

1962

# Floods in Nebraska on Small Drainage Areas Magnitude and Frequency

Emil W. Beckman

Norman E. Hutchison

Follow this and additional works at: <http://digitalcommons.unl.edu/usgspubs>

---

Beckman, Emil W. and Hutchison, Norman E., "Floods in Nebraska on Small Drainage Areas Magnitude and Frequency" (1962).  
*Publications of the US Geological Survey*. 96.  
<http://digitalcommons.unl.edu/usgspubs/96>

This Article is brought to you for free and open access by the US Geological Survey at DigitalCommons@University of Nebraska - Lincoln. It has been accepted for inclusion in Publications of the US Geological Survey by an authorized administrator of DigitalCommons@University of Nebraska - Lincoln.



# Floods in Nebraska on Small Drainage Areas Magnitude and Frequency

GEOLOGICAL SURVEY  
CIRCULAR 458

# Floods in Nebraska on Small Drainage Areas, Magnitude and Frequency

By Emil W. Beckman and Norman E. Hutchison

*Prepared in cooperation with the Nebraska Department of Roads*



GEOLOGICAL SURVEY CIRCULAR 458

Washington 1962

United States Department of the Interior  
STEWART L. UDALL, SECRETARY



Geological Survey  
THOMAS B. NOLAN, DIRECTOR



*Free on application to the U.S. Geological Survey, Washington 25, D. C.*

## CONTENTS

---

	Page		Page
Abstract.....	1	Flood-frequency analysis—Cont.	
Introduction.....	1	Regional flood-frequency analysis....	11
Description of area .....	1	Base period .....	11
Physiography.....	1	Definition of mean annual flood ...	11
Soil .....	1	Homogeneity of records.....	12
Climate .....	2	Composite frequency curves.....	12
Drainage areas .....	3	Relations of mean annual flood....	12
Causes of floods.....	3	Hydrologic areas.....	14
Flood records available .....	3	Application of regional flood-frequency	
Flood-frequency analysis.....	9	data .....	16
Flood frequency at a gaging station ..	9	Tributary areas of natural runoff ...	16
Value .....	9	Stage of flood discharge.....	16
Types of series .....	9	Maximum known floods.....	17
Plotting position.....	10	Summary.....	32
Historical data .....	10	Selected references .....	32
Fitting frequency curves .....	10		
Limitations of a single-station			
analysis .....	10		

## ILLUSTRATIONS

---

		Page
Figure 1. Generalized areas of soil sources in Nebraska.....		2
2. Map of Nebraska showing location of gaging stations used in flood-frequency analysis .....		9
3. Frequency of annual floods, Plum Creek near Smithfield, Nebr. ....		10
4. Map of Nebraska showing flood-frequency regions and hydrologic areas .....		12
5. Composite frequency curves of annual floods, regions A and B, period 1947-59 ..		13
6. Variation of mean annual flood with contributing drainage area in hydrologic areas 1-10 .....		14
7. Relation of maximum discharge to 10 and 25-year floods, region A, areas 1 and 2 .....		28
8. Relation of maximum discharge to 10 and 25-year floods, region A, areas 3 and 4 .....		29
9. Relation of maximum discharge to 10 and 25-year floods, region A, areas 5 and 6 .....		30
10. Relation of maximum discharge to 10 and 25-year floods, region A, area 7.....		31
11. Relation of maximum discharge to 10 and 25-year floods, region B, areas 8, 9, and 10 .....		32

## TABLES

---

		Page
Table 1. Period of record of annual peaks at gaging stations.....		4
2. Maximum stages and discharges at gaging stations .....		18
3. Unusual peak discharges at miscellaneous sites and at short-term gaging stations with contributing drainage areas of 300 square miles or less .....		26

# Floods in Nebraska on Small Drainage Areas, Magnitude and Frequency

By Emil W. Beckman and Norman E. Hutchison

## ABSTRACT

Flood hazard information is needed for small streams as well as for large ones. This report explains methods of defining the magnitude and frequency of floods in Nebraska on uncontrolled and unregulated streams which have about 300 square miles or less of drainage area contributing to surface runoff. Composite frequency curves defined for two flood regions express a ratio of floods with recurrence intervals ranging from 1.1 to 25 years to the mean annual flood. Curves for 10 hydrologic areas were defined to show the relation of the mean annual flood to the contributing drainage area. A flood-frequency curve can be drawn from these two sets of curves for any site in the State within the range of drainage area and recurrence interval that is defined by the base data and not materially affected by the works of man. The two sets of curves are based on all available pertinent data from records of 5 or more years' duration.

This report includes a tabulation of maximum flood peaks at gaging stations used and at a number of miscellaneous sites which have less than 300 square miles of contributing drainage area.

## INTRODUCTION

When loss of life is not a factor, it is generally not economically sound to design structures in or across streams for the maximum flood that may occur. Economic considerations will dictate the choice of a design frequency. An evaluation of these economic factors is beyond the scope of this report. It should be noted that the recurrence interval of a flood does not imply any regularity of occurrence. For an example, at any site, two 25-year floods may occur in consecutive weeks or such a flood may not occur in a period of 50 years.

The purpose of this report is to describe methods by which the magnitude and frequency of floods may be determined for most sites in Nebraska for which the drainage area is less than 300 square miles. The report was prepared in the Lincoln office of the U.S.

Geological Survey, under the direction of Floyd F. LeFever, district engineer, Surface Water Branch, in cooperation with the Nebraska Department of Roads. Financial assistance in the preparation of the report was given by the Bureau of Public Roads.

## DESCRIPTION OF AREA

### PHYSIOGRAPHY

Nebraska has an expansive, gently rolling to rough topography, broken in places by low hills, a few isolated buttes, mesas, ravines, and several relatively shallow, major streams which flow in an easterly direction.

The altitude of the State ranges from 835 feet at the extreme southeast corner to a maximum of 5,340 feet at the western border. The land surface slopes rather consistently to the southeast with an average decline of about 9 feet per mile.

The small streams of Nebraska have a wide variation in slope depending on the topography of their drainage basins. The average fall for individual streams used in this report ranges from about 6 to about 110 feet per mile. The major streams fall from 4 to 8 feet per mile.

### SOIL

Most of the soil mantle of Nebraska originated from four major sources. The general location of these soils is shown on figure 1, which is based on reports by the Nebraska State Planning Board (1941), by Condra (1920), and by Jenkins and others (1946), and was used by Furness (1955).

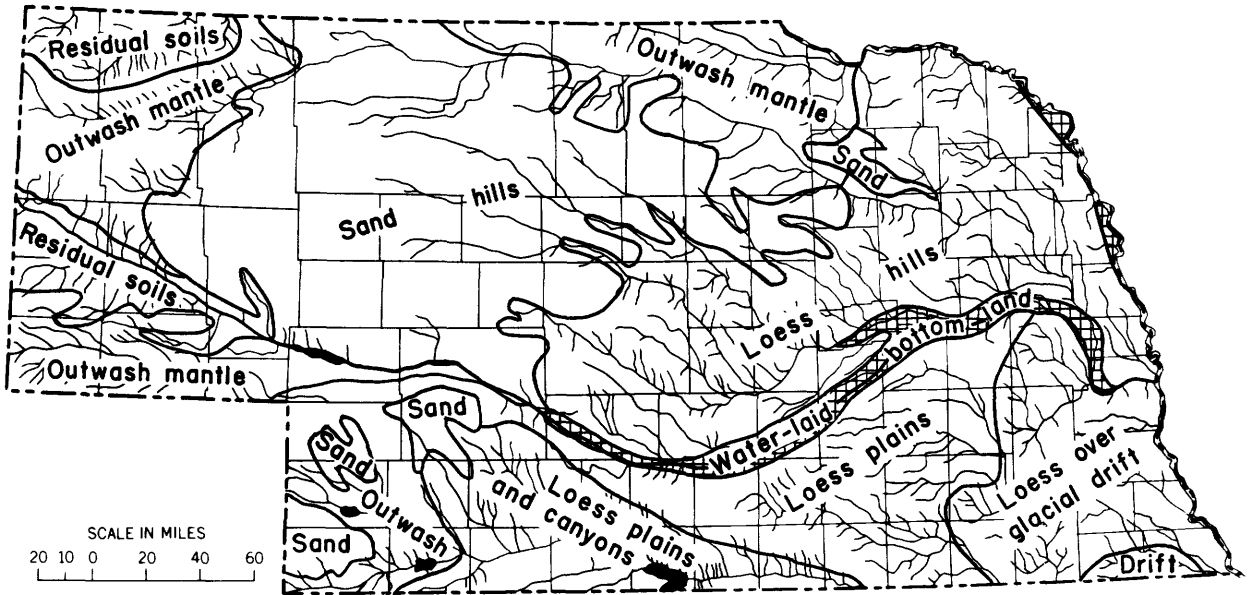


Figure 1. —Generalized areas of soil sources in Nebraska.

Loess silt is the predominant mantle of Nebraska. It is wind transported from both glacial deposits and mountain outwash and is quite uniform in texture but decreases in grain size toward the southeast. It erodes readily when on a steep gradient and usually with a vertical cleavage line. Except for scattered land-locked areas in the headwaters of streams draining relatively level areas of the south-central plains, the drainage patterns are connected and runoff is prompt.

The Sand Hill region, second in areal extent of the four major soil areas, is composed mostly of porous dune sand formed from the weathering and reworking of sandy bedrock and early water and glacial deposits of sand and gravel. Except in the immediate vicinity of the few primary channels, there is no drainage pattern or surface connections to the streams. Rainfall readily reaches the high ground-water table and forms numerous lakes and marshes. Sand Hill streams have a fairly uniform flow which originates from the ground-water table. Flood runoff is minor and comes primarily from the narrow strips of land immediately adjoining the streams.

The outwash mantle from the mountains to the west and northwest is found in several areas along the western and northern parts of the State. The original high-plains surface remains as a variety of topographic forms ranging from comparatively smooth to rolling

as deeply eroded canyons, and as rough broken areas. The soil varies widely in texture. The drainage pattern is generally well defined and runoff is prompt although the slope of each drainage basin is an influencing factor.

Residual soils, the least in areal extent formed in place from sedimentary rocks and are found primarily in several smaller areas of western Nebraska. The ground surface varies from nearly level to undulating, rolling, rough and mountainous. Sedimentary rocks are exposed in the rough badlands. The soil texture also has a wide range in the residual soil areas. The drainage pattern is well defined and runoff is quite prompt.

Water-laid bottom land and areas of glacial drift are exposed to a very limited extent in the State.

#### CLIMATE

The climate of Nebraska is typical of large interior continental areas in the middle latitude; it is characterized by light average annual precipitation, a great range of precipitation from season to season and year to year, and frequent and abrupt changes in temperature and other weather conditions.

The average annual rainfall shows a gradual progressive increase from 14 inches in the extreme western part of the State to 34

inches in the southeastern corner. About 75 percent of the annual precipitation falls during the six-month period April through September and about 42 percent of the annual precipitation falls in May, June, and July. A large part of the summer rainfall occurs during thunderstorms and generally falls at intense rates in short periods of time.

#### DRAINAGE AREAS

The total drainage area of streams in a major part of Nebraska does not contribute to the surface runoff; therefore, it is necessary to determine both the total drainage area and the area which contributes to the stream by surface runoff. Both total and contributing drainage areas are shown for the stations used; however, owing to the lack of complete coverage of good topographic maps of the State, some of the drainage area figures are qualified as approximate. Some of the small drainage areas were determined from aerial-survey photographs obtained from the U.S. Department of Agriculture, Commodity Stabilization Service.

Nebraska is completely mapped by 1:250,000-scale maps of either 50-foot or 100-foot contour intervals. The scale and contour intervals do not permit reliable determination of drainage areas, especially for smaller, fairly level areas or, differentiation between contributing and noncontributing drainage areas.

Topographic maps, in scales varying from 1:24,000 to 1:125,000 and with contour intervals varying from 5 to 20 feet, have been published for about two-thirds of the State.

#### CAUSES OF FLOODS

In Nebraska the annual floods on drainage areas of less than 300 square miles generally

occur during the months April through September. There are some spring breakup floods; they occur most frequently in the Sand Hill region where there is a relatively limited range in discharge.

Rainfall is the primary cause of floods. Much of the rainfall results from thunderstorms and ranges widely in amount, intensity, and distribution, so that the relation of the actual amount of rainfall to the flood peak cannot be correlated. Besides the stream basins physiography which is fairly stable, the following conditions also influence the size of floods: (1) antecedent conditions, (2) direction of the storm, (3) variation of soil infiltration rate, and (4) land use and vegetal cover.

