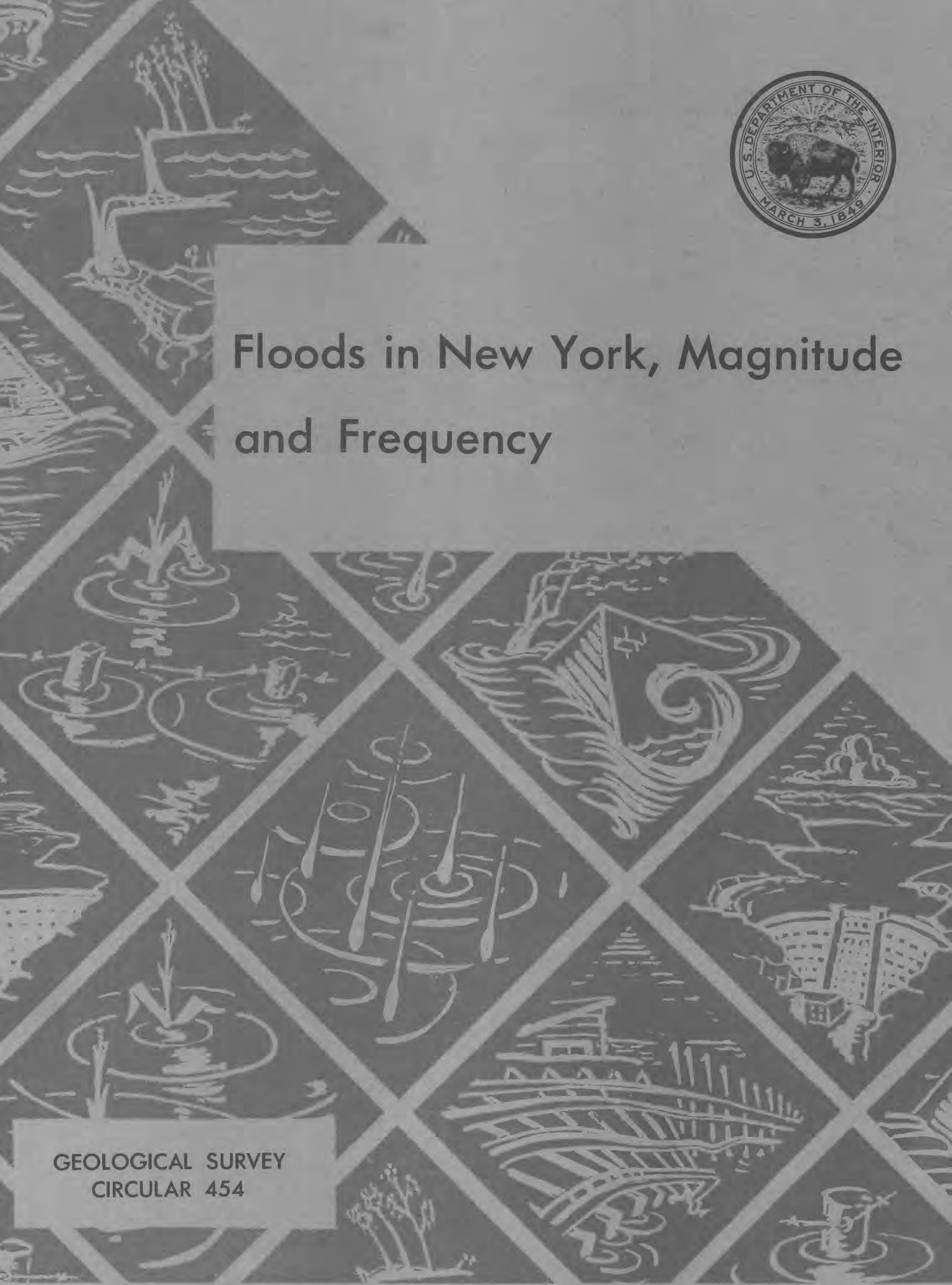

Floods in New York, Magnitude and Frequency

GEOLOGICAL SURVEY
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PREPARED IN COOPERATION WITH NEW YORK STATE

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By F. Luman Robison

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ABSTRACT

This report presents a practical means of predicting the probable magnitude of floods on streams in New York State. Because of the limited amount of data on small drainage basins this method is not applicable to sites where the drainage area is less than 10 square miles or to streams where flood peaks are affected materially by manmade regulation. Flood data based on records collected at gaging stations having 5 or more years of record not affected by unnatural regulation or diversion were used to define two types of curves. The first is a composite frequency curve. It expresses the relationship between the mean annual flood and floods of recurrence intervals ranging from 1.1 to 50 years. The second type defines the relation of the mean annual flood to the drainage area above the site. The result obtainable from the combination of the two curves is a flood-frequency curve for any site in the State, gaged or ungaged, within the range of drainage area and recurrence interval defined by the base data.

INTRODUCTION

In the design of dams, highways, bridges, or any other structures over or adjacent to a stream, consideration should be given to the probability of flood damage. The magnitude and frequency of floods at the site of the proposed structure become major factors in the design or in the flood protection that must be afforded. The method explained in this report will enable the designer to determine the probable magnitude and frequency of floods at most sites on streams in New York State.

Peak discharges at gaging stations used in the analysis are not listed in this report. Annual peaks can be found in the annual series of water-supply papers for Parts 1-B, 3-A, and 4 of the U. S. Geological Survey and in the 1960 publication of the Albany District of the Surface Water Branch of the U. S. Geological Survey titled "Maximum Known Discharges of New York Streams".

This report was prepared in the Albany Office of the U. S. Geological Survey under the direction of D. F. Dougherty, district engineer, Surface Water Branch, in cooperation with New York State Department of Public Works. Valuable assistance was given the author by K. I. Darmer, G. R. Ayer, and F. H. Ruggles of the Albany Office, and A. Rice Green of the Floods Section in Washington.

