Evolution of Design Practice at the Iowa State Highway Commission for the Determination of Peak Discharges at Bridges and Culverts

A.E. 526

Ron Rossmiller

Winter, 1971

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INTRODUCTION

The game is called "Pick a Number." Any number of people can play it. The game begins by one player saying, "Interstate 35 will cross the Skunk River. What discharge should we use for the design of the bridge?" The rest of the players come up with a variety of answers. Who is right and who is wrong? Or is anyone right? Or is anyone wrong? Hydrology is still an art rather than a science.

This paper carries the rather weighty title of "Evolution of Design Practice at the Iowa State Highway Commission for the Determination of Peak Discharges at Bridges and Culverts." Hopefully, this evolving process will lead to a more precise definition of a peak rate of runoff for a selected recurrance interval at a particular site.

In this paper the author will relate where the Highway Commission has been, is now, and will be going in this art of hydrology. He will then offer some examples at a few sites in Iowa to illustrate the use of the various methods. Finally, he will look ahead to some of the pitfalls still lying in wait for us.

THE TALBOT FORMULA

When the author first became aware of the Talbot

Formula, he thought it crude and at best, a bad approximation. He looked upon those who still used this formula as the basis for sizing structures as old-fashioned and out of date. Today we have modern and sophisticated methods of determining structure size and shape using hydrologic and hydraulic principles and techniques.

Yet, - when the author read and reread Professor Talbot's original paper, he was struck by the thought that yes, the method is old-fashioned and out of date. When the paper was written in 1887, almost a century ago, the art of hydrology was barely into its infancy. But more importantly, the principles he enumerated then are those we still live with today. The variables he listed then are the ones that still plague us today. The data and records he asked for then are the data and records we are still asking for today.

Most important of all, though, was his recognition of the basic problem facing the design engineer - the need to make a decision, now. How large a structure shall be built at this particular location. No time to study the problem at length; no time for research. Now. Not too large - it will be too expensive. Not too small - it may wash out, For this, the design engineer needs a tool which is quick, easy to use, and yields good results. And what a tool Professor Talbot gave us. $a=C(A)^{0.75}$

Crude - yes, but consider this. On the primary and secondary road system in Iowa, more than a quarter million culverts and small bridges existing today were designed using the Talbot Formula. Most are still serving us faithfully today.

This formula was the basis for design of all the small bridges and culverts at the Highway Commission until the early 1950s. To this day, some of the County Engineers in Iowa use the Talbot Formula exclusively as the basis for design. Because of this, his paper is a part of our history and has been respectfully included in this paper as Appendix A.

$$a=C(A)^{0.75}$$

a = area of waterway in square feet

A = drainage area in acres

C = A coefficient based upon land use, type of terrain, and shape of watershed[1]

Professor Talbot's comments on the value of C are to be found on page 4 of his paper. Subsequent useage has expanded his comments to the values of C shown in Table 1. Various graphs and tables have also been developed to simplify the use of the formula. Figure 1 and Table 2 are examples of these.

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[1]A.N. Talbot, "The Determination of Water-way for Bridges and Culverts, 1887, p-17.

C = 1, for steep and rocky ground with abrupt slopes
C = 2/3, for rough hill country of moderate slopes
C = 1/2, for uneven valleys, very wide as compared to length
C = 1/3, for rolling agricultural country where the length of valley is three or four times the width
C = 1/5, for level district not affected by snow or severe floods. For still milder conditions or for subdrained lands, decrease C as much as 50%; but increase C for steep side slopes or where the upper part of the valley has a much greater fall than the channel of the culvert.

Table 1. Values of C in the Talbot Formula[2]

Talbot's coefficients are based on a velocity of ten feet per second and roughtly fit a 10-yr. flood in the Middle West.[3]

IOWA CHART NO. 1

In August, 1951, the Bureau of Public Roads published Hydraulic Information Circular No. 1.[4] Figure 1 in this circular was entitled "Peak Rates of Runoff from Small Watersheds" and was based on statistical analyses of actual records of runoff on small agricultural watersheds described

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[2] Handbook of Steel Drainage & Highway Construction Products (New York: American Iron & Steel Institute, 1967), p-91.

[3] Ray K. Linsley, Max A. Kohler and Joseph L. Paulhus, Applied Hydrology (New York: McGraw-Hill Book Co., Inc., 1949), p-574.

[4] Basic Principles of Highway Drainage: Hydraulic Information Circular No. 1, Bureau of Public Roads, 1951.

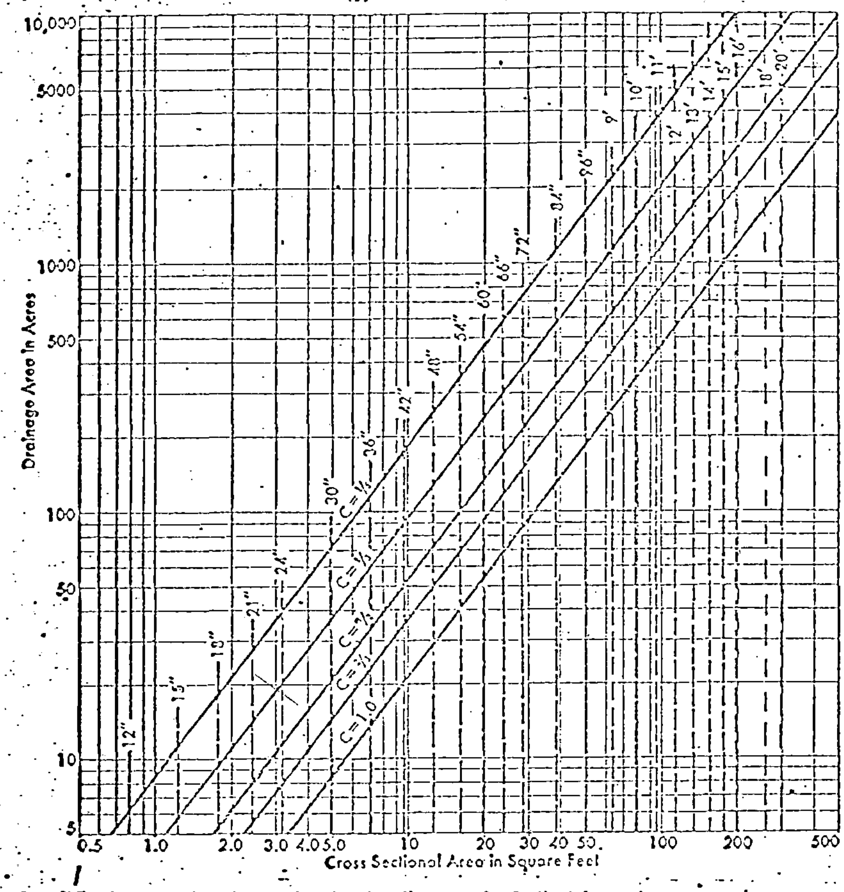

Fig. 1. Culvert size determination by diagram for Talbot formula

Table 2 Acres Drained by Culverts of Various Diameters (Talbot Formula)

Diameter of Culvert in Inches	Area of Waterway Opening in Sq Ft	Mountainous Country C = 1	Rolling Country C = 1/3	Level Country C = 1/5
12	.79	3/4	3	6
15	1.23	1	6	11
18	1.77	2	9	18
21	2.40	3	14	28
24	3.14	5	20	39
30	4.91	8	36	71
36	7.07	14	59	115
42	9.62	20	89	175
48	12.6	29	125	250
54	16.0	40	175	345
60	19.6	55	230	455
66	23.8	70	295	585
72	28.3	85	375	735
78	33.2	105	460	910
84	38.5	130	560	1110
90	44.2	160	680	1340
96	50.3	190	800	1590
102	56.7	220	940	1860
108	63.6	250	1100	2170
114	70.9	290	1270	2510
120	78.5	340	1450	2870
126	86.6	380	1650	3270
132	95.0	430	1880	3710
138	103.9	490	2110	4180
144	113.1	550	2370	4680
150	122.7	610	2640	5210
156	132.7	680	2930	5780
162	143.1	750	3240	6400
168	153.9	820	3570	7050
174	165.1	910	3920	7740
180	176.7	990	4290	8480

by Potter.[5] This figure was subsequently published as figures 1021.10 and 1021.11 (See Figures 2 and 3).

This work by Potter was published in 1950 and outlined the procedures used in deriving these peak runoff rates. The data was analyzed using the theory of extreme values developed by Gumbel and discharges were obtained for a 10-yr. recurrance interval.

Since these Qs were obtained from short-term records, Potter applied three normalcy tests to the rainfall data to determine if they were representative of a long term period. The three tests of rainfall selected were:
(1) comparisons of monthly and annual amounts of rainfall;
(2) comparisons of maximum average rainfall intensities for various time intervals; and (3) comparisons of monthly and annual number of excessive storms.

If these tests proved the rainfall to be abnormal, a correction was applied to the peak rate for a 10-yr. recurrance interval. These corrected peak rates were then plotted against drainage area on log-log-paper. Using this curve in conjunction with the probability curves developed at each station yielded the peak rate for any size watershed for any desired recurrance interval.

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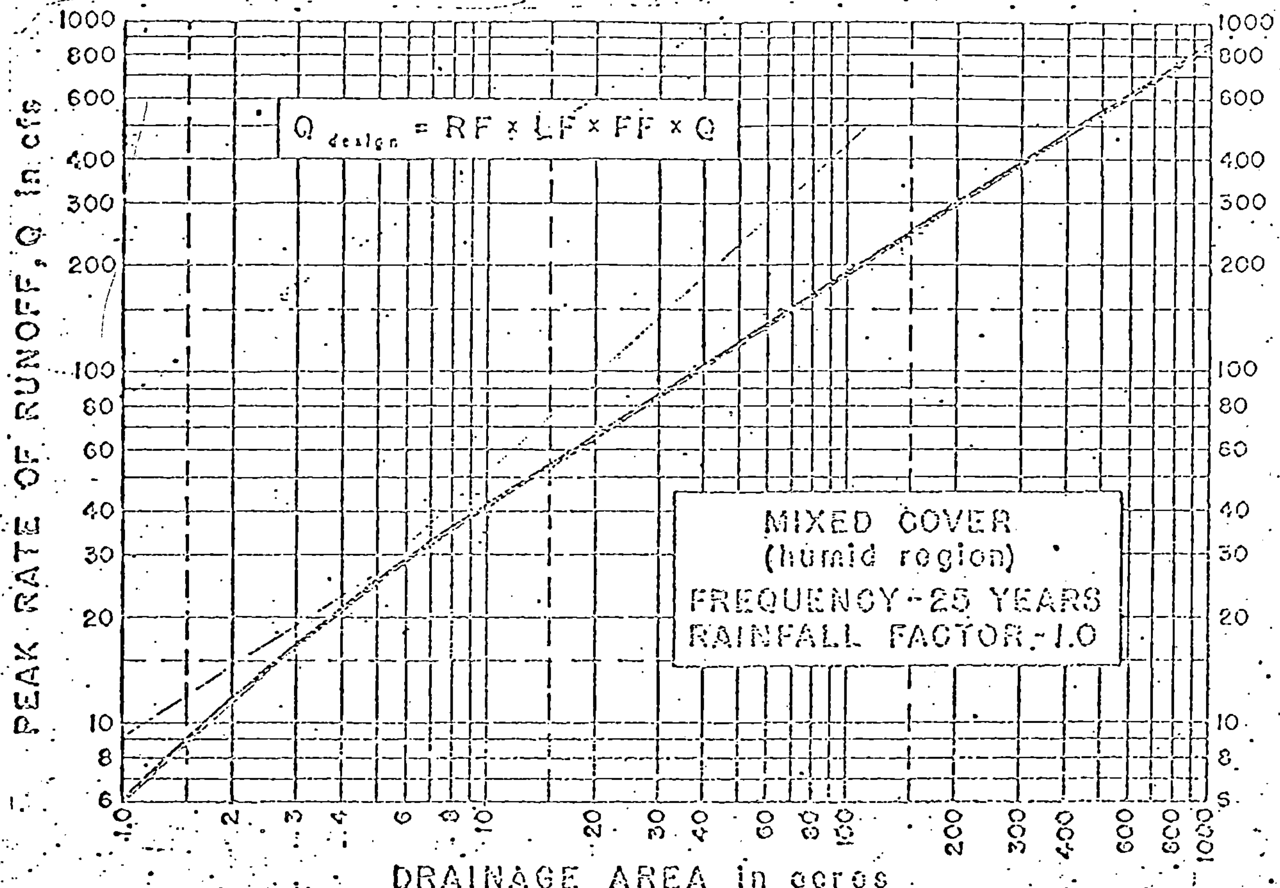
[5] W. D. Potter, "Surface Runoff from Small Agricultural Watersheds, "Research Report No. 11-B, Highway Research Board, 1950.



RAINFALL FACTOR (RF): See Figure 1021.11

LAND USE AND SLOPE FACTORS (LF)

Land Slope	Steep over 2%	Flat 0.2%	Very flat, no ponds
100% Cultivated (row crops)	1.2	0.8	0.25
Mixed cover	1.0	0.6	0.2
Pasture	0.8	0.4	0.1
Woods, deep forest litter	0.3	0.2	0.05

FREQUENCY FACTORS (FF)

Frequency, years	5	10	25	50
Factor	0.6	0.8	1.0	1.2

EXAMPLE

100 acres near Nashville, Tenn., cultivated land sloping about 0.5%, design frequency 10 years.

Solution: (see equation on graph)
Q_{10} = 1.2 x 0.9 x 0.8 x 190
= 170 cfs

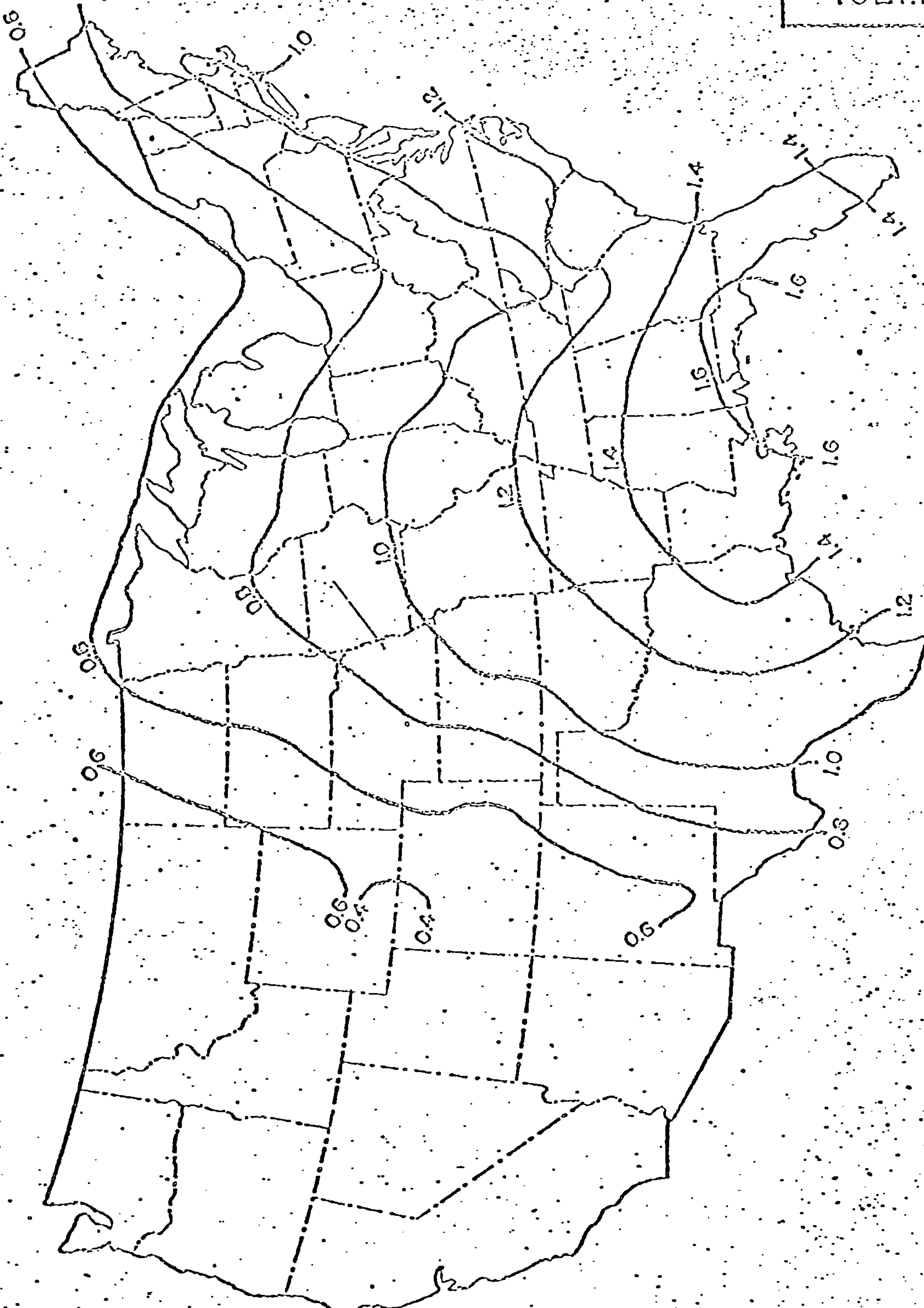
ACCURACY OF BASIC DATA DO NOT JUSTIFY CARRYING MORE THAN TWO SIGNIFICANT FIGURES

SOURCE: Derived in part from Potter "Surface Runoff from Small Agricultural Watersheds", Research Report No. 11-B, Highway Research Board 1950; Land use and slope factors for flat and very flat land slopes are estimated and subject to revision when observed data become available.

AUGUST 1951

BUREAU OF PUBLIC ROADS

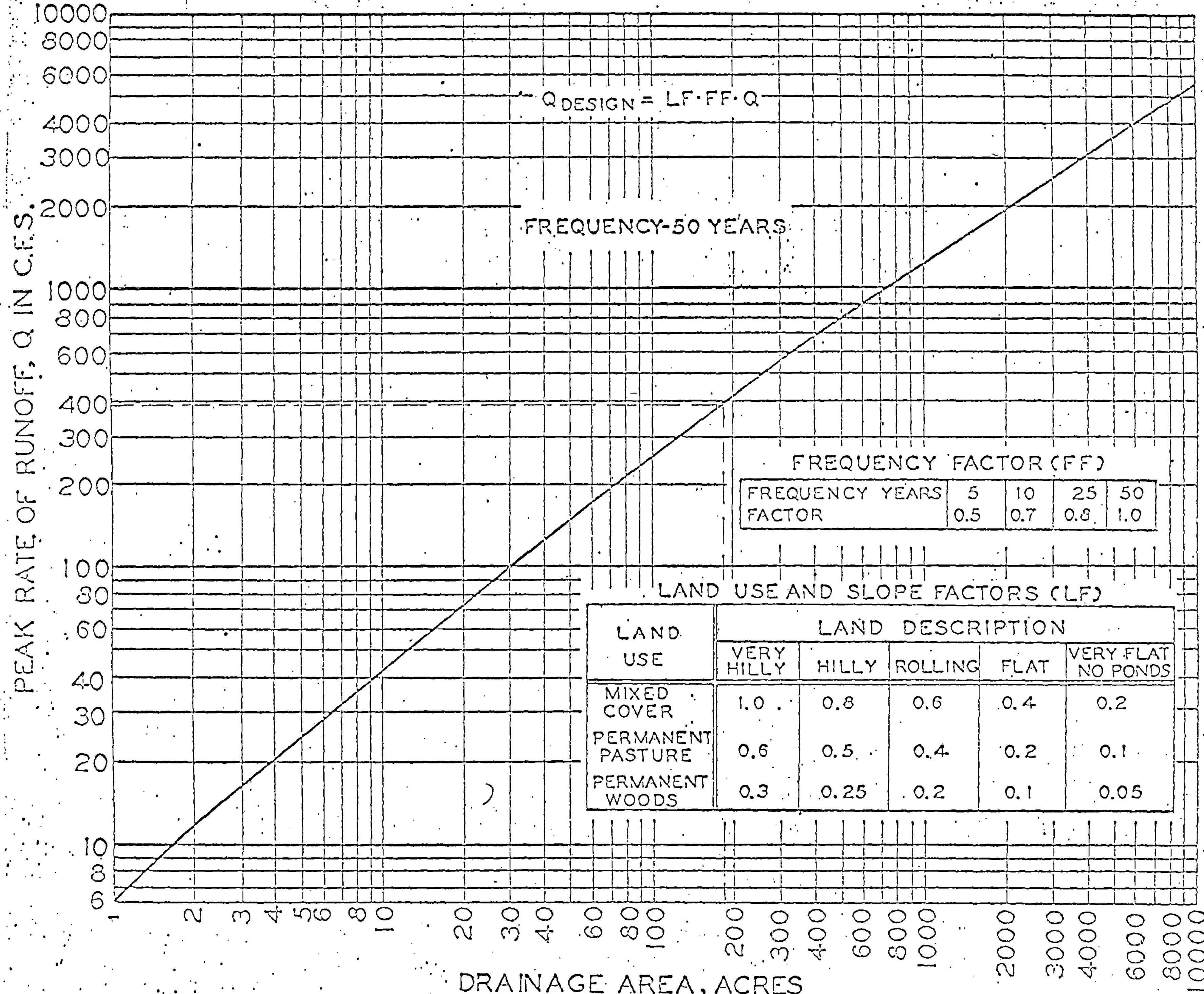
PEAK RATES OF RUNOFF
WATERSHEDS UNDER 1000 ACRES
Figure 2.



BUREAU OF PUBLIC ROADS
JULY 1951

RAINFALL FACTORS
USE WITH FIG. 1021.10 IN ESTIMATING
PEAK RATES OF RUNOFF

Figure 3.



FREQUENCY FACTOR (FF)

FREQUENCY YEARS	5	10	25	50
FACTOR	0.5	0.7	0.8	1.0

LAND USE AND SLOPE FACTORS (LF)

LAND USE	LAND DESCRIPTION				
	VERY HILLY	HILLY	ROLLING	FLAT	VERY FLAT NO PONDS
MIXED COVER	1.0	0.8	0.6	0.4	0.2
PERMANENT PASTURE	0.6	0.5	0.4	0.2	0.1
PERMANENT WOODS	0.3	0.25	0.2	0.1	0.05

Figure 4. Iowa Chart No. 1

Since the Highway Commission normally designs on a 50-yr. recurrance interval, the curve was changed to reflect this and the curve was also extended to 10,000 acres. This revised curve is referred to as Iowa Chart No. 1 (See Figure 4).

BULLETIN No. 1

Bulletin No. 1 was published in April, 1953.[6] This was the first attempt to present this type of information for large drainage areas in an easy to use form which was based on a statistical analysis of streamflow records.

58 gaging stations with drainage areas of over 100 square miles were utilized in this study using a base period of 1918-1950. Using Gumbel's Theory of Extreme Values, a frequency-discharge curve was drawn on a special graph paper developed by Powell. This curve, along with the basic data, was developed for each station. A typical example is shown as Tables 3 and 4 and Figure 5 for the Skunk River near Ames.

The data was then used to formulate a series of regional curves based on a method developed by Dalrymple. This method will be described in detail later in this paper but it consists of four general steps.

1. Select a base period applicable to the records of a region.

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[6] H.H. Schwob, Iowa Floods, Magnitude and Frequency; Iowa Highway Research Board Bulletin No. 1, 1953.

24. Skunk River near Ames, Iowa

Location.—Lat. 42° 04′ 06″, long. 93° 37′ 02″, in SW¼ sec. 23, T. 84 N., R. 24 W., on left bank 2½ miles north of Ames, 3½ miles downstream from Keigley Branch, and 5 miles upstream from Squaw Creek.

Drainage area.—320 sq. mi.

Gage.—Water-stage recorder and concrete control at present site since July 21, 1934. Datum of gage is 893.6 ft. above mean sea level, datum of 1929 (Iowa Highway Commission bench mark). July 28, 1920, to Aug. 24, 1921, inclined staff gage at same site and datum. Aug. 25, 1921, to Aug. 5, 1927, March 31, 1933, to July 20, 1934, water-stage recorder at same site and datum.

Stage-discharge relation.—Defined by current-meter measurements below 6,000 cfs; extended above by logarithmic plotting.

Remarks.—Base for partial-duration series, 1,500 cfs.

Flood magnitude and frequency data

Date	Gage height (feet)	Discharge (cfs)	Annual floods		Partial-duration series	
			Order (M)	Recurrence interval (years)	Order (M)	Recurrence interval (years)
1921 Sept. 17	9.2	3,540	6	4.50	6	4.17
1922 Feb. 23	9.0	3,370	9	3.00	10	2.50
Apr. 12	6.0	1,640			42	.60
July 16	6.1	1,690			40	.62
1923 Mar. 28	6.2	1,670	24	1.12	41	.61
Sept. 28	6.0	1,640			43	.58
1924 Mar. 30	6.3	1,800			38	.66
June 28	8.2	3,010	12	2.25	14	1.79
Aug. 9	6.0	1,640			44	.57
1925 Aug. 7	5.0	1,130	26	1.04		
1926 Sept. 8	6.5	1,900			35	.71
Sept. 19	8.3	3,120	10	2.70	11	2.27
1927 Feb. 5	7.4	2,460	18	1.50	24	1.04
1930 Nov. 24	11.2	5,230	3	9.00		
1933 Apr. 1	6.5	1,990	23	1.17		
1934 Jan. 22	5.4	1,300	25	1.08		
1935 Feb. 15		2,490			23	1.09
Mar. 5	9.0	3,490	7	3.86	7	3.57
June 19	6.5	1,900			36	.69
June 25	8.4	2,950			15	1.67
July 24	7.0	2,190			29	.86
1936 Mar. 10	7.7	2,580	16	1.69	21	1.19

Table 3.

