EXTENT AND FREQUENCY OF FLOODS ON DELAWARE RIVER IN VICINITY OF BELVIDERE, N. J.

By George M. Farlekas

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
Prepared in cooperation with the
DELAWARE RIVER BASIN COMMISSION

Trenton, New Jersey
October 1966
Open-file report

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PREFACE

This is the second of two reports on flood inundation along the Delaware River. This report presents data on the extent, depth, and frequency of flooding of the Delaware River in the vicinity of Belvidere, N.J. The area delineated in the first open-file report (Farlekas, 1965) is from southern limit of this report to the Northampton-Bucks County line.

This flood inundation study is part of an investigative program financed through a cooperative agreement between the U.S. Geological Survey and the Delaware River Basin Commission. The report was prepared under the direction of J. E. McCall, district chief, U.S. Geological Survey, Trenton, N.J. Technical guidance was furnished by J. A. Bettendorf, and A. C. Lendo, hydraulic engineers, Trenton, N.J.

Similar flood inundation studies and reports in the Delaware River basin are in progress or have been completed. Specific information as to location and status of these studies can be obtained from the Delaware River Basin Commission, Trenton, N.J.

The streamflow data for the Delaware River at Belvidere, N.J. have been collected by the U.S. Geological Survey since 1922 in cooperation with the New Jersey Department of Conservation and Economic Development and its predecessor agencies. Additional data were obtained from the Corps of Engineers, U.S. Army; Delaware River Joint Toll Bridge Commission; Pennsylvania Railroad Co.; County Engineer, Warren County, N.J.; and many local utility companies, industrial firms, and residents. Photographs were furnished by the Easton Express of Easton, Pa., Harry W. Gross of Belvidere, N.J., and the Delaware River Joint Toll Bridge Commission.

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[Plate is in pocket]

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INTRODUCTION

Purpose and Scope

A stream overflowing its banks is a natural phenomenon. This natural phenomenon of flooding has occurred on the Delaware River in the past and will occur in the future. The resulting inundation of large areas can cause property damage, business losses and possible loss of life, and may result in emergency costs for protection, rescue, and salvage work. For optimum development of the river valley consistent with the flood risk, an evaluation of flood conditions is necessary. Basic data and the interpretation of the data on the regimen of the streams, particularly the magnitude of floods to be expected, the frequency of their occurrence, and the areas inundated, are essential for planning and development of flood-prone areas.

This report presents information relative to the extent, depth, and frequency of floods on the Delaware River and its tributaries in the vicinity of Belvidere, N.J. Flooding on the tributaries detailed in the report pertains only to the effect of backwater from the Delaware River. Data are presented for several past floods with emphasis given to the floods of August 19, 1955 and May 24, 1942. In addition, information is given for a hypothetical flood based on the flood of August 19, 1955 modified by completed (since 1955) and planned flood-control works.

By use of relations presented in this report the extent, depth, and frequency of flooding can be estimated for any site along the reach of the Delaware River under study. Flood data and the evaluation of the data are presented so that local and regional agencies, organizations, and individuals may have a technical basis for making decisions on the use of flood-prone areas. The Delaware River Basin Commission and the U.S. Geological Survey regard this program of flood-plain inundation studies as a positive step toward flood-damage prevention. Flood-plain inundation studies, when followed by appropriate land-use regulations, are a valuable and economical supplement to physical works for flood control, such as dams and levees. Both physical works and flood-plain regulations are included in the comprehensive plans for development of the Delaware River basin.

Recommendations for land use, or suggestions for limitations of land use, are not made herein. Other reports on recommended general use and regulation of land in flood-prone areas are available (Dola, 1961; White, 1961; American Society of Civil Engineers Task Force on Flood Plain Regulations, 1962; and Goddard, 1963). The primary responsibility for planning for the optimum land use in the flood plain and the implementation of flood-plain zoning or other regulations to achieve such optimum use rest with the state and local interests. The preparation of this report was undertaken after consultation with representatives of the Lehigh-Northampton Counties, Pennsylvania, Joint Planning Commission and the Warren County, New Jersey, Regional Planning Board and after both had demonstrated their need for flood-plain information and their willingness to consider flood-plain regulations.

Location and Extent of Area

The area for this report is along a 15-mile reach of the Delaware River and its flood plain located in Northampton County, Pa., and Warren County, N.J. (pl. 1). Included in the report area are the tributaries and their flood plains inundated by backwater from the Delaware River. The largest community in the project area is Belvidere, N.J. The area of the report can be found on the U.S. Geological Survey 7½-minute topographic quadrangles Bangor, Pa.-N.J., and Belvidere, N.J.-Pa. The southern boundary for this report is latitude 40°45', the bottom of the Bangor, Pa.-N.J., 7½-minute quadrangle. The northern boundary is latitude 40°52'30", the top of the Belvidere, N.J.-Pa., 7½-minute quadrangle. This northern boundary is approximately three miles north of the Belvidere, N.J.-Riverton, Pa. bridge.

The total length of stream channel for which flood data are given is 18.1 miles of which 15.0 miles is the main stem of the Delaware River and the remainder is tributaries.

The Flood Plain

The reach of the Delaware River covered by this report lies in the Great Valley, a part of the Valley and Ridge physiographic province (Fenneman, 1938). The Great Valley consists of two belts of contrasting landforms. The southern belt is a lowland of gentle relief while the northern belt is deeply eroded and several hundred feet higher than the southern belt. The reach below Belvidere, N.J., situated in the southern belt of the Great Valley is in an area of relatively weak carbonate rock forming a lowland of gentle relief. The reach above Belvidere, N.J., lies in a deeply eroded belt of more resistant bedrock of shale, slate, and sandstone. The Delaware River in this reach has steep-sided banks.

In the report area the present Delaware River has little or no flood plain. An old flood plain formed in the geologic past by a much larger stream is the prominent landform. This old flood plain forms the terrace along the present Delaware River.

The effects of glaciers can be found in the area of the report. Pre-Wisconsin glacial deposits occur in the southern part of the area. Deposits of glacial origin of Wisconsin age occur north of Martins Creek, Pa. Fluvial-glacial deposits are found just north of Martins Creek area. The southern limit of the Wisconsin glacier was just below Belvidere. Glacial deposits in the form of stratified glacial drift and terminal moraines are present in the Belvidere area. Unstratified glacial till is the predominant glacial deposit from Belvidere to the northern boundary of the study area (Parker and others, 1964). Several gravel pits located on the flood plain in the report area have been developed from the various glacial deposits.

Concentrated residential and industrial development of the flood plain in the study reach exists only in the Belvidere, N.J., area. Many all-year and summer homes are found along the banks of the Delaware River. In addition, a number of farms and a few commercial and industrial establishments have been developed on the flood plain.

METHOD OF ANALYSIS

Procedures used in this report are similar to "Phase I" methods in U.S. Geological Survey Water-Supply Paper 1526 (Wiitala, Jetter, and Sommerville, 1961). A flood-frequency curve (fig. 1) based on a regional flood-frequency study by Tice (1958) was prepared. High-water profiles of selected floods were also plotted (fig. 2). The computed reduction of stage of a hypothetical recurrence of the flood of August 1955 based on the effect of flood-control structures constructed or planned prior to the date of this report, was furnished by the Corps of Engineers (fig. 2). (The major flood-control structures included are the Tocks Island, General Edgar Jadwin, and Prompton Reservoirs). A flood-inundation map (pl. 1), delineating the areas inundated by the floods of August 1955 and May 1942 was then prepared on the basis of high-water profiles (fig. 2), field surveys, and information supplied by local residents.

Data Available

Streamflow data have been systematically collected since October 1922 at the U.S. Geological Survey gaging station, Delaware River at Belvidere, N.J. A well-defined stage-discharge relation is available for the gaging station. Annual flood elevations and discharges for the gaging stations are listed in table 1. The annual peaks in the table are based on a water year which begins on October 1 and ends on September 30. Elevation of peaks at the gage can be converted to gage heights by subtracting the datum of the gage (226.43 feet above mean sea level). Peak-stage readings from a wire-weight gage on the Belvidere, N.J.-Riverton, Pa. bridge maintained by the Delaware River Joint Toll Bridge Commission were furnished by the Bridge Commission.

The maximum known flood on the Delaware River in the vicinity of Belvidere, N.J. occurred on August 19, 1955. This flood was about 1½ feet higher at the Belvidere gage than the flood of October 10, 1903, the second highest flood of record. Figure 3 illustrates the irregular distribution of major flood events at Belvidere, N.J.; none with peaks above 245.0 feet having occurred in the period of 1956-65.

Flood-crest elevations for the floods of August 19, 1955; October 10, 1903; March 19, 1936; and May 24, 1942 (table 2) for the project area were obtained by field surveys and from published and unpublished records from several sources. Profiles of the floods of August 19, 1955, and October 10, 1903, the two greatest floods known in the Belvidere, N.J. vicinity are shown in figure 2. Lesser floods of March 19, 1936, and May 24, 1942, are included in figure 2 since both were floods of large magnitude occurring in recent times for which accurate data are available.

Photographs (figs. 4-10) show the extent or comparison of the floods of August 1955 and October 1903 in the vicinity of Belvidere, N.J. A photograph (fig. 5) taken near the peak stage on August 19, 1955, shows flood waters over the bottom steel of the Belvidere, N.J.-Riverton, Pa. bridge. Figure 6 is given for comparison and shows the Delaware River at low stage in November 1965. Flood information pertaining to bridges in the area under study is given in table 3. All bridges in the area across the Delaware River were either inundated or their approaches were flooded by the August 1955 flood.

