UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WASHINGTON

FLOODS IN EASTERN MONTANA MAGNITUDE AND FREQUENCY

By

V. K. Berwick

Prepared in cooperation with the
Montana State Highway Commission

Helena, Montana
May 1958

Open-file report

U. S GOVERNMENT PRINTING OFFICE 16—08803-1

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WATER RESOURCES DIVISION

FLOODS IN EASTERN MONTANA
MAGNITUDE AND FREQUENCY

By

V. K. Berwick

Prepared in cooperation with the
Montana State Highway Commission

Helena, Montana
May 1958

Open-file report

CONTENTS

CONTENTS

ILLUSTRATIONS

TABLES

FLOODS IN EASTERN MONTANA MAGNITUDE AND FREQUENCY

By V. K. Berwick

ABSTRACT

This report presents a method of determining the magnitude and frequency of expected floods applicable for any area from 100 to 3,000 square miles in most of eastern Montana. A composite frequency curve is developed that expresses the relation of floods having a recurrence interval of 1.05 to 20 years to the mean annual flood. This composite curve is based on the combined frequency curves for 16 stations having 5 or more years of record. An equation is derived expressing the relation between mean annual flood, drainage area, and mean elevation of the desired basin. The limitations and use of the formula are discussed in the report.

INTRODUCTION

The objective of this report is to illustrate a method which might be used for the determination of the flood expectancy of any basin in the area (fig. 1) and which would relate some of the principal physical characteristics of drainage basins in eastern Montana to the recurrence of recorded floods.

A magnitude and frequency analysis is important in the design of drainage structures where the costs must be weighed against the probable flood damage and interruptions of service. Rarely are drainage structures designed to pass the maximum flood that may occur, because generally it is not economically feasible to provide for such unusual events. A flood-frequency curve for the site determined from records at a single nearby station was once regarded as satisfactory. However, a frequency curve based on the flood experience of several stations is now considered better than one developed from the data obtained at one particular site. The flood data of an individual site is an accurate record of the past, but could be considerably in error for predicting future floods, if the past record is not typical.

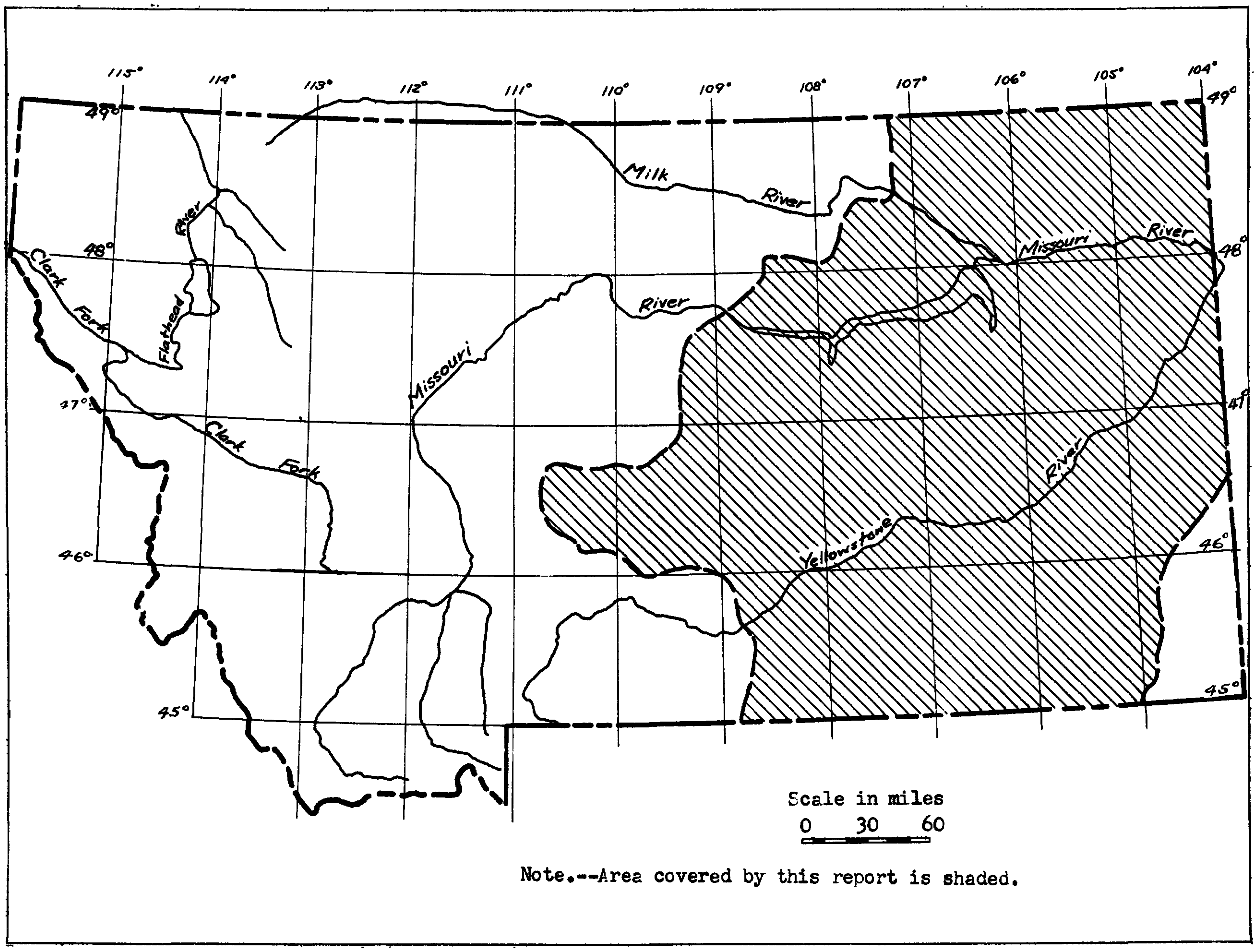

Figure 1.--Map of Montana showing area covered by this report.

Many formulas have been developed for determining the magnitude of expected floods in ungaged areas. Although these empirical formulas may be suitable for the regions used in their derivations, none are especially suited for Montana. The formula contained herein is limited to the range of physical characteristics of the drainage areas used in the derivation.

The discharge measured at a gaging station is the integration of the effects of all of the physical and climatological features of a drainage basin. In the area under study, the effect of certain of these features on flood discharge is considered.

COOPERATION AND SUPERVISION

This report has been prepared under the provisions of the cooperative agreement for water resources investigations between the Montana

State Highway Commission and the U. S. Geological Survey. It was prepared by the author and others in the office of the U. S. Geological Survey, Helena, Montana, under the direction of Frank Stermitz, district engineer.

DESCRIPTION OF THE AREA

The area under study is outlined in figure 1. It comprises about 60,000 square miles in eastern Montana that is homogeneous with respect to flood-frequency characteristics and mean annual flood relation.

Physical Features

Montana has a total area of about 146, 000 square miles of which approximately two-thirds is in the plains region.