The streamflow records used were collected by the U. S. Geological Survey, the Corps of Engineers, and many other agencies who are given credit in the annual series of water-supply papers published by the U. S. Geological Survey.

DATA USED

Streamflow records for periods ranging from 5 to 46 years in length from 128 gaging stations, not materially affected by regulation or diversion, were used in this analysis, together with a limited amount of historical information. The records for Long Island could not be used because of rapidly changing and practically indeterminate drainage areas. Names of stations used are listed in table 1 and their locations are indicated on figure 1. The computed curves for the Delaware River basin shown in the open-file report "Delaware River Basin Flood Frequency" (Tice, 1958) were used for the streams in that basin in New York State. In addition, the completed reports of other neighboring States were examined to be sure that the New York curves were reasonably consistent with the curves for overlapping or contiguous basins.

TYPES OF FLOOD SERIES

Flood data for a gaging station may be analyzed in two ways: as an annual flood series or as a partial-duration series. The latter series is often termed "floods above a base". In the annual flood series the recurrence interval is the average interval of time within which a flood equal to or greater than a given magnitude will occur once as the maximum flood in the water year (October 1 to September 30). In the partial-duration series the recurrence interval is the average interval of time between floods of a given magnitude regardless of their relation to the year or any other period of time. For floods having recurrence intervals of 10 years or more both series give essentially the same results.

The following table by Langbein (1949) shows the comparative values of recurrence intervals for the two series and a means of transforming one to the other:

Recurrence intervals, in years

Annual flood series	Partial-duration series
1.16	0.5
1.58	1.0
2.00	1.45
2.54	2.0
5.52	5.0
10.5	10
20.5	20
50.5	50
100.5	100

The annual flood series has been used in this study because of its relative simplicity.

COMPUTATION OF FLOOD-FREQUENCY CURVES

A detailed step-by-step explanation of the method for computing individual station frequency curves is not included in this report. This information is available in flood-frequency reports previously published, some of which are listed in the bibliography.

Significant features of the method used by the Geological Survey for computing flood frequency are:

(1) Only the maximum momentary peak discharge for each water year (October 1 to September 30) is used.

Table 1. --Inventory of data used to define regional flood-frequency relations

No.	Gaging Station	Drainage area (sq mi)	Mean annual flood (cfs)
	PART 1-A		
2000	Tenmile River at Gaylordsville, Conn.	204	3,100
	PART 1-B		
3120	Hudson River near Newcomb	192	4,210
3135	Cedar River below Chain Lakes, near Indian Lake	160	3,870
3140	Hudson River at Gooley, near Indian Lake	419	9,300
3155	Hudson River at North Creek	792	14,500
3185	Hudson River at Hadley	1,664	21,400
3190	East Branch Sacandaga River at Griffin	114	5,100
3210	Sacandaga River near Hope	491	14,200
3280	Bond Creek at Dunham Basin	14.7	900
3295	Batten Kill at Battenville	394	6,700
3300	Glowegee Creek at West Milton	26.0	704
3305	Kayaderosseras Creek near West Milton	90	1,800
3335	Little Hoosic River at Petersburg	56.1	2,000
3345	Hoosic River near Eagle Bridge	510	10,800
3460	West Canada Creek at Kast Bridge	556	10,600
3480	East Canada Creek at East Creek	291	9,440
3490	Otsquago Creek at Fort Plain	59.2	6,280
3500	Schoharie Creek at Prattsville	236	16,000
3575	Mohawk River at Cohoes	3,456	58,200
3585	Poesten Kill near Troy	89	2,400
3610	Kinderhook Creek at Rossman	329	6,150
3615	Catskill Creek at Oak Hill	98	4,100
3625	Esopus Creek at Coldbrook	192	14,700
3650	Rondout Creek near Lowes Corners	38.5	2,880
3655	Chestnut Creek at Grahamsville	20.9	1,300
3665	Rondout Creek near Lackawack	100	5,700
3680	Wallkill River near Unionville	144	2,000
3685	Rutgers Creek at Gardnerville	59.7	2,300
3690	Pochuck Creek near Pine Island	98.0	1,130
3700	Wallkill River at Pellets Island Mountain	385	4,350
3715	Wallkill River at Gardiner	711	11,400
3725	Wappinger Creek near Wappingers Falls	182	2,600
3735	Fishkill Creek at Beacon	186	2,290
3765	Saw Mill River at Yonkers	25.6	435
4135	East Branch Delaware River at Margaretville	163	7,000
4140	Platte Kill at Dunraven	34.7	1,550
4145	Mill Brook at Arena	25.0	1,810
4150	Tremper Kill near Shavertown	33.0	1,600
4155	Terry Clove Kill near Pepacton	14.1	810
4165	Coles Clove Kill near Pepacton	28.0	1,500
4170	East Branch Delaware River at Downsville	371	12,700
4175	East Branch Delaware River at Harvard	443	17,000
4180	Beaver Kill near Turnwood	40.8	3,200
4185	Beaver Kill at Craigie Clair	82	5,000
4195	Willowemoc Creek near Livingston Manor	63	4,050
4200	Little Beaver Kill near Livingston Manor	19.8	1,430
4205	Beaver Kill at Cooks Falls	241	12,500
4210	East Branch Delaware River at Fishs Eddy	783	28,000
4220	West Branch Delaware River at Delhi	142	4,200
4225	Little Delaware River near Delhi	49.8	2,200
4245	Trout Creek at Cannonsville	49.5	2,400
4255	Cold Spring Brook at China	1.51	85
4260	Oquaga Creek at Deposit	66	2,540
4265	West Branch Delaware River at Hale Eddy	593	16,000
4275	Callicoon Creek at Callicoon	111	5,200
4280	Tenmile River at Tusten	45.0	1,300

