510	30	--------	10,000	2,000
								31	--------	11,300	--------
Mean monthly discharge, in second-feet									1,014	22,410	5,287
Runoff, in inches									.43	10.22	2.33

TABLE 25.—*Gage height and discharge of the Chemung River at Chemung, N. Y., during flood of March 1936—Continued*

GAGE HEIGHT, IN FEET, AND DISCHARGE, IN SECOND-FEET, AT INDICATED TIME, 1936

Hour	Feet	Sec.-ft.	Feet	Sec.-ft.	Feet	Sec.-ft.	Feet	Sec.-ft.	Feet	Sec.-ft.	Feet	Sec.-ft.
	March 8		March 9		March 10		March 11		March 12		March 13	
2	--------	--------	--------	--------	--------	--------	7.80	10,700	15.00	48,500	19.10	87,100
4	--------	--------	--------	--------	5.94	5,800	7.95	11,200	16.00	57,000	18.50	81,000
6	5.38	--------	5.33	--------	--------	--------	8.33	12,300	16.75	63,800	17.70	73,000
8	--------	--------	--------	--------	6.37	6,800	8.60	13,100	17.30	69,000	16.80	64,200
10	--------	--------	--------	--------	--------	--------	9.25	15,600	17.77	73,700	15.80	55,200
12 m.	5.17	[a]4,560	5.23	[a]4,560	6.73	7,710	9.87	18,100	18.20	78,000	14.70	46,100
2	--------	--------	--------	--------	--------	--------	10.25	19,600	18.65	82,500	13.75	38,800
4	--------	--------	--------	--------	7.04	8,540	10.73	21,600	19.00	86,000	12.90	33,400
6	5.31	--------	5.24	--------	--------	--------	11.25	24,200	19.30	89,300	12.20	29,200
8	--------	--------	--------	--------	7.40	9,530	11.90	27,500	19.50	91,500	11.63	26,200
10	--------	--------	--------	--------	--------	--------	12.80	32,800	19.57	92,300	11.15	23,800
12 p.m.	5.41	--------	5.62	--------	7.66	10,300	14.10	41,300	19.43	90,700	10.75	21,800
	March 14		March 15		March 16		March 17		March 18		March 19	
2	10.40	20,200	8.38	12,400	10.00	18,600	14.58	45,100	15.30	50,900	18.23	78,300
4	10.13	19,100	8.40	12,500	10.55	20,800	14.63	45,500	16.20	58,800	17.77	73,700
6	9.90	18,200	8.42	12,600	11.20	24,000	14.64	45,600	16.90	65,100	17.26	68,600
8	9.60	17,000	8.46	12,700	11.80	27,000	14.60	45,300	17.48	70,800	16.77	63,900
10	9.43	16,300	8.51	12,800	12.43	30,600	14.53	44,700	17.86	74,600	16.41	60,700
12 m.	9.18	15,300	8.53	12,900	12.95	33,700	14.40	43,700	18.10	77,000	16.05	57,400
2	8.93	14,300	8.53	12,900	13.42	36,500	14.20	42,100	18.28	78,800	15.80	55,200
4	8.70	13,400	8.53	12,900	13.66	38,100	13.99	40,400	18.43	80,300	15.66	53,900
6	8.52	12,900	8.67	13,300	13.88	39,700	13.86	39,500	18.55	81,500	15.60	53,400
8	8.43	12,600	8.90	14,200	14.12	41,500	13.92	39,900	18.70	83,000	15.64	53,800
10	8.38	12,400	9.28	15,700	14.33	43,100	14.17	41,900	18.69	82,900	15.76	54,800
12 p.m.	8.37	12,400	9.56	16,800	14.49	44,400	14.60	45,300	18.53	81,300	15.94	56,500
	March 20		March 21		March 22		March 23		March 24		March 25	
2	16.13	58,200	12.15	28,900	10.40	20,200	9.35	16,000	8.39	12,500	10.31	19,800
4	16.27	59,400	12.13	28,800	10.20	19,400	9.46	16,400	8.42	12,600	10.75	21,800
6	16.32	59,900	12.21	29,300	10.04	18,800	9.57	16,900	8.46	12,700	11.22	24,100
8	16.24	59,200	12.28	29,700	9.89	18,200	9.61	17,000	8.54	12,900	11.52	25,600
10	15.96	56,600	12.29	29,700	9.70	17,400	9.55	16,800	8.65	13,200	11.77	26,800
12 m.	15.43	51,900	12.18	29,100	9.47	16,500	9.39	16,200	8.77	13,700	11.94	27,700
2	14.70	46,100	12.02	28,100	9.26	15,600	9.15	15,200	8.90	14,200	12.02	28,100
4	14.05	40,900	11.81	27,000	9.17	15,300	8.92	14,300	9.04	14,800	12.05	28,300
6	13.45	36,700	11.56	25,800	9.16	15,200	8.68	13,300	9.19	15,400	12.09	28,500
8	12.95	33,700	11.27	24,400	9.18	15,300	8.55	13,000	9.36	16,000	12.12	28,700
10	12.57	31,400	10.97	22,800	9.24	15,600	8.48	12,700	9.60	17,000	12.19	29,100
12 p.m.	12.28	29,700	10.65	21,200	9.29	15,800	8.41	12,500	9.95	18,400	12.28	29,700
	March 26		March 27		March 28		March 29		March 30		March 31	
2	12.37	30,200	10.68	21,400	10.42	20,300	--------	--------	--------	--------	7.51	9,840
4	12.50	31,000	10.42	20,300	10.64	21,200	9.23	15,500	7.69	10,400	7.63	10,200
6	12.67	32,000	10.28	19,700	10.82	22,100	--------	--------	--------	--------	7.75	10,600
8	12.81	32,900	10.20	19,400	10.95	22,800	8.87	14,100	7.57	10,000	7.89	11,000
10	12.90	33,400	10.15	19,200	11.00	23,000	--------	--------	--------	--------	8.09	11,600
12 m.	12.91	33,500	10.09	19,000	11.01	23,000	8.61	13,100	7.53	9,900	8.25	12,000
2	12.82	32,900	10.02	18,700	10.92	22,600	--------	--------	--------	--------	8.32	12,300
4	12.60	31,600	9.93	18,300	10.73	21,600	8.34	12,300	7.52	9,870	8.30	12,200
6	12.28	29,700	9.92	18,300	10.51	20,600	--------	--------	--------	--------	8.21	11,900
8	11.87	27,400	9.97	18,500	10.25	19,600	8.08	11,500	7.50	9,810	8.13	11,700
10	11.42	25,100	10.02	18,700	9.93	18,300	--------	--------	--------	--------	8.03	11,400
12 p.m.	11.02	23,100	10.22	19,500	9.68	17,300	7.86	10,900	7.47	9,730	7.90	11,000

[a] Mean for the day.

LOCATION.—Water-stage recorder, lat. 42°00′10″, long. 76°38′00″, just below highway bridge three-quarters of a mile southwest of Chemung, Chemung County.

DRAINAGE AREA.—2,530 square miles.

REMARKS.—Records published in Geol. Survey Water-Supply Paper 799.

TABLE 26.—*Computation of volume of direct runoff associated with precipitation period March 9-14, 1936, Chemung River at Chemung, N. Y.*

March	Daily mean discharge (second-feet)	Estimated recession from preceding storm and base runoff (second-feet)	Direct runoff (second-feet)
9	4,560	4,150	410
10	7,740	2,750	4,990
11	19,400	2,500	16,900
12	74,900	2,900	72,000
13	51,200	3,300	47,900
14	[a]15,000	3,700	11,300
15	[a]9,000	4,000	5,000
16	[a]6,800	4,300	2,500
17	[a]5,800	4,600	1,200
18	[a]5,400	5,000	400
Total Sec.-ft.-days	199,800	37,200	162,600 (= 2.39 inches)

[a] Estimated recession under subsequent rise.

TABLE 27.—*Computation of time of center of mass of net supply, and lag intervals, Chemung River at Chemung, N. Y., March 8-14, 1936*

March	Mean areal precipitation (inches)	Estimated snow melt (inches)	Precipitation plus snow melt (inches)	Net supply (inches)	Time from origin (days)	Product (inch-days)
8	0.02	0.09	0.11	0	0	0
9	.09	.35	.44	.26	1	.26
10	.02	.53	.55	.30	2	.60
11	.83	.65	1.48	1.02	3	3.06
12	.71	.35	1.06	.70	4	2.80
13	.21	[a].14	.07	.02	5	.10
14	.01	[a].22	.23	.09	6	.54
	1.89	2.05	3.94	2.39	....	7.36

[a] Estimated result of snowfall and thawing.

Center of mass of net supply occurred $\frac{7.36}{2.39} = 3.08$ days after 12 noon of March 8 = March 11.58.

Time of center of mass of direct runoff was at March 12.96 or 1.38 days (33 hours) after center of mass of net supply.

Peak discharge occurred at 10 p.m. March 12 or 1.34 days (32 hours) after center of mass of net supply.

TABLE 28.—*Computation of volume of direct runoff associated with precipitation period March 15-22, 1936, Chemung River at Chemung, N. Y.*

March	Daily mean discharge (second-feet)	Estimated recession from preceding storm and base runoff (second-feet)	Direct runoff (second-feet)
15	13,300	9,000	4,300
16	32,000	6,800	25,200
17	43,200	5,800	37,400
18	72,200	5,400	66,800
19	61,900	5,500	56,400
20	48,100	5,900	42,200
21	27,400	6,100	21,300
22	[a]16,500	6,100	10,400
23	[a]10,700	6,000	4,700
24	[a]8,200	6,000	2,200
25	[a]6,900	5,900	1,000
26	[a]6,300	5,800	500
Total Sec.-ft.-days	346,700	74,300	272,400 (= 4.00 inches over basin)

[a] Estimated recession under subsequent rise.

TABLE 29.—*Computation of time of center of mass of net supply, and lag intervals, Chemung River at Chemung, N. Y., March 15-21, 1936*

March	Mean areal precipitation (inches)	Estimated snow melt (inches)	Precipitation plus snow melt (inches)	Net supply (inches)	Time from origin (days)	Product (inch-days)
15	0.06	[a]0.46	0.52	0.42	0	0
16	1.17	.41	1.58	1.40	1	1.40
17	1.19	[a].67	.52	.42	2	.84
18	.94	[a].25	.69	.57	3	1.71
19	.81	[a].15	.66	.57	4	2.28
20	.03	.15	.18	.12	5	.60
21	.51	[a].05	.56	.50	6	3.00
	4.71	0	0.71	4.00	....	9.83

[a] Estimated result of snowfall and thawing.

Center of mass of net supply occurred $\frac{9.83}{4.00}$ = 2.46 days after 12 noon of March 15 = March 17.96

Time of center of mass of direct runoff was at March 19.21 or 1.25 days (30 hours) after center of mass of net supply.

Peak discharge occurred at 8 p.m. March 18 or 0.87 days (21 hours) after center of mass of net supply.

SUSQUEHANNA RIVER AT WILKES-BARRE, PA.

Calendar-day precipitation during the flood of March 1936 at rain gages in and near the Susquehanna River Basin above Wilkes-Barre, Pa., listed in table 30, was computed from daily readings at the indicated gages, which were adjusted to a midnight-to-midnight, or calendar-day, basis using as a guide the autographic records of hourly precipitation at Binghamton and Ithaca, N. Y., and at Clarion and Scranton, Pa. For the purpose of combining these daily amounts to compute daily mean areal precipitation, the several stations were assigned the Thiessen weights indicated in table 30. In this table, 25 rain gages are listed, an average of 1 for each 400 square miles of the area, although the gage at Towanda, Pa., covers an area of 890 square miles. However, since the storm rainfall, as shown in figure 11, was fairly uniform, the basin average may not be greatly in error, being 5.65 inches, of which the greatest daily amount, 1.13 inches, fell on March 17.

Daily mean precipitation and daily maximum, minimum, and mean temperatures during the flood period are summarized in table 32. The temperature over the basin averaged 39° F., being below freezing only on 1 day, March 13. It should be noted, however, that the Susquehanna River Basin above Chemung, N. Y., averaged 36.5° F. (2.5° colder) during the period March 9-22, and that temperatures on March 17-19 in the Chemung River Basin were substantially lower than in the remainder of the basin above Wilkes-Barre.

Temperatures during the 30-day antecedent period, February 8 to March 8, as shown in table 31, averaged 10° F. below freezing, although during the latter part of this period there were 6 days that averaged above freezing. No specific information about frost penetration is available.

Fragmentary observations of snow depth made on or about March 9, as reported in Water-Supply Paper 799, indicate a depth of snow over the basin equivalent to 2.6 inches average water content. However, during the subfreezing period December 1 to March 8, there was a total precipitation of 7.4 inches and a total runoff of 3.65 inches, indicating a retention of 3.75 inches, of which a large part probably remained as snow cover, which on March 9 was estimated as 3.0 inches, intermediate between the two limits above defined.

Many observations at Weather Bureau stations in the basin reported negligible snow remaining at the conclusion of the storm period, although several Civilian Conservation Corps camps there reported snow depths ranging as high as 9 inches (water content unknown), and some outside the basin reported even heavier cover. However, during the period March 23 to April 5 while temperatures were generally above freezing, precipitation amounted to 0.6 inch and runoff was 0.7 inch indicating a minimum contribution from remaining snow of 0.1 inch, which from available evidence, was estimated at 0.45 inch water content. The snow-runoff contribution to the flood was therefore 2.55 inches (3.0–0.45).

The following is a summary of rainfall and runoff during the winter season of 1935-36:

Period	Rainfall and runoff (inches)		
	Precipitation	Runoff	Difference
Dec. 1, 1935, to Mar. 8, 1936	7.4	3.65	3.75
Mar. 9–22	5.65	8.45	—2.8
Mar. 23 to Apr. 5	.6	.70	— .1
	13.65	12.80	0.85

A hydrograph of river discharge at Wilkes-Barre, Pa., during the flood period, based on data given in table 33, is shown on figure 13. Direct runoff associated with the first precipitation period, March 9-15, as computed in table 34 was 2.83 inches. Precipitation during this period was 1.51 inches, and snow melt as indicated in table 35, was estimated at 2.10 inches, leaving a residual of 0.78 inch available for ground-water recharge, soil-moisture accretion, and evaporation losses. The estimated daily snow melt given in tables 35 and 37, was computed by distributing the amount on the basis of the degree-days above 32° F. and deducting the snowfall as a negative snow melt so that the total net result equaled 2.55 inches. The snowfall was estimated by reference to data in table 21 and by inspection of the temperature and precipitation records. On March 13 and 17 the snowfall over the basin exceeded the snow melt.

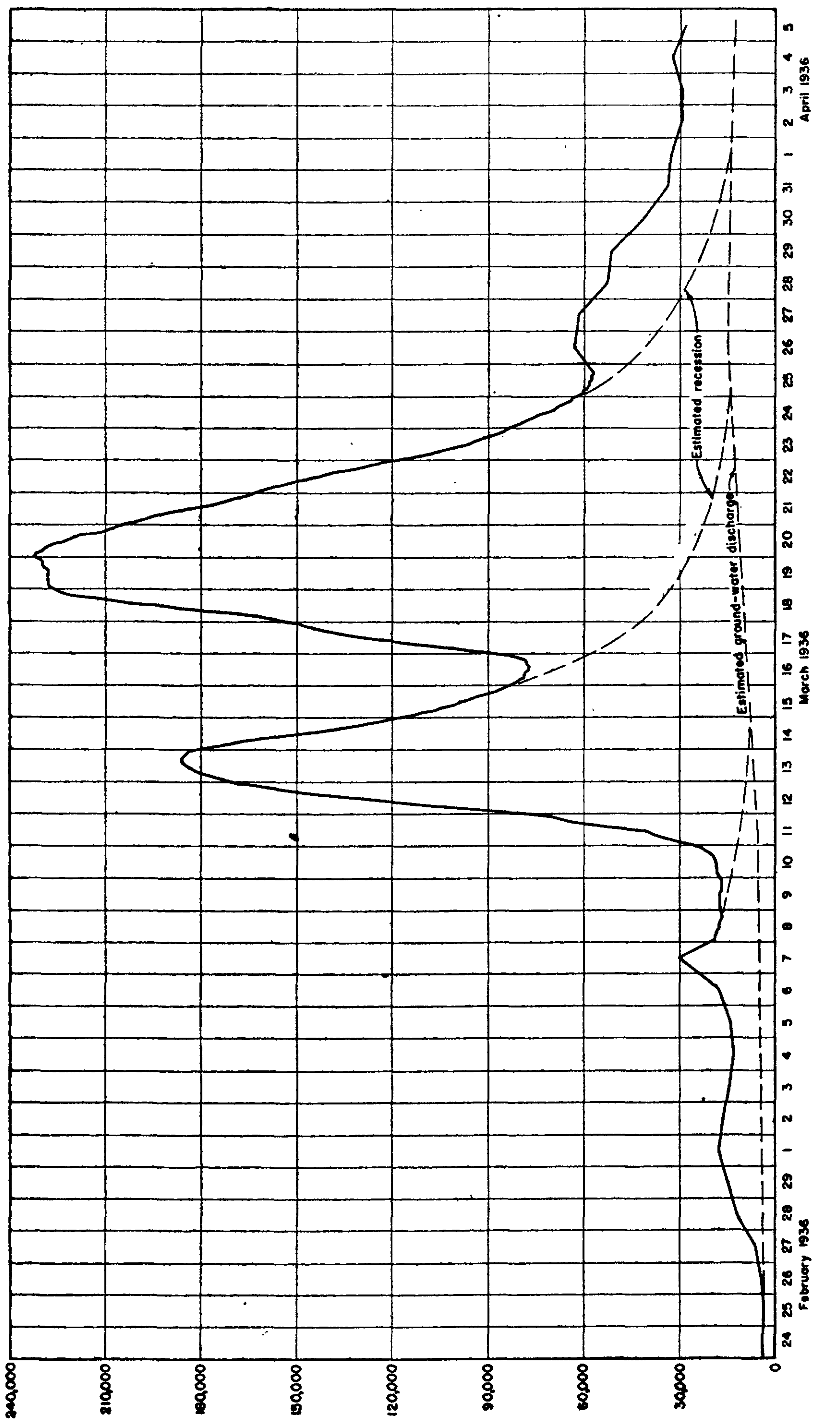

FIGURE 13.—Hydrograph of Susquehanna River at Wilkes-Barre, Pa., showing discharge, March 1936.

TABLE 30.—*Daily precipitation, in inches, at rain gages in and near Susquehanna River basin at Wilkes-Barre, Pa., March 9-21, 1936*

Station	Weight (percent)	March														
		9	10	11	12	13	14	15	Total 9–15	16	17	18	19	20	21	Total 16–21
New York:																
Alfred	3.23	0.12	0.01	0.26	0.42	0.22	0.03	0.02	1.08	0.72	1.14	1.60	0.26	0.04	0.39	3.15
Angelica	.04	.22	--------	.29	.46	.11	.02	.03	1.13	.61	1.76	.70	.50	--------	.32	3.89
Bainbridge	3.95	.35	.11	.19	.44	.22	.08	.02	1.41	.68	.88	.50	.42	--------	.60	3.08
Binghamton	7.98	.34	.03	.17	.48	.04	.02	--------	1.08	1.13	.40	1.38	.95	--------	.63	4.49
Cooperstown	6.80	.83	--------	.08	.37	.23	.09	.05	1.65	1.01	.87	.65	.31	--------	.22	3.06
Cortland	5.77	.34	--------	.21	.78	.31	.11	--------	1.75	.85	1.40	1.07	.35	--------	.60	4.27
Delhi	.83	.32	--------	.13	.53	.14	--------	.04	1.16	.64	1.00	.74	.16	--------	.49	3.03
Elmira	7.07	.22	--------	1.05	.50	.37	--------	--------	2.14	.80	2.25	1.03	.04	--------	1.31	5.43
Haskinville	5.50	.12	--------	.17	.50	.30	.08	.04	1.21	1.04	1.23	.80	.84	--------	.33	4.24
Ithaca	3.15	.16	--------	.57	.54	.15	.06	--------	1.48	1.00	1.18	1.02	.85	--------	.68	4.73
Morrisville	3.49	.17	--------	.15	.25	.15	.07	--------	.79	.22	.70	.96	.26	--------	.35	2.49
Norwich	3.92	.75	--------	.15	.46	.20	.13	.10	1.79	1.28	.64	.72	.21	--------	.35	3.10
Oneonta	3.64	.63	--------	.11	.41	.12	.05	.05	1.37	.68	.58	.70	.35	--------	.64	2.95
Sherburne	3.61	.34	.09	.26	.34	.16	.07	.05	1.31	.71	.70	.44	.35	--------	.29	2.49
Syracuse	.15	.09	--------	.17	.71	.31	.04	.05	1.37	.71	.69	.79	.43	--------	.58	3.20
Pennsylvania:																
Galeton	1.79	.14	.09	1.54	.42	.10	.11	.07	2.47	1.41	2.00	.94	.88	.15	2.69	8.07
Lawrenceville	6.00	--------	.01	.46	.77	.08	.02	.04	1.38	1.26	1.30	.97	.75	--------	.45	4.77
Montrose	6.27	--------	--------	.35	.58	.15	.06	.02	1.16	.43	1.10	1.20	.50	--------	.41	3.64
Morris Run	3.99	.12	.04	1.19	1.06	.05	--------	.04	2.50	1.54	1.45	1.49	.55	.02	.64	5.69
Muncy Valley	.79	--------	.02	.78	1.20	.14	.05	.03	2.22	.20	1.30	1.08	.32	.10	.70	3.70
Pleasant Mt.	3.52	--------	--------	.93	.53	.13	.12	.02	1.73	1.00	1.60	1.60	1.08	--------	.56	5.84
Scranton	5.12	.01	--------	.26	.40	.05	.05	--------	.77	.66	.74	.75	.65	--------	.91	3.71
Towanda	8.94	.13	--------	.70	.75	.04	--------	.04	1.66	1.16	1.47	1.19	.41	--------	.64	4.87
Wellsboro	1.45	.06	.05	.93	.76	.09	.04	.10	2.03	1.22	1.44	.92	.58	.05	.27	4.48
Wilkes-Barre	3.00	--------	.03	.46	.44	.11	.03	--------	1.07	.40	.76	.76	.61	--------	.25	2.78
Average or total	100.00	0.24	0.02	0.44	0.56	0.15	0.06	0.03	1.50	0.90	1.18	0.97	0.48	0.01	0.61	4.15

Direct runoff during the second period totaled 4.38 inches, as a result of 4.15 inches of precipitation and 0.45 inch of snow melt leaving a retention of 0.22 inch.

Ground-water runoff from the entire storm period was approximately 1.25 inches in comparison with a total retention of 1.0 inch, indicating an inconsistency in basic data of at least 0.25 inch.

The lag intervals between center of mass of net supply and center of mass of direct runoff, as computed in tables 35 and 37, were 67 and 70 hours for the first and second flood periods, respectively.

TABLE 31.—*Daily mean temperature*[a] *during 30-day period preceding storm period March 9-21, 1936, Susquehanna River at Wilkes-Barre, Pa.*

Day	Mean temperature (°F.)	Day	Mean temperature (°F.)
Feb.		*Feb.*	
8	11	23	14
9	21	24	29
10	6	25	46
11	9	26	40
12	13	27	39
13	14	28	26
14	25	29	30
15	27	*Mar.*	
16	24	1	20
17	27	2	21
18	15	3	33
19	3	4	42
20	8	5	34
21	11	6	20
22	12	7	25
		8	30
Mean			22

[a] Average of recorded daily maximum and minimum temperatures at Binghamton and Elmira, N. Y., and Scranton and Towanda, Pa.

TABLE 32.—*Daily mean areal precipitation, and temperatures, Susquehanna River at Wilkes-Barre, Pa., March 9-22, 1936*

March	Mean areal precipitation [a] (inches)	Temperature: Maximum [b] (°F.)	Temperature: Minimum [b] (°F.)	Temperature: Average [c] (°F.)
9	0.24	42	31	37
10	.02	50	32	41
11	.44	49	38	44
12	.56	47	33	40
13	.15	37	26	31
14	.06	43	27	35
15	.03	58	30	44
16	.90	52	34	43
17	1.18	50	32	41
18	.97	45	33	39
19	.48	42	33	38
20	.01	53	28	40
21	.61	46	31	38
22	0	47	30	38
	5.65	47	31	39

[a] Midnight to midnight.
[b] Average of readings in Chemung River Basin and at Norwich, N. Y., and at Mt. Pocono and Towanda, Pa.
[c] Average of maximum and minimum.

TABLE 33.—*Gage height and discharge of the Susquehanna River at Wilkes-Barre, Pa., during flood of March 1936*

MEAN DISCHARGE, IN SECOND-FEET, 1936

Day	Feb.	Mar.	Apr.	Day	Feb.	Mar.	Apr.	Day	Feb.	Mar.	Apr.
1	5,700	17,700	33,000	11	4,600	48,800	29,200	21	3,900	184,000	19,700
2	5,600	16,100	29,200	12	4,500	129,000	31,400	22	4,100	144,000	18,900
3	5,400	14,300	29,800	13	4,400	182,000	34,700	23	3,900	99,000	18,500
4	5,300	12,900	32,500	14	4,300	150,000	45,200	24	3,800	72,300	17,700
5	5,200	14,000	28,200	15	4,500	99,400	41,300	25	3,700	59,000	15,700
6	5,100	17,600	28,200	16	4,200	80,200	37,100	26	4,200	63,500	14,000
7	5,000	30,100	32,000	17	4,400	125,000	32,000	27	6,000	62,200	12,600
8	4,900	17,700	37,100	18	4,400	192,000	27,200	28	12,000	52,800	11,600
9	4,750	17,100	33,600	19	4,200	229,000	23,800	29	15,000	51,700	10,700
10	4,700	19,900	30,300	20	4,000	221,000	21,500	30	--------	41,200	10,100
								31	--------	33,900	--------
Mean monthly discharge, in second-feet									5,233	80,560	26,230
Runoff, in inches									.57	9.33	2.93

GAGE HEIGHT, IN FEET, AND DISCHARGE, IN SECOND-FEET, AT INDICATED TIME, 1936

Hour	Feet	Sec.-ft.	Feet	Sec.-ft	Feet	Sec.-ft.	Feet	Sec.-ft.	Feet	Sec.-ft.	Feet	Sec.-ft.
	March 8		March 9		March 10		March 11		March 12		March 13	
2	7.84	18,900	7.40	17,300	7.47	17,700	9.96	29,200	18.27	86,100	27.68	174,000
4	7.78	18,900	7.45	17,300	7.55	18,100	10.64	32,500	19.55	96,900	27.98	178,000
6	7.68	18,500	7.43	17,300	7.62	18,100	11.13	35,300	20.65	106,000	28.20	180,000
8	7.55	18,100	7.42	17,300	7.69	18,500	11.56	38,300	21.73	115,000	28.35	182,000
10	7.48	17,700	7.40	17,300	7.74	18,500	11.93	40,100	22.72	125,000	28.52	183,000
12 m.	7.48	17,700	7.38	17,300	7.80	18,900	12.55	44,500	23.56	133,000	28.66	185,000
2	7.40	17,300	7.34	16,900	7.90	19,300	13.72	51,800	24.35	141,000	28.75	186,000
4	7.30	16,900	7.30	16,900	8.03	19,700	14.70	58,700	25.08	148,000	28.80	186,000
6	7.24	16,500	7.29	16,900	8.24	20,600	15.35	63,700	25.74	154,000	28.80	186,000
8	7.24	16,500	7.30	16,900	8.55	22,400	15.78	66,600	26.30	160,000	28.73	185,000
10	7.26	16,900	7.33	16,900	8.94	23,750	16.29	70,400	26.78	165,000	28.58	184,000
12 p.m.	7.32	16,900	7.40	17,300	9.38	26,200	17.12	76,500	27.24	169,000	28.35	182,000
	March 14		March 15		March 16		March 17		March 18		March 19	
2	28.02	178,000	21.61	115,000	17.78	82,000	19.13	92,600	26.16	159,000	32.75	228,000
4	27.62	173,000	21.20	111,000	17.59	80,400	20.08	101,000	26.59	163,000	32.78	228,000
6	27.13	168,000	20.84	107,000	17.45	78,900	20.91	108,000	27.19	169,000	32.77	228,000
8	26.55	163,000	20.48	105,000	17.35	78,900	21.74	115,000	27.95	178,000	32.77	228,000
10	25.92	156,000	20.11	101,000	17.30	78,100	22.48	123,000	28.78	186,000	32.78	228,000
12 m.	25.30	150,000	19.78	98,600	17.25	77,300	23.09	129,000	29.54	193,000	32.80	228,000
2	24.68	144,000	19.47	96,000	17.25	77,300	23.64	133,000	30.36	203,000	32.85	228,000
4	24.09	138,000	19.16	93,500	17.26	78,100	24.17	139,000	31.00	209,000	32.90	229,000
6	23.52	132,000	18.82	90,200	17.33	78,100	24.65	143,000	31.54	214,000	32.97	230,000
8	23.00	128,000	18.52	87,700	17.52	79,600	25.03	147,000	32.10	221,000	33.00	230,000
10	22.50	123,000	18.23	85,200	17.88	82,800	25.32	150,000	32.42	224,000	33.05	230,000
12 p.m.	22.06	119,000	17.98	83,600	18.40	86,900	25.67	154,000	32.62	226,000	33.06	232,000
	March 20		March 21		March 22		March 23		March 24		March 25	
2	33.07	232,000	30.28	202,000	26.35	161,000	21.70	115,000	17.78	82,000	15.04	60,800
4	33.00	230,000	30.03	198,000	26.08	158,000	21.23	111,000	17.54	79,600	14.91	60,100
6	32.90	229,000	29.73	195,000	25.80	155,000	20.77	107,000	17.29	78,100	14.81	59,400
8	32.75	228,000	29.38	192,000	25.51	152,000	20.35	104,000	17.04	75,700	14.74	58,700
10	32.57	226,000	28.95	188,000	25.20	149,000	20.00	100,000	16.76	74,200	14.66	58,700
12 m.	32.34	223,000	28.63	184,000	24.84	145,000	19.61	96,900	16.52	71,900	14.61	58,000
2	32.10	221,000	28.25	180,000	24.45	141,000	19.31	94,400	16.24	69,600	14.56	58,000
4	31.81	218,000	27.86	176,000	24.04	137,000	19.03	91,800	15.98	68,100	14.53	57,300
6	31.44	213,000	27.52	172,000	23.59	133,000	18.75	90,200	15.75	66,600	14.53	57,300
8	31.12	210,000	27.18	169,000	23.09	129,000	18.48	87,700	15.54	64,400	14.57	58,000
10	30.85	207,000	26.89	166,000	22.62	124,000	18.24	85,200	15.35	63,700	14.68	58,700
12 p.m.	30.55	205,000	26.61	163,000	22.15	120,000	18.01	83,600	15.17	62,300	14.83	59,400

LOCATION.—Water-stage recorder, lat. 41°15′00″, long. 75°53′10″, at Market Street Bridge at Wilkes-Barre, Luzerne County. Zero of gage is 511.94 feet above mean sea level.
DRAINAGE AREA.—9,960 square miles.
REMARKS.—Records published in Geol. Survey Water-Supply Paper 799.

TABLE 34.—*Computation of volume of direct runoff associated with precipitation period March 9-15, 1936, Susquehanna River at Wilkes-Barre, Pa.*

March	Daily mean discharge (second-feet)	Estimated recession from preceding storm and base runoff (second-feet)	Direct runoff (second-feet)
9	17,100	15,000	2,100
10	19,900	12,500	7,400
11	48,800	11,000	37,800
12	129,000	10,000	119,000
13	182,000	9,000	174,000
14	150,000	8,000	142,000
15	99,400	8,000	91,400
16	[a]69,000	9,000	60,000
17	[a]50,000	9,000	41,000
18	[a]37,000	9,000	28,000
19	[a]30,000	10,000	20,000
20	[a]25,000	10,000	15,000
21	[a]20,500	11,000	9,500
22	[a]19,000	12,000	7,000
23	[a]15,500	13,000	2,500
24	[a]14,500	14,000	500
Total Sec.-ft.-days	926,700	169,500	757,200 (= 2.83 inches)

[a] Estimated recession under subsequent rise.

TABLE 35.—*Computations of time of center of mass of net supply, and lag intervals, Susquehanna River at Wilkes-Barre, Pa., March 9-15, 1936*

March	Mean areal precipitation (inches)	Estimated snow melt (inches)	Precipitation plus snow melt (inches)	Net supply (inches)	Time from origin (days)	Product (inch-days)
9	0.24	0.20	0.44	0.32	0	0
10	.02	.48	.50	.39	1	.39
11	.45	.69	1.14	.95	2	1.90
12	.56	[a].29	.85	.71	3	2.13
13	.15	[a]—.04	.11	.05	4	.20
14	.06	[a].05	.11	.04	5	.20
15	.03	[a].43	.46	.37	6	2.22
	1.51	2.10	3.61	2.83	....	7.04

[a] Estimated result of snowfall and thawing.

Center of mass of net supply occurred $\frac{7.04}{2.83}$ = 2.49 days after noon of March 9 = March 11.99.

Time of center of mass of direct runoff was at March 14.79 or 2.80 days (67 hours) after center of mass of net supply.

Peak discharge occurred at March 13.67 or 1.68 days (40 hours) after center of mass of net supply.

TABLE 36.—*Computation of volume of direct runoff associated with precipitation period March 16-21, 1936, Susquehanna River at Wilkes-Barre, Pa.*

March	Daily mean discharge (second-feet)	Estimated recession from preceding storm and base runoff (second-feet)	Direct runoff (second-feet)
16	80,200	69,000	11,200
17	125,000	50,000	75,000
18	192,000	37,000	155,000
19	229,000	30,000	199,000
20	221,000	25,000	196,000
21	184,000	20,500	163,500
22	144,000	19,000	125,000
23	99,000	15,500	83,500
24	72,300	14,500	57,800
25	[a]52,000	15,000	37,000
26	[a]42,000	15,000	27,000
27	[a]33,000	15,000	18,000
28	[a]27,000	15,000	12,000
29	[a]22,500	15,000	7,500
30	[a]18,500	14,000	4,500
31	[a]16,000	14,000	2,000
Total Sec.-ft.-days	1,557,500	383,500	1,174,000 (= 4.38 inches)

[a] Estimated recession under subsequent rise.

TABLE 37.—*Computation of time of center of mass of net supply, and lag intervals, Susquehanna River at Wilkes-Barre, Pa., March 16-21, 1936*

March	Mean areal precipitation (inches)	Estimated snow melt (inches)	Precipitation plus snow melt (inches)	Net supply (inches)	Time from origin (days)	Product (inch-days)
16	0.90	0.33	1.23	1.17	0	0
17	1.18	[a].04	1.14	1.10	1	1.10
18	.97	[a].00	.97	.93	2	1.86
19	.48	[a].03	.51	.48	3	1.44
20	.01	[a].10	.11	.09	4	.36
21	.61	[a].03	.64	.61	5	3.05
	4.15	0.45	4.60	4.38	....	7.81

[a] Estimated result of snowfall and thawing.