The mountain ranges affecting the region are the Big Belt and the Big Snowy Ranges, which are the most prominent to the west, the Cypress Hills in Canada to the north, the Big Horn and the Pryor Mountains along the southwest. The altitude of these mountain ranges varies from 4, 000 to 10, 000 feet above mean sea level; however, the greater portion of the plains region has an altitude from 2, 500 to 3, 500 feet. Most of the streams have relatively flat slopes and fairly broad flood plains.

The drainage areas of the streams used for this study vary from 38.4 to 3,070 square miles,with 10 of the 16 stations falling in the range of 100 to 600 square miles.

The geology of the section of Montana under study is complex. As far as is known, regions of similar geology do not produce any radical differences in flood activity except in the extreme southeastern corner of the State. There some extreme differences in flood behavior were noted for the upper end of the Little Missouri River basin and will require special consideration. There are portions of this upper end of the Little Missouri River basin, known as badlands, which have soils with low infiltration capacity and little or no vegetation. These must be considered to have relatively higher peak discharges. Some of these isolated areas have little or no infiltration, depending on the intensity of the storm.

About 25 percent of the northern portion and about 10 percent of the southern portion of eastern Montana area is cultivated cropland. The remaining area is utilized quite fully for pasture. There are many stock ponds throughout the region and there has been a considerable increase in their number during the study period, 1938-56. Although the effects of these ponds were not evaluated, it is assumed that they do not seriously alter the magnitude or regime of floods in any of the drainage areas considered. The many drainage-basin characteristics are complicated and [illegible] to express in mathematical terms.

Climatological Features

The principal source of precipitation for eastern Montana is the warm moist air from the Gulf of Mexico, while the generally prevailing winds are from the northwest. The winter precipitation comes from the Pacific Coast. These combinations produce more total annual precipitation in the extreme eastern area of Montana and lesser amounts toward the lee side of the mountain.

All the streams are subject to snowmelt peaks in the spring and thunderstorm or rain peaks during the summer. Occasionally, late snowmelt and rain combine to produce peaks that would be difficult to analyze as to the greater contributing factor.

Generally the snowmelt peaks are broad and of fairly long duration with diurnal fluctuations, while the rain peaks are quite sharp and short in duration. Because the warmer weather in the spring moves in a northerly direction, the northern portion of Montana experiences later snowmelt runoff.

FLOOD-FREQUENCY RELATIONS

The method of computing flood frequency has been developed by the continuing efforts of the engineers of the Water Resources Division of the U. S. Geological Survey and others. The two steps generally taken in the analysis are: first, the computation of flood frequencies at each gaging station, and second, the combination of these individual records to define regions with homogeneous flood-frequency relations, and areas with similar characteristics of mean annual flood related to drainage area size.

Flood Frequency at a Gaging Station

Various techniques of determining the frequency of floods at a single gaging station from past records have been developed; however, only the method explained in this report was considered.

Basic data.--The streamflow records from 16 stations (see fig. 2 and table 1) with 5 years or more of operation were used. These 16 stations were selected as those being least affected by storage and diversions.

A common period, 1938-56, was used for all stations in order to place the records on a concurrent basis. For shorter records, the missing peaks were estimated by correlation with peaks of nearby stations to determine the order of magnitude of the known peaks.

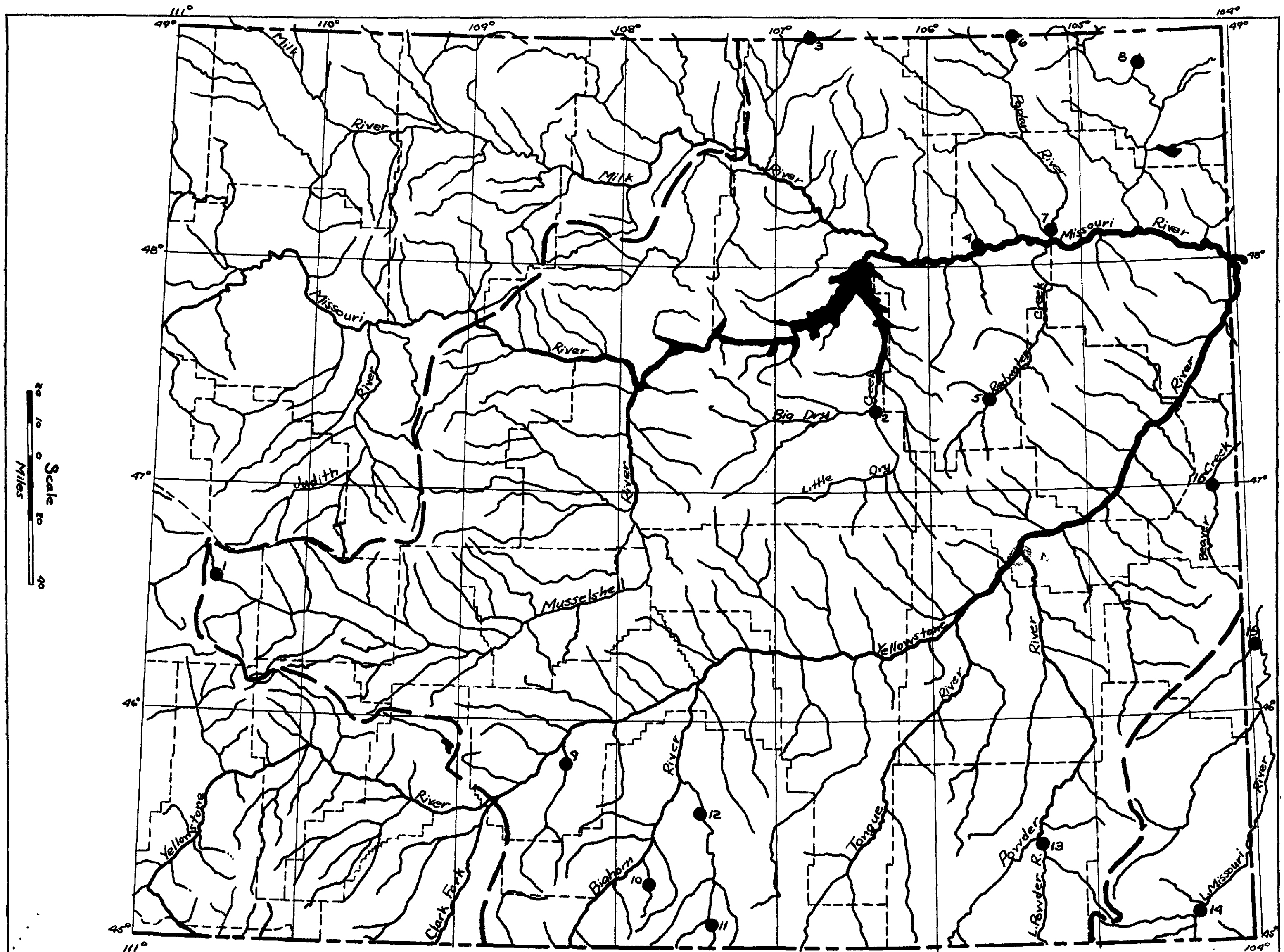

Figure 2.--Map of eastern Montana showing location of gaging stations.
Dashed lines enclose area covered by this report.