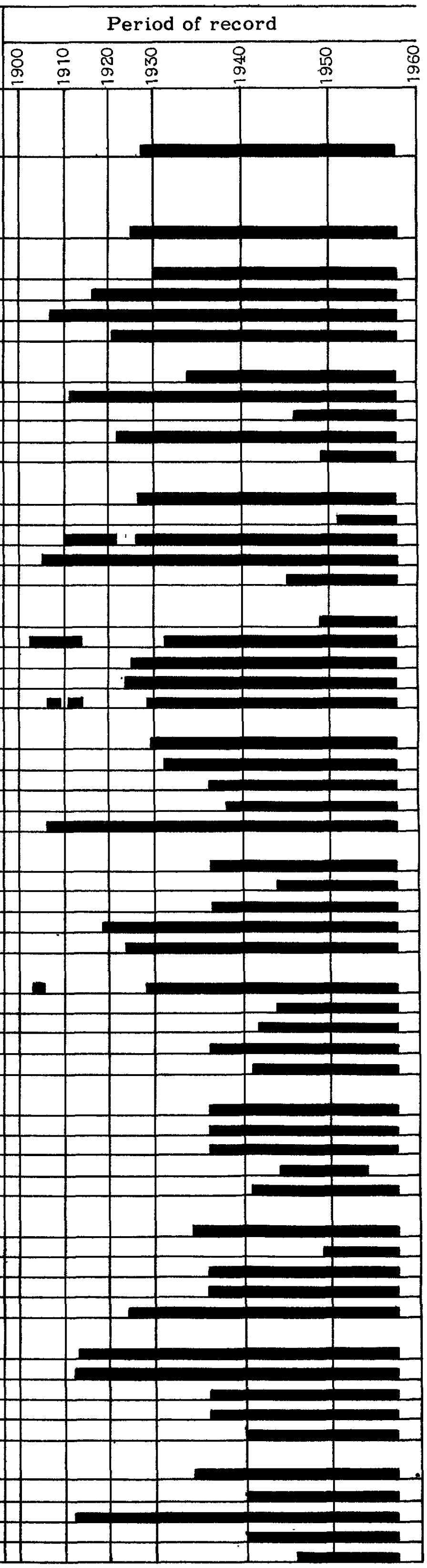


Table 1. --Inventory of data used to define regional flood-frequency relations--Continued

No.	Gaging Station	Drainage area (sq mi)	Mean annual flood (cfs)
	PART 1-B--Continued		
4285	Delaware River above Lackawaxen River near Barryville	2,023	60,000
4340	Delaware River at Port Jervis	3,076	78,000
4350	Neversink River near Claryville	65.6	6,200
4365	Neversink River at Woodbourne	113	7,000
4370	Neversink River at Oakland Valley	222	10,000
4375	Neversink River at Godeffroy	302	11,000
4965	Oaks Creek at Index	103	1,570
4975	Susquehanna River at Colliersville	351	4,800
4985	Charlotte Creek at West Davenport	167	4,400
4990	Otego Creek near Oneonta	108	2,990
5005	Susquehanna River at Unadilla	984	14,200
5010	Unadilla River near New Berlin	196	4,110
5020	Butternut Creek at Morris	59.6	1,830
5025	Unadilla River at Rockdale	518	9,400
5030	Susquehanna River at Conklin	2,240	34,700
5050	Chenango River at Sherburne	264	5,060
5055	Canasawacta Creek near South Plymouth	58.3	2,900
5070	Chenango River at Greene	598	9,400
5075	Genegantslet Creek at Smithville Flats	83.1	2,750
5090	Tioughnioga River at Cortland	296	6,800
5100	Otselic River at Cincinnatus	148	4,800
5105	Otselic River near Upper Lisle	216	6,500
5125	Chenango River near Chenango Forks	1,492	25,000
5135	Susquehanna River at Vestal	3,960	54,700
5140	Owego Creek near Owego	186	6,600
5150	Susquehanna River near Waverly	4,780	69,000
5205	Tioga River at Lindley	770	30,000
5225	Karr Valley Creek at Almond	27.6	3,480
5250	Bennett Creek at Canisteo	95.8	6,350
5260	Tuscarora Creek near South Addison	114	8,210
5265	Tioga River near Erwins	1,370	45,700
5270	Cohocton River at Cohocton	53.3	520
5275	Cohocton River at Avoca	157	3,050
5280	Fivemile Creek near Kanona	68.0	1,660
5295	Cohocton River near Campbell	472	9,700
5305	Newtown Creek at Elmira	79.8	2,500
5310	Chemung River at Chemung	2,530	54,000
	PART 3-A		
110	Great Valley Creek near Salamanca	142	6,100
115	Allegheny River at Red House	1,690	25,700
130	Conewango Creek at Waterboro	290	4,280
	PART 4		
2135	Cattaraugus Creek at Gowanda	428	18,000
2145	Buffalo Creek at Gardenville	145	8,200
2150	Cayuga Creek near Lancaster	93.3	5,590
2155	Cazenovia Creek at Ebenezer	136	7,700
2165	Little Tonawanda Creek at Linden	22.0	1,180
2170	Tonawanda Creek at Batavia	172	4,480
2215	Genesee River at Scio	309	8,000
2230	Genesee River at Portageville	982	23,800
2250	Canaseraga Creek near Dansville	153	4,540
2275	Genesee River at Jones Bridge, near Mt. Morris	1,419	23,500