#### FLOOD RECORDS AVAILABLE

Records for 5 or more years in length of the annual floods not materially affected by regulation and diversion are available for 136 stations in Nebraska which have 300 square miles or less in contributing drainage area. In addition, six stations which have more than 300 square miles of contributing drainage area are included because of their strategic location. These six stations are: White River at Crawford, Ponca Creek at Anoka, Plum Creek near Meadville, Long Pine Creek near Riverview, Bazile Creek near Niobrara and Wood River near Riverdale. Table 1 gives a list, in the downstream order, of the stations used, their drainage area size, and a graphical illustration of the length of record of annual peaks. Of the total of 142 stations, 83 are crest-stage gages, most of which are operated in cooperation with the Nebraska Department of Roads to define the annual peak discharge. Figure 2 shows the location of the 142 stations. The symbols on the map identify the type of station and the number shown on the map corresponds to the number preceding the station name in table 1.



Table 1.—Period of record of annual peaks at gaging stations  
 [Solid bar: Peak stage and (or) discharge. Open bar: Peak stage only]

No.	Gaging station	Drainage area (square miles)		Annual peak record, water years						
		Total	Contributing	1930	1935	1940	1945	1950	1955	1960
	<i>White River basin</i>									
4432	White River tributary near Glen	7.97	7.97							
4437	Soldiers Creek near Crawford	52.6	52.6							
4440	White River at Crawford	313	313	(a)						
4448	Chadron Creek near Chadron	14.9	14.9							
	<i>Ponca Creek basin</i>									
4535	Ponca Creek at Anoka	410	410							
	<i>Niobrara River basin</i>									
4563	Pebble Creek near Dunlap	23.5	23.5							
4564	Cottonwood Creek near Dunlap	82.2	82.2							
4577	Antelope Creek at Gordon	61.1	61.1							
4578	Antelope Creek tributary near Gordon	26.6	26.6							
4585	Bear Creek near Eli	360	78							
4595	Snake River near Burge	620	100							
4610	Minnehaduzza Creek at Valentine	510	200							
4625	Plum Creek near Meadville	581	330							
4635	Long Pine Creek near Riverview	390	390							
	<i>Bazile Creek basin</i>									
4665	Bazile Creek near Niobrara	440	440							
	<i>Omaha Creek basin</i>									
6006	South Omaha Creek tributary near Walthill	2.64	2.64							
6007	South Omaha Creek near Walthill	15.1	15.1							
6008	South Omaha Creek tributary 2 near Walthill	1.51	1.51							
6009	South Omaha Creek at Walthill	51.0	51.0							
6010	Omaha Creek at Homer	170	170							

<sup>a</sup> 1920 (stage only)

Station No.	Location	Value 1	Value 2	Value 3	Value 4	Value 5	Value 6	Value 7	Value 8
<i>Tekamah Creek basin</i>									
6077	South Branch Tekamah Creek near Craig	2.54							2.54
6078	South Branch Tekamah tributary near Tekamah	4.08							4.08
6079	South Branch Tekamah Creek near Tekamah	9.73							9.73
6080	Tekamah Creek at Tekamah	23.0							23.0
<i>New York Creek basin</i>									
6086	New York Creek near Spiker	1.75							1.75
6087	New York Creek tributary near Spiker	1.55							1.55
6088	New York Creek north of Spiker	6.50							6.50
6089	New York Creek east of Spiker	13.9							13.9
6090	New York Creek at Herman	25.4							25.4
<i>Platte River basin</i>									
6840	Red Willow Creek near Bayard	162							162
6870	Blue Creek near Lewellen	267							80
6920	Birdwood Creek near Hershey	286							80
7671	South Fork Plum Creek tributary near Farnam	9.81							9.81
7673	Plum Creek tributary at Farnam	19.8							19.8
7674	North Plum Creek near Farnam	38.3							38.3
7674.1	Plum Creek near Farnam	79.8							79.8
7675	Plum Creek near Smithfield	229							229
7681	East Branch Buffalo Creek tributary near Buffalo	5.24							5.24
7682	East Branch Buffalo Creek near Buffalo	32.8							28.3
7683	East Branch Buffalo Creek tributary 2 near Buffalo	2.10							2.10
7684	West Branch Buffalo Creek near Buffalo	16.3							16.3
7685	Buffalo Creek near Darr	63							58.5
7690	Buffalo Creek near Overton	175							170
7691	Elm Creek tributary near Overton	.54							.54
7692	Elm Creek near Sumner	14.9							14.9
7693	Elm Creek tributary 2 near Overton	5.19							5.19
7695	Elm Creek near Overton	31							31
7707	Wood River near Lodi	12.9							12.9
7708	Wood River near Oconto	26.4							26.4
7709	Wood River at Oconto	44.8							44.8
7709.1	Wood River near Lomax	79.6							77.9
7710	Wood River near Riverdale	379							379
7730	Dry Creek at Cairo	22.2							22.2
7750	Middle Loup River near Seneca	1,140							60

Table 1.—Period of record of annual peaks at gaging stations—Continued

No.	Gaging station	Drainage area (square miles)		Annual peak record, water years						
		Total	Contributing	1930	1935	1940	1945	1950	1955	1961
<i>Platte River basin—Continued</i>										
7755	Middle Loup River at Dunning	1,760	80							
7765	Dismal River at Dunning	1,780	50							
7777	Lillian Creek near Broken Bow	4.77	4.77							
7778	Lillian Creek tributary 2 near Walworth	2.04	2.04							
7826	South Branch Mud Creek tributary near Broken Bow	.43	.43							
7827	South Branch Mud Creek at Broken Bow	400	45.9							
7828	North Branch Mud Creek at Broken Bow	15.5	10.8							
7829	Mud Creek tributary near Broken Bow	5.98	5.98							
7830	Mud Creek near Broken Bow	440	81.1							
7843	Oak Creek near Loup City	41.9	41.9							
7845	Oak Creek near Dannebrog	122	122							
7847	Turkey Creek near Farwell	27.2	27.2							
7855	North Loup River at Brewster	1,890	140							
7860	North Loup River at Taylor	2,210	180							
7875	Calamus River near Burwell	1,260	110							
7891	Davis Creek tributary near North Loup	2.29	2.29							
7892	Davis Creek tributary 2 near North Loup	6.79	6.79							
7893	Davis Creek near North Loup	21.1	21.1							
7894	Davis Creek southwest of North Loup	41.6	41.6							
7895	Davis Creek near Cotesfield	94	94							
7907	West Branch Spring Creek at Brayton	19.5	19.5							
7908	West Branch Spring Creek near Wolbach	36.9	36.9							
7909	Mary's Creek at Wolbach	7.63	7.63							
7911	Spring Creek near Cushing	165	165							
7915	Cedar River near Spalding	794	50							
7935	Beaver Creek at Loretto	311	100							
7950	Shell Creek at Newman Grove	122	122							
7955	Shell Creek near Columbus	270	270							

INTRODUCTION

7980	South Fork Elkhorn River at Ewing	320	190				
8015	Salt Creek watershed 12 at Roca	1.12	1.12				
8025	Salt Creek watershed 34 near Roca	5.72	5.72				
8030	Salt Creek at Roca	174	174				
8035.7	Wahoo Creek tributary near Weston	.31	.31				
8036	North Fork Wahoo Creek near Prague	15.2	15.2				
8037	Dunlap Creek near Weston	8.90	8.90				
8039	North Fork Wahoo Creek at Weston	43.7	43.7				
8040	Wahoo Creek at Ithaca	272	272				
8041	Silver Creek near Cedar Bluff	10.9	(b)				
8042	Silver Creek near Colon	29.9	(b)				
8043	Silver Creek tributary near Colon	14.3	(b)				
8044	Silver Creek tributary at Colon	22.4	(b)				
8045	Silver Creek at Ithaca	72	(b)				
	<i>Weeping Water Creek basin</i>						
8064	Weeping Water Creek at Elmwood	21.4	21.4				
8064.2	Stove Creek near Elmwood	4.94	4.94				
8064.4	Stove Creek at Elmwood	10.0	10.0				
8064.6	Weeping Water Creek at Weeping Water	75.5	75.5				
8064.7	Weeping Water Creek tributary near Weeping Water	1.07	1.07				
8065	Weeping Water Creek at Union	238	238				
	<i>Little Nemaha River basin</i>						
8101	Hooper Creek tributary near Palmyra	7.81	7.81				
8102	Hooper Creek near Palmyra	57.5	57.5				
8103	Owl Creek near Syracuse	25.4	25.4				
8104	Little Nemaha River tributary near Syracuse	.76	.76				
8105	Little Nemaha River near Syracuse	218	218				
	<i>Nemaha River basin</i>						
8155	Muddy Creek at Verdon	188	188				
	<i>Kansas River basin</i>						
8230	North Fork Republican River at Colo., -Nebr., State line	320	130				
8235	Buffalo Creek near Haigler	180	21				
8240	Rock Creek at Parks	180	14				
8360	Blackwood Creek near Culbertson	290	290				
8390	Medicine Creek at Maywood	270	82				

<sup>b</sup>Undetermined amount is noncontributing.

Table 1.—Period of record of annual peaks at gaging stations—Continued

No.	Gaging station	Drainage area (square miles)		Annual peak record, water years						
		Total	Contributing	1930	1935	1940	1945	1950	1955	1960
<i>Kansas River basin—Continued</i>										
8392	Elkhorn Canyon near Maywood	6.74	6.74							
8394	Elkhorn Canyon southwest of Maywood	13.2	13.2							
8395	Brushy Creek near Maywood	130	72							
8396	Frazier Creek near Maywood	11.3	11.3							
8397	Frazier Creek tributary near Maywood	.72	.72							
8398.5	Fox Creek north of Curtis	13.8	13.8							
8399	Fox Creek above Cut Canyon near Curtis	31.8	31.8							
8399.5	Cut Canyon near Curtis	25.6	25.6							
8400	Fox Creek at Curtis	77	77							
8405	Dry Creek near Curtis	20	20							
8415	Mitchell Creek above Harry Strunk Lake	53	53							
8440	Muddy Creek at Arapahoe	243	243							
8500	Turkey Creek at Naponee	138	138							
8502	Cottonwood Creek near Bloomington	15.6	15.6							
8510	Center Creek at Franklin	146	57.4							
8511	West Branch Thompson Creek at Hildreth	27.4	27.4							
8512	West Branch Thompson Creek near Hildreth	56.6	56.6							
8513	West Branch Thompson Creek tributary near Hildreth	13.9	13.9							
8514	West Branch Thompson Creek near Upland	90.8	90.8							
8515	Thompson Creek at Riverton	223	223							
8520	Elm Creek at Amboy	39.2	39.2							
8807.1	School Creek tributary near Harvard	13.1	13.1							
8807.2	School Creek near Harvard	55.1	55.1							
8807.3	School Creek tributary 2 near Harvard	14.0	14.0							
8807.4	School Creek near Saronville	89.4	89.4							
8836	South Fork Big Sandy Creek near Edgar	15.2	15.2							
8837	South Fork Big Sandy Creek near Davenport	32.0	32.0							
8838	South Fork Big Sandy Creek near Carleton	49.4	49.4							
8839	South Fork Big Sandy Creek near Hebron	81.9	81.9							



The annual flood series is used in this report. Where a frequency curve derived from the partial-duration series is desired, an annual-flood curve can be converted to the partial-duration series curve by the relation expressed in the preceding table.

#### PLOTTING POSITION

The analysis of flood data starts with a listing of all the annual peaks at a gaging station. These are ranked according to magnitude starting with 1 as the highest. A time scale must be computed, to obtain a plotting position for the frequency scale. There are several methods, but the one used by the Survey and in this report is

$$T = \frac{n + 1}{m}$$

where

- $T$  is the recurrence interval in years,
- $n$  is the number of years of record,
- $m$  is the order of the magnitude of the flood, the highest being 1.

In the study of historical floods,  $n$  is the number of years in which it is known that the flood was of the order assigned.

Annual floods are plotted on a special form devised by Powell (1943) on which the discharge is plotted on a linear scale as the ordinate and the recurrence interval on a scale graduated on the basis of the theory of extreme values as the abscissa.

#### HISTORICAL DATA

Historical floods can be used to extend the frequency curve of a station to cover a longer period. Historical data, however, are usually confined to stages or comparison of stages above a high base and it is important to define their order of magnitude with respect to a period of time. Historical information on small streams is more difficult to obtain than on larger streams because the duration of the flood is quite short and the number of people affected is very limited. Care must be exercised in assigning discharge values to historical stages because of possible channel changes.

Some information on historical floods was obtained, usually from local residents. Gen-

erally it is confined to the maximum flood during the memory of one or possibly several individuals. Some of the stages noted are beyond the limits of the defined stage-discharge relation, and a discharge could not be estimated.