Table 1.--Factors used in the multiple correlation of mean annual flood with basin characteristics

Sta. No.	Name of station	Drainage area (sq mi)	Mean altitude (ft above msl)	Actual mean annual flood (cfs)
1	North Fork Musselshell River near Delpine	38.4	6,580	115
2	Dry Creek near Van Norman	2,530	2,900	5,000
3	Rock Creek at international boundary	242	2,970	970
4	Wolf Creek near Wolf Point	244	2,570	1,320
5	Redwater Creek at Circle	542	2,900	1,300
6	East Fork Poplar River at international boundary	256	2,660	1,000
7	Poplar River near Poplar	3,070	2,670	4,600
8	Big Muddy Creek at Daleview	330	2,450	1,850
9	Pryor Creek near Billings	425	5,080	620
10	Soap Creek near St. Xavier	111	4,510	370
11	Pass Creek near Wyola	119	5,400	380
12	Little Bighorn River near Crow Agency	1,190	3,840	1,750
13	Little Powder River near Broadus	2,000	4,100	1,600
14	Little Missouri River near Alzada	780	3,980	2,050
15	Little Beaver Creek near Marmarth, N. Dak.	615	3,120	4,200
16	Beaver Creek at Wibaux	351	2,930	1,400

The flood series.--The annual flood series was used in this analysis. In the course of the analysis an attempt was made to separate the peaks resulting from snowmelt and those resulting from rain. The flood-frequency curves drawn by this method lowered the graphical mean annual flood and distorted the shape of the curves in such a way as to make extension undesirable. Since the upper end of the curves resembled those plotted from annual maximums only, and since a drainage structure must carry both snowmelt and rain peaks, the use of annual peaks regardless of source appeared to be the best approach.

Station frequency curve.--The annual peak discharges for each station were listed in order of magnitude, assigning no. 1 to the largest. This procedure established the relative distribution of floods in a given period of years. The time scale, plotted as the abscissa and designated as recurrence interval (R.I.), was fitted to the data by the formula, R.I. = (N+1)/M, where N is the number of years of record and M is the relative magnitude of the event with the largest as 1. The corresponding peak discharges were plotted as ordinates. A smooth curve was then drawn to fit the points plotted. (Station frequency plots are not shown in this report).

Regional Frequency Curve

A frequency curve based on the combined experiences of several stations has more weight than one developed for a single station. A composite flood-frequency curve was drawn combining the flood data for all of the 16 stations in the region. The floods used in developing this curve were expressed in terms of the ratio of each individual flood to the mean annual flood, thus placing the composite curve on a dimensionless basis and making it applicable regardless of the dimensional size of floods.

Regional sampling. --Sampling for a frequency study in a region can be done in two ways, time and areal sampling. Time sampling requires records from a few long-term stations, while areal sampling requires a large number of stations to make clear the various characteristics of the region -- length of record is not of much concern.

Available records did not satisfy either method of sampling. As both long-term records and high density of stations necessary were lacking, the use of the available stations as they are will be helpful until such time as a revised study can be made.

To combine the records of all stations it was necessary to place all of the floods on a comparable basis as to time and physical characteristics.

Selection of comparable floods. --The peak flows of a stream at a given point integrate all of the flood characteristics of a drainage basin; therefore, the mean of the annual peak discharges would be an index of the physical features of the basin that affect flood flows. The graphical mean annual flood, $Q_{2.33}$ (flood with recurrence interval of 2.33 years), as indicated by the individual station flood-frequency curve was used.

All floods were placed on a dimensionless basis by dividing the recorded floods by the mean annual flood for that stream and thus were made comparable with other floods in the region.

Homogeneity test. --Before a group of stations can be combined, a test of homogeneity is necessary to insure that all of the records are selected from a region with uniform flood-frequency characteristics (see table 2). The test determined whether the differences in slope of the individual frequency curves are greater than might occur by chance in random sampling (see fig. 3). Because all the points plotted within these test curves, the variation can be attributed to chance, and the records for the 16 stations can be considered homogeneous.

Table 2.--Data for homogeneity test

Sta. No.	Name of station	Drainage area (sq mi)	$Q_{2.33}$ (cfs)	Q_{10} (cfs)	$\frac{Q_{10}}{Q_{2.33}}$ (ratio)	$Q_{2.33}$ x ratio	Recurrence interval (yrs)	Effective length of record (yrs)
1	North Fork Musselshell River near Delpine	38.4	115	380	3.30	380	9.9	18
2	Dry Creek near Van Norman	2,530	5,000	17,000	3.40	16,500	9.6	17.5
3	Rock Creek at international boundary	242	970	2,600	2.68	3,200	14.4	19
4	Wolf Creek near Wolf Point	244	1,320	9,000	6.82	4,360	4.8	12.5
5	Redwater Creek at Circle	542	1,300	4,900	3.77	4,290	8.5	19
6	East Fork Poplar River at international boundary	256	1,000	2,700	2.70	3,300	15.3	19
7	Poplar River near Poplar	3,070	4,600	28,500	6.20	15,180	5.8	19
8	Big Muddy Creek at Daleview	330	1,850	5,200	2.81	6,100	13.7	14
9	Pryor Creek near Billings	425	620	1,430	2.31	2,050	24	18
10	Soap Creek near St. Xavier	111	370	1,080	2.92	1,220	12.8	17
11	Pass Creek near Wyola	119	380	920	2.42	1,250	17.3	18.5
12	Little Bighorn River near Crow Agency	1,190	1,750	5,400	3.09	5,780	11	19
13	Little Powder River near Broadus	2,000	1,600	4,750	2.97	5,280	11.8	16
14	Little Missouri River near Alzada	780	2,050	5,000	2.44	6,760	18	19
15	Little Beaver Creek near Marmarth, N. Dak.	615	4,200	9,200	2.19	13,860	25	18
16	Beaver Creek at Wibaux	351	1,400	3,800	2.71	4,620	13.7	19