Flood magnitude and frequency data—continued

Date	Gage height (feet)	Discharge (cfs)	Annual floods: Order (M)	Annual floods: Recurrence interval (years)	Partial-duration series: Order (M)	Partial-duration series: Recurrence interval (years)
1937 Mar. 6		2,000	22	1.23	31	0.81
1938 May 4	8.3	2,890	13	2.08	16	1.56
May 17	6.5	1,880			37	.68
June 29	5.8	1,540			50	.50
1939 Mar. 13		2,800	14	1.93	18	1.39
1940 Aug. 13	7.3	2,320	20	1.35	27	.93
1941 Sept. 8	8.6	3,050	11	2.46	13	1.92
1941 Nov. 1	5.9	1,630			46	.54
1942 Sept. 14	8.1	2,530	17	1.59	22	1.14
1943 June 16	6.5	1,910			34	.74
July 31	10.3	4,500	4	6.75	4	6.25
1944 May 20	13.9	8,060	1	27.00	1	25.00
June 12	8.0	2,840			17	1.47
1945 Mar. 16	6.3	1,800			39	.64
May 22	7.7	2,620			20	1.25
June 2	9.7	4,010	5	5.40	5	5.00
1946 Feb. 5	7.1	2,270	21	1.29	28	.89
Mar. 6	5.9	1,600			48	.52
Mar. 13	5.9	1,610			47	.53
1947 June 1	8.2	3,480			8	3.12
June 4	8.2	3,110			12	2.08
June 13	12.0	5,900	2	13.50	2	12.50
June 23	10.8	4,920			3	8.33
June 30	6.4	1,950			33	.76
1948 Feb. 28	5.8	1,590			49	.51
Mar. 19	7.4	2,400	19	1.42	25	1.00
Mar. 27	7.3	2,380			26	.96
1949 Mar. 4		2,700	15	1.80	19	1.32
1950 Mar. 7	8.9	3,420	8	3.38	9	2.78
May 5	6.0	1,640			45	.56
May 9	7.0	2,190			30	.83
June 9	5.8	1,540			51	.49
June 18	6.6	1,960			32	.78

Table 4.

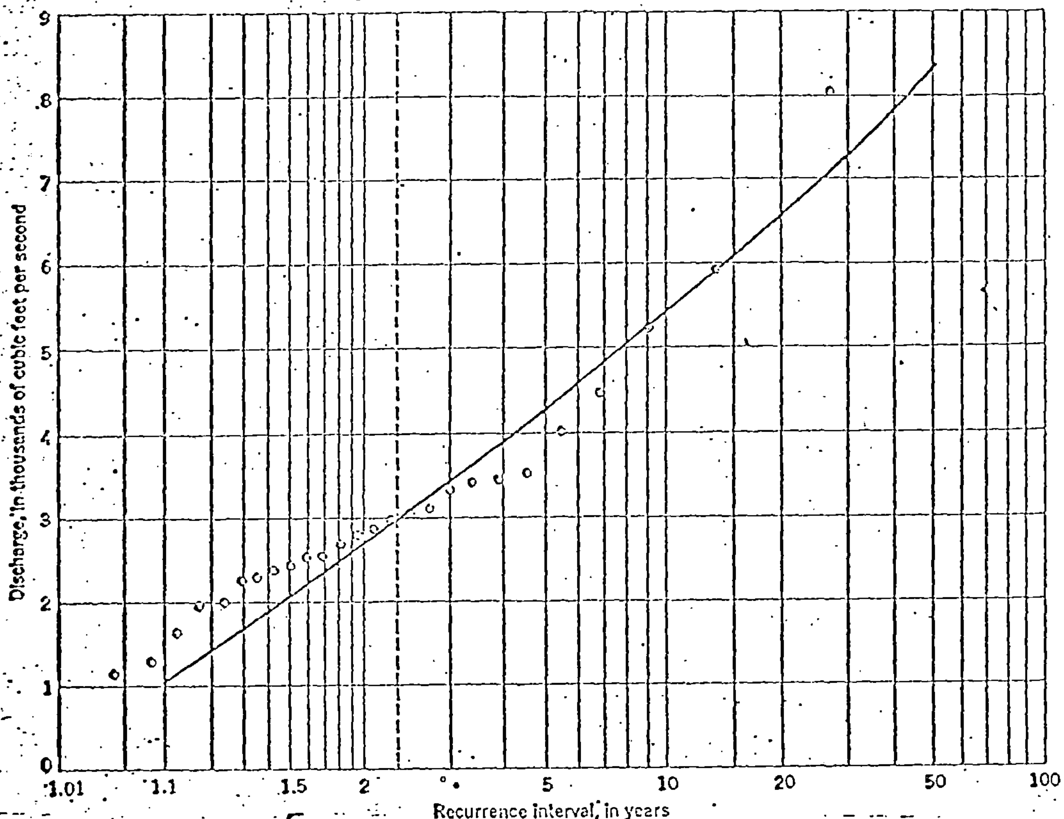

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FIGURE 5. Frequency of annual floods, Skunk River near Ames, Iowa.

2. Test the homogeneity of the records to be used.
3. Combine the homogeneous records to produce a composite frequency curve.
4. Correlate the mean annual flood with a characteristic of the region.

The results of the regionalization are shown in Figures 6, 7, and 8.

The bulletin then outlines five steps necessary to obtain a discharge for a particular recurrance interval and drainage area.

1. Determine the drainage area for the selected site from the best map available.
2. Determine from the map of Figure 6 the lettered region (A-H) within which the site lies.
3. From Figure 8, using the curve lettered the same as the region determined in 2, obtain the mean annual flood for the drainage area that has been measured.
4. From the composite curve of Figure 7, select the ratio corresponding to the desired recurrance interval.
5. Multiply the values obtained in 3 and 4 - this is the flood sought.

BULLETIN No. 7

In December of 1957, Bulletin No. 7 was published. The need for this information is expressed quite well in the introduction to this bulletin.

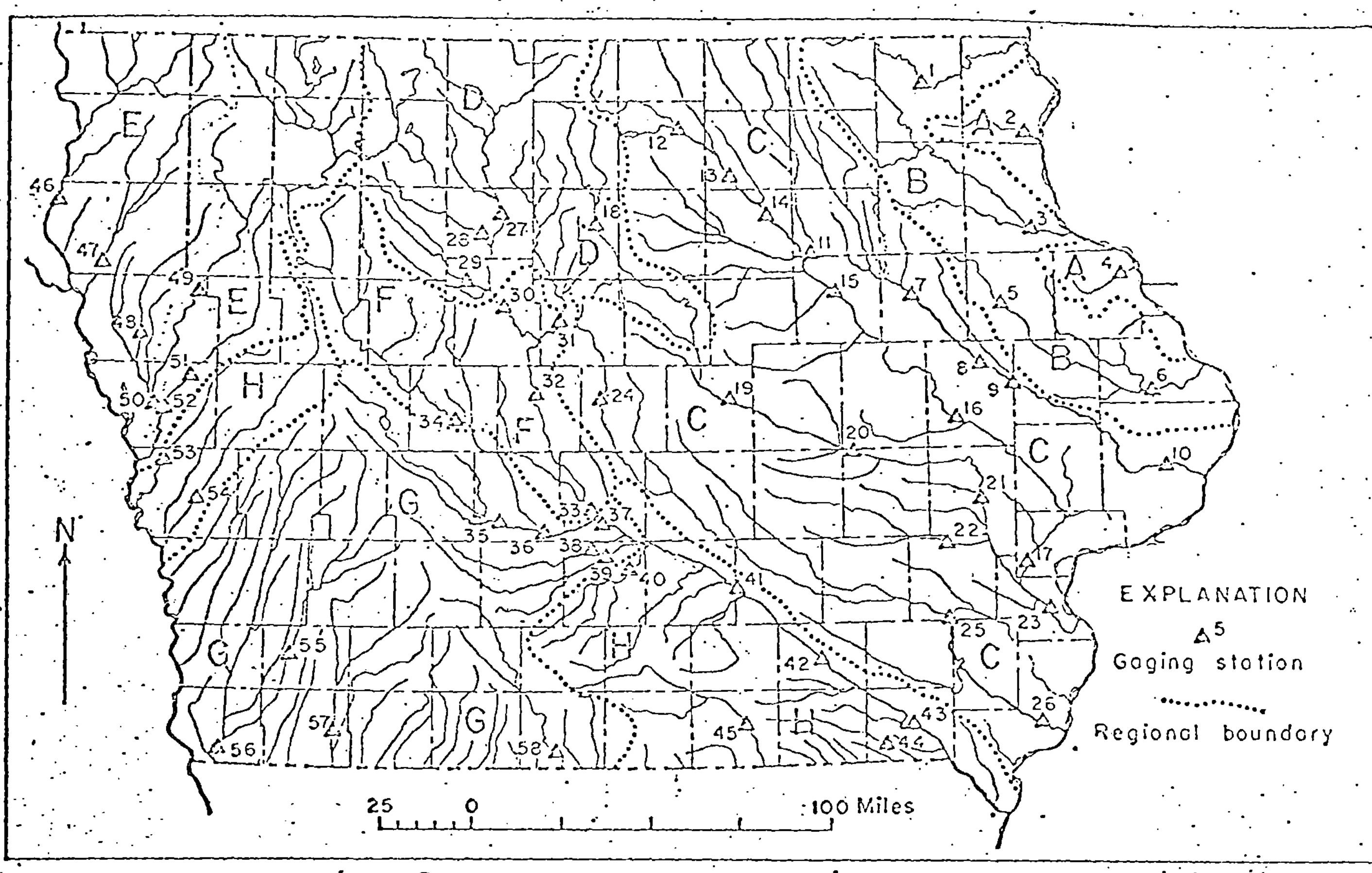

FIGURE 6. Gaging stations and regional boundaries in Iowa.

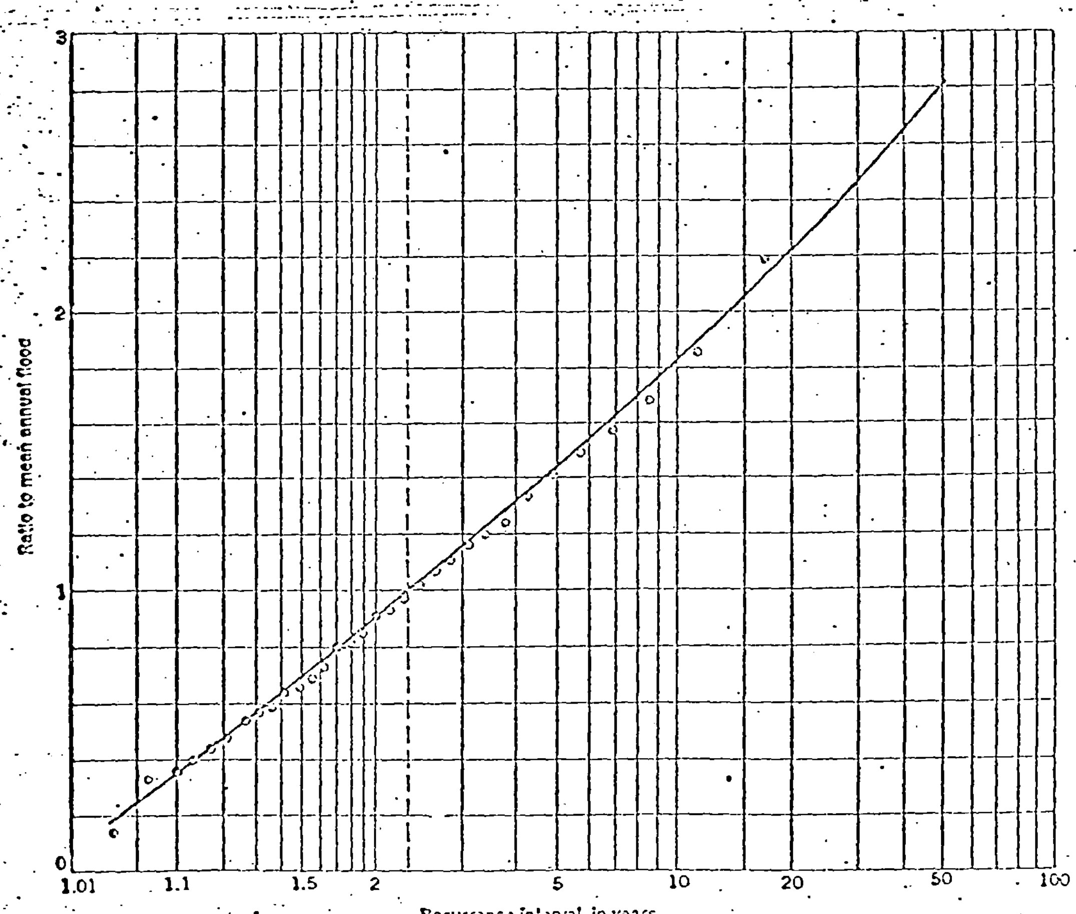

FIGURE 7. Composite curve.

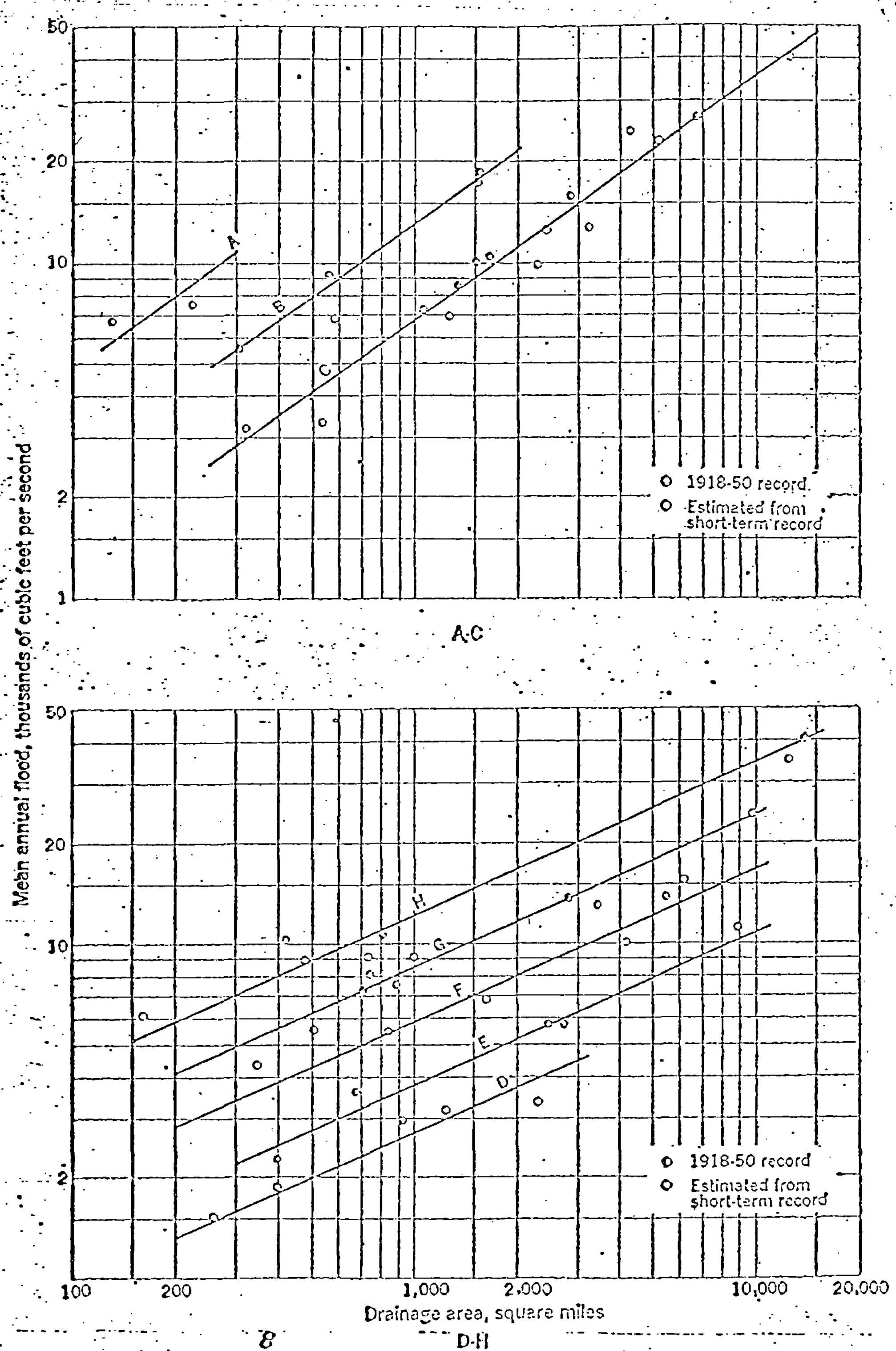

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FIGURE 8. Relation of mean annual flood to drainage area.

One of the most important factors in the hydrologic computation for the design of structures on or over water-courses is the drainage area upstream from the point under consideration. Other hydrologic studies such as low-flow, flood-frequency analysis, rainfall-runoff correlations, stream density, and area-distance make use of this factor as a basic premise for computation. In order that the drainage area information of the interior streams of Iowa be of uniform accuracy and available to all users of these data, this report has been compiled, and the drainage areas of all streams in excess of 5 square miles are listed. For the larger streams, drainage areas have been determined at numerous intermediate points.[7]

These individual drainage areas were calculated in the following manner. First the area of the entire state was very carefully determined to be 56,239 square miles. This figure was independently checked by a summation of the areas of the 99 counties. Drainage areas were outlined on county soil maps using aerial photos, quadrangle sheets, and county drainage maps. These maps were then checked by the county engineers and all changes made by them were incorporated into the final outlines on the soil maps.

Drainage areas were computed on a county basis. The

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[7]O. J. Larimer, Drainage Areas of State Streams: Iowa Highway Research Board Bulletin No. 7, 1957.

large drainage basins were planimetered and adjusted to the area of the county. The smaller areas within the larger drainage basins were then measured and adjusted so that the sum of all the small areas equalled the larger area.

These individual drainage areas in each county were then indexed and tabulated as shown for Story County in Figure 9 and Table 9.

USGS INTERIM REPORT-

The Interim Report is based upon a method outlined in a paper written by Tate Dalrymple in 1949. In this paper he presents a method whereby gaging station records are analyzed and the results presented in such a way that the point data at the gaging station is adapted to apply over a basin or a region. This determination of regional flood frequencies is based upon a 15 step procedure which is as follows.

Step 1. Tabulate flood data for all gaging stations in the region having a record of about five years or more, List the maximum annual flood.

This tabulation is contained in Part II of Bulletin No. 28.[8] It contains the records of 147 gaging stations in Iowa, listing them as a partial duration series. From this listing the maximum annual floods can be obtained. The

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[8] Harlan H. Schwob, Magnitude and Frequency of Iowa Floods: Iowa Highway Research Board Bulletin No. 28, Part II, 1966.

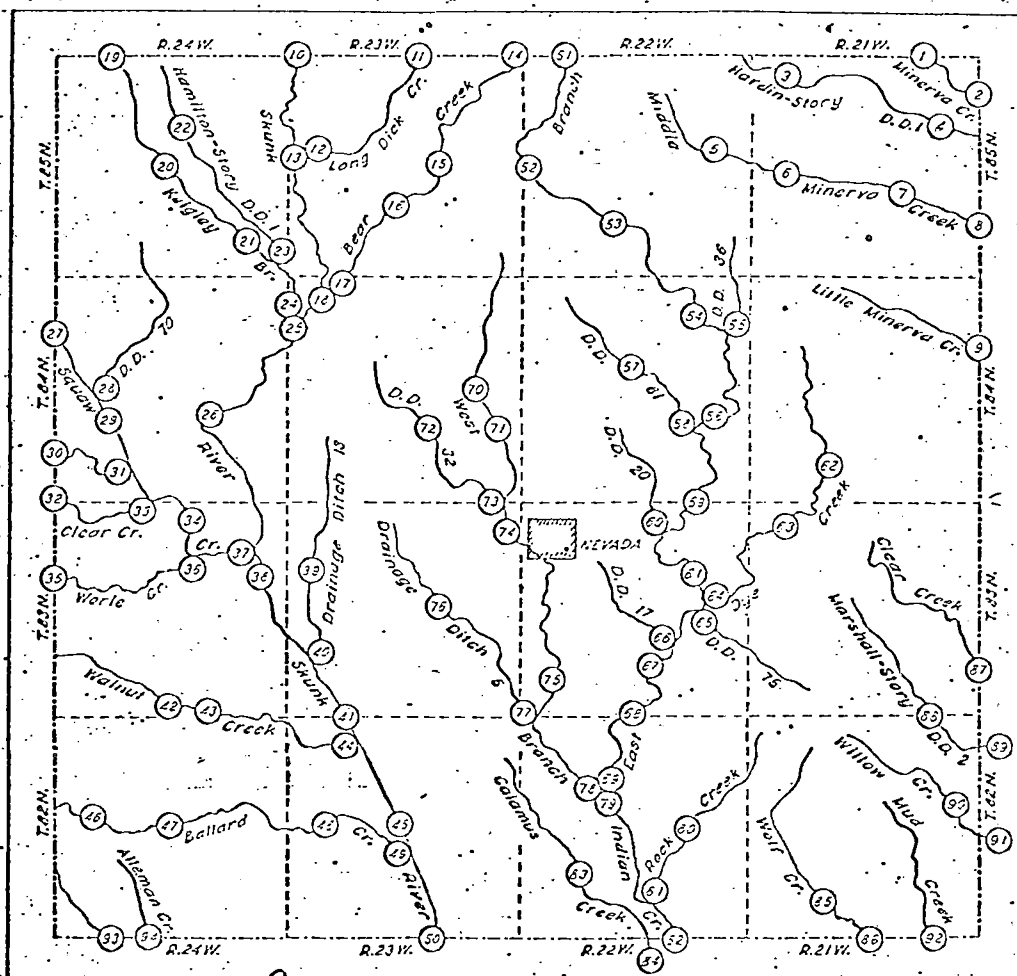

Figure 9. Drainage area index map of Story County, Iowa.

DRAINAGE AREAS OF IOWA STREAMS

Table No. 5 Story County

Area No.	Name of stream	Tributary to	Bank	Point of determination of drainage area: Description	Sec.	T	R	Drainage area (sq mi)
1	Minerva Creek........	Iowa River...........	R	Road crossing, north (county) line	2	85N	21W	30.1
2	....do...............	....do...............	R	East (county) line...............	12	85N	21W	32.4
3	Hardin-Story Drainage Ditch 1.	Minerva Creek........	R	Road crossing, west line..........	5	85N	21W	6.50
4	....do...............	....do...............	R	Road crossing, west line..........	12	85N	21W	12.7
5	Middle Minerva Creek.	....do...............	R	Road crossing, west line..........	13	85N	22W	4.50
6	....do...............	....do...............	R	Road crossing, west line..........	20	85N	21W	11.9
7	....do...............	....do...............	R	Road crossing, west line..........	23	85N	21W	21.4
8	....do...............	....do...............	R	East (county) line...............	25	85N	21W	30.2
9	Little Minerva Creek.	Middle Minerva Creek.	R	Road crossing, east (county) line.	12	84N	21W	7.28
10	Skunk River..........	Mississippi River....	R	North (county) line..............	6	85N	23W	173
11	Long Dick Creek......	Skunk River..........	L	Road crossing, north (county) line	3	85N	23W	25.2
12	....do...............	....do...............	L	At mouth.........................	18	85N	23W	33.4
13	Skunk River..........	Mississippi River....	R	Below Long Dick Creek............	18	85N	23W	218
14	Bear Creek...........	Skunk River..........	L	Road crossing, north (county) line	1	85N	23W	11.5
15	....do...............	....do...............	L	Road crossing, north line.........	22	85N	23W	20.0
16	....do...............	....do...............	L	Road crossing, NW¼...............	28	85N	23W	24.8
17	....do...............	....do...............	L	At mouth.........................	6	84N	23W	31.8
18	Skunk River..........	Mississippi River....	R	Below Bear Creek.................	6	84N	23W	258
19	Keigley Branch.......	Skunk River..........	R	Road crossing, north (county) line	5	85N	24W	18.1
20	....do...............	....do...............	R	Road crossing, north line.........	21	85N	24W	28.8
21	....do...............	....do...............	R	Road crossing, west line..........	36	85N	24W	31.9
22	Hamilton-Story Drainage Ditch 1.	Keigley Branch.......	L	Road crossing, north line.........	15	85N	24W	5.85
23	....do...............	....do...............	L	At mouth.........................	36	85N	24W	10.7
24	Keigley Branch.......	Skunk River..........	R	At mouth.........................	7	84N	23W	46.8
25	Skunk River..........	Mississippi River....	R	Below Keigley Branch.............	7	84N	23W	306
26	....do...............	....do...............	R	Gage above Ames, SW¼.............	23	84N	24W	315
27	Squaw Creek..........	Skunk River..........	R	Road crossing, west (county) line.	7	84N	24W	150
28	Drainage Ditch 70....	Squaw Creek..........	L	At mouth.........................	20	84N	24W	9.02
29	Squaw Creek..........	Skunk River..........	R	Road crossing, west 1/2..........	20	84N	24W	170
30	Onion Creek..........	Squaw Creek..........	R	Road crossing, west (county) line.	30	84N	24W	15.6

drainage areas range in size from 0.3 to 14,000 square miles.

Step 2. Review the station history and make a careful study of the stage-discharge relationship.

The goal here is to make each record consistent within itself and as accurate as all available data permit. A common cause of inconsistency which requires earlier discharges to be recomputed is due to more recent high water discharge measurements which indicate that the originally used rating curve was in error.[9]

Step 3. Select the base period for the study. Usually this will be the period of the longest record.

For this Interim Report, the period used was 1916-1965.

Step 4. Compute the discharge figures for the missing years for each station.

This can be done by means of a correlation curve based on flood peaks. The peak discharge for a floodpeak at a short-term station is plotted against the peak discharge for the corresponding flood at the long-term station. This curve can then be used to compute a discharge for each of the missing years of record (See Figure 10).

Step 5. Number the floods for each station in order of magnitude, numbering the greatest flood 1.

Step 6. Compute the recurrence intervals using the formula:

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[9] Tate Dalrymple, "Regional Flood Frequency," Research Report No. 11-B, Highway Research Board, 1950.

R.I. = (N+1)/M where N is the number of years of record and M is the order number.

Step 7. Plot the discharge versus the recurrence interval and draw the frequency curve to get the 2.33 and 10-yr. floods.

The points are plotted on a form developed by Powell for analysis of flood frequencies by the Gumbel Method. A best fit by eye line is drawn spanning the frequencies from 2 thru 10 years (see figure 11).

Step 8. Test for homogeneity.