Center of mass of net supply occurred $\frac{7.81}{4.38}$ = 1.78 days after noon of March 16 = 18.28.

Time of center of mass of direct runoff was at March 21.20 or 2.92 days (70 hours) after center of mass of net supply.

Peak discharge occurred at March 20.08 or 1.80 days (43 hours) after center of mass of net supply.

SUSQUEHANNA RIVER AT HARRISBURG, PA.

Calendar-day precipitation at rain gages in an near the lower Susquehanna River Basin below Williamsport and Wilkes-Barre, Pa., is given in table 38. Average daily precipitation has been averaged with the precipitation for corresponding days over the basin above Wilkes-Barre and Williamsport. During the first storm period, March 9-15, precipitation averaged 1.74 inches over the basin, the greater part falling on March 11 and 12. During the second storm period, March 16-21, 4.69 inches fell over the basin, the greater part falling on March 17 and 18.

Daily mean precipitation over the basin, taken from table 38, is summarized in table 39 together with the daily maximum, minimum, and mean temperatures. The temperatures listed were computed by averaging readings at a number of places. The daily mean temperature is the average of the daily maximum and minimum. The average temperature for the flood period is 41° F. and each day shown averaged above freezing temperature, although as previously noted there were great variations in temperature, notably in the upper West Branch and Chemung River Basins, where subfreezing temperatures on March 13, 17-19, turned much rainfall into snow with important effects on river stages.

Depth of snow cover on March 9 was estimated as being intermediate between that given in Water-Supply Paper 799, which was based principally upon available measurements of snow depth supplemented by estimates of its density, and that given in the analysis below. Precipitation during the subfreezing period, December 1 to March 8, amounted to about 8.4 inches, and runoff equaled 4.7 inches; the retention of 3.7 inches is indicative of the water content of the maximum possible average snow cover on March 9. Available fragmentary observations reported in Water-Supply Paper 799 indicate an approximate snow cover on March 9 of 3.0 inches. This determination is probably low because of the general lack of representative measurements in rural places, more especially in the mountains. Therefore for the purposes of this analysis an estimate of 3.2 inches was used, intermediate between the limits above defined.

After the flood period, from March 24 to April 5, there was a total rainfall of 0.65 inch over the basin and resultant runoff of 0.6 inch, indicating a minimum contribution from snow remaining on March 23 of essentially zero. It is found, however, that the 0.6-inch runoff at Harrisburg had its origin from the basin above Williamsport and Wilkes-Barre, the lower basin producing negligible runoff. This seems to indicate that there was little, if any, snow remaining in the lower basin. Accordingly, that in the Susquehanna River Basin above Harrisburg was taken as equal to the volume estimated as above Wilkes-Barre and Williamsport converted into inches over the basin above Harrisburg. This amounts to 0.4 inch. The total snow melt during the period was, therefore, 2.8 inches.

The following table contains a summary of the rainfall and runoff amounts, in inches, during the winter season of 1935-36:

Period	Rainfall and runoff (inches)		
	Precipitation	Runoff	Difference
Dec. 1, 1935 to Mar. 8, 1936	8.4	4.7	3.7
Mar. 9–23	6.4	9.0	—2.6
Mar. 24 to Apr. 5	.65	.6	.05
	15.45	14.3	1.15

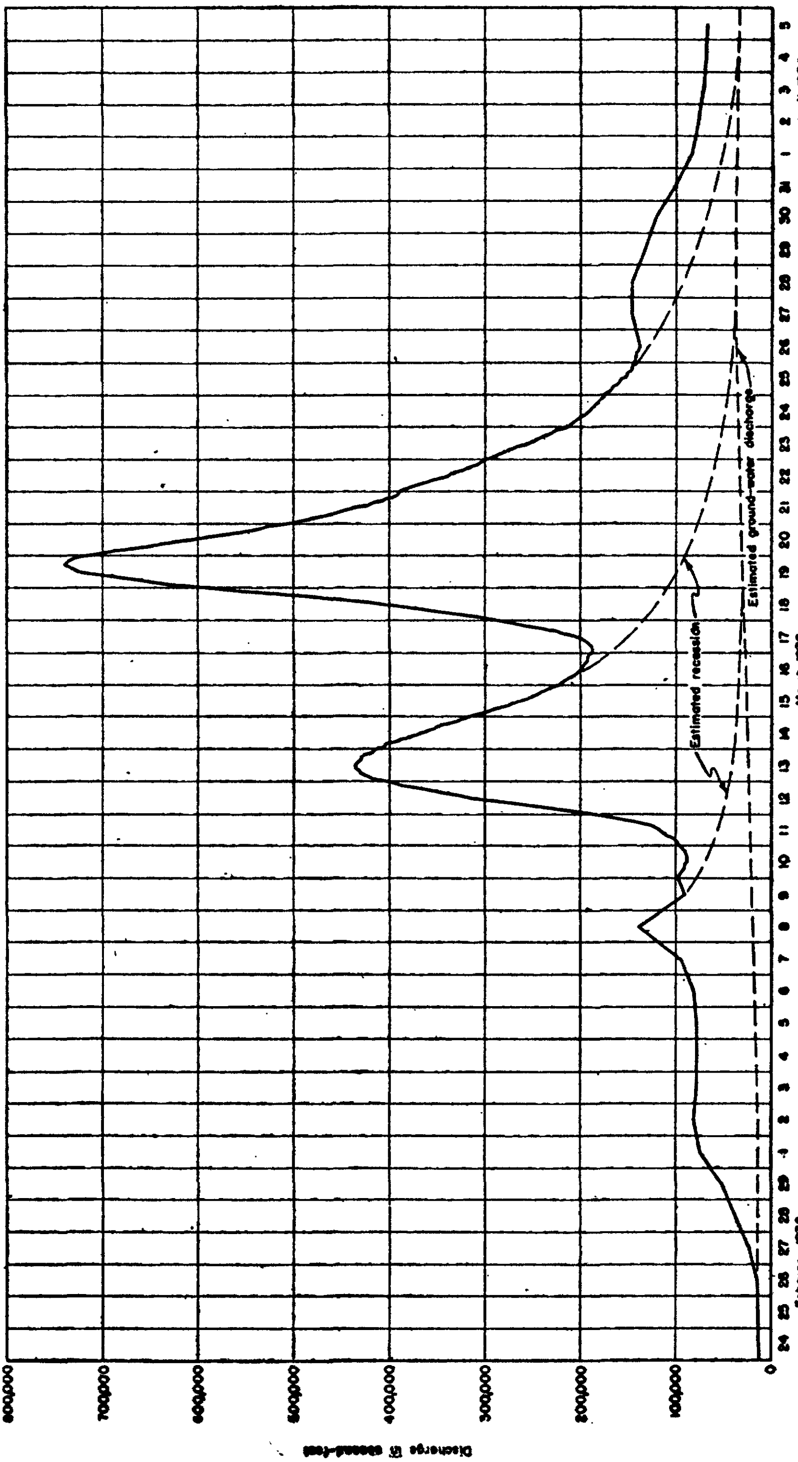

FIGURE 14.—Hydrograph of Susquehanna River at Harrisburg, Pa., showing discharge, March 1936.

TABLE 38.—*Daily precipitation, in inches, at stations in and near lower Susquehanna River basin, March 9-21, 1936*

Station (Pennsylvania)	Altitude (feet)	Weight (percent)	March														
			9	10	11	12	13	14	15	Total 9–15	16	17	18	19	20	21	Total 16–21
Altoona	1,615	1.23	0.10	0.07	0.51	0.35	0.21	0.08	0.08	1.40	1.35	3.80	0.98	0.45	0.06	0.52	7.16
Baker's Summit	1,442	1.84	.03	.09	.75	.45	----	.04	.13	1.49	1.50	3.49	1.73	.50	.04	.39	7.65
Bedford	1,060	2.52	.31	.24	.48	.40	----	----	.02	1.45	1.45	3.40	1.51	.22	.04	.35	6.97
Bellefonte	1,050	.24	----	.10	1.00	.43	----	----	.07	1.60	1.05	1.62	1.28	.92	.07	.50	5.44
Carlisle	467	1.75	----	.12	1.16	.80	.02	----	----	2.10	.17	.77	.81	.45	.09	.64	2.93
Catawissa	520	3.06	----	----	1.08	.81	.04	----	----	1.93	.20	1.25	.28	.58	----	.65	2.96
Chambersburg	580	1.53	----	.17	.41	.63	----	----	----	1.21	.45	1.13	.67	.30	.02	.34	2.91
Gettysburg	553	.03	----	.10	1.00	.87	.02	----	----	1.99	----	.29	.62	.38	.06	.63	1.98
Harrisburg	337	.92	----	.11	1.65	.59	----	----	----	2.35	.29	1.24	.33	.53	.18	.48	3.05
Huntingdon	650	4.04	.03	.09	.72	.55	.02	.07	.07	1.55	1.45	2.27	1.03	.77	----	----	5.52
Kylertown	1,637	.02	.07	----	.66	.56	.11	.17	Tr.	1.57	1.01	4.47	.60	.51	----	.35	6.94
Lebanon	469	.10	.06	.24	1.50	.36	----	----	.05	2.21	.85	1.05	.40	.45	.25	.05	3.05
Lehighton	500	.16	----	.09	.52	.11	----	----	----	.72	.68	1.80	1.00	.60	.23	.30	4.61
Muncy Valley	1,045	3.17	----	.05	.76	1.16	.17	.06	.05	2.25	.20	1.30	1.08	.32	.10	.70	3.70
Newport	420	3.11	.02	.08	.87	.78	.17	.10	.02	2.04	.50	1.05	.40	----	.30	.60	2.85
Pine Grove	540	.94	.02	.24	1.88	.45	----	----	.06	2.65	.90	.95	.41	.15	.16	.59	3.16
State College	1,217	1.52	.03	.12	1.01	.53	.01	.04	.05	1.79	1.13	1.95	1.54	.88	.06	.58	6.14
Sunbury	507	2.60	----	----	.67	.54	.11	----	----	1.32	.30	1.00	.82	.29	----	----	3.73
Towanda	754	.03	.13	----	.70	.75	.04	----	.04	1.66	1.16	1.47	1.19	.41	----	.64	4.87
Weikert	750	2.80	.07	.25	2.00	.50	----	----	----	2.82	.45	1.80	1.30	.95	.20	----	4.70
Wilkes-Barre	540	1.86	Tr.	.03	.46	.44	.11	.03	----	1.07	.40	.76	.76	.61	----	.25	2.78
Williamsport	521	1.62	.04	.05	1.46	1.07	.19	.09	.10	3.00	1.00	1.53	1.02	.40	.31	.61	4.87
Average or total above Wilkes-Barre (a)	----	41.33	0.24	0.02	0.44	0.56	0.15	0.06	0.03	1.50	0.90	1.18	0.97	0.48	0.01	0.61	4.15
Average or total above Williamsport (b)	----	23.58	0.08	0.09	0.92	0.62	0.11	0.08	0.09	1.99	1.20	2.36	1.12	0.64	0.12	0.58	6.02
Average or total over basin above Harrisburg	----	100.00	0.13	0.06	0.74	0.60	0.11	0.06	0.04	1.74	0.91	1.67	1.00	0.52	0.06	0.53	4.69

(a) From Table 30.
(b) From Table 45.

Discharge at 2-hour intervals during the flood period is given in table 40, and figure 14 shows the discharge in graphic form. The figure also shows the methods used in separating the total stream flow into ground-water and direct runoff and the division of the total flood period into its two distinct rises.

The volume of direct runoff associated with 1.74 inches of precipitation during the period, March 9-15, as computed in table 41, was 2.92 inches. The total snow melt during this period was figured at 2.0 inches and was estimated to have occurred in daily amounts, as indicated in tables 42 and 44. These estimates have been made by distributing the total snow melt of 2.8 inches on the basis of effective thawing temperatures, making allowance for snowfall in certain parts of the basin as a negative snowfall (see p. 10). Considering the basin as a whole, snow melt exceeded snowfall on all but one day, March 13.

As computed in table 43, direct runoff, associated with 4.69 inches of precipitation during the second period March 16-21, was 4.53 inches. An estimated snow melt of 0.80 inch was contributed to runoff during this period.

As a quantitative index of basin characteristics, the lag intervals between center of net supply and direct runoff have been computed in tables 42 and 44. These values, 86 hours during the first period and 83 during the second, are a measure of the average time required for the collection of flood waters at Harrisburg.

Ground-water runoff during the entire flood period was computed as 1.5 inches, which is 0.28 inch less than the difference between total precipitation (6.43 inches) plus snow melt (2.8 inches) and total direct runoff (7.45 inches). The 0.28-inch difference, although subject to considerable percentage error, is indicative of small field-moisture accretion and evaporation losses, considering the total amount of water involved in the flood.

TABLE 39.—*Daily mean areal precipitation, and temperatures, Susquehanna River at Harrisburg, Pa., March 9-21, 1936*

March	Mean areal precipitation [a] (inches)	Temperature		
		Maximum (°F.)	Minimum (°F.)	Mean (°F.)
9	0.13	45	34	39
10	.06	54	35	44
11	.74	51	42	46
12	.60	49	32	40
13	.11	36	26	31
14	.06	47	27	37
15	.04	60	35	45
16	.91	53	36	44
17	1.67	52	34	43
18	1.00	50	35	42
19	.52	43	33	38
20	.06	52	29	40
21	.53	46	32	39
	6.43	49	33	41

[a] Midnight to midnight.

TABLE 40.—*Gage height and discharge of the Susquehanna River at Harrisburg, Pa., during flood of March 1936*

MEAN DISCHARGE, IN SECOND-FEET, 1936

Day	Feb.	Mar.	Apr.	Day	Feb.	Mar.	Apr.	Day	Feb.	Mar.	Apr.
1	18,000	75,000	84,000	11	13,000	130,000	94,500	21	15,000	440,000	47,600
2	18,000	81,000	75,800	12	12,500	304,000	91,900	22	14,000	342,000	43,300
3	17,000	78,000	71,600	13	12,000	424,000	89,300	23	13,500	258,000	40,600
4	16,000	78,000	68,800	14	12,000	368,000	86,700	24	13,000	193,000	39,200
5	16,000	78,000	67,300	15	12,500	267,000	91,900	25	13,000	157,000	36,600
6	15,500	82,000	80,200	16	13,000	203,000	86,700	26	15,000	138,000	34,000
7	15,000	95,000	114,000	17	14,000	219,000	75,800	27	23,000	146,000	31,600
8	14,500	140,000	119,000	18	15,000	414,000	65,800	28	38,000	146,000	28,400
9	14,000	91,000	112,000	19	16,000	691,000	58,300	29	53,000	132,000	26,700
10	13,500	93,200	101,000	20	15,500	614,000	52,000	30	--------	121,000	25,300
								31	--------	99,600	--------
Mean monthly discharge, in second-feet									16,910	216,100	68,000
Runoff, in inches									.76	10.34	3.15

GAGE HEIGHT, IN FEET, AND DISCHARGE, IN SECOND-FEET, AT INDICATED TIME, 1936

Hour	March 8 Feet	March 8 Sec.-ft.	March 9 Feet	March 9 Sec.-ft.	March 10 Feet	March 10 Sec.-ft.	March 11 Feet	March 11 Sec.-ft.	March 12 Feet	March 12 Sec.-ft.	March 13 Feet	March 13 Sec.-ft.
2	14.30	--------	8.90	--------	8.12	98,300	8.10	98,300	12.70	204,000	21.08	414,000
4	13.05	--------	8.87	--------	8.00	96,000	8.22	101,000	13.60	225,000	21.38	423,000
6	12.20	--------	8.83	--------	7.90	93,700	8.38	105,000	14.62	248,000	21.58	429,000
8	11.50	--------	8.78	--------	7.80	91,400	8.58	110,000	15.60	271,000	21.70	432,000
10	11.00	--------	8.70	--------	7.76	91,400	8.77	115,000	16.55	294,000	21.76	436,000
12 m.	10.40	[a]140,000	8.65	[a]91,000	7.73	89,100	9.00	119,000	17.35	314,000	21.76	436,000
2	9.94	--------	8.60	--------	7.72	89,100	9.24	124,000	18.05	329,000	21.71	432,000
4	9.52	--------	8.57	--------	7.74	89,100	9.58	133,000	18.70	347,000	21.65	429,000
6	9.25	--------	8.50	--------	7.78	91,400	10.00	143,000	19.30	363,000	21.56	429,000
8	9.10	--------	8.45	--------	7.82	91,400	10.60	156,000	19.78	377,000	21.38	423,000
10	9.00	--------	8.38	--------	7.90	93,700	11.20	170,000	20.20	388,000	21.22	417,000
12 p.m.	8.95	--------	8.25	--------	7.98	96,000	11.90	186,000	20.65	400,000	21.08	414,000

Hour	March 14 Feet	March 14 Sec.-ft.	March 15 Feet	March 15 Sec.-ft.	March 16 Feet	March 16 Sec.-ft.	March 17 Feet	March 17 Sec.-ft.	March 18 Feet	March 18 Sec.-ft.	March 19 Feet	March 19 Sec.-ft.
2	20.85	406,000	17.17	309,000	13.32	218,000	12.02	189,000	16.90	302,000	26.95	614,000
4	20.68	403,000	16.80	299,000	13.15	216,000	12.04	189,000	17.60	319,000	27.50	637,000
6	20.44	394,000	16.43	290,000	12.95	211,000	12.08	191,000	18.30	337,000	28.20	659,000
8	20.15	388,000	16.05	280,000	12.78	207,000	12.20	193,000	19.00	355,000	28.70	678,000
10	19.85	377,000	15.70	273,000	12.64	202,000	12.40	198,000	19.78	377,000	29.30	701,000
12 m.	19.52	369,000	15.36	266,000	12.50	200,000	12.78	207,000	20.60	400,000	29.75	721,000
2	19.20	361,000	15.00	257,000	12.40	198,000	13.18	216,000	21.50	426,000	30.05	729,000
4	18.87	352,000	14.70	250,000	12.30	195,000	13.70	227,000	22.40	454,000	30.25	736,000
6	18.56	345,000	14.35	243,000	12.20	193,000	14.30	241,000	23.28	484,000	30.33	740,000
8	18.18	334,000	14.10	236,000	12.15	193,000	14.90	255,000	24.20	514,000	30.20	736,000
10	17.87	326,000	13.78	229,000	12.10	191,000	15.55	271,000	25.15	549,000	30.00	729,000
12 p.m.	17.50	316,000	13.50	223,000	12.05	189,000	16.25	285,000	26.00	578,000	29.75	721,000

Hour	March 20 Feet	March 20 Sec.-ft.	March 21 Feet	March 21 Sec.-ft.	March 22 Feet	March 22 Sec.-ft.	March 23 Feet	March 23 Sec.-ft.	March 24 Feet	March 24 Sec.-ft.	March 25 Feet	March 25 Sec.-ft.
2	29.40	705,000	23.70	497,000	20.05	383,000	16.40	290,000	12.96	211,000	11.22	170,000
4	28.90	686,000	23.25	480,000	19.80	377,000	16.17	285,000	12.82	207,000	11.10	168,000
6	28.40	667,000	22.90	470,000	19.45	366,000	15.90	278,000	12.70	204,000	10.96	166,000
8	27.90	648,000	22.50	458,000	19.10	358,000	15.65	271,000	12.50	200,000	10.80	161,000
10	27.38	629,000	22.10	445,000	18.75	350,000	15.30	264,000	12.30	195,000	10.68	159,000
12 m.	26.90	611,000	21.75	436,000	18.42	339,000	15.00	256,000	12.10	191,000	10.56	156,000
2	26.50	596,000	21.40	423,000	18.18	334,000	14.78	252,000	11.96	189,000	10.44	152,000
4	25.95	578,000	21.15	417,000	17.80	324,000	14.43	243,000	11.80	184,000	10.35	152,000
6	25.50	560,000	20.80	406,000	17.50	316,000	14.18	238,000	11.70	182,000	10.25	147,000
8	25.00	542,000	20.50	397,000	17.23	309,000	13.95	234,000	11.60	180,000	10.18	147,000
10	24.55	528,000	20.30	391,000	16.92	302,000	13.62	225,000	11.45	175,000	10.10	145,000
12 p.m.	24.10	510,000	20.20	388,000	16.70	297,000	13.18	216,000	11.38	175,000	10.00	143,000

[a] Mean for the day.

LOCATION.—Chain gage, lat. 40°15′35″, long. 76°53′05″, at Walnut Street Bridge, Harrisburg, Dauphin County. Zero of gage is 290.04 feet above mean sea level.

DRAINAGE AREA.—24,100 square miles.

REMARKS.—Records published in Geol. Survey Water-Supply Paper 799.

TABLE 41.—*Computation of volume of direct runoff associated with precipitation period, March 9-15, 1936, Susquehanna River at Harrisburg, Pa.*

March	Daily mean discharge (second-feet)	Estimated recession from preceding storm and base runoff (second-feet)	Direct runoff (second-feet)
9	91,000	91,000	0
10	93,200	69,000	24,200
11	130,000	57,000	73,000
12	304,000	50,000	254,000
13	424,000	44,000	380,000
14	368,000	40,000	328,000
15	267,000	37,000	230,000
16	[a]195,000	35,000	160,000
17	[a]150,000	34,000	116,000
18	[a]120,000	32,000	98,000
19	[a]100,000	31,000	69,000
20	[a]85,000	32,000	53,000
21	[a]73,000	33,000	40,000
22	[a]63,000	34,000	29,000
23	[a]55,000	35,000	20,000
24	[a]50,000	36,000	14,000
25	[a]45,000	37,000	8,000
26	[a]42,000	37,000	5,000
27	[a]39,000	37,000	2,000
Total Sec.-ft.-days	2,694,200	801,000	1,893,200 (= 2.92 inches)

[a] Estimated recession under subsequent rise.

TABLE 42.—*Computation of time of center of mass of net supply, and lag intervals, Susquehanna River at Harrisburg, Pa., March 9-15, 1936*

March	Mean areal precipitation (inches)	Estimated snow melt (inches)	Precipitation plus snow melt (inches)	Net supply (inches)	Time from origin (days)	Product (inch-days)
9	0.13	0.25	0.38	0.28	0	0
10	.06	.51	.57	.44	1	.44
11	.74	.63	1.37	1.14	2	2.28
12	.60	[a].28	.88	.73	3	2.19
13	.11	[a].04	.07	.02	4	.08
14	.06	[a].05	.11	.06	5	.30
15	.04	.32	.36	.25	6	1.50
	1.74	2.00	3.74	2.92	....	6.79

[a] Estimated result of snowfall and thawing.

Center of mass of net supply occurred $\frac{6.79}{2.92} = 2.33$ days after noon of March 9 = March 11.83.

Time of center of mass of direct runoff was at March 15.41 or 3.58 days (86 hours) after center of mass of net supply.

Peak discharge occurred at March 13.46 or 1.63 days (39 hours) after center of mass of net supply.

TABLE 43.—*Computation of volume of direct runoff associated with precipitation period March 16-21, 1936, Susquehanna River at Harrisburg, Pa.*

Day	Daily mean discharge (second-feet)	Estimated recession from preceding storm and base runoff (second-feet)	Direct runoff (second-feet)
Mar.			
16	203,000	195,000	8,000
17	219,000	150,000	69,000
18	414,000	120,000	294,000
19	691,000	100,000	591,000
20	614,000	85,000	529,000
21	440,000	73,000	367,000
22	342,000	63,000	279,000
23	258,000	55,000	203,000
24	193,000	50,000	143,000
25	157,000	45,000	112,000
26	130,000	42,000	88,000
27	108,000	39,000	69,000
28	93,000	38,000	55,000
23	80,000	38,000	42,000
30	70,000	37,000	33,000
31	60,000	37,000	23,000
Apr.			
1	52,000	36,000	16,000
2	45,000	35,000	10,000
3	40,000	35,000	5,000
Total Sec.-ft.-days	4,209,000	1,273,000	2,936,000 (= 4.53 inches)

TABLE 44.—*Computation of time of center of mass of net supply, and lag intervals, Susquehanna River at Harrisburg, Pa., March 16-21, 1936*

March	Mean areal precipitation (inches)	Estimated snow melt (inches)	Precipitation plus snow melt (inches)	Net supply (inches)	Time from origin (days)	Product (inch-days)
16	0.91	0.25	1.16	0.97	0	0.97
17	1.67	[a].10	1.77	1.52	1	1.52
18	1.00	[a].17	1.17	.98	2	1.96
19	.52	[a].08	.60	.47	3	1.41
20	.06	.15	.21	.13	4	.52
21	.53	[a].05	.58	.46	5	2.30
	4.69	0.80	5.49	4.53	....	8.68

[a]Estimated result of snowfall and thawing.

Center of mass of net supply occurred $\frac{8.68}{4.53}$ = 1.92 days after noon of March 16 = March 18.42

Time of center of mass of direct runoff was at March 21.88 or 3.46 days (83 hours) after center of mass of net supply.

Peak discharge occurred at March 19.75 or 1.33 days (32 hours) after center of mass of net supply.

WEST BRANCH OF SUSQUEHANNA RIVER AT WILLIAMSPORT, PA.

Daily precipitation at the several stations in and near the basin, computed on the basis of distribution at nearby recording rain gages so as to conform with the calendar day, is given in table 45. In combining the several records to obtain the average over the basin, they have been assigned the Thiessen weights indicated. In table 45, 15 rain gages are listed, about one for each 380 square miles of the area. The rain gage at Clearfield, Pa., has the greatest weight, being alone in an area of about 930 square miles. Precipitation over the basin during the storm averaged 8.01 inches, of which 1.99 inches fell during the period, March 9-15 and 6.02 inches fell from March 16-21. The areal distribution, shown on figure 11, indicates that the West Branch Basin received greater precipitation than did any other part of the Susquehanna River Basin, the amount exceeding 10 inches locally. This excess was largely due to the precipitation in the second storm period.

Table 46 lists daily mean precipitation and the daily maximum, minimum, and mean temperatures in the basin. Temperatures listed are the average of those observed at Williamsport, Clearfield, and Lawrenceville, Pa. The average temperatures for all but one day, March 13, were above freezing, the general average being 39° F. The most significant variation in temperature occurred on March 16, 17, 18, and 19, the records of which follow:

Station	Variation in temperature (° F.) on —							
	March 16		March 17		March 18		March 19	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
Williamsport	48	40	63	36	60	39	56	34
Clearfield	45	35	41	28	40	31	38	32
Lawrenceville	55	32	34	30	38	31	39	31
Average	49	36	45	31	46	34	44	32

The above records show that on 3 of the 4 days in question a difference in temperature of 15° to 30° F. existed between the observed maxima at Williamsport and Lawrenceville, with temperatures at Clearfield not widely different from those at Lawrenceville. The drop in temperature that occurred over parts of the basin on March 17 was the result of the migration of a cold air mass, whose front stagnated along a line over the basin. This drop in temperature, although a part of the meteorologic factors that were in the background of the flood, was also of direct consequence on the intensity of the flood in this area in that, during the 3 days of heavy precipitation, it caused much snow instead of rain, and thus temporarily kept much water out of stream channels.

Daily mean temperatures during the 30 days antecedent to the storm period are given in table 47. The average during the 30 days was 24° F., remaining below freezing until February 25, although active thawing did not begin until March 9. The effect of thawing temperatures during the preliminary period appears to settle the snow cover, that is, to increase its density or "ripen" it.

The water content of the snow cover on March 9 is given in Water-Supply Paper 799 as 4.0 inches, based on fragmentary observations of depth of snow in and near the basin, and estimates of the density. The West Branch Basin not only had the greatest precipitation of any of the tributaries of the Susquehanna River Basin but also contained much of the region with greatest snow depth. The subfreezing season, during which snow accumulated, began on December 1 and continued until March 8. Precipitation during this season averaged 8.4 inches and runoff equaled 4.6 inches, indicating that the maximum possible snow cover on March 8 would be 3.8 inches, which value was adopted for use in this analysis.

The following method was used to estimate the amount of snow remaining after the termination of the storm period on March 22: Precipitation during March 24-31 totaled 0.65 inch and the runoff was 1.15 inches, indicating a minimum possible contribution from melting snow of 0.5 inch. Based on this indication and limited available observations reported in Water-Supply Paper 799, the amount of snow on March 22 was estimated as 0.65 inch water content, and the net snow melt as 3.15 inches (3.8–0.65).

A hydrograph of flood discharge based on data given in table 48 is shown on figure 15. In common with other streams there were two separate stream rises, associated with the two periods of precipitation. Figure 15 shows the manner of separation into direct runoff and ground-water flow and the division between the storm rises. As given in table 49 the volume of direct runoff associated with the first storm period March 9-15 was 3.10 inches. The precipitation during March 9-15 was 1.99 inches and net snow melt as shown in table 50 was estimated at 2.30 inches, the total being 4.29 inches. Snowfall occurred on March 12-15, but only on March 13 did it exceed the amount of thaw.

The volume of direct runoff associated with the second precipitation period March 16-21 as given in table 51, equaled 5.63 inches. Precipitation from March 16-21 was 6.02 inches and snow melt as shown in table 52, was estimated at 0.85 inch. Snowfall exceeded snow melt on March 17. The greatest amount of snow melt during the flood was estimated to have occurred on March 11 (0.78 inch), the day with greatest average temperature, while the snow cover was still generally plentiful over the entire basin.

TABLE 45.—*Daily precipitation, in inches, at stations in and near West Branch of* ***Susquehanna River basin*** ***at Williamsport, Pa., March 9-21, 1936***

[In this table "T" indicates a trace]

Station (Pennsylvania)	Altitude (feet)	Weight (percent)	March														
			9	10	11	12	13	14	15	Total 9-15	16	17	18	19	20	21	16-21
Altoona	1,650	3.58	0.10	0.07	0.51	0.35	0.21	0.08	0.08	1.40	1.35	3.80	0.98	0.45	0.06	0.52	7.16
Bellefonte	1,050	6.69	---	.10	1.00	.43	---	---	.07	1.60	1.05	1.62	1.28	.92	.07	.50	5.44
Cedar Run	800	10.72	.09	.05	1.28	1.02	.23	.07	.22	2.96	1.12	2.19	1.25	.65	.30	.49	6.00
Clearfield	1,120	16.33	.16	.10	.63	.36	.16	.13	.10	1.64	1.70	2.10	1.60	1.10	.03	.17	6.70
Ebensburg	2,000	3.10	.17	.17	.32	.40	.06	.12	.09	1.33	1.40	1.85	1.08	.22	.08	.60	5.23
Galeton	1,325	9.31	.14	.09	1.54	.42	.10	.11	.07	2.47	1.41	2.00	.94	.88	.15	2.69	8.07
Kylertown	1,637	11.29	.07	---	.66	.56	.11	.17	T	1.57	1.01	4.47	.60	.51	---	.35	6.94
Morris Run	1,750	3.05	.12	.04	1.19	1.06	.05	---	.04	2.50	1.54	1.45	1.49	.55	.02	.64	5.69
Muncy Valley	1,045	.14	---	.02	.78	1.20	.14	.05	.03	2.22	.20	1.30	1.08	.32	.10	.70	3.70
Renova	672	14.36	.10	.07	.49	.64	.19	.04	.09	1.62	.93	2.59	1.00	.20	.10	.13	4.95
Smethport	1,500	7.64	.01	---	.22	.12	.02	.20	.25	.82	1.00	2.25	.85	.48	.13	.17	4.88
State College	1,217	3.38	.03	.12	1.01	.53	.01	.04	.05	1.79	1.13	1.95	1.54	.88	.06	.58	6.14
Wiekert	750	1.29	.07	.25	2.00	.50	---	---	---	2.82	.45	1.80	1.30	.95	.20	---	4.70
Wellsboro	1,419	3.72	.06	.05	.93	.76	.09	.04	.10	2.03	1.22	1.44	.92	.58	.05	.27	4.48
Williamsport	521	5.40	.04	.05	1.46	1.07	.19	.09	.10	3.00	1.00	1.53	1.02	.40	.31	.61	4.87
Average or total	---	100.00	0.08	0.09	0.92	0.62	0.11	0.08	0.09	1.99	1.20	2.36	1.12	0.64	0.12	0.58	6.02

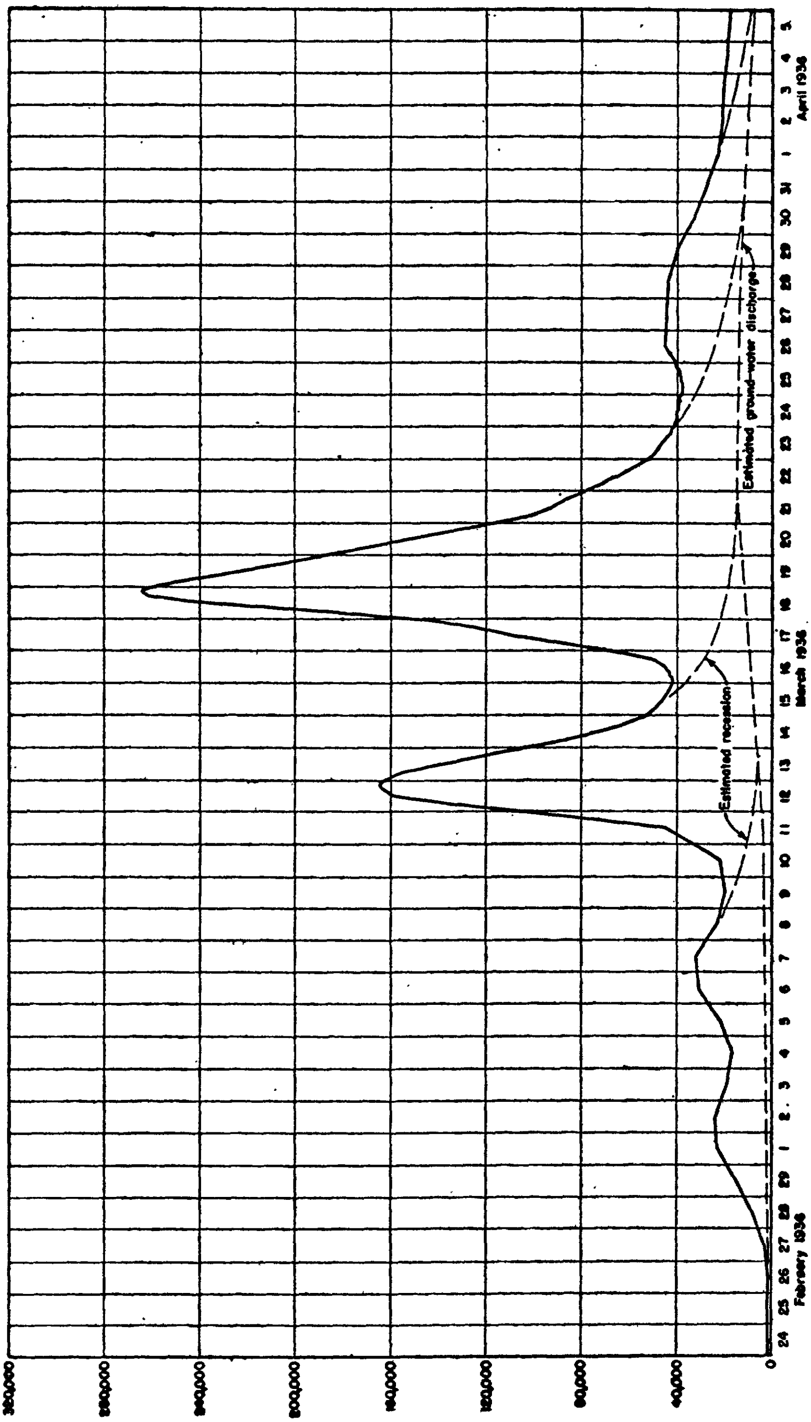

FIGURE 15.—Hydrograph of West Branch of Susquehanna River at Williamsport, Pa., showing discharge, March 1936.