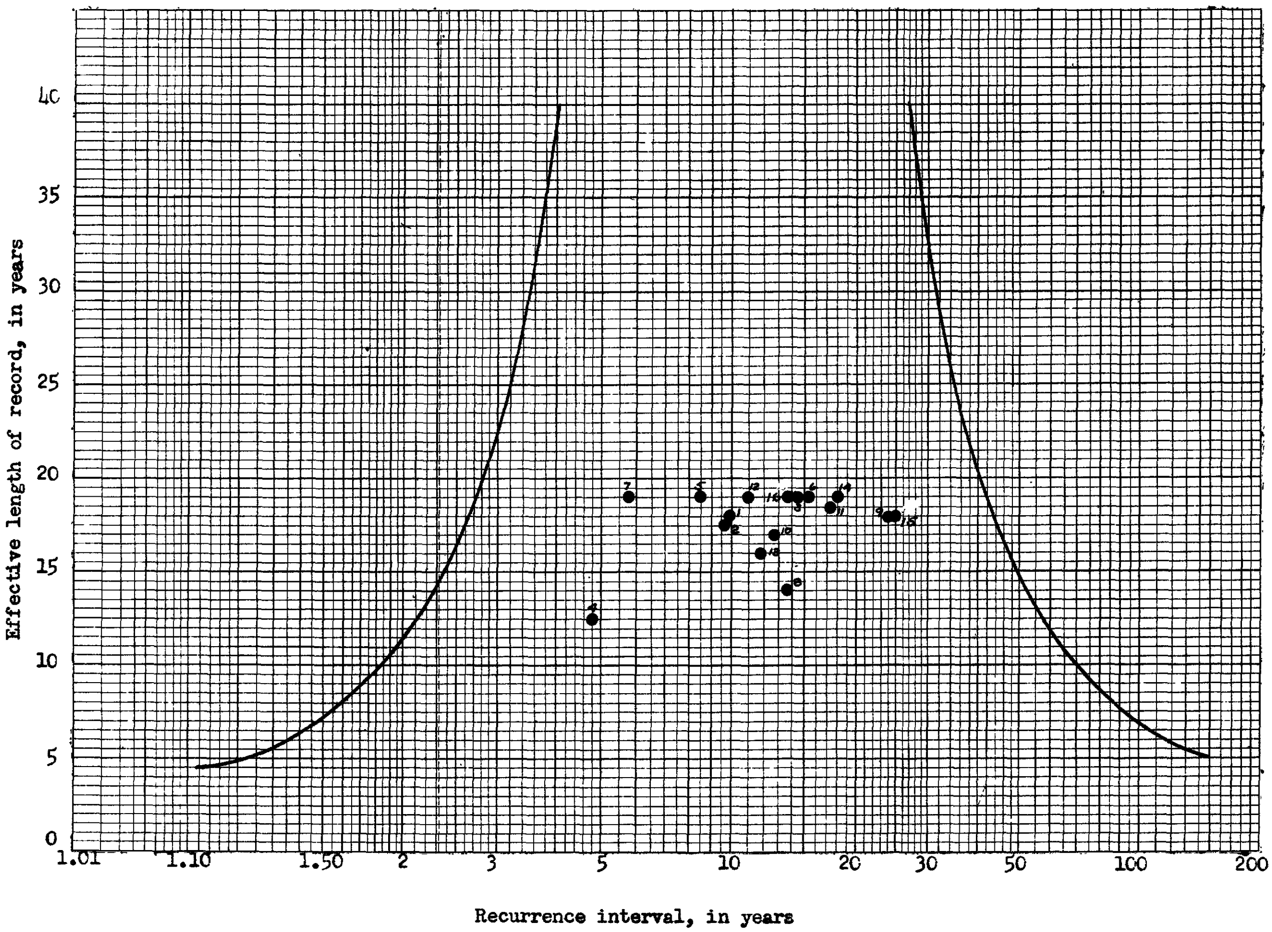

Figure 3.--Homogeneity test graph.

Composite frequency curve.--Since the requirements for homogeneity were satisfied, all stations were grouped together for the purpose of computing average flood ratios for each recurrence interval. The flood ratios for all the recorded floods for each recurrence interval were listed and the median flood ratios were selected from this tabulation. Each median flood ratio was then plotted to its corresponding recurrence interval on a frequency graph and an average or composite frequency curve drawn. This curve (fig. 4) with flood discharge expressed in terms of ratio to mean annual flood, was based on all significant discharge record in the standard period, and probably represents the most likely flood-frequency values for the region. The ratio to mean annual flood for any recurrence interval can be obtained from the composite flood-frequency curve. The magnitude of the discharge at a desired recurrence interval is obtained by multiplying this ratio by the mean annual flood.

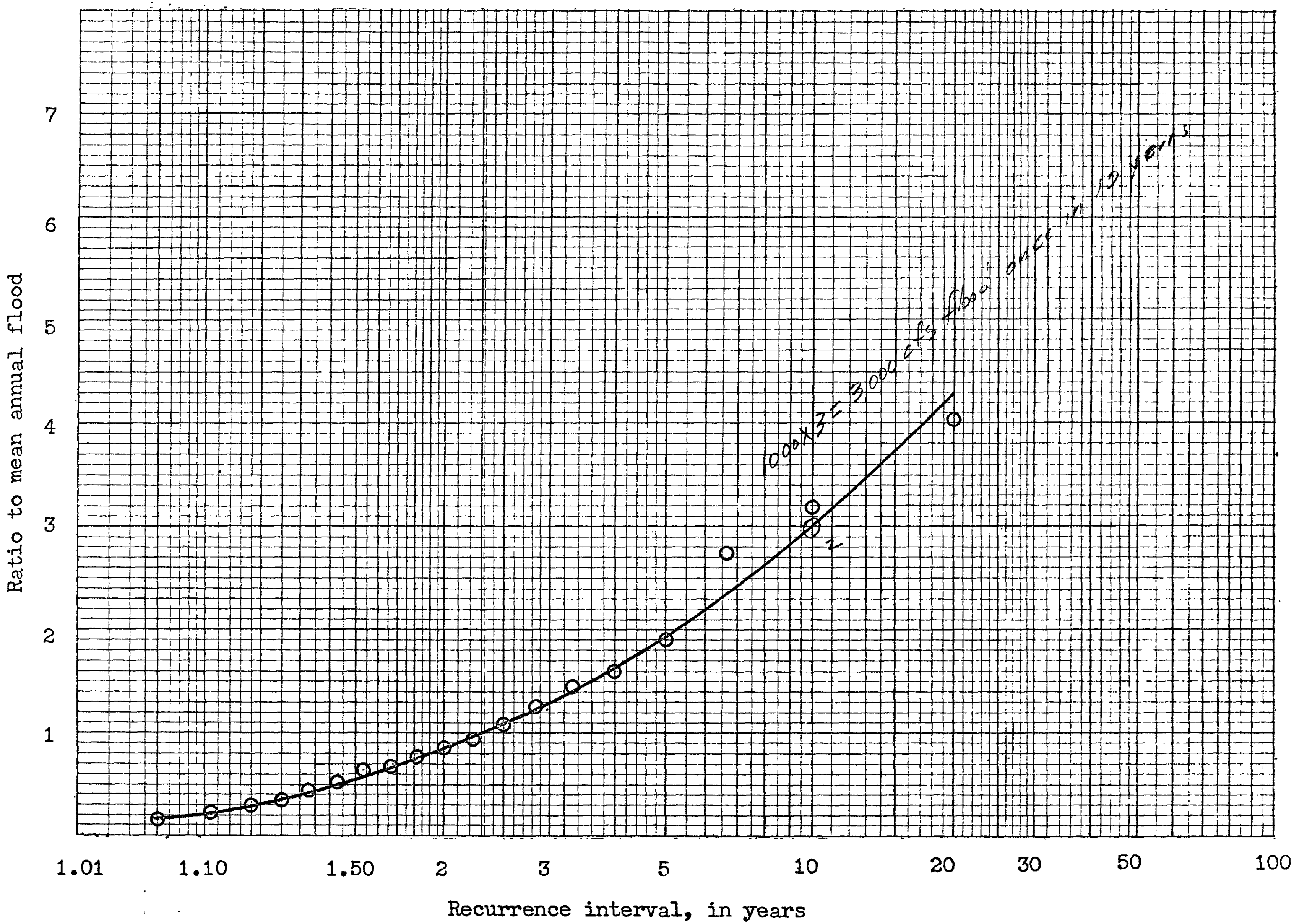

Figure 4.--Composite flood-frequency curve for eastern Montana.