This requires a study of the 10-yr. Flood for each station. The recurrence interval for an averaged flood (the calculations for this area shown on Table 6) are plotted against the length of record at each station as shown on Figure 12. Dalrymple describes the reason for this test as follows:

> Tentatively assume that each station represents a different sample from a single homogeneous record. If this is so, then the recurrence intervals will not differ among themselves by an amount greater than can be attributed to change. A figure has been set up to test this supposition. It shows within what range of recurrence intervals we can expect an estimate of a 10-yr. flood to be. The range, of course, is rather great with short records and as one would expect, the range narrows down with long records. If all points as listed above plot within the limits, we may reasonably conclude that the records are acceptably homogeneous.[10]

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[10] Ibid., p-13.

TABLE 6

DATA FOR HOMOGENEITY TEST FOR GAGING STATIONS IN MAUMEE RIVER BASIN

No.	Gaging Station	Drainage Area	Mean Annual Flood, $Q_{2.33}$	10-yr. Flood, Q_{10}	Ratio, $\frac{Q_{10}}{Q_{2.33}}$	$Q_{2.33}$ x 1.38	Recurrence Interval for Q of Column 7	Period of Record
1	2	3	4	5	6	7	8	9
		sq. mi.	sec. ft.	sec. ft.		sec. ft.	yr.	yr.
1	St. Joseph River near Blakeslee, Ohio	369	2,900	4,000	1.38	4,000	10	6
2	St. Joseph River near Fort Wayne, Ind.	1,060	8,300	10,600	1.28	11,500	21	8
3	Maumee River at Antwerp, Ohio	2,049	15,200	22,300	1.47	21,000	7	37
4	Maumee River near Defiance, Ohio	5,530	48,300	68,000	1.41*	66,700	9	22
5	Maumee River at Waterville, Ohio	6,314	52,500	70,800	1.35*	72,400	12	25
6	Cedar Creek at Auburn, Ind.	93	908	1,090	1.20	1,253	45	6
7	St. Marys River near Willshire, Ohio	355	3,720	5,050	1.36	5,130	11	7
8	St. Marys River near Fort Wayne, Ind.	753	7,700	10,600	1.38	10,600	10	18
9	Bean Creek at Powers, Ohio	238	2,900	3,550	1.22	4,000	30	8
10	Tiffin River at Stryker, Ohio	444	4,080	5,430	1.34	5,630	13	17
11	Tiffin River near Brunersburg, Ohio	766	6,500	8,550	1.32	8,970	14	7
12	Auglaize River near Fort Jennings, Ohio	333	5,850	8,200	1.40	8,070	9	23
13	Auglaize River near Defiance, Ohio	2,329	27,000	42,700	1.58	37,300	6	34
14	Ottawa River at Allentown, Ohio	168	2,930	4,200	1.43	4,040	8	19
15	Ottawa River at Kalida, Ohio	315	4,800	7,300	1.52	6,620	7	5
16	Blanchard River near Findlay, Ohio	343	5,600	7,850	1.40	7,730	9	22
17	Blanchard River at Glandorf, Ohio	643	8,600	12,100	1.41	11,900	9	16
	Average Ratio				1.38			

*The mean of these two was used to compute the average.

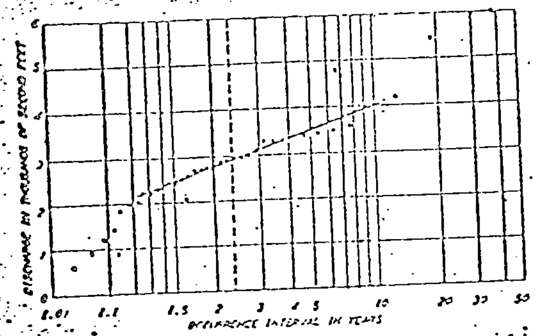


Figure 11. Preliminary Frequency Curve

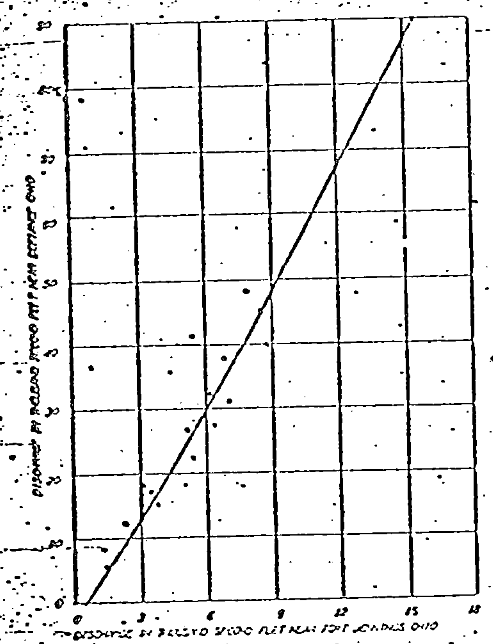


Figure 10. Discharge Correlation

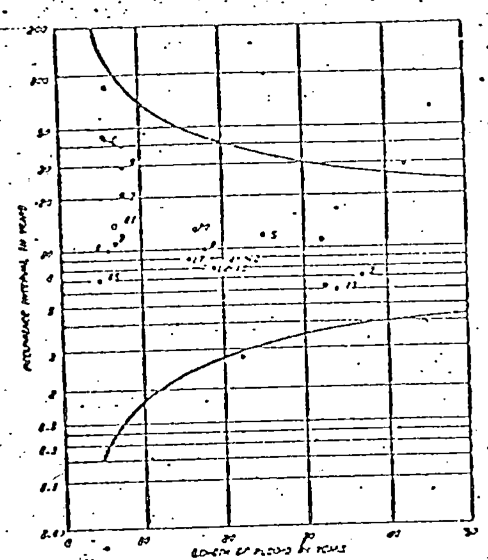


Figure 12. Homogeneity Test

TABLE 7.

TABULATION OF FLOOD DATA, MAUMEE RIVER BASIN

Sta. No.	Station and Location	Drainage Area sq. mi.	Water Year	1912	1913	1914	1947	1948	Adjusted Mean sec. ft.
1	St. Joseph River near Blakeslee, Ohio	369	Date cfs. order ratio	3,400[a] 9	6,000[a] 1	2,700[a] 21	2,750[a] 20	2,450[a] 26	2,900
2	St. Joseph River near Fort Wayne, Ind.	1,060	Date cfs. order ratio	9,450[a] 9	Mar. 16,500 1 1.99	7,900[a] 19	Apr. 24 6,970 27 .840	Feb. 29 6,800 28 .819	8,300
3	Maumee River at Antwerp, Ohio	2,049	Date cfs. order ratio	Apr. 2 19,200 8 1.26	Mar. 27 40,000 1 2.63	May 13 14,300 19 .941	June 4 11,600 27 .763	Feb. 29 11,900 25 .783	15,200
37	Blanchard River at Glandorf Ohio	643	Date cfs. order ratio	9,900[a] 12	26,000[a] 1	7,600[a] 21	June 9 11,300 4 1.31	Mar. 23 9,110 14 1.06	8,600

[a] Computed

TABLE B 6

PLOTTING POSITIONS FOR MEDIAN FLOOD RATIOS, 1912-48, MAUMEE RIVER BASIN

Order Number	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	Median Ratio	Plotting Position
Col. 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1		1.99	2.63							1.71			3.33			2.86		2.63	38.0
2	1.88		1.72		1.58			1.74		1.44	1.54	1.50	1.78	1.76		1.66	1.73	1.72	19.0
3		1.23	1.48		1.54				1.26	1.39		1.45	1.67	1.72		1.46	1.45	1.46	12.7
4	1.37		1.39		1.36				1.23			1.35	1.46			1.38	1.31	1.36	9.50
5			1.39			1.18				1.26			1.44			1.33	1.27	1.30	7.60
6		1.22	1.36		1.24					1.24			1.44	1.32		1.20		1.24	6.33
7			1.36					1.22				1.26	1.40					1.31	5.43
8	1.18	1.20	1.26			1.21							1.37					1.20	4.75
9			1.23	1.18					1.13			1.21				1.14		1.18	4.22
10			1.21		1.14	1.08	1.15	1.06			1.13		1.27					1.14	3.80
11			1.13		1.10	1.03						1.19	1.19			1.10		1.12	3.43
12			1.10		1.10		1.06					1.17	1.16	1.07				1.10	3.17
13			1.08					1.05		1.07			1.16					1.05	2.92
14			1.03	1.08								1.08	1.15	1.06		1.07	1.06	1.07	2.71
15			1.03		1.04	1.01					1.04		1.02	.996				1.02	2.53
16			1.02		1.02	1.01				1.00		1.06	1.01			1.03		1.02	2.33
17			.993		1.02			.974					.989			1.00	.996	.994	2.24
18			.993		.998			.961		.980				.955			.977	.978	2.11
19			.941		.962							.923	.944			.964		.944	2.00
20			.941		.949				.996	.973			.930	.925		.893		.941	1.90
21			.927					.929				.885	.874	.894		.875		.890	1.81
22			.914		.934							.885	.833				.872	.885	1.73
23			.882	.895				.860		.881			.826	.884				.832	1.65
24			.829		.880		.788	.852				.783	.815	.864		.826	.845	.829	1.58
25			.783		.872					.804			.792	.853			.779	.798	1.52
26			.763		.866		.736			.789		.750	.778		.798	.723		.770	1.46
27		.840	.763		.848					.784	.861	.735	.775	.805				.794	1.41
28		.819	.744							.767								.767	1.36
29			.744		.789			.669				.670	.760				.687	.716	1.31
30	.769	.802	.710				.629	.659				.656	.696	.758				.703	1.27
31			.698		.720		.619	.644	.607				.667	.751		.589		.656	1.23
32			.671		.697			.627				.615	.644	.744	.715		.523	.658	1.19
33	.648	.731	.581	.622				.576		.490	.680	.601	.637			.511	.519	.601	1.15
34			.574		.596			.476	.552			.547	.559	.693	.464	.502	.453	.550	1.12
35			.494		.488			.455	.479	.355	.357	.395	.448	.423	.290	.275	.395	.409	1.09
36	.317		.256		.240			.386	.297	.289		.256	.307	.314	.265	.214	.221	.277	1.06
37			.222		.206		.152	.260			.154	.236	.194			.171		.200	1.03

Step 9. List the annual floods in a block table for homogeneous stations, and record the mean annual, or 2.33 year flood (See Table 7).

Step 10. Compute the ratio of the annual flood to the mean annual flood for each year of actual record. This ratio is shown on the fourth line of data for each station in Table 7.

Step 11. Tabulate the flood ratios, listing the ratios for each order number on one line or in one column. These ratios are shown in Table 8.

Step 12. Determine the median flood ratio for each order number and record the corresponding recurrence intervals. (See Table 8).

Step 13. Plot the median flood ratios recurrence intervals and draw the composite frequency curve. In general, do not extrapolate above the 50-yr. frequency curve.

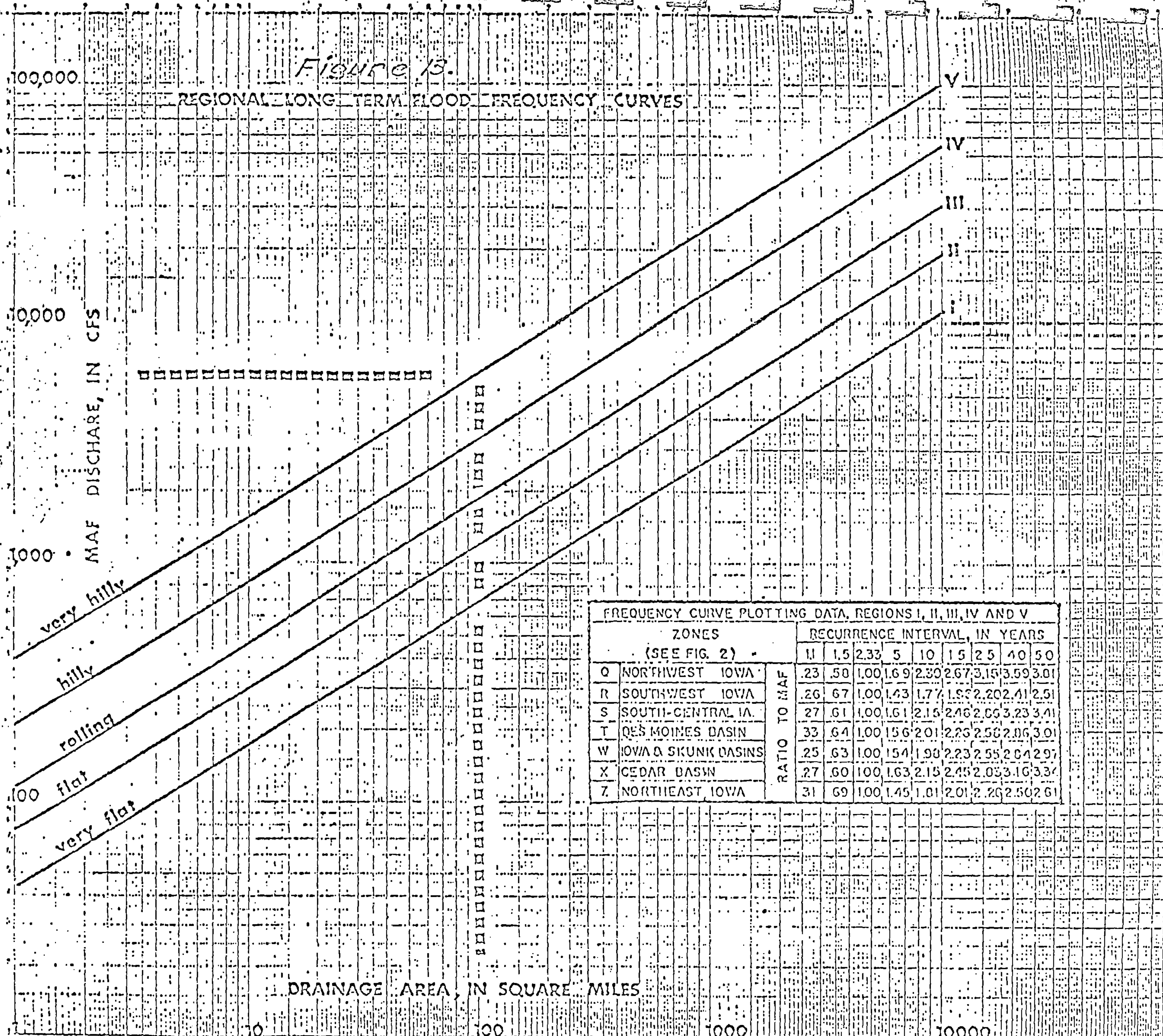
Step 14. Plot the mean annual floods versus drainage area. Draw a curve, or curves, to show the relation applicable for the region.

Step 15. Determine the flood frequency for any place in the region from the curves of steps 13 and 14.

In the Interim Report, Step 13 has been shown as a table in Figure 13. Step 14 has been drawn as a family of

Figure 13.

REGIONAL LONG TERM FLOOD FREQUENCY CURVES



FREQUENCY CURVE PLOTTING DATA, REGIONS I, II, III, IV AND V

ZONES (SEE FIG. 2)			RECURRENCE INTERVAL, IN YEARS								
			1.1	1.5	2.33	5	10	15	25	40	50
Q	NORTHWEST IOWA	RATIO TO MAF	.23	.50	1.00	1.69	2.30	2.67	3.15	3.59	3.01
R	SOUTHWEST IOWA		.26	.67	1.00	1.43	1.77	1.93	2.20	2.41	2.51
S	SOUTH-CENTRAL IA.		.27	.61	1.00	1.61	2.15	2.46	2.85	3.23	3.41
T	DES MOINES BASIN		.33	.64	1.00	1.56	2.01	2.26	2.58	2.86	3.01
W	IOWA & SKUNK BASINS		.25	.63	1.00	1.54	1.90	2.23	2.55	2.84	2.97
X	CEDAR BASIN		.27	.60	1.00	1.63	2.15	2.45	2.85	3.16	3.34
Z	NORTHEAST IOWA		.31	.69	1.00	1.45	1.81	2.01	2.26	2.50	2.61

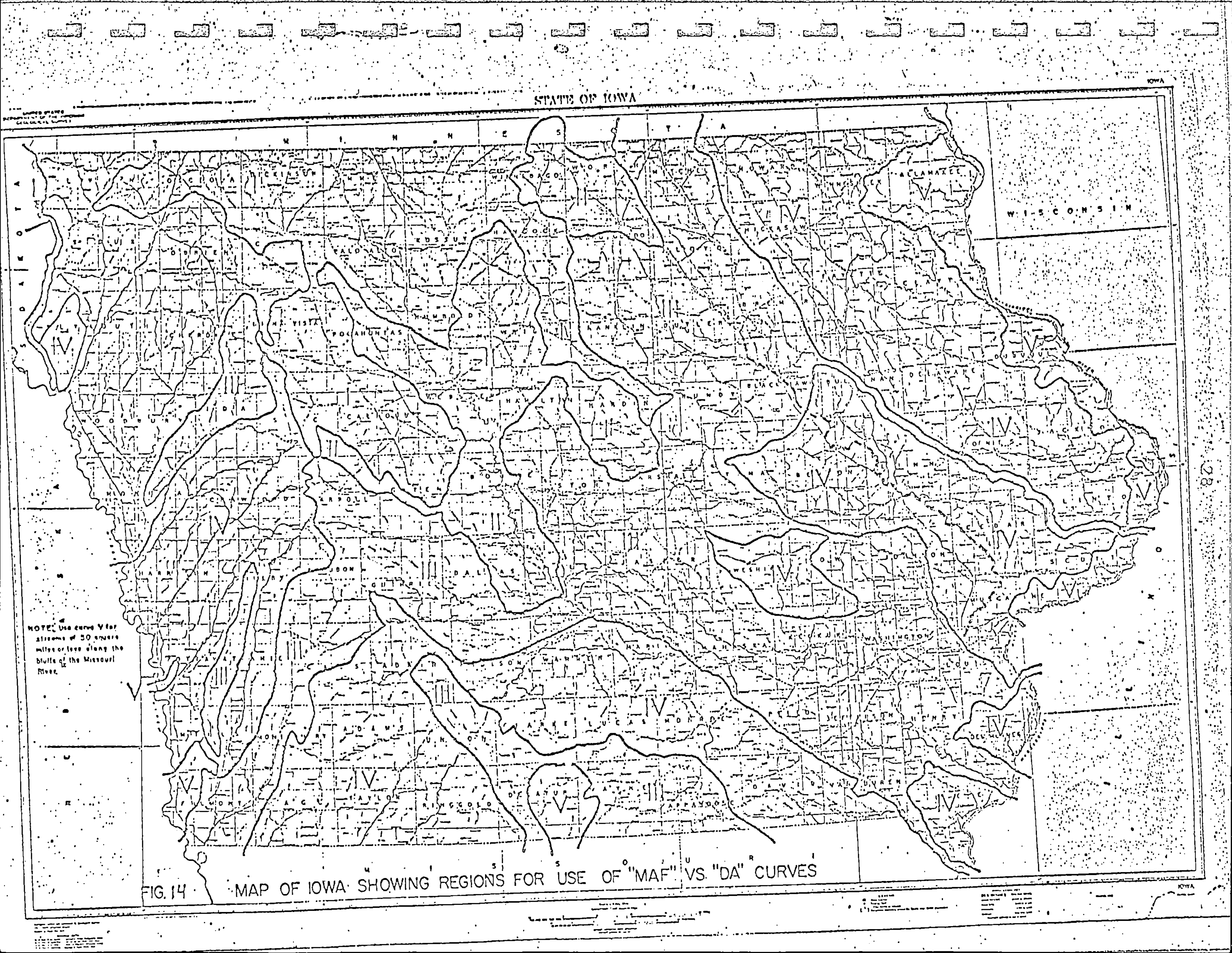


FIG. 14 MAP OF IOWA SHOWING REGIONS FOR USE OF "MAF" VS. "DA" CURVES

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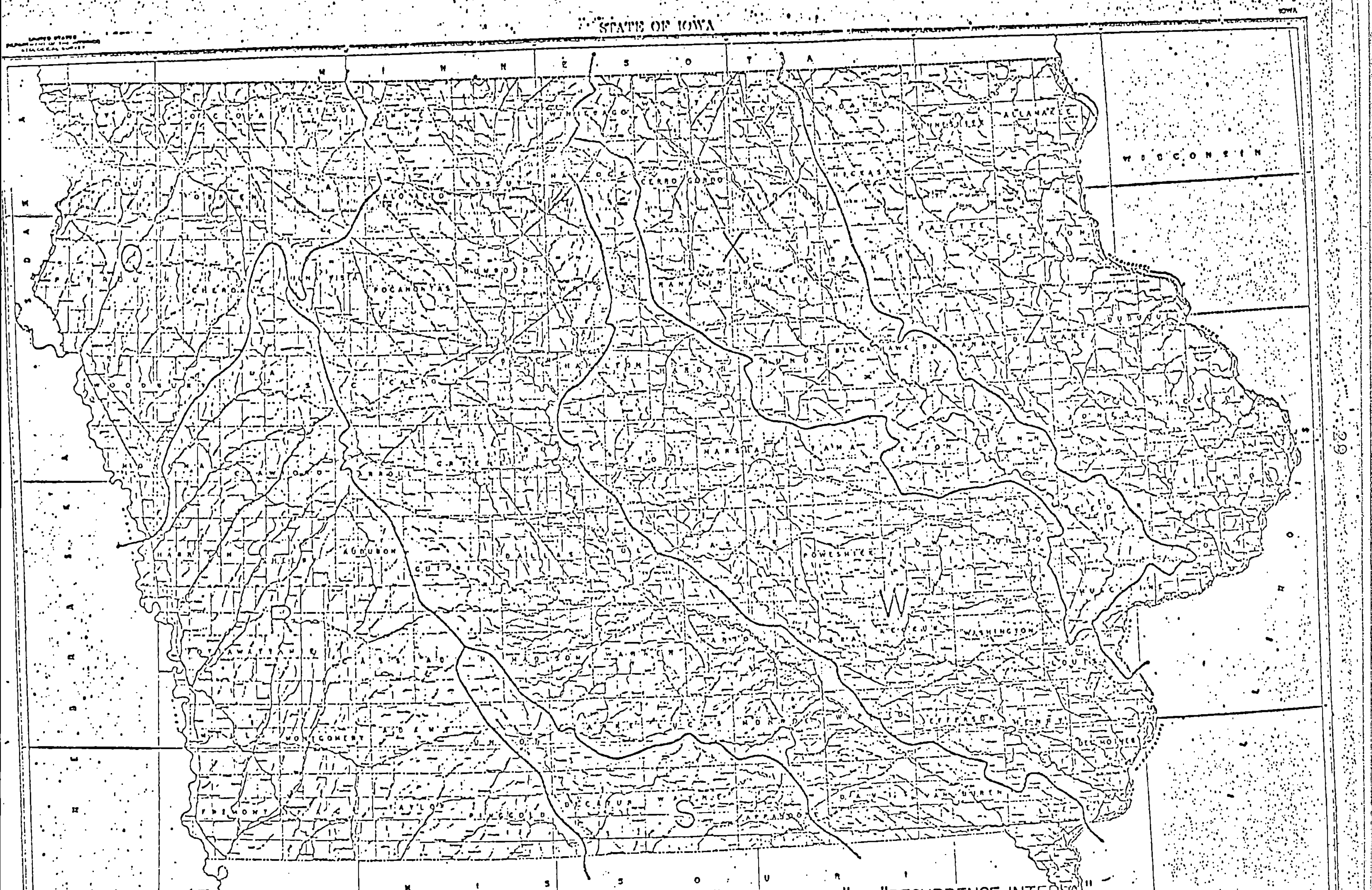

FIG. 15 MAP SHOWING ZONES FOR USE OF TABULATED "RATIO TO MAF" VS "RECURRENCE INTERVAL"

straight lines in Figure 13, Figure 14 gives the type of terrain at the site to be used in determining the MAF. Figure 15 gives the region to be used for the desired recurrance interval.

BULLETIN NO. 28

Bulletin No. 28, which was published in July of 1965, is the Interim Report carried one step further.[11] Instead of correlating the MAF to one watershed characteristic, drainage area, a regression equation using multiple correlations was developed using a computer.

Three independent variables were finally selected: area, slope, and precipitation.

A - Drainage area in square miles

S - The main channel slope in feet per mile between points 10 and 85 percent above the point of interest. L is the length in miles measured along the main channel, and the upstream tributary with the largest drainage area, to the divide.

P - The normal annual precipitation in inches over the basin for the 1931 - 1960 period.

The regression equation using all 147 stations was $MAF = 0.000377A^{.819}S^{.711}P^{2.982}$. The multiple correlation

[11]Harlan H. Schwob, Magnitude and Frequenct of Iowa Floods: Iowa Highway Research Board Bulletin No. 28, Part I, 1966.

coefficient was 0.92 and the standard error of estimate for the dependent variable was 41.4 percent. The above equation did not predict the MAF equally well for the entire state. Two regions seemed to have different relations.

These two regions yielded the following equations.

(A) $MAF = 0.000009856A^{.856}S^{.806}P^{3.926}$

(B) $MAF = 50.22A^{.707}S^{.367}$

For area A, the multiple correlation coefficient was 0.94 and the standard error of estimate was 37.9 percent. For area B, these statistics were 0.94 and 30.4 percent.

Several tables and graphs have been developed to aid in the solution of these equations. Figure 16 shows in which regions of the state that equations A and B should be used. This figure also shows which region (I or II) is applicable in determining the ratio to the MAF (see Figure 17). Figure 18 is used to determine the annual precipitation at the site. Table 9 gives the solution to $0.000009856P^{3.926}$. Figures 19 thru 22 give the solution to the other variables in the equations. For drainage areas over 700 square miles, graphs similar to Figure 23 have been developed to determine P and S. For areas under 700 square miles, S has to be determined from a quadrangle map.