Ground-water runoff associated with the storm period March 9-22 was 2.0 inches, which, added to the total direct runoff of 8.73 inches, makes a total runoff of 10.73 inches from a total precipitation and snow melt of 11.16 inches leaving indicated balance of only 0.43 inch for field-moisture accretion and evaporation losses.

The lag interval between the occurrence of precipitation and snow melt and the passage of the resultant direct runoff at Williamsport was 49 hours for the first storm period and 50 hours for the second.

TABLE 46.—*Daily mean areal precipitation, and temperatures, West Branch of Susquehanna River at Williamsport, Pa., March 9-21, 1936*

March	Mean areal precipitation[a] (inches)	Temperature		
		Maximum[b] (°F.)	Minimum[b] (°F.)	Mean[c] (°F.)
9	0.08	43	34	38
10	.09	52	34	43
11	.92	49	41	45
12	.62	48	31	40
13	.11	37	24	30
14	.08	43	25	34
15	.09	56	29	42
16	1.20	49	36	42
17	2.36	45	31	38
18	1.12	46	34	40
19	.64	44	32	38
20	.12	51	28	39
21	.58	46	31	39
	8.01	47	32	39

[a]Midnight to midnight.
[b]Average of observations at Clearfield, Lawrenceville, and Williamsport, Pa.
[c]Average of maximum and minimum.

TABLE 47.—*Daily mean temperature[a], West Branch of Susquehanna River at Williamsport, Pa., February 8 to March 8, 1936*

Day	Mean temperature (°F.)	Day	Mean temperature (°F.)
Feb.		*Feb.*	
8	13	23	12
9	22	24	30
10	14	25	40
11	11	26	37
12	13	27	40
13	17	28	29
14	30	29	29
15	31	*Mar.*	
16	24	1	28
17	30	2	20
18	17	3	32
19	5	4	39
20	5	5	39
21	12	6	25
22	13	7	27
		8	29
Mean			24

[a]Average of recorded daily maximum and minimum temperatures at Clearfield, Lawrenceville, and Williamsport.

TABLE 48.—*Gage height and discharge of the West Branch of the Susquehanna River at Williamsport, Pa., during flood of March 1936*

MEAN DISCHARGE, IN SECOND-FEET, 1936

Day	Feb.	Mar.	Apr.	Day	Feb.	Mar.	Apr.	Day	Feb.	Mar.	Apr.
1	2,500	23,000	23,900	11	1,800	45,000	21,900	21	1,900	94,200	10,000
2	2,400	24,000	20,900	12	1,750	145,000	22,400	22	1,850	64,600	9,500
3	2,300	19,000	20,400	13	1,750	137,000	22,900	23	1,750	46,500	8,980
4	2,200	17,000	19,000	14	1,700	74,600	21,400	24	1,700	40,100	7,970
5	2,100	22,000	17,100	15	1,700	47,100	19,000	25	1,650	39,100	7,320
6	2,050	31,000	19,800	16	1,650	48,400	17,100	26	1,700	45,500	6,690
7	2,000	32,000	30,200	17	1,700	107,000	15,300	27	3,000	44,900	6,230
8	1,950	23,000	32,300	18	1,800	218,000	13,600	28	8,000	44,500	5,930
9	1,900	20,000	26,400	19	2,100	225,000	11,900	29	15,000	40,000	5,640
10	1,850	22,000	23,400	20	2,000	153,000	11,200	30	--------	31,900	5,780
								31	--------	27,800	--------
Mean monthly discharge, in second-feet									2,612	62,970	16,140
Runoff, in inches									.50	12.80	3.17

GAGE HEIGHT, IN FEET, AND DISCHARGE, IN SECOND-FEET, AT INDICATED TIME, 1936

Hour	March 8 Feet	March 8 Sec.-ft.	March 9 Feet	March 9 Sec.-ft.	March 10 Feet	March 10 Sec.-ft.	March 11 Feet	March 11 Sec.-ft.	March 12 Feet	March 12 Sec.-ft.	March 13 Feet	March 13 Sec.-f.
2	------	------	------	------	------	------	------	------	17.58	104,000	23.27	161,000
4	------	------	------	------	------	------	------	------	19.22	120,000	23.03	158,000
6	------	------	------	------	------	------	------	------	20.72	135,000	22.67	155,000
8	------	------	------	------	------	------	------	------	21.85	146,000	22.27	151,000
10	------	------	------	------	------	------	------	------	22.67	155,000	21.80	146,000
12 m.	------	[b]23,000	------	[b]20,000	------	[b]22,000	------	[b]45,000	23.07	159,000	21.25	140,000
2	------	------	------	------	------	------	------	------	23.32	161,000	20.67	135,000
4	------	------	------	------	------	------	------	------	23.45	162,000	20.07	129,000
6	------	------	------	------	------	------	------	------	23.56	164,000	19.43	122,000
8	------	------	------	------	------	------	------	------	23.66	165,000	18.73	115,000
10	------	------	------	------	------	------	------	------	23.56	164,000	18.08	109,000
12 p.m.	------	------	------	------	------	------	------	------	23.42	162,000	17.47	103,000

Hour	March 14 Feet	March 14 Sec.-ft.	March 15 Feet	March 15 Sec.-ft.	March 16 Feet	March 16 Sec.-ft.	March 17 Feet	March 17 Sec.-ft.	March 18 Feet	March 18 Sec.-ft.	March 19 Feet	March 19 Sec.-ft.
2	16.86	97,000	12.00	52,400	10.58	42,800	14.38	72,800	23.08	159,000	32.81	256,000
4	16.30	91,000	11.78	50,900	10.61	42,800	15.21	80,300	24.00	168,000	32.20	250,000
6	15.76	86,100	11.59	49,500	10.66	43,500	16.05	88,100	25.38	182,000	31.57	244,000
8	15.27	81,300	11.41	48,100	10.73	43,500	16.83	96,000	26.78	196,000	31.00	238,000
10	14.78	76,500	11.26	47,400	10.86	44,800	17.50	103,000	28.63	214,000	30.35	232,000
12 m.	14.30	71,800	11.12	46,100	10.99	45,400	18.11	109,000	30.25	230,000	29.72	225,000
2	13.88	68,200	11.00	45,400	11.13	46,100	18.63	114,000	31.42	242,000	29.12	219,000
4	13.50	64,600	10.88	44,800	11.36	48,100	19.15	120,000	32.47	253,000	28.48	213,000
6	13.15	62,000	10.78	44,100	11.72	50,200	19.62	124,000	33.30	261,000	27.85	206,000
8	12.81	58,600	10.67	43,500	12.23	53,900	20.18	130,000	33.54	263,000	27.25	200,000
10	12.52	56,200	10.60	42,800	12.87	59,400	20.85	136,000	33.56	264,000	26.70	195,000
12 p.m.	12.25	53,900	10.55	42,800	13.62	65,500	21.78	146,000	33.32	261,000	26.08	189,000

Hour	March 20 Feet	March 20 Sec.-ft.	March 21 Feet	March 21 Sec.-ft.	March 22 Feet	March 22 Sec.-ft.	March 23 Feet	March 23 Sec.-ft.	March 24 Feet	March 24 Sec.-ft.	March 25 Feet	March 25 Sec.-ft.
2	25.48	183,000	18.10	109,000	14.79	76,500	11.81	50,900	10.34	41,000	9.86	38,600
4	24.88	177,000	17.65	104,000	14.51	73,700	11.66	50,200	10.26	41,000	9.85	38,000
6	24.28	171,000	17.29	101,000	14.25	70,900	11.52	48,800	10.20	40,400	9.85	38,000
8	23.67	165,000	16.97	98,000	13.98	69,100	11.38	48,100	10.17	40,400	9.87	38,600
10	23.13	159,000	16.68	95,000	13.70	66,400	11.26	47,400	10.16	40,400	9.90	38,600
12 m.	22.55	154,000	16.41	92,000	13.45	63,700	11.12	46,100	10.15	40,400	9.93	38,600
2	21.95	148,000	16.21	90,000	13.20	62,000	11.00	45,400	10.13	39,800	9.97	39,200
4	21.32	141,000	16.01	88,100	12.90	59,400	10.87	44,800	10.11	39,800	10.01	39,200
6	20.70	135,000	15.78	86,100	12.67	57,800	10.73	43,500	10.07	39,800	10.05	39,200
8	20.07	129,000	15.55	84,200	12.41	55,400	10.63	42,800	10.03	39,200	10.09	39,800
10	19.47	123,000	15.31	81,300	12.17	53,900	10.51	42,200	9.97	39,200	10.16	40,400
12 p.m.	18.88	117,000	15.05	78,400	11.99	52,400	10.41	41,600	9.92	38,600	10.27	41,000

[a] Supplemental records: Mar. 18, 9 p.m., 33.57 ft., 264,000 sec.-ft.
[b] Mean for the day.

LOCATION.—Water-stage recorder, lat. 41°14′15″, long. 76°59′55″, at highway bridge at Williamsport, Lycoming County. Zero of gage is 494.55 feet above mean sea level.

DRAINAGE AREA.—5,682 square miles.

REMARKS.—Records published in Geol. Survey Water-Supply Paper 799.

TABLE 49.—*Computation of volume of direct runoff associated with precipitation period March 9-15, 1936, West Branch of Susquehanna River at Williamsport, Pa.*

March	Daily mean discharge (second-feet)	Estimated recession from preceding storm and base runoff (second-feet)	Direct runoff (second-feet)
9	20,000	16,000	4,000
10	22,000	12,500	9,500
11	45,000	10,000	35,000
12	145,000	8,000	137,000
13	137,000	7,500	129,500
14	74,600	7,500	67,100
15	47,100	8,800	38,300
16	[a]32,000	10,000	22,000
17	[a]25,000	11,000	14,000
18	[a]21,000	12,000	9,000
19	[a]18,000	13,000	5,000
20	[a]16,500	14,000	2,500
Total Sec.-ft.-days	603,200	130,300	472,900 (= 3.10 inches)

[a]Estimated recession under subsequent rise.

TABLE 50.—*Computation of time of center of mass of net supply, and lag intervals, West Branch of Susquehanna River at Williamsport, Pa., March 9-15, 1936*

March	Mean areal precipitation (inches)	Estimated snow melt (inches)	Precipitation plus snow melt (inches)	Net supply (inches)	Time from origin (days)	Product (inch-days)
9	0.08	0.29	0.37	0.21	0	0
10	.09	.69	.78	.62	1	.62
11	.92	.78	1.70	1.37	2	2.74
12	.62	[a].28	.90	.64	3	1.92
13	.11	[a]—.05	.06	.01	4	.04
14	.08	[a].01	.09	.01	5	.05
15	.09	[a].30	.39	.24	6	1.44
	1.99	2.30	4.29	3.10	....	6.81

[a]Estimated result of snowfall and thawing.

Center of mass of net supply occurred $\frac{6.81}{3.10}$ = 2.20 days after noon of March 9 = March 11.70.

Time of center of mass of direct runoff was at March 13.73 or 2.03 days (49 hours) after center of mass of net supply.

Peak discharge occurred at March 12.83 or 1.13 days (27 hours) after center of mass of net supply.

TABLE 51.—*Computation of volume of direct runoff associated with precipitation period March 16-21, 1936, West Branch of Susquehanna River at Williamsport, Pa.*

March	Daily mean discharge (second-feet)	Estimated recession from preceding storm and base runoff (second-feet)	Direct runoff (second-feet)
15	47,100	47,100	0
16	48,400	32,000	16,400
17	107,000	25,000	82,000
18	218,000	21,000	197,000
19	225,000	18,000	207,000
20	153,000	16,500	136,500
21	94,200	16,000	78,200
22	64,600	16,000	48,600
23	46,500	15,500	31,000
24	[a]36,000	15,000	21,000
25	[a]29,000	14,500	14,500
26	[a]25,000	14,000	11,000
27	[a]21,500	13,500	8,000
28	[a]18,000	13,000	5,000
29	[a]16,000	12,800	3,200
30	[a]12,800	12,500	300
Total Sec.-ft.-days	1,162,100	302,400	859,700 (= 5.63 inches)

[a]Estimated recession under subsequent rise.

TABLE 52.—*Computation of time of center of mass of net supply, and lag intervals, West Branch of Susquehanna River at Williamsport, Pa., March 16-21, 1936*

March	Mean areal precipitation (inches)	Estimated snow melt (inches)	Precipitation plus snow melt (inches)	Net supply (inches)	Time from origin (days)	Product (inch-days)
16	1.20	0.33	1.53	1.28	0	0
17	2.36	[a]–.01	2.35	2.02	1	2.02
18	1.12	.22	1.34	1.11	2	2.22
19	.64	.17	.81	.63	3	1.89
20	.12	[a].14	.26	.14	4	.56
21	.58	[a]0	.58	.45	5	2.25
	6.02	0.85	6.87	5.63	....	8.94

[a]Estimated result of snowfall and thawing.

Center of mass of net supply occurred $\frac{8.94}{5.63}$ = 1.59 days after 12 noon of March 16 = March 18.09.

Time of center of mass of direct runoff was at March 20.16 or 2.07 days (50 hours) after center of mass of net supply.

Peak discharge occurred at March 18.88 or 0.79 day (19 hours) after center of mass of net supply.

FLOOD OF MARCH 1920, GENESEE RIVER AT ST. HELENA, N. Y.

The Genesee River Basin was the only one studied in which the maximum winter flood of record did not occur in March 1936. The maximum flood was that of March 1920 and was the result of rapid melting of a heavy snow cover during a few days of high temperature, together with a very moderate rainfall. The occurrence of so small an amount of rainfall with a flood of the magnitude of that of March 1920 in the Genesee River Basin is very unusual.

Records of precipitation at all Weather Bureau stations in and near the basin are given in table 53. Three of these stations are within the drainage basin and three others are not far from it, so that the determination of rainfall was probably fairly reliable. More than half the total storm precipitation of 0.88 inch fell on March 12. The daily precipitation listed in table 54 is that which was estimated to have fallen within the indicated calendar day on the basis of the regular daily records and of hourly records at Buffalo and Rochester, N. Y. Available records of hourly precipitation are given in table 55. The maximum total storm precipitation recorded was 2.03 inches at Bolivar just off the western watershed, and the minimum was 0.26 inch at Lauterbrunnen at the lower end of the basin. Figure 16 shows an isohyetal map of total storm rainfall.

Daily mean areal precipitation together with daily temperature is shown in table 56. Temperatures were highest on March 10, 11, and 12, during which period they ranged between 59° and 29° and averaged 43° F. The temperature on the morning of March 13 dropped to 12° F., and the temperatures on March 14 were continuously below freezing. Most of the precipitation on those days fell as snow. At the recording

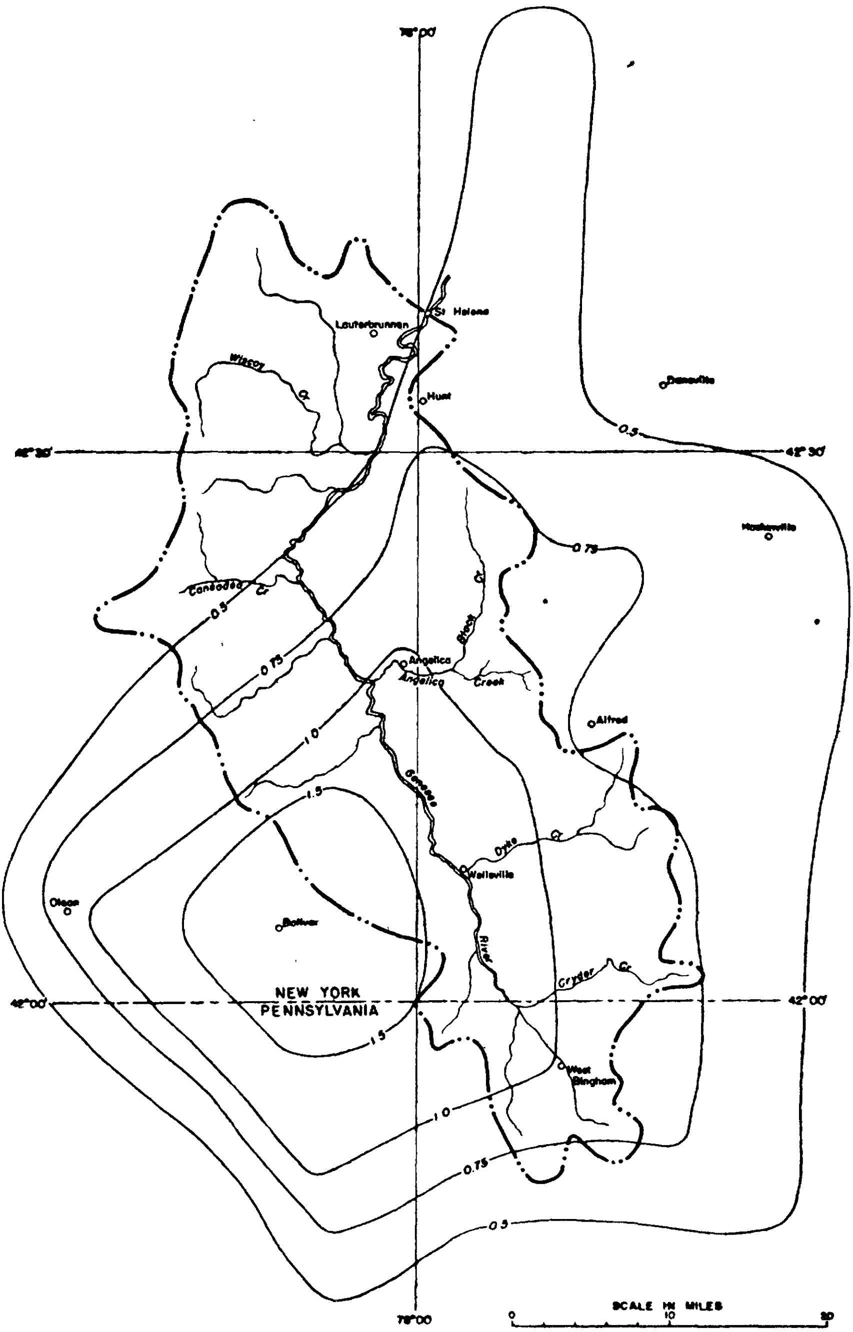

FIGURE 16.—Map of Genesee River basin above St. Helena, N. Y., showing lines of equal precipitation, March 11-14, 1920.

rain gages listed in table 55, the Weather Bureau reported all the precipitation falling on March 13 and 14 as snow.

Little is known of the extent of frost in the ground at the beginning of the storm period. Table 57 indicates that temperatures averaged freezing or below each day during the 30-day antecedent period February 9 to March 9. The average 30-day temperature was 19° F. which was 5° below normal. This evidence would suggest that frost was present in the ground where not insulated by snow cover sufficiently to prevent it.

The only direct information on snow cover is that given in table 58, which lists measurements of the depth of the snow on the ground made by observers of the Weather Bureau. No data are available concerning its water content. Substantial amounts of snow were measured at several places on March 8 and 9, which were rapidly depleted until March 13 when there was additional snowfall.

The storm period ended March 14 with some snow still on the ground, less deep than that on March 9 but of unknown water content. The data given in table 58 are generally inadequate for determining water equivalent of the snow cover on March 9 or on March 14, so the analysis below was used to supplement them.

The temperatures of the period December 1919 to March 10, 1920, were generally subfreezing. During this time there was a total precipitation of 6.4 inches over the basin, and runoff totaled 1.9 inches, leaving a retention of 4.5 inches, of which the greater part was probably snow. The estimate of average water content on March 9 was placed at 3 inches, since that is the maximum that seemed consistent with the data given in table 58.

An estimate of the snow remaining after the close of the storm period was similarly made. The total precipitation from March 15 to March 20 was 0.15 inch and the total direct runoff associated with the events of the same period was 0.76 inch, indicating a minimum contribution to runoff from snow of 0.61 inch. Based on measurement on March 15 at Alfred and Angelica, N. Y., and West Bingham, Pa., and an estimated water content of 50 percent, the snow cover remaining after the storm was estimated at 0.8 inch, the net snow melt from March 10-14 being of 2.2 inches (= 3.0-0.8 as entered in table 61).

Discharge during the flood period is given in table 59 and plotted as a hydrograph on figure 17. The total direct runoff associated with the period March 10-14 as computed in table 60 was 2.08 inches. Precipitation and estimated snow melt totaled 3.08 inches, indicating a retention of 1.0 inch. Ground-water runoff was computed, however, as equal to 0.80 inch, leaving an indicated 0.20 inch for soil-moisture accretion and evaporation losses.

Table 61 shows the procedure of computing the lag interval between net supply and direct runoff. Twelve-hourly precipitation was computed

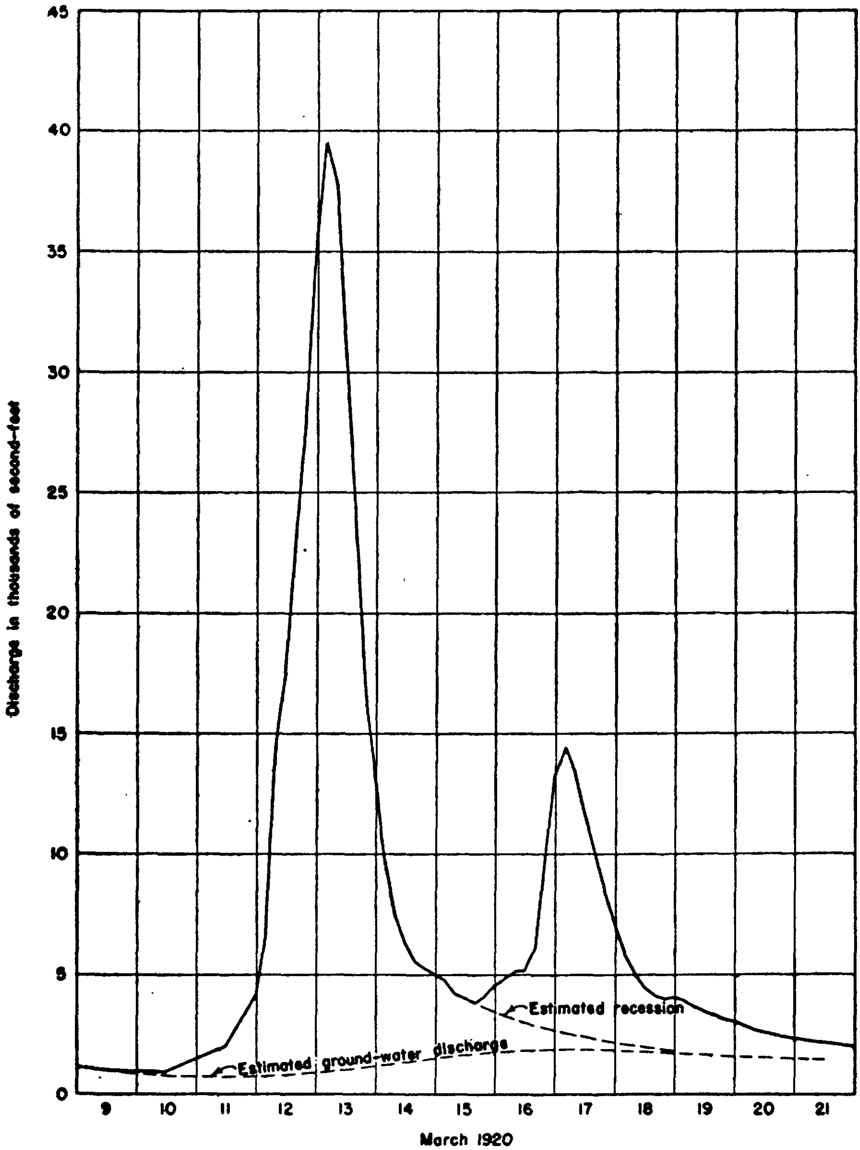

FIGURE 17.—Hydrograph of Genesee River at St. Helena, N. Y., showing discharge, March 1920.

from daily and hourly records of rainfall. Snow melt was computed by distributing the estimated snow melt of 2.2 inches on the basis of daily temperatures above freezing, snowfall being treated as negative snow melt. The total supply was reduced to net supply and the time of its center of mass computed as shown.

The time interval between the net supply and the center of mass of direct runoff was 32 hours, and that between the net supply and the peak discharge was 26 hours.

TABLE 53.—*Daily precipitation, in inches, at stations in and near Genesee River basin above St. Helena, N. Y., March 11-14, 1920*

[Measured in afternoon except as noted]

Station	March				
	11	12	13	14	Total 11-14
New York:					
Alfred	0.16	0.17	0.31	0.05	0.69
Angelica	.02	.45	.40	.16	1.03
Bolivar	.75	.80	.48	....	2.03
Dansville	....	.12	.28	....	.40
Haskinville	.12	.07	.45	....	.64
Hunt	.10	.30	.28	....	.68
Leuterbrunnen	.03	.12	.11	....	.26
Olean[a]	.13	.43	.12	.20	.88
York	....	.27	.28	.04	.59
Hemlock	.11	.12	.11	....	.34
Pennsylvania:					
W. Bingham	.10	.35	.50	....	.95

[a]Measured in the morning, the amount then recorded being for the preceding 24 hours.

TABLE 54.—*Daily precipitation, in inches, at stations in and near Genesee River basin above St. Helena, N. Y., March 10-14, 1920*

Station	Altitude (feet)	Weight (percent)	March					
			10	11	12	13	14	Total 10-14
New York:								
Alfred	1,840	12.7	0.04	0.12	0.28	0.22	0.03	0.69
Angelica	1,420	33.1	0	.02	.59	.34	.08	1.03
Bolivar	1,800	8.0	.19	.56	.97	.31	0	2.03
Hunt	1,150	11.4	.03	.07	.40	.18	0	.68
Lauterbrunnen	1,260	16.8	0	.03	.16	.07	0	.26
Pennsylvania:								
West Bingham	1,171	18.0	.03	.07	.52	.33	0	.95
Average or total	--------	100.0	0.03	0.09	0.48	0.26	0.03	0.88

TABLE 55.—*Hourly precipitation, in inches, at recording gages in and near Genesee River basin, March 8-20, 1920*

[In this table "T" indicates a trace]

Station	Day	a.m.												p.m.												Total	Estimated amount precipitation reported as snow (inches)
		1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12		
Buffalo, N. Y. U. S. Weather Bureau.	8					T	T	0.01	T												T	0.01	0.01	0.01	0.01	0.05	0.05
	9	0.02	0.02	0.02	0.02	0.02	0.01	.01	T	T													T	T		.12	.12
	10																									0	0
	11			.01	.02	.02	.01	T	T	T	T	T	T	T	T	T						T	T	T	T	.06	0
	12	T	T	.03	.07	.07	.06	.02	T							0.03	0.01				T	T	T	T	.01	.30	.01
	13	T	T	T	.01	T	.01	T	T	T	0.01	0.01	0.01	0.01	0.02	.02	.02	0.02	0.01	0.01	T	T				.16	.16
	14																									0	0
	15																				T	T	T			T	0
	16			T	T	.01																	T	T		.01	0
	17															T					T	T				T	T
	18																									0	0
	19											T	.04	.08	.08	.08	.06	.02					T	T	T	.36	.04
	20	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	.21	
Ithaca, N. Y. U. S. Weather Bureau.	8																									0	0
	9					T	T	T	T	T	T	T														T	T
	10																									0	0
	11					T	.01	.02	.02	.03	.04	.04	.04	.01										T	.01	.22	0
	12	.02	.02	.03	.03	.02	.02	.01	T	T	T								T							.15	0
	13				T	.01	.02	.02	.02	.03	.04	.04	.04	.04	.04	.03	.03	.01	.01	.01	0.01	T	.01	T	T	.41	.41
	14	T	T																							T	T
	15																									0	0
	16				T	T	.01	.01	.01	T																.03	0
	17																T	T	T	T	T	T	T	T	T	T	T
	18	T	T	T	T	T	T	T	T	T	T															T	T
	19											T							T	T	.01					.01	.01
	20			T	.01	.02	.02	.03	.04	.03	.02	.01	.01	.01	.01	.01	.01	.01	T	T	T	T				.24	.24
Rochester, N. Y. U. S. Weather Bureau.	8																					T	.01	.01	.01	.03	.03
	9	.01	.01	.01	T			T	T	.01	T	.01	T											T	.01	.06	.06
	10	T	T																							T	0
	11						T	T	.01	.01	T															.02	0
	12				.03	.09	.02	.03	.04	T	T						.15	.06								.42	0
	13		T	.01				T	T	.02	.01	.02	.02	.03	.04	.04	.04	.03	.03	.04	.04	.05	.05	.04	.04	.55	.55
	14	.03	.02	.01	T																					.06	.06
	15																									0	0
	16				.01	.03		T																.01	T	.05	0
	17	.01	.01											T	T	T	.01	T	T	T	T					.03	.01
	18																									0	0
	19													T	.01	.13	.05	.12	.09	T						.40	.20
	20			T	.02	.04	.06	.04	.04	.02	.01	.01	T	.01	T	T										.25	.25

TABLE 55.—*Hourly precipitation, in inches, at recording gages in and near Genesee River basin, March 8-20, 1920*

Station	Day	a.m. 1	2	3	4	5	6	7	8	9	10	11	12	p.m. 1	2	3	4	5	6	7	8	9	10	11	12	Total	Estimated amount precipitation reported as snow (inches)
Syracuse, N. Y. U. S. Weather Bureau.	8	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	0	0
	9	----	----	----	*	*	*	*	*	*	*	*	*	*	T	----	----	----	----	----	----	----	----	----	----	T	T
	10	----	----	----	----	----	----	----	T	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	T	0
	11	----	----	----	----	----	----	----	*	*	*	*	.12	*	T	----	----	----	----	----	----	----	----	----	----	.12	0
	12	----	----	----	----	*	*	*	.24	*	*	.10	----	----	----	----	----	----	----	T	----	----	----	----	----	.34	0
	13	----	----	----	----	----	----	*	T	*	*	*	*	*	*	*	*	*	*	*	.30	*	*	*	.05	.35	.35
	14	*	*	*	*	*	*	*	.05	T	----	----	----	T	T	T	----	----	----	----	----	----	----	----	----	.05	.05
	15	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	T	T	0
	16	*	*	*	*	*	*	*	.10	.01	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	.11	0
	17	----	----	----	----	----	----	----	----	----	----	----	----	----	----	*	*	*	*	*	.01	T	----	----	----	.01	.01
	18	----	----	----	----	----	----	----	T	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	T	T
	19	----	----	----	----	----	----	----	----	----	----	----	----	*	*	*	*	*	*	*	.20	*	*	*	.05	.25	.17
	20	*	*	*	*	*	*	*	.10	*	*	*	*	*	*	*	*	.02	----	----	----	----	----	----	----	.12	.12

*Included in following measurement.

TABLE 56.—*Daily mean areal precipitation and temperature, Genesee River at St. Helena, N. Y., March 9-15, 1920*

March	Mean areal precipitation[a] (inches)	Maximum[b] (°F.)	Minimum[b] (°F.)	Mean[c] (°F.)
9	0	41	20	30
10	.03	50	35	42
11	.09	47	29	38
12	.48	59	42	50
13	.26	50	12	31
14	.03	28	8	18
15	0	47	6	26
Mean, 10-14	0.89	47	25	36

[a]Midnight to midnight.
[b]Average of reading at Alfred, Angelica, Bolivar, Hunt, Lauterbrunnen, N. Y., and West Bingham, Pa.
[c]Average of maximum and minium.

TABLE 57.—*Daily mean temperature, Genesee River at St. Helena, N. Y., February 9 to March 9, 1920*

Day	Mean temperature[a] (°F.)	Day	Mean temperature[a] (°F.)
Feb.		*Feb.*	
9	20	25	15
10	28	26	7
11	26	27	3
12	28	28	10
13	31	29	18
14	30	*Mar.*	
15	18	1	12
16	3	2	24
17	16	3	32
18	22	4	32
19	7	5	28
20	10	6	11
21	11	7	8
22	26	8	16
23	20	9	30
24	27		
Mean			19

[a]Average of recorded daily maximum and minimum temperatures at Alfred, Angelica, Bolivar, Lauterbrunnen, N. Y., and West Bingham, Pa.

TABLE 58.—*Snow depth and snowfall at Weather Bureau stations in and near Genesee River above St. Helena, N. Y., March 7-17, 1920*

[In this table "T" indicates a trace]

Station	Time of observation	March																					
		7		8		9		10		11		12		13		14		15		16		17	
		Snowfall	Snow cover	Snowfall	Snow cover	Snowfall	Snow cover	Snowfall	Snow cover	Snowfall	Snow cover	Snowfall	Snow cover	Snowfall	Snow cover	Snowfall	Snow cover	Snowfall	Snow cover	Snowfall	Snow cover	Snowfall	Snow cover
New York:																							
Alfred	6 p.m.	0.3	14.0	0	13.0	0	12.0	0	[a]9.0	0	4.0	0	1.0	3.1	4.0	0.5	4.0	0	2.0	0	1.0	0	T
Angelica	5 p.m.	0	10.0	0	------	0	------	0	------	0	------	0	------	4.0	4.0	0	4.0	0	0	0	------	0	------
Bolivar	p.m.	0	------	0	------	1	------	0	------	0	------	0	------	4.0	------	0	------	0	------	0	------	0	------
Buffalo	8 p.m.	T	7.0	.1	7.0	1.8	6.6	0	4.0	0	3.0	0	2.0	1.7	3.3	T	2.5	0	1.7	0	Γ	T	T
Dansville	5 p.m.	------	3	------	3.0	------	1	------	------	------	------	------	------	------	3	------	2.0	------	------	------	------	------	------
Elmira	9:30 a.m.	0	5.0	0	5.0	0	5.0	0	2.0	0	1.0	0	T	5.5	2.5	0	5.5	0	5.5	0	1.0	0	T
Haskinville	p.m.	0	------	0	------	.4	------	0	------	0	------	0	------	4.5	------	0	------	0	------	0	------	0	------
Lauterbrunnen	6 p.m.	T	7.0	0	7.0	T	T	0	T	0	T	0	T	3.0	3.0	0	T	0	T	0	T	0	T
Rochester	8 p.m.	.6	12.0	0	11.0	1.5	11.0	0	8	0	5.0	0	T	6.5	6.0	3.5	7.0	0	3.0	0	T	.1	T
Syracuse	8 p.m.	2	20.0	0	20.0	T	18.0	0	13.5	0	12.0	0	4	3.0	7.0	1.0	7.0	0	4.5	0	2.0	.1	0.5
Pennsylvania:																							
West Bingham	6 p.m.	0	------	0	------	0	------	0	------	------	------	------	------	5.0	5.0	0	5.0	0	3.0	0	0	2.0	2.0

[a] End of sleighing weather, continuous since December 25, 1919.