Derivation of the Mean Annual Flood

In order to use the regional flood-frequency curves, a study was made of the basin characteristics that might affect the determination of the mean annual flood.

Basin characteristics.--The drainage area was the first and most easily obtained characteristic, and was found to correlate fairly well with mean annual flood. Considerable error would result, however, from estimating the mean annual flood from drainage area alone.

The mean altitude of a drainage basin was found to have correlative value. The mean altitude was obtained by using a grid system and interpolation between contours. The grid system consisted of a rectangular coordinate overlay on the drainage area, and the altitudes at the intersections were listed. The arithmetical average of these altitudes was obtained and used as the mean altitude of the drainage basin. Contour mapping is available through the Army Map Service for almost the entire state. The derived "mean altitude" factor very likely incorporates the influence of geology, slope, vegetation and precipitation. The separate development of these characteristics was not feasible because of lack of adequate reference material.

Other factors that could well affect mean annual floods are precipitation, geology, vegetation, basin shape, basin slope, aspect, and storage. Data were insufficient for introducing any of these factors into the multiple correlation.

The mean altitude and drainage area were used in a multiple correlation to derive the mean annual flood for eastern Montana, except for the Little Missouri River basin above Marmarth, N. Dak., where the mean annual flood based on records for stations 14 and 15 (see fig. 2) was considerably higher than that for other regions studied in Montana and North Dakota. Surface geology may be one factor responsible for the extreme deviation. Flood-frequency relations for Little Missouri River basin above Marmarth, N. Dak. should be developed from stream-flow records in only that area.

Formula.--The formula for mean annual flood as derived from 14 gaging stations in the area by multiple correlation is:

$$Q_{2.33} = 6.21 \times 10^6 \frac{A^{0.533}}{E^{1.45}},$$

where A = drainage area, in square miles, and E = mean altitude of drainage basin, in feet above mean sea level. Standard error of estimate ranges between +19 percent and -16 percent. The curves of figure 5 may be used in lieu of the formula for ease of application.

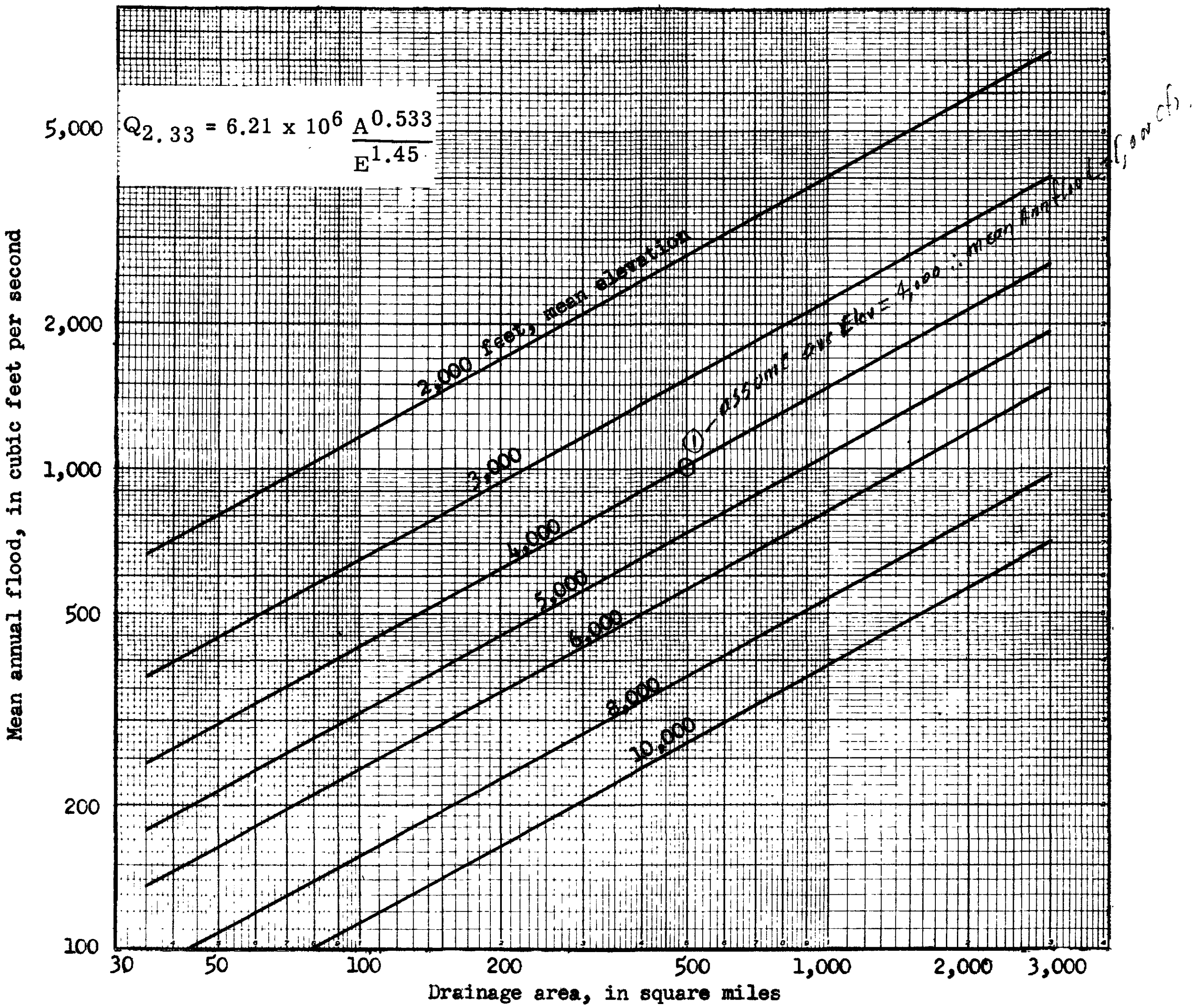

Figure 5.--Variation of mean annual flood with drainage area and mean elevation.

Limitations.--The use of the formula is limited by the range and quantity of the basic data used to define it. The formula should not be applied to any area outside its region of derivation (shaded area of fig. 1). Extrapolation of the curves of figure 5 beyond the limits shown should be considered highly uncertain; the formula should be restricted to similar limits.