U.S. Geological Survey 7½ -minute topographic maps, at a scale of 1:24,000, were used as a base to show areal extent of flooding and provide planimetric control. Vertical control points used in obtaining low-water elevations, flood-crest elevations, and the cross section of the Pequest River were established by the U.S. Coast and Geodetic Survey, New Jersey Geodetic Control Survey, or the Corps of Engineers. Bench marks used for vertical control are listed in table 4. Primary vertical control for cross sections of the Delaware River was from U.S. Coast and Geodetic Survey bench marks. Elevations in this report are referenced to sea-level datum of 1929.

Delaware River mileage used in this report conforms with the mileage system adopted by the Delaware River Basin Commission. The origin or zero mile is at the mouth of Delaware Bay at the intersection of a line between Cape May Light in New Jersey and the tip of Cape Henlopen, Delaware, with the centerline of the navigation channel. Mileages on the tributaries of the Delaware River are measured from the mouth of the respective tributary.

Magnitude and Frequency of Floods

A regionalized flood-frequency curve (fig. 1) was defined for the Delaware River at Belvidere, N.J. gaging station and applies to the Delaware River reach covered by this report. The curve, based on Tice's "Delaware River Basin Flood Frequency" (1958) open-file report and converted to partial-duration series, was derived by procedures explained by Dalrymple (1960). Regional frequency relations for the Delaware River were developed by Tice (1958) using a base period of 1913-55 and historical record extending back to 1692. Recurrence interval, as applied to flood events, is the number of years on the average within which a given flood will be equaled or exceeded once.

The estimated recurrence interval of the flood of August 1955 is more than 150 years 1/. The floods of October 1903, March 1936, and May 1942 have estimated recurrence intervals of 115 years, 25 years, and 5 years, respectively.

Future floods will be reduced significantly by existing and planned flood-control works in the Delaware River basin. According to the Corps of Engineers, Philadelphia District, the latest designs for these flood-control works would reduce the depth of flooding of a hypothetical recurrence of the August 1955 flood at Belvidere, N.J. gage by about eight feet. The Tocks Island Reservoir as planned by the Corps of Engineers provide, by far, the greatest amount of flood reduction. The flood-control works will decrease significantly the frequency of floods of a given size or the size of flood from a given storm but will not eliminate the flood threat.

1/ Recurrence interval estimated by method outlined by Dalrymple (1960). Estimated frequencies of extreme floods may vary depending on the method of computation.

Magnitude and frequency of any past or future flood can be estimated by the use of the regionalized flood-frequency curve. Any major changes of the hydrologic conditions, such as building upstream flood-control structures, will alter flood frequency. Flood reduction due to added flood-control structures must be taken into account in estimating magnitude and frequency of future floods. Information concerning the use and interpretation of frequency curves can be found in several published reports; for example, Dalrymple, (1960); Gumbel, (1945); and Langbein, (1949).

Practical applications of magnitude and frequency relations should be based on elevations referenced to sea-level datum of 1929. To aid any subsequent study and field survey, a list of bench marks and reference points and their elevations are given in table 4. These bench marks and reference points were used for vertical control in obtaining field data.

Flood Profiles

Flood profiles of the Delaware River (fig. 2) based on known flood-crest elevations at many points were determined for the floods of: August 1955; October 1903; March 1936; and May 1942. By use of flood profiles, flood-frequency relations can be extended to all sites along the Delaware River reach of this report and is explained in detail in the report.

The flood-crest elevations used in determining the profiles were obtained by the following means. Field investigations were undertaken in the faill of 1964 to locate high-water marks and high-water levels. Inquiry of local residents and industrial firms helped to define the flood marks. The elevations of these flood marks were obtained by levels to bench marks. Flood-crest elevations were also obtained from publications and various agency records. In addition, low-water elevations were determined by field survey. All flood-crest elevations, as well as low-water elevations used in this report are listed in table 2.

The following profiles of the Delaware River are shown in figure 2 for comparison with the flood profiles; low-water profile of November 17, 1964, thalweg profile, and profile showing approximate elevation of top of bank. The thalweg, a line connecting the lowest points in the stream channel, was determined from cross sections furnished by the Corps of Engineers. The profile showing approximate elevation of top of bank is a line connecting the lowest points on either right or left or both banks where inundation will begin. It is based on cross sections and is interpolated between cross sections with use of a topographic map.

Areal Extent of Flooding

The areal extent of flooding of the floods of August 19, 1955 and May 24, 1942 are delineated on plate 1 and figure 11. The flood boundary of August 19, 1955 was delineated on 1:24,000 scale U.S. Geological Survey topographic maps on the basis of field investigations supplemented by an analysis of profile data. The flood boundary of May 24, 1942 was delineated mainly on the basis of profile data. By means described on page 11 the areal extent of other floods of specific frequency can be estimated. Flooding on tributaries as shown on plate 1 and figure 11 was due only to backwater from the Delaware River. Floods primarily on the tributaries would have a different frequency and profile.

The profile for the hypothetical August 19, 1955, flood modified by existing and planned flood-control projects approximates the profile of the flood of May 24, 1942, for most of the reach (fig. 2). The areal extent of inundation for this modified August 19, 1955, flood is nearly equivalent to the areal extent of inundation of the flood of May 24, 1942 as delineated on plate 1.

Depth of Flooding

The more significant difference between a large and a small flood in the study reach is depth of flooding. The depth of flooding is heightened by the confining effect of the valley walls.

Twelve cross sections (figs. 12-17) illustrate graphically the depth of flooding at the sites on the Delaware River and the Pequest River for the floods of August 19, 1955, October 10, 1903, March 19, 1936, and May 24, 1942. Low-water level of November 17, 1964 is given for comparison. The data for all cross sections, with the exception of the Pequest River cross section, were furnished by the Corps of Engineers, and are based upon field surveys of August 1964. Field data for the Pequest River cross section were obtained by the U.S. Geological Survey in the summer of 1965. Flood and low-water elevations used in figures 12-17 were determined from figure 2. All cross sections are viewed looking downstream.

The depth of flooding can be estimated by subtracting the ground elevation from the water-surface elevation, obtained from the profile (fig. 2) for the appropriate river mileage. Ground elevations can be estimated from a topographic map, or preferably, by ground surveys. By use of frequency and profile relations, presented in detail below, the depth of flooding at any site along the reach of the Delaware River considered in the report, can be estimated.

USE OF FREQUENCY AND PROFILE RELATIONS

Frequency and profile relations can be used to: (1) estimate the frequency of the lowest flood that would inundate a specific site; (2) estimate the depth of flooding at a specific site by a flood of a given frequency; (3) delineate areas subject to a specific frequency of flooding. For all three procedures, as well as to estimate the frequency of any flood, an understanding of frequency and profile relations is required.

The frequency of a flood profile given on figure 2 can be determined from the regionalized frequency curve (fig. 1) for the U.S. Geological Survey gaging station. The frequency determined at the gaging site for a particular flood is approximately the same along the flood profile for the entire reach covered by this report. Frequency estimates for the flood profiles in figure 2 are given on page 6. The frequency of the profile of any flood, hypothetical or real, which plots between any two flood profiles in figure 2 is similarly estimated by applying the corresponding flood elevation at the Belvidere gage to figure 1. The profile of this flood may be assumed to have the same proportional position between two given profiles in figure 2 as it would have at the Belvidere gage. Specific examples of the use of the frequency and profile relations are given in the following paragraph.

To estimate the frequency of the lowest flood that would inundate a specific site, it is first necessary to determine the ground elevation and river stationing for the site. Ground elevation can be approximated from a topographic map (pl. 1) or, preferably, can be determined by levels from a bench mark. River stationing can be determined from plate 1. Figures 1 and 2 can then be used to estimate the frequency of the lowest flood that would inundate a specific site. To illustrate, consider a site at mile 201 with a ground elevation of 270 feet. On figure 2 we find that the elevation of 270 feet at mile 201 plots between the 1936 and 1903 profiles and that it is higher than the elevation for the 1936 flood by one third of the distance between the two profiles. The flood elevation at the Belvidere gage corresponding to the 270-foot elevation at mile 201 is then estimated as 252.6 feet. The recurrence interval, from figure 1, is estimated as 40 years.

To estimate the depth of flooding at a specific site by a flood of a given frequency, ground elevation and river stationing must be known. Ground elevations and river stationing at the site can be determined by methods suggested above. The elevation of the flood of the selected frequency is obtained from figures 1 and 2, similar to the method explained above, for the site indicated by the stationing. Depth of flooding is determined by subtracting the ground elevation from the flood elevation. To illustrate consider the following example. Information on depth of flooding at a site with an elevation of 262 feet at mile 201.0 is desired for a flood with a recurrence interval of 15 years. The elevation of a flood at the Belvidere gage with a 15-year frequency is determined from figure 1 as 250 feet. Then, by proportional methods described previously, the elevation for the 15-year flood for a site at mile 201.0, is about 267 feet above mean sea level. The depth of flooding is obtained by subtracting the ground elevation (262 feet) from the flood elevation (267 feet). The depth of flooding is approximately 5 feet. Conversely, the frequency of a flood of a given depth at a specific site can be estimated. The ground elevation is added to the given depth of flooding to obtain the elevation of the flood at the site. Figures 1 and 2 can then be used to estimate frequency. Consider the same site at mile 201.0 with a ground elevation of 263 feet above mean sea level. Add the ground elevation to the depth of flooding being considered to obtain the flood elevation. If the depth of flooding being considered is 8 feet, the flood elevation would therefore be 271 feet above mean sea level. By use of similar proportions between two profiles in figure 2 and in conjunction with figure 1, the frequency of recurrence of a site at an elevation of 271 feet at mile 201.0 is approximately 70 years.

Areas subject to a specific frequency of flooding can be delineated by the following procedure. Draw the profile of the selected frequency proportionally spaced between two profiles given in figure 2, by means explained above. The extent of flooding for the selected frequency can be delineated on the ground or on plate 1 by using elevations of the drawn profile in conjunction with appropriate river stationing.

LIMITATIONS

Procedures recommended in the report should be used with full knowledge of limitations involved. It is essential to evaluate correctly the results in the report.