TABLE 59.—*Gage height and discharge of Genesee River at St. Helena, N. Y., during flood of March 1920*

MEAN DISCHARGE, IN SECOND-FEET, MARCH 1920

Day	Sec.-ft.	Day	Sec.-ft.	Day	Sec.-ft.	Day	Sec.-ft.	Day	Sec.-ft.	Day	Sec. ft.
1	220	6	1,500	11	2,000	16	6,640	21	2,140	26	4,530
2	220	7	1,900	12	18,600	17	11,390	22	2,140	27	4,310
3	220	8	1,300	13	28,800	18	4,770	23	3,130	28	2,890
4	260	9	1,000	14	7,050	19	3,490	24	3,900	29	2,290
5	440	10	950	15	4,240	20	2,640	25	4,100	30	2,000
										31	1,600
Mean monthly discharge, in second-feet											4,215
Runoff, in inches											4.78

GAGE HEIGHT, IN FEET, AND DISCHARGE, IN SECOND-FEET, AT INDICATED TIME, 1920

Hour	Feet	Sec.-ft.	Feet	Sec.-ft.	Feet	Sec.-ft.	Feet	Sec.-ft.	Feet	Sec.-ft.	Feet	Sec.-ft.
	March 10		March 11		March 12		March 13		March 14		March 15	
3	5.87		6.20		10.37	6,630	12.27	39,400	7.70	10,200	6.04	4,840
6	5.82		6.33		9.29		12.25	39,200	7.24	8,370	5.86	4,440
9	5.80		6.43		8.91	15,400	11.90	36,100	6.87	7,070	5.68	4,060
12 m.	5.79	[a] 950	6.61	[a] 2,000	9.33	17,400	11.31	30,800	6.59	6,190	5.65	4,000
3	5.80		6.64		10.12	21,800	10.65	25,600	6.35	5,560	5.52	3,740
6	5.82		7.51		10.64	25,500	9.75	19,600	6.23	5,270	5.63	3,960
9	5.86		7.76		11.27	30,500	8.86	15,100	6.18	5,150	5.73	4,160
12 p.m.	6.05		8.71	4,200	11.85	35,600	8.25	12,400	6.11	4,990	5.90	4,530

Hour	Feet	Sec.-ft.	Feet	Sec.-ft.	Feet	Sec.-ft.	Feet	Sec.-ft.	Feet	Sec.-ft.
	March 16		March 17		March 18		March 19		March 20	
3	6.05	4,860	8.73	14,400	6.51	5,980	5.60	3,900	5.06	2,880
6	6.14	5,060	8.66	14,100	6.25	5,320	5.53	3,760	5.02	2,810
9	6.16	5,110	8.42	13,100	6.04	4,840	5.46	3,620	4.98	2,740
12 m.	6.21	5,220	8.06	11,600	5.84	4,400	5.37	3,450	4.91	2,620
3	6.41	5,720	7.76	10,400	5.74	4,180	5.30	3,320	4.86	2,540
6	7.02	7,540	7.44	9,160	5.68	4,060	5.25	3,220	4.82	2,470
9	7.86	10,800	7.15	8,020	5.65	4,000	5.19	3,110	4.78	2,410
12 p.m.	8.48	13,300	6.84	6,940	5.66	4,020	5.14	3,020	4.76	2,380

[a] Mean for the day.

LOCATION.—Water-stage recorder, lat. 42°37′20″, long. 77°59′20″, at highway bridge in St. Helena, Wyoming County, 1½ miles downstream from Wolf Creek.

DRAINAGE AREA.—1,017 square miles.

REMARKS.—Records supersede those published in Water-Supply Paper 504.

TABLE 60.—*Computation of volume of direct runoff associated with precipitation period March 10-14, 1920, Genesee River at St. Helena, N. Y.*

March	12-hour period ending	Daily mean discharge (second-feet)	Estimated recession from preceding storm and base runoff (second-feet)	Direct runoff (second-feet)
10	12 m.	900	900	0
	12 p.m.	1,000	800	200
11	12 m.	1,200	800	400
	12 p.m.	2,800	750	2,050
12	12 m.	10,900	800	10,100
	12 p.m.	26,000	900	25,100
13	12 m.	37,200	950	36,250
	12 p.m.	20,400	1,100	19,300
14	12 m.	8,700	1,250	7,450
	12 p.m.	5,380	1,400	3,980
15	12 m.	4,460	1,550	2,910
	12 p.m.	[a]3,700	1,700	2,000
16	12 m.	[a]3,200	1,800	1,400
	12 p.m.	[a]2,800	1,900	.105
17	12 m.	[a]2,600	1,950	650
	12 p.m.	[a]2,300	1,900	400
18	12 m.	[a]2,100	1,850	250
	12 p.m.	[a]1,950	1,800	150
Total Sec.-ft.-days		68,795	12,050	56,745 (= 2.08 inches)

[a] Estimated recession under subsequent rise.

TABLE 61.—*Computation of time of center of mass of net supply, and lag intervals, Genesee River at St. Helena, N. Y., March 9-14, 1920*

March	12-hour period ending	Mean areal precipitation (inches)	Estimated snow melt (inches)	Precipitation plus snow melt (inches)	Estimated net supply (inches)	Time from origin (days)	Product (inch-days)
9.........	12 p.m......	0.00	0.12	0.12	0.00	0.0	0.000
10.........	12 m........	0.00	.20	.20	.11	.5	.055
	12 p.m......	.03	.40	.43	.30	1.0	.300
11.........	12 m........	.06	.10	.16	.08	1.5	.120
	12 p.m......	.03	.29	.32	.22	2.0	.440
12.........	12 m........	.35	.42	.77	.59	2.5	1.470
	12 p.m......	.13	.68	.81	.63	3.0	1.890
13.........	12 m........	.16	[a].08	.08	.03	3.5	.105
	12 p.m......	.09	[a].10	.19	.12	4.0	.480
14.........	12 m........	.03	[a].03	0	.00	4.5	.000
	12 p.m......	.00	.00	0	.00	5.0	.000
		0.88	2.20	3.08	2.08	....	4.860

[a] Estimated result of snowfall and thawing.

Center of mass of net supply occurred $\frac{4.860}{2.11}$ = 2.30 days after 6 p.m. of March 9 (origin) = March 12.05.

Time of center of mass of direct runoff was at March 13.40 or 1.35 days (32 hours) after center of mass of net supply.

Peak discharge occurred at 3 a.m. March 13 or 1.08 days (26 hours) after center of mass of net supply.

SNOW-RUNOFF STUDIES

Flood-crest discharge rates are the result of two factors, the volume of runoff and its concentration with respect to time. The maximum volume of direct runoff associated with the nonwinter floods in table 63 is 3.47 inches, whereas the maximum volume of runoff for the winter floods is 5.63 inches. The characteristically greater volume of runoff during winter floods in the northeast is attributable to contributions from snow as well as to decreased retentive capacity of the ground during the winter season.

However, inspection of the ratio between the volume of direct runoff during the maximum 24 hours and the total volume of direct runoff for both the winter and nonwinter floods, discloses that the higher ratios prevailed during the nonwinter season, indicating more sharply concentrated runoff. The greater volumes and decreased concentration characteristic of winter floods are partially compensating factors.

The concentration of runoff during winter floods is affected by the intensity of rainfall and by the rate of melting of the snow cover. The rate of melting is related primarily to the magnitude of the thawing temperatures and in a secondary way to the amount of snow remaining on the ground. It seems to approach a limit lower than observed rates of rainfall. Rate of wind movement and relative humidity are other factors of more indirect influence.

In the absence of continuous measurements of snow cover, the difference between measured runoff and precipitation has provided a basis for approximating the amount of water released from the snow cover to stream flow as melt or slush, which has been studied in relation to temperature. The following procedure was adopted for this purpose: Beginning with the end of a subfreezing period, a graph of stream flow was plotted upon which was drawn the estimated position of the line representing base flow. A table was prepared listing daily values of the total discharge and the estimated apportionment in base flow and direct runoff. A cumulative table of total discharge was prepared, which gave the total discharge in second-foot days past the gage from the end of the subfreezing period until midnight of each indicated day. These values of total discharge were adjusted for the estimated ground-water storage and channel storage based on the daily rates of base flow and direct runoff. In general the ground storage on any day in second-foot-days was determined from the rate of base flow in second-feet using appropriate ground-water storage curves as shown in figure 2 and the channel storage, on any day, as equal to the average lag interval, in days, times the concurrent rate of direct runoff, in second-feet.

These volumes of storage were added to the total discharge to obtain the total runoff into the stream channels from the beginning of the thaw up to the indicated day. From the total runoff, converted into equivalent depths in inches, was subtracted the cumulative precipitation over the basin as indicated by available rain gages. The difference equaled the runoff from snow, less the amounts that were added to field moisture and the amount that evaporated. The excess in temperature above 32° F. was computed for each day on the basis of daily recorded maximum and minimum temperatures, at two or more Weather Bureau stations. Account was taken for thawing temperature during those days when part of the day was above and part below 32° F. The daily degree-day excess above 32° F. was cumulated over the same period as the computed snow runoff. Figure 18 shows a plot of the computed cumulative

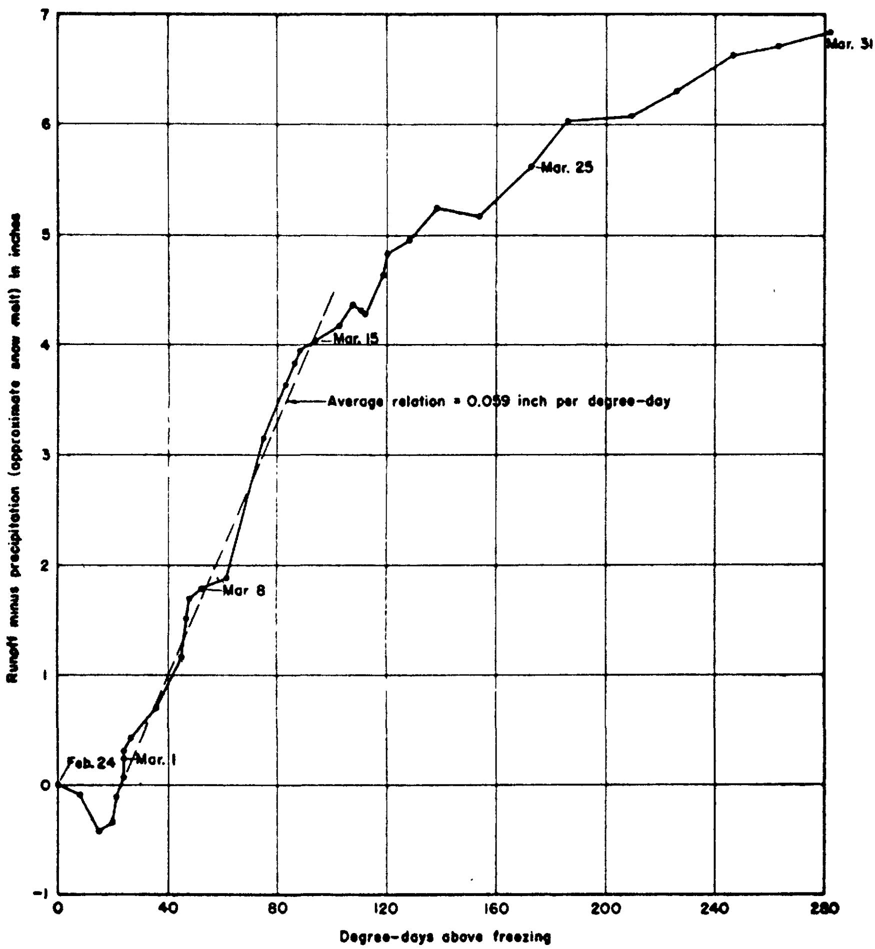

FIGURE 18.—Relation between cumulative snow runoff and degree-days above freezing, Driftwood Branch of Sinnemahoning Creek at Sterling Run, Pa., February-March 1936.

snow runoff against the measured cumulative degree-day excess above 32° F. during March 1936 at Sterling Run, Pa., for Driftwood Branch of Sinnemahoning Creek, a tributary of the West Branch of the Susquehanna River.

The thaw began on February 25, but there was no apparent snow melt until February 29 or until about 25 degree-days had been accumulated. From then until March 15, snow runoff continued to increase steadily in a manner approximately proportionate to the cumulative degree-day thawing temperature. Snow runoff continued after March 15 until the end of the month but at a decreasing rate. Apparently March 15 marked the end of the most favorable snow exposure, and the subsequent decreasing rate of snow runoff was an indication that the quantity of snow was decreasing. After the snow was gone, the curve flattened and, as there was precipitation in excess of runoff, turned downward.

The general trend of relation, as indicated on figure 18, between computed snow runoff and thawing temperatures during the period ending March 15, when the heat was most efficient in producing snow runoff, shows 0.059 inch of snow runoff per degree-day. The indicated rate is not the absolute maximum for the period, as is clearly shown by examination of the figure, which also suggests that for a given drainage basin and a given extent of snow cover there is no uniform rate per degree-day at which water is released from the snow cover. Possibly the melt that is produced by thawing temperatures first accumulates in the snow as capillary water, a process known as ripening, and may be suddenly released as runoff by the application of even a small quantity of additional thawing heat, when it may, under some circumstances, carry with it some of the unmelted snow that had become sodden. However, it would seem that the volumes that can be so stored and released are limited to a portion of the total volume of snow cover on the ground.

In an areal sense snow melting over basins may be conceived to occur normally. At a given time the highest northerly slopes may be in their original state, perhaps with absorbed rain; lower down, in more exposed positions, snow is ripening, and still lower in the basin and on southerly slopes there may be active thawing and release of snow melt perhaps with some slush. In the lowest and most exposed parts of a basin the snow may be all gone and the ground bare. Basin-wide averages therefore may not indicate the rate of melting and release of snow within the area in which active thawing is taking place. This normal behavior also suggests that simultaneous basin-wide ripening and thawing may produce critical rates of snow runoff.

The following is a tabulation of the results of the studies of the rate of snow melt for essentially complete snow cover:

TABLE 62.—*Rates and depths of snow melt*

Stream	Period	Rate (inches per degree-days above 32°F.)	Snow melt at indicated rates (inches)	Approx. water content of initial depth (inches)
New York:				
Genesee River at St. Helena...	March 1920	0.06	2.5	3.5
Sugar River at Talcottville....	April 1928	.05	6.0	9.5
Sacandaga River near Hope....	March 1936	.04	6.0	8.0
Little Beaver Kill near Livingston Manor	.....do......	.07	2.5	7.0
Pennsylvania:				
Driftwood Branch of Sinnemahoning Creek at Sterling Run	.....do......	.06	4.0	7.5

The above determinations do not take account of snow or rainfall added to field moisture or evaporated, and therefore may be low. Moreover, the computed rates may be in error to the extent that the determination of the temperature factor was not sufficiently refined because of incomplete records and inadequate allowance for variations over the area. No adjustments were made for any difference in altitude between the thermometers and the drainage basin. For these reasons the computed degree-day excess seems subject to a large percent of error for temperature near freezing point. The results, however, are fairly consistent and compare with the results of other investigators.

Clyde[11] found the rate of melting of snow cover in Gooseberry Creek in Utah during 1928 to average 0.09 inch per degree-day above 32° F., for an initial depth of snow of 17.2 inches water content. He also found the rate of melting of snow cores in the laboratory to vary between 0.046 and 0.083 inch per degree-day of thawing heat. Using the temperature and runoff data given by Clyde on figure 6 of his report[12] a maximum rate of melting of 0.083 inch per degree-day was obtained by the methods used in the present study. Clyde's studies indicate greater rates of melting than for those here recorded, perhaps because the Gooseberry Creek area had a greater initial depth of snow cover than had any of the basins listed in table 62. The amount of snow melted in Gooseberry Creek Basin at the rate of 0.083 inch of snow cover was 4 inches or about a third of the total initial depth. The maximum rate per degree-day applicable to two-thirds of the initial depth of about 12 inches of water content, was 0.062 inch.

Preliminary studies of the rate of snow melting reported in Water-Supply Paper 799 indicated that runoff from snow at a mean temperature of 31° F., during the 14-day period March 9–22, was negligible

[11] Clyde, G. D., Snow-melting characteristics: Bull. 231, Utah Agri. Expt. Sta., August 1931.
[12] Clyde, G. D., op. cit., p. 17.

and that for each degree-day above this temperature the runoff from melting snow increased between 0.03 and 0.05 inch. This, however, was a general average from which there were notable local variations. Snow melt associated with the flood period of March 17–20, 1936, in the upper Pemigewasset River Basin in New Hampshire amounted to 8.2 inches. Temperature in the basin during the flood period totaled about 52 degree-days above freezing, indicating that melting in this basin averaged 0.16 inches per degree-day.

NONWINTER FLOODS

A summary of rainfall and runoff data for the major floods of record for eight different basins during the nonwinter seasons are listed in table 63. The depth of rainfall that produced these floods ranged from an average of 3.0 inches in 4 days over the Sacandaga River Basin above Hope, N. Y., to an average of 4.96 inches in 6 days over the Susquehanna River Basin above Harrisburg, Pa. The duration of rainfall of 0.01 inch or more per hour, based on available records of hourly rainfall, ranged between 34 and 63 hours, in a manner that was generally proportional to the length of the storm period. Because of the sparsity of recording rain-gage stations, information regarding hourly intensities in the area of heaviest rainfall is generally deficient, but daily rainfall figures afford some clue to possible intensities. The maximum 24-hour amount for the storms listed in table 63 was 14 inches, which was measured in the center of the storm of July 1935 in New York. The next highest amount, 8.48 inches, fell in 24 hours at York, Pa., from August 22–23, 1933. These high 24-hour rainfall figures suggest the occurrence of local runoff intensities on small areas, which probably greatly exceeded that observed from the larger drainage areas reported in table 63.

Maximum observed rates of discharge, which are the principal flood characteristics, are given in table 63 expressed in second-feet and in inches per hour from the indicated drainage areas. These rates are related to the integration of the difference between rates of rainfall and retention as smoothed and modified by transmission through the numberless converging routes of the stream system and by the action of channel storage.

The volumes of direct runoff associated with the floods listed in table 63 varied between 1.39 and 3.44 inches, and the volume of groundwater runoff between 0.30 and 1.10 inches. Total runoff ranged between 1.75 and 4.22 inches. The amount of runoff that will result from a given volume of rainfall during nonwinter conditions is influenced by the antecedent moisture conditions. The rate of base flow prior to the flood has been used by some investigators as an index of such moisture conditions. Figure 19 shows a study of the volumes of rainfall and runoff

existed in the West Branch of the Susquehanna River before the storm of April 27 to May 4, 1909.

The ratio between the volume of direct runoff during the maximum 24-hour period and the total volume of direct runoff for the flood rise is a measure of the concentration of runoff with respect to time. Its value is affected by the variable durations of the storms as well as the more uniform influence of storage and other channel characteristics of the basins. However, it affords a convenient way of expressing the resultant effects of the latter factors. The computed ratios varied between 27 and 60 percent, being generally near the lower limit for the larger drainage basins, and the upper limit for the smaller drainage basins. The lag intervals between center of mass of net supply to center of mass of direct runoff as listed in table 63 are a measure of the channel characteristics of the different basins and as such are inversely related to the concentration ratios. The product of the concentration ratio in percent and the lag, in hours, ranged between 1,700 and 2,600, having less variation than either the values of the concentration ratio or the lag interval, thus demonstrating to some degree this inverse relationship. Further study of this subject is presented in the section "Rates of flood discharge."

FLOOD OF JULY 1921, SACANDAGA RIVER NEAR HOPE, N. Y.

The flood of July 11, 1921, at Hope, N. Y., was probably the result

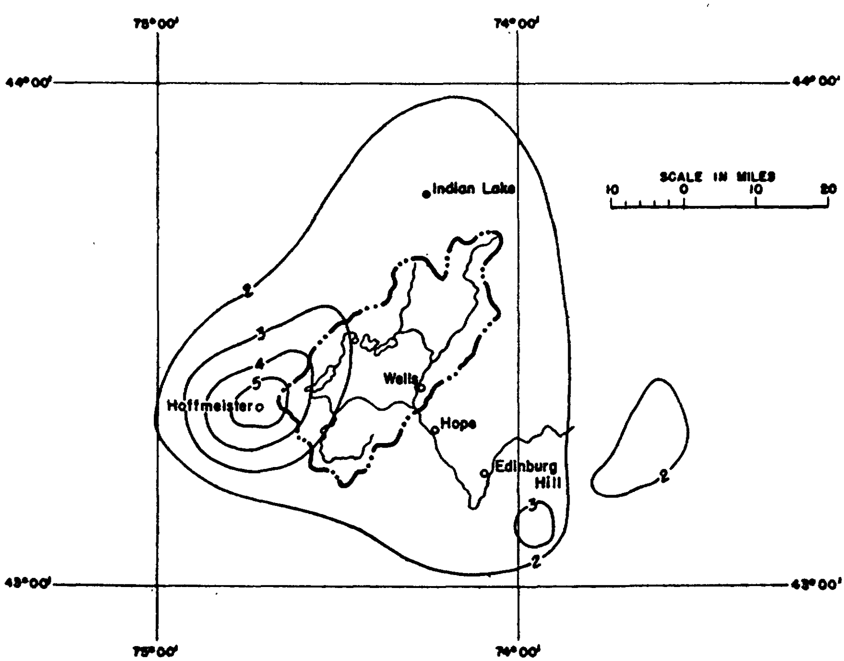

FIGURE 20.—Map of Sacandaga River basin above Hope, N. Y., showing lines of equal precipitation, July 8-12, 1921.

of heavy local downpours in the basin. There were no rainfall measurements within the basin. The river-gage observer at Hope, however, reported a cloudburst on July 11. The lack of competent quantitative rainfall information removes most of the force of any analysis of the rainfall and runoff relation of this storm and flood.

The prevalent temperature around July 11 was above normal and the weather was notable for thunderstorms. Thus, the United States Weather Bureau reports that thunderstorms were observed at 31 stations in New York on July 8, at 28 stations on July 9, 32 stations on July 10, 17 stations on July 11, and 11 stations on July 12. It is likely that the intensity of these storms was confined to small areas and was not associated with any frontal action between air masses of different character.

The isohyetal map shown on figure 20 is based on available published records of the United States Weather Bureau in the region, but may be unreliable for the Sacandaga River Basin because of deficient information. The average rainfall for the basin, according to the map is 3.0 inches, which seems unlikely to have been great enough to produce the

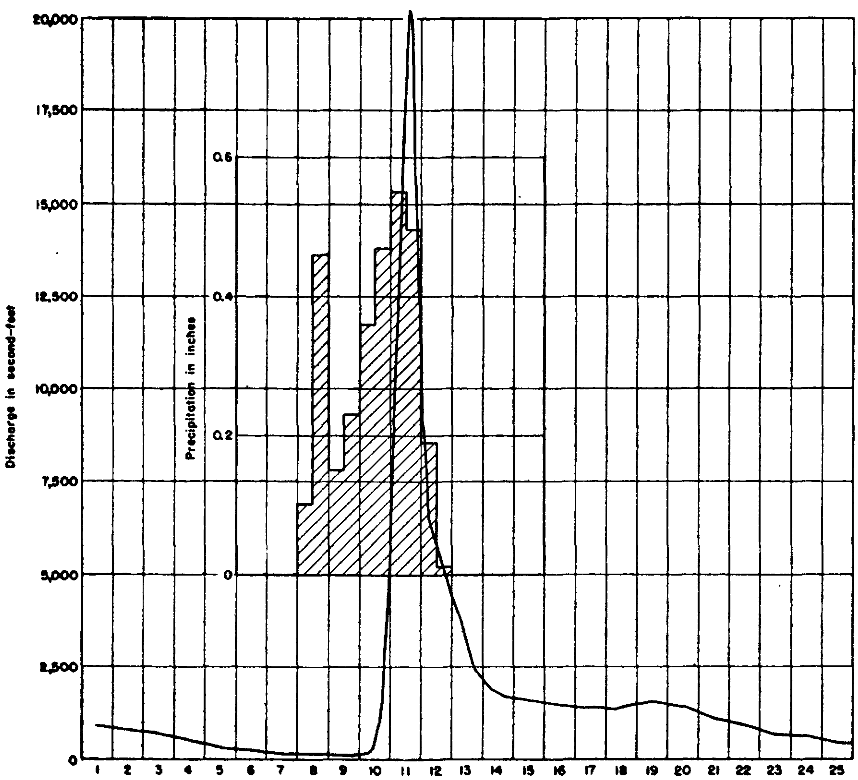

FIGURE 21.—Hydrograph of Sacandaga River near Hope, N. Y., showing discharge, July 1921, and precipitation, July 8-12, 1921.

Table 64.—*Precipitation, in inches, for 12-hour periods, at rain gages near Sacandaga River basin above Hope, N. Y., July 8-12, 1921*

Station (New York)	Altitude (feet)	Weight (per-cent)	12-hour period ending	July 8	July 9	July 10	July 11	July 12	Total 8-12
Gloversville	850	8	12 m.	0	0	0.05	0.05	0	1.93
			12 p.m.	.48	1.27	.05	.03	0	
Hoffmeister	1,860	51	12 m.	.60	.80	.21	.54	.35	5.39
			12 p.m.	1.78	0	.42	.69	0	
Indian Lake	1,660	41	12 m.	0	.03	.60	.65	.03	2.86
			12 p.m.	.27	.30	.62	.34	.02	
Average or total		100	12 m.	0.10	0.15	0.36	0.55	0.19	3.01
			12 p.m.	.46	.23	.47	.49	.01	

Table 65.—*Gage height and discharge of Sacandaga River near Hope, N. Y., during flood of July 1921*

MEAN DISCHARGE, IN SECOND-FEET, JULY 1921

Day	Sec.-ft.	Day	Sec.-ft.	Day	Sec.-ft.	Day	Sec.-ft.	Day	Sec.-ft.	Day	Sec.-ft.
1	910	6	202	11	14,600	16	1,470	21	1,110	26	380
2	820	7	161	12	6,130	17	1,380	22	910	27	340
3	700	8	150	13	3,080	18	1,380	23	660	28	310
4	525	9	139	14	1,780	19	1,560	24	525	29	305
5	320	10	1,230	15	1,590	20	1,440	25	438	30	295
										31	322
Mean monthly discharge, in second-feet											1,457
Runoff, in inches											3.42

GAGE HEIGHT,[a] IN FEET, AND DISCHARGE, IN SECOND-FEET, AT INDICATED TIME, 1921

Hour	July 8 Feet	July 8 Sec.-ft.	July 9 Feet	July 9 Sec.-ft.	July 10 Feet	July 10 Sec.-ft.	July 11 Feet	July 11 Sec.-ft.	July 12 Feet	July 12 Sec.-ft.	July 13 Feet	July 13 Sec.-ft.
2							6.55	8,000	6.85	9,000		
4							7.15	10,100	6.40	7,530		
6							7.70	12,300	6.05	6,500		
8					1.95	202	8.20	14,500				
10					2.20	310	8.60	16,500				
12 m.					2.5	465	8.95	18,400	5.75	5,660		
2					2.85	700	9.20	19,800				
4					3.25	1,060	9.20	19,800				
6	1.80	147	1.75	132	3.75	1,620	8.85	17,800	5.50	4,990	4.30	2,390
8					4.45	2,650	8.45	15,700				
10					5.20	4,230	7.95	13,400				
12 p.m.			1.80	147	5.85	5,930	7.45	11,200	5.25	4,360		

Hour	July 14 Feet	July 14 Sec.-ft.	July 15 Feet	July 15 Sec.-ft.	July 16 Feet	July 16 Sec.-ft.	July 17 Feet	July 17 Sec.-ft.	July 18 Feet	July 18 Sec.-ft.
7 a.m.	3.95	1,880	3.75	1,620	3.65	1,500	3.55	1,380	3.50	1,330
6 p.m.	3.80	1,680	3.70	1,560	3.60	1,440	3.55	1,380	3.60	1,440

[a] Supplemental records: July 8, 7 a.m., 1.82 ft., 154 sec.-ft. July 9, 7 a.m., 1.78 ft., 141 sec.-ft. July 10, 7 a.m., 1.85 ft., 164 sec.-ft. July 11, 3 p.m., 9.30 ft., 20,400 sec.-ft. July 13, 7 a.m., 5.00 ft., 3,760 sec.-ft.

Location.—Inclined staff gage, lat. 43°21′10″, long. 74°16′13″, 1½ miles below junction of East and West Branches of Sacandaga River and 4½ miles above Hope, Hamilton County.

Drainage area.—491 square miles.

Remarks.—Records supersede those published in Geol. Survey Water-Supply Paper 521.

maximum nonwinter flood of 28 years' record in that river, particularly where it followed a period of subnormal precipitation and excess temperature. No information is available concerning rates of rainfall.

Table 64 lists the estimated time distribution of rainfall at the indicated rain gages near the basin during the storm period, based on observers' notations of the beginning and ending of rainfall.

The river discharge at Hope during the flood is given in table 65, and is graphically shown on figure 21. The volume of direct runoff as computed in table 66 was 1.94 inches, leaving an apparent retention of 1.06 inches. Ground-water runoff accounted for 0.65 inch of this retention, leaving 0.41 inch for field-moisture accretion and evaporation-transpiration losses.

The sharp concentration of the rainfall may be discerned from the fact that 57 percent of the direct runoff occurred during 24 hours, compared with 35 and 27 percent during the two winter floods of March 1936 as reported in table 1. The interval between the centers of estimated effective rainfall and direct runoff was 38 hours. This interval is about 10 hours less than for the March 1936 floods and may indicate that the storm centered near the lower part of the basin as suggested by the river observer's notation of a cloudburst on July 11. The interval between the center of effective precipitation and the peak discharge was 25 hours.

TABLE 66.—*Computation of volume of direct runoff associated with precipitation period July 8-12, 1921, Sacandaga River near Hope, N. Y.*

July	12-hour period ending	Daily mean discharge (second-feet)	Estimated recession from preceding storm and base runoff (second-feet)	Direct runoff (second-feet)
9	12 p.m.	135	135	0
10	12 m.	210	165	45
	12 p.m.	2,250	200	2,050
11	12 m.	12,270	250	12,020
	12 p.m.	16,910	310	16,600
12	12 m.	7,260	370	6,890
	12 p.m.	5,000	440	4,560
13	12 m.	3,760	510	3,250
	12 p.m.	2,390	590	1,800
14	12 m.	[a]1,880	610	1,270
	12 p.m.	[a]1,550	620	930
15	12 m.	[a]1,280	610	670
	12 p.m.	[a]1,080	600	480
16	12 m.	[a]900	600	300
	12 p.m.	[a]800	600	200
17	12 m.	[a]700	600	100
	12 p.m.	[a]630	600	30
18	12 m.	[a]600	600	0
Total				
Sec.-ft.-½ days		59,605	8,410	51,195
Sec.-ft.-days		29,802	4,205	25,597 (= 1.94 inches)

[a] Estimated recession under subsequent rise.

STORM OF JULY 1935

Hollister Johnson has described the storm and flood of July 1935 in New York State in a report[13] that lists the records of available rainfall and maximum flood discharges, with discussion of the meteorology of the storm. Johnson says, "A series of extraordinarily severe thunderstorms during the night of July 7 and the morning of July 8, 1935, speedily brought many small streams to destructive heights before the inhabitants could realize the situation in which they were caught." Thus the storm causing the flood consisted of several more or less localized electrical storms during the period July 7 to 10.

[13] Johnson, Hollister, The New York State flood of July 1935: Geol. Survey Water-Supply Paper 773E, 1936.

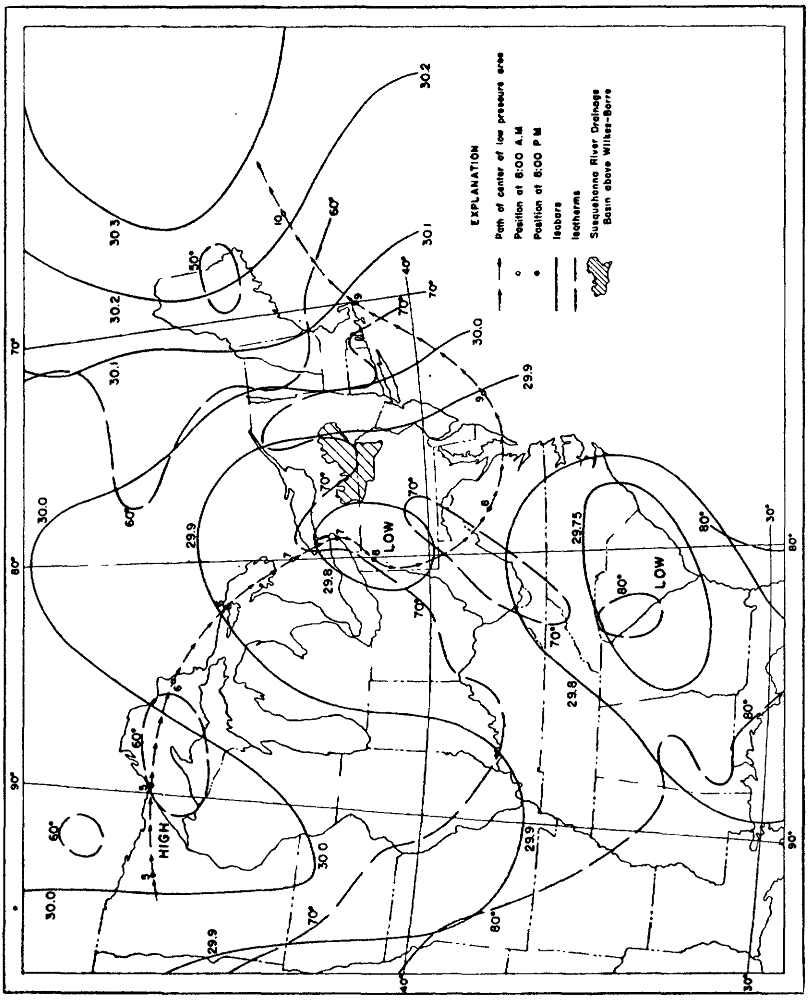

FIGURE 22.—Map of eastern United States showing position of storm, 8 a.m. (E.S.T.), July 8, 1935.