Application of Flood Formula

The application of the formula to a given area is accomplished by obtaining the values for the various basin characteristics and then employing these values to get the mean annual flood. The mean annual flood is then used with the composite frequency curve to solve for the magnitude of the flood at the desired frequency.

Method for determining basin characteristics.--Obtain the drainage area in square miles, from the best map available, using a planimeter. The mean altitude is computed by averaging elevations at intersections of a grid overlay.

Use of formula and curve.--The formula is readily solved by the use of a slide rule or logarithims. However, the value of the mean annual flood is also obtainable from the curves of figure 5.

Use of composite frequency curve.--After the mean annual flood has been computed, the magnitude of the flood for the selected frequency is determined. Select the flood ratio that corresponds to the desired recurrence interval from figure 4. This ratio is multiplied by the mean annual flood, and the result is the magnitude of the flood that can be expected to be equaled or exceeded on the average of once in the number of years of the selected recurrence interval.

Limitations

The methods given herein for computing the magnitude and frequency of floods should be considered provisional. As more stations are included in the network and longer records obtained, more information will be available to add confidence to the present study and will undoubtedly lead to revisions and improvement. For the present, the lack of flood records and the range of gaged drainage areas definitely limits the use of the method outlined. It is anticipated that this report will be revised when enough additional information is available to warrant further study.

GAGING-STATION FLOOD DATA

Flood data for 16 stations in the Missouri River basin are presented in this section. Available annual flood dates, stages, and discharges are listed for the water years 1938-56, used as the standard period. In many cases, the annual maximum stage occurred at a different time from the maximum discharge, generally because of backwater from ice. In such cases, two entries are made for the year, one of which shows the maximum stage, and the other the maximum discharge with corresponding stage if available. The annual maximum daily discharge without the corresponding gage height is listed in several instances when the maximum instantaneous discharge could not be determined.

Underlines in the tabular data have the following significance:

1. Line in "Water year" column means a gap in the record.
2. Line beginning at "Date" column and extending through "Discharge" column means change in site and datum with no gap in record.
3. Line in only "Gage height" column means change in datum only.
4. Line in "Date" and "Discharge" columns means change in site but no change in datum.
5. No underlines used if changes in site and/or datum have been adjusted to present site and datum.

Standard footnotes listed below are used in succeeding tabulations:

a Backwater from ice.
b Maximum daily discharge.
c Unknown.
d Estimated; second highest since 1872.
e Highest since 1872.

Musselshell River Basin

1. North Fork Musselshell River near Delpine, Mont.

Peak stages and discharges

Water year	Date	Gage height (feet)	Discharge (cfs)	Water year	Date	Gage height (feet)	Discharge (cfs)
1940	June 9	0.81	14	1950	Apr. 1	4.63	423
1941	June 17	1.57	61	1951	Feb. 10	[a]3.45	-
1942	June 3	2.99	199		Apr. 2	2.57	116
1943	Mar. 29	2.65	156	1952	Apr. 13	2.24	120
1944	Mar. 30	1.38	48	1953	June 7	1.80	79
1945	Mar. 21	1.78	76	1954	Apr. 4	[a]2.00	-
					Apr. 5	--	[b]25
1946	Mar. 27	2.51	146	1955	June 20	1.58	62
1947	Mar. 17	3.08	210				
1948	Apr. 15	3.92	304	1956	Dec. 28, 1955	[a]2.03	-
1949	Apr. 11	2.30	105		Apr. 15	1.57	54

Dry Creek Basin

2. Dry Creek near Van Norman, Mont.

Peak stages and discharges

Water year	Date	Gage height (feet)	Discharge (cfs)	Water year	Date	Gage height (feet)	Discharge (cfs)
1940	Aug. 1	4.11	1,170	1950	Apr. 2	--	[b]4,000
					Apr. 2	[a]7.90	--
1941	Sept. 8	4.92	1,950				
1942	June 4	6.07	3,620	1951	Sept. 1	4.15	858
1943	Mar. 24	[a]8.18	6,340	1952	Apr. 1	11.60	18,600
1944	June 18	8.31	7,420	1953	May 30	8.41	8,210
	Mar. 17	[a]8.84	--	1954	Aug. 17	7.00	6,400
1945	July 14	2.40	91	1955	July 6	5.01	1,600
1946	Feb. 22, 23	--	[b]900	1956	Mar. 19	--	[b]960
	Feb. 22	[a]5.01	--				
1947	Mar. 21	13.39	24,600				
	Mar. 21	[a]15.26	--				
1948	June 5	5.85	2,540				

Milk River Basin

3. Rock Creek at international boundary

Peak stages and discharges

Water year	Date	Gage height (feet)	Ice effect (feet)	Discharge (cfs)
1938	Mar. 17	8.96	-0.90	793
	Mar. 17	9.70	(c)	--
1939	Mar. 25	11.40		2,410
1940	Apr. 18	6.63	- .21	469
1941	Mar. 22	9.06	-1.50	526
1942	Apr. 3	6.26		422
1943	Mar. 30	11.18		2,070
1944	Apr. 2	8.58	- .60	776
1945	Mar. 14	8.81	- .30	892
1946	Mar. 20	6.12	-1.00	271
1947	Apr. 3	8.19		822
1948	July 14	9.26		1,060
1949	Apr. 1	4.50	- .35	166
1950	Apr. 16	10.37		1,330
1951	Apr. 10	11.02	(c)	--
	Apr. 28	7.98	- .10	756
1952	Apr. 15	11.91		3,310
1953	June 9	5.59		330
1954	Apr. 7	11.40	- .10	2,250
1955	Apr. 2	10.99	- .09	1,700
1956	Mar. 27	[a]7.90	- .78	604

Wolf Creek Basin

4. Wolf Creek near Wolf Point, Mont.

Peak stages and discharges

Water year	Date	Gage height (feet)	Discharge (cfs)	Water year	Date	Gage height (feet)	Discharge (cfs)
1950	Apr. 18	5.30	188				
1951	Apr. 5	6.06	324				
1952	Apr. 7	9.25	7,050				
1953	June 3	7.29	1,010				
1954	Apr. 4	12.9	9,780				
1956	Mar. 23		100				

Redwater Creek Basin

5. Redwater Creek at Circle, Mont.

Peak stages and discharges

Water year	Date	Gage height (feet)	Discharge (cfs)	Water year	Date	Gage height (feet)	Discharge (cfs)
1938	July 4	14.33	3,460	1947	Mar. 23	--	4,180
1939	Mar. 19	11.17	1,880		Mar. 23	[a]14.10	--
1940	June 8	3.78	9.5	1948	June 14	9.12	1,040
				1949	Mar. 22	11.1	1,820
1941	Feb. 19,25,26,	[a]3.41	--	1950	Apr. 2	[a]9.28	--
	Mar. 3,4,6,7,8				Apr. 7	7.75	612
	Sept. 10	.77	4.9				
1942	Mar. 9	4.24	341	1951	Mar. 22	--	[b]520
1943	Mar. 24	[a]13.8	1,500		Mar. 22	[a]9.26	--
1944	June 17	18.5	6,220	1952	Mar. 31	12.36	5,740
1945	Feb. 9	[a]8.69	--	1953	June 29	10.83	1,970
	Mar. 11,12	--	[b]80	1954	Aug. 16	8.12	721
				1955	Mar. 10	--	[b]950
1946	Feb. 23	9.81	1,090		Mar. 10	9.70	--
	July 17	9.20	1,090	1956	Mar. 19	[a]8.51	--
					Mar. 20	7.88	538

