CIVIL WORKS INVESTIGATIONS
PROJECT CW-151
FLOOD VOLUME STUDIES-WEST COAST

RESEARCH NOTE NO. 1

FREQUENCY OF NEW ENGLAND FLOODS

JULY 1958

U. S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
SACRAMENTO, CALIFORNIA

ART PABST

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1. Statement of Problem. During the last 40 years of runoff record on most of the New England streams, several large floods have occurred that are excessive in comparison with the lesser floods observed in the same period. Because of this, flood-frequency curves in the New England area exhibit a sharp upward curvature at the upper end in comparison to frequency curves derived for other areas in the United States. Although the great general storm of March 1936 resulted in the largest flood observed on major New England streams during the 300-year historical period, consideration of this fact does not fully explain the sharp upward curvature. On some of the smaller basins, for example, the hurricane flood of August 1955 (Hurricane Diane) resulted in flood magnitudes that were previously estimated to be in excess of 10,000-year values.

2. While it is indeed reasonable that in a country as large as the United States, floods in excess of the 100-year value would be expected to occur every year somewhere, and therefore, 1,000-year or even 10,000-year floods could be expected to occur somewhere during the historical records, procedures for computing the frequency of such rare floods are not reliable enough to identify them with assurance. Consequently, if a frequency study indicates the maximum flood of record to be in excess of the 1,000-year value, it is likely that the flood frequency estimate is erroneous. If such is the case, then an effort should be made to devise procedures to take into account factors which were possibly overlooked.

3. Several individuals have suggested that the principal reason for the upward curvature of frequency curves in New England is that hurricane and non-hurricane floods are combined into a single series. This suggestion is based on the reasoning that the normal run of floods resulting from one cause does not reflect flood potential from an independent cause. The Philadelphia District of the Corps of Engineers has examined this possibility in making a frequency study for the Delaware River Basin. The study, made under the direction of Russell Morgan and technical supervision of Marshall Iakisch, involved segregating hurricane and non-hurricane floods, and met with considerable success. It is the purpose of this New England study to formulate methods of segregating hurricane and non-hurricane floods and to construct separate frequency curves of each flood type, using analytical procedures currently employed in CWI studies. Flood frequencies computed in this manner will be compared to observed frequencies. It is not the intent of this study to reduce the indicated recurrence intervals of great floods in the New England region, but rather to determine whether there is a physical or logical explanation of the unusual results heretofore obtained and, in the light of the New England data, to re-examine the methods of analysis now in use.

4. Description of Study. For the purpose of this study, twelve long-record stream gaging stations widely distributed within the New England area were selected. Locations and pertinent data relative to these stations are shown on Chart 1. The period of record studied was limited to the last 40 years because data on hurricanes during the earlier years are unreliable. Maximum mean-daily flows at each of the stations were selected in five different ways as follows:

a. Maximum annual non-hurricane floods occurring between 15 October and 15 July.

b. Maximum annual floods occurring between 15 July and 15 October (hurricane season).

c. Maximum annual hurricane floods (alternative to b)

d. All known hurricane floods (alternative to b)

e. Maximum annual floods, regardless of type

5. Frequency curves for each of the five selected series of floods were plotted graphically for each station, and the computed best-fit log-normal curve was superimposed on the plotted data. The series listed in subparagraph b, c, and d above showed about the same degree of correlation between the plotted points and the computed curves. The series consisting of annual maximum hurricane events (series c) parallels series a and is based on a logical, rather than arbitrary, rule of selection. Therefore, this series and the series corresponding to subparagraphs a and e above were selected for presentation in this report. Since almost one-half of the years did not experience hurricane floods, the annual maximum hurricane series at each station consists of a lesser number of events than do the other series.

6. The list of hurricane floods used was compiled from various hurricane reports. The various reports available were not consistent, and it is felt that, particularly in the early years, some of the actual hurricane events have not been listed. Hurricane floods used in this study are as follows:

Hurricane Flood Dates by 10-year Periods

1916-25	1926-35	1936-45	1946-55
23 Jul 1916	5 Oct 1927	19 Sep 1936	30 Aug 1949
1 Oct 1920	11 Aug 1928	21 Sep 1938	20 Aug 1950
25 Oct 1923	3 Oct 1929	22 Aug 1939	12 Sep 1950
27 Aug 1924	17 Sep 1932	2 Oct 1939	2 Sep 1952
1 Oct 1924	24 Aug 1933	2 Sep 1940	15 Aug 1953
	18 Sep 1933	19 Sep 1940	8 Sep 1953
	20 Jun 1934	17 Oct 1943	31 Aug 1954
	9 Sep 1934	2 Aug 1944	12 Sep 1954
	5 Sep 1935	15 Sep 1944	16 Oct 1954
		22 Oct 1944	14 Aug 1955
		27 Jun 1945	18 Aug 1955
		19 Sep 1945	21 Sep 1955