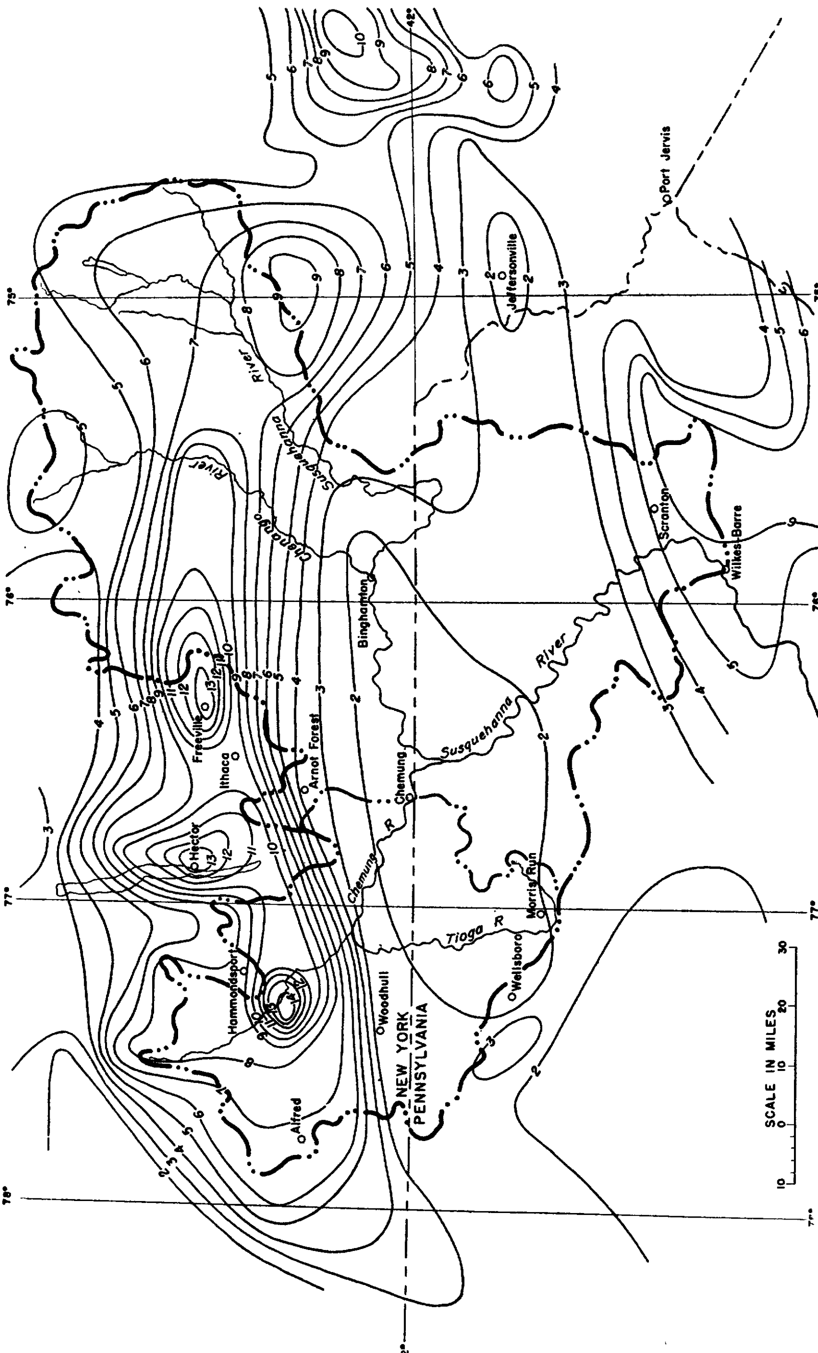

Figure 23.—Map of upper Susquehanna River basin showing lines of equal precipitation, noon July 6 to noon July 10, 1935.

The storm originated in a meteorological disturbance that centered over Minnesota on July 5. (See fig. 22.) The normal eastward movement was blocked by the presence of a high-pressure area of cold air centering over Hudson Bay. By 8 a.m., July 8 (see fig. 22), the low-pressure area centered over western New York, and the cold front lay in an east-west position over southern New York close to the 70° isothermal line shown on figure 22. Wind directions on the surface weather map of July 8 indicate the movement of warm air from the South Atlantic and the movement of cold air from the northeast towards the frontal region in New York. The weather map therefore suggests that the heavy rainfall was the result of pressure contrasts that created a condition in which a continuous stream of warm moist air was being rapidly carried aloft over a wedge of colder air and which resulted in condensation of the moisture contained in the warm air mass.

The flood was particularly disruptive on the smaller streams in southern New York, some of which reached discharge rates exceeding 2,000 second-feet per square mile (3.1 inches per hour), thus indicating very high rates of precipitation over local areas that were greatly in excess of the capacity of the land to absorb it. Measurements indicate that 1-day rainfall on these areas exceeded 14 inches. Figure 23 shows an isohyetal map of the rainfall from noon of July 6 to and including July 10, based upon records of rainfall published by Johnson, and one additional record as reported below.

Rainfall at Cohocton, N. Y. (lat. 42°30′10″, long. 77°29′50″) as observed by the United States Soil Conservation Service at 8 a.m. of the indicated days:

July	Rainfall (inches)
6	0
7	.61
8	6.70
9	.91
10	.05
11	0

The New Jersey State Water Policy Commission has prepared a series of maps showing the areal distribution of rainfall at intervals during the storm, and from these maps the maximum rainfall during 6-hour, 12-hour, 18-hour, 24-hour, and 36-hour periods have been determined. The area enclosed within the isohyetal lines on these maps has been measured, and the mean precipitation computed. The results are shown on figure 24.

The storm of July 1935 produced the greatest flood on record in many of the smaller streams in central New York, and produced the greatest summer flood of record on the Chemung River at Chemung, N. Y., and on the Susquehanna River at Wilkes-Barre, Pa.

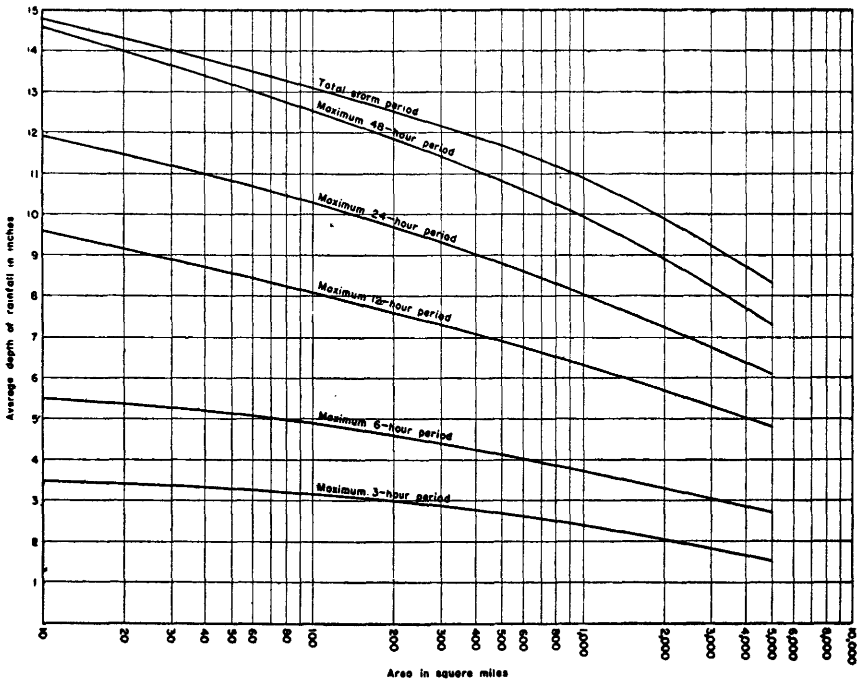

FIGURE 24.—Curves showing average depth of rainfall over indicated areas during periods of maximum intensity, storm of July 6-10, 1935.

FLOODS OF JULY 1935

CHEMUNG RIVER AT CHEMUNG, N. Y.

Rainfall for 12-hour periods during the storm at several rain gages in and near the basin is given in table 67. The total storm rainfall, from July 6–10, averaged 4.90 inches over the basin, of which about 3.5 inches fell in the 24-hour period between noon of July 7 and noon of July 8. As shown in figure 23, the storm centered over the valley of the Cohocton River where local precipitation exceeded 14 inches and small tributary streams reached record-breaking heights. However, the precipitation averaged only about 2 inches over the upper Tioga River which drains the southerly part of the basin. The Tioga River Basin above Lindley, N. Y. (770 square miles), contributed a relatively negligible runoff.

The discharge during the flood is given in table 68 and is plotted as a hydrograph on figure 25. Direct runoff associated with the 4.90 inches of precipitation from July 6–10 was 1.91 inches, leaving a retention of 2.99 inches. Ground-water runoff accounted for about 0.3 inch, indicating that field-moisture accretion and evaporation losses averaged 2.69 inches over the basin.

As computed by methods previously explained, the infiltration index was 0.17 inch per hour. The time interval between center of mass of

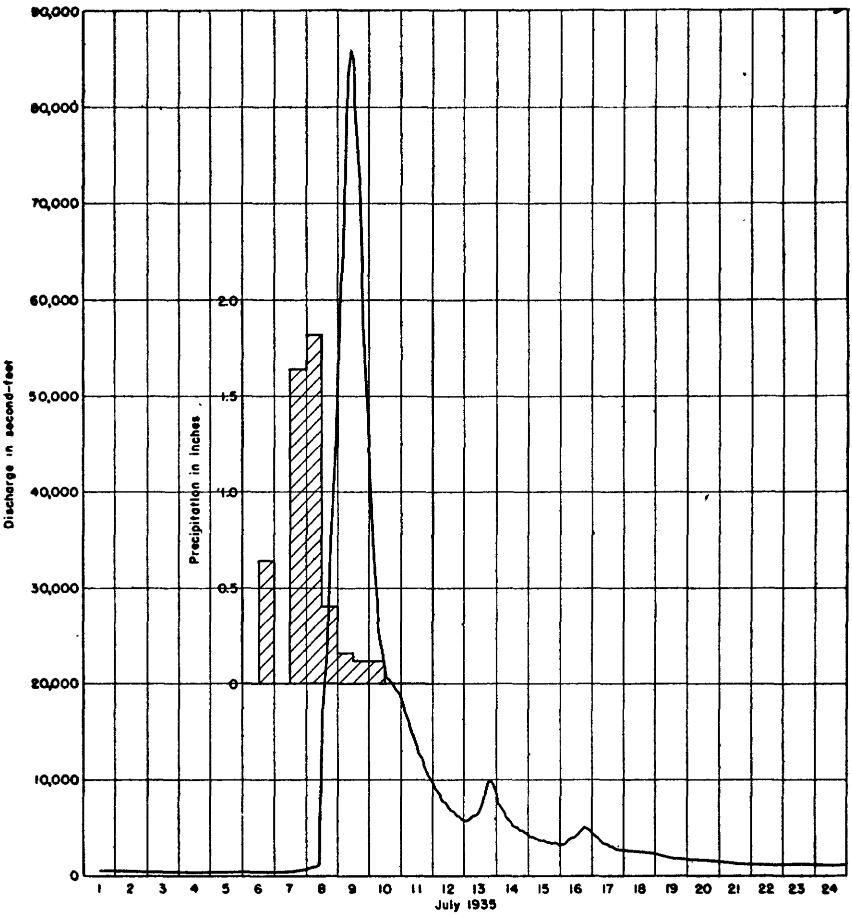

FIGURE 25.—Hydrograph of Chemung River at Chemung, N. Y., showing discharge, July, and precipitation, July 6-10, 1935.

TABLE 67.—*Precipitation, in inches, for 12-hour periods, at stations in and near Chemung River basin, July 6-10, 1935*

Station	12-hour period ending									Total
	July 6	July 7		July 8		July 9		July 10		
	12 p.m.	12 m.	12 p.m.	12 m.	12 p.m.	12 m.	12 p.m.	12 m.	12 p.m.	
New York:										
Alfred	0.06	0.00	1.86	3.20	0.70	0.14	0.32	0.36	0.00	6.64
Arnot	.42	.00	1.22	1.07	.65	.43	.15	.13	.00	4.07
Burdett	2.00	.00	4.66	4.08	.32	.04	.00	.02	.04	11.16
Ithaca	1.12	.00	3.62	3.92	.68	.19	.07	.04	.00	9.64
Elmira	.10	.00	.56	.79	.21	.08	.03	.00	.00	1.77
Hammondsport	1.90	.00	3.34	2.94	.26	.18	.08	.05	.00	8.75
Haskinville	.75	.00	2.66	2.77	.53	.00	.43	.52	.00	7.66
Woodhull	.16	.00	.75	.89	.30	.22	.08	.06	.00	2.46
Pennsylvania:										
Lawrenceville	.63	.00	.39	.52	.16	.12	.06	.08	.00	1.94
Morris Run	.00	.00	.07	.92	.65	.28	.06	.03	.00	2.01
Basin average	0.64	0.00	1.64	1.82	0.40	0.16	0.12	0.12	0.00	4.90

TABLE 68.—*Gage height and discharge of Chemung River at Chemung, N. Y., during flood of July 1935*

MEAN DISCHARGE, IN SECOND-FEET, JULY 1935

Day	Sec.-ft.	Day	Sec.-ft.	Day	Sec.-ft.	Day	Sec.-ft.	Day	Sec.-ft.	Day	Sec.-ft.
1	555	6	431	11	13,790	16	4,170	21	1,270	26	4,320
2	511	7	520	12	7,380	17	3,380	22	1,140	27	2,240
3	471	8	16,040	13	7,570	18	2,320	23	1,200	28	1,490
4	444	9	68,800	14	5,800	19	1,850	24	1,070	29	1,310
5	431	10	24,740	15	3,683	20	1,560	25	1,390	30	1,500
										31	1,140
Mean monthly discharge, in second-feet											5,888
Runoff, in inches											2.86

GAGE HEIGHT, IN FEET, AND DISCHARGE, IN SECOND-FEET, AT INDICATED TIME, 1935

Hour	July 7		July 8		July 9		July 10		July 11		July 12	
	Feet	Sec.-ft.	Feet	Sec.-ft.	Feet	Sec.-ft.	Feet	Sec.-ft.	Feet	Sec.-ft.	Feet	Sec.-ft.
2	2.22	444	2.70	810	16.8	58,200	14.15	37,000	10.04	17,800	7.29	9,220
4	2.22	444	2.81	910	17.6	66,000	13.3	32,100	9.77	16,900	7.13	8,780
6	2.24	457	2.85	950	18.5	75,500	12.6	28,600	9.54	16,100	6.97	8,350
8	2.27	477	2.90	1,000	19.2	83,200	11.95	25,400	9.30	15,200	6.82	7,940
10	2.29	490	3.15	1,260	19.45	86,000	11.35	22,900	9.03	14,400	6.67	7,550
12 m.	2.30	497	7.50	9,810	19.35	84,800	10.95	21,300	8.78	13,600	6.52	7,170
2	2.32	511	10.0	17,700	18.9	79,900	10.8	20,700	8.52	12,900	6.39	6,850
4	2.34	526	11.55	23,700	18.25	72,800	10.7	20,300	8.28	12,100	6.28	6,580
6	2.40	569	12.85	29,800	17.5	65,000	10.58	19,800	8.05	11,400	6.18	6,340
8	2.45	607	14.05	36,400	16.65	56,800	10.49	19,500	7.83	10,800	6.09	6,140
10	2.50	645	15.1	43,800	15.85	49,800	10.39	19,100	7.65	10,200	6.01	5,950
12 p.m.	2.57	701	16.0	51,000	14.95	42,600	10.25	18,600	7.46	9,700	5.93	5,780

Hour	July 13		July 14		July 15		July 16		July 17	
	Feet	Sec.-ft.	Feet	Sec.-ft.	Feet	Sec.-ft.	Feet	Sec.-ft.	Feet	Sec.-ft.
2	5.90	5,710	6.74	7,730	5.18	4,230	4.66	3,250	5.22	4,310
4	6.05	6,040	6.50	7,120	5.12	4,120	4.70	3,320	5.08	4,040
6	6.18	6,340	6.29	6,610	5.04	3,970	4.84	3,590	4.95	3,800
8	6.20	6,390	6.11	6,180	4.99	3,870	4.95	3,800	4.84	3,590
10	6.24	6,490	5.94	5,800	4.92	3,740	5.04	3,970	4.74	3,400
12 m.	6.41	6,900	5.81	5,510	4.86	3,620	5.13	4,140	4.68	3,280
2	6.74	7,730	5.68	5,240	4.80	3,510	5.26	4,380	4.60	3,140
4	7.18	8,920	5.58	5,030	4.76	3,430	5.44	4,740	4.52	3,000
6	7.53	9,900	5.48	4,820	4.71	3,340	5.59	5,050	4.45	2,880
8	7.55	9,960	5.40	4,660	4.69	3,300	5.59	5,050	4.40	2,800
10	7.31	9,280	5.32	4,500	4.67	3,270	5.49	4,840	4.34	2,700
12 p.m.	7.01	8,460	5.24	4,350	4.66	3,250	5.37	4,600	4.30	2,640

LOCATION.—Water-stage recorder, lat. 42°00′10″, long. 76°38′00″, just below highway bridge three-quarters of a mile southwest of Chemung, Chemung County.

DRAINAGE AREA.—2,530 square miles.

REMARKS.—Records supersede those published in Geol. Survey Water-Supply Paper 781.

TABLE 69.—*Computation of volume of direct runoff associated with precipitation period July 7-10, 1935, Chemung River at Chemung, N. Y.*

July	Daily mean discharge (second-feet)	Estimated recession from preceding storm and base runoff (second-feet)	Direct runoff (second-feet)
7	520	500	20
8	16,040	600	15,440
9	68,800	900	67,900
10	24,740	1,300	23,440
11	13,790	1,500	12,290
12	7,380	1,450	5,930
13	[a]4,300	1,400	2,900
14	[a]2,750	1,350	1,400
15	[a]1,800	1,300	500
16	[a]1,350	1,250	100
17	[a]1,150	1,150	0
Total Sec.-ft.-days	142,620	12,700	129,920 (= 1.91 inches)

[a] Estimated recession under subsequent rise.

effective rainfall to the center of mass of direct runoff was 45 hours and that to the peak discharge rate 30 hours.

SUSQUEHANNA RIVER AT WILKES-BARRE, PA.

The total precipitation over the basin of the Susquehanna River above Wilkes-Barre, Pa., as shown on figure 23 averaged 4.66 inches for the period July 6–10. The daily amounts at several gages in and near the basin are listed in table 70. Of the total rainfall, 75 percent fell on July 7 and 8.

The discharge during the flood is given in table 71 and plotted as a hydrograph on figure 26. Direct runoff associated with the precipitation period July 6–10 as computed in table 72 was 1.52 inches, indicating a retention of 3.14 inches. Ground-water runoff was 0.38 inch leaving a net retention of 2.76 inches as field-moisture accretion and evaporation losses.

The infiltration index as computed by methods previously explained was about 0.17 inch per hour, the same as that for the Chemung River Basin during this storm. The interval between centers of mass of effective rainfall and direct runoff was 77 hours and the interval between the center of mass of effective rainfall and the peak rate of discharge was 54 hours.

TABLE 70.—*Daily precipitation, in inches, at stations in and near Susquehanna River basin above Wilkes-Barre, Pa., July 6-10, 1935*

[In this table "T" indicates a trace]

Station	Altitude (feet)	Weight (percent)	July 6	July 7	July 8	July 9	July 10	Total 6–10
New York:								
Angelica	1,420	0.04	0.26	1.85	2.82	1.13	0	5.80
Alfred	1,840	3.23	.05	1.97	3.80	.38	.44	6.64
Bainbridge	1,006	3.95	0	2.73	2.20	.56	.19	5.56
Binghamton	858	10.18	.27	.07	1.02	.31	.22	1.89
Cooperstown	1,200	6.80	.28	2.06	3.03	.44	.71	6.52
Cortland	1,129	5.77	.57	3.69	5.70	1.32	.26	11.54
Delhi	1,460	.83	0	2.84	5.73	.36	.52	9.45
Elmira	863	7.07	.10	.56	1.00	.11	0	1.77
Haskinville	1,620	5.50	.76	2.90	3.10	.43	.52	7.71
Ithaca	872	3.15	1.12	3.62	4.60	.26	.04	9.64
Lawrenceville	1,000	6.00	.62	.42	.67	.16	.07	1.94
Morrisville	1,325	3.49	1.03	2.88	1.70	.32	23	6.16
Norwich	1,015	3.92	1.10	4.01	4.23	.37	.08	9.79
Oneonta	1,112	3.65	.49	2.73	3.57	.21	.12	7.12
Sherburne	1,037	3.61	.16	2.52	1.88	.47	.06	5.09
Syracuse	400	.15	.19	2.05	1.25	.13	T	3.62
Pennsylvania:								
Galeton	1,325	1.79	.04	.58	1.10	.22	0	1.94
Morris Run	1,750	3.99	0	.28	1.35	.35	.03	2.01
Muncy Valley	1,045	.79	.13	.55	.98	.75	0	2.41
Pleasant Mount	1,820	4.91	0	0	.82	1.63	0	2.45
Scranton	746	5.88	[a]1.68	0	1.39	2.60	0	3.99
Towanda	754	10.81	.18	.39	.97	.39	0	1.93
Wellsboro	1,419	1.45	0	.30	.65	.10	T	1.05
Wilkes-Barre	540	3.04	0	.28	1.72	2.86	1.03	5.89
Average or total	--------	100.0	0.34	1.41	2.09	0.67	0.15	4.66

[a] Very local rainfall, not included in average.

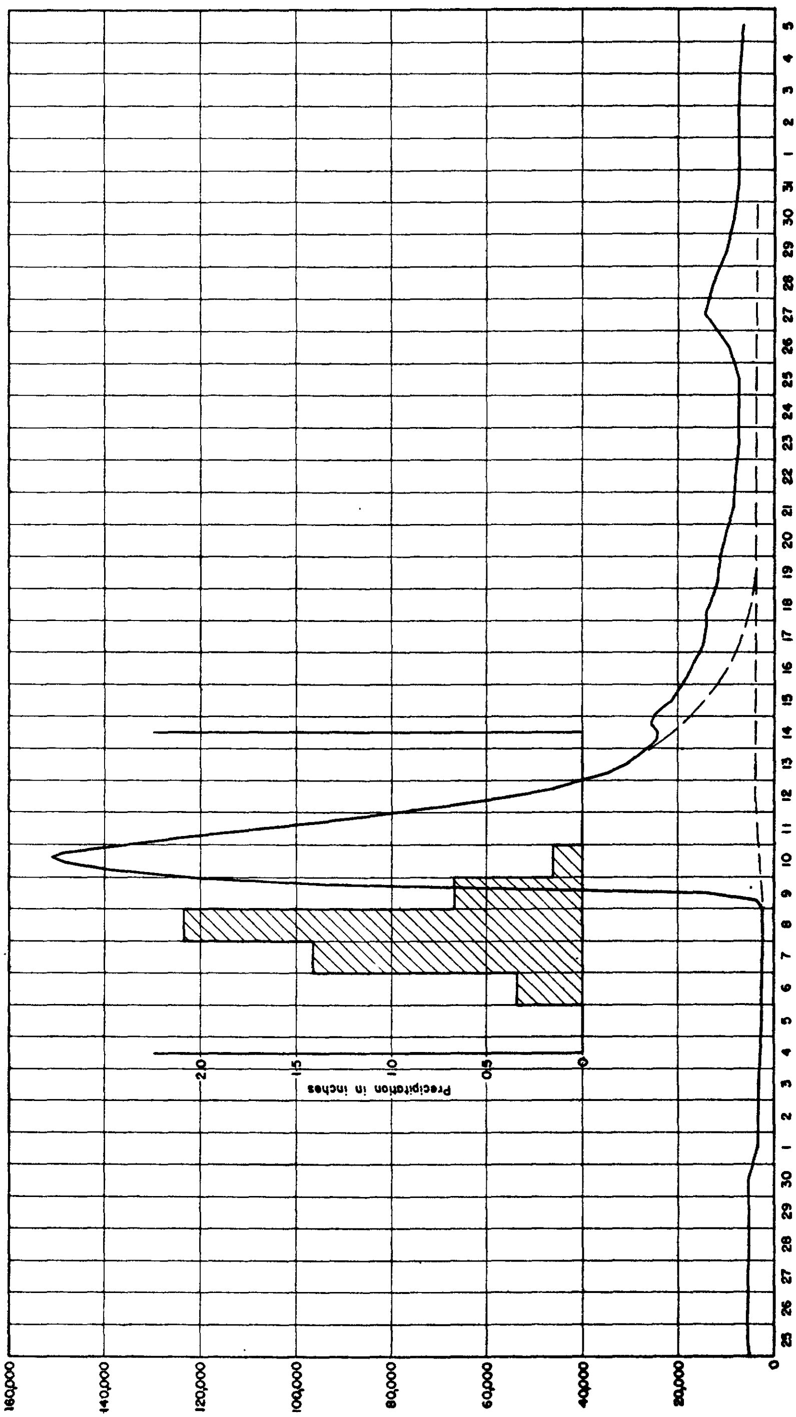

FIGURE 26.—Hydrograph of Susquehanna River at Wilkes-Barre, Pa., showing discharge, July, and precipitation, July 6-10, 1935.

TABLE 71.—*Gage height and discharge of Susquehanna River at Wilkes-Barre, Pa., during flood of July 1935*

MEAN DISCHARGE, IN SECOND-FEET, JULY 1935

Day	Sec.-ft.	Day	Sec.-ft.	Day	Sec.-ft.	Day	Sec.-ft.	Day	Sec.-ft.	Day	Sec.-ft.
1	3,780	6	2,520	11	115,000	16	17,300	21	9,200	26	9,420
2	3,380	7	2,600	12	56,200	17	14,600	22	8,080	27	14,600
3	3,190	8	2,600	13	31,600	18	13,600	23	7,540	28	12,900
4	2,930	9	43,900	14	25,200	19	11,900	24	7,540	29	10,100
5	2,680	10	142,000	15	22,000	20	10,700	25	7,280	30	8,360
										31	7,540
Mean monthly discharge, in second-feet											20,330
Runoff, in inches											2.35

GAGE HEIGHT, IN FEET, AND DISCHARGE, IN SECOND-FEET, AT INDICATED TIME, 1935

Hour	Feet	Sec.-ft.	Feet	Sec.-ft.	Feet	Sec.-ft.	Feet	Sec.-ft.	Feet	Sec.-ft.
	July 7		July 8		July 9		July 10 [a]		July 11	
6	2.24	2,680	2.18	2,600	2.79	3,670	24.30	140,000	22.50	123,000
12 m.	2.17	2,520	2.21	2,600	6.51	13,950	25.20	149,000	20.75	107,000
6	2.15	2,520	2.19	2,600	18.80	90,160	25.18	149,000	19.16	93,500
12 p.m.	2.16	2,520	2.19	2,600	22.44	122,000	24.15	139,000	17.48	79,650
	July 12		July 13		July 14		July 15		July 16	
6	15.80	66,640	10.98	34,700	9.10	24,700	8.77	23,300	7.64	18,100
12 m.	14.15	55,200	10.30	30,850	9.12	24,700	8.44	21,500	7.44	17,300
6	12.80	45,820	9.88	28,700	9.31	25,700	8.14	20,150	7.23	16,500
12 p.m.	11.77	39,500	9.37	26,200	9.20	25,200	7.88	19,300	7.00	15,700
	July 17		July 18		July 19		July 20		July 21	
6	6.79	15,000	6.56	14,300	5.94	11,900	5.59	11,000	5.03	9,200
12 m.	6.66	14,650	6.41	13,600	5.88	11,900	5.45	10,400	4.93	8,920
6	6.60	14,300	6.22	12,900	5.80	11,600	5.32	10,100	4.82	8,640
12 p.m.	6.60	14,300	6.06	12,550	5.72	11,300	5.19	9,800	4.72	8,360

[a] Peak discharge: July 10, 2:30 p.m., 151,000 sec.-ft.

LOCATION.—Water-stage recorder, lat. 41°15'00", long. 75°53'10", at Market Street Bridge at Wilkes-Barre, Luzerne County, 116 miles above mouth of Toby Creek. Zero of gage is 511.94 feet above mean sea level.

DRAINAGE AREA.—9,960 square miles.

REMARKS.—Records of daily mean discharge published in Geol. Survey Water-Supply Paper 781.

TABLE 72.—*Computation of volume of direct runoff associated with precipitation period July 6-10, 1935, Susquehanna River at Wilkes-Barre, Pa.*

July	Daily mean discharge (second-feet)	Estimated recession from preceding storm and base runoff (second-feet)	Direct runoff (second-feet)
8	2,600	2,600	0
9	43,900	3,000	40,900
10	142,000	3,400	138,600
11	115,000	3,800	111,200
12	56,200	4,000	52,200
13	31,600	4,000	27,600
14	[a]21,000	4,000	17,000
15	[a]14,200	4,000	10,200
16	[a]9,800	4,000	5,800
17	[a]6,700	4,000	2,700
18	[a]4,800	4,000	800
19	[a]4,000	4,000	0
Total Sec.-ft.-days	451,800	44,800	407,000 (= 1.52 inches)

[a] Estimated recession under subsequent rise.

STORM OF AUGUST 21-25, 1933

The storm of August 21–25 was of the tropical hurricane type that originated in the vicinity of the Leeward Islands and appeared off the coast of the Carolinas on August 23. As shown on figure 27, the center

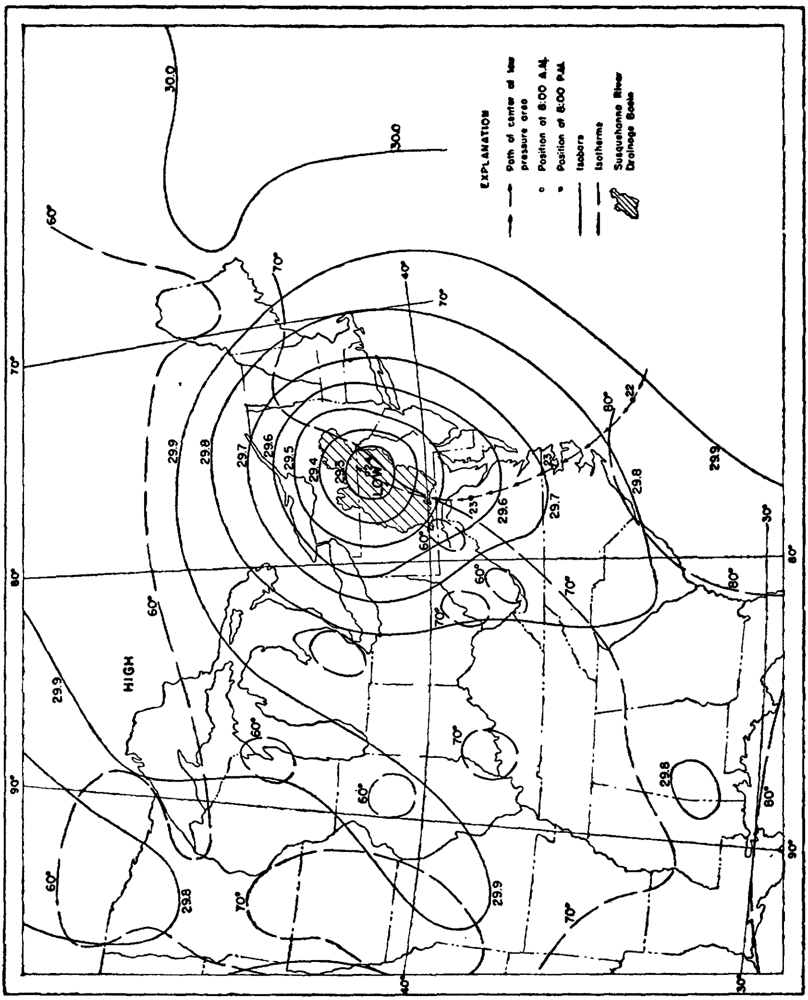

FIGURE 27.—Map of eastern United States showing position of storm, 8 a.m. (E.S.T.), August 24, 1933.

of the low-pressure area followed a northwesterly path and crossed the length of the Susquehanna Valley during the afternoon of August 23 and the morning of the 24th, and then continued northeastward across New York State. It was accompanied by torrential rains of such intensity over the southern tip of the drainage basin that all existing records of rainfall for Pennsylvania were broken. At York 13.28 inches were recorded during the 3-day period, 7 p.m. August 21 to 7 p.m. August 24, of which 8.48 inches fell within 24 hours.

Records of daily rainfall during the storm are available in published reports of the United States Weather Bureau.[14] Since records of hourly rainfall, however, are not so generally available, these records are included in this report as table 73.

Plate 1 is an isohyetal map, based on all available records of precipitation, showing the precipitation from August 20 to 25, 1933. There were three areas of outstandingly high precipitation, one in southern Delaware, the second at York, Pa., and the third in the Catskill Mountain region in New York. The line joining these areas generally marks the region of maximum rainfall, which lay east of but parallel to the storm track shown on figure 27.

The storm was unique in the great depths of precipitation it brought to large areas. Thus, according to the Miami Conservancy District, the rainfall in 5 days averaged 10 inches over 6,000 square miles. The area that received more than 5 inches probably exceeded 50,000 square miles and compared closely with the hurricane storm of September 17–21, 1938[15], which centered in New England.

The storm resulted in major floods in the affected area, and more notably, produced, at Marietta, Pa., the largest known nonwinter flood in the Susquehanna River, which drains an area of 25,990 square miles. The storm also produced the maximum flood during the period of record, 1912–39, on the East Branch of the Delaware River at Fishs Eddy, N. Y. Hydrologic data with respect to the August 1933 floods in these two basins are given on pages 101–112.

FLOODS OF AUGUST 1933

EAST BRANCH OF DELAWARE RIVER AT FISHS EDDY, N. Y.

There was only one record of rainfall for the flood within the basin, that of the Weather Bureau at Roxbury, N. Y., and as a result the determination of mean areal rainfall may be inaccurate. The city of New York, through its Board of Water Supply, maintains a number of rainfall stations in the areas to the east of the basin. All available records are given in table 74, and plate 1 is a map of the area with isohyetal lines of total rainfall during the period August 20–25, 1933, based on these records. The mean areal precipitation was computed by Thiessen's method to be 6.22 inches. Table 75 lists precipitation for 6-hour periods at the indicated rain gages during the storm. The 6-hour rainfall amounts are based on the daily measurements of rainfall supplemented by dis-

[14] Climatological data of the United States, August 1933.

[15] Paulsen, C. G., and others, Hurricane floods of September 1938: U. S. Geol. Survey Water-Supply Paper 867, p. 83, 1940.