BULLETIN NO. 13

The purpose of Bulletin No. 13 was to describe the various flow frequency methods most commonly used by federal

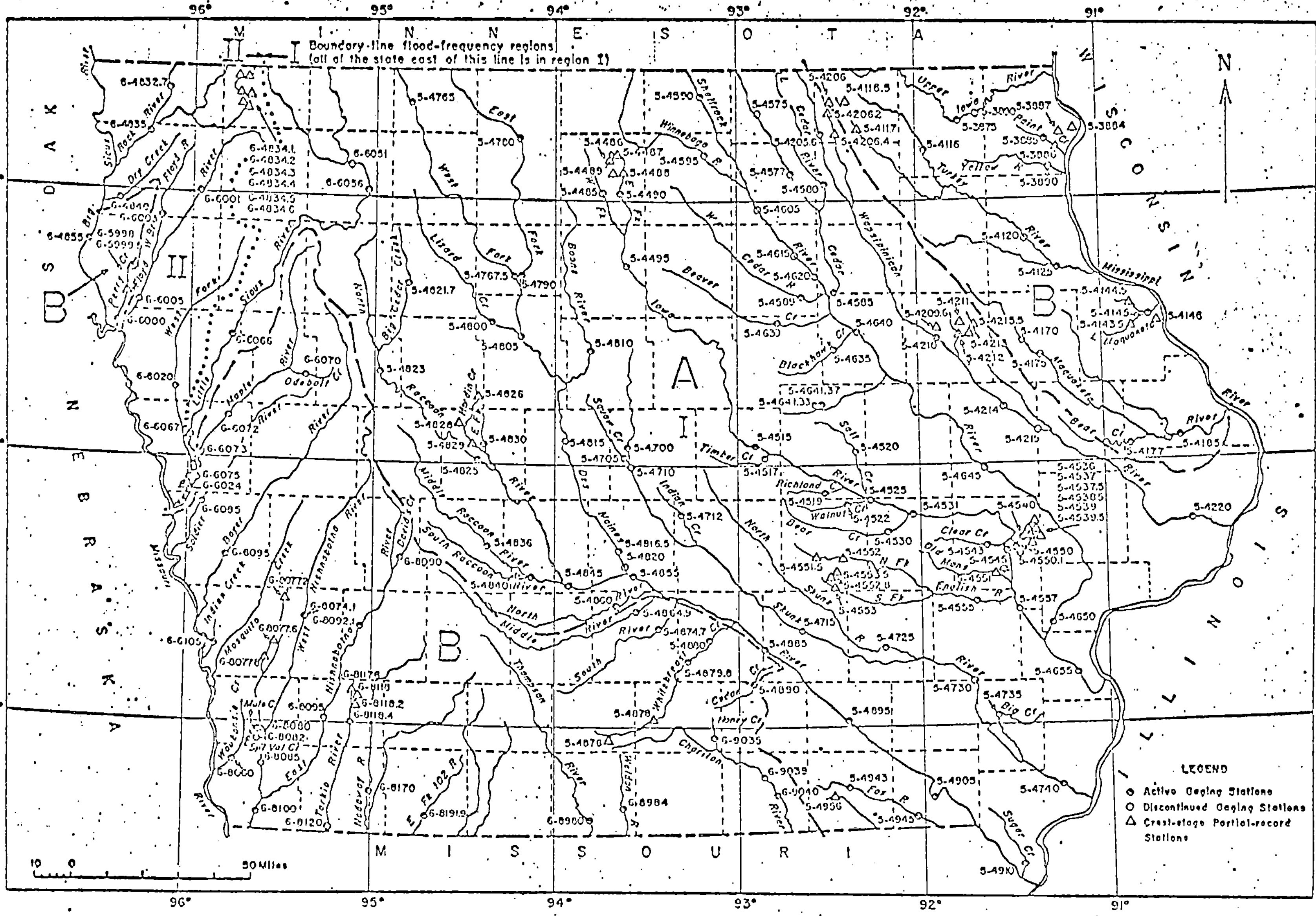

Fig. 16

Map of Iowa showing gaging stations, index flood areas A and B, and flood-frequency regions I and II.

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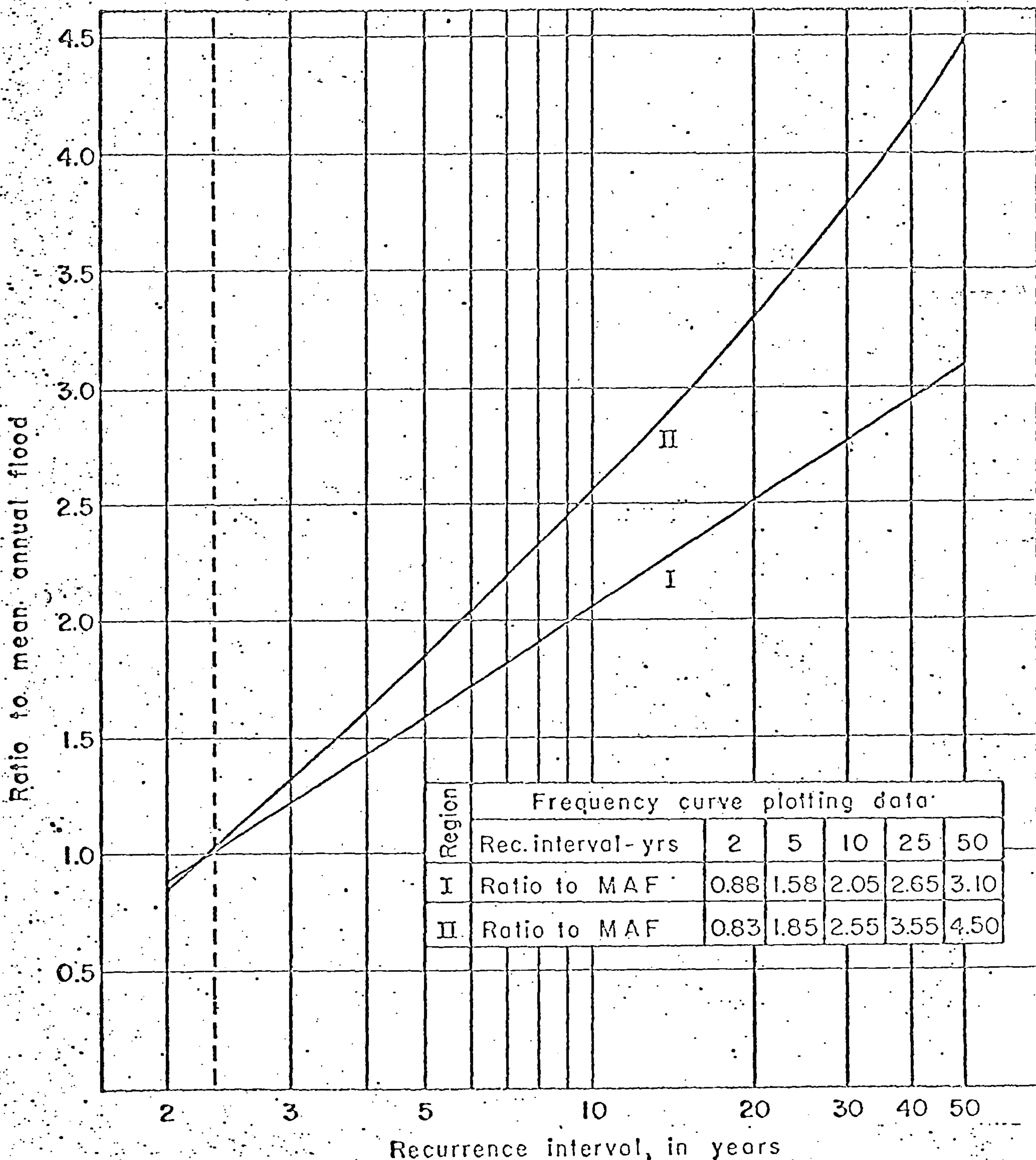

Region	Frequency curve plotting data					
	Rec. interval - yrs	2	5	10	25	50
I	Ratio to MAF	0.88	1.58	2.05	2.65	3.10
II	Ratio to MAF	0.83	1.85	2.55	3.55	4.50

Figure 17. Regional flood-frequency curves for Iowa.

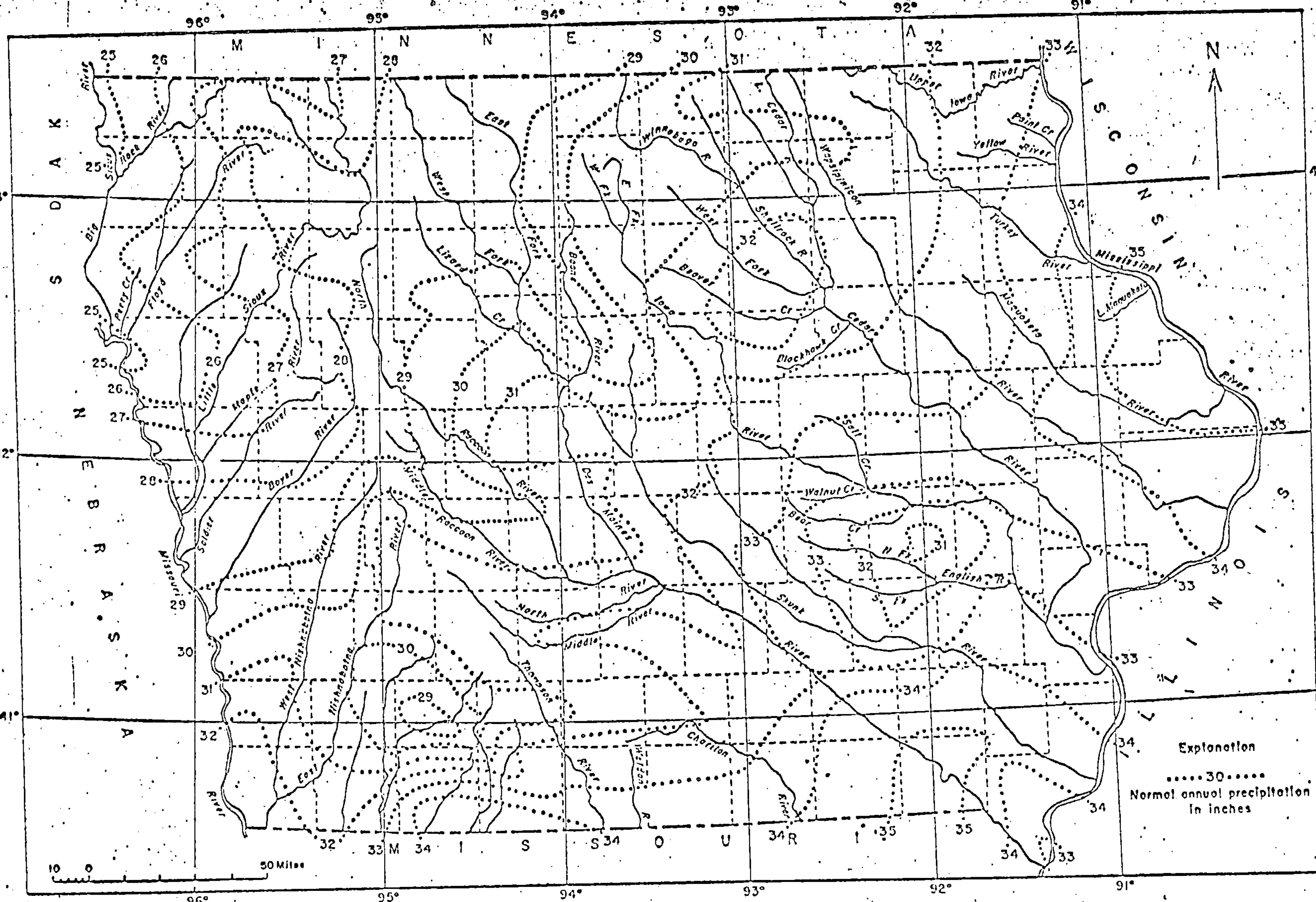

Fig. 18.
Isohyetal map of Iowa normal annual precipitation.

TABLE [illegible]9. Values of 0.000009856 $P^{3.926}$ in the regression equation for area A

Precipitation, in inches	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
25	3.033	3.083	3.133	3.183	3.235	3.285	3.335	3.386	3.437	3.488
26	3.539	3.595	3.652	3.708	3.764	3.820	3.877	3.934	3.991	4.048
27	4.105	4.168	4.231	4.294	4.357	4.420	4.483	4.546	4.610	4.673
28	4.736	4.805	4.874	4.943	5.013	5.083	5.153	5.223	5.293	5.363
29	5.433	5.510	5.586	5.663	5.740	5.817	5.894	5.971	6.048	6.126
30	6.204	6.290	6.376	6.462	6.547	6.633	6.719	6.804	6.890	6.976
31	7.062	7.155	7.249	7.343	7.436	7.530	7.624	7.717	7.811	7.905
32	8.000	8.102	8.203	8.305	8.407	8.510	8.612	8.715	8.817	8.920
33	9.022	9.135	9.248	9.361	9.474	9.587	9.700	9.813	9.926	10.04
34	10.15	10.27	10.39	10.51	10.62	10.74	10.86	10.99	11.12	11.25
35	11.37	11.50	11.63	11.76	11.89	12.02	12.15	12.28	12.42	12.56

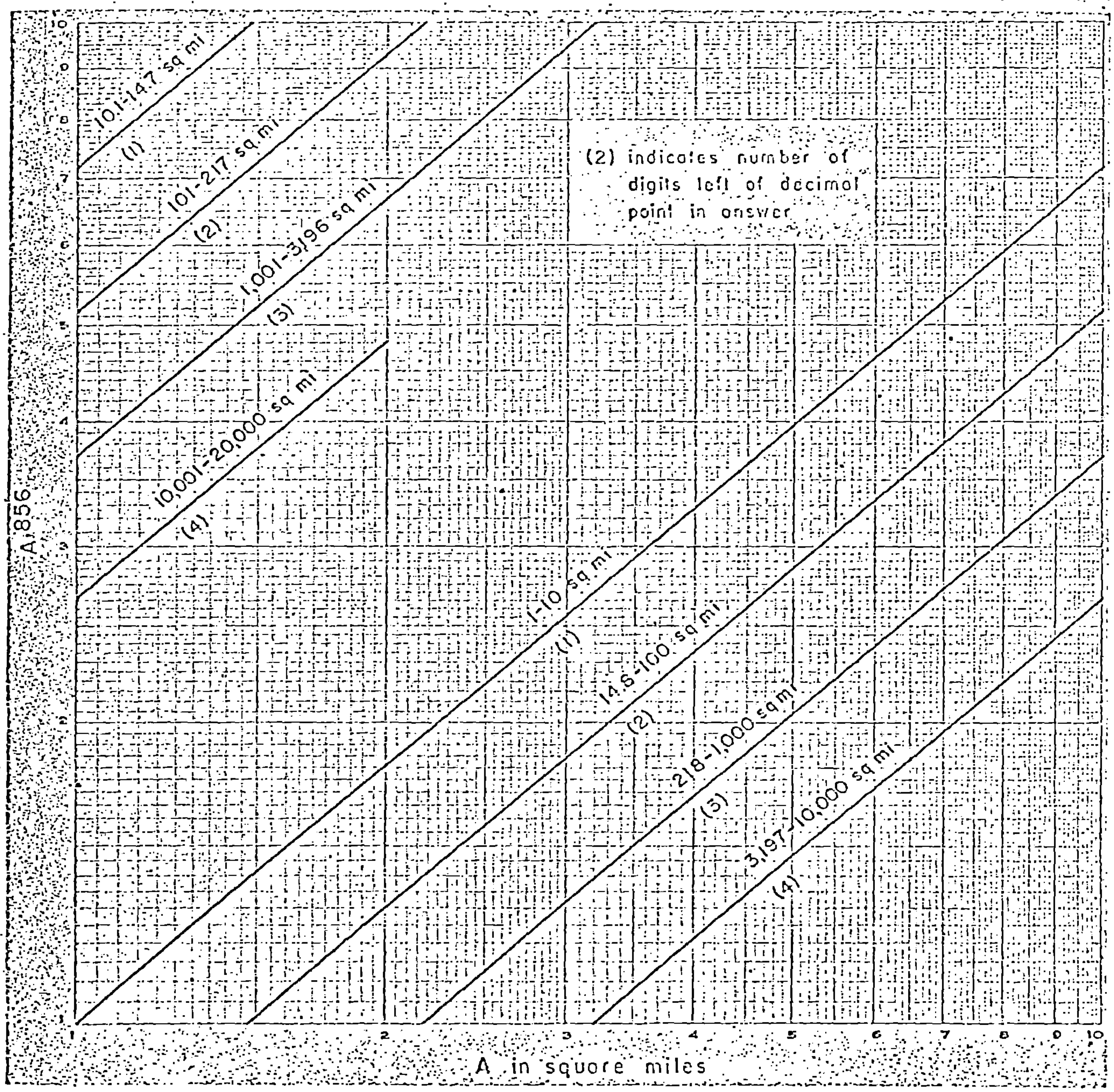

Figure 19. Graph of solution of $A^{.856}$ for area A.

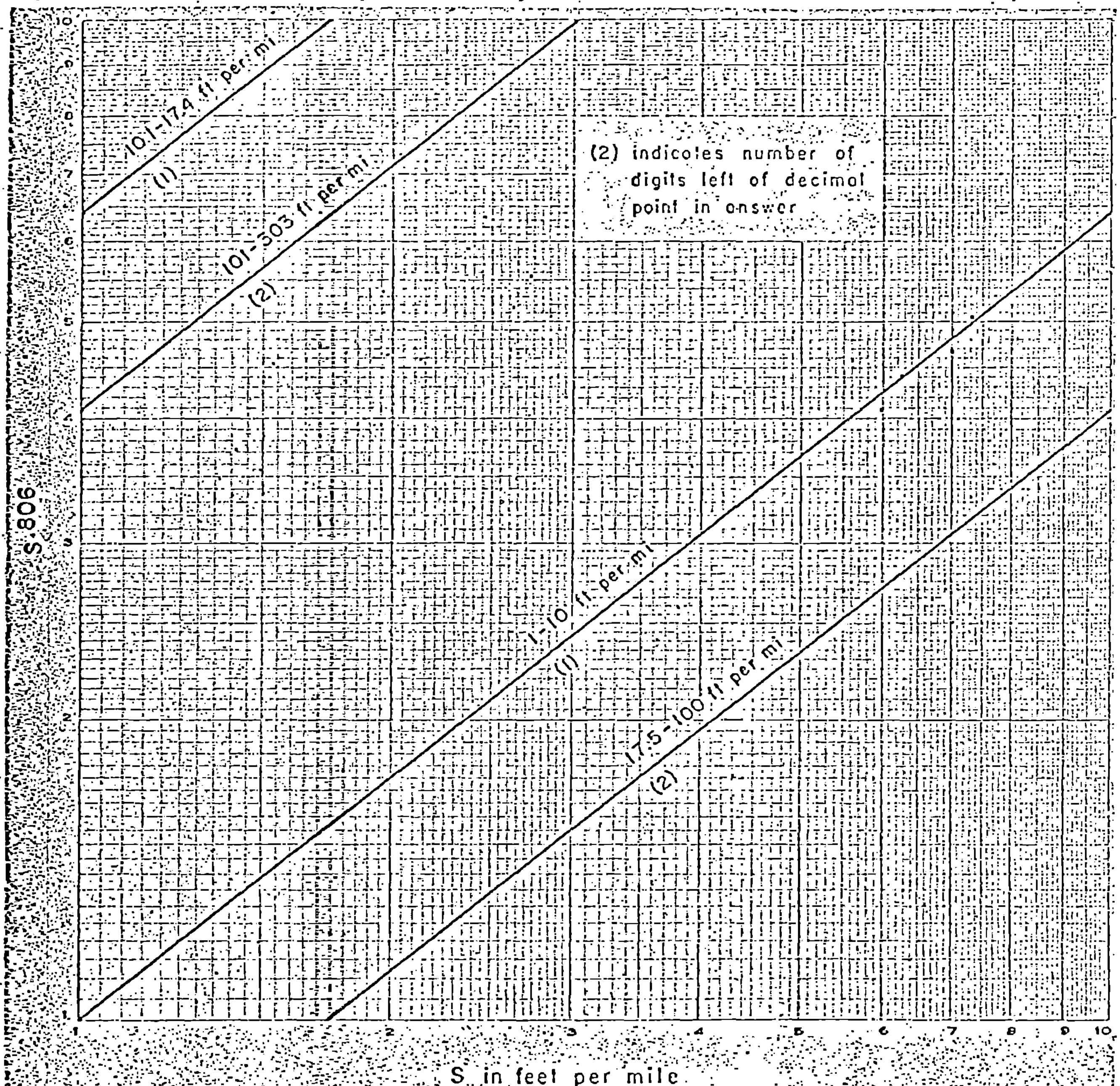

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Figure . Graph of solution of $S^{.806}$ for area A.

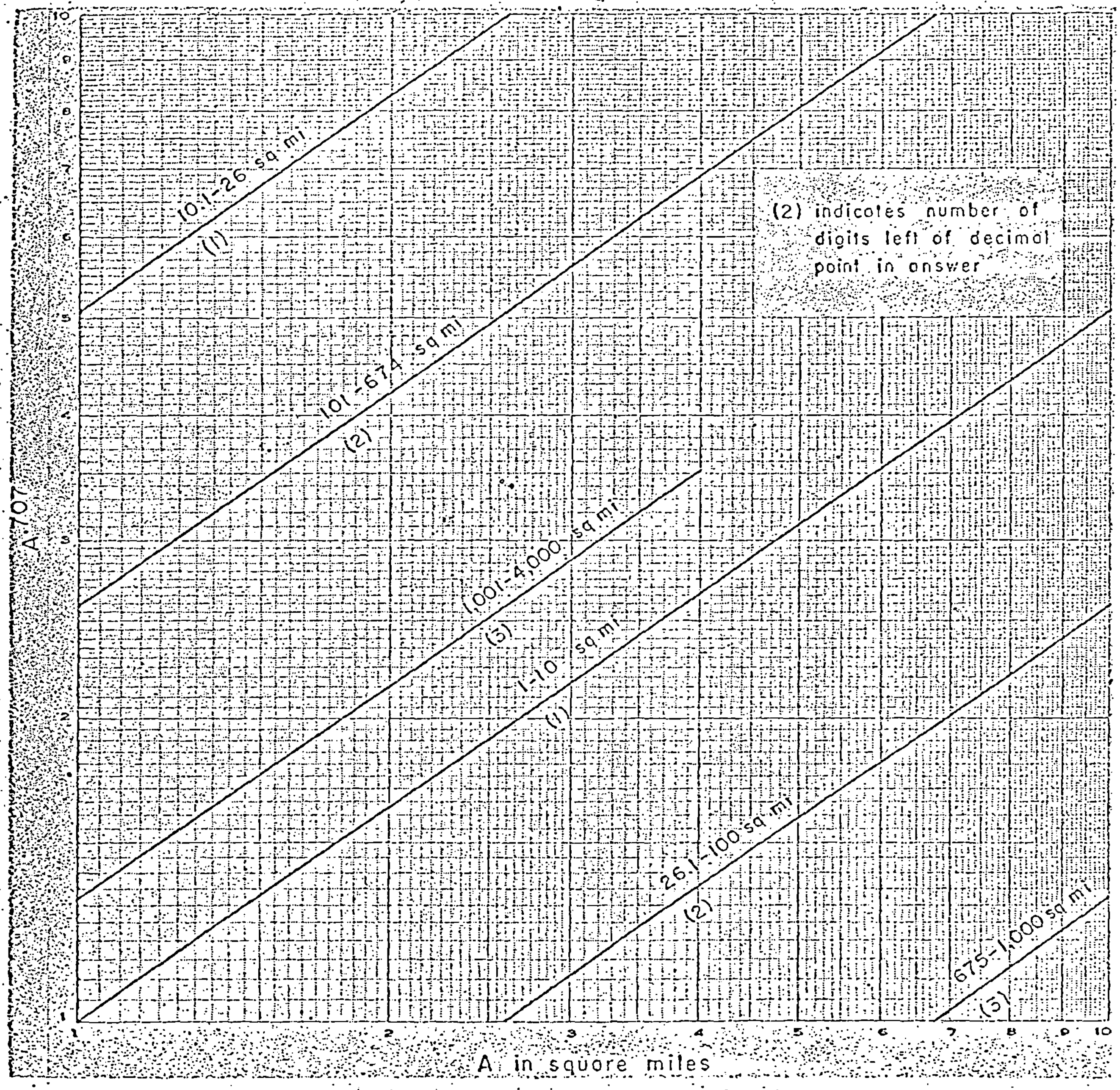

Figure 21. Graph of solution of $A^{.707}$ for area B.