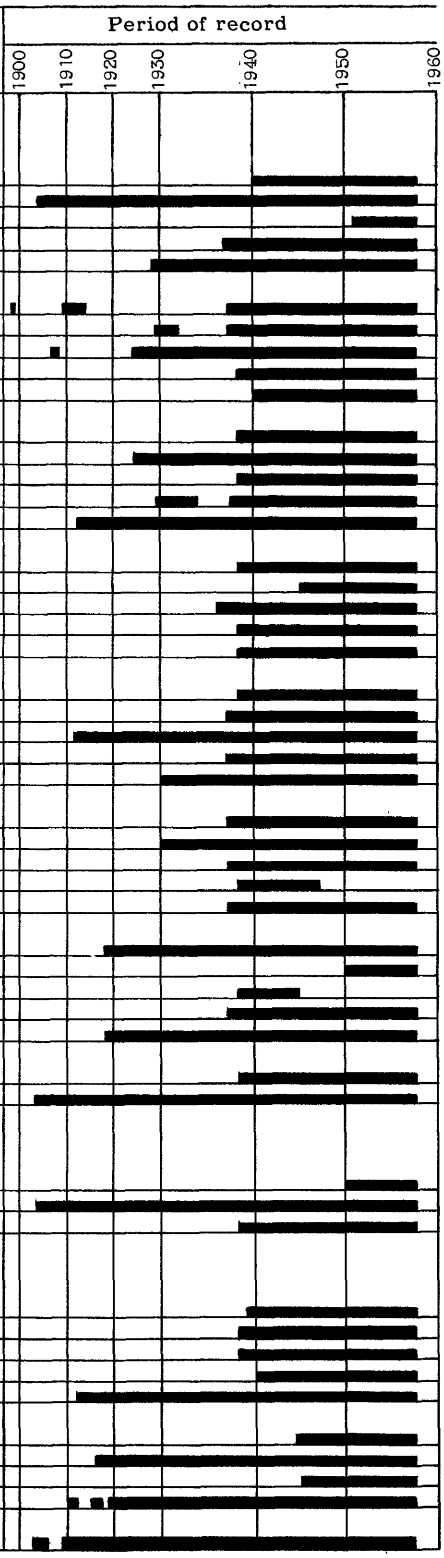
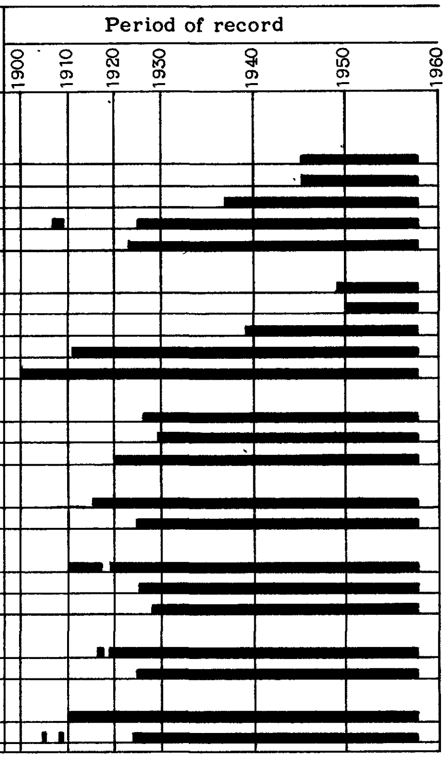


Table 1.--Inventory of data used to define regional flood-frequency relations--Continued

No.	Gaging Station	Drainage area (sq mi)	Mean annual flood (cfs)
	PART 4--Continued		
2305	Oatka Creek at Garbutt	208	3,100
2310	Black Creek at Churchville	123	1,790
2330	Cayuga Inlet near Ithaca	36.7	1,380
2340	Fall Creek near Ithaca	124	3,700
2425	East Branch Fish Creek at Taberg	189	7,500
2435	Oneida Creek at Oneida	112	4,650
2440	Chittenango Creek near Chittenango	67.7	2,190
2450	Limestone Creek at Fayetteville	85.7	3,240
2525	Black River near Boonville	295	5,810
2545	Moose River at McKeever (Moose River)	365	7,900
2560	Independence River at Donnattsburg	91.7	2,090
2587.5	Deer River at Deer River	98.1	4,380
2605	Black River at Watertown	1,876	23,000
2625	West Branch Oswegatchie River near Harrisville	258	4,100
2650	Grass River at Pyrites	335	4,840
2690	St. Regis River at Brasher Center	616	7,750
2700	Salmon River at Chasm Falls	132	1,770
2715	Great Chazy River at Perry Mills	247	3,360
2740	West Branch Ausable River (head of Ausable River) near Lake Placid	116	3,950
2750	East Branch Ausable River at Au Sable Forks	198	7,200
2755	Ausable River near Au Sable Forks	448	10,900
2765	Bouquet River at Willsboro	275	4,500