#### FITTING FREQUENCY CURVES

After the flood discharges for each station have been plotted against their computed recurrence intervals, a curve is drawn on the basis of the plotted points. The relatively short length of most streamflow records and the probable inaccuracies of small samplings do not warrant analytical curve fitting. Therefore, a visual best fit smooth curve is used in this report to average the points. It is known that the maximum flood or floods of record may have a recurrence interval considerably greater than the period of record. Therefore, in drawing a best fit smooth-frequency curve, more weight is given to the lower floods than to the higher floods. Figure 3 shows a plot of the frequency of annual floods for Plum Creek near Smithfield, Nebr.

#### LIMITATIONS OF A SINGLE STATION ANALYSIS

Generally the 25-year or the 50-year flood is selected as the design flood. Table 1 shows that there are no gaging stations in Nebraska

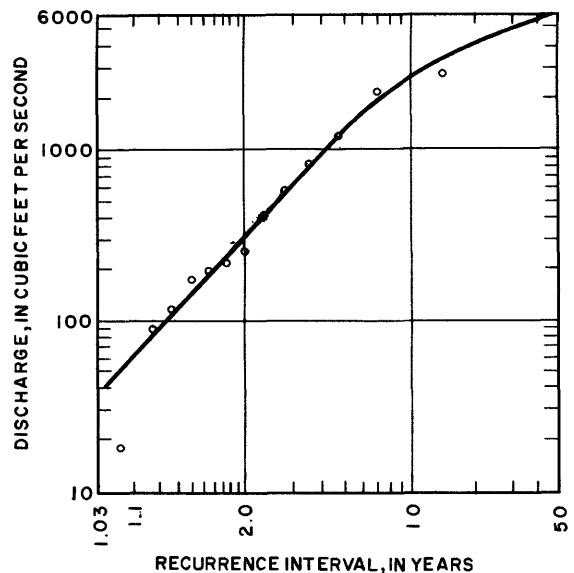


Figure 3. —Frequency of annual floods, Plum Creek near Smithfield, Nebr.

with less than a 300 square mile drainage area which have 50 years of record of annual peaks and that there are only 5 stations which have more than 25 years of record of annual peaks. Of the total 142 stations, 113 have only 10 years or less of record of annual peaks. To define a 25-year or 50-year flood would require extensive extrapolation from the trend of the plotting position of lesser floods. The error of the curve could be considerable at its outer extremity.

The random manner in which flood events are distributed with respect to time is another limitation to frequency graphs based on records at a single station.

The maximum departure to be expected between flood magnitudes or frequencies computed from relatively short records and their true (long-term) values increases with the magnitude of the flood and decreases with the length of record (Benson, 1960). The following table, based on Benson's study, shows the length of record required at a single site to define the frequency of floods of various magnitudes with 10 and 25 percent of the true value 19 out of 20 times.

Magnitude of flood, in recurrence intervals	Length of record, in years	
	10 percent	25 percent
2.33-year.....	40	12
10-year.....	90	18
25-year.....	105	31
50-year.....	110	39

Although the figures in the above table are based on a hypothetical study, they give an indication of the possible errors, from chance alone, in frequency graphs based on short-term records for a single station. A comparison of the lengths of stream records available in Nebraska on drainage areas of 300 square miles and less (table 1) with those indicated by Benson (1960) suggests that very few records in the State are long enough to define reliably the mean annual flood, and the floods of infrequent occurrence are less accurately defined. Analysis on a regional basis is used as a solution to the flood-frequency definition.

**REGIONAL FLOOD-FREQUENCY ANALYSIS**

A flood-frequency curve based on a number of stations has greater reliability than a curve from a single station. In order to com-

bine the records for a number of stations, two requirements must be met. The first condition is that all the records must be reduced to a common time basis or base period, and the second is that the stations must have frequency graphs of the same general shape and slope, within limits of chance, so that they may be considered homogeneous.

**BASE PERIOD**

Table 1 shows graphically the length of usable records at the 142 gaging stations. Not all stations have records of the same length. If they are to be combined, records must be on the same time basis. The actual length of a short-period record of at least 5 years' duration can be extended by correlation with the long-term record of a nearby station. This correlation, however, is more sensitive for small streams than for larger streams and requires a long-term station in the immediate vicinity. Therefore, because there is such meager distribution of long-term stations within the State, the base period selected is 1947-59. Inasmuch as this base period is so short, it was also necessary to analyze records for 33 long-term stations having drainage areas greater than 300 square miles. This analysis was made for the period 1929-59 in order to establish the relation of the short base period to a 31-year period.

The actual record at each station either included or was extended to the 13-year base period, and for the 33 long-term stations mentioned above, to the 31-year period by computing a discharge figure for each year of no record. These computed discharges, which are based on correlation with records for long-term stations, are used only to assign the more nearly correct order numbers to annual peaks of record.

**DEFINITION OF MEAN ANNUAL FLOOD**

According to the theory of extreme values as applied to floods by Gumbel (1945), the arithmetic mean of the annual peak discharges in an infinitely long series is equal to the discharge corresponding to the 2.33-year recurrence interval. This definition is generally accepted, and the 2.33-year flood determined graphically is used as the mean annual flood for this report. Annual-flood



data for each of the individual gaging stations were adjusted to the 13-year base period (1947-59).

#### HOMOGENEITY OF RECORDS

The test for homogeneity of records involves determining whether differences in slopes of individual frequency curves are greater than might occur by chance in random sampling. This statistical test has a 95-percent confidence level, that is, one station in 20 may plot outside the limits of the test graph. The slope of each individual station frequency curve is expressed by the ratio of the 10-year flood to the mean annual flood. The average ratio derived from the group was multiplied by the mean annual flood for each individual station and the corresponding recurrence interval was determined from the station frequency graph. The recurrence interval thus obtained was then plotted against the effective length of record in years on the specially designed test graph. The effective length of record is the number of annual floods of record plus one-half the number of estimated annual floods used to complete the base period.

The test applied to the 142 gaging stations used in this report indicates two homogeneous flood regions in Nebraska which are designated as regions A and B. The regional boundaries are shown in figure 4. Region B

is the Sand Hills, and region A consists of the remaining part of the State. There are 132 stations in region A and 10 stations in region B.

#### COMPOSITE FREQUENCY CURVES

In order to compare flood records at different gaging stations and combine them to define composite flood relations, it is necessary to convert the floods to a dimensionless basis. This was done by computing the ratio of floods of selected recurrence intervals to the mean annual flood for each gaging station in a homogeneous region. The median ratio of each selected recurrence interval was then plotted against the corresponding recurrence interval to give the composite frequency curve for each homogeneous region (fig. 5).

#### RELATIONS OF MEAN ANNUAL FLOOD

The composite frequency curves as derived in the preceding section define dimensionless ratios of the mean annual flood to floods of other recurrence intervals. In order to define the flood-frequency curve in terms of discharge for a specific site, the magnitude of the mean annual flood is required. The magnitude of the mean annual flood is obtained by relating it to measurable characteristics of the drainage basin.

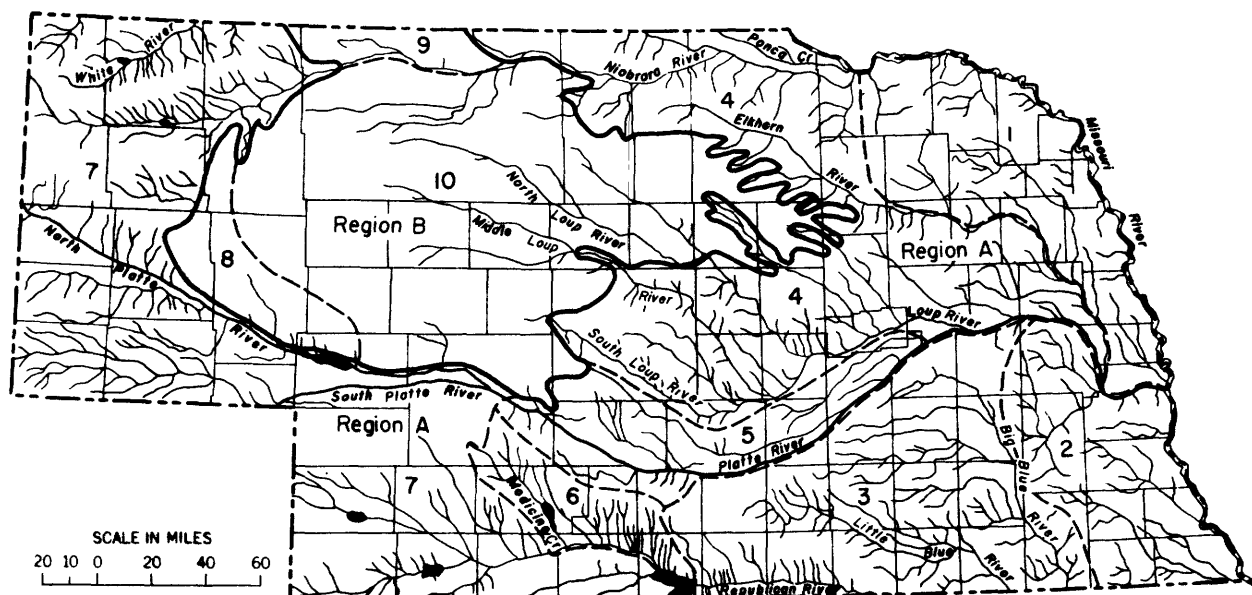


Figure 4. —Map of Nebraska showing flood-frequency regions and hydrologic areas.

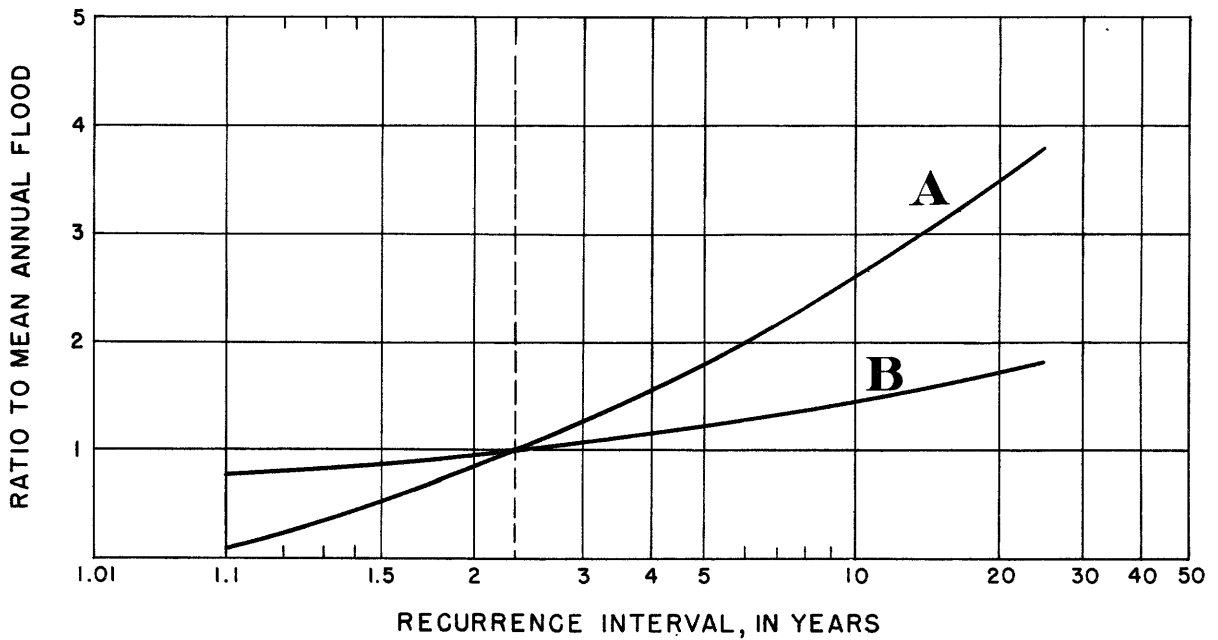


Figure 5.—Composite frequency curves of annual floods, regions A and B, period 1947-59.

The physiographic factors which may influence the mean annual flood at a given point are size of the drainage basin, shape of the basin, alignment of the basin with the prevailing direction of storm travel, channel storage, artificial or natural storage in lakes or ponds, slope of stream, land slope, stream density, stream pattern, altitude, depth and porosity of soil mantle, vegetal cover and land use. Some of these factors are difficult to evaluate and therefore cannot be used in a correlation.

The mean flow of a stream is a hydrologic measure that integrates all factors of runoff and thus includes an indication of flood potential. Because the majority of the station records used in this report are from crest-stage gages at which total runoff is not measured, the mean flow had to be determined from streams which have larger drainage areas and which are not always strategically located.