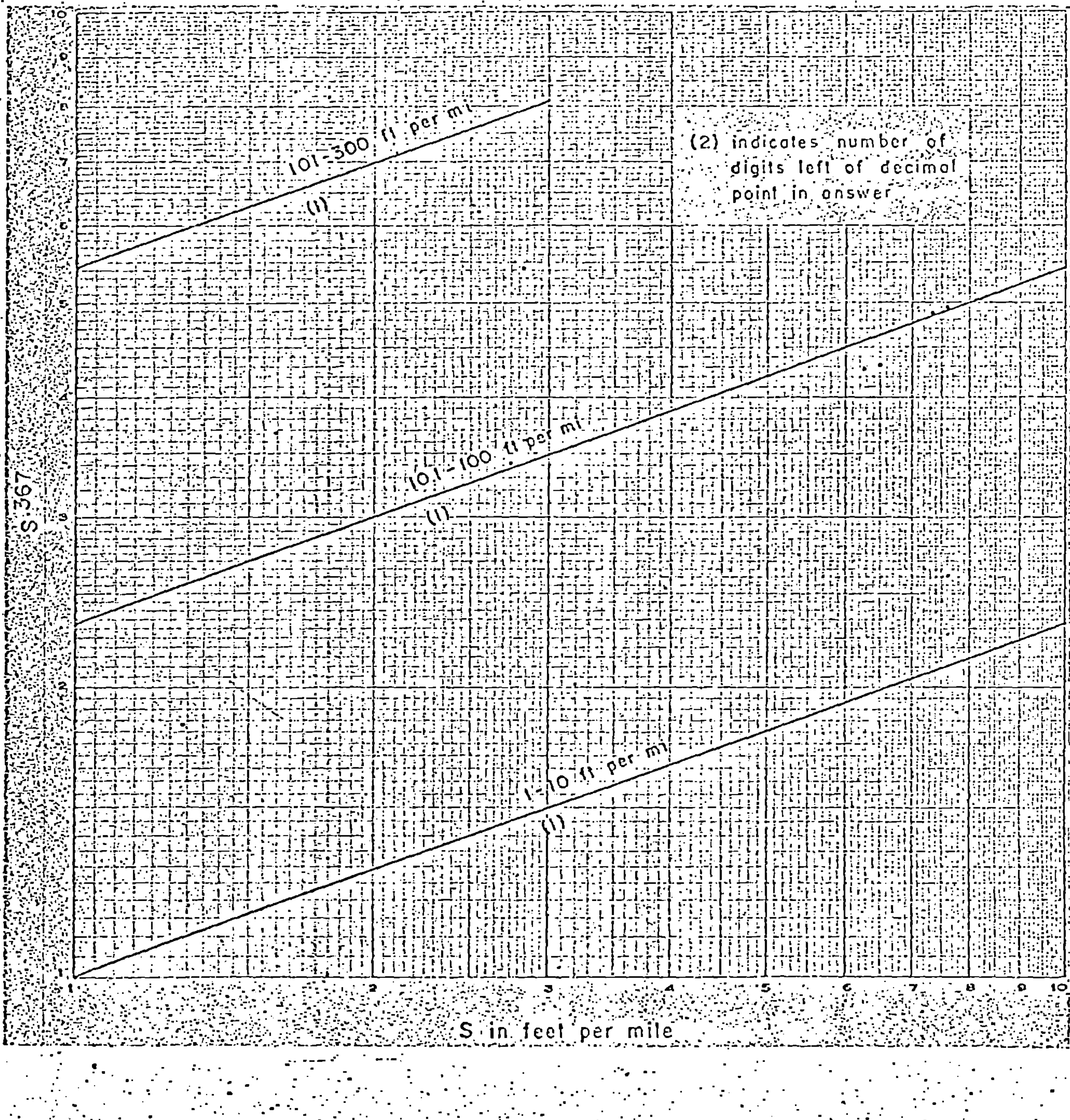

Figure 22. Graph of solution of $S^{.367}$ for area B.

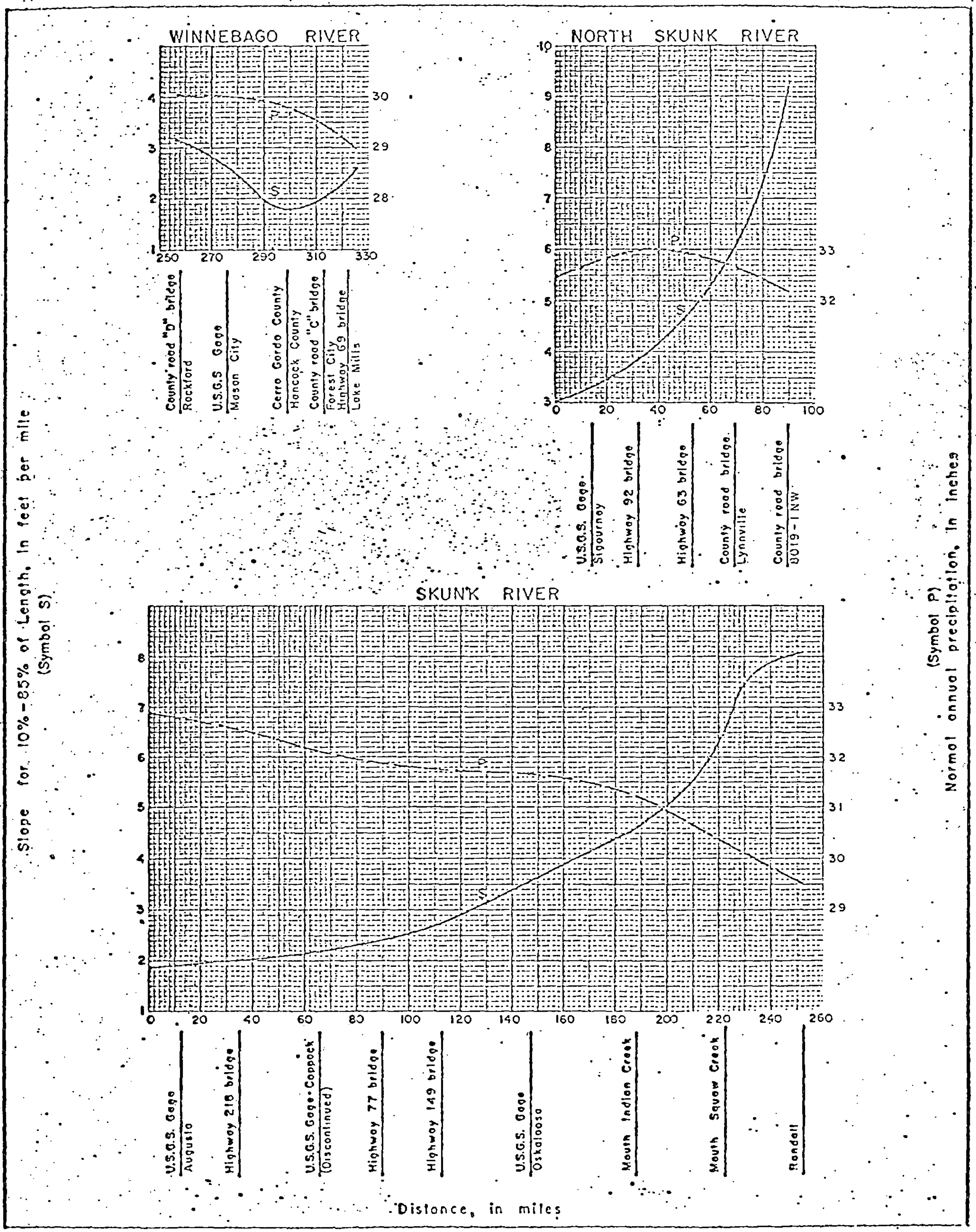

Figure 23. Slope and normal precipitation data for Winnebago, North Skunk, and Skunk Rivers.

agencies at the present time.

This was accomplished by first reviewing basic statistical principles. The application of these principles to flow frequency analysis was shown by tracing the historical development of the various methods in use today. Procedures and items common to the several methods were discussed and included types of data, time elements, probability paper, transformation of data, plotting-position formulas, fitting of frequency lines, outliers, historical events, discontinuous records and estimation of missing record, compensation for changed physical conditions, zero items of data, statistical test of significance, confidence limits and applications of frequency analysis.

Five methods currently in use were then described in the following manner. In the following descriptions each method is presented in the words of its originator if he is known or a typical proponent if the originator is not known. This is done to give an idea of the reasoning used to justify the approach taken in developing the method. Each description is followed by a summary of current usage.[12] The five methods described were the Hazen, Pearson Type III, Gumbel, gamma, and graphical distribution-free methods.

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[12]Methods of Flow Frequency Analysis: Bulletin No. 13, Subcommittee on Hydrology, Inter-Agency Committee on Water Resources, 1966.

BULLETIN NO. 15

The purpose of this bulletin was stated in the forward by Stewart L. Udall, Chairman of the Water Resources Council as follows:

> With the growing need for improved flood plain management, desireability of a basic, uniform method of establishing flood frequencies for general use throughout the Nation is manifest. A consistent approach to the estimation of the average annual flood losses - a major analytical component in determination of the best measure, or best combination of measures, in flood plain management - is dependent upon equable analysis of flood frequencies whether determined by federal, state, local government or private engineers.[13]

With this in mind, the Hydrology Committee studied six methods. Three fitted the data well and showed no bias. The recommended method is one of the three. Based on their studies, the Committee made the following recommendations:

1. They agreed that the state of the art was such that complete standardization was not feasible or appropriate. A base method should be adopted with the provision that other methods can be used where justification is presented.

2. Based upon several items, the log-Pearson Type III distribution (with the log-normal as a special case) is recommended for adoption as a base method for flood frequencies.

3. Because of the importance of flood flow frequency estimates in the field of water resources development and programs for managing flood losses, member agencies are encouraged to improve techniques and procedures in this field.

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[13] A Uniform Technique for Determining Flood Flow Frequencies: Bulletin No. 15, Hydrology Committee, Water Resources Council, 1967.

The bulletin concluded by discussing several additional considerations in flow-frequent analysis. These were short record of flood flows, determining discharges for ungaged basins, outliers, zero items of data, and the variability of the skew coefficient.

On the following pages is a description of the base method.

The outline of work is as follows:

1. Transform the list of N annual flood magnitudes Y_1, Y_2, ... , Y_N to a list of corresponding logarithmic magnitudes X_1, X_2, ... , X_N.

2. Compute the mean of the logarithms:

$$M = \frac{\sum X}{N}$$

3. Compute the standard deviation of the logarithms:

$$S = \sqrt{\frac{\sum x^2}{N - 1}}$$

$$= \sqrt{\frac{\sum X^2 - (\sum X)^2 / N}{N - 1}}$$

4. Compute the coefficient of skewness:

$$g = \frac{N \sum x^3}{(N - 1)(N - 2)S^3}$$

$$= \frac{N^2 \sum X^3 - 3N \sum X \sum X^2 + 2(\sum X)^3}{N(N - 1)(N - 2)S^3}$$

5. Compute the logarithms of discharges at selected recurrence intervals or percent chance:

$$\log Q = M + K S$$

Take K from Table 11 or Table 12 for the computed value of g and the selected recurrence interval or percent chance. Log Q is the logarithm of a flood discharge having the same recurrence interval or percent chance.

6. Find the antilog of log Q to get the flood discharge Q.[1]

Tables of K Values

Tables 11 and 12 were made from larger and more complete tables prepared by H. Leon Harter (Mathematical Statistician, Wright-Patterson Air Force Base) and the U.S. Soil Conservation Service. Copies of those tables are available, free of charge, from the Central Technical Unit, Soil Conservation Service, 269 Federal Center Building, Hyattsville, Md. 20782.

Y = arithmetic magnitude of an annual flood event
X = logarithmic magnitude of Y
N = number of events in the record being used
M = mean of the X's
x = X - M
S = standard deviation of the X's
g = skew coefficient
K = Pearson Type III coordinates expressed in number of standard deviations from the mean for various recurrence intervals or percent chance
Q = computed flood flow for a selected recurrence interval or precent chance

Table 10, Symbols used in log-Pearson Type III Method

Table II.2.- K values for positive skew coefficients

Skew Coefficient (g)	1.0101	1.0526	1.1111	1.2500	2	5	10	25	50	100	200
	Recurrence Interval in Years										
	Percent Chance										
	99	95	90	80	50	20	10	4	2	1	0.5
3.0	-0.667	-0.665	-0.660	-0.636	-0.396	0.420	1.180	2.278	3.152	4.051	4.970
2.9	-0.690	-0.688	-0.681	-0.651	-0.390	0.440	1.195	2.277	3.134	4.013	4.909
2.8	-0.714	-0.711	-0.702	-0.666	-0.384	0.460	1.210	2.275	3.114	3.973	4.847
2.7	-0.740	-0.736	-0.724	-0.681	-0.376	0.479	1.224	2.272	3.093	3.932	4.783
2.6	-0.769	-0.762	-0.747	-0.696	-0.368	0.499	1.238	2.267	3.071	3.889	4.718
2.5	-0.799	-0.790	-0.771	-0.711	-0.360	0.518	1.250	2.262	3.048	3.845	4.652
2.4	-0.832	-0.819	-0.795	-0.725	-0.351	0.537	1.262	2.256	3.023	3.800	4.584
2.3	-0.867	-0.850	-0.819	-0.739	-0.341	0.555	1.274	2.248	2.997	3.753	4.515
2.2	-0.905	-0.882	-0.844	-0.752	-0.330	0.574	1.284	2.240	2.970	3.705	4.444
2.1	-0.946	-0.914	-0.869	-0.765	-0.319	0.592	1.294	2.230	2.942	3.656	4.372
2.0	-0.990	-0.949	-0.895	-0.777	-0.307	0.609	1.302	2.219	2.912	3.605	4.298
1.9	-1.037	-0.984	-0.920	-0.788	-0.294	0.627	1.310	2.207	2.881	3.553	4.223
1.8	-1.087	-1.020	-0.945	-0.799	-0.282	0.643	1.318	2.193	2.848	3.499	4.147
1.7	-1.140	-1.056	-0.970	-0.808	-0.268	0.660	1.324	2.179	2.815	3.444	4.069
1.6	-1.197	-1.093	-0.994	-0.817	-0.254	0.675	1.329	2.163	2.780	3.388	3.990
1.5	-1.256	-1.131	-1.018	-0.825	-0.240	0.690	1.333	2.146	2.743	3.330	3.910
1.4	-1.318	-1.168	-1.041	-0.832	-0.225	0.705	1.337	2.128	2.706	3.271	3.828
1.3	-1.383	-1.206	-1.064	-0.838	-0.210	0.719	1.339	2.108	2.666	3.211	3.745
1.2	-1.449	-1.243	-1.086	-0.844	-0.195	0.732	1.340	2.087	2.626	3.149	3.661
1.1	-1.518	-1.280	-1.107	-0.848	-0.180	0.745	1.341	2.066	2.585	3.087	3.575
1.0	-1.588	-1.317	-1.128	-0.852	-0.164	0.758	1.340	2.043	2.542	3.022	3.489
.9	-1.660	-1.353	-1.147	-0.854	-0.148	0.769	1.339	2.018	2.498	2.957	3.401
.8	-1.733	-1.388	-1.166	-0.856	-0.132	0.780	1.336	1.993	2.453	2.891	3.312
.7	-1.806	-1.423	-1.183	-0.857	-0.116	0.790	1.333	1.967	2.407	2.824	3.223
.6	-1.880	-1.458	-1.200	-0.857	-0.099	0.800	1.328	1.939	2.359	2.755	3.132
.5	-1.955	-1.491	-1.216	-0.856	-0.083	0.808	1.323	1.910	2.311	2.686	3.041
.4	-2.029	-1.524	-1.231	-0.855	-0.066	0.816	1.317	1.880	2.261	2.615	2.949
.3	-2.104	-1.555	-1.245	-0.853	-0.050	0.824	1.309	1.849	2.211	2.544	2.856
.2	-2.178	-1.586	-1.258	-0.850	-0.033	0.830	1.301	1.818	2.159	2.472	2.763
.1	-2.252	-1.616	-1.270	-0.846	-0.017	0.836	1.292	1.785	2.107	2.400	2.670
0	-2.326	-1.645	-1.282	-0.842	0	0.842	1.282	1.751	2.054	2.326	2.576

Table 12.--K values for negative skew coefficients

Skew Coefficient (g)	Recurrence Interval in Years										
	1.0101	1.0526	1.1111	1.2500	2	5	10	25	50	100	200
	Percent Chance										
	99	95	90	80	50	20	10	4	2	1	0.5
0	-2.326	-1.645	-1.282	-0.842	0	0.842	1.282	1.751	2.054	2.326	2.576
-.1	-2.400	-1.673	-1.292	-0.836	0.017	0.846	1.270	1.716	2.000	2.252	2.482
-.2	-2.472	-1.700	-1.301	-0.830	0.033	0.850	1.258	1.680	1.945	2.178	2.388
-.3	-2.544	-1.726	-1.309	-0.824	0.050	0.853	1.245	1.643	1.890	2.104	2.294
-.4	-2.615	-1.750	-1.317	-0.816	0.066	0.855	1.231	1.606	1.834	2.029	2.201
-.5	-2.686	-1.774	-1.323	-0.808	0.083	0.856	1.216	1.567	1.777	1.955	2.108
-.6	-2.755	-1.797	-1.328	-0.800	0.099	0.857	1.200	1.528	1.720	1.880	2.016
-.7	-2.824	-1.819	-1.333	-0.790	0.116	0.857	1.183	1.488	1.663	1.806	1.926
-.8	-2.891	-1.839	-1.336	-0.780	0.132	0.856	1.166	1.448	1.606	1.733	1.837
-.9	-2.957	-1.858	-1.339	-0.769	0.148	0.854	1.147	1.407	1.549	1.660	1.749
-1.0	-3.022	-1.877	-1.340	-0.758	0.164	0.852	1.128	1.366	1.492	1.588	1.664
-1.1	-3.087	-1.894	-1.341	-0.745	0.180	0.848	1.107	1.324	1.435	1.518	1.581
-1.2	-3.149	-1.910	-1.340	-0.732	0.195	0.844	1.086	1.282	1.379	1.449	1.501
-1.3	-3.211	-1.925	-1.339	-0.719	0.210	0.838	1.064	1.240	1.324	1.383	1.424
-1.4	-3.271	-1.938	-1.337	-0.705	0.225	0.832	1.041	1.198	1.270	1.318	1.351
-1.5	-3.330	-1.951	-1.333	-0.690	0.240	0.825	1.018	1.157	1.217	1.256	1.282
-1.6	-3.388	-1.962	-1.329	-0.675	0.254	0.817	0.994	1.116	1.166	1.197	1.216
-1.7	-3.444	-1.972	-1.324	-0.660	0.268	0.808	0.970	1.075	1.116	1.140	1.155
-1.8	-3.499	-1.981	-1.318	-0.643	0.282	0.799	0.945	1.035	1.069	1.087	1.097
-1.9	-3.553	-1.989	-1.310	-0.627	0.294	0.788	0.920	0.996	1.023	1.037	1.044
-2.0	-3.605	-1.996	-1.302	-0.609	0.307	0.777	0.895	0.959	0.980	0.990	0.995
-2.1	-3.656	-2.001	-1.294	-0.592	0.319	0.765	0.869	0.923	0.939	0.946	0.949
-2.2	-3.705	-2.006	-1.284	-0.574	0.330	0.752	0.844	0.888	0.900	0.905	0.907
-2.3	-3.753	-2.009	-1.274	-0.555	0.341	0.739	0.819	0.855	0.864	0.867	0.869
-2.4	-3.800	-2.011	-1.262	-0.537	0.351	0.725	0.795	0.823	0.830	0.832	0.833
-2.5	-3.845	-2.012	-1.250	-0.518	0.360	0.711	0.771	0.793	0.798	0.799	0.800
-2.6	-3.889	-2.013	-1.238	-0.499	0.368	0.696	0.747	0.764	0.768	0.769	0.769
-2.7	-3.932	-2.012	-1.224	-0.479	0.376	0.681	0.724	0.738	0.740	0.740	0.741
-2.8	-3.973	-2.010	-1.210	-0.460	0.384	0.666	0.702	0.712	0.714	0.714	0.714
-2.9	-4.013	-2.007	-1.195	-0.440	0.390	0.651	0.681	0.683	0.689	0.690	0.690
-3.0	-4.051	-2.003	-1.180	-0.420	0.396	0.636	0.660	0.666	0.666	0.667	0.667

EXAMPLES

The following examples will demonstrate the use of each of the methods discussed to this point. These particular examples have been chosen because they illustrate the problems listed in Bulletin No. 15: outliers, short record of flood flow, determination of discharges for ungaged basins, and the variability of the skew coefficient. The US Geological Survey in Iowa is currently conducting a study which hopefully will produce some guidelines to handle these problems.

The Talbot Formula and Iowa Chart No. 1 Methods have been omitted in those problems which have a drainage area larger than 30 square miles since these two methods are intended for use on smaller drainage areas only. In other examples the Bulletin No. 1 Method has been omitted because the lower limit on its use is 100 square miles.

MAF is used as the abbreviation for the mean annual flood. N is the number of years of record at the gaging station.

The computer output for determining Q_{50} in each of the examples using the log-Pearson Type III Method are presented in Appendices B thru G.

Example 1

Normal

Name: Cedar River

Location: Cedar Rapids

Drainage Area: 6,510 sq. mi.

Character: Rolling

Bulletin No. 1 : Region C

MAF - 27,000 cfs

Ratio to MAF = 2.8

$Q_{50} = (27,000)(2.8) = 75,600$ cfs

Interim Report : Region X-III

MAF = 24,000 cfs

Ratio to MAF = 3.34

$Q_{50} = (24,000)(3.34) = 80,200$ cfs

Bulletin No. 28: Region A-I

S = 2.34 ft./mi. P = 31.3 in.

MAF = (7.343)(1,840)(1.98)

= 26,700 cfs

Ratio to MAF = 3.10

$Q_{50} = 82,800$ cfs

log-Pearson : N = 67

$Q_{50} = 77,600$ cfs (See Appendix B)

Example 2

Outlier

Name: Pine Creek

Location: Buchanan Co., near Winthrop

Drainage Area: 28.6 sq. mi.

Character: Steeply Rolling

Talbot Formula

$a = (0.5)(18,300)^{0.75} = 800$ sq. ft.

$Q = 800 \times 10 = 8000$ cfs

Iowa Chart No. 1

$Q_{50} = (0.7)(1.0)(8,200) = 5,700$ cfs

Interim Report : Region Z-IV

MAF = 1,600 cfs

Ratio to MAF = 2.61

$Q_{50} = (1,600)(2.61) = 4,180$ cfs

Bulletin No. 28 : Region A-I

S = 14.0 ft./mi. P = 32.5 in.

MAF = (8.510)(17.7)(8.40)

= 1,270 cfs

Ratio to MAF = 3.10

$Q_{50} = (1,270)(3.10) = 3,940$ cfs

Example 2 - cont.

Outlier

log-Pearson (see Appendix C)

N	Max. Q	Q_{50}
20	24,200	32,000
19	14,500	18,200
18	10,600	10,800
17	5,030	5,600

Question?

Can we have 3 outliers in 20 years of record?

Example 3

Short Period of Record

Name: Skunk River

Location: Story Co., near Ames

Drainage Area: 556 sq. mi.

Character: Rolling

Bulletin No. 1 : Region C

MAF = 4,400 cfs

Ratio to MAF = 2.8

Q_{50} = (4,400)(2.8) = 12,300 cfs

Interim Report : Region W-III

MAF = 5,300 cfs

Ratio to MAF = 2.97

Q_{50} = (5,300)(2.97) = 15,800 cfs

Bulletin No. 28 : Region A-I

S = 6.63 ft./mi. P = 30.6 in.

MAF = (6.719)(223)(4.6) = 6,900 cfs

Ratio to MAF = 3.10

Q_{50} = (6,900_(3.10) = 21,400 cfs

log-Pearson : N = 17

Q_{50} = 9,600 cfs (see Appendix D)

Example 4

Long Record but no Major Floods

Name: Skunk River

Location: Story Co., near Ames

Drainage A ea: 315 sq. mi.

Character: Rolling

Bulletin No. 1 : Region C

MAF = 2,500 cfs

Ratio to MAF = 2.8

Q_{50} = (2,500)(2.8) = 7,000 cfs

Interim Report: Region W-III

MAF = 3,900 cfs

Ratio to MAF = 2.97

Q_{50} = (3,900)(2.97) = 11,600 cfs

Bulletin No. 28

S = 7.34 ft./mi. P = 30.0 in.

MAF = (6.204)(137)(5.0)

= 4,250 cfs

Ratio to MAF = 3.10

Q_{50} = (4,250)(3.10) = 13,200 cfs

log-Pearson : N = 45

Q_{50} = 7,100 cfs (see Appendix E)

Example 5

Length of Record

Name:	Big Sioux River
Location:	Woodbury Co., at Akron
Drainage Area:	9,030 sq. mi.
Character:	Gently Rolling

Bulletin No. 1 : Region E

MAF = 10,500 cfs

Ratio to MAF = 2.8

Q_{50} = (10,500)(2.8) = 30,200 cfs

Interim Report : Region Q-II

MAF = 18,000 cfs

Ratio to MAF = 3.81

Q_{50} = (18,000)(3.81) = 68,500 cfs

Bulletin No. 28 : Region B-II

MAF = 12,500 cfs

Ratio to MAF = 4.50

Q_{50} = (12,500)(4.50) = 56,300 cfs

Example 5 - cont.

Length of Record

log-Pearson (see Appendix F)

N	Thru	Max. Q	50 yr.	100 yr.	200 yr.
24	1952	33,000	31,700	34,400	36,800
32	1960	49,500	41,900	47,200	52,000
34	1962	54,300	49,000	56,500	63,800
40	1968	54,300	49,400	57,200	64,600
41	1969	80,800	62,000	74,600	87,400

The dual bridges on Interstate 29 over the Big Sioux River were constructed in 1959. The 1962 flood destroyed the northbound bridge. Total cost of the original bridge, the replacement bridge, and other remedial work now approaches one million dollars. The 1969 flood rose to an elevation four feet <u>lower</u> than the 1952 flood.

Example 6

Ungaged Basin

Name:	Brewer Creek
Location:	Hamilton Co., in Webster City
Drainage Area:	22.5 sq. mi.
Character:	Flat

Talbot Formula

$a = (0.167)(14,400) = 216$ sq. ft.

$Q = (216)(10) = 2,160$ cfs

Iowa Chart No. 1

$Q_{50} = (0.4)(1.0)(7,100) = 2,850$ cfs

Interim Report : Region T-II

MAF = 500 cfs

Ratio to MAF = 3.01

$Q_{50} = (500)(3.01) = 1,500$ cfs

Bulletin No. 28 : Region A-I

$S = 9.8$ ft./mi. $P = 29.0$ in.

MAF = (5.433)(14.4)(6.3)

= 490 cfs

Ratio to MAF = 3.10

$Q_{50} = (490)(3.10) = 1,520$ cfs

Example 6 - cont.

Ungaged Basin

log - Pearson

Since this is an ungaged site, several gaged sites of various drainage areas in the same region with similar basin characteristics were used to define a regional curve for Q_{50}. These results are shown in Appendix G and Figure 24.

$$Q_{50} = 170A^{0.7}$$

$$= (170(22.5)^{0.7}$$

$$= 1,500 \text{ cfs}$$

Example 7

Variability of Skew Coefficient

Site	D.A.	N	Cs
Pine Creek	28.3	20	0.697
Pine Creek	28.3	19	0.578
Pine Creek	28.3	18	0.408
East Branch Iowa River	133	23	0.216
Pine Creek	28.3	17	-0.063
Hardin Creek	43.7	18	-0.065
Hardin Creek	101	19	-0.177
East Branch Iowa River	7.9	18	-0.220
East Branch Iowa River	2.2	17	-0.490
Lizard Creek	257	30	-0.492
Big Sioux River	9030	41	-0.533
Cedar River	6510	67	-0.552
Boone River	844	30	-0.575
Big Sioux River	9030	34	-0.622
Big Sioux River	9030	40	-0.701
Big Sioux River	9030	32	-0.764
East Fork Hardin Creek	24.0	18	-0.817
Big Sioux River	9030	24	-0.886
Skunk River	315	45	-0.985
Big Cedar Creek	80.0	10	-1.251
Skunk River	556	17	-1.908

Example 7 - cont.