It is emphasized that the term "recurrence interval" does not imply that floods will occur on a regular schedule. A flood having a recurrence interval of 25 years indicate only the probability that a flood of that magnitude will be equaled or exceeded on the average of 4 times in 100 years.

The flood-frequency curve (fig. 1) is based on a regionalized relation defined by Tice (1958) from procedures outlined by Dalrymple (1960). Hydrologic conditions are not constant. Therefore, any changes in the stream that would upset the present hydrologic conditions may have an effect on the flood-frequency relation. Changes such as stream dredging, straightening, filling and building of flood walls would alter the stage-discharge relation and thus alter the stage-frequency relation. Likewise completion of upstream reservoirs would reduce the peak flood discharge for a given storm. A flood similar in size to the flood of August 19, 1955, would be modified by existing and the completion of planned flood-control works. Figure 2 illustrates this modification based on latest designs as computed by the Corps of Engineers for the projects. The use of past flood data to estimate magnitude and frequency of future floods must take into account channel changes and effects of completed flood control works.

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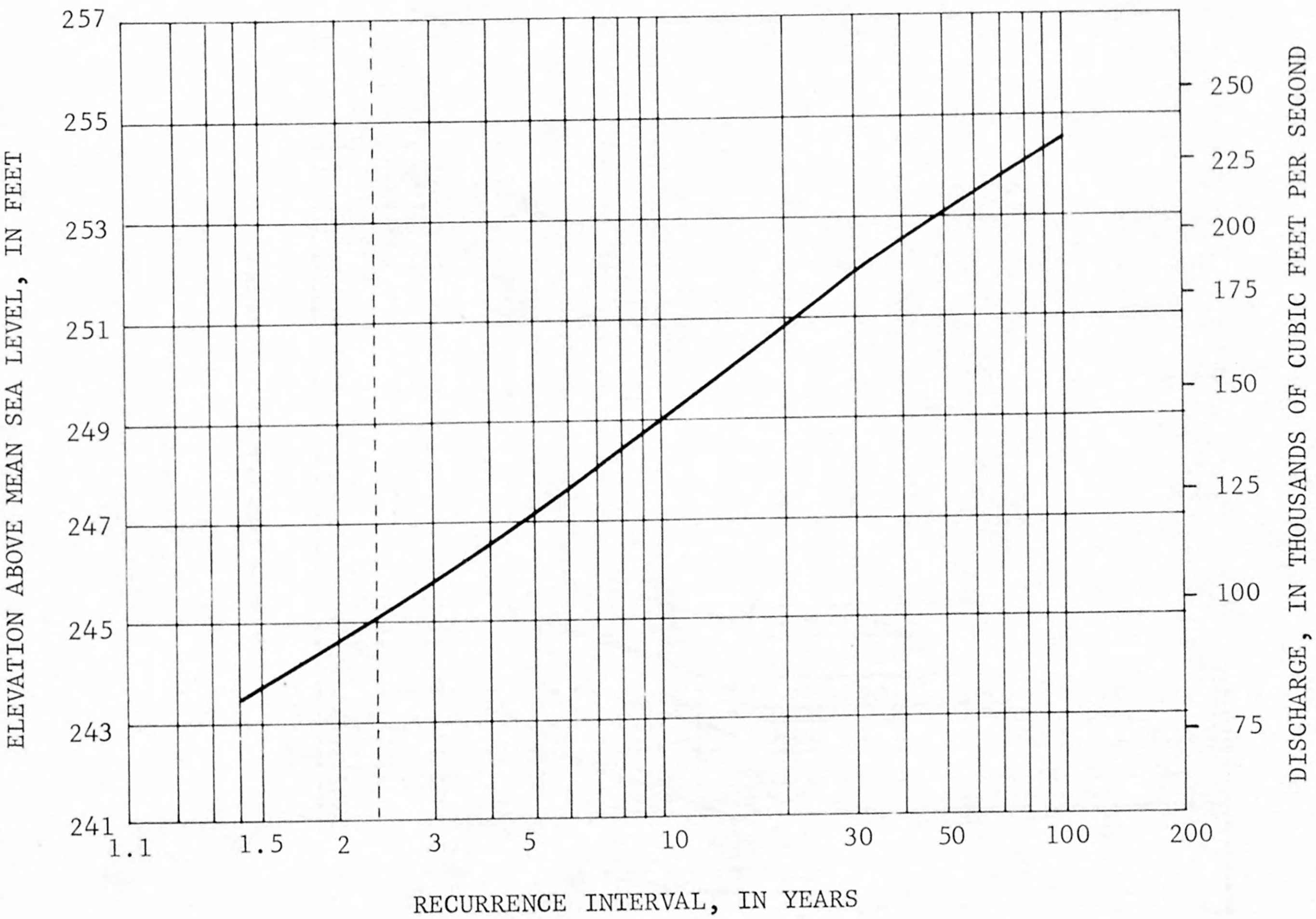

Figure 1.--Frequency of floods on Delaware River at Belvidere, N.J.

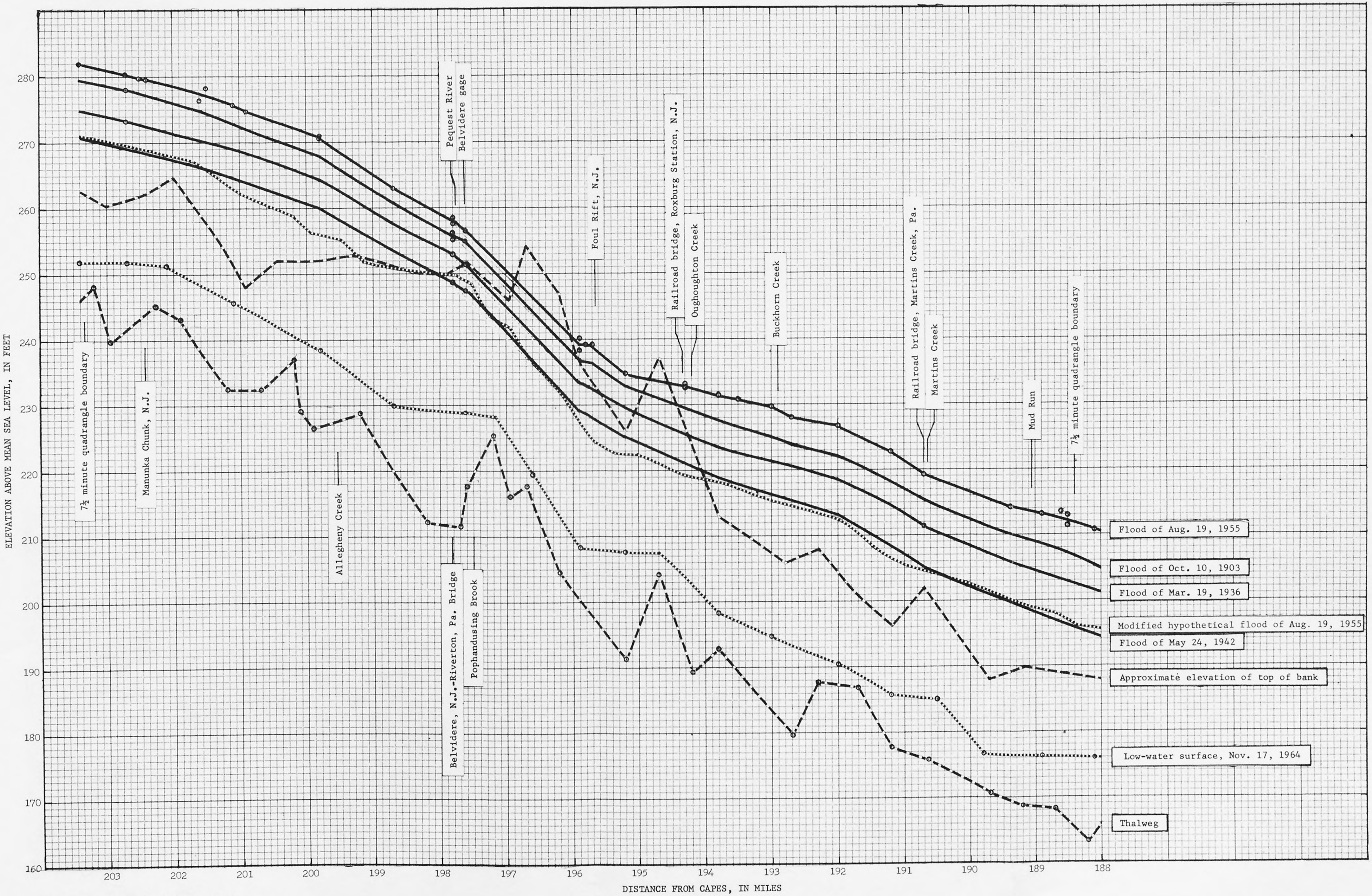

Figure 2.-- Profiles of Delaware River.