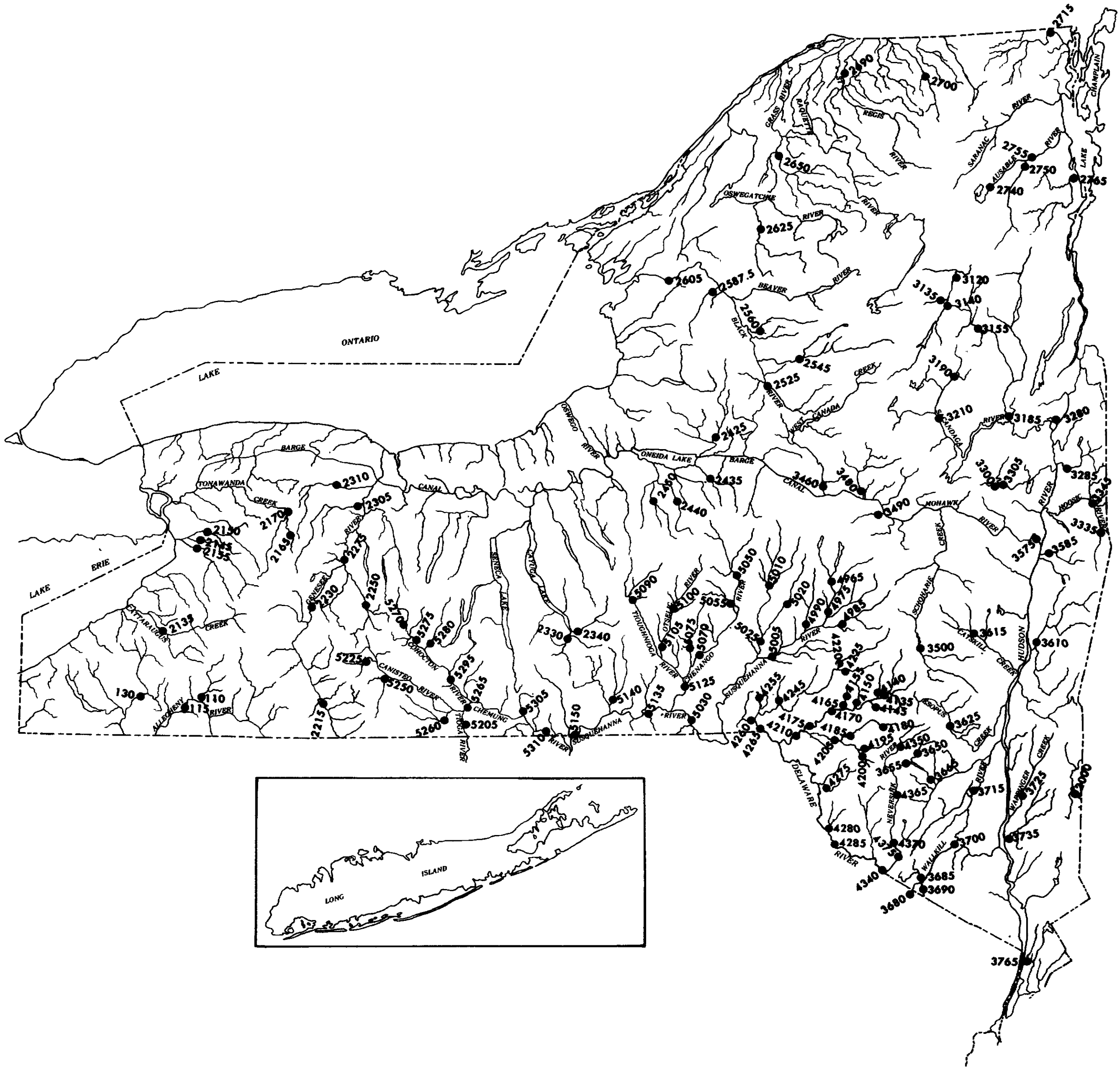


Figure 1.--Map of New York showing location of gaging stations used in the analysis.

(2) Recurrence intervals are computed by the formula T=(n+1)/m, where T is in years, n is number of years of record, and m is the order number of each flood, the greatest being numbered 1.

(3) Curves are fitted graphically.

(4) The mean annual flood is defined as the flood having a recurrence interval of 2.33 years.

Recurrence interval is the average interval of time within which a flood of given magnitude will be equaled or exceeded once. Thus, a 25-year flood will be equaled or exceeded on the average once in 25 years. Frequency of occurrence may also be expressed in terms of probability. For example, a 25-year flood can be considered as one that has a 4 percent chance of occurring in any one year.

Regional Flood-Frequency Curves

By combining the frequency curves for individual stations within a homogeneous region in the State, it was found that four different regional flood-frequency curves were applicable, in addition to those already computed by Tice (1958) for the Delaware River basin. The curves and regions in which each is applicable have been designated as A, B, C, D, E, F, and G (fig. 2). The curves represent the discharge as a ratio to the mean annual flood (fig. 3).

Region A. --Comprises most of the State, except the southeastern portion. From figure 1, it is evident that there are areas where records of sufficient length are not available. One such area borders on the southern and eastern shores of Lake Ontario. Since the topography and other characteristics of that area are similar to those in much of region A, curve A is used for the streams in that area. Two base periods, 1913-58 and 1939-58, were used in defining this region, and the frequency curve for the short period was adjusted to that for the long period.

Region B. --Includes the area west of the Hudson River, south of the Catskill Mountains and from the northern edge of the Catskills north to the foothills of the Adirondack mountains. On the east the northern portion of this region extends to the foothills of the Berkshire and Green mountains and north to the Poultney River and the Vermont State line. The southern part of this region consists principally of the Wallkill River basin. In this basin the storage effect of extensive flood plains reduces the mean annual floods, and the hurricanes and coastal storms cause a sharp rise at points on the curve above the 10-year frequency. The northern part lies in an area with moderate precipitation. It is also affected by hurricane and coastal storm activity but to a slightly lesser degree than in the regions farther south. The base periods used for this region are 1928-58 and 1939-58, and the frequency curve for the short period was adjusted to that for the long period.

Region C. --Consists of the area east of the Hudson River from about the Rensselaer-Columbia County line south to New York City. It also includes a small section west of the Hudson River, adjacent to New Jersey, drained by the Ramapo River. Snowfall is light so the mean annual floods are rather small. Hurricanes and coastal storms often bring heavy rains causing floods which have high ratios to the mean annual floods. This accounts for the sharp rise in the frequency curve above a 10-year recurrence interval. The base periods and adjustment used for this region are the same as for region B.

Region D. --Includes the streams west of the Hudson River, draining the northern and eastern slopes of the Catskill Mountains. Snowfall is heavy resulting in large mean annual floods. Hurricanes and coastal storms are responsible for many of the floods in this region. Also contributing to the flood magnitude is the orographic effect of the Catskill Mountain peaks, which causes the rainfall to be heavier on the eastern than on the western slopes. Curve D is also applicable to the Deer River and other streams draining the Tug Hill plateau, east of Lake Ontario. The periods and adjustment used for this region are the same as for regions B and C.

Region E. --The curve for region E applies only to the main stem of the Neversink River.

Region F. --The curve for region F applies to all the streams in the Delaware River basin in New York State, except the main stems of the Neversink and Delaware Rivers.

Region G. --The curve for region G applies to the main stem of the Delaware River.