Only site change No Datum change

Poplar River Basin

6. East Fork Poplar River at international boundary

Peak stages and discharges

Water year	Date	Gage height (feet)	Ice effect (feet)	Discharge (cfs)
1938	Mar. 15	11.08	(c)	950
1939	Mar. 22	12.40		2,760
1940	Apr. 15	9.60	-1.20	953
1941	Mar. 27	8.87	- .15	752
1942	Mar. 13,14	7.91	(c)	--
	Apr. 2	6.09		530
1943	Mar. 25	12.8	(c)	--
	Mar. 29	10.74		2,050
1944	Apr. 6	--		b40
	Aug. 9	3.50		--
1945	Mar. 13	--		b180
	Mar. 13	7.20	(c)	--
1946	Mar. 14	10.21	-2.58	522
1947	Mar. 25	10.52	(c)	
	Apr. 11	7.94		992
1948	Apr. 16	11.39		2,310
1949	Mar. 27	--		b360
	Mar. 27	8.05	(c)	--
1950	Apr. 14	--		1,790
	Apr. 14	12.02	(c)	--
1951	Apr. 7	8.96	(c)	--
	Apr. 30	6.95	- .40	592
1952	Apr. 7	12.10	-1.76	1,890
1953	Mar. 30	6.91	-2.01	250
1954	Apr. 6	11.34	- .05	2,270
	Apr. 6	11.52	(c)	--
1955	Apr. 1	11.35	-1.60	1,650
	Apr. 1	11.61	(c)	--
1956	Mar. 25	6.93	-2.10	281

Poplar River Basin

7. Poplar River near Poplar, Mont.

Peak stages and discharges

Water year	Date	Gage height (feet)	Discharge (cfs)	Water year	Date	Gage height (feet)	Discharge (cfs)
1938	Mar. 15	9.7	4,670	1947	Mar. 23	[a]10.40	--
1939	Mar. 24	12.60	11,600		Apr. 13	8.88	2,000
1940	Apr. 14	9.7	3,920	1948	Mar. 25	[a]11.84	--
					Apr. 19	11.03	3,960
1941	Mar. 25	[a]10.12	---	1949	Mar. 28	---	[b]1,500
	Mar. 29	8.40	2,060		Mar. 28	[a]9.74	--
1942	Mar. 17	--	[b]800	1950	Apr. 20	13.87	6,210
	Mar. 17	[a]8.30	---				
1943	Mar. 25	[a]12.8	---	1951	May 1	8.06	2,210
	Mar. 26	12.4	[b]11,000	1952	Apr. 7	16.98	27,800
1944	Apr. 5	7.51	1,000	1953	Mar. 31	7.28	1,760
1945	Mar. 14	[a]9.92	---	1954	Apr. 6	17.86	37,400
	Mar. 20	8.92	2,780	1955	Mar. 31	---	[b]9,000
					Mar. 31	[a]15.87	--
1946	July 9	17.18	40,000	1956	Mar. 27	---	[b]580

Note.--Records for 1938-47 from gage near Bredette (drainage area, 2,840 sq mi).

Big Muddy Creek Basin

8. Big Muddy Creek at Daleview, Mont.

Peak stages and discharges

Water year	Date	Gage height (feet)	Discharge (cfs)
1948	Apr. 18	16.58	2,920
1949	Mar. 28	[a]11.67	551
1950	Apr. 15	15.73	1,080
1951	May 1	16.45	2,420
1952	Apr. 7	17.15	6,360
1953	June 4	12.62	664
1954	Apr. 6	16.70	3,500
1955	Apr. 1	16.73	5,510
1956	Mar. 26	---	[b]60
	Mar. 26	[a]6.03	--

Yellowstone River Basin

9. Pryor Creek near Billings, Mont.

Peak stages and discharges

Water year	Date	Gage height (feet)	Discharge (cfs)	Water year	Date	Gage height (feet)	Discharge (cfs)
1938	June 24	7.9	1,230	1947	Mar. 19	--	[b]890
1939	Mar. 19	[a]4.72	--		Mar. 19	[a]11.25	--
	June 18	3.35	332	1948	Mar. 15	7.30	--
1940	Mar. 2	[a]3.49	--		Apr. 20	3.95	464
	Apr. 16	2.83	208	1949	Feb. 27	[a]3.82	--
1941	Sept. 8	4.68	607		June 3	2.22	133
1942	May 14	9.2	1,500	1950	Feb. 19	[a]3.77	--
1943	Mar. 26	--	[b]1,000		Feb. 25	--	[b]230
	Mar. 26	[a]10.68	--				
1944	Mar. 19	[a]9.16	--	1951	Mar. 22	[a]9.82	761
	June 19	7.66	1,150	1952	May 22	4.25	424
1945	Mar. 12	[a]5.73	--	1953	Jan. 12	[a]2.50	--
	June 11	4.28	538		June 7	2.43	145
				1956	March	--	800
1946	June 12	3.98	489				

10. Soap Creek near St. Xavier, Mont.

Peak stages and discharges

Water year	Date	Gage height (feet)	Discharge (cfs)	Water year	Date	Gage height (feet)	Discharge (cfs)
1939	June 2	5.70	230	1947	Mar. 17	[a]11.50	--
1940	Apr. 22	6.80	415		June 21	10.21	707
				1948	Apr. 19	10.34	727
1941	Sept. 7	5.51	220	1949	Mar. 23	[a]7.02	240
1942	May 13	13.4	1,300	1950	Jan. 21	[a]7.26	--
1943	Mar. 25	8.8	527		June 13	5.01	186
1944	June 18	13.00	1,020				
1945	June 13	6.44	295	1951	Mar. 15	[a]>6.00	--
					Mar. 26	4.20	140
1946	Mar. 27	5.89	255	1952	Mar. 30	6.80	319
				1953	June 4	3.35	85