7. Results of Study. The frequency curves of annual maximum floods (regardless of type), annual maximum non-hurricane floods, and annual maximum hurricane floods derived in this report are shown on Chart 2. It will be noted that, in the case of hurricane floods, the plotted data fit the computed log-normal curves reasonably well in most cases, but occasionally suggest an upward curvature of the frequency curve. The plotted data of the non-hurricane floods almost consistently show an upward curvature of the frequency data relative to the log-normal distribution. In order to summarize the data for all twelve stations in such a way as to demonstrate the average curvature, the floods at all stations that were in excess of the indicated 100-year value were counted. Similarly, the floods that were between the 50-year and 100-year indicated values were counted, and so forth until the entire range of frequency was covered. Comparison of these aggregate numbers with those indicated by the straight line frequency curve is shown on Chart 3.

8. It will be noted on Chart 3 that the hurricane-type floods evidence a slight upward curvature throughout the range of the frequency curve. The non-hurricane floods evidence a sharp upward curvature only in the upper range of floods. Since it was known that the largest non-hurricane general flood that has occurred in New England in the past 300 years is that 1936, it was felt that perhaps this one flood may have been unduly responsible for the upward curvature shown by the non-hurricane floods. In order to examine the effect of this one flood, the 1936 flood events were subtracted from the frequency count and the aggregate points replotted. This comparison, shown on Chart 3, is somewhat better, but there still is a tendency toward upward curvature.

9. Since the frequency curve of hurricane floods is based on fewer events than the years of record, plotting of the curve was based on the percentage of floods rather than on the percentage of years. In order to convert the frequency in percentage of floods to the frequency per hundred years, the indicated exceedence frequency must be multiplied by the ratio of the number of floods used to the number of years of record. This adjustment of the hurricane frequency curves is illustrated on Chart 2.

10. When floods are segregated according to cause or type, and where the separate frequency curves of annual maximum events are plotted as in this study, it is often desirable to obtain a frequency curve of annual floods regardless of type. In order to do this, the following formula developed in the Philadelphia District is employed:

$$\frac{P_3}{100} = \frac{P_1}{100} + \frac{P_2}{100} - \frac{P_1 P_2}{10,000}$$

in which:

P_1 = the exceedence frequency of annual maximum non-hurricane floods

P_2 = exceedence frequency of annual maximum hurricane floods

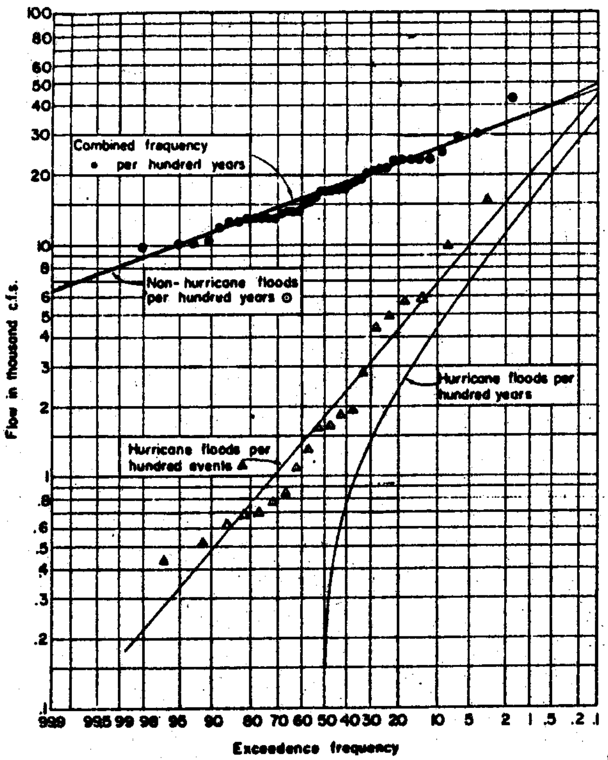
P_3 = exceedence frequency of annual maximum floods, regardless of type combination of frequencies using this formula is illustrated on Chart 2.

11. It will be noted on Chart 2 that the observed annual maximum events regardless of type at practically all stations are much more frequent in the range of higher floods than is indicated by the computed combination frequency curves. This may be due to the fact that the March 1936 and even the November 1927 non-hurricane floods are much more rare events than would be expected to occur in the 40-year period studied. Also, the hurricane flood of August 1955 is considered to be much rarer than can be expected in the 40 years studied. On the other hand, it is possible that the technique employed, although successful in most regions of the United States, is not applicable in New England. Consideration was given to flood segregation other than between hurricane and non-hurricane types, but it was concluded that other types were not distinct or sufficiently independent.