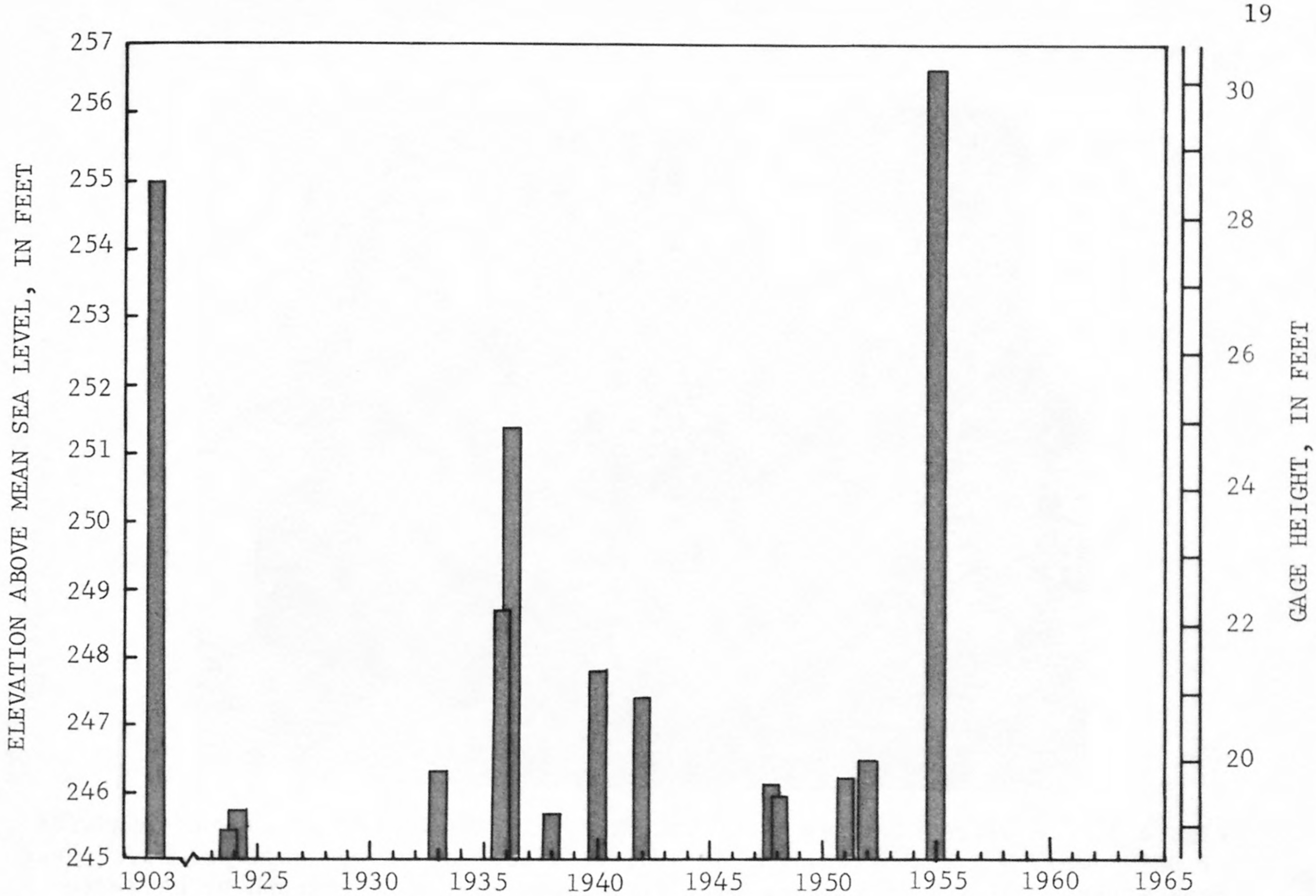

Figure 3.--Floods above 245.0-foot elevation, Delaware River at Belvidere, N.J., 1903, 1923-1965.

Figure 4.--Delaware River at Riverton, Pa., August 19, 1955. Road leading to Belvidere, N.J.-Riverton, Pa. bridge inundated. View looking west. Photograph by Easton Express.

Figure 5.--Delaware River at Belvidere, N.J., August 19, 1955. Downstream side of Belvidere, N.J.-Riverton, Pa. bridge, view looking west. Delaware River near peak stage. Water flowing over part of bridge steel. Photograph by Delaware River Joint Toll Bridge Commission.

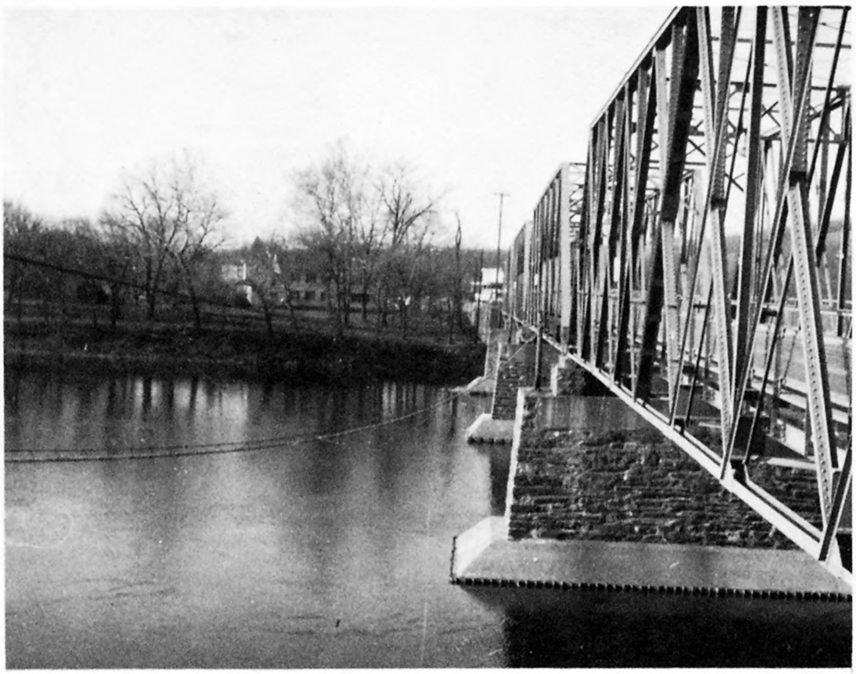

Figure 6.--Delaware River at Belvidere, N.J., November 1965. Downstream side of Belvidere, N.J.-Riverton, Pa. bridge, view looking west. Delaware River at low stage.

Figure 7.--Delaware River near Manunka Chunk, N.J., August 19, 1955. U.S. Route 46 (at mile 201.5) inundated at site of Ivan Sanderson's Jungle Zoo. Photograph by Easton Express.

Figure 8.--Pequest River at Belvidere, N.J., August 19, 1955. Intersection of Market and Water Streets inundated. Photograph by Easton Express.

Figure 9.--Pequest River at Belvidere, N.J., October 10, 1903. Water Street looking west. Elevated railroad bridge over Water Street in background. Photograph by Harry W. Gross.

Figure 10.--Pequest River at Belvidere, N.J., August 19, 1955. View of Water Street looking west 52 years later. Elevated railroad bridge over Water Street in background. Photograph by Harry W. Gross.

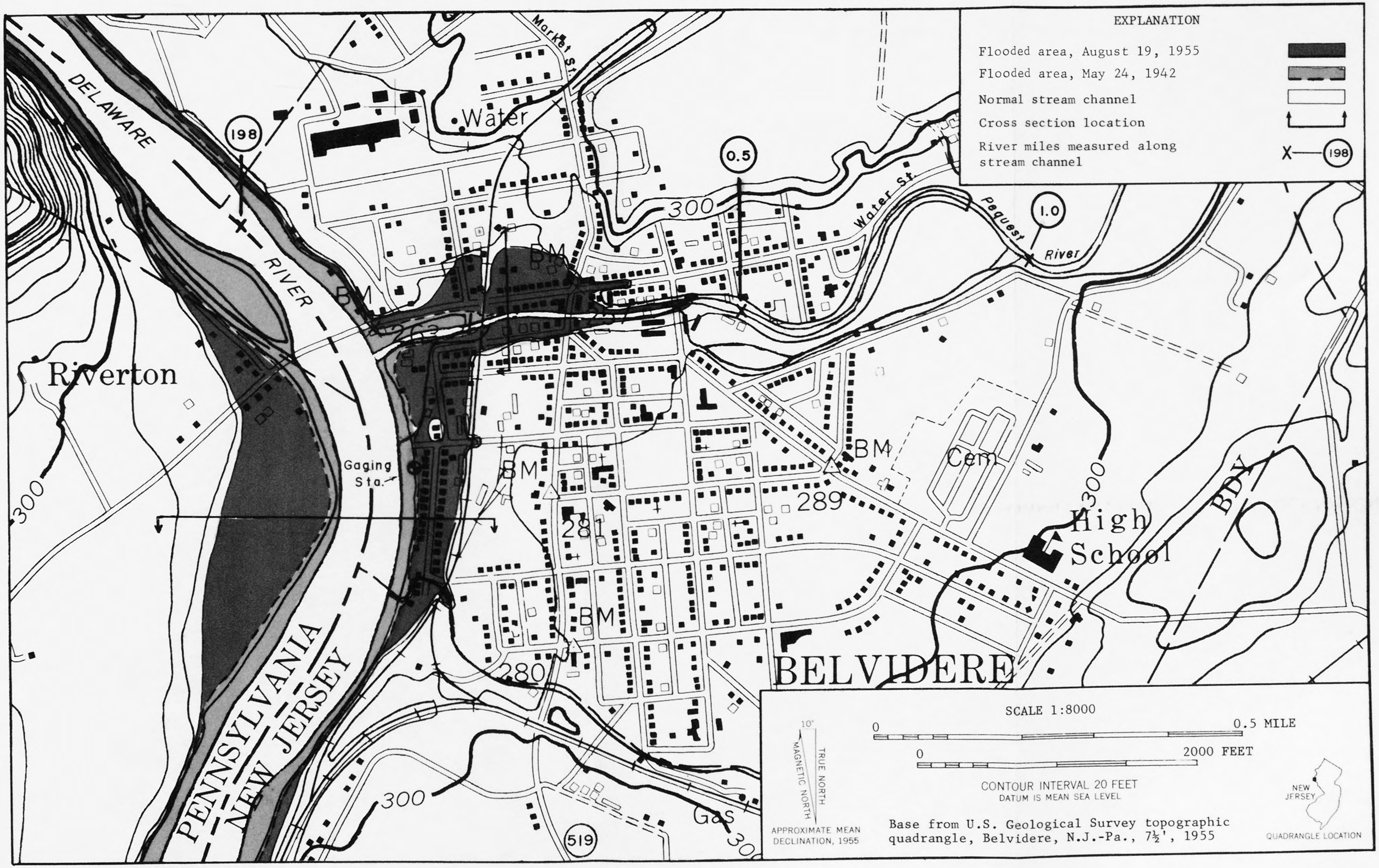

Figure 11.--Map of inundation at Belvidere, N.J. by Delaware River.