The mean annual flood was correlated graphically with contributing drainage area, mean flow, stream slope, and shape of basin factor. The drainage area size, the mean flow, and stream slope are all significant factors, drainage area and mean flow being the most significant. The correlations, however, do not give consistent results and inasmuch as mean flow was inadequately defined, the contributing drainage area alone was

used to define a relation with the mean annual flood. Along with variations in mean flow, other factors or combination of factors that influence floods are not reflected in the size of the basin, but their effect is related in areas having somewhat similar physical features. Accordingly, the State was subdivided into 10 hydrologic areas shown in figure 4. Except for the boundaries of the regions A and B which are also boundaries of hydrologic areas, the boundaries of the hydrologic areas follow the drainage divides or major streams.

Records for the 33 long-term stations mentioned under "Base Period" above were used in order to define mean annual flood relations with respect to time. The graphical definition of the mean annual flood for the 31-year (1929-59) base period was compared to the mean annual flood defined by the 13-year (1947-59) base period at each of the 33 individual stations which are distributed around and within the State. This study revealed that the average correction factor required to adjust the mean annual flood from the 13-year period to the 31-year period in the 10 hydrologic areas is as follows:

Area	Correction factor
1 and 2.....	0.816
3 and 4.....	.925
5, 8, 9, and 10.....	1.00
6 and 7.....	1.08

The above adjustments are reasonably well established in all areas except in area 7 where there is considerable spread in results for individual stations used to define the average correction.

The mean annual flood for each station determined from the 13-year period was corrected by the average correction factor for the hydrologic area in which the station was located. For each of the 10 hydrologic areas, the corrected mean annual flood for each station in that area was plotted against the contributing drainage area for the station. Curves were drawn to average all the data in each area. The variation of mean annual

flood with contributing drainage area for each of the 10 hydrologic areas is shown in figure 6.

HYDROLOGIC AREAS

Area 1, as shown in figure 4, is the north-east corner of the State. It includes all the smaller streams downstream from the Niobrara River and upstream from the Platte River which are direct tributaries of the Missouri River. It also includes the left bank tributaries of the Elkhorn River which are downstream from the Sand Hill area. The area is generally quite hilly. The variation of the mean annual flood with drainage area is defined by 15 stations.

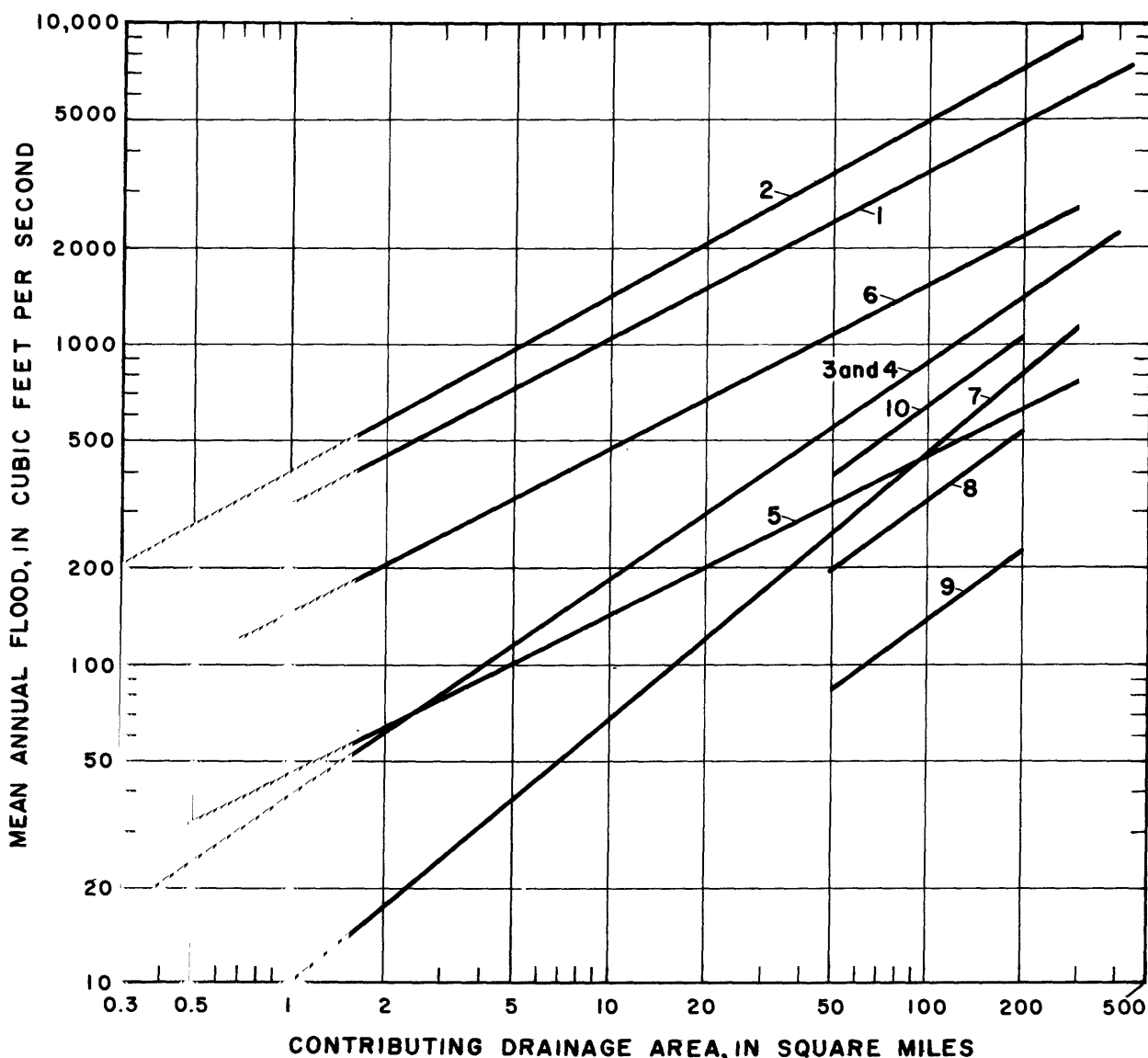


Figure 6. —Variation of mean annual flood with contributing drainage area in hydrologic areas 1-10.

Area 2 is the southeast corner of the State. It includes Salt Creek, a tributary of the Platte River, and all direct tributaries of the Missouri River in the State downstream from the Platte River. This area is also quite hilly except for a flat area in Saunders County which probably is the remains of an old Platte River channel. The five Silver Creek stations included in this report are in this flat area and their drainage areas include many depressions which trap water and prevent it from reaching the stream. Available topographic maps for this flat area do not distinguish between the contributing and the noncontributing area. Twenty-five stations are in area 2, but because the contributing drainage of the five Silver Creek stations is not defined, the curve of variation of mean annual flood with drainage area is drawn on the basis of the data from the 20 remaining stations. The mean annual floods are higher than those in area 1 because of the greater mean annual rainfall and resulting greater mean flow.

Area 3 (fig. 4) consists of the south-central plains of the State. It contains the Big Blue River, the Little Blue River, and the tributaries of the Republican River downstream from Harlan County Dam. The headwaters of these streams drain gentle sloping land, and there are some depressions which trap runoff and prevent it from reaching the streams. Seventeen stations are used to define the variation of the mean annual flood with drainage area.

Area 4 (fig. 4) includes Ponca Creek, the tributaries of the lower part of the Niobrara River, the upper part of the Elkhorn River and all its right-bank tributaries, the Loup River basin downstream from the Sand Hills, and the left-bank tributaries of the Platte River between the Loup River and the Elkhorn River. This area has a wide variety of topography and soils. Flood flow at some of the stations is materially affected by the proximity of the porous Sand Hills. Generally, it is possible to determine the contributing drainage area if good topographic maps are available. Good topographic maps have not been made for this area; therefore, some of the drainage areas are listed as approximate. Twenty-eight stations are used to define the variation of the mean annual flood with the contributing drainage area. The resulting curve is so similar to that for area 3 that one curve is shown on figure 6 as representative of both hydrologic areas.

Area 5 (fig. 4) includes the small tributaries of the Platte River in the central part of the State. The area contains some low rolling hills at the headwaters of the streams and at the perimeter of the area but toward the interior the land and stream slopes become less. As the drainage area increases, channel storage becomes a factor in reduction of the mean annual flood. Twenty-one stations are used to define the variation of the mean annual flood with drainage area.

Area 6 (fig. 4) includes the Medicine Creek basin and all left-bank tributaries of the Republican River between Medicine Creek and Harlan County Dam. This area is very hilly and contributes to surface runoff, except for the upper reaches of the Medicine Creek basin where part of the Sand Hills is located. Thirteen stations are used for defining the variation of the mean annual flood with the drainage area.

Area 7 (fig. 4) is the western part of the State that includes drainage basins of the Republican, South Platte, North Platte, Niobrara, and White Rivers. This area has a wide variety of topography and soils. Some parts of the Republican River basin have depressions and sandy areas which do not contribute to surface runoff. Thirteen stations are used to define the relation of the mean annual flood to the contributing drainage area. The definition in area 7 is considered to be the poorest in the State.

Area 8 is the southwestern part of the Sand Hills as shown in figure 4; it is defined on the basis of only one station record. The station frequency curve indicates that mean annual floods are considerably lower than those defined in area 10. The relation of the mean annual flood to contributing drainage area is defined by the one station and the slope of the relationship curve defined in area 10.

Area 9 (fig. 4) is the part of the Sand Hills north of the Niobrara River. As in area 8, only one station record is available. The station frequency curve indicates that mean annual floods are considerably lower than those in area 10. The relationship curve, as shown in figure 6, is based on the one station record and the slope of the relationship curve defined for area 10.

Area 10 (fig. 4) contains the greater part of the Sand Hills which generally drain to the

south and east. Only the area immediately adjacent to the streams contributes to surface runoff; the high base flow comes from ground water. The contributing drainage areas of the eight stations in this area are not very well defined and are listed as approximate. The range in size of the contributing drainage area is from 50 to 140 square miles.

The definition of the mean annual flood with respect to contributing drainage area covers the range of drainage area from 1 to 300 square miles in hydrologic areas 1-7. The range of drainage area defined in areas 8-10 is from 50 to 200 square miles.

## APPLICATION OF REGIONAL FLOOD-FREQUENCY DATA

### TRIBUTARY AREAS OF NATURAL RUNOFF

This section gives step-by-step procedures for determining the magnitudes of floods in Nebraska having any recurrence interval up to 25 years at any site not subject to man-made regulation or control that has a contributing drainage area between 1 and 300 square miles in region A and between 50 and 200 square miles in region B (fig. 4).

1. Determine the total and contributing drainage areas at the site. The contributing drainage area is that part of the total basin area that contributes directly to surface runoff.

2. From figure 4, obtain the number of the hydrologic area and the flood region in which the site is located.

3. With the contributing drainage area (step 1) and the number of the hydrologic area (step 2), determine the mean annual flood for the site from figure 6.

4. With the flood region (step 3) determine the ratio to the mean annual flood for the flood of the selected frequency of recurrence from figure 5.

5. Multiply the ratio of the selected flood to the mean annual flood (step 4) by the mean annual flood determined in step 3 to obtain the flood magnitude at the site. If a complete frequency graph is desired, repeat steps 4 and 5 for a number of recurrence intervals.

It must be emphasized that the curves cannot be extrapolated with confidence beyond the limits of the base data from which the curves were derived.

### STAGE OF FLOOD DISCHARGE

This report deals specifically with the frequency of flood discharges. Flood stage corresponding to these discharges may also be of primary concern in the design of certain structures and in other related studies. For rock-lined or firm-bedded streams at sites not subject to variable backwater from downstream inflow or structures, a stage-discharge relation provides a ready solution to the problem. For shifting-channel streams of Nebraska and where variable backwater may exist, the stage corresponding to the selected discharge may be approximated only after extensive research. If the stage is to be investigated, the engineer will find the site in question to be in one of two categories:

1. Site at or near an established gaging station. Gaging stations have been maintained at several hundred sites in Nebraska. Locations of those established prior to September 30, 1950, are described in reports of the Geological Survey (Water-Supply Papers 1309 and 1310). Stations established since 1950 are described in the annual series of water-supply papers entitled "Surface Water Supply of the United States." A reasonable stage-discharge relation has been established at each of the small-area stations used for this report, and may be examined in the Lincoln office of the Geological Survey. For sites at or near gaging stations, it is usually possible to obtain stage data that are adequate for most purposes.