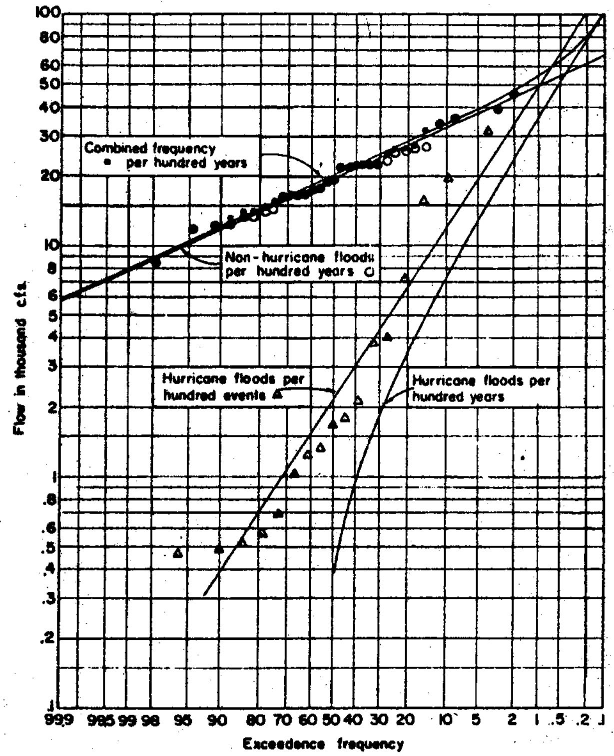
12. Conclusions. As indicated on Charts 2 and 3, segregation of floods into hurricane and non-hurricane types does not entirely eliminate the excess of observed large floods over the computed frequencies. This discrepancy may be due either to inadequacy of technique or to unusually excessive floods during the 40-year period studied. If the evidence presented herein were the only evidence available for judging the adequacy of the techniques employed, it would cast strong doubt on their validity. However, the techniques have been successfully employed in most other sections of the country, and it is only reasonable to expect a serious excess of large floods in some regions and a serious shortage of large floods in other regions. Therefore the evidence contained herein is not conclusive. As a matter of fact, there is a feeling among hydrologists familiar with the New England region that the floods of 1936, 1955, and even 1927 are indeed very rare events. Accordingly, it is concluded that the techniques employed are not disproved by the excessive number of large floods in New England. As a matter of fact, it is believed that the relation between plotted points and computed curves on Chart 2 is added evidence that the large New England floods are truly rare. Indicated exceedence intervals in years of the largest floods are as follows:

	Hurricane Floods		Non-hurricane floods	
	18 Aug 1955	Sep 1938	Mar 1936	Nov 1927
Mattawawkeag R.	minor	minor	20	2
Piscatiquis R.	minor	minor	50	5
Dead R.	-	minor	130	3
Androscoggon R.	minor	3	600	20
Pemigewasset R.	minor	50	200	75
Souhegan R.	minor	30	120	5
Blackstone (Kettle Brook)	200	20	60	5
Quinebaug R.	250	65	120	7
White R.	minor	10	30	5000*
Moss Brook	3	85	200	60
Quaboag R.	250	230	60	2
Housatonic R.	3	100	50	8

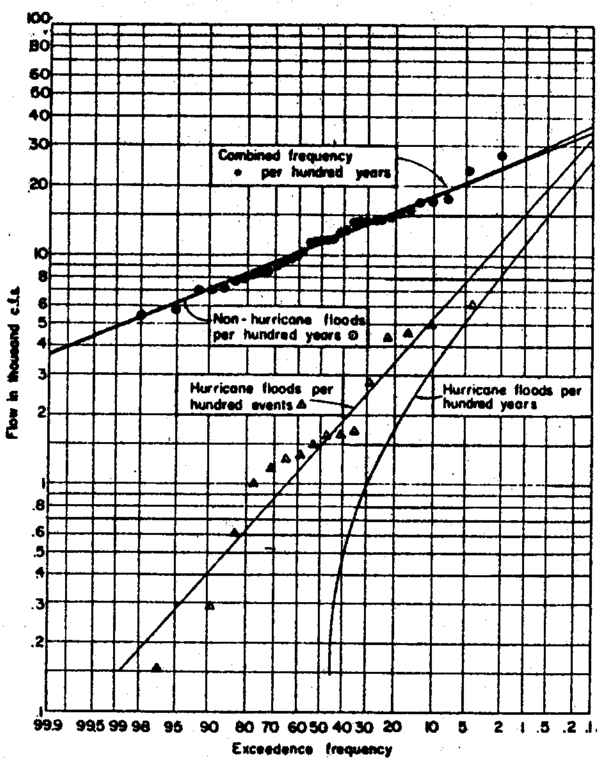
*Based on estimated daily flow of 80,000 cfs