Yellowstone River Basin

11. Pass Creek near Wyola, Mont.

Peak stages and discharges

Water year	Date	Gage height (feet)	Discharge (cfs)	Water year	Date	Gage height (feet)	Discharge (cfs)
1938	May 20	3.00	360	1947	June 20	4.60	1,120
1939	Mar. 19	[a]3.68	--	1948	Feb. 18	(a)	[b]400
	June 2	3.00	180	1949	Jan. 14	[a]2.94	--
1940	Jan. 27,28	[a]2.64	--		Apr. 14	--	[b]100
	Feb. 29						
	Apr. 27,28	2.34	91	1951	Mar. 24	[a]4.01	--
					Mar. 26	2.38	274
1941	Apr. 13	3.30	463	1952	Mar. 29	[a]5.23	--
1942	May 13	4.08	785		Apr. 5	2.49	307
1943	Mar. 25	[a]6.22	--	1953	June 15	2.66	361
	Mar. 26	3.22	412	1954	Feb. 1	[a]2.56	--
1944	June 4	4.82	1,150		Apr. 6	1.80	131
1945	Feb. 8	[a]2.99	--	1955	Apr. 11	[a]2.88	--
	June 12	2.91	395		Apr. 15	2.13	199
1946	Mar. 28	3.0	451	1956	Mar. 19	[a]3.87	--
					May 29	2.34	247

12. Little Bighorn River near Crow Agency, Mont.

Peak stages and discharges

Water year	Date	Gage height (feet)	Discharge (cfs)	Water year	Date	Gage height (feet)	Discharge (cfs)
1938	May 21,31	6.85	1,370	1948	Apr. 20	7.80	1,730
1939	Mar. 21	[a]10.52	3,310	1949	Mar. 1	[a]6.18	--
1940	June 15	5.70	687		Mar. 28	--	[b]600
				1950	Feb. 27	[a]8.01	--
1941	May 15	6.32	970		June 19	5.70	630
1942	June 6	9.76	2,740				
1943	Mar. 26	[a]13.01	--	1951	Feb. 10	[a]8.63	--
	Mar. 26	12.60	4,400		Mar. 26	--	[b]650
1944	June 6	11.84	3,980	1952	Mar. 28	[a]7.73	--
1945	Mar. 14	[a]8.54	--		Mar. 30	7.67	1,550
	June 9	7.90	1,780	1953	June 16	7.32	1,470
				1954	May 23	6.00	765
1946	June 13	--	[b]1,600	1955	Apr. 15	6.98	1,360
1947	Mar. 17	--	[b]4,000		Apr. 19	7.01	--
	Mar. 18	10.32	--				
1948	Feb. 28	[a]8.52	--	1956	Mar. 22	8.33	1,960
					Mar. 22	[a]10.60	--

Yellowstone River Basin

13. Little Powder River near Broadus, Mont.

Peak stages and discharges

Water year	Date	Gage height (feet)	Discharge (cfs)	Water year	Date	Gage height (feet)	Discharge (cfs)
1938	June 23	8.00	1,270	1949	Mar. 5	[a]7.44	1,600
1939	Mar. 14	[a]12.00	1,780	1950	Apr. 3	6.16	1,320
1940	Aug. 17	15.2	6,780				
				1951	Sept. 6	4.43	734
1941	June 1	11.96	3,370	1952	Mar. 18	[a]6.59	1,300
1942	May 13	6.12	670		Mar. 18	[a]7.21	--
1943	Mar. 26	[a]10.81	[b]1,190	1953	June 15,	8.94	2,340
1948	Mar. 16	[a]10.59	--	1956	July 2	3.10	287
	June 18	5.87	1,220				

Note.--Records 1938-43 from gage near Biddle (drainage area, 1,540 sq mi) adjusted by 0.65 power of ratio of drainage areas (factor, 1.19).

Little Missouri River Basin

14. Little Missouri River near Alzada, Mont.

Peak stages and discharges

Water year	Date	Gage height (feet)	Discharge (cfs)	Water year	Date	Gage height (feet)	Discharge (cfs)
1938	May 31	5.55	794	1948	June 18	16.08	3,690
1939	Mar. 24	7.9	1,420	1949	Mar. 7	[a]14.41	--
1940	Aug. 19	9.6	1,600		Mar. 22	12.85	2,230
				1950	Apr. 12	11.82	1,860
1941	June 11	12.54	2,820				
1942	June 6	12.90	3,000	1951	June 17	5.89	490
1943	Mar. 27	11.81	2,500	1952	Mar. 31	[a]11.09	--
1944	Apr. 4	--	[b]6,000		Apr. 1	10.51	1,400
1945	Mar. 14	--	[b]1,100	1953	May 29	11.34	1,630
	Mar. 14	[a]8.94	--	1954	Apr. 6	8.28	792
				1955	May 19	11.23	1.780
1946	May 24	13.01	3,040				
1947	June 23	14.42	2,850	1956	Mar. 23	--	[b]886
					Mar. 24	[a]9.50	--

Little Missouri River Basin

15. Little Beaver Creek near Marmarth, N. Dak.

Peak stages and discharges

Water year	Date	Gage height (feet)	Discharge (cfs)	Water year	Date	Gage height (feet)	Discharge (cfs)
1939	July 6	12.2	5,500	1947	Mar. 23	--	6,250
1940	Aug. 9	6.66	1,130	1948	June 14	14	6,700
				1949	Mar. 23	[a]10.5	3,300
1941	June 10	6.56	2,670	1950	Apr. 7	11.5	4,600
1942	May 30	6.11	2,440				
1943	Feb. 19	[a]9.02	--	1951	Sept. 3	6.21	2,230
	Mar. 24	8.40	4,000	1952	Apr. 6	13.9	12,700
1944	June 22	12.5	9,260	1953	June 20	6.56	2,170
1945	Mar. 15	7.6	2,700	1954	Sept. 6	9.49	4,820
				1955	June 27	7.81	2,990
1946	July 8	8.20	3,700	1956	July 10	4.98	1,070

16. Beaver Creek at Wibaux, Mont.

Peak stages and discharges

Water year	Date	Gage height (feet)	Discharge (cfs)	Water year	Date	Gage height (feet)	Discharge (cfs)
1921	June	--	[d]10,000	1946	Dec. 2, 1945	[a]9.95	--
					July 10	8.50	480
1929	June 7	--	[e]30,000	1947	Mar. 23	[a]13.39	--
					Mar. 23,24	--	[b]2,000
1938	Apr. 26	7.14	1,310	1948	July 4	11.5	2,380
1939	Mar. 21	10.8	3,780	1949	Mar. 23	[a]11.69	--
1940	Apr. 24	4.78	91		Mar. 28	11.15	2,140
				1950	Mar. 21	[a]9.97	--
1941	Mar. 6,7	[a]7.65	--		Apr. 8	9.58	1,100
	Mar. 29	5.96	33				
1942	June 7	10.70	1,840	1951	Mar. 23	[a]11.16	--
1943	Mar. 24	--	[b]3,000		Mar. 24	--	[b]400
	Mar. 24	[a]13.44	--	1952	Apr. 8	13.0	3,760
1944	Apr. 1	[a]11.90	--	1953	June 24	7.00	104
	Apr. 5	11.0	2,040	1954	Apr. 7	10.16	1,210
1945	Mar. 11	[a]11.05	--	1955	Mar. 10	--	[b]1,000
	Mar. 13	--	[b]1,000		Mar. 10	[a]10.80	--
				1956	Mar. 24	--	[b]44
					Mar. 24	[a]6.76	--