2. Site not near an established gaging station. The stage corresponding to a discharge of selected recurrence interval must generally be obtained through the medium of a stage-discharge relation. The extent of the investigation required to establish such a relation will depend upon the accuracy requirements. The following methods of deriving a stage-discharge relation are noted in decreasing order of reliability. (a) If the need for data can be anticipated far enough in advance, discharge measurements may be obtained to define the relation up to the maximum discharge observed in the period. The

relation may be extended by the application of measured channel characteristics to appropriate hydraulic formulas. Shifting-channel characteristics may be investigated by studies of bed material and some long-term changes may be obtained from local residents. (b) If the need for data is immediate, the discharge for a past flood may be computed by hydraulic formulas if adequate floodmarks can be recovered and one point on the stage-discharge relation curve thereby established. A direct measurement of discharge at the time of the visit will provide one other point. (c) A method has been used to develop ratings for stable channels from the product of the stream slope at zero flow or low flow and characteristics of conveyance at a typical cross section. This method is unsuited to streams with unstable channel beds.

### MAXIMUM KNOWN FLOODS

The design of major hydraulic structures whose failure may cause loss of life should consider the maximum probable flood rather than one that may be expected to occur in a defined period of years. A prerequisite to such an analysis is the record of maximum known floods.

Maximum known stages and discharges at the 142 gaging stations used in the flood-frequency analyses are shown in table 2. The stations are listed in downstream order and the number preceding the station name corresponds with the numbers shown in table 1 and figure 2. The flood region and hydrologic area in which the station is located is shown as well as the total and contributing drainage area. The contributing drainage area is used to compute the peak discharge in cubic feet per second per square mile. The period of known floods is that for which the stage or discharge is known to be the greatest. The stage is given for each maximum discharge except for stations 7730 and 7829. The discharge at these two stations had been determined from an indirect measurement prior to the establishment of the gage and there is no datum tie between the survey and the gage. Where the maximum stage and the maximum discharge are not concurrent, a change in the

stage-discharge relation is indicated, and no discharge figure is shown for the maximum stage. Some periods of known floods for the maximum stage are extended on the basis of recovered floodmarks beyond the period of known floods for the maximum defined discharge. For such periods, a leader line has been placed in the discharge column to indicate that the discharge for this known stage could not be defined within allowable limits of accuracy. A leader line in other columns is also used to indicate that the information could not be determined.

Twenty-five unusual peak discharges have been collected at miscellaneous sites or at short-term gaging stations which have 300 square miles or less contributing drainage area. These data are shown in table 3. The sites are listed in downstream order. Gaging stations having records of insufficient length to be included in the flood-frequency analysis have been operated or are being operated at numbered sites. Unnumbered sites are miscellaneous sites where only one observation has been made.

As shown in figure 5, there is a great difference in the composite frequency curve for region A and for region B, and the curves of figure 6 show that the mean annual flood for a given drainage area can vary considerably between hydrologic areas. A separate illustration was developed, therefore, for each of the 10 hydrologic areas on which the 10- and 25-year recurrence interval floods are shown as a curve to compare with the maximum discharge at the stations and miscellaneous sites in that hydrologic area. The maximum discharge at the 142 stations used in this frequency analysis are shown as open circles, and the maximum discharge at the miscellaneous sites and short-term gaging stations which are listed in table 3 are shown as closed circles. The gaging stations are identified by the last four or five digits of the index number, in order to correspond with those shown in tables 2 and 3.

The relation of the maximum discharge to the 10- and 25-year floods in the 10 hydrologic regions are shown in figures 7-11.

Table 2.—Maximum stages and discharges at gaging stations

Number	Gaging station	Flood region and hydrologic area	Drainage area (square miles)		Period of known floods	Maximum stage and discharge			Station mean annual flood (Q <sub>2.33</sub> in cfs)	Ratio of maximum to Q <sub>2.33</sub>
			Total	Contributing		Date	Gage height (feet)	Discharge (Cfs)		
	<i>White River basin</i>									
6A-4432	White River tributary near Glen	A7	7.97	7.97	1953-59	Sept. 20, 1955	13.30	300	32	9.4
4437	Soldiers Creek near Crawford	A7	52.6	52.6	1955-59	July 10, 1958	21.90	3,970	691	5.7
4440	White River at Crawford	A7	313	313	1931-44, 1948-59	Mar. 15, 1948	6.88	2,000	961	2.1
4448	Chadron Creek near Chadron	A7	14.9	14.9	1953-59	July 10, 1958	7.7	1,610	238	6.8
	<i>Ponca Creek basin</i>									
4535	Ponca Creek at Anoka	A4	410	410	1949-59	Apr. 2, 1950	15.0	6,770	1,850	3.7
	<i>Niobrara River basin</i>									
4563	Pebble Creek near Dunlap	A7	23.5	23.5	1953-59	July 28, 1953	12.88	2,740	562	4.9
4564	Cottonwood Creek near Dunlap	A7	82.2	82.2	1948, 1951-59	July 28, 1951	20.10	28,100	1,296	21.7
4577	Antelope Creek at Gordon	A7	61.1	61.1	1953-59	May 24, 1958	17.86	4,740	76	5.8
4578	Antelope Creek tributary near Gordon.	A7	26.6	26.6	1953-59	June 17, 1955	16.69	1,900	63	30.2
4585	Bear Creek near Eli	B9	360	78	1948-53, 1950-53	May 20, 1951	5.07	145	115	1.3
4595	Snake River near Burge	B10	620	100	1948-59	Mar. 14, 1953	5.20	---	---	---
4610	Minnechadza Creek at Valentine	A4	510	200	1948-59	May 26, 1955	4.04	577	470	1.2
4625	Plum Creek near Meadville	A4	581	330	1948-59	Mar. 30, 1952	6.58	894	185	4.8
4635	Long Pine Creek near Riverview	A4	390	390	1948-59	May 25, 1952	4.46	820	536	1.5
					1949-53, 1955-59	June 19, 1953	9.72	---	---	---
						Aug. 20, 1951	10.24	5,410	1,200	4.5
4665	Bazile Creek near Niobrara	A1	440	440	1951-59	June 16, 1957	19.96	68,600	9,790	7.0

MAXIMUM KNOWN FLOODS

<i>Omaha Creek basin</i>											
6B-6006	South Omaha Creek tributary near Walthill.	A1	2.64	2.64	1950-59	June 16, 1957	14.57	1,410	534	343	4.1
6007	South Omaha Creek near Walthill	A1	15.1	15.1	1950-59	June 21, 1954	18.71	10,100	669	1,220	8.3
6008	South Omaha Creek tributary 2 near Walthill.	A1	1.51	1.51	1950-59	June 20, 1954	12.90	2,150	1,424	424	5.1
6009	South Omaha Creek at Walthill	A1	51.0	51.0	1951-59	June 13, 1957	24.92	14,200	278	1,470	9.7
6010	Omaha Creek at Homer	A1	170	170	1920-59 1946-59	June 4, 1940 July 2, 1958	<sup>a</sup> 32.5 23.62	14,400	84.7	4,080	3.5
<i>Tekamah Creek basin</i>											
6077	South Branch Tekamah Creek near Craig.	A1	2.54	2.54	1950-59	July 15, 1950	21.3	<sup>a</sup> 2,580	1,020	661	3.9
6078	South Branch Tekamah Creek tributary near Tekamah.	A1	4.08	4.08	1950-59	do	19.3	<sup>a</sup> 1,800	441	694	2.6
6079	South Branch Tekamah Creek near Tekamah.	A1	9.73	9.73	1950-59	Apr. 21, 1954	20.17	3,130	322	1,060	3.0
6080	Tekamah Creek at Tekamah	A1	23.0	23.0	1950-59	July 15, 1950 Aug. 13, 1958	14.26 15.10	4,400	191	2,190	2.0
<i>New York Creek basin</i>											
6086	New York Creek near Spiker	A1	1.75	1.75	1952-59	June 15, 1957	16.19	1,380	789	359	3.8
6087	New York Creek tributary near Spiker.	A1	1.55	1.55	1951-59	June 21, 1957	17.80	1,580	1,020	392	4.0
6088	New York Creek north of Spiker	A1	6.50	6.50	1951-59	do	23.40	3,160	486	1,040	3.0
6089	New York Creek east of Spiker	A1	13.9	13.9	1950-59	July 2, 1951	24.14	6,020	433	1,320	4.6
6090	New York Creek at Herman	A1	25.4	25.4	1944, 1946-59,	June 11, 1944	<sup>e</sup> 20.8				
<i>Platte River basin</i>											
6840	Red Willow Creek near Bayard	A7	162	162	1932-59	May 10, 1942	7.8				
6870	Blue Creek near Lewellen	B8	267	267	1931-59	July 3, 1956 May 20, 1938	7.33 <sup>f</sup> 4.46	2,320 <sup>g</sup> 723	14.3 9.0	1,260 278	1.8 2.6
6920	Birdwood Creek near Hershey	B10	286	286	1932-59	Dec. 21, 1945	<sup>f</sup> 4.93				
7671	South Fork Plum Creek tributary near Farnam.	A5	9.81	9.81	1951-59	Dec. 15, 1940 Apr. 1, 1949	5.12 4.35	1,770	22.1	470	3.8
7673	Plum Creek tributary at Farnam	A5	19.8	19.8	1925-59 1951-59	June 8, 1951 June 22, 1948 June 8, 1951	13.88 <sup>h</sup> 18.8 13.36	1,170 2,070	119 105	440 150	2.7 13.8

See footnotes at end of table.



## FLOODS IN NEBRASKA ON SMALL DRAINAGE AREAS, MAGNITUDE AND FREQUENCY

Table 2.—Maximum stages and discharges at gaging stations—Continued

Number	Gaging station	Flood region and hydrologic area	Drainage area (square miles)		Period of known floods	Maximum stage and discharge				Station mean annual flood (Q <sub>2.33</sub> in cfs)	Ratio of maximum to Q <sub>2.33</sub>	
			Total	Contributing		Date	Gage height (feet)	Cfs	Cfs per square mile			
Platte River basin—Continued												
6B-7674	North Plum Creek near Farnam	A5	38.3	38.3	1947, 1951-59	June 22, 1947	17.8					
7674.1	Plum Creek near Farnam	A5	79.8	79.8	1947, 1951-59	June 8, 1951	14.3	385	10.1	200	1.9	
7675	Plum Creek near Smithfield	A5	229	229	1947-59	Apr. 22, 1957	12.20	170	2.1	140	1.2	
7681	East Branch Buffalo Creek tributary near Buffalo.	A5	5.24	5.24	1947-59	June 23, 1947	23.41	2,800	12.2	410	6.8	
7682	East Branch Buffalo Creek near Buffalo.	A5	32.8	28.3			19.4					
7683	East Branch Buffalo Creek tributary 2 near Buffalo.	A5	2.10	2.10	1951-59	July 19, 1958	18.26	1,570	55.5	170	9.2	
7684	West Branch Buffalo Creek near Buffalo.	A5	16.3	16.3	1951-59	June 12, 1958	12.52	172	81.9	40	4.3	
7685	Buffalo Creek near Darr	A5	63	58.5	1947-59	July 19, 1958	15.81	475	29.1	85	5.6	
7690	Buffalo Creek near Overton	A5	175	170	1949-58	June 22, 1947	18.4	9,000	154	260	34.6	
7691	Elm Creek tributary near Overton	A5	.54	.54	1951-59	July 10, 1958	13.59	142	263	54	2.6	
7692	Elm Creek near Sumner	A5	14.9	14.9	1951-59	do	14.41	271	18.2	100	2.7	
7693	Elm Creek tributary 2 near Overton.	A5	5.19	5.19	1951-59	do	13.03	276	53.2	203	1.4	
7695	Elm Creek near Overton	A5	31	31	1935-58	1935	20.22					
7707	Wood River near Lodi	A5	12.9	12.9	1947-58	June 22, 1947	19.65	8,000	258	380	21.1	
7708	Wood River near Oconto	A5	26.4	26.4	1952-59	June 16, 1955	11.63	142	11.0	90	1.6	
7709	Wood River at Oconto	A5	44.8	44.8	1950, 1952-59	June 17, 1954	14.47	790	29.9	600	1.3	
7709.1	Wood River near Lomax	A5	79.6	77.9	1952-59	July 19, 1958	18.58	2,390	53.3	450	5.3	
					1952-59	July 19, 1958	19.67	1,470	18.9	320	4.6	