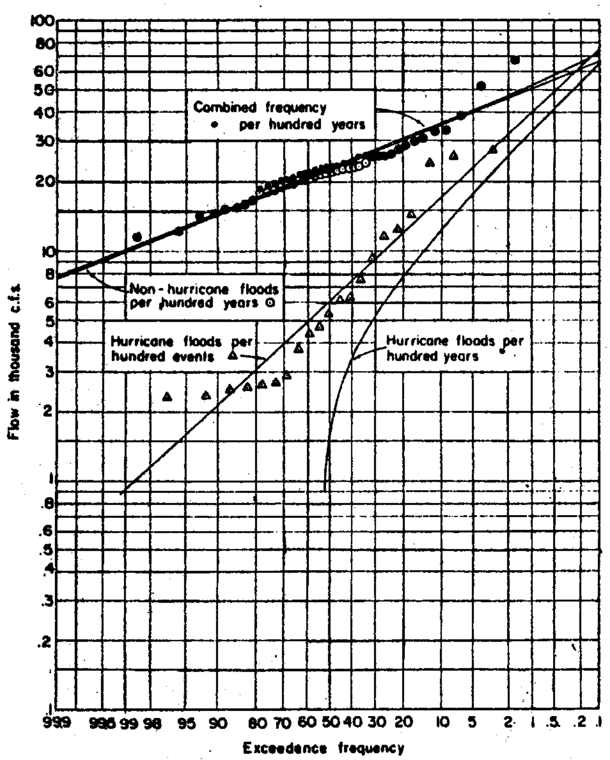
33 & 34 MATTAWAMKEAG R. NR. MATTAWAMKEAG, ME.



40. PISCATAQUIS R. AT MEDFORD, ME.



61. DEAD R. AT THE FORKS, ME.



81. ANDROSCOGGIN R. AT RUMFORD, ME.

COMPARISON OF COMPUTED AND OBSERVED FLOOD FREQUENCIES

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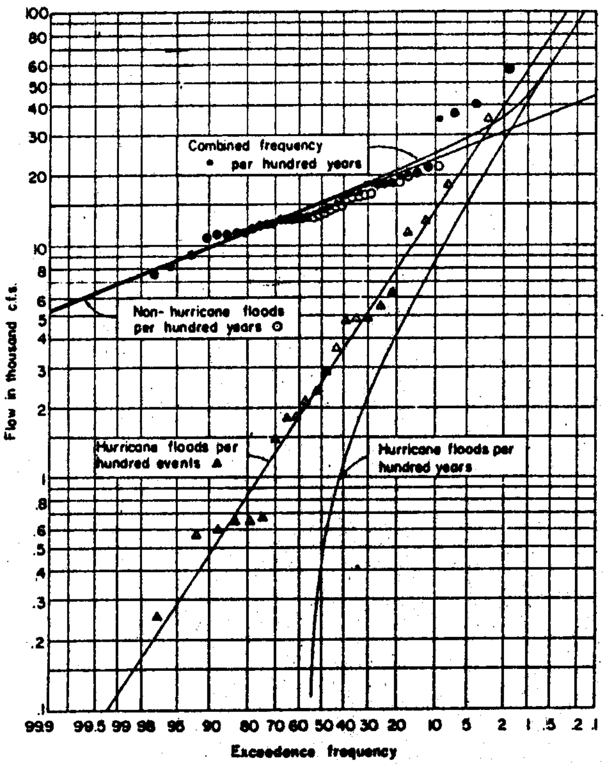
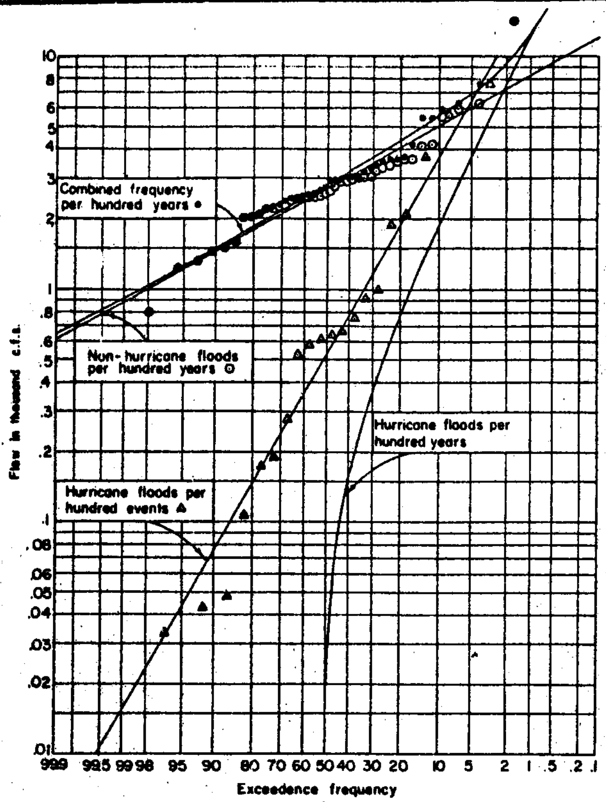
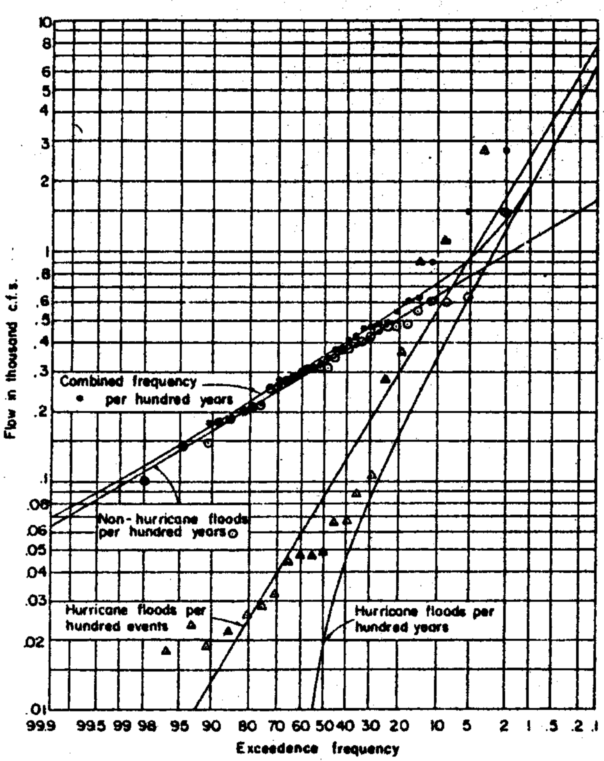