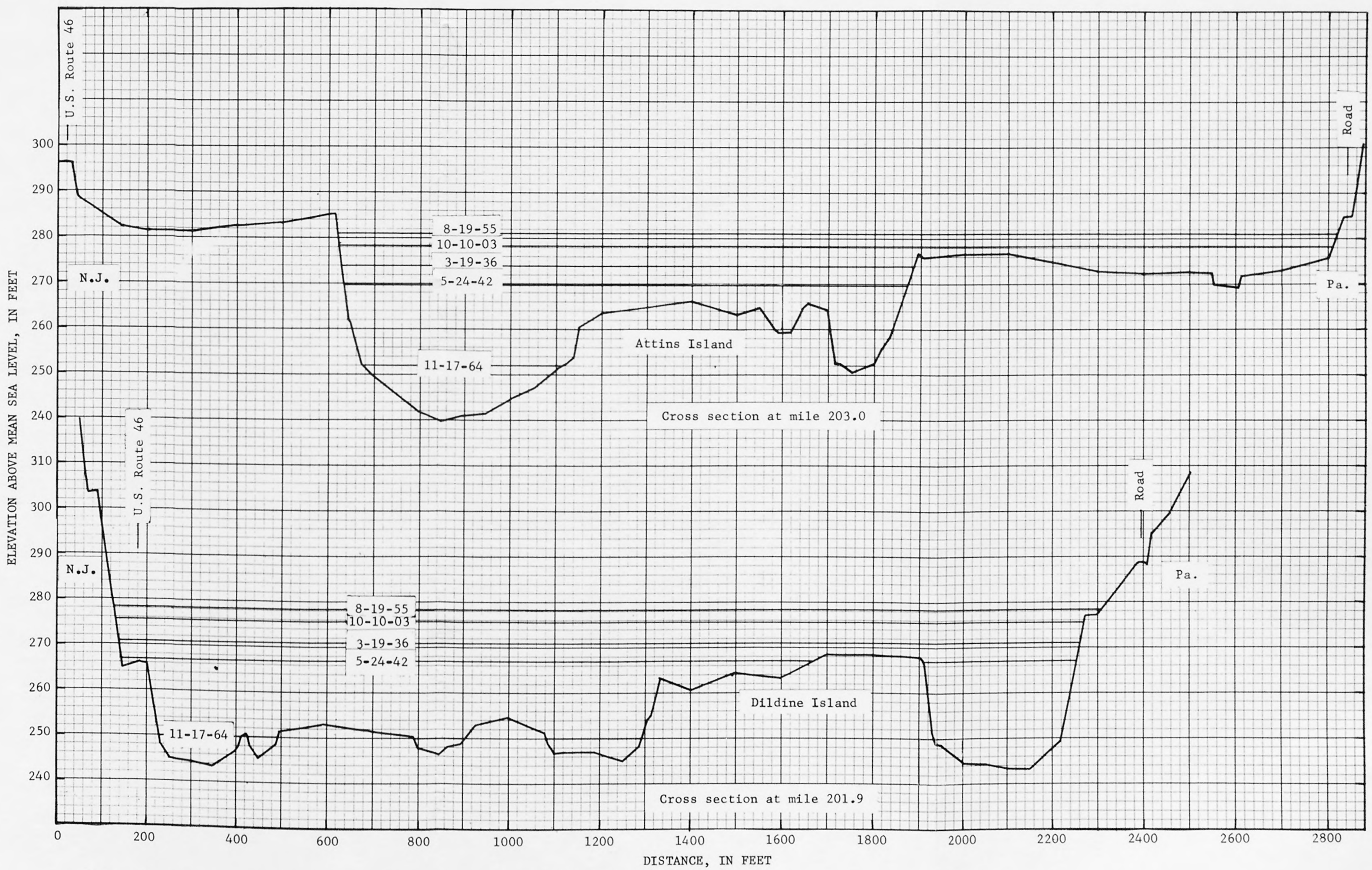

Figure 12.--Cross sections of Delaware River at miles 203.0 and 201.9.

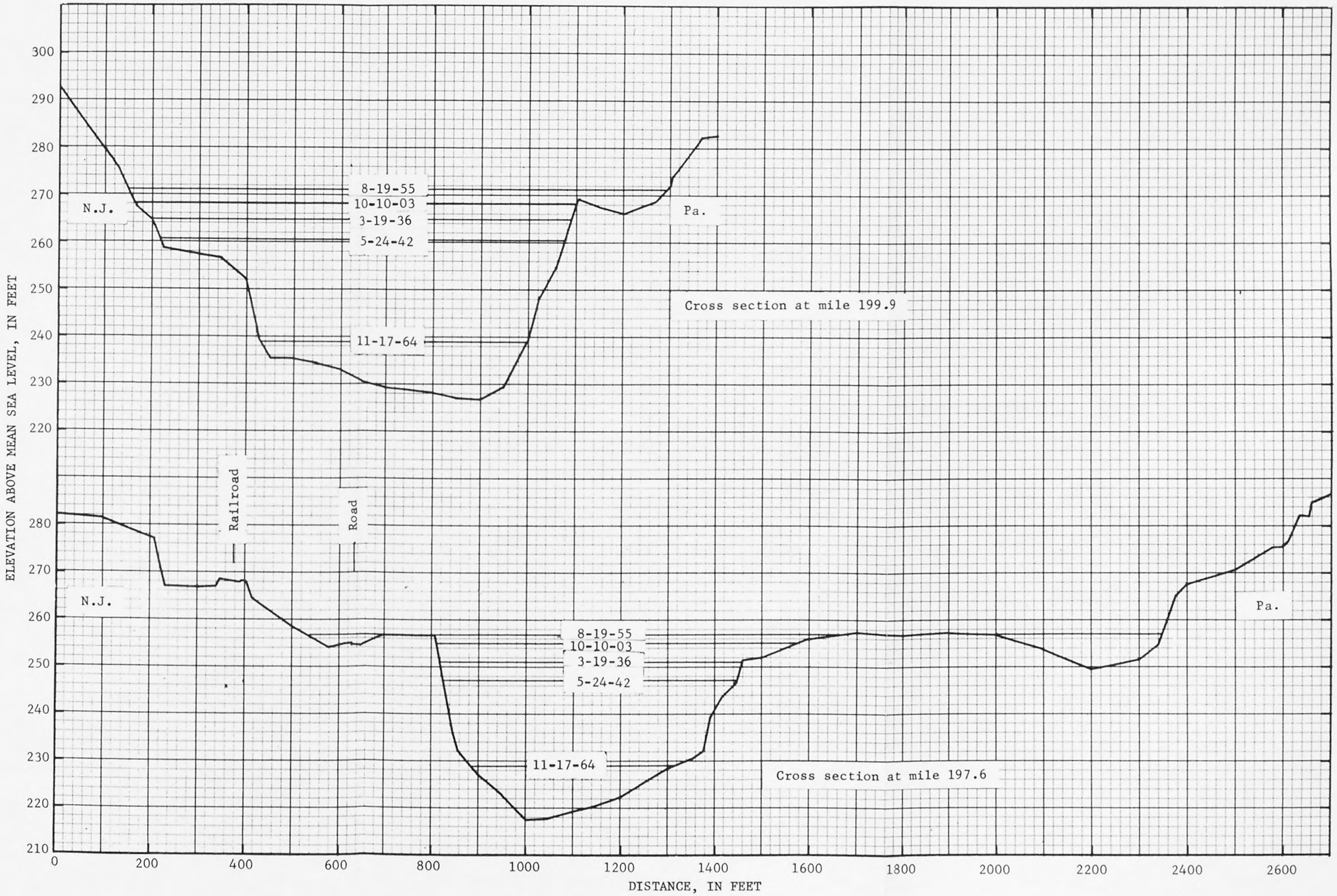

Figure 13.--Cross sections of Delaware River at miles 199.9 and 197.6.