Variability of Skew Coefficient

From the list on the previous page, it can be seen that the skew coefficient displays great variability and is very sensitive to the sample size and the variability in the items of data themselves. Pine Creek is a good example of this. Eliminating each outlier in turn changes the skew coefficient from 0.697 to -0.063.

Several writers have commented on the use of the skew coefficient as a regional factor and on its use at all when the sample size is small. In Foster's original work he stated that "as the coefficient of skew, computed from a short record, has a tendency to be too small, a value of coefficient of skew = 0.60 was adopted as typical of streams of New York State."[14]

In 1936, J. J. Slade, Jr. tested the significance of these skew coefficients and showed conclusively that skewness is never a truly significant characteristic when the sample from which it is computed has less than about 140 items . . . and that it is quite meaningless to use this measure when there are 50 or fewer items.[15]

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[14] H.A. Foster, "Theoretical Frequency Curves," Amer. Soc. Civil Engr., Trans., v. 87, 1924, p-168.

[15] W.D. Potter, "Surface Runoff from Small Agricultural Watersheds," Research Report No. 11-B, Highway Research Board, 1950, p-27.

Current usage of the Pearson Type III Method discourages computation of the skew coefficient when the sample size is less than 100 events. However, a predetermined value of skew based on national or regional statistics may be selected when the use of a skew coefficient appears justified.[16]

Prasad acknowledges Slade's work and then states that this implies that the log-Pearson model may not be used for most frequency analysis at present because for most stations less than 60 years of data are available. It is true that the coefficient of skewness is a more sensitive parameter than the mean or the standard deviation. The present study, however, shows that the use of the coefficient of skewness improves the fit of the frequency line in the case of maximum annual flood peaks regardless of the number of years of record.[17]

CONCLUSION

We appear to have come a long way from the Talbot Formula to the log-Pearson Method. Today we have a wealth of records (but never enough and never at the right place),

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[16]Methods of Flow Frequency Analysis: Bulletin No. 13, Subcommittee on Hydrology, Inter-Agency Committee on Water Resources, 1966, p-22.

[17]Ramanand Prasad, "Frequency Analysis of Hydrologic Information," a paper presented at Annual Conference of the Hydraulics Division, Amer. Soc. Civil Engr., 1970, p-10.

electronic computers, and a better understanding of the processes involved in the hydrologic cycle.

But - the basic premise of statistical hydrology is that the records of past events are the results of natural processes which are unchanging. Clouds form; rain falls; interception, retention, infiltration, and runoff occur; evapotranspiration takes place; and then the cycle begins all over again. A never ending cycle - or is it?

Clouds are seeded to bring rain. Other experiments are performed to dissipate clouds. Forests are cut down to be replaced by farms and cities. Potholes are filled to reduce ponding and increase crop yield. Hillsides are terraced and contour farmed to reduce soil erosion and increase crop yield. A corn field gives way to a shopping center and a parking lot. Channels are straightened and obstructions removed in the name of flood control. We have Coralville, Red Rock, Saylorville, Rathbun, Hickory Grove, Don Williams, and hundreds, if not thousands, of farm ponds.

From the standpoint of hydrology, however, there has been a widespread destruction of the hydrologic character of the observed water data. The U.S. Geological Survey has advertised this fact widely by requesting the establishment of hydrologic benchmarks throughout the country. A hydrologic benchmark is an area, untouched by man, in which the water data collected can be expected to depict reliably the effects of natural conditions on the flow of streams and the fluctuations in ground-water levels. In short, as water data have been changed in character due to water-development projects, The Survey has found it increasingly difficult to act as an observer and interpreter of hydrologic fact and has been forced to devise and advocate heroic measures in order to maintain its identity as a scientific agency and perform the services required of it by law.[18]

The name of the game is still "Pick a Number."

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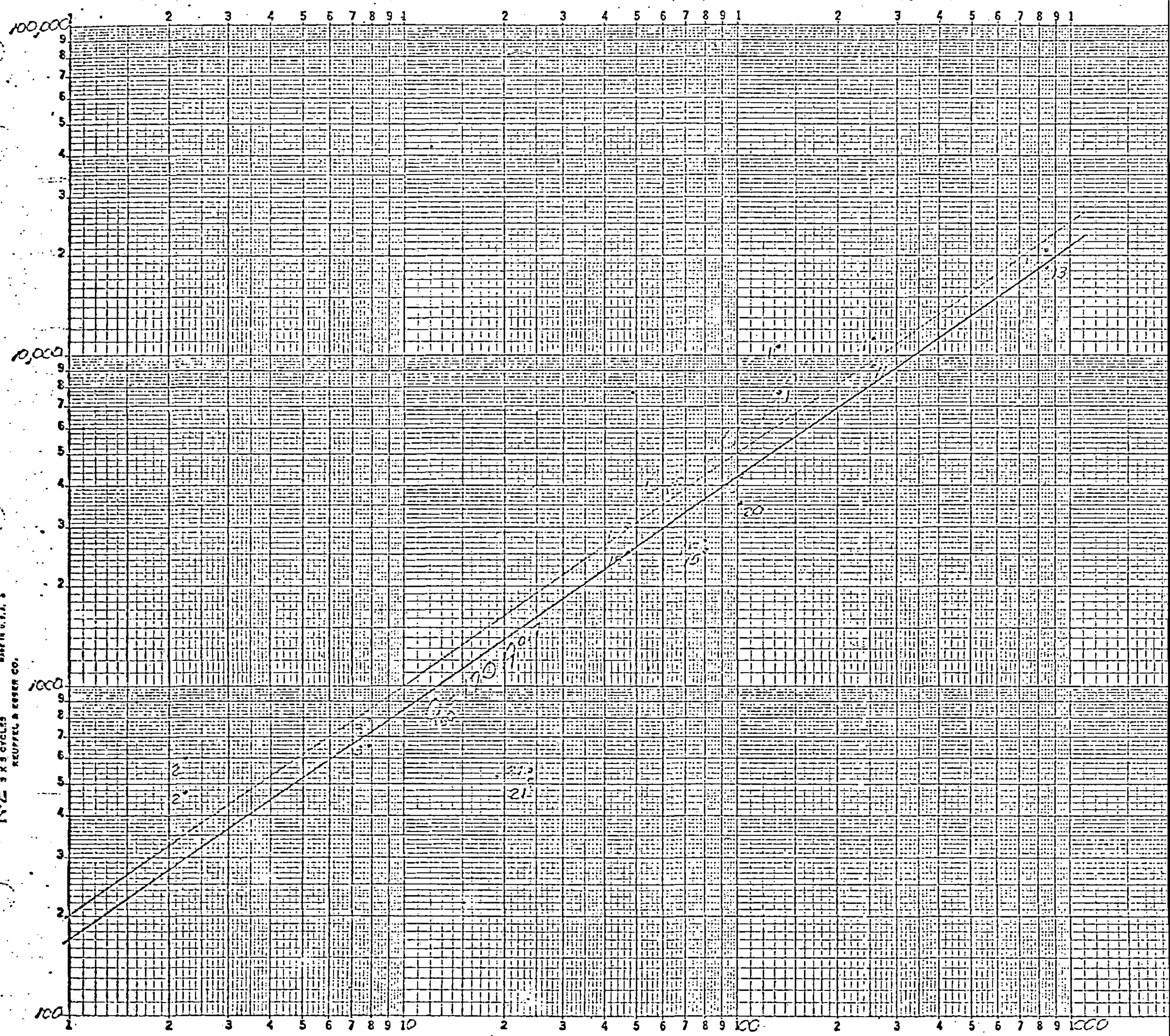
[18] Raphael G. Kazman, Modern Hydrology (New Yor, Harper & Row, Publishers, 1965), pp. 257-258.



Brewers Creek
FN-17-3(2)--21-40

Figure 24. Regional Curve for Q_{50}.

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Talbot, A. N. "The Determination of Water-Way for Bridges and Culverts" Reprint from Selected Papersof the Civil Engineers Club, University of Illinois, 1887-88, No. 2. pp. 14-22.

Appendix A

Paper by Prof. A. N. Talbot

(Copy of the original Talbot paper from Selected Papers of the Civil Engineers' Club of the University of Illinois, 1887-88, No. 2, pp. 14-22. Reproduced for historical and background purposes only.)

THE DETERMINATION OF WATER-WAY FOR BRIDGES AND CULVERTS

By A. N. TALBOT
Ass't Professor of Engineering and Mathematics

In general, little consideration has been given to the proportioning of the span of culverts and bridges. Boxes, pipes, and small bridges are guessed off by the subordinate engineer. Too often a mistaken size causes a washout of great magnitude, entailing cost of repairs and loss of traffic. Nearly as frequently extravagant ideas of requirements cause greatly increased cost of construction. Indeterminate though the problem be, it demands an intelligent treatment. Any one can make a culvert or bridge large enough; it is the province of the engineer to design one of sufficient but not excessive size. Perhaps in the majority of bridge locations, bluffs or a well-marked channel determines the width of the bridge opening, so that the amount of water is a subordinate feature, or the size of the opening can be decided upon by inspection of the profile. Very often, however, there is no such guide and no good evidence of the height of the stream at the opening. This paper will consider such cases. What I have to offer is not universally applicable -- and no rule of thumb will fit the case.

Here let me warn you that the question is not one which can be determined with mathematical exactness. The problem is more or less indeterminate -- decimal places do not give accurate results with uncertain data. Do not then be troubled because similar conditions give varying results.

In the construction of a new railroad, considerations of first cost, time, and a lack of knowledge of the amount of future traffic, as well as ignorance of the physical features of the country, usually require that temporary structures be first put in, to be replaced by masonry and iron later. An excessive size for these temporary structures may not be very objectionable -- often a trestle will for the time be cheaper than an embankment. With increased resources, permanent improvements will be made. In the meantime an incidental but very important duty of the engineer is to make a careful study of the requirements of the road. Upon the judgment and ability displayed in this depends most of the economical value of culverts, abutments and piers, and the supervision of the construction is not difficult. High-water mark of streams and the effect of floods even in water-courses ordinarily dry should be recorded and notes of required water-way taken. With these data the proper proportioning of the permanent structures becomes an easy task.

Culverts

The difficulty of deducing a rational formula to determine the necessary span or water-way of a culvert draining a given area will be appreciated on examining the following conditions which enter into the problem:

(1) The variation of the rate of rainfall in different localities.

(2) Paucity of data, since records are generally given as so much per day and rarely per hour, while the duration of the severe storm is not recorded.

(3) The melting of snow with a heavy rain.

(4) The permeability of the surface of the ground, depending upon the kind of soil, condition of vegetation and cultivation, etc.

(5) The degree of saturation of the ground and the amount of evaporation.

(6) The character and inclination of the surface to the point where the water accumulates in the water-course proper.

(7) The inclination or slope of the water-course to the point considered.

(8) The shape of the area drained and the position of the feeders.

The importance of the last item will be seen in comparing a spoon-shaped area, shown at (b) in the accompanying cut, where the main water-course is fed by branches from both sides so arranged that water from the whole area reaches the culvert at the same time, with a long, narrow basin, shown at (a), in which before the water from the upper part reaches the opening the rainfall from the lower portion has been carried away and the severe part of the storm is past. In large areas this is an important consideration.

In constructing such a formula, then, we should have to decide between 1 and 3 inches of rainfall per hour; upon the proportion of the rainfall reaching the stream, which is given in reliable data as varying from 15 to 50 percent, and in case of snow to a quantity even greater than the rainfall; to estimate the time required to find its way through grass and brush, over flat and steep, until the water-course is reached, and then with the imperfect formula for flow in channels to correct for retardation by bends and brush and grass; and finally to decide upon what proportion of the water carried down the stream would reach the opening at the same time. As any of these estimates might be in error 200 or 300 percent, the final result would not be reliable.

Before deciding upon a method, I desire to emphasize the fact that any formula will be approximate, that the estimation of the values of the different conditions entering into the subject will be almost wholly a matter of judgment, so that the formula must be considered more as a guide to the judgment than as a working rule. Mathematical exactness is neither warranted by nor required by the problem. The question is not one of 10 or 20 percent of increase. If a 2-foot pipe is insufficient, a 3-foot pipe will probably be the next size, an increase of 225 percent. If a 6-foot arch culvert proves too small, an 8-foot will be used. The real question is whether we want an 8-foot culvert or a 2-foot pipe. Approximation is all we can hope for, and fortunately is all we require.

At first thought it would appear that the amount of water to pass through an opening, other things being equal, will be directly proportional to the area drained. For small areas this is nearly true, but as we have seen in the case of the long, narrow drainage area there will be a variation from the direct proportion as the size of the basin increases.

The slope of the culvert is not considered nor is the increased discharge of large openings per square foot of area, as nearly the same proportion will be found as in the channel above.

Maj. E. D. T. Myers' formula is the only one in general use. It is

$$\text{Area of water-way in square ft.} = C\sqrt{\text{Drainage Area in Acres}},$$

where C is a variable coefficient for which 1 is used in ordinary, slightly rolling prairie or agricultural land, 1.5 in hilly ground, the value rising to 4 in mountainous and rocky ground. This gives values which are ample for small drainage areas, in fact too large. For large areas the results are too small. The defect for small areas is apparent from the fact that the discharge will be then nearly proportional to the acreage, while the formula makes 40 acres require only twice as much as 10 acres. With judicious use, this formula has done good service, but it has many defects.

It has been suggested that observations be made at the culvert to find the depth of water there for a known rainfall. A maximum rate of rainfall could then be assumed, and the maximum water-way calculated by simple proportion. The objection to this method is the fact that a double amount of rainfall will give more than double the discharge, since the ground has become saturated and since obstructions will have less effect on the flow.

The only formula for finding the discharge for a given rainfall over a given area approaching to reliability is that of the Swiss hydraulician, Mr. Burkli-Ziegler, which was derived from observations on heavy storms in Zurich, together with information from other European localities. For feet measure it is

$$\text{Quantity of discharge per acre in cubic feet per second} = c\,a\sqrt[4]{\frac{S}{A}}.$$

c is a coefficient depending upon the character of the ground and having 0.31 for an average value; R the rainfall in cubic feet per second per acre, which roughly may be used as 1 cubic foot per second per acre for each 1 inch of rainfall; s the fall per 1,000, and A the area in acres. Proper substitutions in this would give the volume of flow, from which the necessary water-way could be calculated, but it will be better to use only deductions from this.

Since by this formula the quantity discharged per acre varies inversely as the fourth power of the area drained, the volume of discharge from the whole area will vary as $\frac{A}{\sqrt[4]{\frac{S}{A}}}$, or $A^{3/4}$; and, assuming the same velocity through the culvert as in the stream above, the opening will vary likewise. This assumption will be true when the grade of the culvert is the same as that of the stream above and when the smaller coefficient of friction in the culvert over that of the channel itself is counteracted by the resistance to entering the culvert. We may then write

$$a = C\sqrt[4]{A^3}\text{, or}$$

$$\text{Area of water-way in sq. ft.} = C\sqrt[4]{\frac{(\text{Drainage area})^3}{\text{in acres.}}}\text{,}$$

for which the coefficient C must be determined.

By comparison with the formula of Burkli-Ziegler and with the flood flow of streams up to several of 77 square miles area, I conclude that for rolling agricultural country subject to floods at time of melting of snow, and with the length of valley three or four times the width, 1/3 is the proper value of C. If the stream is longer in proportion to the area, decrease C. In districts not affected by accumulated snow, and where the length of the valley is several times the width, 1/5 or 1/6 or even less may be used. C should be increased for steep side slopes, especially if the upper part of the valley has a much greater fall than the channel at the culvert.

In any case, the judgment must be the main dependence, the formula being a guide to it. On a road already constructed the C may be determined for the character of surface along that line by comparing the formula with high-water mark of a known drainage area. Experience and observation on similar water-courses is the most valuable guide. A knowledge of the action of streams of similar situations in floods and of the effects of peculiar formations and slopes is of far more value than any extended formula.

The drainage area may be obtained with sufficient accuracy from a county map, or by walking up and across the basin.

The following table shows the values as given by the Myers' formula

$\underline{a} = 1\sqrt{A}$ and $\underline{a} = 1/3\ A^{3/4}$. $\underline{a}$ is in square feet in both cases:

Acreage	Myers	Talbot	Acreage	Myers	Talbot
10	3.2	1.9	200	14.1	17.7
20	4.5	3.2	400	20.0	29.8
40	6.3	5.3	640	25.3	42.4
80	8.9	8.9	1000	31.6	59.3
100	10.0	10.5	2000	44.7	99.7
160	12.6	15.0	6400	80.0	238.5

According to the Myers formula a 12-inch pipe will not drain an acre, which is absurd on its face.

Incidentally, I may say that I have found that for average slope in small rivers the flood discharge per square mile is about

$$\frac{500 \text{ cu. ft. per second}}{\sqrt[4]{\text{Area in sq. miles}}}$$

Bridges

Ordinarily the distance between banks and the prevailing grade line on either side determines the length of span and the amount of water-way. Large streams having well-established channels will not present any difficulties -- an inspection of the profile is the only thing needed. With small rivers and creeks, especially in regions subject to floods and having no well-defined banks and high-water channel, a more extended investigation is necessary. The requisite water-way should be determined before the permanent iron bridges are constructed.

In brief, the process is to find the flood discharge of the stream and the average flood velocity at the bridge opening. Their quotient will give the necessary area of the opening, from which the width may be determined.

The flood discharge can not be taken by the more accurate method of finding the average velocity of the section by the current meter, for even if the engineer were present at the time of the highest water known, time and other circumstances would not permit the gauging.

The best method is to find the sectional area of the high-water stage, and in connection with the slope calculate the flood discharge.

To this end select several sections above or below the bridge at points where the high-water mark may be certainly and accurately determined and at distances apart depending upon the size of the stream.

If a tributary enters between the section and the bridge, its discharge must be determined similarly and applied. Select as straight and uniform a reach as possible, for bends, crooks, obstructions and other irregularities will increase the error of the result. The stream itself may be sounded in a boat rowed in range or secured to a rope stretched across the stream. The remainder of the cross-section may be taken in the usual way of leveling to secure a profile. Care must be taken that the section is at right angles to the current. The height of high water is the most difficult and unsatisfactory detail to be found. The position of drift wood and the evidence of residents will be the principal means. Divergence of opinion and irreconcilable evidence must be sorted out by an exercise of common sense. In any case high water on one bank or in the middle of the stream may vary considerably from that on the other side. From the accepted notes the area of the flood discharge is calculated.

The slope is best determined by taking the elevation of two well-defined high-water marks, one above and one below the section and at least 1,000 feet apart, provided the reach is straight and of nearly uniform section for that distance; or it may be found that the slope of the stream at its usual stage will give fair results. In case of low water or none, the fall of the bottom of the channel will give the slope approximately. If the cross-section of the channel varies much, neither the slope of the bottom nor of high-water will give the proper inclination.

Various formulas have been proposed for estimating the discharge of a stream or open channel. Most of them are of the form $V = c\sqrt{RS}$, known as the Chezy formula. In this V = velocity in feet per second. S = rate of fall or sine of slope. R = hydraulic mean radius = $\frac{\text{area}}{\text{wetted perimeter}}$. c = a coefficient, formerly thought to be constant, but now known to be variable and to depend upon roughness of channel and change of section of the stream, upon depth, slope and even upon the velocity. In fact the velocity does not vary as the square root of R and S. The formula is based upon the assumption that the resistance to flow varies as the square of the velocity and as the proportion of the water that is in contact with the wetted surface, neither of which is exactly true. Fteley's formula for conduits, $V = c\,R^{.62}\,S^{1/2}$ gives close results for the kind of channels it was derived from.

However, the form of the Chezy formula is now generally accepted, and a modification is made in c according to the other conditions. Kutter's formula for this coefficient is

$$C = \frac{41.6 + \frac{1.811}{n} + \frac{.00281}{S}}{1 + \left(41.6 + \frac{.00281}{S}\right)\frac{n}{\sqrt{R}}}$$

where n is a coefficient of resistance of the channel with values varying from .030 to .035 for rivers. Hamilton Smith, Jr., a late authority in hydraulics, rejects Kutter's formula as untrustworthy. He further says: "For conduits or canals with rough channel, we regard it as almost useless to propose any other formula than $V = c \cdot R\,S$; it is impossible to assign with any reasonable degree of accuracy any numerical value to the resistance of the channel for streams, and as it is such a controlling quantity in any equation of which it forms a part, such uncertainty must always make the equation simply approximate."

For our purpose then it will be best to use the Chezy formula, using the judgment and comparing with known values of c for streams that have been gauged.

The following values have been found by experiment:

Irrigating ditches with rough sides, sharp curves, fall of 15 to 20 feet to the mile and depth of 2 to 4 feet, $c = 30$ to 50.

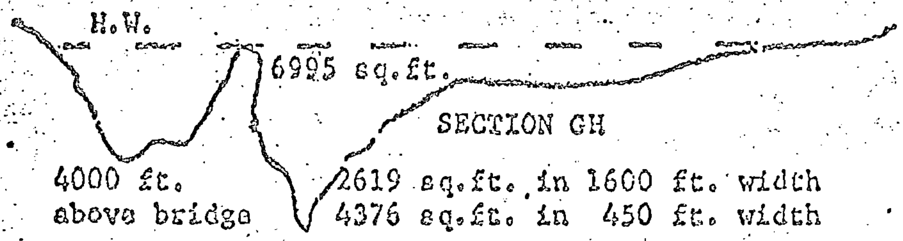
Creeks and small streams, with uneven channels and many obstructions, $c = 50$ to 70.

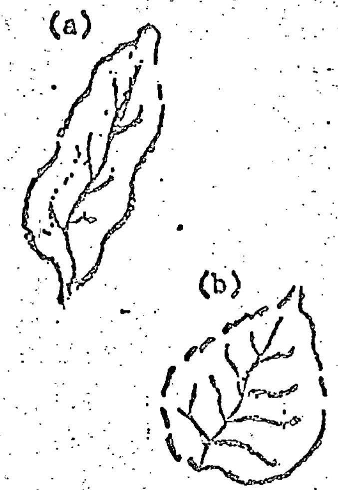
Small rivers with depth of 10 feet or more and width of 100 to 400 feet, $c = 60$ to 90.

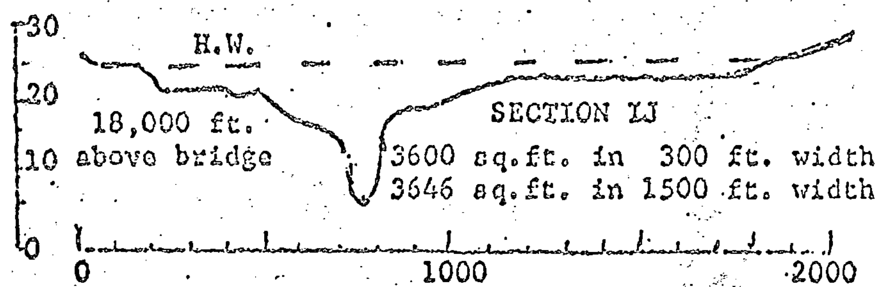
Rivers with smooth banks and channel and straight course, $c = 100$. For large rivers this must be increased.

Fortunately, for our purpose the absolute volume of discharge is not necessary, since we shall finally divide the discharge by the velocity at the bridge to get the required area of water-way, and a difference in coefficients will not show a great discrepancy.

Having calculated the velocity, multiply it by the area of cross-section to determine the volume of discharge; average the quantities found from the different sections and get the average velocity. If the situation admits it, one of the sections should be at the bridge opening. By dividing the total discharge (using the average of the different calculations) by the calculated or an assumed velocity at the bridge, the necessary area of water-way is obtained; then, from the depth and cross-section of the channel, the necessary length and height of the opening is found. Large discrepancies may be expected in the results for the different sections.







As an illustration of what I mean, I give the record of surveys of Apishapa River in Colorado. Two cross-sections of the stream, one 4,000 feet and the other 18,000 feet above the bridge, are given. The banks were overflowed and the shallowness of the outer sections required a smaller *c*, so in the calculations the cross-sections are divided into two compartments, a shallow and a deep one, the latter including the portion or the section within the principal banks of the stream. Then separate computations are made for each compartment. The hydraulic mean depth, *R*, is found by dividing the area of either portion of the section by its width. The coefficient *c* is assumed to be 90 in the deep portion and 70 in the shallow. The results are shown as follows:

Section GH

	c	Area in sq.ft.	R	S	V	Volume
Deep Comp.	90	4,376	9.72	.0018	11.88	51,986
Shallow Comp.	70	2,619	1.64	.0018	3.78	9,900
Total		6,995				61,886

Average velocity, 8.85 feet per second

Section IJ

	c	Area in sq.ft.	R	S	V	Volume
Deep Comp.	90	3,600	12.00	.0018	13.23	47,628
Shallow Comp.	70	3,646	2.43	.0018	4.62	16,844
Total		7,246				64,472

Average velocity, 8.90 feet per second
Average volume of discharge, 63,179

Using the same slope for the section at the bridge opening, the velocity there would be nearly 16. Since at this point there certainly would be back-water from the river, this value was thrown out, and the average of the velocities in the deep compartment of the other sections, 12.5 feet per second, was taken as the average velocity at the bridge opening. Dividing 63,179, the average volume of discharge, by this velocity, gives a necessary water-way of 5055 square feet.

An examination of the profile at the bridge will determine the length of span necessary to secure that water-way. However, in the case referred to, it was decided to excavate the channel from abutment to abutment to the depth of the bottom of the stream. The resulting uniform depth was 25 feet. The area of water-way, 5055, divided by this depth, gives 202 as the necessary width. The span must be increased to allow for the amount taken up by the piers, etc.