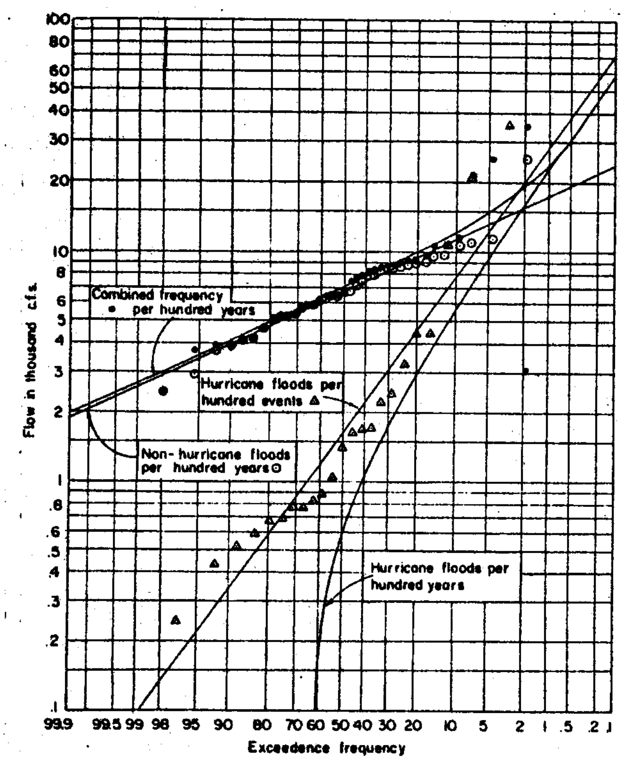
124. PEMIGEWASSET R. AT PLYMOUTH, N.H.