Hydrologic Area Curves

The mean annual flood is influenced by many factors. Some of these are drainage area; shape of the basin and its alignment with the prevailing direction of storm travel; land and stream slopes; elevation; geology of the basin; flood water storage in stream channels, swamps and lakes; type of vegetal cover; and land use. On the basis of data presently available, this study indicated that drainage area is the only significant factor, therefore it is used to define the hydrologic area curves. By plotting the mean annual flood for all the stations used in the report against the respective drainage area, 10 hydrologic areas were defined. Curves numbered 1-11 (fig. 4) apply to areas as numbered on figure 5, except for the main stem of the Delaware River for which curve 11 applies.

An attempt was made to evaluate the effect of lakes and swamps on peak discharges, but on the basis of present records no significant effect could be defined. The damping effect of storage is no doubt reflected in the relatively low discharges from curve 7 of mean annual flood versus drainage area. Most of the unregulated Adirondack streams, although affected by considerable spring snowmelt, do not produce high mean annual floods, probably due to the effect of storage in lakes and swamps.

Slope of the stream was also investigated as a flood factor but considerably more data than now available would be necessary in order to define the effect. Where records have been obtained at a station in mountainous terrain and also at a station in the flat land of the same stream, the mean annual flood at the former station has a much higher ratio to drainage area than that at the latter.

THE DESIGN FLOOD

Before using the method described for determining the magnitude of the design flood it is necessary to decide on a recurrence interval. If the type of structure or its location are such that flooding would cause loss of life or great financial loss, then the design may be for a flood which will probably never be exceeded. However, for most structures the design will probably be for floods with a recurrence interval selected on the basis of economics. It is likely that most design floods will fall within the frequency range presented in this report.

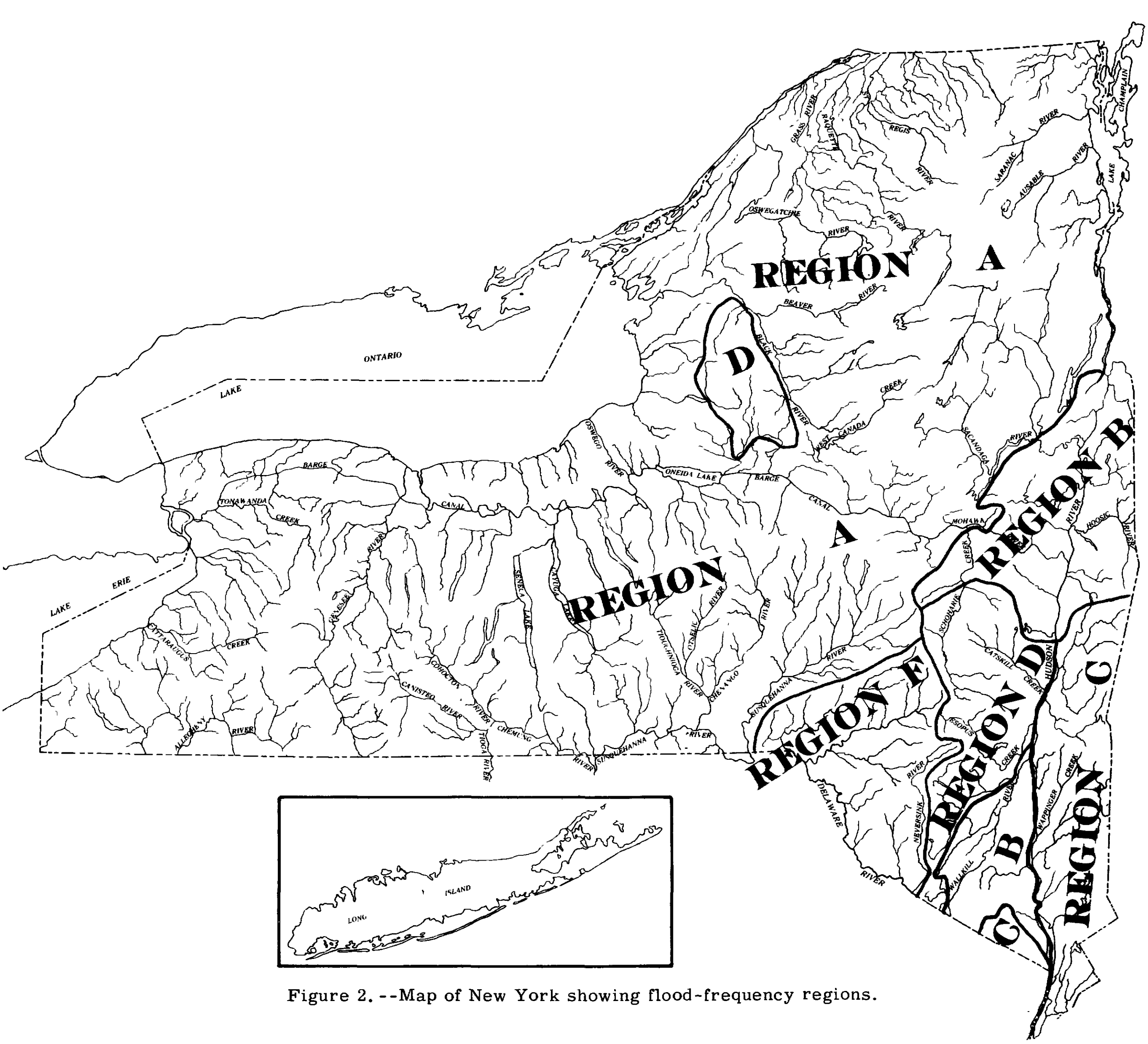


Figure 2. --Map of New York showing flood-frequency regions.