Not enough importance is attached to the shape of the channel at and below the bridge opening. Even when the channel is excavated to the full width of the opening under the bridge, the full capacity of the bridge opening will not be utilized unless the enlarged channel is extended down stream until the flood water has a chance to escape over the flat below without a reduction in velocity and a consequent obstruction to the water that is at that time coming through the opening. In fact, the shape of the channel just below the bridge has as much to do with the capacity as the opening itself. Above the bridge, whatever may be the shape of the opening, the pressure of the water on all sides and the tendency to dam up tends to force the water through the opening with increased velocity. Below it, any decreased section or turn in the course obstructs the current and greatly impedes the velocity of water at that time flowing through the opening. The principle is similar to the ajutage with curved form used in the experiments in Physics. Many bridges have come under my observation whose efficiency could be doubled with little expense by modifying the channel in this way.

It was my intention to treat the amount of back-water caused by the contraction of the channel at the bridge and by the obstruction of the piers, but the length of this article requires that that subject be given in a separate paper.

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Appendix B

Cedar River

N = 67

5-4645. Cedar River at Cedar Rapids, Iowa

Location.--Lat 41 deg.58 min.20 sec., long 91 deg.40 min.05 sec., in SE¼NW¼ sec.28, T.83 N., R.7 W., on right bank 500 ft upstream from Eighth Avenue Bridge in Cedar Rapids, 2.7 miles upstream from Prairie Creek, and at mile 112.7 above mouth of Iowa River.

Drainage area.--6,510 sq mi.

Gage.--Nonrecording prior to Aug. 20, 1920; recording thereafter. Datum of gage is 700.47 ft above mean sea level, datum of 1929.

Stage-discharge relation.--Defined by current-meter measurements.

Remarks.--Base for partial-duration series, 15,000 cfs.

Peak stages and discharges

Water year	Date	Gage height (feet)	Discharge (cfs)
1851	June	[a]20	[a]65,000
1903	May 31, 1903	16.85	53,600
1904	Mar. 26, 1904	6.45	11,800
1905	Mar. 23, 1905	9.05	23,000
	May 20, 1905	8.1	19,000
1906	Feb. 28, 1906	8.4	19,400
	Mar. 30, 1906	17.6	55,700
1907	July 20, 1907	8.5	19,800
	Aug. 17, 1907	8.2	18,600
1908	May 30, 1908	8.8	21,000
	June 26, 1908	8.0	17,800
1909	Mar. 30, 1909	9.1	22,100
	Apr. 22, 1909	7.4	15,400
~~1910~~	Nov. 19, 1909	8.0	17,800
	Dec. 2, 1909	7.4	15,400
	Dec. 11, 1909	8.4	19,400
1910	Mar. 14, 1910	9.6	24,100
1911	Feb. 16, 1911	7.1	14,300
1912	Apr. 1, 1912	17.2	54,000

Peak stages and discharges

Water year	Date	Gage height (feet)	Discharge (cfs)
1913	Mar. 18, 1913	9.2	22,500
1914	June 19, 1914	7.8	17,000
1915	Feb. 25, 1915	10.3	26,800
	Mar. 28, 1915	12.0	33,600
	June 2, 1915	11.5	31,600
	Sept. 28, 1915	9.4	23,300
1916	Mar. 30, 1916	10.0	25,700
	Apr. 25, 1916	7.4	15,400
	June 6, 1916	8.1	18,200
1917	Mar. 26, 1917	17.4	54,900
	June 13, 1917	8.3	19,000
1918	June 7, 1918	11.0	28,200
1919	Mar. 20, 1919	11.4	29,700
	Apr. 15, 1919	9.4	21,800
1920	Mar. 30, 1920	7.6	14,800
1921	June 1, 1921	8.40	17,900
1922	Feb. 27, 1922	9.1	21,000
1923	Apr. 4, 1923	7.80	16,000
1924	Aug. 22, 1924	10.54	26,300
1925	June 18, 1925	7.00	12,800
1926	Sept. 21, 1926	6.70	11,500
1927	May 25, 1927	6.77	11,800
1928	Feb. 12, 1928	9.5	22,200
	Aug. 29, 1928	11.05	29,200
1929	Mar. 18, 1929	20.00	64,000
	Apr. 20, 1929	9.3	21,400
1930	Feb. 24, 1930	6.90	12,200

5-4645. Cedar River at Cedar Rapids, Iowa-- (Continued)

Peak stages and discharges

Water year	Date	Gage height (feet)	Discharge (cfs)
1931	Sept. 26, 1931	4.10	3,270
~~1932~~	Nov. 28, 1931	8.4	~~17,900~~
1932	Apr. 2, 1932	8.73	19,100
	June 23, 1932	8.4	17,900
1933	Apr. 4, 1933	18.6	58,400
1934	Apr. 9, 1934	5.55	8,620
1935	Mar. 8, 1935	10.38	26,900
1936	Mar. 15, 1936	9.45	22,700
	Mar. 27, 1936	8.9	20,600
1937	Feb. 21, 1937	9.3	22,300
	Mar. 9, 1937	13.61	40,700
	June 17, 1937	9.6	23,500
1938	Sept. 21, 1938	6.93	12,900
1939	Mar. 18, 1939	8.67	19,700
1940	Apr. 4, 1940	4.86	5,540
1941	Mar. 21, 1941	8.0	17,100
1942	June 7, 1942	8.9	19,100
	Aug. 3, 1942	12.6	33,900
1943	Mar. 31, 1943	7.91	15,800
1944	May 25, 1944	8.5	17,900
	June 18, 1944	11.43	29,100
	June 23, 1944	9.2	20,300
1945	Mar. 19, 1945	17.09	52,300
	May 31, 1945	8.8	19,700
	June 5, 1945	9.2	21,200
1946	Jan. 9, 1946	10.8	27,100
	Mar. 11, 1946	9.2	21,200
	Mar. 17, 1946	.9	23,700
	Sept. 24, 1946	8	16,200

5-4645. Cedar River at Cedar Rapids, Iowa--(Continued)

Peak stages and discharges

Water year	Date	Gage height (feet)	Discharge (cfs)
1947	Apr. 16, 1947	8.3	18,000
	June 6, 1947	13.5	37,000
	June 16, 1947	18.23	56,200
	July 6, 1947	8.6	19,100
1948	Mar. 3, 1948	12.82	34,500
	Mar. 20, 1948	12.6	33,900
1949	Mar. 7, 1949	11.75	30,800
	Mar. 31, 1949	8.3	18,000
1950	Mar. 11, 1950	12.45	33,000
	Apr. 1, 1950	9.8	23,400
	June 26, 1950	7.9	16,600
1951	Feb. 27, 1951	[b]12.51	[a]30,000
	Mar. 31, 1951	13.54	39,300
	Apr. 11, 1951	17.22	54,100
	May 2, 1951	13.45	38,900
	June 3, 1951	8.42	19,400
	June 30, 1951	12.00	33,300
	July 10, 1951	8.35	19,400
	Aug. 30, 1951	7.56	16,300
1952	Apr. 5, 1952	10.40	27,000
1953	Aug. 10, 1953	7.29	15,200
1954	June 26, 1954	14.02	41,400
1955	Mar. 5, 1955	[b]5.67	[a] 8,100
1956	Apr. 6, 1956	4.69	5,400
1957	June 20, 1957	6.00	9,900
1958	June 13, 1958	4.58	5,240
1959	Mar. 21, 1959	8.75	21,000
	Mar. 30, 1959	9.77	25,800

5-4645. Cedar River at Cedar Rapids, Iowa--(Continued)

Peak stages and discharges

Water year	Date	Gage height (feet)	Discharge (cfs)
1960	Jan. 13, 1960	8.60	20,400
	Apr. 2, 1960	16.75	55,100
	May 7, 1960	11.59	32,400
1961	Mar. 8, 1961	7.62	17,600
	Mar. 31, 1961	19.66	73,000
1962	Apr. 2, 1962	15.15	50,000
	Sept. 7, 1962	8.11	18,900
1963	Mar. 19, 1963	7.26	15,600
1964	May 8, 1964	4.43	4,270
1965	Mar. 6, 1965	11.19	32,100
	Apr. 10, 1965	18.51	66,800
	Sept. 26, 1965	10.04	27,200

a About
b Affected by ice

~~Feb~~ 1966	Oct. 5, 1966	10.51	29,200
1967	June 16, 1967	7.41	16,000
1968	Aug. 7, 1968	8.79	22,200
1969	July 12, 1969	16.58	54,500

```
login(bridge,bridge01)
GOOD MORNING; USER 05; TIME  11:20:59  9/18/70;
load (1pear3)
xeq
Enter name, drainage area and gage number of watershed.
Cedar River      6,510 sq. mi.      Gage No. 5-4645
Any changes in identification input?  Enter yes or no.
no
Enter number of years of record.
N
67
Any changes in value of N?  Enter yes or no.
no
Enter values of maximum annual discharge.
Y(1)
53600
Y(2)
11800
Y(3)
23000
Y(4)
19000
Y(5)
19800
Y(6)
21000
Y(7)
22100
Y(8)
24100
Y(9)
14300
Y(10)
54000
Y(11)
22500
Y(12)
17000
Y(13)
33600
Y(14)
25700
Y(15)
54900
Y(16)
28200
Y(17)
29700
Y(18)
14800
Y(19)
17900
Y(20)
21000
Y(21)
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Y(22)
26300
Y(23)
12800
Y(24)
11500
Y(25)
11800
Y(26)
29200
Y(27)
64000
Y(28)
12200
Y(29)
3270
Y(30)
19100
Y(31)
58400
Y(32)
8620
Y(33)
26900
Y(34)
22700
Y(35)
40700
Y(36)
12900
Y(37)
19700
Y(38)
5540
Y(39)
17100
Y(40)
33900
Y(41)
15800
Y(42)
29100
Y(43)
52300
Y(44)
19700 ≈ 19470
Y(45)
56200
Y(46)
34500
Y(47)
30800
Y(48)
33000
Y(49)
54100
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27000
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15200
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Y(53)
8100
Y(54)
5400

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9900
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Y(57)
25800
Y(58)
55100
Y(59)
73000
Y(60)
50000
Y(61)
15600
Y(62)
4270
Y(63)
66800
Y(64)
29200
Y(65)
16000
Y(66)
22200
Y(67)
54500
Any changes in discharge input?  Enter yes or no.
yes
Which Q?
fix
4
Y(4)
55700
Any changes in discharge input?  Enter yes or no.
yes
Which Q?
fix
44
Y(44)
27100
Any changes in discharge input?  Enter yes or no.
no

M=  4.353          S=  0.307          g=   -0.552

Enter K value corresponding to recurrance
interval and value of g.
ayk
1.747
Any changes in value of K?  Enter yes or no.
no
Enter recurrance interval in years.
RI
50
Any changes in value of recurrance interval?  Enter yes or no.
no

Cedar River     6,510 sq. mi.     Gage No. 5-4645

Q=  77588 cfs

Recurrance Interval=     50 years
```

```
Do you want Q for a different recurrance interval?
Enter yes or no.
yes


Enter K value corresponding to recurrance
interval and value of g.
ayk
1.916
Any changes in value of K?  Enter yes or no.
no
Enter recurrance interval in years.
RI
100
Any changes in value of recurrance interval?  Enter yes or no.
no


Cedar River     6,510 sq. mi.     Gage No. 5-4645


Q=  87446 cfs

Recurrance Interval=    100 years


Do you want Q for a different recurrance interval?
Enter yes or no.
yes


Enter K value corresponding to recurrance
interval and value of g.
ayk
2.060
Any changes in value of K?  Enter yes or no.
no
Enter recurrance interval in years.
RI
200
Any changes in value of recurrance interval?  Enter yes or no.
no


Cedar River     6,510 sq. mi.     Gage No. 5-4645


Q=  96828 cfs

Recurrance Interval=    200 years


Do you want Q for a different recurrance interval?
Enter yes or no.
no
Do you want to determine Q for another watershed?
Enter yes or no.
no

.
END OF JOB.
logout
TIME 11:36:15; TIME USED: CPU 00        ; TERM 00:15:16; PAGE 00:29:49;
```

Appendix C

Pine Creek

5-4212. Pine Creek near Winthrop, Iowa

Location.--$SW\frac{1}{4}$ sec.34, T.89 N., R.8 W., at Illinois Central RR bridge, 500 ft upstream from U.S. Highway 20 and 2.5 miles southwest of Winthrop, Buchanan County.

Drainage area.--28.3 sq mi.

Gage.--Crest-stage gage. Datum is arbitrary.

Stage-discharge relation.--Defined by current-meter and indirect measurements.

Remarks.--Only annual peaks are shown.

Peak stages and discharges

Water year	Date	Gage height (feet)	Discharge (cfs)	
1950	Sept. 21, 1950	21.70	14,500	2
1951	June 2, 1951	18.74	10,600	3
1952	Mar. 10, 1952	13.47	1,090	10
1953	Feb. 20, 1953	13.43	1,070	11
1954	Apr. 30, 1954	12.35	650	16
1955	Feb. 20, 1955	12.19	590	17
1956		c	300	19
1957	June 17, 1957	13.27	990	12
1958		c	200	20
1959	June 25, 1959	13.94	1,360	9
1960	Mar. 30, 1960	15.17	2,450	7
1961	Mar. 5, 1961	12.82	800	15
1962	May 5, 1962	16.68	5,030	4
1963	Mar. 18, 1963	13.17	962	13
1964	Apr. 3, 1964	12.78	803	14
1965	Apr. 2, 1965	14.69	1,940	8

1966 - 3,050; 1967 - 532; 1968 - 24,200; 1969 - 2,500

```
xeq
Enter name, drainage area and gage number of watershed.
Pine Creek     28.3 sq. mi.     Gage No. 5-4212
Any changes in identification input? Enter yes or no.
no
Enter number of years of record.
N
20
Any changes in value of N?  Enter yes or no.
no
Enter values of maximum annual discharge.
Y(1)
14500
Y(2)
10600
Y(3)
1090
Y(4)
1070
Y(5)
650
Y(6)
590
Y(7)
300
Y(8)
990
Y(9)
200
Y(10)
1360
Y(11)
2450
Y(12)
800
Y(13)
5030
Y(14)
962
Y(15)
803
Y(16)
1940
Y(17)
3050
Y(18)
532
Y(19)
24200
Y(20)
2500
Any changes in discharge input?  Enter yes or no.
yes
Which Q?
fix
20
Y(20)
2500
Any changes in discharge input?  Enter yes or no.
```

M= 3.195 S= 0.545 g= 0.697

Enter K value corresponding to recurrance
interval and value of g.
ayk
2.406
Any changes in value of K? Enter yes or no.
no
Enter recurrance interval in years.
RI
50
Any changes in value of recurrance interval? Enter yes or no.
no

Pine Creek 28.3 sq. mi. Gage No. 5-4212

Q= 32032 cfs

Recurrance Interval= 50 years

Do you want Q for a different recurrance interval?
Enter yes or no.
no
Do you want to determine Q for another watershed?
Enter yes or no.
yes

```
Enter name, drainage area and gage number of watershed.
Pine Creek     28.3 sq. mi.      5-4212
Any changes in identification input?  Enter yes or no.
no
Enter number of years of record.
N
19
Any changes in value of N?  Enter yes or no.
no
Enter values of maximum annual discharge.
Y(1)
14500
Y(2)
10600
Y(3)
1090
Y(4)
1070
Y(5)
650
Y(6)
590
Y(7)
300
Y(8)
990
Y(9)
200
Y(10)
1360
Y(11)
2450
Y(12)
800
Y(13)
5030
Y(14)
962
Y(15)
803
Y(16)
1940
Y(17)
3050
Y(18)
532
Y(19)
2500
Any changes in discharge input?  Enter yes or no.
no


M=  3.133            S=  0.480            g=     0.578


Enter K value corresponding to recurrance
interval and value of g.
ayk
```

2.348
Any changes in value of K? Enter yes or no.
no
Enter recurrance interval in years.
RI
50
Any changes in value of recurrance interval? Enter yes or no.
no

Pine Creek 28.3 sq. mi. 5-4212

Q= 18193 cfs

Recurrance Interval= 50 years

Do you want Q for a different recurrance interval?
Enter yes or no.
no
Do you want to determine Q for another watershed?
Enter yes or no.
yes

```
login(bridge,brødge01)
GOOD MORNING; USER 03; TIME  10:42:32  9/18/70;
load (lpear3)
xeq
Enter name, drainage area and gage number of watershed.
Pine Creek      28.3 sq. mi.      Gage No. 5-4212
Any changes in identification input?  Enter yes or no.
no
Enter number of years of record.
N
18
Any changes in value of N?  Enter yes or no.
no
Enter values of maximum annual discharge.
Y(1)
10600
Y(2)
1090
Y(3)
1070
Y(4)
650
Y(5)
590
Y(6)
300
Y(7)
990
Y(8)
200
Y(9)
1360
Y(10)
2450
Y(11)
800
Y(12)
5030
Y(13)
962
Y(14)
803
Y(15)
1940
Y(16)
3050
Y(17)
532
Y(18)
2500
Any changes in discharge input?  Enter yes or no.
no

M=  3.076            S=  0.422                 0.408

Enter K value corresponding to
```

Enter K value corresponding to recurrance
interval and value of g.
ayk
2.265
Any changes in value of K? Enter yes or no.
no
Enter recurrance interval in years.
RI
50
Any changes in value of recurrance interval? Enter yes or no.
no

Pine Creek 28.3 sq. mi. Gage No. 5-4212

Q= 10765 cfs

Recurrance Interval= 50 years

Do you want Q for a different recurrance interval?
Enter yes or no.
no
Do you want to determine Q for another watershed?
Enter yes or no.
no

END OF JOB.

logout
TIME 10:47:38; TIME USED: CPU 00:00:07; TERM 00:05:05; PAGE 00:09:24;

```
login(bridge,bridge01)
GOOD AFTERNOON; USER 04; TIME  13:47:31  9/18/70;
load (lpear3)
xeq
Enter name, drainage area and gage number of watershed.
Pine Creek     28 sq. mi.     Gage No. 5-8812
Any changes in identification input?  Enter yes or no.
no
Enter number of years of record.
N
17
Any changes in value of N?  Enter yes or no.
no
Enter values of maximum annual discharge.
Y(1)
1090
Y(2)
1070
Y(3)
650
Y(4)
590
Y(5)
300
Y(6)
990
Y(7)
200
Y(8)
1300
Y(9)
2450
Y(10)
800
Y(11)
5030.
Y(12)
962
Y(13)
803
Y(14)
1940
Y(15)
3050
Y(16)
532
Y(17)
2500
Any changes in discharge input?  Enter yes or no.
no


M=  3.020            S=  0.360            g=   -0.063


Enter K value corresponding to recurrance
interval and value of g.
ayk
2.020
```

```
Any changes in value of K?  Enter yes or no.
no
Enter recurrance interval in years.
RI
50
Any changes in value of recurrance interval?  Enter yes or no.
no


Pine Creek      28 sq. mi.      Gage No. 5-4212


Q=   5590 cfs

Recurrance Interval=      50 years


Do you want Q for a different recurrance interval?
Enter yes or no.
no
Do you want to determine Q for another watershed?
Enter yes or no.
no


END OF JOB.
_




logout
TIME 13:52:26; TIME USED: CPU 00:00:05; TERM 00:04:54; PAGE 00:00:00;
```

Appendix D

Skunk River

N=17

5-4710. Skunk River below Squaw Creek near Ames, Iowa

Location.--Lat 42 deg.00 min.30 sec., long 93 deg.35 min.40 sec., in $NE\frac{1}{4}NW\frac{1}{4}$ sec.13, T.83 N., R.24 W., on right bank 15 ft downstream from highway bridge, a quarter of a mile downstream from Squaw Creek, 1 mile downstream from bridge on U.S. Highway 30, 2 miles southeast of Ames, and at mile 222.6.

Drainage area.--556 sq mi.

Gage.--Recording. Datum of gage is 867.10 ft above mean sea level, datum of 1929.

Stage-discharge relation.--Defined by current-meter measurements.

Remarks.--Base for partial-duration series, 2,500 cfs.

Peak stages and discharges

Water year	Date	Gage height (feet)	Discharge (cfs)
1944	May 19, 1944	13	~~10,000~~
1953	May 1, 1953	5.47	1,620
1954	June 1, 1954	10.92	6,500
	June 11, 1954	11.92	7,980
	June 16, 1954	7.63	3,200
	June 22, 1954	8.36	3,820
	Aug. 22, 1954	8.53	3,950
	Aug. 26, 1954	9.26	4,700
	Aug. 28, 1954	12.36	8,700
1955	Oct. 14, 1954	6.81	2,680
~~1955~~	July 10, 1955	6.73	~~2,540~~
1956	May 13, 1956	3.05	638
1957	June 16, 1957	11.58	6,360
	July 4, 1957	8.54	3,950
1958	June 8, 1958	6.95	2,610
	June 13, 1958	6.93	2,610
	July 2, 1958	11.13	6,120
	July 4, 1958	12.82	8,550
1959	Mar. 20, 1959	8.69	3,860
	May 31, 1959	10.57	5,520

5-4710. Skunk River below Squaw Creek near Ames, Iowa--(Continued)

Peak stages and discharges

Water year	Date	Gage height (feet)	Discharge (cfs)
1960	Mar. 30, 1960	13.20	9,260
	May 7, 1960	9.47	4,600
1961	Feb. 23, 1961	7.98	3,450
	Mar. 15, 1961	8.05	3,380
	June 7, 1961	7.11	2,680
	Aug. 1, 1961	7.97	3,310
	Sept. 30, 1961	8.27	3,520
1962	Mar. 26, 1962	10.70	5,900
	May 8, 1962	10.47	5,140
	May 29, 1962	9.32	4,280
	June 9, 1962	7.32	2,820
	July 15, 1962	11.87	6,330
	July 20, 1962	7.96	3,310
1963	Apr. 29, 1963	8.56	3,520
	May 12, 1963	10.20	4,780
1964	May 8, 1964	8.84	3,600
	June 23, 1964	9.80	4,440
1965	Mar. 1, 1965	11.87	6,410
	Apr. 1, 1965	11.82	6,350
	Apr. 6, 1965	12.59	7,340
	June 5, or 6, 1965		[a] 3,800
	Sept. 20, 1965	8.36	3,720

a About

1966	June 12, 1966	11.45	6,380
1967	June 8, 1967	9.90	4,960
1968	June 25, 1968	12.07	7,310
1969	March 20, 1969	12.15	6,620

N=17

```
Enter name, drainage area and gage number of watershed.
Skunk River      556 sq. mi.      Gage No. 5-4710
Any changes in identification input?  Enter yes or no.
no
Enter number of years of record.
N
17
Any changes in value of N?  Enter yes or no.
no
Enter values of maximum annual discharge.
Y(1)
1620
Y(2)
8700
Y(3)
2680
Y(4)
638
Y(5)
6360
Y(6)
8550
Y(7)
5520
Y(8)
9260
Y(9)
3520
Y(10)
6330
Y(11)
4780
Y(12)
4440
Y(13)
7340
Y(14)
6380
Y(15)
4960
Y(16)
7310
Y(17)
6620
Any changes in discharge input?  Enter yes or no.
no

M=  3.679          S=  0.298          g=   -1.908

Enter K value corresponding to recurrance
interval and value of g.
ayk
1.020
Any changes in value of K?  Enter yes or no.
no
Enter recurrance interval in years.
```

```
RI
50
Any changes in value of recurrance interval?  Enter yes or no.
no


Skunk River      556 sq. mi.      Gage No. 5-4710


Q=   9625 cfs

Recurrance Interval=      50 years


Do you want Q for a different recurrance interval?
Enter yes or no.
no
Do you want to determine Q for another watershed?
Enter yes or no.
no


END OF JOB.
```

Appendix E

Skunk River

N = 45

5-4700. Skunk River near Ames, Iowa

Location.--Lat 42 deg.04 min.05 sec., long 93 deg.37 min.05 sec., in NW¼SW¼ sec.23, T.84 N., R.24 W., on left bank 2.5 miles north of Ames, 3.5 miles downstream from Keigley Branch, 5.2 miles upstream from Squaw Creek, and at mile 228.1.

Drainage area.--315 sq mi.

Gage.--Nonrecording prior to Aug. 25, 1921; recording thereafter. Datum of gage is 893.61 ft above mean sea level, datum of 1929. (Iowa Highway Commission bench mark).

Stage-discharge relation.--Defined by current-meter measurements.

Remarks.--Base for partial-duration series, 1,500 cfs.