156. SOUHEGAN R. AT MERRIMACK, N. H.

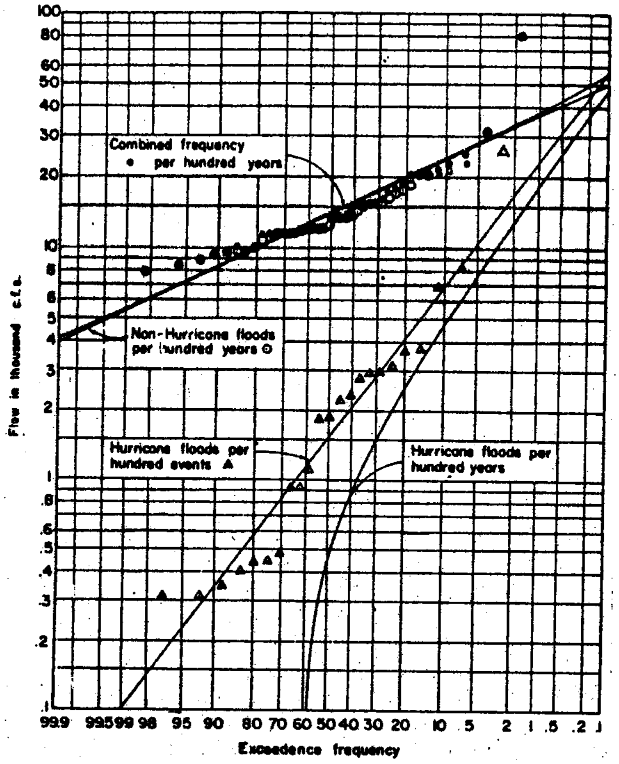


182. BLACKSTONE R. (KETTLE BROOK) AT WORCESTER, MASS.

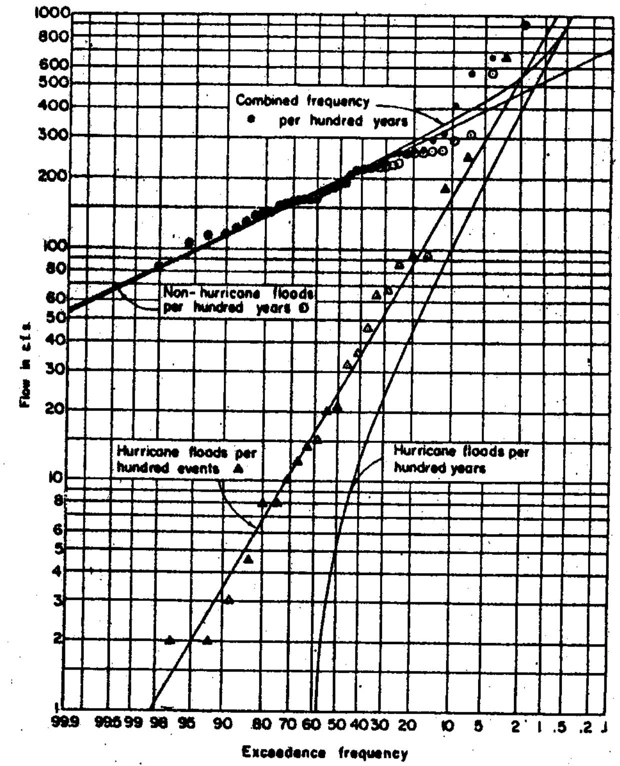


210. QUINEBAUG AT JEWETT CITY, CONN.

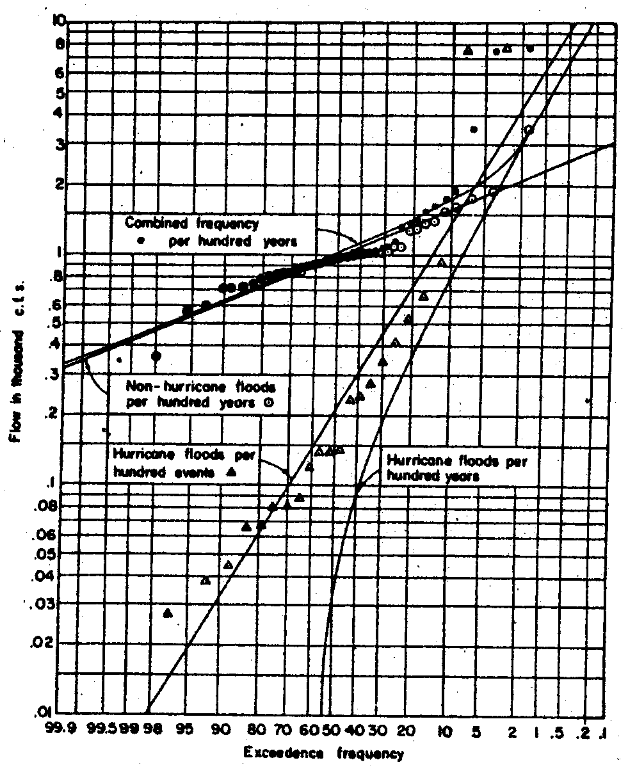
COMPARISON OF COMPUTED AND OBSERVED FLOOD FREQUENCIES



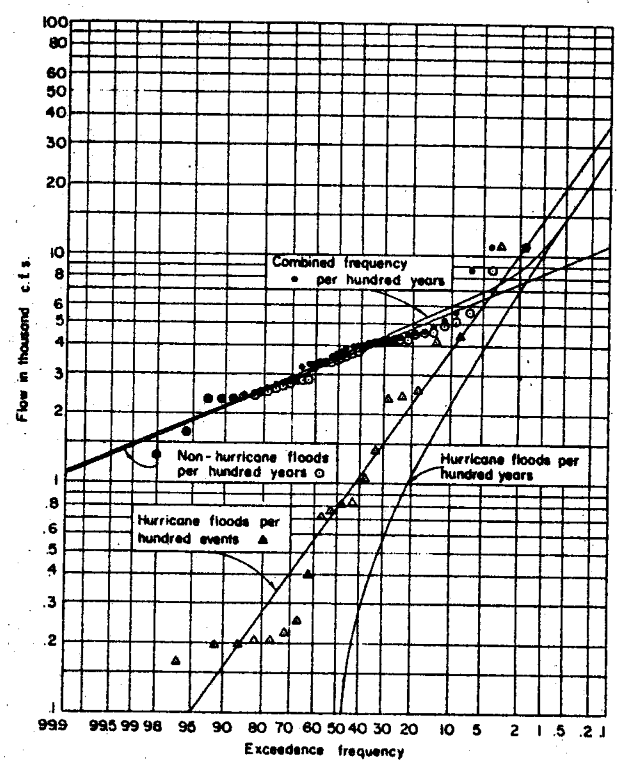
241. WHITE R. AT WEST HARTFORD, VT.