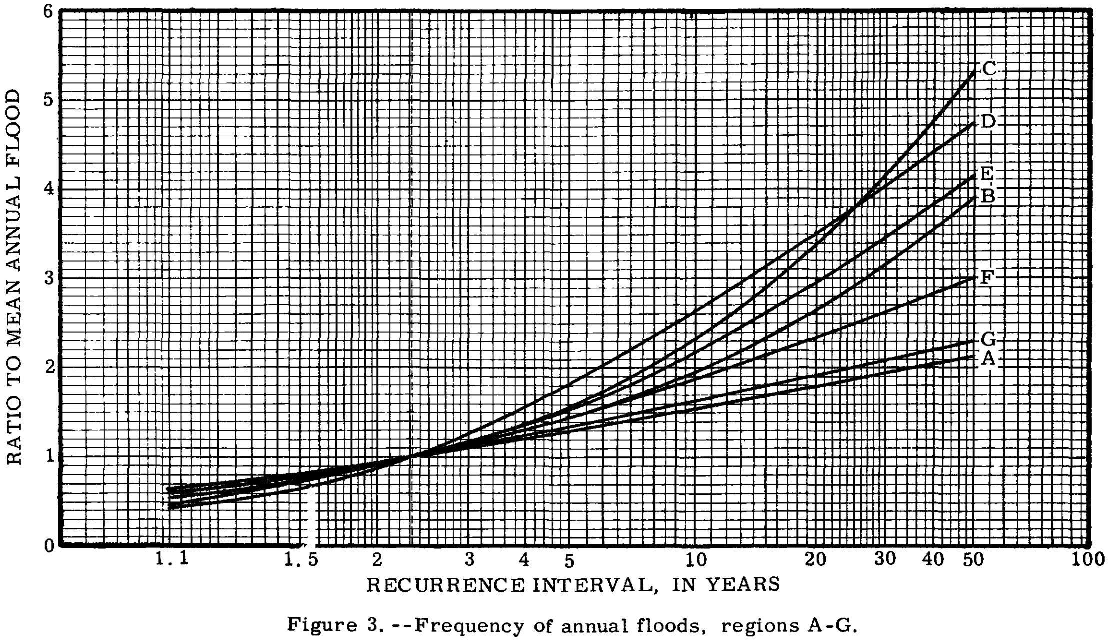


Figure 3. --Frequency of annual floods, regions A-G.

Determination of Design Flood

Once the recurrence interval of the design flood is selected, its magnitude may be determined by the following procedure:

1. Determine drainage area in square miles above the selected site.

2. From figure 5 determine the hydrologic area in which the site is located.

3. Determine the mean annual flood for the site from the appropriate curve in figure 4.

4. From figure 2 identify the flood-frequency region in which the site is located.

5. Determine ratio to mean annual flood for the selected recurrence interval from appropriate curve in figure 3.

6. Multiply the ratio to mean annual flood (step 5) by the mean annual flood (step 3) to obtain the design-flood magnitude.

A complete flood-frequency curve for a specific site in New York State may be obtained by repeating steps 5 and 6 for various recurrence intervals. The frequency curve obtained by this method is generally a better indication of the frequency of future floods at a site than a curve from streamflow records at the site alone.

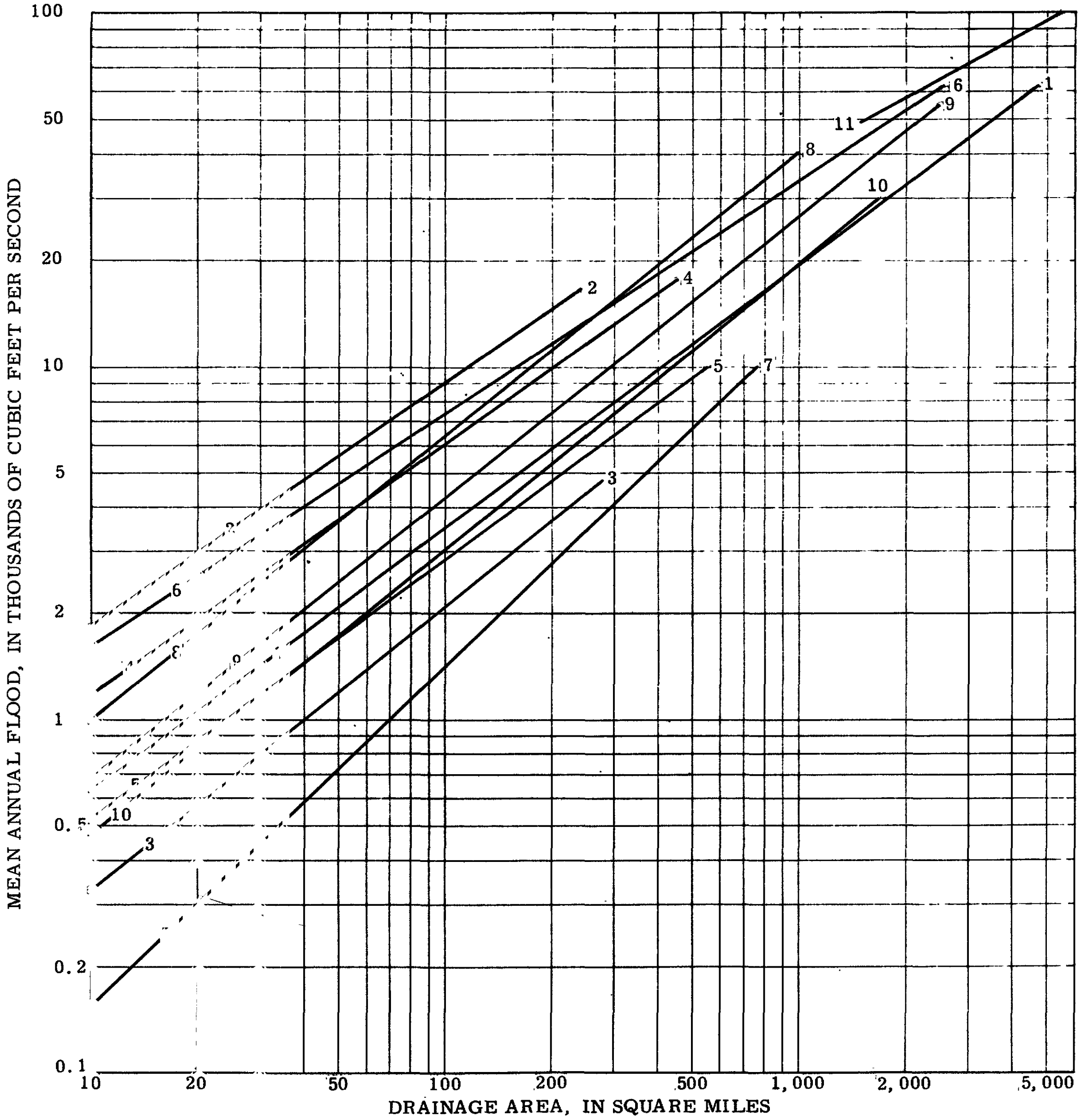


Figure 4. --Variation of mean annual flood with drainage area in hydrologic areas 1-11.