TABLE 73.—*Hourly precipitation, in inches, at recording rain gages in and near Susquehanna and upper Delaware River basins, August 20-25, 1933*

[In this table "T" indicates a trace]

Station	Day	a.m.												p.m.												Total
		1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	
Binghamton, N. Y. U. S. Weather Bureau.	20																									
	21													T	T						T	T	T	T	T	T
	22	0.04	0.02	0.03	0.23	0.07	0.04	0.08	0.31	0.78	0.35	0.24	0.07	0.01	0.02	T						T	T	T		2.29
	23								T			T	.01	.03	T	0.01	0.03	0.05	0.03	0.03	0.11	0.14	0.22	0.28	0.23	1.17
	24	.17	T	.06	.11	.11	.07	.07	.11	.04	T	T	T	T	.01	T	T	.03	T	T	T	T	T	T	T	.78
	25	T	T	T	T	.01	T	.01	T																	.02
Kingston, N. Y. City of Kingston, N. Y.	20																									
	21																				.02		.01	.07	.04	.14
	22	.06	.04	.21	.14	.11	.17	.03	.12	.09	.14	.07	.20	.10	.01	.01										1.50
	23																.01	.01	.02	.02	.04	.04	.48	.16	.31	1.09
	24	.30				.05	.06	.06	.14	.11	.16	.10	.03	.01												1.02
	25																									
Truxton, N. Y. U. S. Geological Survey.	20																									
	21																									
	22	.01	.04	.02	.03	.10	.13	.05	.04	.05	.05	.06	.17	.10	.10	.09	.15	.06								1.25
	23															.03	.02	.03	.02	.02	.06	.09	.15	.10	.14	.66
	24	.18	.20	.09	.10	.11	.11	.05	.10	.06	.07	.01			.02	.04	.02	.02	.03			.03				1.24
	25	.01	.01	.01	.01	.03	.05		.02																	.14
Voorheesville, N. Y. R. E. Horton.	20																									
	21																		.01		.01				.02	.04
	22	.07	.08	.05	.15	.04				.02	.01	.01				.03										.46
	23																			.08	.11	.07	.05	.15	.27	.73
	24	.14	.75	.05		.03	.07	.25	.24	.13	.07	.07	.07													1.87
	25		.02	.04																						.06
Harrisburg, Pa. U. S. Weather Bureau.	20	.03	T																	T				T	.02	.05
	21												T	T	T	T	T	T	T	T	.01	.03	T	T	.01	.05
	22	T	T	T	.03	T	T	.01	.11	.02	.40	.10	.46	.06	.06	T	T		T	T	T	T	T	T	T	1.25
	23			T	T			T	.06	.08	.03	.03	.14	.29	.21	.12	.21	.30	.34	.99	.42	.28	.27	.46	.43	4.66
	24	.22	.22	.17	.01																					.62
	25																									
Philadelphia, Pa. U. S. Weather Bureau.	20																									
	21				.02	.04	.04	.06	.04	T	.08	.06	.13	.15	.03	T	.02	.03	.02	.04	.17	.07	.01	T	.06	1.07
	22	.04	.01	T	.02	.02	.72	T	T	T	T	T	T	T	T					T	T	.01	T	.01	T	.83
	23	T	T	T	T	.03	.14	.05	.22	.04	.18	.42	.55	.63	.28	.23	.18	.36	.31	.01	T	.02	.04	.04	.01	3.74
	24	T	.01	T	.01	T	T	T																		.02
	25																									

Scranton, Pa. U. S. Weather Bureau.	20	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
	21	----	----	----	----	----	----	----	----	----	----	----	----	T	T	T	.01	T	T	.03	.07	.03	.07	.04	.04	.29
	22	.02	.01	.05	.12	.22	.11	.10	.06	.42	.22	.15	.03	T	T	T	T	----	----	----	----	----	----	----	----	1.51
	23	----	----	----	----	T	----	----	----	T	.02	T	T	.06	.03	.08	.18	.37	.38	.50	.35	.41	.04	.03	.01	2.46
	24	.01	.01	.01	.08	.07	.05	.07	.02	.13	.11	T	T	----	T	T	----	----	----	----	----	----	T	----	----	.56
	25	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
Baltimore, Md. U. S. Weather Bureau.	20	T	----	----	----	----	----	----	----	----	----	----	----		----	----	----	----	T	----	----	----	----	----	----	T
	21	----	----	T	.03	.05	.04	.01	.01	T	.04	.06	.03	T	.06	.42	.91	.50	.20	.16	.08	.01	.01	.01	T	2.63
	22	.02	.13	.05	.01	.09	.27	.08	.08	T	----	T	T	----	----	T	T	----	----	T	T	T	T	T	T	.73
	23	T	T	T	T	.11	.14	.07	.36	.35	.39	.58	.55	.72	.65	.61	1.02	.53	.34	.40	.19	.41	.16	.03	.01	7.62
	24	T	----	----	----	----	----	----	----	T	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	T
	25	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----

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tribution of rainfall as indicated by the hourly records of rainfall listed in table 73. According to table 75 rainfall was greatest during the 12-hour period 6 p.m. August 23 to 6 a.m. August 24, when there was an average rainfall of 2.45 inches over the basin.

River discharge during the flood period is given in table 77 and graphically on figure 28. Direct runoff associated with the storm as

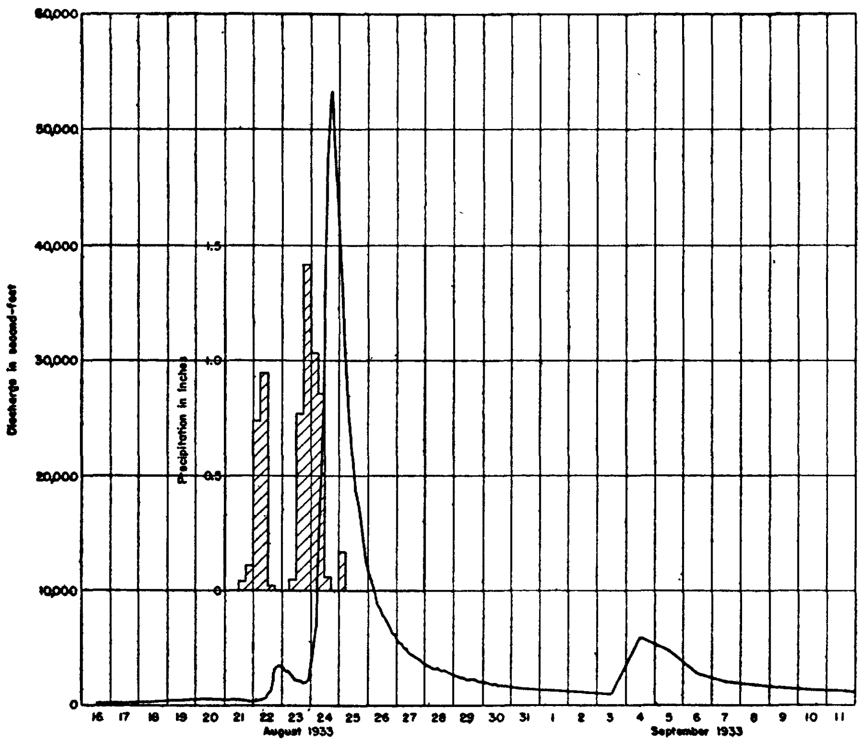

FIGURE 28.—Hydrograph of East Branch of Delaware River at Fishs Eddy, N. Y., showing discharge, August-September, and precipitation, August 21-25, 1933.

computed in table 76 was 3.44 inches, leaving a retention of 2.78 inches. Ground-water runoff accounted for 0.90 inch of this retention, leaving 1.88 inches as field-moisture accretion and evaporation-transpiration losses. The infiltration index as computed was 0.09 inch per hour.

The interval between centers of mass of effective rainfall and direct runoff was 37 hours, and the interval between center of mass of effective rainfall and the peak rate of discharge was 19 hours.

TABLE 74.—*Daily recorded rainfall, in inches, at stations in and near East Branch of Delaware River at Fishs Eddy, N. Y., August 20-25, 1933*

Station (New York)	Altitude (feet)	August						
		20	21	22	23	24	25	Total 20-25
Bainbridge [a]	1,006	--------	--------	1.08	0.93	2.00	0.84	4.85
Delhi [b]	1,460	0.01	--------	1.68	.12	3.00	.32	5.13
Grahamsville [c]	943	--------	1.95	.22	2.26	.32	--------	4.75
Grand Gorge [c]	1,400	.04	.87	.67	2.66	.45	--------	4.69
Jeffersonville [b]	1,240	--------	.01	1.65	.07	2.72	--------	4.45
Lackawack [c]	--------	--------	2.26	.38	5.88	.09	--------	8.61
Peekamoose [c]	--------	--------	2.50	1.95	10.08	1.45	--------	15.98
Pine Hill [c]	1,500	--------	1.15	1.15	5.30	1.30	--------	8.90
Prattsville [c]	1,160	--------	.92	.57	3.16	.57	--------	5.22
Roxbury [b]	1,490	--------	.05	1.03	.45	3.70	.05	5.28
Slide Mountain [c]	1,665	--------	1.72	1.34	6.46	3.37	--------	12.89
Sundown [c]	--------	--------	1.77	.87	4.36	.33	--------	7.33

[a] U. S. Weather Bureau station, observation made in morning and recorded as of same day.
[b] U. S. Weather Bureau station, observations made near sunset.
[c] New York City Board of Water Supply station, read at 8 a.m. and recorded as of the preceding day.

TABLE 75.—*Precipitation, in inches, for 6-hour periods, at stations in and near East Branch of Delaware River at Fishs Eddy, N. Y., August 20-25, 1933*

Station (New York)	Weight (per-cent)	6-hour period ending	August					
			20	21	22	23	24	25
Bainbridge	0.6	6 a.m.	0.00	0.00	0.88	0.00	0.49	0.14
	--------	12 m.	.00	.00	.91	.05	.66	.00
	--------	6 p.m.	.00	.07	.02	.79	.04	.00
	--------	12 p.m.	.00	.13	.00	.67	.00	.00
Delhi	25.8	6 a.m.	.00	.00	.53	.00	.95	.32
	--------	12 m.	.00	.00	1.05	.01	.69	.00
	--------	6 p.m.	.01	.00	.02	.11	.05	.00
	--------	12 p.m.	.00	.08	.00	1.31	.00	.00
Grahamsville	8.3	6 a.m.	.00	.00	1.59	.00	.55	.05
	--------	12 m.	.00	.00	.22	.05	.25	.00
	--------	6 p.m.	.00	.13	.00	.90	.02	.00
	--------	12 p.m.	.00	.23	.00	.76	.00	.00
Grand Gorge	0.4	6 a.m.	.00	.04	.71	.00	.65	.07
	--------	12 m.	.00	.00	.66	.06	.36	.00
	--------	6 p.m.	.00	.06	.01	1.05	.02	.00
	--------	12 p.m.	.00	.10	.00	.90	.00	.00
Jeffersonville	26.0	6 a.m.	.00	.00	.52	.00	.86	.00
	--------	12 m.	.00	.00	1.03	.00	.63	.00
	--------	6 p.m.	.00	.01	.02	.07	.04	.00
	--------	12 p.m.	.00	.08	.00	1.19	.00	.00
Pine Hill	18.4	6 a.m.	.00	.00	.93	.00	1.28	.02
	--------	12 m.	.00	.00	1.13	.13	1.03	.00
	--------	6 p.m.	.00	.08	.02	2.10	.07	.00
	--------	12 p.m.	.00	.14	.00	1.79	.00	.00
Prattsville	0.5	6 a.m.	.00	.00	.75	.00	.77	.09
	--------	12 m.	.00	.00	.56	.07	.45	.00
	--------	6 p.m.	.00	.06	.01	1.25	.03	.00
	--------	12 p.m.	.00	.11	.00	1.07	.00	.00
Roxbury	12.4	6 a.m.	.00	.00	.33	.00	1.17	.05
	--------	12 m.	.00	.00	.64	.03	.85	.00
	--------	6 p.m.	.00	.05	.01	.42	.06	.00
	--------	12 p.m.	.00	.05	.00	1.62	.00	.00
Slide Mountain	7.6	6 a.m.	.00	.00	1.40	.00	1.57	.53
	--------	12 m.	.00	.00	1.31	.15	2.66	.00
	--------	6 p.m.	.00	.12	.03	2.56	.18	.00
	--------	12 p.m.	.00	.20	.00	2.18	.00	.00
Average or total	100.0	6 a.m.	0.00	0.00	0.74	0.00	1.03	0.17
	--------	12 m.	.00	.00	.95	.05	.86	.00
	--------	6 p.m.	.00	.04	.02	.77	.06	.00
	--------	12 p.m.	.00	.11	.00	1.42	.00	.00

TABLE 76.—*Gage height and discharge of East Branch of Delaware River at Fishs Eddy, N.Y., during flood of August 1933*

MEAN DISCHARGE, IN SECOND-FEET, 1933

Day	Aug.	Day	Aug.	Day	Aug.	Day	Sept.	Day	Sept.	Day	Sept.
16	282	21	360	26	8,270	1	1,300	6	2,840	11	1,260
17	237	22	1,480	27	4,630	2	1,160	7	2,240	12	1,120
18	237	23	2,530	28	3,200	3	1,120	8	1,870	13	1,000
19	388	24	31,080	29	2,400	4	5,960	9	1,620	14	1,160
20	488	25	22,120	30	1,860	5	4,940	10	1,440	15	2,390
				31	1,500						

Mean discharge, Aug. 16 to Sept. 15, in second-feet	3,630
Runoff, in inches	5.34

GAGE HEIGHT, IN FEET, AND DISCHARGE, IN SECOND-FEET, AT INDICATED TIME, 1933

Hour	Feet	Sec.-ft.	Feet	Sec.-ft.	Feet	Sec.-ft.	Feet	Sec.-ft.	Feet	Sec.-ft.	Feet	Sec.-ft.
	August 20		August 21		August 22		August 23		August 24 [a]		August 25	
2	3.21	600	2.76	388	2.64	343	5.95	3,120	7.10	4,920	17.00	35,500
4	3.13	560	2.74	381	2.68	358	5.87	3,020	8.21	7,160	15.96	31,300
6	3.09	540	2.73	377	2.77	392	5.75	2,860	10.50	12,800	15.00	27,500
8	3.04	515	2.72	373	2.92	457	5.60	2,680	12.41	18,600	14.20	24,600
10	3.00	495	2.70	365	3.29	644	5.45	2,500	14.59	25,900	13.53	22,200
12 m.	2.96	476	2.68	358	3.68	896	5.30	2,330	17.24	36,600	12.96	20,200
2	2.92	457	2.66	351	3.94	1,080	5.17	2,190	19.39	47,000	12.38	18,500
4	2.89	443	2.65	347	5.03	2,040	5.07	2,080	20.45	52,500	11.88	17,000
6	2.86	430	2.62	336	5.94	3,110	4.99	2,000	20.36	52,000	11.40	15,600
8	2.83	417	2.62	336	6.10	3,330	4.98	1,990	19.76	48,800	10.97	14,300
10	2.82	413	2.63	340	6.12	3,360	5.14	2,150	18.91	44,600	10.55	13,000
12 p.m.	2.79	400	2.64	343	6.05	3,260	6.57	4,020	18.06	40,300	10.16	11,900

Hour	Feet	Sec.-ft.	Feet	Sec.-ft.	Feet	Sec.-ft.	Feet	Sec.-ft.	Feet	Sec.-ft.
	August 26		August 27		August 28		August 29		August 30	
2	9.84	11,100	7.31	5,510	6.05	3,620	5.27	2,680	4.69	2,050
4	9.52	10,300	7.17	5,270	5.96	3,500	5.20	2,600	4.64	2,000
6	9.23	9,580	7.05	5,070	5.89	3,410	5.15	2,540	4.60	1,960
8	8.97	8,940	6.93	4,880	5.82	3,320	5.10	2,490	4.56	1,920
10	8.76	8,440	6.84	4,730	5.76	3,250	5.05	2,440	4.52	1,880
12 m.	8.56	7,980	6.75	4,600	5.70	3,180	5.01	2,390	4.49	1,850
2	8.37	7,570	6.65	4,440	5.65	3,120	4.97	2,350	4.46	1,820
4	8.19	7,190	6.55	4,300	5.59	3,050	4.92	2,290	4.43	1,790
6	8.00	6,800	6.45	4,150	5.52	2,960	4.88	2,250	4.40	1,760
8	7.81	6,420	6.35	4,010	5.46	2,890	4.84	2,200	4.37	1,730
10	7.63	6,080	6.24	3,860	5.40	2,820	4.78	2,140	4.34	1,710
12 p.m.	7.48	5,800	6.15	3,740	5.33	2,740	4.72	2,080	4.31	1,680

[a] Peak discharge: August 24, 5 p.m., 53,300 sec.-ft.

LOCATION.—Water-stage recorder, lat. 41°58′00″, long. 75°10′50″, at railroad bridge in Fishs Eddy, Delaware County, 4½ miles below mouth of Beaver Kill. Zero of gage is 950.84 feet above mean sea level.

DRAINAGE AREA.—783 square miles.

REMARKS.—Records supersede those given in Geol. Survey Water-Supply Paper 741.

TABLE 77.—*Computation of volume of direct runoff associated with precipitation period August 21-25, 1933, East Branch of Delaware River at Fishs Eddy, N. Y.*

Day	12-hour period ending	Daily mean discharge (second-feet)	Estimated recession from preceding storm and base runoff (second-feet)	Direct runoff (second-feet)
Aug. 21	12 m.	385	385	0
	12 p.m.	343	343	0
22	12 m.	465	320	145
	12 p.m.	2,500	285	2,215
23	12 m.	2,835	305	2,530
	12 p.m.	2,230	335	1,895
24	12 m.	14,860	365	14,495
	12 p.m.	47,300	430	46,870
25	12 m.	28,500	500	28,000
	12 p.m.	15,720	560	15,160
26	12 m.	9,720	620	9,100
	12 p.m.	6,820	680	6,140
27	12 m.	5,100	740	4,360
	12 p.m.	4,155	800	3,355
28	12 m.	3,430	860	2,570
	12 p.m.	2,970	910	2,060
29	12 m.	2,550	950	1,600
	12 p.m.	2,245	990	1,255
30	12 m.	1,965	1,040	925
	12 p.m.	1,760	1,070	690
31	12 m.	1,600	1,100	500
	12 p.m.	1,500	1,130	370
Sept. 1	12 m.	1,390	1,160	230
	12 p.m.	1,310	1,190	120
2	12 m.	1,220	1,220	0
Total				
Sec.-ft.-½ days		162,873	18,288	144,585
Sec.-ft.-days		81,436	9,144	72,292 (= 3.44 inches)

SUSQUEHANNA RIVER AT MARIETTA, PA.

Precipitation between August 20–25, 1933, was computed to average 4.13 inches over the basin using records listed in table 78. Rainfall listed in this table for August 21–25, inclusive, is for the calendar day and was prepared on the basis of daily readings, made in the morning or in the afternoon, supplemented by records of hourly precipitation at gages listed in table 73. According to the isohyetal lines of total storm precipitation which are shown on plate 1, precipitation was greater in the eastern part of the basin, and the maximum of 13.82 inches fell in the lower basin at York, Pa.

The discharge at Marietta, Pa., during the storm period is given in table 79, and graphically on figure 29. Direct runoff associated with the storm as computed in table 80 totaled 1.39 inches, leaving a retention of 2.74 inches, of which about 0.36 inch appeared as ground-water runoff. Field-moisture accretion and evaporation-transpiration losses therefore totaled 2.38 inches. The average infiltration index over the basin was 0.15 inch per hour.

The interval between centers of effective rainfall and direct runoff was computed as 81 hours, which may be less than for uniform rain over

TABLE 78.—*Precipitation, in inches, at rain gages in and near Susquehanna River basin above Marietta, Pa., August 21-31, 1933*

[In this table "T" indicates a trace]

Station	Altitude (feet)	Weight (percent)	August												
			21	22	23	24	25	Total 21-25	26	27	28	29	30	31	Total 21-31
New York:															
Alfred	1,840	1.24		0.19	1.18	1.90		3.27	0.01	0.26					3.54
Angelica	1,420	.02			.71	1.05		1.76		.23					1.99
Bainbridge	1,006	1.51	0.36	1.35	1.60	1.26	0.28	4.85							4.85
Binghamton	858	3.06	T	2.29	1.17	.78	.02	4.26							4.26
Cooperstown	1,200	2.61	.31	.64	.67	1.26	.03	2.91							2.91
Cortland	1,129	2.21		.30	.79	1.01	1.48	3.58							3.58
Delhi	1,460	.32		1.68	1.12	2.21	.11	5.12	.01	.03	0.01		0.05		5.22
Elmira	863	2.71		.90	2.52	.05		3.47	.05						3.52
Haskinville	1,620	2.11		.20	1.20	1.25		2.65			T				2.65
Ithaca	872	1.21		.70	.90	.82	.01	2.43	.04	.31					2.78
Morrisville	1,325	1.34		1.30	1.15	1.07	.09	3.61							3.61
Norwich	1,015	1.50	.42	.88	.74	1.31		3.35							3.35
Oneonta	1,112	1.40	.40	.95	.83	1.47	.03	3.68							3.68
Sherburne	1,037	1.38	.35	.68	1.00	.88	.18	3.09							3.09
Syracuse	400	.06		.76	.63	.84	.04	2.27							2.27
Pennsylvania:															
Altoona	1,615	1.92		.26	1.80	.47		2.53						0.02	2.55
Baker's Summit	1,442	1.71		.55	1.33	.47		2.35			.02			.05	2.42
Bedford	1,060	2.34		.50	1.20	.20		1.90		.19	.01				2.10
Bellefonte	1,050	1.69		.31	3.39	.53		4.23							4.23
Catawissa	520	2.90	.15	.73	4.09	.58		5.55							5.55
Carlisle	467	2.58	.04	1.30	3.27	.77		5.38			.01			.03	5.42
Cedar Run	800	2.34		.65	2.15	.40		3.20		.08		0.12	.58		3.98
Chambersburg	580	1.42	.10	1.02	2.91	.69		4.72	.07		.01			.08	4.88
Clearfield	1,120	3.57		.20	.90	.23		1.33							1.33
Ebensburg	2,000	.68		.30	1.75	.47		2.52							2.52
Galeton	1,325	2.72		.86	1.20	.92		2.98		.10					3.08
Gettysburg	553	1.06	.23	1.13	1.99	.30		3.65			.70			.04	4.39
Hamburg	535	.02	.90	2.47	2.10	1.76		7.23							7.23
Harrisburg	337	1.87	.05	1.25	4.66	.62		6.58							6.58
Huntingdon	650	3.75		.36	3.00	.50		3.86	.10	.04					4.00
Kylertown	1,637	2.48		.17	1.33	.52		2.02							2.02
Lebanon	469	1.40	1.28	2.90	3.82			8.00	.01						8.01
Lancaster	255	.09	.90	2.30	2.75	.20		6.15							6.15
Lawrenceville	1,000	2.30		.71	1.05	1.53		3.29		.50					3.79
Montrose	1,680	2.40		1.90	1.10	.70		3.70	.40		.50				4.60
Morris Run	1,750	2.19		.64	1.25	1.40		3.29	.47						3.76
Muncy Valley	1,045	3.28	.18	.50	2.72	1.21		4.61		.08	T				4.69
Newport	420	2.88		.48	4.25	1.50		6.23			.19				6.42
Pine Grove	540	1.60	1.20	2.14	3.37	.74		7.45	.02		.02				7.49
Pleasant Mount	1,820	1.35	.80	2.34	3.80	.50		7.44							7.44

Renova	672	3.14			2.24	.35		2.59		.10		.15		2.84
Scranton	746	1.96	.29	1.51	2.46	.56		4.82	.20					5.02
Smethport	1,500	1.67		T	1.25	.39		1.64			.68			2.32
State College	1,217	2.15		.21	3.30	.69		4.20					.02	4.22
Sunbury	520	2.41	.14	.80	3.04	1.06		5.04		.33				5.37
Towanda	754	3.46	.36	.99	1.13	1.18		3.66	.01	.02	.16			3.85
Weikert	750	2.88		.82	2.70	1.10		4.62				.20		4.82
Wellsboro	1,419	1.37		.77	1.38	1.57		3.72	.43				.12	4.27
Wilkes-Barre	540	2.95	.70	.94	1.44	.70		3.78		1.80				5.58
Williamsport	521	2.68		.36	3.66	1.74		5.76			.01			5.77
York	400	2.11	1.29	4.54	6.41	1.58		13.82						13.82
Average or total		100.00	0.17	0.88	2.19	0.85	0.04	4.13	0.04	0.08	0.04	0.01		4.30

NOTE.—Entries for August 26–31, inclusive, have not been adjusted on a midnight to midnight basis.

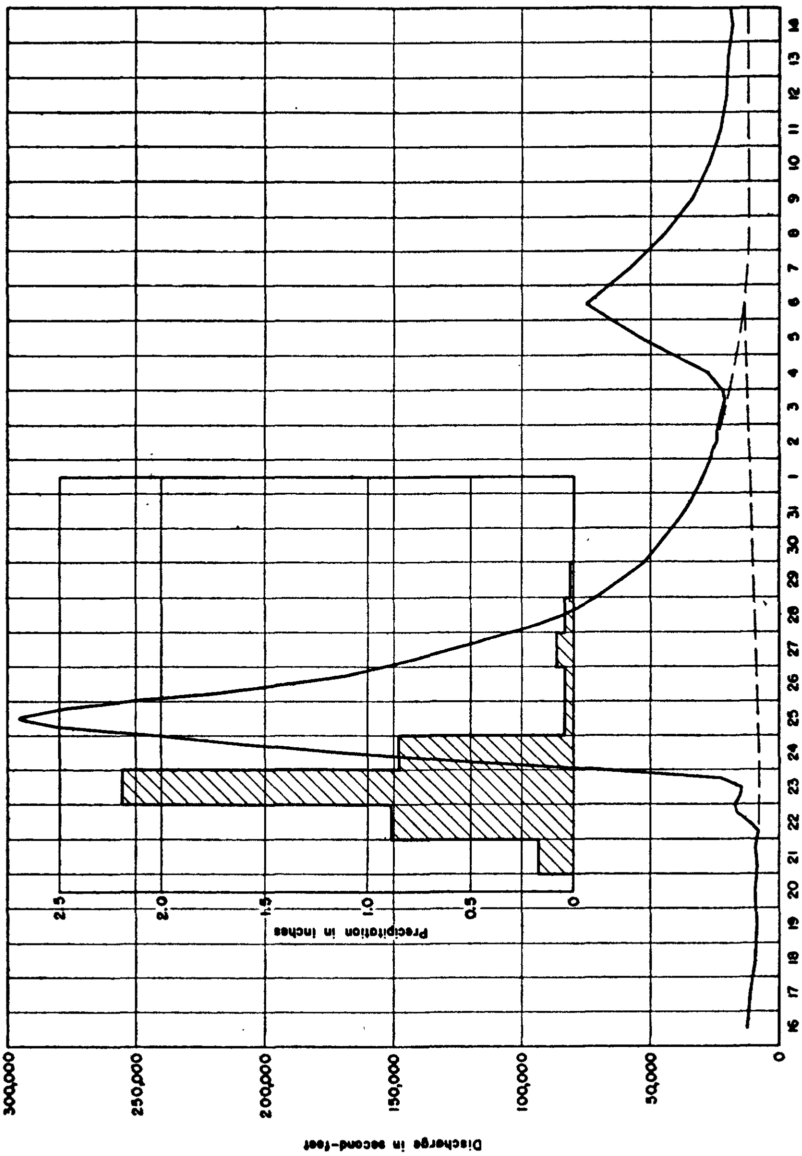

FIGURE 29.—Hydrograph of Susquehanna River at Marietta, Pa., showing discharge, August-September, and precipitation, August 21-29, 1933.

the basin, because the storm rainfall was greater in the lower than in the upper basin. The interval between center of effective rainfall and the peak discharge at Marietta was 46 hours.

TABLE 79.—*Gage height and discharge of Susquehanna River at Marietta, Pa., during flood of August 1933*

MEAN DISCHARGE, IN SECOND-FEET, 1933

Day	Aug.	Sept.	Day	Aug.	Sept.	Day	Aug.	Sept.	Day	Aug.	Sept.	Day	Aug.	Sept.
1	6,720	31,500	7	6,160	58,400	13	14,700	20,200	19	9,080	75,600	25	287,000	25,000
2	5,680	25,900	8	5,880	44,600	14	13,500	18,800	20	9,860	59,700	26	190,000	23,400
3	6,060	22,600	9	6,370	34,500	15	12,600	20,200	21	8,720	48,200	27	121,000	21,800
4	18,300	27,900	10	6,990	27,700	16	12,200	38,500	22	12,400	37,700	28	80,400	20,200
5	9,540	54,000	11	14,100	23,400	17	11,600	82,700	23	22,900	31,500	29	58,400	19,500
6	6,760	75,600	12	21,600	21,000	18	9,740	107,000	24	159,000	27,700	30	45,800	18,100
												31	37,700	-------
Mean monthly discharge, in second-feet													39,700	38,100
Runoff, in inches													1.76	1.63

GAGE HEIGHT, IN FEET, AND DISCHARGE, IN SECOND-FEET, AT INDICATED TIME, 1933

Hour	Feet	Sec.-ft.	Feet	Sec.-ft.	Feet	Sec.-ft.	Feet	Sec.-ft.	Feet	Sec.-ft.
	August 21		August 22		August 23		August 24		August 25 [a]	
6	33.55	8,750	33.43	8,280	34.77	15,620	42.27	119,700	48.93	281,600
12 m	33.16	6,840	34.02	11,070	34.63	14,960	44.52	168,700	49.43	295,700
6	33.70	9,490	34.85	16,280	35.70	22,340	46.00	205,100	48.84	278,800
12 p.m.	33.48	8,510	35.03	17,300	39.42	66,470	47.26	238,300	47.77	251,500
	August 26		August 27		August 28		August 29		August 30	
6	46.54	217,600	43.25	139,100	40.97	93,850	39.38	66,470	38.31	50,110
12 m	45.38	190,300	42.74	128,100	40.51	84,760	39.07	61,790	38.08	47,390
6	44.47	168,700	42.14	115,500	40.09	77,840	38.79	57,260	37.88	44,770
12 p.m.	43.80	152,600	41.51	103,400	39.72	71,240	38.53	52,910	37.70	42,230

Hour	Feet	Sec.-ft.	Feet	Sec.-ft.	Feet	Sec.-ft.	Feet	Sec.-ft.
	August 31		September 1		September 2		September 3	
6	37.52	39,770	36.82	31,890	36.17	26,280	35.78	23,100
12 m	37.34	37,390	36.69	30,880	36.02	24,650	35.66	22,340
6	37.13	35,100	36.46	28,950	35.96	24,650	35.61	21,590
12 p.m.	36.99	34,000	36.30	27,140	35.88	23,870	35.70	22,340

[a] Peak discharge: August 25, 11:30 a.m., 296,000 second-feet.

LOCATION.—Water-stage recorder, lat. 40°03′15″, long. 76°31′50″, 420 feet above mouth of Chickies Creek and 1 mile downstream from Marietta, Lancaster County. Zero of gage is 200.00 feet above mean sea level.

DRAINAGE AREA.—25,990 square miles.

REMARKS.—Records of daily mean discharge published in Geol. Survey Water-Supply Paper 741.

TABLE 80.—*Computation of volume of direct runoff associated with precipitation period August 21-25, 1933, Susquehanna River at Marietta, Pa.*

Day	Daily mean discharge [a] (second-feet)	Estimated recession from preceding storm and base runoff (second-feet)	Direct runoff (second-feet)
Aug.			
21	8,530	8,530	0
22	11,800	8,500	3,300
23	22,900	8,500	14,400
24	161,000	8,600	152,400
25	274,000	9,000	265,000
26	194,000	9,400	184,600
27	127,300	9,800	117,500
28	84,760	10,200	74,560
29	60,260	10,600	49,660
30	46,070	11,000	35,070
31	37,390	11,500	25,890
Sept.			
1	30,880	12,000	18,880
2	25,450	12,400	13,050
3	[b]22,000	12,800	9,200
4	[b]18,000	13,200	4,800
5	[b]16,500	13,600	2,900
6	[b]14,500	14,000	500
Total Sec.-ft.-days	1,155,340	183,630	971,710 (= 1.39 inches)

[a] Based on records published in Water-Supply Paper 741.

[b] Estimated recession under subsequent rise.

FLOOD OF MAY 1894, SUSQUEHANNA RIVER AT HARRISBURG, PA.

The storm of May 17–23, 1894, which produced the greatest non-winter flood of record at Harrisburg, Pa., had its origin in a low-pressure area that appeared over the Great Lakes region on May 17. The low pressure followed a southeastward path over West Virginia and Virginia, where it stagnated and merged with a similar area that had come up from the Gulf region. It finally moved out to sea on May 21. Figure 30 shows the position of the low-pressure area on May 20, 1894, when heavy rainfall was general over the Susquehanna River Basin. Rainfall began early on May 17 and was nearly continuous until May 26. Daily recorded rainfall as given in table 81 indicates that the heaviest portion occurred on May 19–21. The maximum 24-hour rainfall of 5.94 inches was measured at Quakertown, Pa., on May 21. The flood which crested at Harrisburg on May 22 was apparently produced by the rains during May 17–23. The rainfall that followed on May 24–26 was assumed to have produced a second and smaller rise that began on May 25 at Harrisburg, reaching its crest at about 12 p.m. of May 26, and was therefore not directly considered in this study.

Plate 2 is an isohyetal map showing total storm rainfall in the Susquehanna River Basin, May 17–23, 1894. The average over the basin was 4.96 inches. Precipitation was general over the entire basin but was

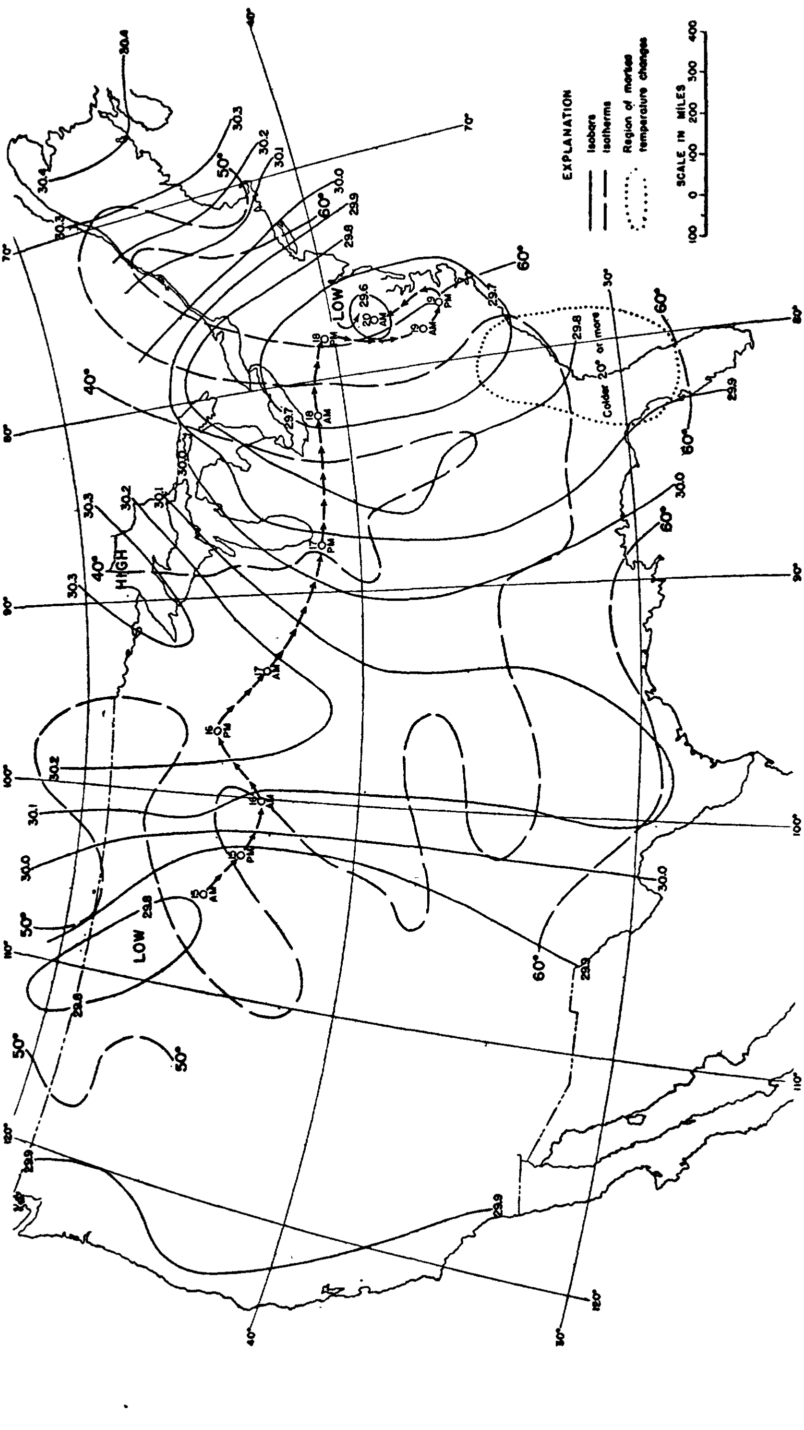

FIGURE 30.—Map of United States showing position of storm, 8 a.m. (E.S.T.), May 20, 1894.