274. MOSS BROOK AT WENDELL DEPOT, MASS



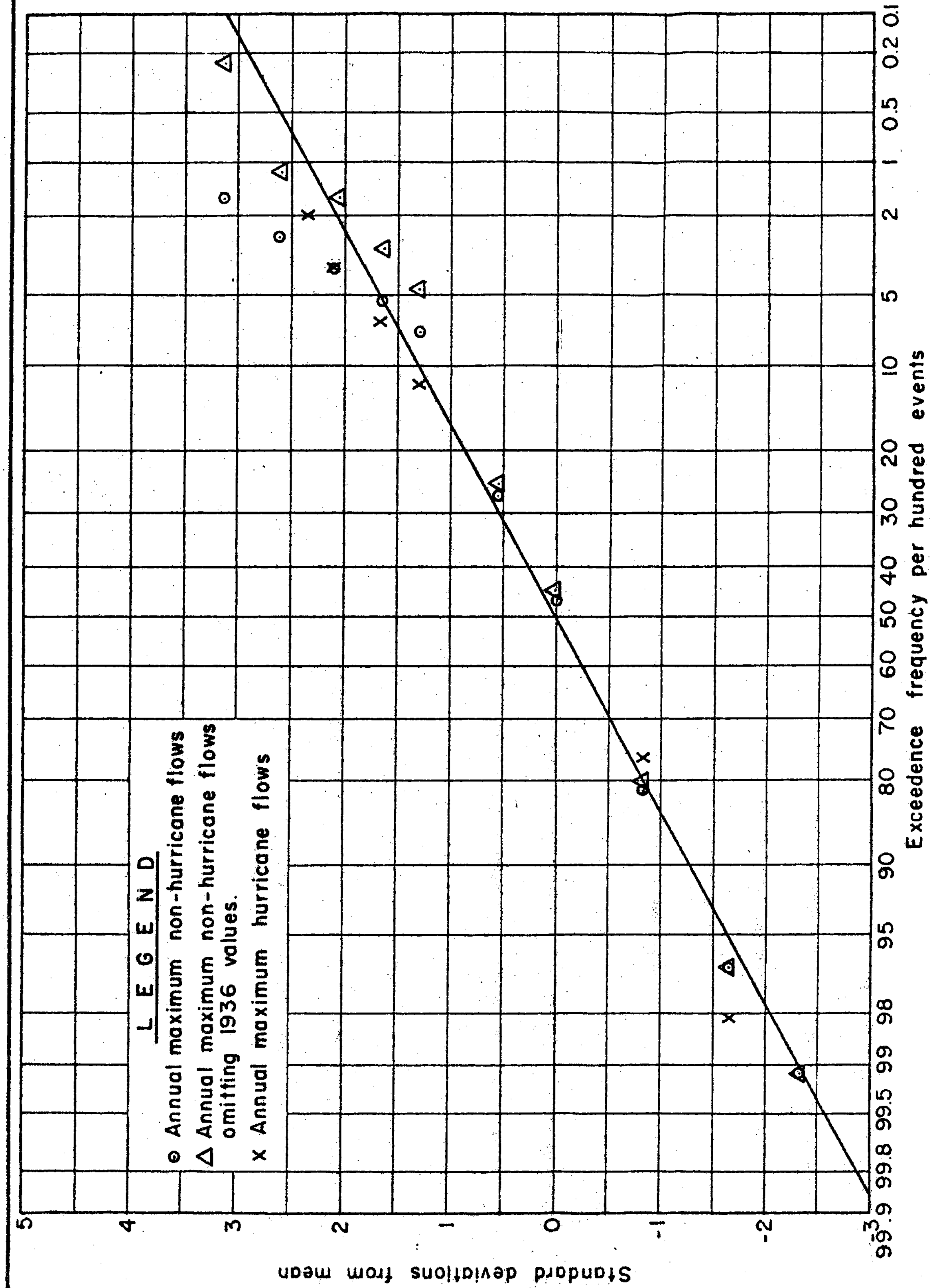
294. QUABOAG R. AT WEST BRIMFIELD, MASS.