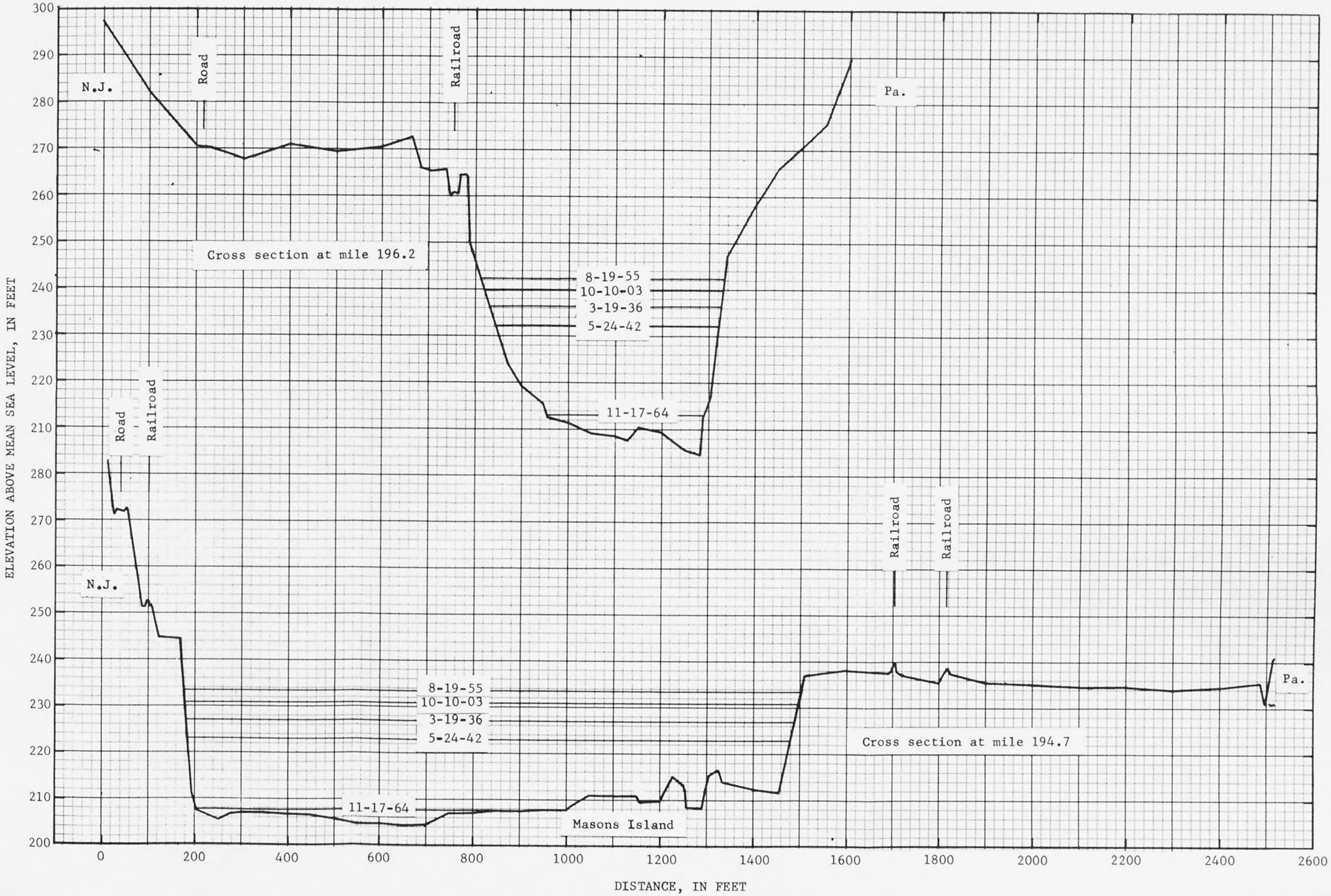

Figure 14 .--Cross sections of Delaware River at miles 196.2 and 194.7.

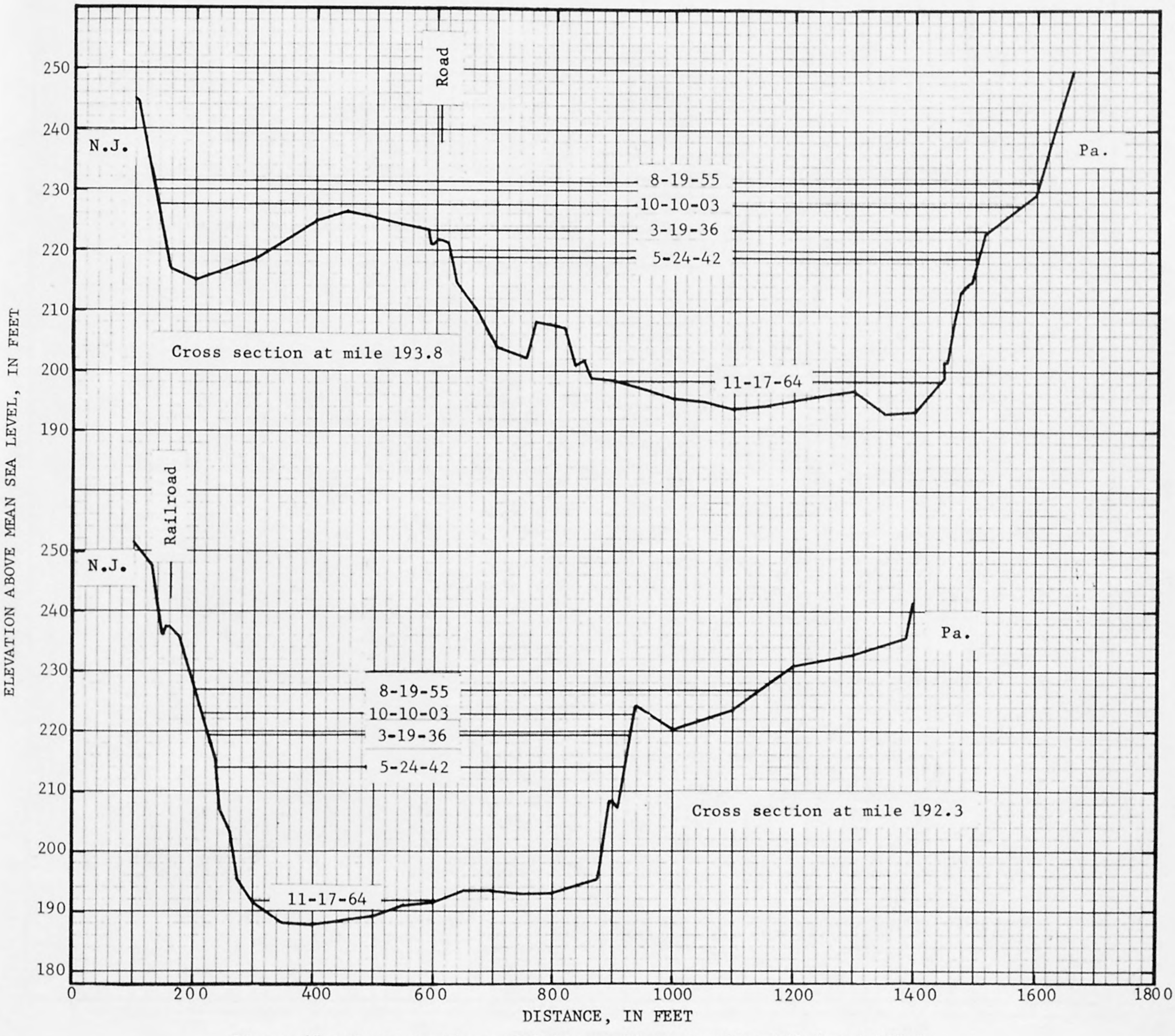

Figure 15.--Cross sections of Delaware River at miles 193.8 and 192.3.

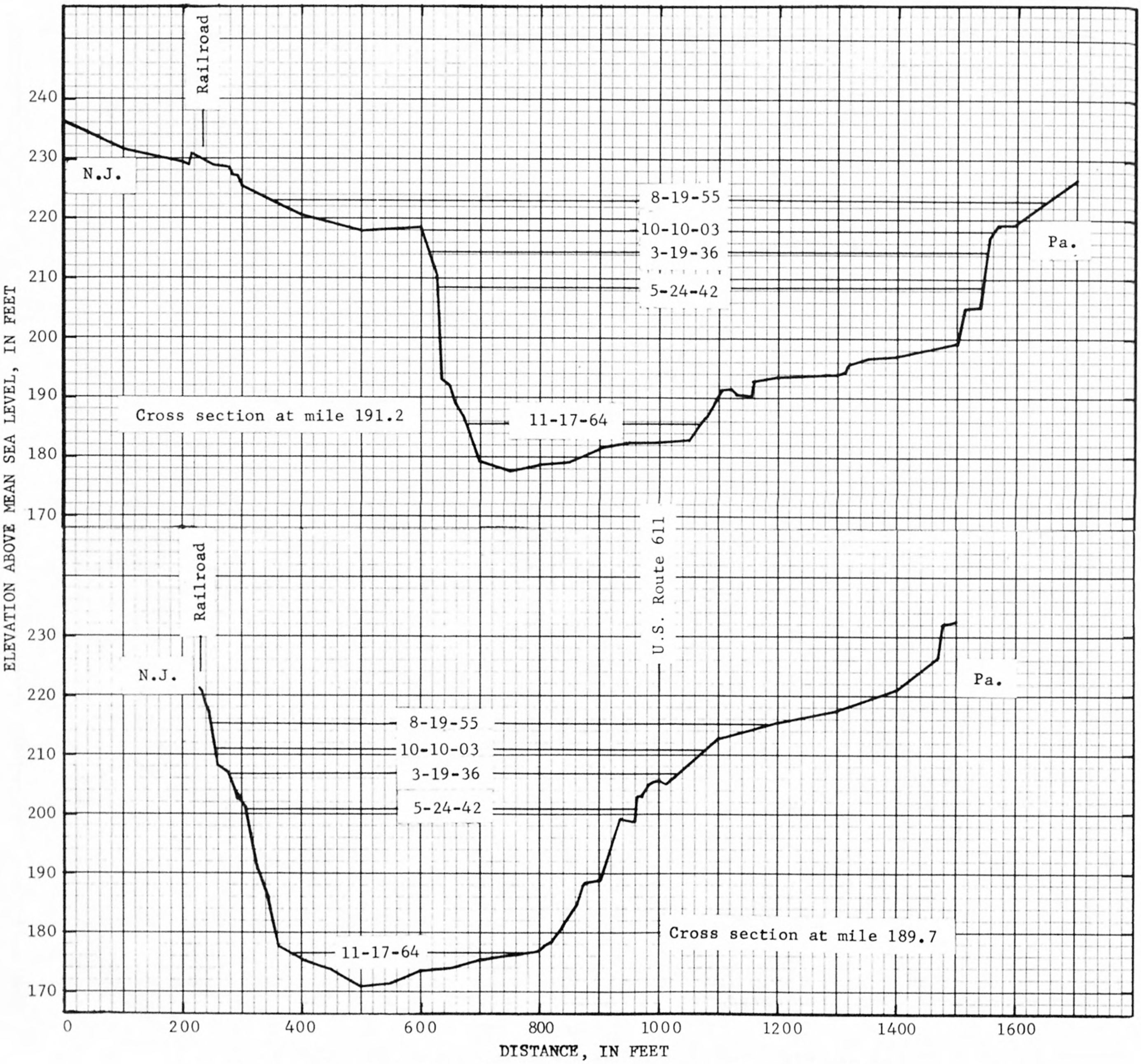

Figure 16.--Cross sections of Delaware River at miles 191.2 and 189.7.