MAXIMUM KNOWN FLOODS

7710	Wood River near Riverdale	A5	379	379	1946-59	June 22, 1947	19.75	20,000	52.8	710	28.2
7730	Dry Creek at Cairo	A5	22.2	22.2	1949-53	June 6, 1949	---	1,100	46.6	570	1.9
7750	Middle Loup River near Seneca	B10	60	1,140	1950-53	May 27, 1953	7.64	586	---	---	---
7755	Middle Loup River at Dunning	B10	80	1,760	1948-53	Jan. 7, 1949	2.61	457	7.6	372	1.2
7765	Dismal River at Dunning	B10	50	1,780	1946-59	Aug. 8, 1950	2.09	830	10.4	670	1.2
7777	Lillian Creek near Broken Bow	A4	4.77	4.77	1946-59	Mar. 31, 1949	7.02	996	19.9	564	1.8
7778	Lillian Creek tributary 2 near Walworth.	A4	2.04	2.04	1946-59	Sept. 13, 1958	3.90	---	---	---	---
7826	South Branch Mud Creek tributary near Broken Bow.	A4	.43	.43	1946-59	Jan. 19, 1947	5.21	---	---	---	---
7827	South Branch Mud Creek at Broken Bow.	A4	45.9	400	1932, 1946-59	May 26, 1952	3.18	---	---	---	---
7828	North Branch Mud Creek at Broken Bow.	A4	15.5	15.5	1946-59	June 22, 1947	e12.2	930	195	74	12.6
7829	Mud Creek tributary near Broken Bow.	A4	5.98	5.98	1951-59	Aug. 12, 1951	e12.4	585	287	37	15.8
7830	Mud Creek near Broken Bow.	A4	81.1	440	1951-59	July 18, 1958	12.43	184	428	74	2.5
7843	Oak Creek near Loup City	A4	41.9	41.9	1948-59	June 17, 1956	16.41	1,790	39.0	74	24.2
7845	Oak Creek near Dannebrog	A4	122	122	1951-59	do	16.16	1,550	144	194	8.0
7847	Turkey Creek near Farwell	A4	27.2	27.2	1945, 1951-59	May 27, 1945	---	1,500	251	74	20.3
7855	North Loup River at Brewster	B10	140	1,890	1946-51	Feb. 25, 26, 1950	4.20	870	---	---	---
7860	North Loup River at Taylor	B10	180	2,210	1937-59	June 14, 1951	b3.40	a1,600	11.4	840	1.9
7875	Calamus River near Burwell	B10	110	1,260	1941-59	do	6.50	e2,830	15.7	1,400	2.0
7891	Davis Creek tributary near North Loup.	A4	2.29	2.29	1951-59	Feb. 25, 1957	e9.5	---	---	---	---
7892	Davis Creek tributary 2 near North Loup.	A4	6.79	6.79	1951-59	Mar. 19, 1950	5.19	---	---	---	---
7893	Davis Creek near North Loup	A4	21.1	21.1	1951-59	May 16, 1951	3.76	1,060	9.6	558	1.9
7894	Davis Creek southwest of North Loup.	A4	41.6	41.6	1951-59	July 3, 1951	17.74	a906	396	324	2.8
						July 14, 1957	16.82	722	106	194	3.7
						do	15.68	1,820	86.3	695	2.7
						June 16, 1957	e21.5	---	---	---	---
						June 16, 1957	19.35	2,220	53.4	1,040	2.1

See footnotes at end of table.

Table 2.—Maximum stages and discharges at gaging stations—Continued

Number	Gaging station	Flood region and hydrologic area	Drainage area (square miles)		Period of known floods	Maximum stage and discharge			Station mean annual flood (Q <sub>2.33</sub> in cfs)	Ratio of maximum to Q <sub>2.33</sub>	
			Total	Contributing		Date	Gage height (feet)	Discharge			Cfs per square mile
Platte River basin—Continued											
6B-7895	Davis Creek near Cotesfield	A4	94	94	1948-58	July 9, 1958	12.73	1,720	18.3	805	2.1
7907	West Branch Spring Creek at Brayton.	A4	19.5	19.5	1945-59	July 16, 1945	18.4	3,700	190	1,660	2.2
7908	West Branch Spring Creek near Wolbach.	A4	36.9	36.9	1951-59	May 10, 1953	17.20	4,040	109	1,200	3.4
7909	Mary's Creek at Wolbach	A4	7.63	7.63	1952-59	Apr. 5, 1958	13.78	---	---	---	---
					1952-57, 1959	May 20, 1959	11.79	215	28.2	202	1.1
7911	Spring Creek near Cushing	A4	165	165	1948-59	May 10, 1953	24.56	5,350	32.4	1,410	3.8
7915	Cedar River near Spalding	A4	794	50	1945-53, 1958-59	June 23, 1947	7.50	4,000	80.0	592	6.8
7935	Beaver Creek at Loretto	A4	311	100	1946-53	June 2, 1950	11.74	4,570	45.7	1,260	3.6
7950	Shell Creek at Newman Grove	A4	122	122	1892-1959	July 18, 1950	20.20	12,000	98.4	2,680	4.5
7955	Shell Creek near Columbus	A4	270	270	1913-59	June 2, 1947	21.7	---	---	---	---
7980	South Fork Elkhorn River at Ewing.	A4	320	190	1944, 1947-53	June 3, 1950	21.38	5,970	22.1	1,490	4.0
8015	Salt Creek subwatershed 12 at Roca.	A2	1.12	1.12	1954-59	June 21, 1947	7.22	3,400	17.9	648	5.3
8025	Salt Creek subwatershed 34 near Roca.	A2	5.72	5.72	1954-59	July 10, 1958	7.95	528	471	408	1.3
8030	Salt Creek at Roca	A2	174	174	1909-59	July 2, 1956	9.93	---	---	---	---
8035.7	Wahoo Creek tributary near Weston.	A2	.31	.31	1950-59	Aug. 18, 1956	9.89	2,600	455	784	3.3
					1950-59	May 8, 1950	26.0	67,000	385	7,510	8.9
8036	North Fork Wahoo Creek near Prague.	A2	15.2	15.2	1951-59	June 1, 1951	13.90	550	1,774	224	2.5
8037	Dunlap Creek near Weston	A2	8.90	8.90	1950-59	May 31, 1951	30.68	12,800	842	2,860	4.5
8039	North Fork Wahoo Creek at Weston.	A2	43.7	43.7	1901-59	Aug. 2, 1959	31.12	12,800	842	2,860	4.5
					1901-59	May 31, 1951	18.20	4,130	464	1,310	3.2
8040	Wahoo Creek at Ithaca	A2	272	272	1910-59	Aug. 2, 1959	22.36	9,600	220	2,700	3.6
					1910-59	Aug. 2, 1959	23.22	45,300	167	4,570	9.9

MAXIMUM KNOWN FLOODS

8041	Silver Creek near Cedar Bluffs	A2	10.9	-----	1894-- 1959	--do-----	15.02	4,040	-----	653	6.2
8042	Silver Creek near Colon	A2	29.9	-----	1894-- 1959	--do-----	19.22	12,000	-----	1,320	9.1
8043	Silver Creek tributary near Colon.	A2	14.3	-----	1894-- 1959	--do-----	17.32	5,000	-----	261	19.2
8044	Silver Creek tributary at Colon	A2	22.4	-----	1894-- 1959	--do-----	19.29	4,640	-----	351	13.2
8045	Silver Creek at Ithaca	A2	72	-----	1894-- 1959	--do-----	16.92	21,600	-----	816	26.5
<i>Weeping Water Creek basin</i>											
8064	Weeping Water Creek at Elmwood	A2	21.4	21.4	1950-59	May 9, 1950	<sup>e</sup> 24.6	7,600	355	2,640	2.9
8064.2	Stove Creek near Elmwood	A2	4.94	4.94	1950-59	--do-----	<sup>e</sup> 18.2	5,370	1,087	2,020	2.7
8064.4	Stove Creek at Elmwood	A2	10.0	10.0	1950-59	--do-----	<sup>e</sup> 23.0	9,500	950	2,010	4.7
8064.6	Weeping Water Creek at Weeping Water.	A2	75.5	75.5	1882-- 1959	--do-----	<sup>e</sup> 18.5	30,300	401	3,920	7.7
8064.7	Weeping Water Creek tributary near Weeping Water.	A2	1.07	1.07	1950-59	May 15, 1954	18.02	1,160	1,084	416	2.8
8065	Weeping Water Creek at Union	A2	238	238	1947-59	May 9, 1950	<sup>j</sup> 26.80	60,300	253	4,900	12.3
<i>Little Nemaha River basin</i>											
8101	Hooper Creek tributary near Palmyra.	A2	7.81	7.81	1950-59	June 1, 1951	16.55	3,090	396	1,140	2.7
8102	Hooper Creek near Palmyra	A2	57.5	57.5	1950-59	May 9, 1950	<sup>e</sup> 23.0	47,600	828	4,490	10.6
8103	Owl Creek near Syracuse	A2	25.4	25.4	1950-59	--do-----	<sup>e</sup> 30.6	<sup>a</sup> 16,000	630	2,860	5.6
8104	Little Nemaha River tributary near Syracuse.	A2	.76	.76	1950-59	--do-----	<sup>e</sup> 16.6	1,280	1,684	465	2.8
8105	Little Nemaha River near Syracuse.	A2	218	218	1950-59	--do-----	<sup>e</sup> 36.7	225,000	1,032	12,200	18.4
<i>Nemaha River basin</i>											
8155	Muddy Creek at Verdon	A2	188	188	1953-59	July 10, 1958	31.50	31,900	170	9,470	3.4
<i>Kansas River basin</i>											
8230	North Fork Republican River at Colo.-Nebr. State line.	A7	320	130	1931-59	Apr. 28, 1947	5.92	2,110	16.2	611	3.5
8235	Buffalo Creek near Haigler	A7	180	21	1941-59	June 27, 1948	4.37	<sup>a</sup> 140	6.7	38	3.6
8240	Rock Creek at Parks	A7	180	14	1941-59	Sept. 3, 1951	3.80	95	6.8	43	2.2
8360	Blackwood Creek near Culbertson	A7	290	290	1946-59	June 17, 1955	14.64	1,650	5.7	648	2.5

See footnotes at end of table.

Table 2.—Maximum stages and discharges at gaging stations—Continued

Number	Gaging station	Flood region and hydrologic area	Drainage area (square miles)		Period of known floods	Maximum stage and discharge			Station mean annual flood (in cfs) $Q_{2.33}$ to $Q_{2.33}$	Ratio of maximum to $Q_{2.33}$	
			Total	Contributing		Date	Gage height (feet)	Cfs			Cfs per square mile
<i>Kansas River basin—Continued</i>											
6B-8390	Medicine Creek at Maywood	A6	207	82	1951-59	May 20, 1951	<sup>b</sup> 9.90	<sup>a</sup> 2,120	25.9	314	6.8
8392	Elkhorn Canyon near Maywood	A6	6.74	6.74	1952-59	July 5, 1956	17.44	1,220	181	303	4.0
8394	Elkhorn Canyon southwest of Maywood.	A6	13.2	13.2	1952-59	---do---	<sup>a</sup> 27.2	8,660	656	864	10.0
8395	Brushy Creek near Maywood.	A6	130	72	1906-59	June 21, 1947	<sup>e</sup> 30.4	<sup>a</sup> 70,000	972	2,590	27.0
8396	Frazier Creek near Maywood.	A6	11.3	11.3	1952-59	July 5, 1956	<sup>e</sup> 27.30	11,200	991	972	11.5
8397	Frazier Creek tributary near Maywood.	A6	.72	.72	1952-59	---do---	11.53	483	671	162	3.0
8398.5	Fox Creek north of Curtis	A6	13.8	13.8	1952-59	May 19, 1959	12.85	2,080	151	454	4.6
8399	Fox Creek above Cut Canyon near Curtis.	A6	31.8	31.8	1951-59	May 20, 1951	23.0	2,810	88.4	594	4.7
8399.5	Cut Canyon near Curtis	A6	25.6	25.6	1951-59	July 14, 1952	19.6	1,560	60.9	551	2.8
8400	Fox Creek at Curtis	A6	77	77	1947-58	June 21, 1947	<sup>e</sup> 27.3	---	---	---	---
8405	Dry Creek near Curtis	A6	20	20	1951-58	May 31, 1951	15.35	3,340	43.4	778	4.3
8415	Mitchell Creek above Harry Strunk Lake.	A6	53	53	1947-58	June 21, 1947	<sup>e</sup> 27.7	<sup>m</sup> 25,900	1,300	940	27.6
8440	Muddy Creek at Arapahoe	A6	243	243	1888-1959	June 21, 1948	<sup>e</sup> 28	---	---	---	---
8500	Turkey Creek at Naponee	A3	138	138	1950-59	May 20, 1951	17.35	5,230	98.7	983	5.3
8502	Cottonwood Creek near Bloomington.	A3	15.6	15.6	1947-59	June 22, 1947	<sup>e</sup> 31	---	---	---	---
8510	Center Creek at Franklin	A3	146	57.4	1951-59	June 16, 1957	24.62	7,280	30.0	2,700	2.7
8511	West Branch Thompson Creek at Hildreth.	A3	27.4	27.4	1948-53	Sept. 20, 1950 <sup>n</sup>	9.50	1,920	13.9	694	2.8
8512	West Branch Thompson Creek near Hildreth.	A3	56.6	56.6	1948-56	June 4, 1955	6.65	1,100	70.5	500	2.2
8513	West Branch Thompson Creek tributary near Hildreth.	A3	13.9	13.9	1948-56	Sept. 20, 1950	<sup>e</sup> 6.8	3,150	54.9	278	11.3
8514	West Branch Thompson Creek near Upland.	A3	90.8	90.8	1953-59	Aug. 15, 1958	13.93	1,290	47.1	398	3.2
					1953-59	June 15, 1957	18.35	1,670	29.5	407	4.1
					1953-59	---do---	18.20	907	65.3	324	2.8
					1953-59	---do---	14.89	2,040	22.5	555	3.7