333. HOUSATONIC R. NEAR GREAT BARRINGTON, MASS

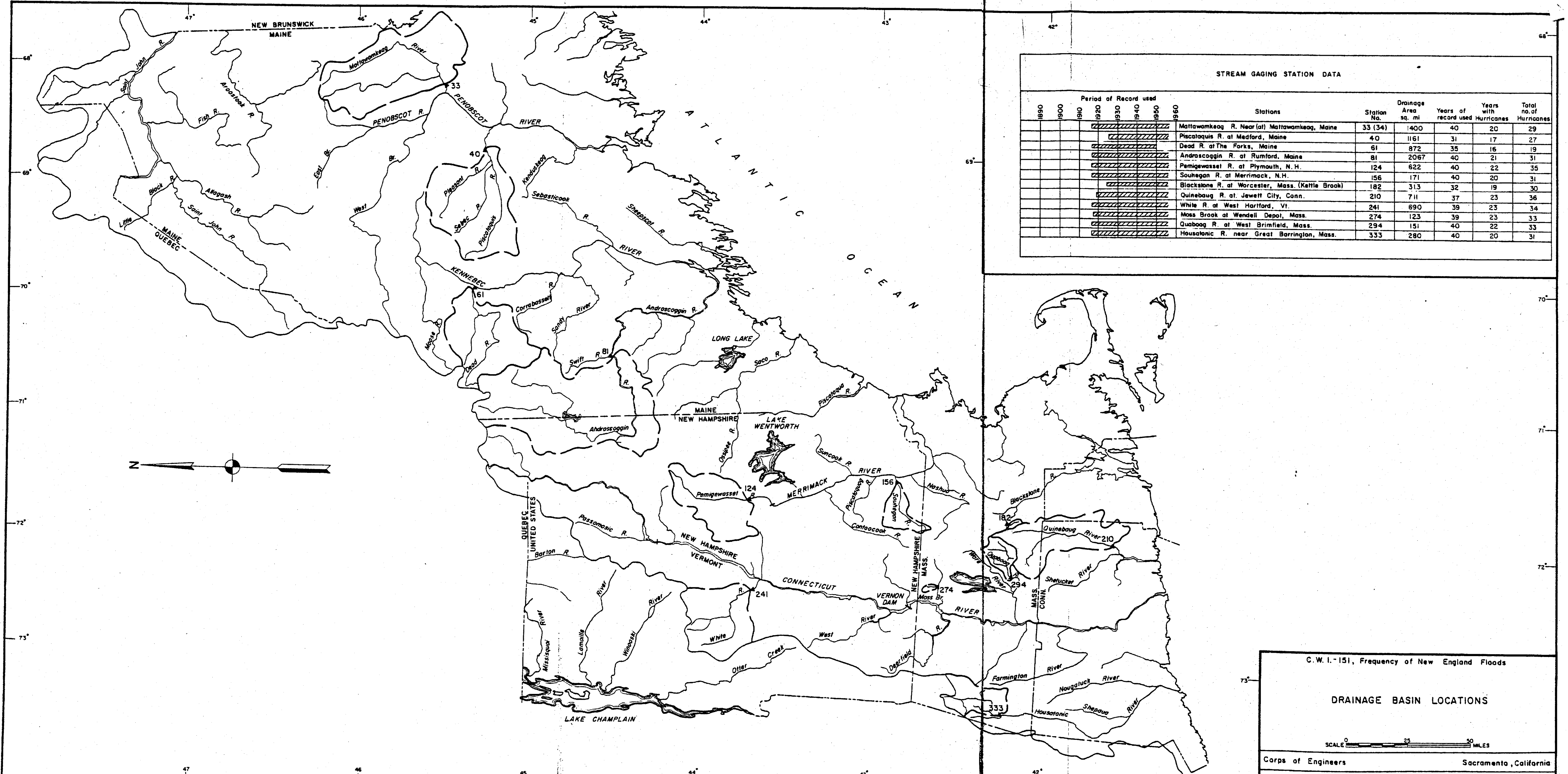
COMPARISON OF COMPUTED AND OBSERVED FLOOD FREQUENCIES

JULY 1958



COMPARISON OF TOTAL FREQUENCY COUNT FOR 12 STATIONS

JULY 1958



STREAM GAGING STATION DATA

Period of Record used (1890, 1900, 1910, 1920, 1930, 1940, 1950, 1960)	Stations	Station No.	Drainage Area sq. mi	Years of record used	Years with Hurricanes	Total no. of Hurricanes
	Mattawamkeag R. Near (at) Mattawamkeag, Maine	33 (34)	1400	40	20	29
	Piscataquis R. at Medford, Maine	40	1161	31	17	27
	Dead R. at The Forks, Maine	61	872	35	16	19
	Androscoggin R. at Rumford, Maine	81	2067	40	21	31
	Pemigewasset R. at Plymouth, N.H.	124	622	40	22	35
	Souhegan R. at Merrimack, N.H.	156	171	40	20	31
	Blackstone R. at Worcester, Mass. (Kettle Brook)	182	313	32	19	30
	Quinebaug R. at. Jewett City, Conn.	210	711	37	23	36
	White R. at West Hartford, Vt.	241	690	39	23	34
	Moss Brook at Wendell Depot, Mass.	274	123	39	23	33
	Quaboag R. at West Brimfield, Mass.	294	151	40	22	33
	Housatonic R. near Great Barrington, Mass.	333	280	40	20	31

C.W. I.-151, Frequency of New England Floods

DRAINAGE BASIN LOCATIONS

SCALE 0 25 50 MILES

Corps of Engineers — Sacramento, California