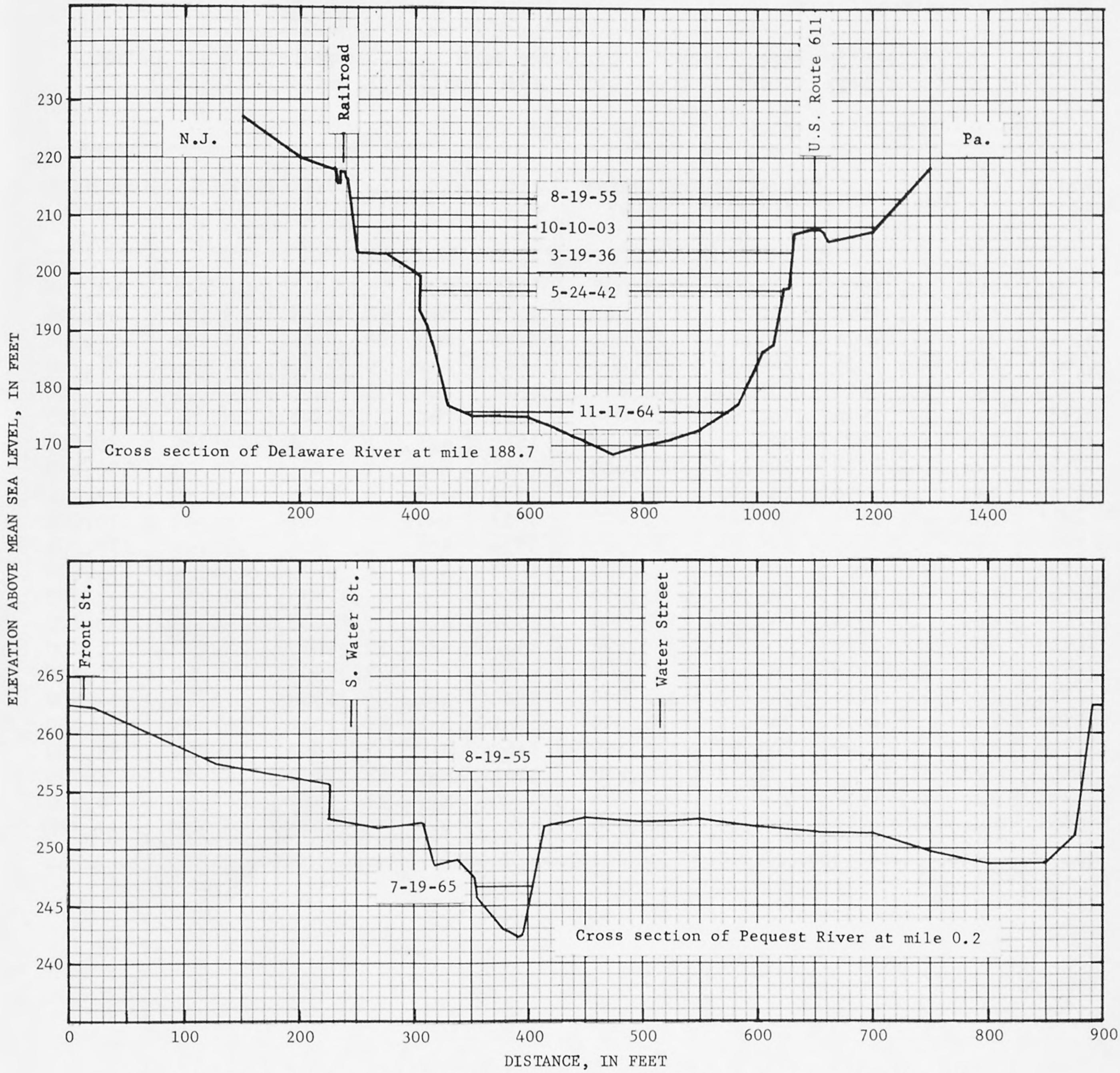

Figure 17.--Cross section of Delaware River at mile 188.7 and Pequest River at mile 0.2.

Table 1.--Maximum annual floods, Delaware River at Belvidere, N.J., 1904, 1923-64

[197.6 miles above Capes. Drainage area, 4,535 square miles. Datum of gage is 226.43 feet above mean sea level, datum of 1929.]

Water year	Date	Elevation (feet)	Discharge (cfs)	Water year	Date	Elevation (feet)	Discharge (cfs)
1904	Oct. 10, 1903	255.03	220,000	1944	Nov. 10, 1943	240.48	63,100
1923	Mar. 24, 1923	242.13	77,000	1945	Mar. 18, 1945	241.08	68,700
1924	Apr. 7, 1924	245.43	114,000	1946	May 29, 1946	241.05	68,500
1925	Oct. 1, 1924	245.73	118,000	1947	Apr. 6, 1947	243.36	91,200
1926	Apr. 10, 1926	238.45	43,800	1948	Mar. 23, 1948	246.11	119,800
1927	Nov. 17, 1926	244.93	108,000	1949	Dec. 31, 1948	245.91	117,700
1928	Oct. 20, 1927	243.23	84,400	1950	Apr. 5, 1950	241.86	76,300
1929	Mar. 15, 1929	242.33	79,000	1951	Mar. 31, 1951	246.18	120,600
1930	Mar. 9, 1930	237.73	38,400	1952	July 10, 1952	242.96	87,200
1931	Mar. 30, 1931	238.83	46,800	1953	Dec. 12, 1952	246.43	122,000
1932	Apr. 2, 1932	240.03	57,000	1954	Feb. 18, 1954	237.43	38,000
1933	Aug. 25, 1933	246.33	122,000	1955	Aug. 19, 1955	256.64	273,000
1934	Mar. 6, 1934	243.65	92,900	1956	Oct. 16, 1955	244.56	93,300
1935	Dec. 2, 1934	241.46	70,900	1957	Apr. 7, 1957	240.33	55,700
1936	Mar. 19, 1936	251.43	179,000	1958	Dec. 22, 1957	242.12	70,300
1937	Feb. 23, 1937	240.93	67,200	1959	Jan. 23, 1959	243.91	86,800
1938	Sept.22, 1938	245.70	116,000	1960	Apr. 5, 1960	243.99	87,600
1939	Dec. 7, 1938	242.31	81,000	1961	Feb. 26, 1961	242.83	76,600
1940	Apr. 1, 1940	247.83	138,300	1962	Apr. 2, 1962	240.64	58,200
1941	Dec. 31, 1940	239.08	50,900	1963	Mar. 28, 1963	242.51	73,700
1942	May 24, 1942	247.40	133,700	1964	Mar. 11, 1964	242.13	70,400
1943	Dec. 31, 1942	245.05	108,600	1965	Feb. 9, 1965	237.70	36,900

Table 2.--Flood-crest elevations in the Belvidere, N.J. vicinity

Delaware River						
Miles above Capes	Description	Flood elevations above mean sea level, in feet				Low water Nov. 17, 1964, in feet
		Oct. 10, 1903	Mar. 19, 1936	May 24, 1942	Aug. 19, 1955	
188.1	Harmony Station, N.J., on house of Mr. Earl S. Hayes, left bank..................				a210.6	176.1
188.5	Sandts Eddy, Pa. (near), 2.2 miles downstream from mouth of Martins Creek, right bank.............................				b211.4	
188.5	Sandts Eddy, Pa. (near), on house of Mrs. E. Ulmer, Route 611, right bank......				a212.9	
188.6	Sandts Eddy, Pa. (near), on Mineral Springs Hotel, Route 611, right bank.............				*a213.4	
188.9	Harmony Station, N.J., on storeroom bldg. of Mr. Edward Navone, left bank..........				213.0	176.2
189.4	Sandts Eddy, Pa., on Lehigh Portland Cement Co. bldg., Route 611, right bank...				a214.2	
189.8	Sandts Eddy, Pa. (near), right bank........					176.7
190.5	Martins Creek, Pa., right bank.............					185.0
190.7	Martins Creek, Pa., at Alpha Cement Co., downstream from Martins Creek, right bank....................................				c219.3	

Table 2.--Flood-crest elevations in the Belvidere, N.J. vicinity--Continued

Delaware River--Continued

Miles above Capes	Description	Flood elevations above mean sea level, in feet				Low water Nov. 17, 1964, in feet
		Oct. 10, 1903	Mar. 19, 1936	May 24, 1942	Aug. 19, 1955	
190.7	Martins Creek, Pa., railroad bridge, right bank		d211.3			
191.2	Martins Creek Station, N.J., on garage of Mr. John Moser, left bank				222.8	185.6
192.0	Martins Creek, Pa. (near), on scale house and gravel bin of W. J. Lowe & Sons Sand and Gravel Co., right bank				a226.7	190.3
192.7	Hillendale, Pa., approx. 2.0 miles above mouth of Martins Creek. Upstream jamb of 2-car brick garage, approx. 100 ft upstream from road to river, right bank				b228.0	
193.0	Hutchinson, N.J., 50 ft shoreward of Pennsylvania R.R. underpass, left bank				c229.5	194.7
193.5	Hutchinson, N.J., on house of Mr. Joseph Smith, left bank				a230.8	
193.8	Roxburg Station, N.J., approx. 0.7 mile upstream from Hutchinson, N.J. Front shoreside corner of garage, downstream and inshore from home of J. W. Smith, left bank				b231.3	198.2