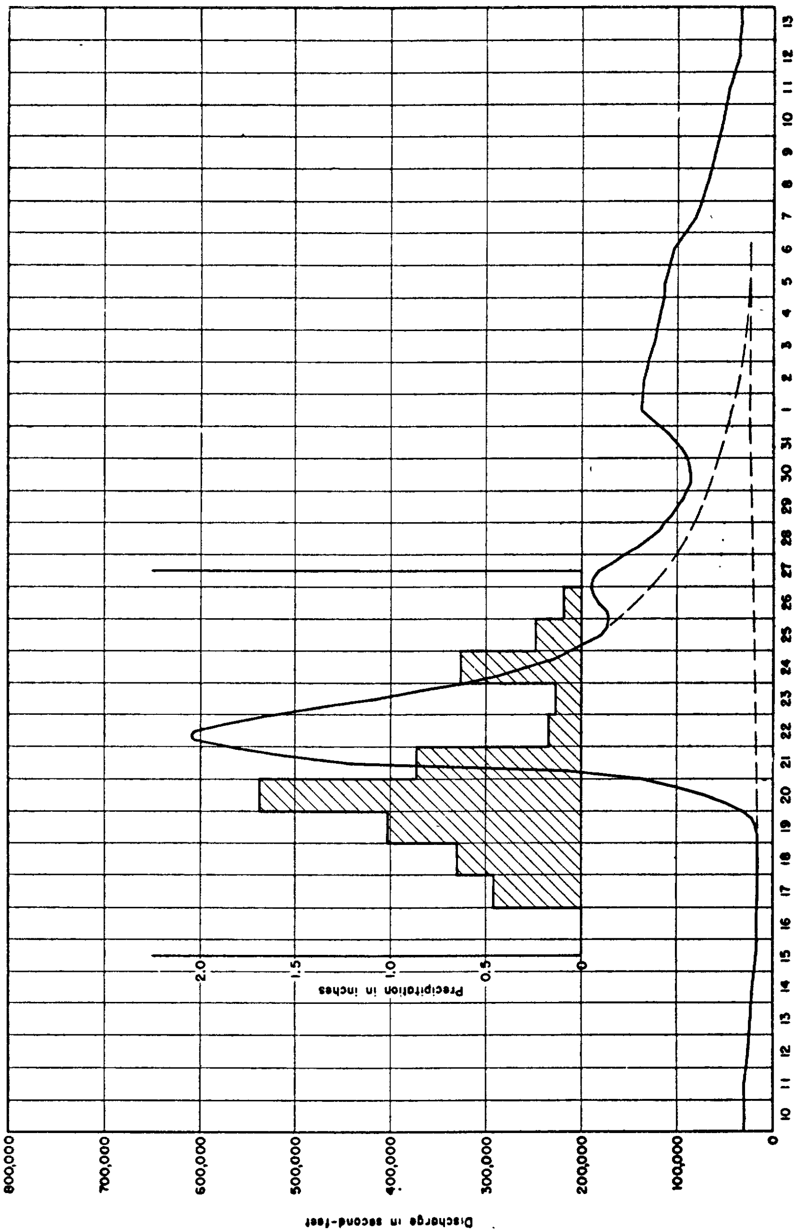

FIGURE 31.—Hydrograph of Susquehanna River at Harrisburg, Pa., showing discharge, May-June, and precipitation, May 16-26, 1894.

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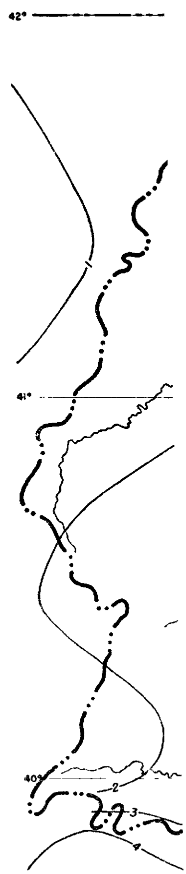

MAP OF SUSQUE

TABLE 82.—*Hourly precipitation, in inches, at recording Weather Bureau rain gages near Susquehanna River basin, May 16-24, 1894*

[In this table "T" indicates a trace]

Station	Day	a.m.												p.m.												Total
		1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	
Philadelphia, Pa.	16																		T	0.02	0.06	0.03	0.02	0.02	T	0.15
	17	0.01	0.03							T	0.02	0.02														.08
	18																			T	.60	.15	.02	.01	0.01	.79
	19												T	0.05	T											.05
	20	.05	.07	0.02	0.06	T	0.05	0.15	T	T	.04	.20	0.31	.02	0.03	0.06	0.04	0.13	0.08	.08	.03	.04	.09	.23	.27	2.02
	21	.05	.04	.13	.21	0.40	.30	.15	0.10	0.05	.09	.07	.08	.04	.08	.10	.10	.06	.05	.06	.08	.08	.07	.04	.02	2.45
	22	.01	T	T	T	T	T	T	T	.01	T	T	.01	.01	T					T	.01	T	T	T	.01	.06
	23	T												T			T	.09	.10					T	.03	.22
	24	.02	.07	.04	.01	.02	.04	.07	.12	.23	.10	.03	.38	.01						T	.21	T		T		1.35
Baltimore, Md.	16																	.05								.05
	17					.05									.05											.10
	18																	.15	.10	.05			.15	.04	.05	.54
	19															.05							.05			.10
	20	[a]	[a]	[a]	[a]	[a]	[a]	[a]	.29								[a]	[a]	[a]	.23			.55	.35	.25	1.67
	21	.05	.05	.05															[a]	[a]	[a]	[a]	[a]	.01		.16
	22												.05												.01	.06
	23													.75	.05					.05	.10	.15	.10	.05		1.25
	24																.01	.10	.05							.16

[a] Included in following measurement.

pany, which gives times of beginning and ending of rainfall on a number of days, May 17–26, 1894.

May		Rainfall (inches)
17	7:30 a.m. to 12 m.	0.52
18	4:20 p.m. to 5 p.m.	.12
19	2 a.m. to 4 a.m.	.48
19	4 p.m. to 12 p.m.	.96
20	12:01 a.m. to 12 p.m.	2.88
21	12:01 a.m. to 12 p.m.	2.88
22	12:01 a.m. to 6 a.m.	.72
24	7 a.m. to 12 p.m.	1.72
25	12:01 a.m. to 12 m.	.18
26	6:30 p.m. to 7 p.m.	.18

TABLE 83.—*Gage height and discharge of Susquehanna River at Harrisburg, Pa., during flood of May 1894*

MEAN DISCHARGE, IN SECOND-FEET, 1894

Day	May	June	Day	May	June	Day	May	June	Day	May	June	Day	May	June
1	46,100	139,000	7	27,100	82,500	13	23,000	33,900	19	19,900	24,000	25	185,000	18,400
2	44,900	138,000	8	28,100	69,000	14	21,000	32,700	20	94,400	30,400	26	180,000	20,100
3	39,900	126,000	9	30,400	60,600	15	18,400	32,700	21	385,000	29,300	27	175,000	19,200
4	35,000	118,000	10	30,400	52,600	16	18,400	31,500	22	575,000	24,900	28	129,000	20,100
5	30,400	114,000	11	30,400	47,400	17	16,700	29,300	23	423,000	21,900	29	99,700	17,600
6	28,100	104,000	12	24,900	37,400	18	16,700	26,100	24	251,000	18,400	30	88,500	21,000
												31	105,000	-------
Mean monthly discharge, in second-feet													104,000	51,300
Runoff, in inches													4.97	2.38

GAGE HEIGHT, IN FEET, AND DISCHARGE, IN SECOND-FEET, AT INDICATED TIME, 1894

Hour	Feet	Sec.-ft.	Feet	Sec.-ft.	Feet	Sec.-ft.	Feet	Sec.-ft.	Feet	Sec.-ft.
	May 18		May 19		May 20		May 21		May 22 [a]	
6	2.3	16,000	2.3	16,000	4.9	50,600	12.8	212,300	25.5	605,500
12 m	2.3	16,000	2.5	18,000	6.2	72,200	20.9	445,800	25.5	605,500
6	2.3	16,000	2.9	22,400	7.8	101,800	22.9	512,600	24.6	572,600
12 p.m.	2.3	16,000	3.7	32,800	9.6	138,200	24.4	565,400	23.3	526,500
	May 23		May 24		May 25		May 26		May 27	
6	21.8	475,400	15.6	287,100	12.0	192,400	11.2	173,600	11.8	187,600
12 m	20.1	420,200	14.5	256,900	11.5	180,500	11.6	182,800	11.5	180,500
6	18.5	371,000	13.5	230,300	11.2	173,600	11.8	187,600	11.0	169,000
12 p.m.	16.9	324,100	12.7	209,800	11.1	171,300	11.9	190,000	10.4	155,600

Hour	Feet	Sec.-ft.	Feet	Sec.-ft.	Feet	Sec.-ft.	Feet	Sec.-ft.
	May 28		May 29		May 30		May 31	
6	9.7	140,300	8.0	105,600	7.0	86,600	7.4	94,200
12 m	9.2	129,800	7.7	99,900	7.0	86,600	7.8	101,800
6	8.7	119,600	7.4	94,200	7.1	88,500	8.2	109,600
12 p.m.	8.4	113,600	7.2	90,400	7.2	90,400	8.6	117,600

[a] Peak discharge: May 22, 6:30 to 9:30 a.m., 613,000 sec.-ft.

LOCATION.—Staff gage, lat. 40°15′35″, long. 76°53′05″, at Harrisburg water supply pumping station, Harrisburg, Dauphin County.

DRAINAGE AREA.—24,100 square miles.

REMARKS.—Discharge based on once daily readings on staff gage.

The observer at Smethport, Pa., reported that 1.90 inches of rain and hail fell between 7 p.m. and 8:15 p.m. on May 17, and the observer at Addison, N. Y., reported 1.27 inches between 1 p.m. and 2 p.m. on May 18.

The discharge at Harrisburg during the flood is given in table 83 and shown as a hydrograph in figure 31. Direct runoff associated with the storm of May 17–23 as computed in table 84 was 3.44 inches.

The difference between average rainfall and direct runoff is 1.52 inches, of which 0.75 inch appeared as ground-water runoff, leaving 0.77 inch for field-moisture accretion and evaporation-transpiration losses.

The interval between center of mass of effective rainfall and direct runoff was 99 hours. This lag interval is greater than that found for the Susquehanna River at Marietta during the August 1933 storm. The latter storm centered in the lower basin, which would shorten the lag interval, whereas that of May 1894 was heavier in the upper reaches of the basin, probably accounting for some of the difference.

TABLE 84.—*Computation of volume of direct runoff associated with storm period May 17-23, 1894, Susquehanna River at Harrisburg, Pa.*

Date	Daily mean discharge (second-feet)	Estimated recession from preceding storm and base runoff (second-feet)	Direct runoff (second-feet)
May			
18	16,700	16,700	0
19	19,900	17,300	2,600
20	94,400	17,900	76,500
21	385,000	18,500	366,500
22	575,000	19,100	555,900
23	423,000	19,700	403,300
24	251,000	20,300	230,700
25	[a]180,000	20,900	159,100
26	[a]145,000	21,500	123,500
27	[a]114,000	22,100	91,900
28	[a]90,000	22,700	67,300
29	[a]75,000	23,300	51,700
30	[a]61,000	23,900	37,100
31	[a]51,000	24,500	26,500
June			
1	[a]43,000	25,000	18,000
2	[a]36,000	25,000	11,000
3	[a]31,000	25,000	6,000
4	[a]27,000	25,000	2,000
5	[a]25,000	25,000	0
Total Sec.-ft.-days	2,643,000	413,400	2,229,600 (= 3.44 inches)

[a] Estimated recession under subsequent rise.

FLOOD OF APRIL-MAY 1909, WEST BRANCH OF SUSEQUEHANNA RIVER AT WILLIAMSPORT, PA.

The storm, which brought an average rainfall of 3.66 inches in 5 days to the basin of the West Branch of the Susquehanna River above Williamsport, Pa., was associated with an extratropical cyclone that had

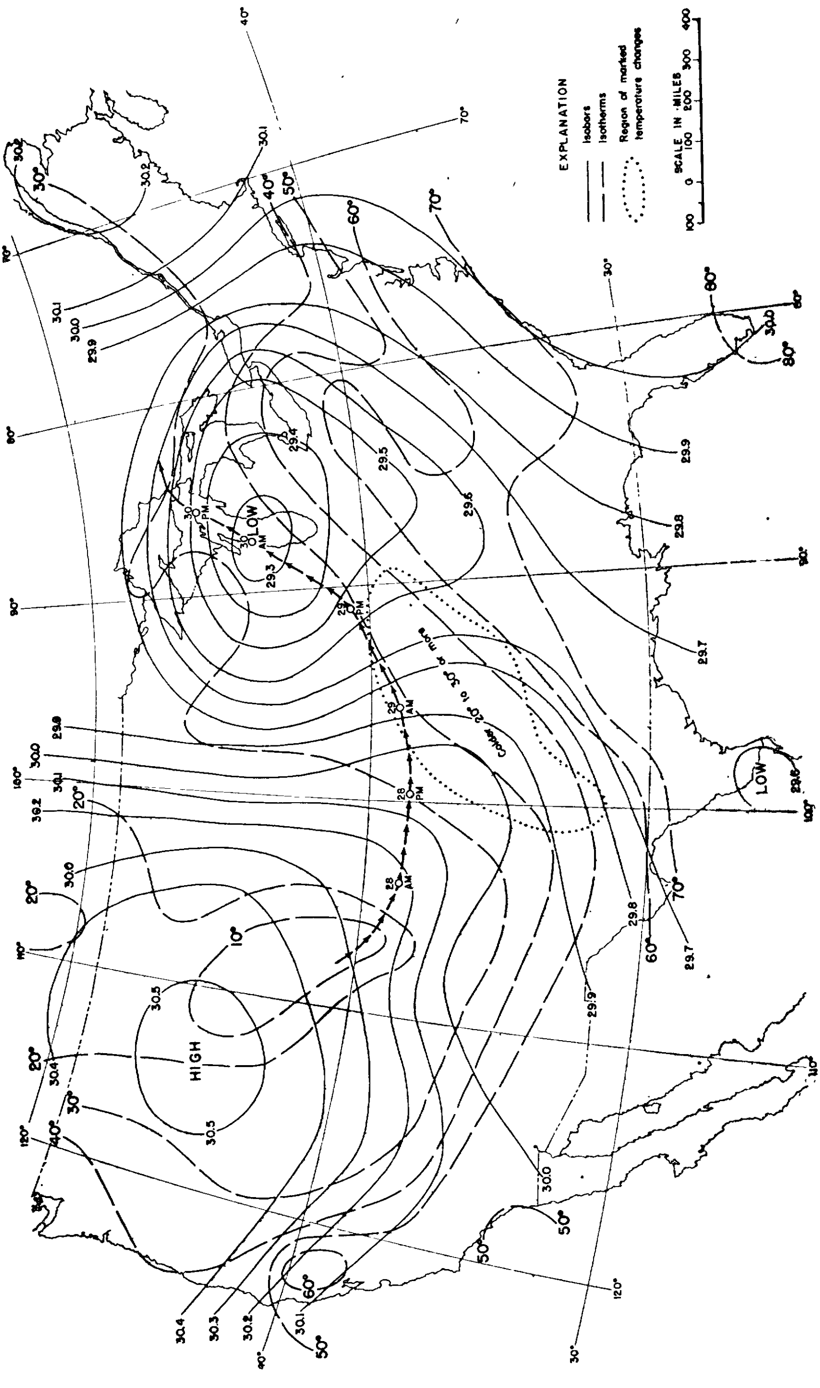

FIGURE 32.—Map of United States showing position of storm, 8 a.m. (E.S.T.), April 30, 1909.

its origin in the Rocky Mountain region near Salt Lake City. As shown on figure 32, the low-pressure area reached the Great Lakes on April 30. Active rainfall over the West Branch of the Susquehanna River Basin from April 29 to May 1 resulted in the flood peak of May 1. Additional rainfall after May 1 and until May 5, although not of the same amount or intensity and not adding to the flood height, contributed materially

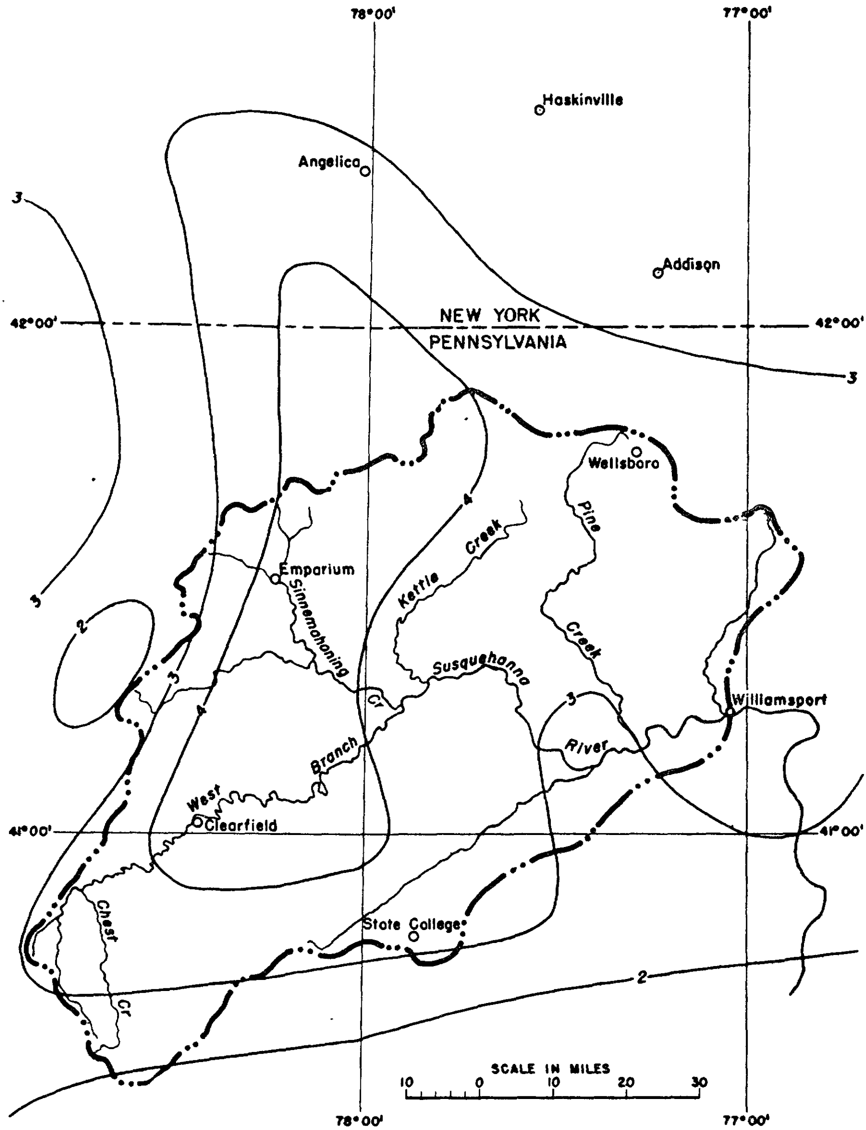

FIGURE 33.—Map of basin of West Branch of Susquehanna River above Williamsport, Pa., showing lines of equal precipitation, April 27-May 1, 1909.

to the volume of stream flow while the flood was receding and has therefore been included in this compilation. Total rainfall over the basin in 8 days from April 27 to May 4 was 4.08 inches. The storm followed a 30-day period in which precipitation was about 25 percent above normal.

Figure 33 shows lines of equal precipitation, April 27 to May 1, based on the available records of the United States Weather Bureau. There were broad areas without rainfall measurements and the actual amounts may differ considerably from that shown, particularly in the regions of high precipitation.

Daily rainfall at rain gages in and near the basin during the flood period are listed in table 85. Rainfall in this table is that for the 24-hour period ending at 7 p.m. of the indicated day. All rain gages were read at 7 p.m., and the table lists the daily precipitation as measured except for the Renovo gage, which was read in the morning and for which the measurements were adjusted to conform with the others. Rainfall was greatest on April 29 and 30, when there was 2.72 inches of rain over the basin.

Precipitation fell mainly as rain but temperatures on some days, as shown in table 86, dropped below the freezing point and there were reports of local snowfall. At State College, Pa., the report of the Weather Bureau observer that the ground was frozen on April 24 and 25, suggests that soil conditions were not uniformly favorable for the retention of rainfall.

The records of gage height and discharge at the gaging station at Williamsport, Pa., during the flood period is given in table 87 and a discharge hydrograph is shown on figure 34. The direct runoff as computed in table 88 was 2.84 inches, indicating a retention of 1.24 inches, of which it was computed that ground-water runoff accounted for 1.10 inches. The remaining 0.14 inch seems too low to represent field-moisture accretion and evaporation-transpiration losses. However, the rate of ground-water discharge at the beginning of the flood was about 10,000 second-feet or 1.75 second-feet per square mile. This is the highest rate observed for any of the nonwinter floods studied in this report and discloses moisture conditions before the flood not favorable for the retention of rainfall.

Lack of automatic rainfall recorders in or near the storm area prohibits the computation of infiltration capacity.

The interval between centers of effective rainfall and direct runoff as computed in table 89 was 56 hours, which is about 6 hours longer than during the March 1936 flood as reported in table 1. As the March 1936 storm was generally uniform over the area, the differences in lag interval probably is partly a result of the April-May 1909 storm centering in the upper basin.

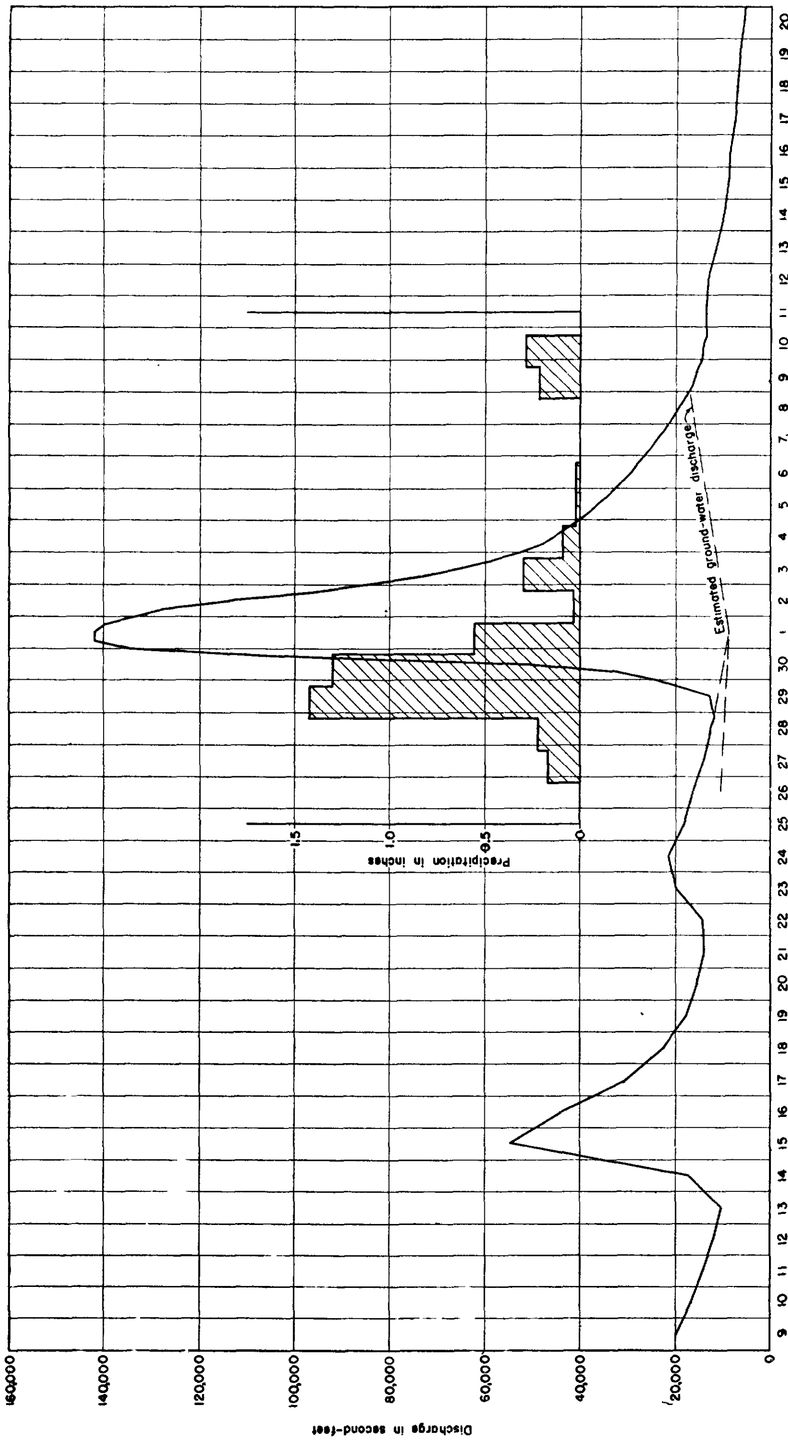

FIGURE 34.—Hydrograph of West Branch of Susquehanna River at Williamsport, Pa., showing discharge, April-May, and precipitation, April 26-May 10, 1909.

TABLE 85.—*Daily precipitation,* [a] *in inches, at stations in and near West Branch of Susquehanna River basin above Williamsport, Pa., April 27 to May 10, 1909*

[In this table "M" indicates a record missing]

Station (Pennsylvania)	Altitude (ft.)	Weight (percent)	April				May		May									
			27	28	29	30	1	Total Apr. 27-May 1	2	3	4	Total Apr. 27-May 4	5	6	7	8	9	10
Altoona	1,181	6.83	0.44	------	0.71	0.60	0.16	1.91	------	0.17	------	2.08	------	0.03	------	------	0.52	0.33
Bellefonte	826	7.64	.15	------	.80	2.12	.56	3.63	------	.60	------	4.23	------	.11	------	------	.09	.22
Clearfield	1,107	21.21	.30	0.40	1.33	1.71	[b].60	4.34	M	M	M	------	M	M	M	M	M	M
Emporium	1,050	14.82	.27	.23	2.56	.44	.96	4.46	0.10	.16	------	4.72	------	------	------	------	.24	.32
Le Roy	1,400	.83	------	.08	2.06	.54	.66	3.34	.03	.26	0.29	3.92	0.10	.18	0.04	------	------	.20
Lock Haven	560	9.36	------	.10	.73	1.01	.53	2.37	.01	.50	.15	3.03	.05	------	------	------	.10	.28
Renovo	------	16.89	.10	.22	1.05	1.78	.17	3.32	.05	.14	.20	3.71	.04	------	------	------	------	.23
State College	1,191	3.96	.03	------	1.23	1.61	.69	3.56	.02	.40	.09	4.07	.05	------	------	------	.25	.37
Wellsboro	1,327	11.63	------	.27	2.30	.62	.59	3.78	.04	.16	.07	4.05	------	------	------	------	.73	.35
Williamsport	530	6.83	.04	.40	1.00	1.87	.67	3.98	------	.34	.04	4.36	------	------	------	------	------	.22
Average or total	------	100.0	0.17	0.22	1.42	1.30	0.55	3.66	0.03	0.30	0.09	4.08	0.02	0.02	------	------	0.21	0.28

[a] 7 p.m. to 7 p.m.
[b] Estimated.

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TABLE 86.—*Daily mean areal precipitation and temperature, West Branch of Susquehanna River at Williamsport, Pa., April 27 to May 4, 1909*

Day	Mean areal precipitation [a] (inches)	Maximum (°F.)	Minimum (°F.)	Mean[b] (°F.)
April				
27	0.17	60	33	47
28	.22	53	31	42
29	1.42	49	30	40
30	1.30	64	37	50
May				
1	.55	57	40	48
2	.03	47	34	40
3	.30	49	32	40
4	.09	54	38	46
Total or average	4.08	54	34	44

[a] 7 p.m. to 7 p.m.
[b] Average of maximum and minimum.

TABLE 87.—*Gage height and discharge at indicated time, West Branch of Susquehanna River at Williamsport, Pa., April-May 1909*

MEAN DISCHARGE, IN SECOND-FEET, 1909

Day	April	May	Day	April	May	Day	April	May	Day	April	May	Day	April	May
1	10,400	141,000	7	10,000	24,400	13	10,400	11,500	19	17,600	6,580	25	18,100	4,470
2	9,690	124,000	8	18,100	19,900	14	17,200	10,000	20	15,400	5,750	26	16,200	4,220
3	9,360	70,000	9	19,900	16,200	15	54,600	9,030	21	13,600	5,490	27	14,000	3,980
4	9,030	47,400	10	16,700	14,000	16	44,100	8,710	22	14,000	5,230	28	12,800	5,230
5	8,710	37,400	11	14,000	13,600	17	30,200	7,780	23	19,900	4,970	29	12,800	6,580
6	8,090	30,200	12	11,900	13,200	18	22,400	7,170	24	21,400	4,720	30	36,800	6,580
												31	-------	6,020
Mean monthly discharge, in second-feet													17,900	21,800
Runoff, in inches													3.54	4.46

GAGE HEIGHT, IN FEET, AND DISCHARGE, IN SECOND-FEET, AT INDICATED TIME, 1909

Hour	April 27 Feet	April 27 Sec.-ft.	April 28 Feet	April 28 Sec.-ft.	April 29 Feet	April 29 Sec.-ft.	April 30 Feet	April 30 Sec.-ft.	May 1[a] Feet	May 1[a] Sec.-ft.
6	5.20	14,600	4.80	12,800	4.70	12,400	8.80	32,400	20.95	142,000
12 m	5.10	14,100	4.75	12,800	5.15	14,600	11.85	50,800	20.95	142,000
6	5.00	13,700	4.65	12,000	5.95	18,300	17.90	107,000	20.75	140,000
12 p.m.	4.90	13,300	4.60	12,000	7.10	23,600	20.45	135,000	20.40	135,000

Hour	May 2 Feet	May 2 Sec.-ft.	May 3 Feet	May 3 Sec.-ft.	May 4 Feet	May 4 Sec.-ft.	May 5 Feet	May 5 Sec.-ft.	May 6 Feet	May 6 Sec.-ft.
6	19.70	127,000	14.50	73,400	11.45	47,900	9.85	38,000	8.50	30,800
12 m	18.40	113,000	13.60	65,300	10.95	45,200	9.50	36,300	8.20	29,200
6	16.90	97,000	12.75	58,600	10.55	42,700	9.15	34,600	7.95	28,200
12 p.m.	15.60	83,900	12.05	52,300	10.20	40,300	8.85	32,400	7.70	26.600

Hour	May 7 Feet	May 7 Sec.-ft.	May 8 Feet	May 8 Sec.-ft.	May 9 Feet	May 9 Sec.-ft.	May 10 Feet	May 10 Sec.-ft.
6	7.40	25,100	6.45	20,200	5.65	16,400	5.15	14,600
12 m	7.15	24,100	6.25	19,300	5.50	15,900	5.10	14,100
6	6.90	22.600	6.05	18,300	5.35	15,400	5.05	13,700
12 p.m.	6.65	21,200	5.15	17,300	5.25	14,600	5.00	13,700

[a] Peak discharge: May 1, 8 a.m., 142,000 second-feet, gage height 21.0 feet.

LOCATION.—Chain gage, lat. 41°14′15″, long. 76°59′55″, at highway bridge at Williamsport, Lycoming County. Zero of gage is 494.55 feet above mean sea level.

DRAINAGE AREA.—5,682 square miles.

REMARKS.—Records of daily mean discharge published in Geol. Survey Water-Supply Paper 261.

TABLE 88.—*Computation of volume of direct runoff associated with precipitation period April 27 to May 4, 1909, West Branch of Susquehanna River at Williamsport, Pa.*

Day	Daily mean discharge (second-feet)	Estimated recession from preceding storm and base runoff (second-feet)	Direct runoff (second-feet)
Apr.			
28	12,430	12,430	0
29	15,425	11,320	4,105
30	68,600	10,210	58,390
May			
1	140,000	9,100	130,900
2	112,000	10,100	101,900
3	66,200	11,200	55,000
4	45,880	12,200	33,680
5	36,275	13,300	22,975
6	29,240	14,300	14,940
7	24,115	15,400	8,715
8	19,260	16,500	2,760
9	15,900	15,900	0
Total Sec.-ft.-days	585,325	151,960	433,365 (= 2.84 inches)

TABLE 89.—*Computation of time of center of mass of net supply, and lag intervals, West Branch of Susquehanna River at Williamsport, Pa., April 27 to May 4, 1909*

Day	Mean areal precipitation [a] (inches)	Estimated net supply (inches)	Time from origin (days)	Product (inch-days)
Apr.				
27	0.17	0	0	0
28	.22	.09	1	.09
29	1.42	1.10	2	2.20
30	1.30	1.00	3	3.00
May				
1	.55	.39	4	1.56
2	.03	.01	5	.05
3	.30	.22	6	1.32
4	.09	.04	7	.28
	4.08	2.84	....	8.50

[a] 7 p.m. to 7 p.m.

Center of mass of net supply occurred $\frac{8.50}{2.84}$ = 3.00 days after 7 a.m. April 27 = April 30.29.