CONCLUSIONS

The accuracy of the information obtained from this report is a function of the data available. The curves presented are based on all known data existing through the 1958 water year. The frequency curves (recurrence interval-ratio to mean annual flood) cannot be extrapolated with confidence beyond 50 years. Neither should the drainage area-mean annual flood curves be extended in either direction beyond the limits shown. Lack of information on drainage areas of less than 10 square miles limits the accuracy of the lower ends of the mean annual flood curves.

On Long Island the physiography is being changed so rapidly by construction of new housing, and commercial and industrial developments, that it is practically impossible to compute even reasonably accurate drainage areas. Therefore, the curves here presented should not be used for Long Island streams. Also, extensive regulation prohibits the use of any of these curves on the Mohawk River below Delta Dam and on the Hudson River below Hadley.

Since this study was designed to produce a reasonable answer to frequency of floods in terms of the average occurrence of such events, it obviously cannot be used to predict the date of occurrence of any specific future flood. On the basis of present knowledge regarding the causes of floods, there seems to be no reason why several major floods could not occur in any given area within a single year or a short period of years. Conversely, many years may elapse without any major floods.

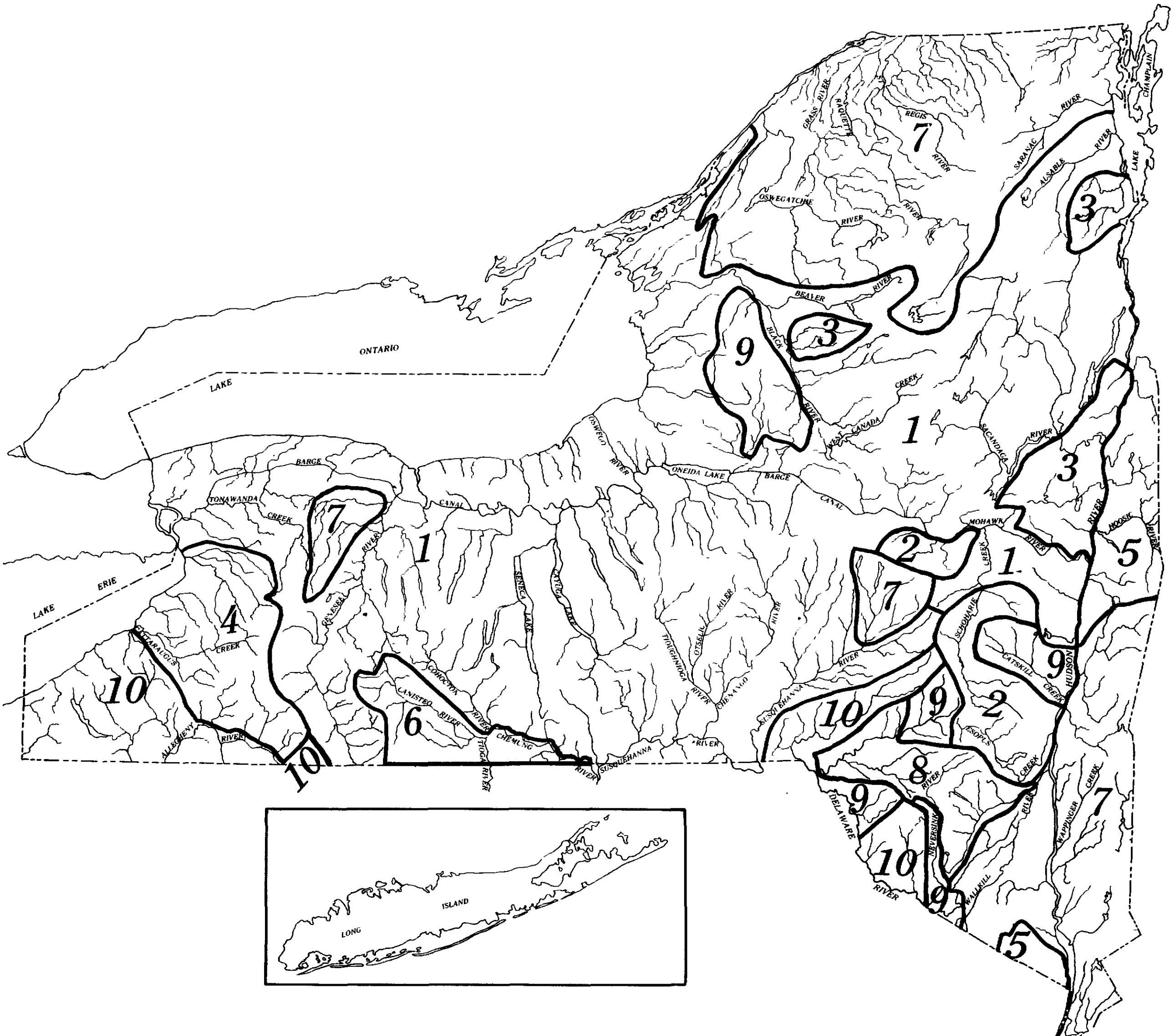


Figure 5.--Map of New York showing hydrologic areas.

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