8515	Thompson Creek at Riverton.-----	A3	223	223	1948-56	July 9, 1950	13.22	12,200	54.7	2,220	5.5
8520	Elm Creek at Amboy.-----	A3	39.2	39.2	1948-53	Sept. 20, 1950	9.45	3,860	98.5	964	4.0
8807.1	School Creek tributary near Harvard.	A3	13.1	13.1	1952-59	Sept. 6, 1958	12.14	164	12.5	104	1.6
8807.2	School Creek near Harvard.-----	A3	55.1	55.1	1953-59	July 10, 1958	16.74	960	17.4	440	2.2
8807.3	School Creek tributary 2 near Harvard.	A3	14.0	14.0	1953-59	-----do-----	16.17	510	36.4	213	2.4
8807.4	School Creek near Saronville.-----	A3	89.4	89.4	1952-59	July 14, 1952	<sup>e</sup> 17.6	1,280	14.3	888	1.4
8836	South Fork Big Sandy Creek near Edgar.	A3	15.2	15.2	1953-59	Aug. 16, 1957	13.56	595	39.1	185	3.2
8837	South Fork Big Sandy Creek near Davenport.	A3	32.0	32.0	1950, 1952-59	July 9, 1950	<sup>h</sup> 17.3	<sup>a</sup> 1,400	43.8	352	4.0
8838	South Fork Big Sandy Creek near Carleton.	A3	49.4	49.4	1952-59	July 14, 1952	<sup>e</sup> 16.4	1,740	35.2	629	2.8
8839	South Fork Big Sandy Creek near Hebron.	A3	81.9	81.9	1952-59	June 27, 1952	<sup>e</sup> 21.8	3,160	38.6	1,520	2.1

<sup>a</sup> Approximate.

<sup>b</sup> Maximum observed.

<sup>c</sup> Approximate natural peak.

<sup>d</sup> Regulated peak; affected by backwater.

<sup>e</sup> From floodmark.

<sup>f</sup> Datum then in use.

<sup>g</sup> Adjusted for diversion.

<sup>h</sup> From information by local residents.

<sup>j</sup> Present site and datum.

<sup>k</sup> Exceeded by flood of Apr. 24, 1935.

<sup>m</sup> At site 2-3/4 miles upstream, from slope-area measurement.

<sup>n</sup> One of the greatest floods known occurred June 22, 1947; stage and discharge unknown.

Table 3.—Unusual peak discharges at miscellaneous sites and at short-term gaging stations with contributing drainage area of 300 square miles or less

Number	Stream and place of determination	Tributary to—	Flood region and hydrologic area	Drainage area (square miles)		Period of known floods	Maximum stage and discharge			
				Total	Contributing		Date	Gage height (feet)	Discharge	Cfs per square mile
6A-4433	White River basin Deep Creek near Glen, SE $\frac{1}{4}$ sec. 32, T. 31 N., R. 53 W.	White River -----	A7	10.9	10.9	1952-59	Aug. 15, 1953	16.42	3,050	280
4562	Niobrara River basin Pebble Creek near Esther, NW $\frac{1}{4}$ sec. 10, T. 30 N., R. 49 W.	Cottonwood Creek.	A7	3.07	3.07	1953-59	July 28, 1953	18.67	2,000	651
4631	Bone Creek tributary near Ainsworth, NW $\frac{1}{4}$ sec. 17, T. 30 N., R. 22 W.	Long Pine Creek.	A4	.39	.39	1956-59	July 3, 1959	12.11	150	385
4632	Bone Creek tributary 2 near Ainsworth, SE $\frac{1}{4}$ sec. 8, T. 30 N., R. 21 W.	-----do-----	A4	2.18	2.18	1958-59	May 30, 1958	10.93	60	27.5
4633	Sand Draw tributary near Ainsworth, NW $\frac{1}{4}$ sec. 6, T. 30 N., R. 22 W.	Bone Creek -----	A4	1.07	1.07	1956-59	July 3, 1959	12.54	126	118
	Platte River basin Dead Horse Creek tributary at Loup City, SE $\frac{1}{4}$ sec. 7, T. 15 N., R. 14 W.	Middle Loup River.	A4	3.2	3.2	-----	June 17, 1954	-----	944	295
	Dead Horse Creek at Loup City, NW $\frac{1}{4}$ sec. 17, T. 15 N., R. 14 W.	-----do-----	A4	6.2	6.2	-----	-----do-----	-----	2,410	389
	Elm Creek near Fremont, SE $\frac{1}{4}$ sec. 34, T. 17 N., R. 8 E.	Platte River -----	A2	4.7	4.7	-----	Aug. 2, 1959	-----	2,840	604
	Union Creek tributary near Madison, NW $\frac{1}{4}$ sec. 8, T. 21 N., R. 1 W.	Elkhorn River -----	A4	2.5	2.5	-----	June 2, 1950	-----	2,560	1,024





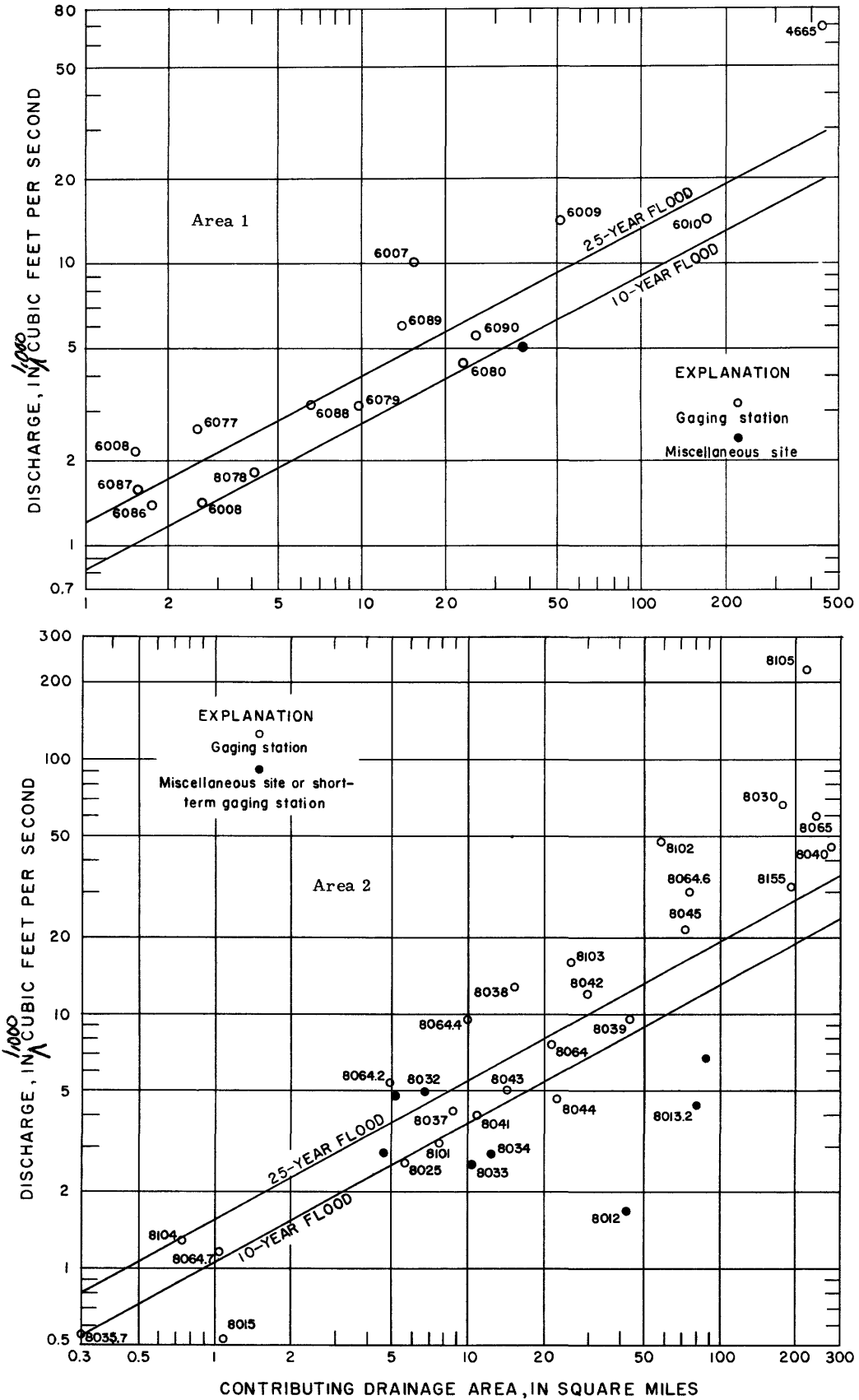


Figure 7.—Relation of maximum discharge to 10 and 25-year floods, region A, areas 1 and 2.



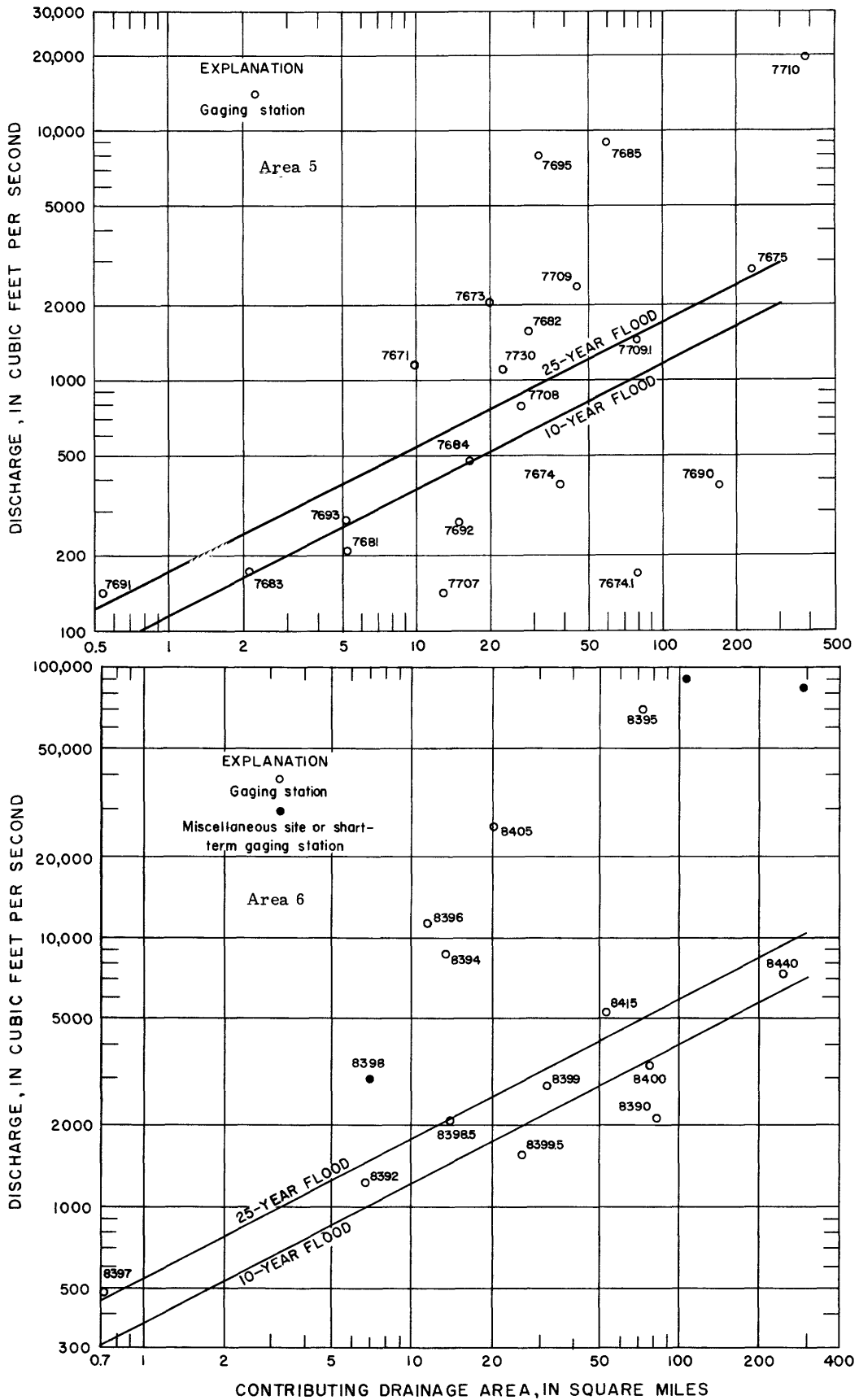


Figure 9.—Relation of maximum discharge to 10 and 25-year floods, region A, areas 5 and 6.