Time of center of mass of direct runoff was at April 32.62 or 2.33 days (56 hours) after center of graph of net supply.

Peak discharge occurred at 8 a.m. May 1 or 1.05 days (25 hours) after center of graph of net supply.

FLOOD OF MAY 1916, GENESEE RIVER AT ST. HELENA, N. Y.

The flood of May 1916 in the Genesee River Basin was the result of heavy 3-day precipitation, centering on May 16 and following a 30-day period in which the precipitation was 20 percent above normal. The precipitation was associated with an extra-tropical cyclone whose position on May 16 is shown on figure 35.

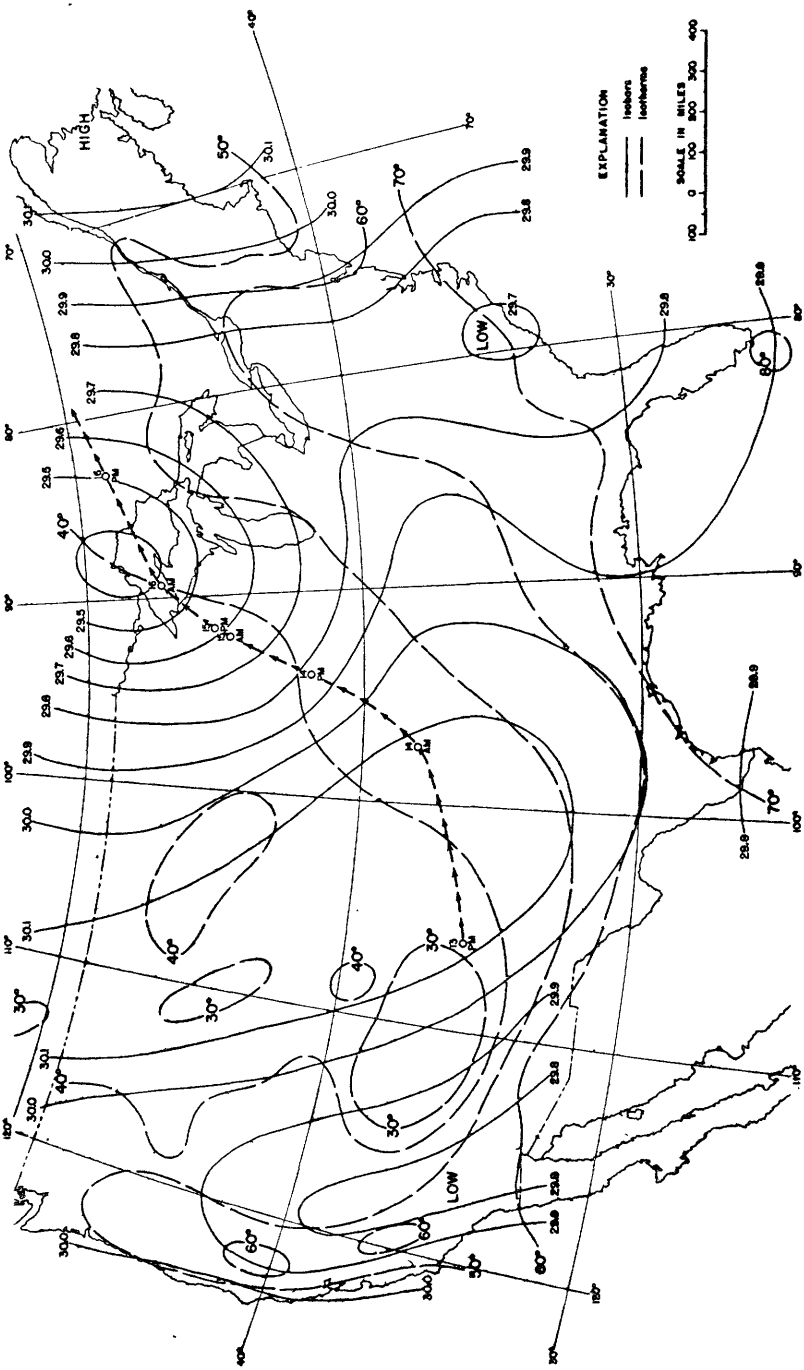

FIGURE 35.—Map of United States showing position of storm, 8 a.m. (E.S.T.), May 16, 1916.

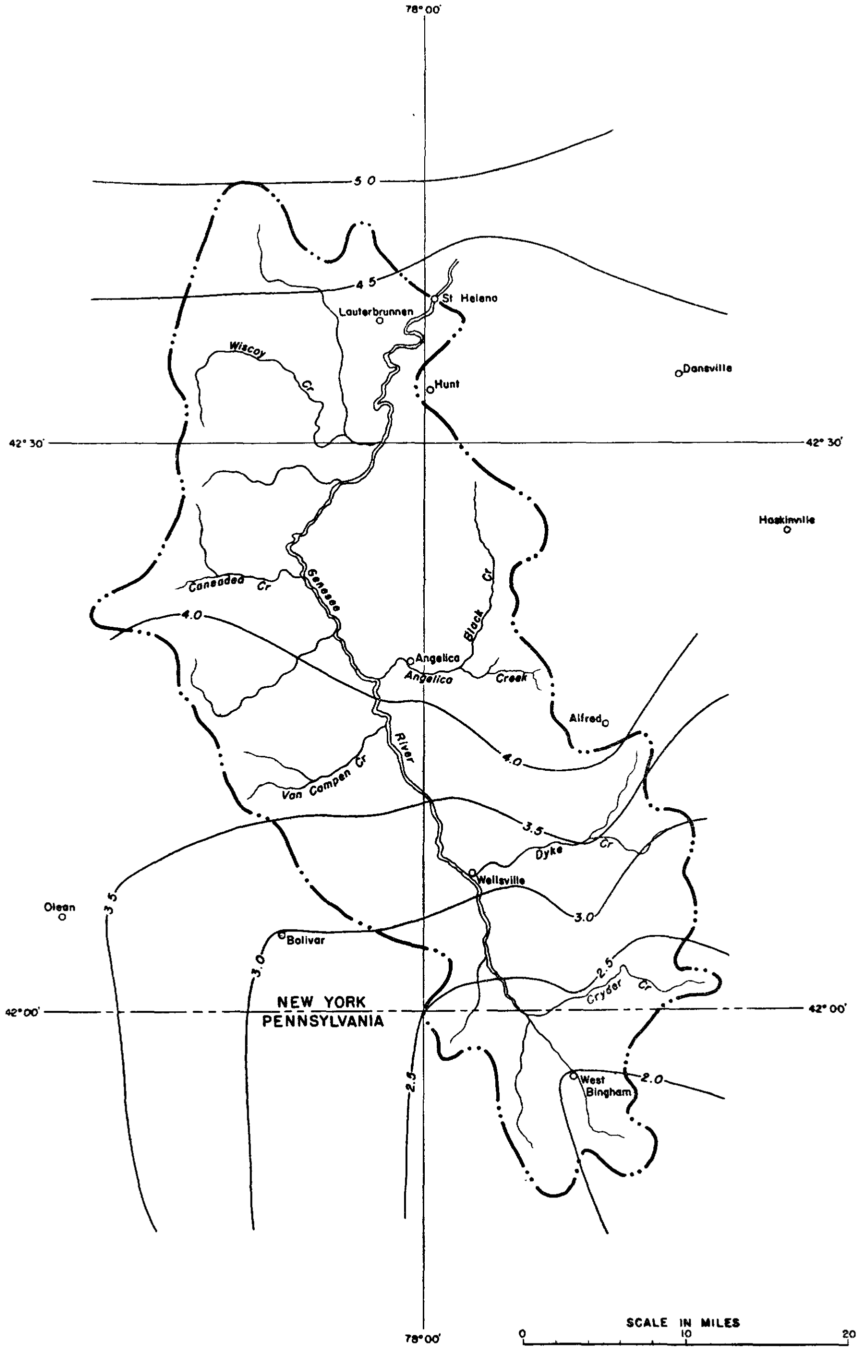

FIGURE 36.—Map of Genesee River basin above St. Helena, N. Y., showing lines of equal precipitation, May 14-20, 1916.

Precipitation at the several rain gages in and near the basin for each calendar day during the storm period is listed in table 90. Of the average storm rainfall of 3.67 inches over the basin, 2.64 inches fell on May 16. The recording rain gage at Rochester, N. Y., listed in table 91, indicates that although it rained nearly all day, most of the precipitation fell during the latter half. Figure 36 shows an isohyetal map of the total storm precipitation based on published Weather Bureau records of rainfall. The precipitation progressively increased from 2 inches in the upper basin to 5 inches in the lower basin.

The discharge at bi-hourly intervals during the storm is published in table 92 and is shown as a hydrograph on figure 37. Direct runoff asso-

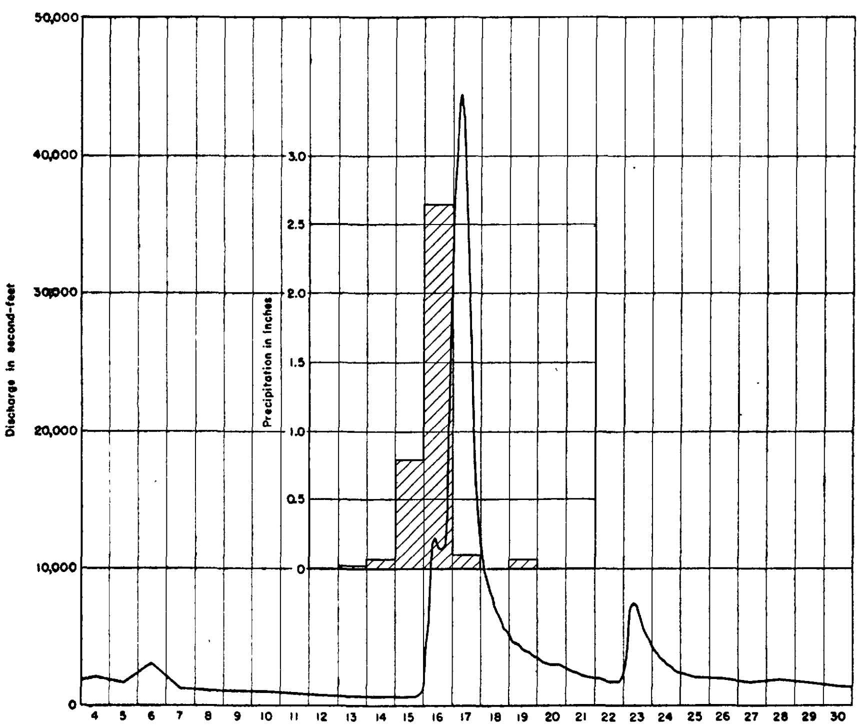

FIGURE 37.—Hydrograph of Genesee River at St. Helena, N. Y., showing discharge, May, and precipitation, May 12-21, 1916.

ciated with the storm as computed in table 94 was 1.96 inches, leaving a retention of 1.71 inches. Ground-water runoff as computed was 0,68 inch, leaving 1.03 inches for field-moisture accretion and evaporation-transpiration losses.

The infiltration capacity as computed averaged 0.07 inch per hour, the lowest of any of the nonwinter storms studied.

Table 93 shows the computation of the lag intervals between rainfall and runoff. The time of the center of mass of effective rainfall is based on mean areal 12-hourly rainfall reduced to net supply by methods previously explained. The time interval between center of rainfall and runoff was computed as 29 hours and that between the center of rainfall and the peak discharge at St. Helena was 21 hours.

TABLE 90.—*Daily precipitation, in inches, at rain gages in and near Genesee River at St. Helena, N. Y., May 13-19, 1916*

Station	Altitude (feet)	Weight (percent)	May							
			13	14	15	16	17	18	19	Total 13-19
New York:										
Alfred	1,840	12.7	0.04	0.14	0.67	3.07	0.11	0.00	0.08	4.11
Angelica	1,420	33.1	.00	.02	1.15	2.87	.07	.00	.03	4.14
Bolivar	1,800	8.0	.05	.15	.28	2.20	.20	.00	.10	2.98
Hunt	1,150	11.4	.01	.06	1.65	2.25	.03	.00	.20	4.20
Lauterbrunnen	1,260	16.8	.03	.08	.53	3.37	.11	.00	.05	4.17
Pennsylvania:										
W. Bingham	1,171	18.0	.00	.00	.21	1.66	.10	.00	.00	1 97
Average or total	--------	100.0	0.02	0.06	0.80	2.64	0.09	0.00	0.06	3.67

TABLE 91.—*Hourly precipitation, in inches, at recording Weather Bureau gages near Genesee River basin, May 13-24, 1916*

[In this table "T" indicates a trace]

Station	Day	a.m. 1	a.m. 2	a.m. 3	a.m. 4	a.m. 5	a.m. 6	a.m. 7	a.m. 8	a.m. 9	a.m. 10	a.m. 11	a.m. 12	p.m. 1	p.m. 2	p.m. 3	p.m. 4	p.m. 5	p.m. 6	p.m. 7	p.m. 8	p.m. 9	p.m. 10	p.m. 11	p.m. 12	Total
Buffalo, N. Y.	13																									
	14												T	T	0.04	0.05	0.02	0.02	0.04	0.01						0.18
	15		T	0.07	0.16	0.22	0.09	0.03	0.01	T	0.01								T				T	0.02	T	.61
	16		T	.02	T	.01	T	.03	.01		.01						T		.08	.09	0.04	0.01				.30
	17															T	T	T	T							T
	18													T	T			T			T					T
	19					T	.01															T	T	.01		.02
	20																									
	21																									
	22								T	T	T	0.04	0.06	0.15	.04	.14	.03	.01	.04	.13	.02	T		T	T	.66
	23	0.01	0.01	.03	.03	T																				.08
	24																									
Ithaca, N. Y.	13																									
	14													T	T	a	a	a	a	a	.04					.04
	15				T																				T	T
	16																	a	a	a	.08	a	a	a	1.15	1.23
	17	a	a	a	a	a	a	a	.86	a	a	.12												T	.01	.99
	18																	T	T							T
	19														.05	T							0.03			.08
	20			.01																						.01
	21																									
	22														a	a	a	a	a	a	.32	a	a	a	.34	.66
	23	a	a	a	.22																					.22
	24																									
Rochester, N. Y.	13																									
	14															.01	.01	.01	.03	.02	T					.08
	15					.07	.13	.10	.07		T	T							.01	.11	.16		T	.01	T	.66
	16	.17	.01	.05	.13	.12		.01	.01	0.25	.06	T	.01	.03		.09	.45	.38	.39	.30	.12	.14	.14	.05	.04	2.95
	17	.01															T	T	.01							.01
	18																	T	T	T					T	T
	19								T															.02	.04	.06
	20	.01																								.01
	21																									
	22										T	.01	.02	T	.12	.10	.05	.10	.09	.06	.13	.15		T	T	.83
	23	.02	.03	.03																						.08
	24																									

Syracuse, N. Y.	13																									
	14															T	.01	.01	.01	.03	.06	T				.12
	15							.07	.04	T		.03	.02								T		T	.09	.01	.26
	16	T					.01	.17													.03	.19	.60	.24	.21	1.45
	17	.15	.12	.13	.03	.05	.07	.09	.06	.05	.06	.02	.01	.04	T		.01			.01	.01					.91
	18			.02				T	T	.01		T		T	T							T				.03
	19																								T	T
	20			T	.07	T																				.07
	21																									
	22													T		T	.01	.07	.01	T	.03	.06	.10	.03	.02	.33
	23	.01	.01	.01	T	.03	T	T	T	T																.06
	24															T										T
Harrisburg, Pa.	13								T																	T
	14																									
	15								T	T	T															T
	16											T	.01	T	T	T	T	T	T	.01	T	T	.01	.02	.08	.13
	17	.04	.03	T	.01	.01							T	T				.01								.10
	18																			T						T
	19																						T	T		T
	20																									
	21																									
	22																	T	T	T	.03	.10	.08	.07	.09	.37
	23	.06	.06	.09	.09	.01	.03	.01	T	T	T	T	T	T									T	T		.35
	24																									

*Included in following measurement.

TABLE 92.—*Gage height and discharge of Genesee River at St. Helena, N. Y., during flood of May 1916*

MEAN DISCHARGE, IN SECOND-FEET, MAY 1916

Day	Sec.-ft.	Day	Sec.-ft.	Day	Sec.-ft.	Day	Sec.-ft.	Day	Sec.-ft.	Day	Sec.-ft.
1	2,000	6	1,300	11	779	16	11,600	21	2,250	26	1,930
2	1,640	7	1,150	12	676	17	31,300	22	1,810	27	1,560
3	1,460	8	1,020	13	602	18	7,600	23	5,730	28	1,790
4	2,000	9	970	14	562	19	4,160	24	3,110	29	1,570
5	1,580	10	870	15	662	20	3,040	25	2,080	30	1,280
										31	1,170

Mean monthly discharge, in second-feet	3,202
Runoff, in inches	3.63

GAGE HEIGHT, IN FEET, AND DISCHARGE, IN SECOND-FEET, AT INDICATED TIME, 1916

Hour	May 14 Feet	May 14 Sec.-ft.	May 15 Feet	May 15 Sec.-ft.	May 16 Feet	May 16 Sec.-ft.	May 17 Feet	May 17 Sec.-ft.	May 18 Feet	May 18 Sec.-ft.	May 19 Feet	May 19 Sec.-ft.
2	3.31	566	3.31	566	5.64	3,830	11.88	35,900	7.75	10,600	6.07	4,880
4	3.28	550	3.28	550	6.42	5,860	12.36	40,200	7.55	9,800	6.01	4,730
6	3.30	560	3.32	572	7.57	9,880	12.73	43,600	7.35	9,020	5.93	4,520
8	3.30	560	3.34	584	8.00	11,700	12.81	44,400	7.22	8,530	5.87	4,380
10	3.30	560	3.45	655	8.11	12,200	12.63	42,700	7.00	7,750	5.81	4,230
12 m.	3.29	555	3.41	627	7.93	11,400	12.13	38,100	6.85	7,230	5.77	4,140
2	3.31	566	3.41	627	7.91	11,300	11.44	32,300	6.71	6,760	5.71	3,990
4	3.27	545	3.42	634	7.94	11,400	10.68	26,800	6.56	6,290	5.65	3,860
6	3.29	555	3.46	662	8.01	11,700	9.73	20,800	6.45	5,950	5.61	3,760
8	3.30	560	3.57	746	8.62	14,600	8.90	16,100	6.33	5,600	5.54	3,610
10	3.32	572	3.77	930	9.77	21,000	8.41	13,600	6.26	5,400	5.49	3,500
12 p.m.	3.32	572	3.96	1,130	11.13	29,900	8.01	11,700	6.16	5,120	5.45	3,420

Hour	May 20 Feet	May 20 Sec.-ft.	May 21 Feet	May 21 Sec.-ft.	May 22 Feet	May 22 Sec.-ft.	May 23 Feet	May 23 Sec.-ft.	May 24 Feet	May 24 Sec.-ft.
2	5.41	3,330	5.01	2,580	4.55	1,860	5.57	3,670	5.72	4,020
4	5.35	3,210	4.96	2,490	4.54	1,850	6.42	5,860	5.62	3,700
6	5.31	3,130	4.92	2,420	4.51	1,800	6.84	7,200	5.50	3,520
8	5.29	3,090	4.87	2,340	4.49	1,780	6.93	7,500	5.41	3,330
10	5.26	3,030	4.83	2,280	4.47	1,750	6.90	7,400	5.32	3,150
12 m.	5.26	3,030	4.80	2,230	4.43	1,690	6.75	6,900	5.23	2,980
2	5.25	3,020	4.76	2,170	4.44	1,710	6.57	6,320	5.16	2,850
4	5.25	3,020	4.73	2,120	4.44	1,710	6.38	5,740	5.11	2,760
6	5.21	2,940	4.69	2,060	4.45	1,720	6.23	5,310	5.04	2,630
8	5.16	2,850	4.66	2,020	4.52	1,820	6.10	4,960	4.97	2,510
10	5.12	2,780	4.63	1,980	4.64	1,990	5.97	4,620	4.93	2,440
12 p.m.	5.07	2,690	4.59	1,920	4.82	2,260	5.84	4,310	4.88	2,360

LOCATION.—Water-stage recorder, lat. 42°37′20″, long. 77°59′20″, at highway in St. Helena, Wyoming County, 1½ miles downstream from Wolf Creek.

DRAINAGE AREA.—1,017 square miles.

REMARKS.—Records supersede those published in Geol. Survey Water-Supply Paper 434.

TABLE 93.—*Computation of time of center of mass of net supply, and lag intervals, Genesee River at St. Helena, N. Y., May 13-19, 1916*

May	12-hour period ending	Mean areal precipitation (inches)	Estimated net supply (inches)	Time from origin (days)	Product (inch-days)
13	12 p.m.	0.02	0.00	0.0	0.00
14	12 m.	.03	.00	.5	.00
	12 p.m.	.03	.00	1.0	.00
15	12 m.	.55	.25	1.5	.38
	12 p.m.	.25	.09	2.0	.18
16	12 m.	.76	.43	2.5	1.07
	12 p.m.	1.88	1.15	3.0	3.45
17	12 m.	.02	.00	3.5	.00
	12 p.m.	.07	.02	4.0	.08
18	12 m.	.00	.00	4.5	.00
	12 p.m.	.00	.00	5.0	.00
19	12 m.	.06	.02	5.5	.11
	12 p.m.	.00	.00	6.0	.00
		3.67	1.96	....	5.27

Center of mass of net supply occurred $\frac{5.27}{1.96} = 2.69$ days after 6 p.m. of May = May 16.44.

Time of center of mass of direct runoff was at May 17.66 or 1.22 days (29 hours) after center of mass of net supply.

Peak discharge occurred at 8 a.m. May 17 or 0.89 day (21 hours) after center of mass of net supply.

TABLE 94.—*Computation of volume of direct runoff associated with precipitation of May 13-19, 1916, Genesee River at St. Helena, N. Y.*

May	12-hour period ending	Daily mean discharge (second-feet)	Estimated recession from preceding storm and base runoff (second-feet)	Direct runoff (second-feet)
14	12 p.m.	560	560	0
15	12 m.	585	555	30
	12 p.m.	740	600	140
16	12 m.	8,220	670	7,550
	12 p.m.	15,040	800	14,240
17	12 m.	40,250	900	39,350
	12 p.m.	22,350	1,000	21,350
18	12 m.	9,180	1,100	8,080
	12 p.m.	6,015	1,200	4,815
19	12 m.	4,560	1,300	3,260
	12 p.m.	3,750	1,400	2,350
20	12 m.	3,160	1,400	1,760
	12 p.m.	2,910	1,350	1,560
21	12 m.	2,440	1,350	1,090
	12 p.m.	2,070	1,350	720
22	12 m.	[a]1,800	1,300	500
	12 p.m.	[a]1,600	1,300	300
23	12 m.	[a]1,475	1,300	175
	12 p.m.	[a]1,400	1,300	100
24	12 m.	[a]1,350	1,300	50
Total				
Sec.-ft.-½ days		129,455	22,035	107,420
Sec.-ft.-days		64,728	11,018	53,710 (= 1.96 inches)

[a] Estimated recession under subsequent rise.

RATES OF FLOOD DISCHARGE

The rates of flood discharge are generally the most important flood characteristic. The maximum rate of discharge determines the height to which a given river will rise and the velocities that will occur. The flood crest discharge is a function of many factors among which three are significant: (1) the volume of supply as it may be influenced by the quantity of rainfall or snow melt and by the absorptive qualities of the ground, (2) the time distribution of the supply, and ultimately (3) the storage capacities and other hydraulic characteristics of the ground and river-channel system. The first two mentioned are variables and are different for each storm. They have been described insofar as permitted by available data for each flood. The last factor on the other hand is relatively fixed, and its effect may be measured in most respects by the basin lag interval as described by Langbein.[16] This section of the report is directed toward a discussion of the influence of the volume of supply and its time distribution on the discharges during the major winter and nonwinter floods studied.

The ratio between the total volume of rainfall and snow melt and the maximum rate of rainfall, plus total snow melt, tends to be an inverse measure of the concentration of the supply. Likewise the ratio between the total volume of direct runoff and the peak rate of discharge tends to be an inverse measure of the concentration of the runoff. If the total volumes were expressed in inches and the maximum rates in inches per hour, these two ratios would have the dimensions of hours, and when compared, might serve as a measure of the degree of smoothing produced by the various basin and channel factors in the transition from precipitation supply to stream flow.

For convenience the two ratios are termed, respectively, equivalent duration of supply and equivalent duration of direct runoff, inasmuch as instead of the actual time distributions of supply or direct runoff, they define the widths of single rectangular bar graphs of heights equal to the maximum rates of supply and of direct runoff and of areas corresponding to the respective volumes in inches. Algebraically these ratios can be expressed as follows:

$$\frac{\text{Volume of supply}}{p} = \text{equivalent duration of supply} \qquad (1)$$

$$\frac{\text{Volume of direct runoff}}{q} = \text{equivalent duration of direct runoff} \qquad (2)$$

where p is the maximum rate of mean areal rainfall (plus snow melt) in inches per hour, and q is the maximum rate of discharge from direct runoff in inches per hour. As not all of the supply produces direct runoff, ratio 1 preferably should be evaluated in terms of the net supply. To accomplish this, separate coefficients of runoff are applied to the

[16] Langbein, W. B., Channel storage and unit hydrograph characteristics: Am. Geophys. Union Trans., 1940, pp. 620–628.

numerator and denominator of this ratio, or in other words the volume of supply is placed equal to the total volume of direct runoff, and an estimate is made of the amount that the peak rate of supply was reduced by infiltration or absorption by the ground. Generally the peak rate of supply is reduced by a smaller percentage than is the total volume.

Instantaneous crest-discharge data are available for many drainage basins, but this is not true with respect to short-period rainfall data. Therefore in order to place the rainfall and runoff data on a comparable basis, p in equation 1, and q in equation 2, were evaluated as the mean rates, in inches per hour, over a selected period that was less than half the lag interval for the particular basin depending on the limitations of the available rainfall data.

Table 95 lists the values of the factors in equations 1 and 2 and the computed values of the equivalent duration of net supply and direct runoff. In this table the maximum rate of effective supply, column 6, is the mean areal rate of rainfall (plus snow melt) reduced by an amount sufficient to account for the infiltration. The maximum rate of direct runoff in column 9 is equal to the maximum average rate over a period equal to that listed in column 7.

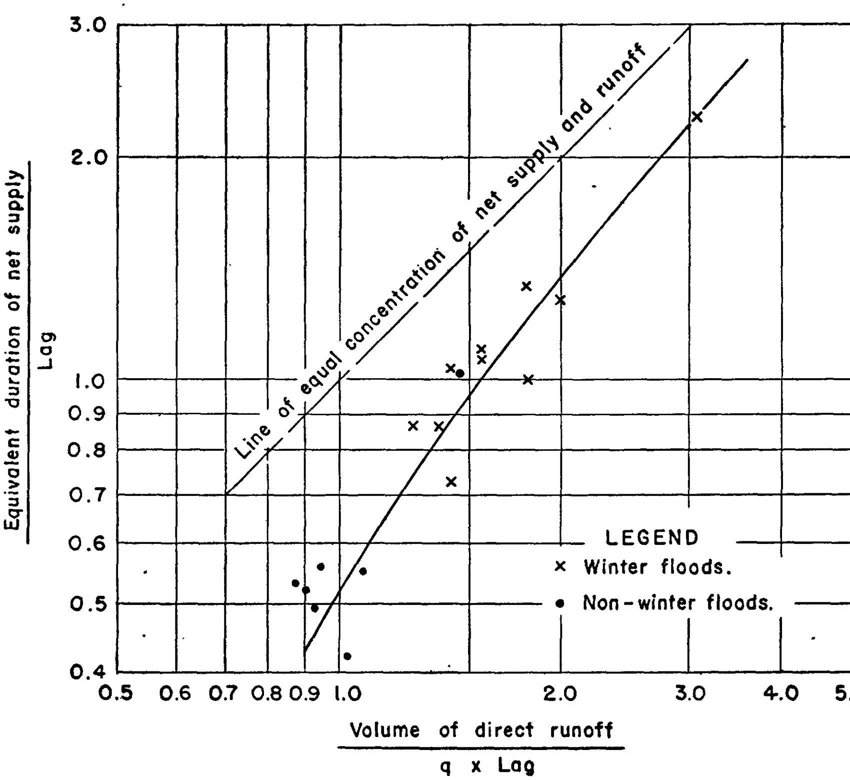

FIGURE 38.—Concentration of direct runoff in relation to concentration of net supply.

Figure 38 shows the result of plotting the computed equivalent duration of net supply against the computed equivalent duration of direct runoff in terms of runoff when both are expressed in ratio to the lag. The figure shows that the duration of runoff $\left(\frac{\text{volume of direct runoff}}{q \times \text{lag}}\right)$ increases with the duration of the supply and that for the long storms the graph tends to approach the line of equal concentration of supply and runoff.

The positions of the plotted points shown are dependent among other things on the quality of the rainfall data. If more short-period rainfall data were available, it might be expected that greater variations in intensity would be disclosed with the result that points would tend to plot below those shown on figure 38.

The average rate of flood discharge, as reported in table 95 for the seven greatest nonwinter floods (omitting Susquehanna River at Marietta, Pa.), is 0.051 inch per hour, and the average rate of flood discharge for the greatest winter floods at the same seven stations is 0.056 inch per hour or 1.10 times as great. There are three factors given in table 95 that are of influence in these rates, namely (1) lag interval, (2) volume of direct runoff, and (3) equivalent duration of net supply.

The lag intervals are respectively 54 and 50 hours, nearly equal, indicating that the channel and related hydraulic basin factors were sensibly constant in their effects during the nonwinter and winter floods studied. The volumes of direct runoff, however, averaged, respectively, 2.44 inches for the nonwinter floods and 4.24 inches for the winter floods, the latter being 1.74 times as great. Other conditions being the same, flood discharge rates are directly proportional to the volume of runoff. But according to the data in table 95, the equivalent duration of net supply for the group of nonwinter floods averaged 41 hours and that for the winter floods 64 hours, indicating that the volumes of net supply during the winter season are spread over a longer interval and so are less concentrated with respect to time. The decreased concentration during winter tends to compensate for the larger volume of direct runoff during that season.

The decrease in concentration of supply cannot be directly converted into differences in discharges. However, table 95 also lists the equivalent durations of direct runoff for each flood, which are inverse measures of the concentration of the direct runoff and as such are inversely proportional to the flood discharges, other factors such as volume and lag interval being the same. Thus the average equivalent duration of direct runoff during the nonwinter season is 55 hours and that during the winter season 82 hours for the same seven basins. Other factors being constant, flood discharges in the winter would be $\frac{55}{82} = 0.67$ times non-

TABLE 95.—*Concentration of rainfall and runoff during major winter and nonwinter floods*

Drainage basin	Storm period	Drainage area (sq. mi.)	Lag interval (hours)	Volume of direct runoff (inches)	Maximum amount of net supply in indicated period		Equivalent duration of net supply (hours)	Maximum rate of direct runoff (inches per hour)	Equivalent duration of direct runoff (hours)
					amount (inches)	period (hours)			
Nonwinter floods:									
Sacandaga River near Hope, N. Y.	July 8-12, 1921	491	38	1.94	[a] 0.39	12	60	0.056	35
East Branch of Delaware River at Fishs Eddy, N. Y.	Aug. 21-25, 1933	783	37	3.44	1.14	6	18	.100	34
Chemung River at Chemung, N. Y.	July 7-10, 1935	2,530	45	1.91	.96	12	24	.049	39
Susquehanna River at Wilkes-Barre, Pa.	July 7-10, 1935	9,960	77	1.52	.46	12	40	.022	69
Susquehanna River at Harrisburg, Pa.	May 17-23, 1894	24,100	99	3.44	.75	12	55	.037	93
Susquehanna River at Marietta, Pa.	Aug. 21-25, 1933	25,990	81	1.39	.50	12	33	.017	82
West Branch of Susquehanna River at Williamsport, Pa.	Apr. 27 to May 4, 1909	5,682	56	2.84	.60	12	57	.035	81
Genesee River at St. Helena, N. Y.	May 14-20, 1916	1,017	29	1.96	.74	6	16	.064	31
Average [b]			54	2.44			41	0.051	55
Winter floods:									
Sacandaga River near Hope, N. Y.	Mar. 8-14, 1936	491	52	1.88	0.50	12	45	0.029	65
Sacandaga River near Hope, N. Y.	Mar. 15-22, 1936	491	45	5.25	[a] .73	12	86	.066	80
East Branch of Delaware River at Fishs Eddy, N. Y.	Mar. 9-15, 1936	783	34	3.08	.53	6	35	.064	48
East Branch of Delaware River at Fishs Eddy, N. Y.	Mar. 15-21, 1936	783	36	5.45	.90	6	36	.084	65
Chemung River at Chemung, N. Y.	Mar. 9-14, 1936	2,530	33	2.39	[a] .55	12	52	.049	49
Chemung River at Chemung, N. Y.	Mar. 15-21, 1936	2,530	30	4.00	1.40	24	68	.044	91
Susquehanna River at Wilkes-Barre, Pa.	Mar. 9-15, 1936	9,960	67	2.83	.95	24	71	.027	105
Susquehanna River at Wilkes-Barre, Pa.	Mar. 16-21, 1936	9,960	70	4.38	1.17	24	90	.031	141
Susquehanna River at Harrisburg, Pa.	Mar. 9-14, 1936	24,100	86	2.92	1.14	24	62	.024	121
Susquehanna River at Harrisburg, Pa.	Mar. 16-21, 1936	24,100	83	4.53	1.52	24	72	.040	113
West Branch of Susquehanna River at Williamsport, Pa.	Mar. 9-15, 1936	5,682	49	3.10	1.37	24	54	.041	76
West Branch of Susquehanna River at Williamsport, Pa.	Mar. 16-21, 1936	5,682	50	5.63	2.02	24	67	.063	90
Genesee River at St. Helena, N. Y.	Mar. 10-14, 1920	1,017	32	2.08	[a] .63	12	40	.056	37
Average [c]			50	4.24			64	0.056	82

[a] Rate of net supply based on all available data is less than rate of discharge; not used in preparation of figure 38.
[b] Omitting Susquehanna River at Marietta.
[c] Using floods associated with maximum crests only.

winter discharges. The net result of increased volume and decreased concentration on flood discharges during the winter floods with respect to the nonwinter floods is therefore $1.74 \times 0.67 = 1.16$. The net effect on the average in the basins studied, therefore, appears to be nearly but not entirely compensating.

It is of interest to note that in two of the smaller basins studied the nonwinter flood-crest discharges exceeded those in winter even though the volumes of direct runoff for all basins were greater during the maximum winter floods than during the maximum nonwinter floods of record. As a generalization it might be ventured that basins of the size studied, being less influenced by short-period concentrations of rainfall, usually attain their greatest flood heights in the winter season, when snow and unfavorable ground and vegetal conditions result in large volumes of runoff. In basins smaller than those studied, there is the possibility that the increased concentration of precipitation into short periods of time may produce discharge rates exceeding those produced by the larger but less concentrated net supply in winter.

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