Table 2.--Flood-crest elevations in the Belvidere, N.J. vicinity--Continued

Delaware River--Continued

Miles above Capes	Description	Flood elevations above mean sea level, in feet: Oct. 10, 1903	Mar. 19, 1936	May 24, 1942	Aug. 19, 1955	Low water Nov. 17, 1964, in feet
194.3	Riverton, Pa. (near), about 3.7 miles south of Riverton, Pa. Mark on chimney of 1-story white shingled house, right bank..				b232.6	
194.3	Martins Creek, Pa. (near), on shed of Mr. Norman Black, Depues Ferry Road, right bank..............................				*a233.1	
195.2	Riverton, Pa. (near), about 2.6 miles south of Riverton, Pa., on side of manhole, approx. 10 ft upstream of Security Office of Pennsylvania Power & Light Co., Martins Creek Station, right bank.........				ab234.9	a207.8
195.7	Foul Rift, N.J., on tree near house of Mr. Thomas Ballas, left bank.............				a239.3	
195.8	Foul Rift, N.J. (near), 2.2 miles below Belvidere, N.J. Mark on left side of back door, 5 houses downstream from Pennsylvania R.R. underpass, identified as "The Penthouse", left bank............				b239.3	
195.9	Foul Rift, N.J. (near), 2.1 miles below Belvidere, N.J. Back porch stream side, at top of door jamb on 1st house upstream from Pennsylvania R.R. underpass, left bank....................................				b238.4	

Table 2.--Flood-crest elevations in the Belvidere, N.J. vicinity--Continued

Delaware River--Continued

Miles above Capes	Description	Flood elevations above mean sea level, in feet				Low water Nov. 17, 1964, in feet
		Oct. 10, 1903	Mar. 19, 1936	May 24, 1942	Aug. 19, 1955	
195.9	Foul Rift, N.J. (near), on house of Mrs. Caroline Garner, left bank...............				a240.2	208.4
196.6	Belvidere, N.J. (near), left bank..........					219.4
197.6	Belvidere, N.J. USGS gage, 500 ft downstream from Pequest River, left bank.....	e255.0	251.4	247.4	256.6	229.0
197.8	Belvidere, N.J., disk set vertically in the northeast concrete wingwall of bridge, over Delaware River; it is set vertically and on the upriver side of wingwall, 32.7 ft north of centerline of road; 2.2 ft down from top of wall and 4.0 ft west of east end of wall, left bank.............				*f257.7	
197.8	Belvidere, N.J., highway bridge, left bank.	g256.2	dg253.0	g248.7	g253.0	
197.8	Belvidere, N.J., on upstream face of highway bridge, on left wingwall and 5.0 ft below top of wall and 5.0 ft inshore of angle in wall, left bank................	*b255.1			b258.5	
198.7	Riverton, Pa. (near), on house of Mr. Paul Healey, right bank......................				a263.0	229.5
199.8	Riverton, Pa. (near), on house of Mr. John Wilford, Old Hartzel Ferry Rd., right bank................................				a270.4	238.6

Table 2.-- Flood-crest elevations in the Belvidere, N.J. vicinity--Continued

Delaware River--Continued

Miles above Capes	Description	Flood elevations above mean sea level, in feet Oct. 10, 1903	Mar. 19, 1936	May 24, 1942	Aug. 19, 1955	Low water Nov. 17, 1964, in feet
199.8	Riverton, Pa. (near), about 1.8 miles above Riverton, Pa. On upstream front corner of cottage, downstream from main house, right bank...............................				b270.7	
200.9	Riverton, Pa. (near), about 2.8 miles above Riverton, Pa. Mark at bottom of metal fence post, approx. 200 ft rear of home owned by William Fisk, right bank........				b274.6	
201.1	Riverton, Pa. (near), on house of Mr. Warren Berger, right bank................				275.6	245.6
201.5	Riverton, Pa. (near), about 3.6 miles above Riverton, Pa. Mark on tree, 4 ft to right of bungalow, on upstream end. Opposite lower end Manunka Chunk Island, right bank...............................				b278.3	
201.6	Manunka Chunk, N.J. (near), south of Manunka Chunk, N.J. Mark on pole, south end of former wild animal zoo owned by Mr. Ivan Sanderson, left bank............				b276.4	
202.1	Manunka Chunk, N.J. (near), left bank......					251.1

Table 2.-- Flood-crest elevations in the Belvidere, N.J. vicinity--Continued

Delaware River--Continued

Miles above Capes	Description	Flood elevations above mean sea level, in feet Oct. 10, 1903	Mar. 19, 1936	May 24, 1942	Aug. 19, 1955	Low water Nov. 17, 1964, in feet
202.4	Manunka Chunk, N.J., on Ayers Garage and Service Station, Route 46, left bank.....				279.6	
202.7	Manunka Chunk, N.J. (near), on house of Mr. Albert Kitchen, Route 46, left bank. (Note HWM due to river overflowing left bank at mile 202.5).....................				279.7	
202.7	Manunka Chunk, N.J. (near), riverbank near house of Mr. Albert Kitchen, Route 46, left bank............................				a280.3	251.9
202.7	Riverton, Pa. (near), on storage house of Mr. Ralph Smith, right bank..............	a278.0	a273.3		280.4	
203.4	Manunka Chunk, N.J. (near), on barn of Mr. S. J. Stackhouse, Route 46, left bank....				282.0	252.0

Table 2.--Flood-crest elevations in the Belvidere, N.J. vicinity--Continued

Pequest River

Miles above mouth	Description	Flood elevations above mean sea level, in feet: Oct. 10, 1903	Mar. 19, 1936	May 24, 1942	Aug. 19, 1955	Low water July 19, 1965, in feet
0.2	Belvidere, N.J., on Gardner Lumber Co. bldg., 85 South Water Street, left bank..........				*a258.0	246.7
0.25	Belvidere, N.J., on L. E. Ritter Lumber Co., South Water and Greenwich Streets, left bank..................................				*a257.9	
0.3	Belvidere, N.J., on Widener Bros. Hardware Store, Water and Market Streets, right bank..................................				a258.2	

* Flood marker

Sources of data:

a Local resident or industrial firm

b Corps of Engineers

c Water-Supply Paper 1420

d Water-Supply Paper 799

e Mangan, J. W., 1942, Elevations of major floods along Pennsylvania rivers

f N.J. Geodetic Control Survey

g Delaware River Joint Toll Bridge Commission

Table 3.--Flood data for bridges across Delaware River in vicinity of Belvidere, N.J.

Miles above Capes	Bridge	Thalweg elevation, in feet	Floor elevation, in feet	Elevation of 1955 flood crest, in feet	Elevation of low steel, in feet	Depth of submergence of low steel by 1955 flood, in feet
190.70	Pennsylvania Railroad (Martins Creek, Pa.)....	175.3	225.0	219.3	214.7	4.6
194.36	Pennsylvania Railroad (Roxburg, N.J.).........	193.3	244.8	233.1	231.6	1.5
197.81	Belvidere, N.J.-Riverton, Pa.	211.6	260.7	258.5	256.7	1.8

Table 4.--Mean sea level reference points

Miles above Capes	Description	Elevation above mean sea level, in feet
	Delaware River	
188.7	Nail on top of stone retaining wall east side of Route 611, 150 ft ± south of Esso station, right bank..................	209.82
189.8	Bolt on top of headwall, west side of Route 611, between poles JP-LB186 and JP-LB185, right bank.....................	205.55
190.3	Crosscut on top of S.E. bolt in concrete base of railroad signal crossing sign on west side of Route 611. Track leading to Portland Cement Co., right bank.........	210.45
191.3	Spike in base of pole along Pennsylvania Railroad, left bank.....................	230.51
192.3	Nail in base of pole along Pennsylvania Railroad, left bank.....................	238.84
193.0	Bolt in west side of concrete railroad bridge over road at Hutchinson, N.J., left bank................................	239.74
193.8	Top of concrete guardpost west side of River Road, left bank....................	223.89
194.1	Bolt in west face of railroad bridge over road from Roxburg, N.J., left bank.......	248.91
194.7	USC&GS B M L 180, in Northampton County, Pa., about 3.2 miles southwest along highway from the intersection of Market and Water Streets at Belvidere, Warren County, N.J., at a concrete bridge, 2 ft northeast of the southwest end, in the southwest end of the concrete foundation of the bannister, 13.3 ft east of a pole, 12.1 ft northwest of the center line of the highway, and about 6 inches higher than the highway. A standard disk, stamped "L 180 1942", right bank.................	276.712

Table 4.--Mean sea level reference points--Continued

Miles above Capes	Description	Elevation above mean sea level, in feet
	Delaware River--Continued	
196.2	Top of railroad milepost 63-5, west side of Pennsylvania Railroad, left bank......	262.50
196.5	Nail in base of pole south of signal tower along Pennsylvania Railroad, left bank...	262.36
198.6	Bolt on top of concrete retaining wall 200 ft downstream from "Up Camp" Cottage, right bank..............................	253.79
199.8	Square mark on front right corner of concrete porch slab, Wilfords Residence, Old Hartzel Ferry Road, right bank.......	269.24
201.1	Spike in base of 12 inch walnut tree on curve of dirt road, right bank...........	267.89
202.4	N.J. Geodetic Control Survey mon. 5564, White Twp., Warren Co., N.J. A standard NJGCS disk set in concrete, flush with the ground on the east side of the highway leading from Bridgeville to Delaware. It is 1.75 miles north from the intersection of Route 46 and county road leading to Belvidere, and 267 ft north of the intersection of the Pennsylvania R.R. and Delaware Lackawanna & Western R.R. Said intersection lies 120 ft east of the center line of Route 46, left bank.......	285.837
203.0	Nail in base of pole KT 304 in open field, left bank..............................	285.27
	Pequest River	
*0.3	USC&GS B M E 23 RESET, at Belvidere, Warren County, N.J., at the intersection of Water and Market Streets, 40.3 ft east of the center line of Market Street, 24.3 ft south of the center line of Water Street, and surrounded by a sidewalk. A standard disk, stamped "E 23 1942 RESET 1946", and set in the top of a concrete post flush with the sidewalk, left bank............	257.011

* Miles above mouth.