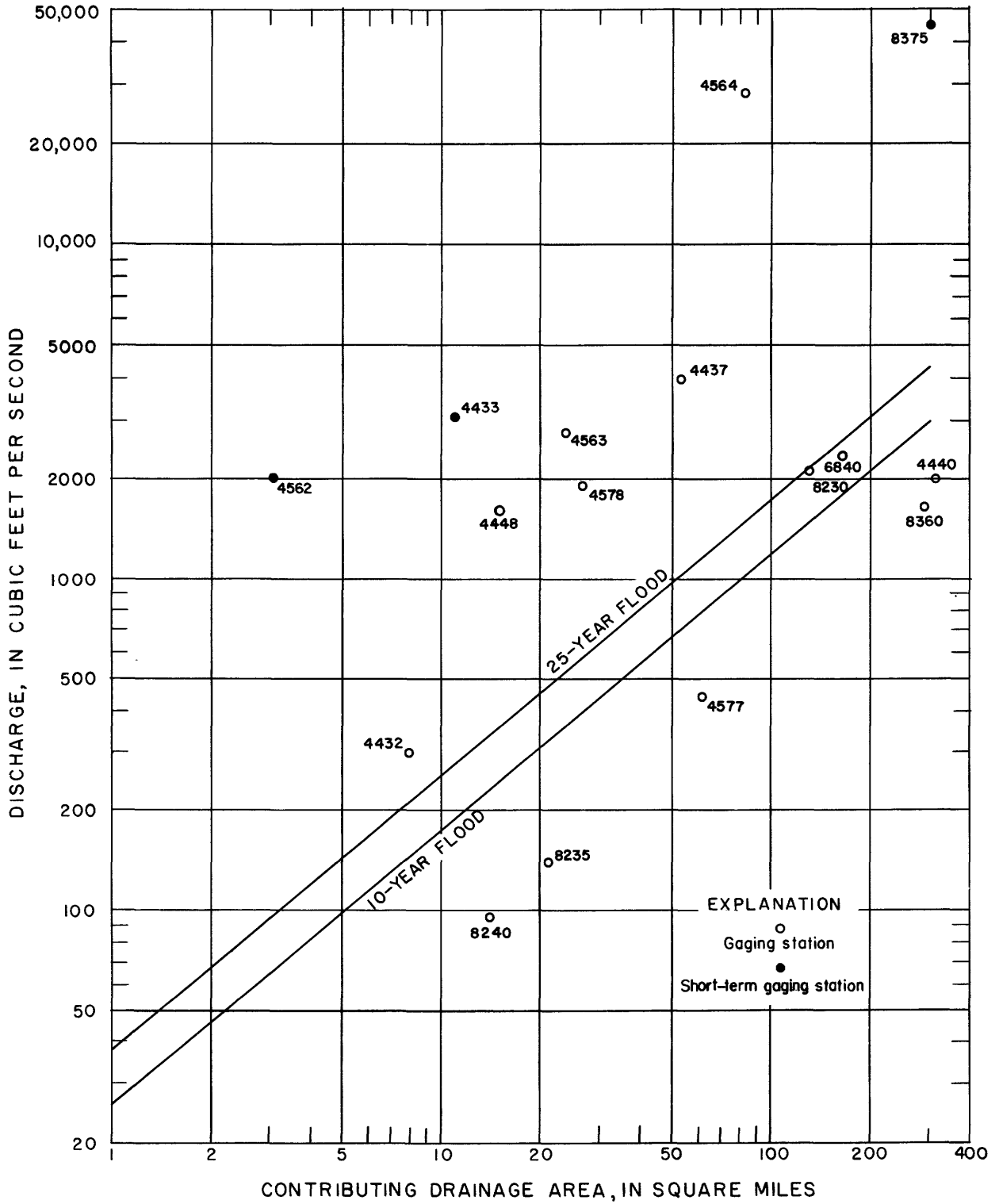


Figure 10. —Relation of maximum discharge to 10 and 25-year floods, region A, area 7.

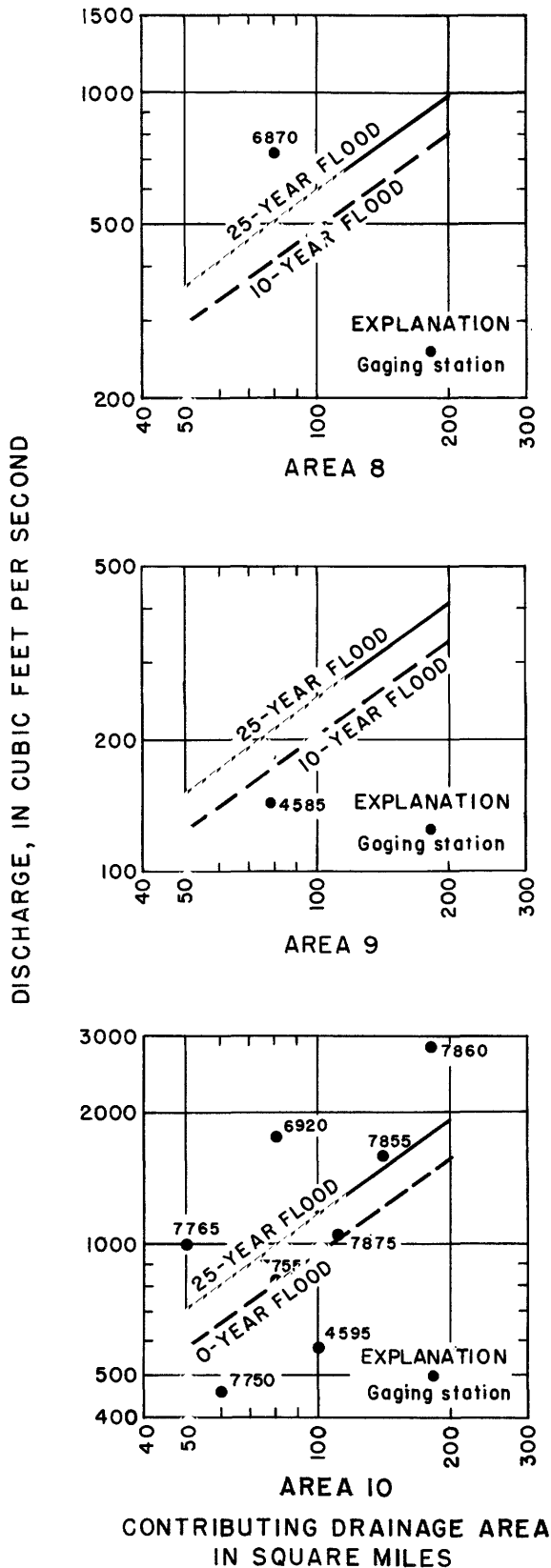


Figure 11. —Relation of maximum discharge to 10 and 25-year floods, region B, areas 8, 9 and 10.

## SUMMARY

The accuracy of flood magnitudes for selected recurrence intervals obtained by methods outlined in this report is contingent upon the number of stations used, and the length of each record. When more data are obtained and, perhaps, improved methods of analysis are developed, better definition of the flood regime will be possible.

The curves presented are based on all available annual peak data through the 1959 water year on uncontrolled and unregulated streams having 300 square miles or less contributing drainage area, and 5 or more years' record of annual peaks. The regional frequency curves cannot be extrapolated with confidence beyond 25 years. The drainage area-mean annual flood curves should not be extended beyond the limits shown.

The curves presented in this report should not be used on controlled and regulated streams.

## SELECTED REFERENCES

- Benson, M. A., 1960, Characteristics of frequency curves based on a theoretical 1,000-year record, in Dalrymple, Tate, Flood-frequency analyses: U.S. Geol. Survey Water-Supply Paper 1543-A, p. 51-74.
- Berwick, V. K., 1958, Floods in eastern Montana, magnitude and frequency: U.S. Geol. Survey open-file report.
- Bigwood, B. L., and Thomas, M. P., 1955, A flood-flow formula for Connecticut: U.S. Geol. Survey Circ. 365.
- Bodhaine, G. L., and Robinson, W. H., 1952, Floods in western Washington, frequency and magnitude in relation to drainage basin characteristics: U.S. Geol. Survey Circ. 191.
- Carter, R. W., 1951, Floods in Georgia, frequency and magnitude: U.S. Geol. Survey Circ. 100.
- Chow, Ven Te, 1950, Discussion of W. B. Langbein's paper "Annual floods and the partial-duration flood series:" Am. Geophys. Union Trans., v. 30, p. 939-941.
- Condra, G. E., 1920, The soil resources of Nebraska: The Nebraska Conservation and Soil Survey, Univ. of Nebraska, Bull. 15, p. 1-76.
- Cragwall, J. S., Jr., 1952, Floods in Louisiana, magnitude and frequency: Louisiana Dept. of Highways.

- Cross, W. P., and Webber, E. E., 1959, Floods in Ohio, magnitude and frequency: Ohio Dept. of Natural Resources, Div. of Water Bull. 32.
- Dalrymple, Tate, 1960, Flood-frequency analyses: U.S. Geol. Survey Water-Supply Paper 1543-A.
- Darling, J. M., 1959, Floods in Maryland, magnitude and frequency: U.S. Geol. Survey open-file report.
- Ellis, D. W., and Edelen, G. W., Jr., 1960, Flood frequency, pt. 3 of Kansas stream-flow characteristics: Kansas Water Resources Board Tech. Rept. 3.
- Furness, L. W., 1955, Floods in Nebraska, magnitude and frequency: Nebraska Dept. of Roads and Irrigation, p. 2-3.
- Green, A. R., and Hoggatt, R. E., 1960, Floods in Indiana, magnitude and frequency: U.S. Geol. Survey open-file report.
- Gumbel, E. J., 1945, Floods estimated by probability method: Eng. News-Rec., v. 134, no. 24, p. 833-837.
- Jenkins, D. S., and others, 1946, The origin, distribution, and airphoto identification of United States soils: U.S. Dept. of Commerce, Civil Aeronautics Adm., Tech. Devel. Rept. 52, pl. 1.
- Langbein, W. B., 1949, Annual floods and the partial-duration series: Am. Geophys. Union Trans., v. 30, p. 879-881.
- McCabe, J. A., 1958, Floods in Kentucky, magnitude and frequency: U.S. Geol. Survey open-file report.
- McCabe, J. A., and Crosby, O. A., 1959, Floods in North and South Dakota, frequency and magnitude: U.S. Geol. Survey open-file report.
- Mitchell, W. D., 1954, Floods in Illinois, magnitude and frequency: Illinois Div. of Waterways, Dept. of Public Works and Buildings.
- Nebraska State Planning Board, 1941, Water resources of Nebraska: p. 1-19.
- Peirce, L. B., 1954, Magnitude and frequency of floods in Alabama: U.S. Geol. Survey Circ. 342.
- Powell, R. W., 1943, A simple method of estimating flood frequencies: Civil Eng., v. 13, no. 2, p. 105-106.
- Pride, R. W., 1958, Floods in Florida, magnitude and frequency: U.S. Geol. Survey open-file report.
- Prior, C. H., 1949, Magnitude and frequency of floods in Minnesota: Minnesota Dept. Conserv., Div. of Waters Bull. 1.
- Rantz, S. E., and Riggs, H. C., 1949, Magnitude and frequency of floods in the Columbia River basin, in Floods of May-June 1948 in Columbia River basin: U.S. Geol. Survey Water-Supply Paper 1080.
- Riggs, H. C., 1955, Floods in North Carolina, magnitude and frequency: U.S. Geol. Survey open-file report.
- Schwob, H. H., 1953, Iowa floods, magnitude and frequency: Iowa Highway Research Board Bull. 1.
- Searcy, J. K., 1955, Floods in Missouri, magnitude and frequency: U.S. Geol. Survey Circ. 370.
- Tice, R. H., 1958, Delaware River basin, flood frequency: U.S. Geol. Survey open-file report.
- U.S. Geological Survey, Water Resources Division, 1952, Floods in Youghiogheny and Kiskiminetas River basins, Pennsylvania and Maryland, frequency and magnitude: U.S. Geol. Survey Circ. 204.