Peak stages and discharges

Water year	Date	Gage height (feet)	Discharge (cfs)
1921	Sept.17, 1921	9.2	3,540
1922	Feb. 23, 1922	9.0	3,370
1923	Mar. 28, 1923	6.22	1,670 ←
	Sept.28, 1923	6.0	1,530
1924	Mar. 30, 1924	6.3	1,680
	June 28, 1924	8.21	3,010 ←
	Aug. 9, 1924	6.0	1,500
1925	Aug. 7, 1925	5.0	905
1926	Sept. 8, 1926	6.5	1,900
	Sept.19, 1926	8.26	3,120 ←
1927	Feb. 5, 1927	7.4	2,460
1931	Nov. 24, 1930	11.2	5,230
1933	Apr. 1, 1933	6.47	1,990
1934	Jan. 22, 1934	[b] 5.39	[a] 600
1935	Feb. 15, 1935	[b] 7.8	2,490
	Mar. 5, 1935	9.0	3,490 ←
	June 19, 1935	6.5	1,900
	June 25, 1935	8.4	2,960
	July 24, 1935	7.0	2,190

5-4700. Skunk River near Ames, Iowa--(Continued)

Peak stages and discharges

Water year	Date	Gage height (feet)	Discharge (cfs)
1936	Mar. 10, 1936	7.7	2,580
1937	Mar. 6, 1937	[a]8.4	3,000
1938	May 4, 1938	8.3	2,890
	May 17, 1938	6.5	1,880
	June 29, 1938	5.8	1,540
1939	Mar. 14, 1939	[b]10.5	3,230
1940	Aug. 13, 1940	7.3	2,320
1941	Sept. 8, 1941	8.6	3,050
~~1942~~	Nov. 1, 1941	5.9	~~1,630~~
1942	Sept. 14, 1942	8.1	2,530
1943	June 16, 1943	6.5	1,910
	July 31, 1943	10.3	4,500
1944	May 20, 1944	13.9	8,060
	June 12, 1944	8.0	2,840
1945	Mar. 16, 1945	6.3	1,800
	May 22, 1945	7.7	2,620
	June 2, 1945	9.7	4,010
1946	Feb. 5, 1946	7.1	2,270
	Mar. 6, 1946	5.9	1,600
	Mar. 13, 1946	5.9	1,610
1947	June 1, 1947	8.63	3,740
	June 4, 1947	8.18	3,400
	June 13, 1947	11.95	6,550
	June 23, 1947	10.80	5,400
	June 30, 1947	6.4	2,200
1948	Feb. 28, 1948	5.8	1,630
	Mar. 19, 1948	7.35	2,620
	Mar. 27, 1948	7.3	2,600
1949	Mar. 4, 1949	[b]10.52	[a]3,000

5-4700. Skunk River near Ames, Iowa--(Continued)

Peak stages and discharges

Water year	Date	Gage height (feet)	Discharge (cfs)
1950	Mar. 7, 1950	8.86	3,820
	May 5, 1950	6.0	1,810
	May 9, 1950	7.0	2,410
	June 9, 1950	5.8	1,690
	June 18, 1950	6.6	2,170
1951	Feb. 26, 1951	5.75	1,690
	Mar. 29, 1951	10.90	5,320
	May 2, 1951	6.75	2,290
	June 2, 1951	10.35	4,920
	June 20, 1951	6.25	1,930
	July 4, 1951	7.07	2,470
1952	July 9, 1952	5.73	1,630
1953	May 1, 1953	4.71	980
1954	June 1, 1954	7.84	3,180
	June 10, 1954	13.66	8,630
	June 16, 1954	6.37	2,110
	June 22, 1954	5.88	1,770
	Aug. 27, 1954	8.27	3,520
1955	Oct. 15, 1954	5.22	1,340
1956	Sept. 4, 1956	3.49	376
1957	June 16, 1957	8.28	3,540
	July 4, 1957	6.52	2,200
1958	July 2, 1958	6.55	2,270
	July 4, 1958	7.85	3,150
	July 11, 1958	5.78	1,720
1959	Mar. 20, 1959	5.60	1,590
	May 31, 1959	5.83	1,720
1960	Mar. 30, 1960	10.33	6,210
	May 7, 1960	5.59	1,590
1961	Feb. 23, 1961	5.71	1,990
	Mar. 15, 1961	5.51	1,770
	Aug. 2, 1961	5.51	1,770

5-4700. Skunk River near Ames, Iowa--(Continued)

Peak stages and discharges

Water year	Date	Gage height (feet)	Discharge (cfs)
1962	Mar. 26, 1962	6.91	3,010
	May 7, 1962	7.53	3,510
	May 30, 1962	5.72	1,970
	July 14, 1962	9.02	4,300
	July 22, 1962	5.72	1,970
1963	Apr. 30, 1963	5.65	1,820
1964	May 8, 1964	5.31	1,570
	June 22, 1964	5.91	2,170
1965	Mar. 1, 1965		[a]1,800
	Apr. 2, 1965		[a]3,300
	Apr. 6, 1965	9.43	5,260
	May 27, 1965	6.55	2,730
	June 6, 1965	5.75	2,020
	Sept.20, 1965	6.92	3,030
	Sept.28, 1965	5.34	1,610
1966	Feb. 9, 1966	6.92	[b]2,900
1967	June 8, 1967	6.63	2,790
1968	June 25, 1968	8.74	4,890
1969	July 10, 1969	8.49	4,380

a About
b Affected by ice

N = 45

```
Enter name, drainage area and gage number of watershed.
Skunk River      315 sq. mi.      Gage No. 5-4700
Any changes in identification input?  Enter yes or no.
no
Enter number of years of record.
N
45
Any changes in value of N?  Enter yes or no.
no
Enter values of maximum annual discharge.
Y(1)
3540
Y(2)
3370
Y(3)
1670
Y(4)
3010
Y(5)
905
Y(6)
3120
Y(7)
2460
Y(8)
5230
Y(9)
1990
Y(10)
600
Y(11)
3490
Y(12)
2580
Y(13)
3000
Y(14)
2890
Y(15)
3230
Y(16)
2320
Y(17)
3050
Y(18)
2530
Y(19)
4500
Y(20)
8060
Y(21)
4010
Y(22)
2270
Y(23)
6550
Y(24)
2620
```

Y(25)
3000
Y(26)
3820
Y(27)
5320
Y(28)
1630
Y(29)
980
Y(30)
8630
Y(31)
1340
Y(32)
376
Y(33)
3540
Y(34)
3150
Y(35)
1720
Y(36)
6210
Y(37)
1990
Y(38)
4300
Y(39)
1820
Y(40)
2170
Y(41)
5260
Y(42)
2900
Y(43)
2790
Y(44)
4890
Y(45)
4380
Any changes in discharge input? Enter yes or no.
no

M= 3.445 S= 0.271 g= -0.985

Enter K value corresponding to recurrance
interval and value of g.
ayk
1.513
Any changes in value of K? Enter yes or no.
no
Enter recurrance interval in years.
RI
50
Any changes in value of recurrance interval? Enter yes or no.
no

Skunk River 315 sq. mi. Gage No. 5-4700

Q= 7146 cfs

```
Recurrance Interval=      50 years

Do you want Q for a different recurrance interval?
Enter yes or no.
no
Do you want to determine Q for another watershed?
Enter yes or no.
yes
```

Appendix F

Big Sioux River

6-4855. Big Sioux River at Akron, Iowa

Location.--Lat 42 deg. 49 min. 40 sec., long 96 deg. 33 min. 50 sec., in W½ sec. 31, T.93 N., R.48 W., on left bank 300 ft downstream from county highway bridge in Akron, and 2-3/4 miles upstream from Union Creek.

Drainage area.--9,030 sq mi.

Gage.--Recording. Prior to December 3, 1934, nonrecording. Datum of gage is 1,118.90 ft above mean sea level, datum of 1929.

State-discharge relation.--Defined by current-meter measurements.

Remarks.--Only annual peaks shown.

Peak stages and discharges

Water year	Date	Gage height (feet)	Discharge (cfs)
1926	Sept. 18, 1926	19.4	
1929	Mar. 15, 1929	18.6	20,800
1930	June 6, 1930	9.9	3,740
1931	Aug. 9, 1931	5.6	1,390
1932	Mar. 1, 1932	18.0	16,900
1933	Sept. 5, 1933	17.8	14,200
1934	June 8, 1934	16.1	10,600
1935	Mar. 10, 1935		a 3,000
1936	Mar. 12, 1936	18.6	18,000
1937	May 26, 1937	13.1	5,760
1938	July 4, 1938	17.5	12,700
1939	Mar. 17, 1939		a 6,300
1940	Apr. 2, 1940	17.3	11,700
1941	Mar. 25, 1941	13.5	5,820
1942	June 4, 1942	19.2	21,400
1943	June 18, 1943	17.4	12,000

6-4855. Big Sioux River at Akron, Iowa--continued

Peak stages and discharges

	Water year	Date	Gage height (feet)	Discharge (cfs)
	1944	Feb. 29, 1944	18.2	15,900
	1945	Mar. 14, 1945	17.4	12,300
	1946	Mar. 5, 1946	15.3	8,970
	1947	June 15, 1947	16.8	10,500
	1948	Mar. 21, 1948	18.5	10,800
	1949	Mar. 8, 1949	17.1	11,400
	1950	June 18, 1950	13.4	5,450
	1951	Apr. 6, 1951	19.66	28,800
N=24	1952	Apr. 1, 1952	19.75	33,000
	1953	June 8, 1953	19.33	21,800
	1954	June 22, 1954	19.95	21,700
	1955	Mar. 11, 1955	12.25	4,940
	1956	June 17, 1956	8.13	1,840
	1957	June 21, 1957	19.57	19,400
	1958	Apr. 8, 1958	5.98	1,120
	1959	June 3, 1959	16.93	8,430
N=32	1960	Apr. 1, 1960	21.56	49,500
	1961	Mar. 5, 1961	16.18	9,050
N=34	1962	Mar. 31, 1962	22.08	54,300
	1963	Aug. 7, 1963	7.59	1,650
	1964	Apr. 4, 1964	9.30	2,540
	1965	April 8, 1965	20.85	21,000
	1966	Feb. 12, 1966	19.85	16,500
	1967	March 5, 1967	14.79	5,300
N=40	1968	June 27, 1968	4.80	635
41	1969	April 9, 1969	22.99	80,800

```
login(bridge,bridge01)
GOOD AFTERNOON; USER 03; TIME  12:56:34  9/23/70;
load (1pear3)
xeq
Enter name, drainage area and gage number of watershed.
Little Sioux River       9,030 sq. mi.       Gage No. 6-4855
Any changes in identification input?  Enter yes or no.
yes
Enter name, drainage area and gage number of watershed.
Little Sioux River       9,030 sq. mi.       Gage No. 6-4855
Any changes in identification input?  Enter yes or no.
yes
Enter name, drainage area and gage number of watershed.
Big Sioux River at Akron       9,030 sq. mi.       Gage No. 6-4855
Any changes in identification input?  Enter yes or no.
no
Enter number of years of record.
N
24
Any changes in value of N?  Enter yes or no.
no
Enter values of maximum annual discharge.
Y(1)
20800
Y(2)
3740
Y(3)
1390
Y(4)
16900
Y(5)
14200
Y(6)
10600
Y(7)
3000
Y(8)
18000
Y(9)
5760
Y(10)
12700
Y(11)
6300
Y(12)
11700
Y(13)
5820
Y(14)
21400
Y(15)
12000
Y(16)
15900
Y(17)
12300
```

```
8970
Y(19)
10500
Y(20)
10800
Y(21)
11400
Y(22)
5450
Y(23)
28800
Y(24)
33000
Any changes in discharge input?  Enter yes or no.
no

M=  4.006          S=  0.318          g=   -0.886

Enter K value corresponding to recurrance
interval and value of g.
ayk
1.557
Any changes in value of K?  Enter yes or no.
no
Enter recurrance interval in years.
RI
50
Any changes in value of recurrance interval?  Enter yes or no.
no

Big Sioux River at Akron      9,030 sq. mi.      Gage No. 6-4855

Q=  31674 cfs

Recurrance Interval=     50 years

Do you want Q for a different recurrance interval?
Enter yes or no.
yes

Enter K value corresponding to recurrance
interval and value of g.
ayk
1.670
Any changes in value of K?  Enter yes or no.
no
Enter recurrance interval in years.
RI
100
Any changes in value of recurrance interval?  Enter yes or no.
no

Big Sioux River at Akron      9,030 sq. mi.      Gage No. 6-4855

Q=  34403 cfs

Recurrance Interval=    100 years
```

```
Do you want Q for a different recurrance interval?
Enter yes or no.
yes

Enter K value corresponding to recurrance
interval and value of g.
ayk
1.761
Any changes in value of K?  Enter yes or no.
no
Enter recurrance interval in years.
RI
200
Any changes in value of recurrance interval?  Enter yes or no.
no

Big Sioux River at Akron      9,030 sq. mi.      Gage No. 6-4855

Q=  36770 cfs

Recurrance Interval=    200 years

Do you want Q for a different recurrance interval?
Enter yes or no.
no
Do you want to determine Q for another watershed?
Enter yes or no.
yes
Enter name, drainage area and gage number of watershed.
_
```

Big Sioux River at Akron 9,030 sq. mi. Gage No 604855
Any changes in identification input? Enter yes or no.
yes
Enter name, drainage area and gage number of watershed.
Big Sioux River at Akron 9,030 sq. mi. Gage No. 6-4855
Any changes in identification input? Enter yes or no.
no
Enter number of years of record.
N
32
Any changes in value of N? Enter yes or no.
no
Enter values of maximum annual discharge.
Y(1)
20800
Y(2)
3740
Y(3)
1390
Y(4)
16900
Y(5)
14200
Y(6)
10600
Y(7)
3000
Y(8)
18000
Y(9)
5760
Y(10)
12700
Y(11)
6300
Y(12)
11700
Y(13)
5820
Y(14)
21400
Y(15)
12000
Y(16)
15900
Y(17)
12300
Y(18)
8970
Y(19)
10500
Y(20)
10800
Y(21)
11400
Y(22)
5450
Y(23)
28800

33000
Y(25)
21800
Y(26)
21700
Y(27)
4940
Y(28)
1840
Y(29)
19400
Y(30)
1120
Y(31)
8430
Y(32)
49500
Any changes in discharge input? Enter yes or no.
no

M= 3.992 S= 0.388 g= -0.764

Enter K value corresponding to recurrance
interval and value of g.
ayk
1.627
Any changes in value of K? Enter yes or no.
no
Enter recurrance interval in years.
RI
50
Any changes in value of recurrance interval? Enter yes or no.
no

Big Sioux River at Akron 9,030 sq. mi. Gage No. 6-4855

Q= 41916 cfs

Recurrance Interval= 50 years

Do you want Q for a different recurrance interval?
Enter yes or no.
yes

Enter K value corresponding to recurrance
interval and value of g.
ayk
1.759
Any changes in value of K? Enter yes or no.
no
Enter recurrance interval in years.
RI
100
Any changes in value of recurrance interval? Enter yes or no.
no

Big Sioux River at Akron 9,030 sq. mi. Gage No. 6-4855

Q= 47156 cfs

Recurrance Interval= 100 years

Do you want Q for a different recurrance interval?
Enter yes or no.
yes

Enter K value corresponding to recurrance
interval and value of g.
ayk
1.869
Any changes in value of K? Enter yes or no.
no
Enter recurrance interval in years.
RI
200
Any changes in value of recurrance interval? Enter yes or no.
no

Big Sioux River at Akron 9,030 sq. mi. Gage No. 6-4855

Q= 52019 cfs

Recurrance Interval= 200 years

Do you want Q for a different recurrance interval?
Enter yes or no.
no
Do you want to determine Q for another watershed?
Enter yes or no.
yes

Enter name, drainage area and gage number of watershed.
Big Sioux River at Akron 9,030 sq. mi. Gage No. 6-4855
Any changes in identification input? Enter yes or no.
no
Enter number of years of record.
N
34
Any changes in value of N? Enter yes or no.
no
Enter values of maximum annual discharge.
Y(1)
20800
Y(2)
3740
Y(3)
1390
Y(4)
16900
Y(5)
14200
Y(6)
10600
Y(7)
3000
Y(8)
18000
Y(9)
5760
Y(10)
12700
Y(11)
6300
Y(12)
11700
Y(13)
5820
Y(14)
21400
Y(15)
12000
Y(16)
15900
Y(17)
12300
Y(18)
8970
Y(19)
10500
Y(20)
10800
Y(21)
11400
Y(22)
5450
Y(23)
28800
Y(24)
33000

```
Y(25)
21800
Y(26)
21700
Y(27)
4940
Y(28)
1840
Y(29)
19400
Y(30)
1120
Y(31)
8430
Y(32)
49500
Y(33)
9050
Y(34)
54300
Any changes in discharge input?  Enter yes or no.
no

M=  4.013            S=  0.397            g=   -0.622

Enter K value corresponding to recurrance
interval and value of g.
ayk
1.707
Any changes in value of K?  Enter yes or no.
no
Enter recurrance interval in years.
RI
50
Any changes in value of recurrance interval?  Enter yes or no.
no

Big Sioux River at Akron     9,030 sq. mi.     Gage No. 6-4855

Q=  48967 cfs

Recurrance Interval=     50 years

Do you want Q for a different recurrance interval?
Enter yes or no.
yes

Enter K value corresponding to recurrance
interval and value of g.
ayk
1.864
Any changes in value of K?  Enter yes or no.
no
Enter recurrance interval in years.
RI
100
Any changes in value of recurrance interval?  Enter yes or no.
no
```

```
Q=  56519 cfs

Recurrance Interval=    100 years


Do you want Q for a different recurrance interval?
Enter yes or no.
yes


Enter K value corresponding to recurrance
interval and value of g.
ayk
1.996
Any changes in value of K?  Enter yes or no.
no
Enter recurrance interval in years.
RI
200
Any changes in value of recurrance interval?  Enter yes or no.
no


Big Sioux River at Akron     9,030 sq. mi.     Gage No. 6-4855


Q=  63762 cfs

Recurrance Interval=    200 years


Do you want Q for a different recurrance interval?
Enter yes or no.
no
Do you want to determine Q for another watershed?
Enter yes or no.
yes
```

Enter name, drainage area and gage number of watershed.
Big Sioux River at Akron 9,030 sq. mi. Gage No. 6-4855
Any changes in identification input? Enter yes or no.
no
Enter number of years of record.
N
40
Any changes in value of N? Enter yes or no.
no
Enter values of maximum annual discharge.
Y(1)
20800
Y(2)
3740
Y(3)
1390
Y(4)
16900
Y(5)
14200
Y(6)
10600
Y(7)
3000
Y(8)
18000
Y(9)
5760
Y(10)
12700
Y(11)
6300
Y(12)
11700
Y(13)
5820
Y(14)
21400
Y(15)
12000
Y(16)
15900
Y(17)
12300
Y(18)
8970
Y(19)
10500
Y(20)
10800
Y(21)
11400
Y(22)
5450
Y(23)
28800
Y(24)

33000
Y(25)
21800
Y(26)
21700
Y(27)
4940
Y(28)
1840
Y(29)
19400
Y(30)
1120
Y(31)
8430
Y(32)
49500
Y(33)
9050
Y(34)
54300
Y(35)
1650
Y(36)
2540
Y(37)
21000
Y(38)
16500
Y(39)
5300
Y(40)
635
Any changes in discharge input? Enter yes or no.
yes
Which Q?
fix
40
Y(40)
635
Any changes in discharge input? Enter yes or no.
no

M= 3.953 S= 0.445 g= -0.701

Enter K value corresponding to recurrance
interval and value of g.
ayk
1.662
Any changes in value of K? Enter yes or no.
no
Enter recurrance interval in years.
RI
50
Any changes in value of recurrance interval? Enter yes or no.
no

Big Sioux River at Akron 9,030 sq. mi. Gage No. 6-4855

Q= 49354 cfs

Recurrance Interval= 50 years

Do you want Q for a different recurrance interval?
Enter yes or no.
yes

Enter K value corresponding to recurrance
interval and value of g.
ayk
1.805
Any changes in value of K? Enter yes or no.
no
Enter recurrance interval in years.
RI
100
Any changes in value of recurrance interval? Enter yes or no.
no

Big Sioux River at Akron 9,030 sq. mi. Gage No. 6-4855

Q= 57150 cfs

Recurrance Interval= 100 years

Do you want Q for a different recurrance interval?
Enter yes or no.
yes

Enter K value corresponding to recurrance
interval and value of g.
ayk
1.925
Any changes in value of K? Enter yes or no.
no
Enter recurrance interval in years.
RI
200
Any changes in value of recurrance interval? Enter yes or no.
no

Big Sioux River at Akron 9,030 sq. mi. Gage No. 6-4855

Q= 64636 cfs

Recurrance Interval= 200 years

Do you want Q for a different recurrance interval?
Enter yes or no.
no
Do you want to determine Q for another watershed?
Enter yes or no.
yes
Enter name, drainage area and gage number of watershed.
_

Big Sioux River at Akron 9,030 sq. mi. Gage No. 6-4855
Any changes in identification input? Enter yes or no.
no
Enter number of years of record.
N
41
Any changes in value of N? Enter yes or no.
no
Enter values of maximum annual discharge.
Y(1)
20800
Y(2)
3740
Y(3)
1390
Y(4)
16900
Y(5)
14200
Y(6)
10600
Y(7)
3000
Y(8)
18000
Y(9)
5760
Y(10)
12700
Y(11)
6300
Y(12)
11700
Y(13)
5820
Y(14)
21400
Y(15)
12000
Y(16)
15900
Y(17)
12300
Y(18)
8970
Y(19)
10500
Y(20)
10800
Y(21)
11400
Y(22)
5450
Y(23)
28800
Y(24)
33000
Y(25)
21800
Y(26)
21700

```
Y(27)
4940
Y(28)
1840
Y(29)
19400
Y(30)
1120
Y(31)
8430
Y(32)
49500
Y(33)
9050
Y(34)
54300
Y(35)
1650
Y(36)
2540
Y(37)
21000
Y(38)
16500
Y(39)
5300
Y(40)
635
Y(41)
80800
Any changes in discharge input?  Enter yes or no.
no

M=  3.976          S=  0.464          g=   -0.533

Enter K value corresponding to recurrance
interval and value of g.
ayk
1.758
Any changes in value of K?  Enter yes or no.
no
Enter recurrance interval in years.
RI
50
Any changes in value of recurrance interval?  Enter yes or no.
no

Big Sioux River at Akron     9,030 sq. mi.     Gage No. 6-4855

Q=  62045 cfs

Recurrance Interval=     50 years

Do you want Q for a different recurrance interval?
Enter yes or no.
yes

Enter K value corresponding to recurrance
interval and value of g.
```

```
1.930
Any changes in value of K?  Enter yes or no.
no
Enter recurrance interval in years.
RI
100
Any changes in value of recurrance interval?  Enter yes or no.
no


Big Sioux River at Akron     9,030 sq. mi.     Gage No. 6-4855


Q=  74573 cfs

Recurrance Interval=    100 years


Do you want Q for a different recurrance interval?
Enter yes or no.
yes


Enter K value corresponding to recurrance
interval and value of g.
ayk
2.078
Any changes in value of K?  Enter yes or no.
no
Enter recurrance interval in years.
RI
200
Any changes in value of recurrance interval?  Enter yes or no.
no


Big Sioux River at Akron     9,030 sq. mi.     Gage No. 6-4855


Q=  87361 cfs

Recurrance Interval=    200 years


Do you want Q for a different recurrance interval?
Enter yes or no.
no
Do you want to determine Q for another watershed?
Enter yes or no.
no


END OF JOB.
logout
TIME 13:48:10; TIME USED: CPU 00:00:25; TERM 00:51:36; PAGE 01:42:21;
```

Appendix G

Brewer Creek

5-4486. East Branch Iowa River above Hayfield, Iowa

Location.--Near south quarter corner sec.4, T.96 N., R.24 W., at bridge, 1.5 miles southeast of Hayfield, Hancock County.

Drainage area.--2.23 sq mi.

Gage.--Crest-stage gage. Datum is arbitrary.

Stage-discharge relation.--Defined by current-meter measurements below and extended above 150 cfs by logarithmic plotting.

Remarks.--Only annual peaks are shown.

Peak stages and discharges

Water year	Date	Gage height (feet)	Discharge (cfs)
1953	June 4, 1953	3.02	24.2
1954	June 19, 1954	7.15	209
1955	July 6, 1955	2.25	10.6
1956	July 2, 1956	2.05	8.0
1957		c	2.0
1958	June 4, 1958	2.65	17.0
1959	May 21, 1959	6.77	186
1960	Mar. 29, 1960	4.67	75
1961	Mar. 26, 1961	70.3	196
1962	Aug. 31, 1962	3.34	31.1
1963	May 13, 1963	4.25	59
1964	Sept. 7, 1964	4.25	58
1965	Apr. 6, 1965	7.31	250

c Peak stage did not reach bottom of gage

1966 22

1967 40

1968 26

1969 200

```
login(bridge,bridge01)
GOOD AFTERNOON; USER 03; TIME  12:50:50  2/08/71;
        load (lpear3)
        xeq
        Enter name, drainage area and gage number of watershed.
        East Branch Iowa River   2.23 sq. mi.   Gage No. 5-4486
        Any changes in identification input?  Enter yes or no.
        no
        Enter number of years of record.
        N
        17
        Any changes in value of N?  Enter yes or no.
        no
        Enter values of maximum annual discharge.
        Y(1)
        24
        Y(2)
        209
        Y(3)
        11
        Y(4)
        8
        Y(5)
        2
        Y(6)
        17
        Y(7)
        186
        Y(8)
        75
        Y(9)
        196
        Y(10)
        31
        Y(11)
        59
        Y(12)
        58
        Y(13)
        250
        Y(14)
        22
        Y(15)
        40
        Y(16)
        26
        Y(17)
        200
        Any changes in discharge input?  Enter yes or no.
        no

        M=  1.629          S=  0.585          g=   -0.490

        Enter K value corresponding to recurrance
        interval and value of g.
        ayk
        1.783
```

Any changes in value of K? Enter yes or no.
no
Enter recurrance interval in years.
RI
50
Any changes in value of recurrance interval? Enter yes or no.
no

East Branch Iowa River 2.23 sq. mi. Gage No. 5-4486

Q= 470 cfs

Recurrance Interval= 50 years

Do you want Q for a different recurrance interval?
Enter yes or no.
yes

Enter K value corresponding to recurrance
interval and value of g.
ayk
1.962
Any changes in value of K? Enter yes or no.
no
Enter recurrance interval in years.
RI
100
Any changes in value of recurrance interval? Enter yes or no.
no

East Branch Iowa River 2.23 sq. mi. Gage No. 5-4486

Q= 598 cfs

Recurrance Interval= 100 years

Do you want Q for a different recurrance interval?
Enter yes or no.
no
Do you want to determine Q for another watershed?
Enter yes or no.
yes

5-4487. East Branch Iowa River near Hayfield, Iowa

Location.--NW¼ sec.35, T.97 N., R.24 W., at bridge on County Road "B", 2 miles east of Hayfield, Hancock County.

Drainage area.--7.94 sq mi.

Gage.--Crest-stage gage. Datum is arbitrary.

State-discharge relation.--Defined by current-meter measurements.

Remarks.--Only annual peaks are shown.

Peak stages and discharges

Water year	Date	Gage height (feet)	Discharge (cfs)
1952	Mar. 29, 1952	6.45	122
1953	Aug. 4, 1953	7.26	172
1954	June 18, 1954	13.01	457
1955	July 6, 1955	6.50	51
1956	July 31, 1956	6.80	60
1957	June 23, 1957	7.11	69
1958	June 4, 1958	9.52	187
1959	May 21, 1959	11.89	357
1960	Mar. 29, 1960	6.33	34
1961	Mar. 26, 1961	12.16	260
1962	July 5, 1962	9.17	166
1963	July 19, 1963	8.90	173
1964	Sept. 7, 1964	10.73	220
1965	Apr. 6, 1965	[b]13.67	370

b Affected by ice

1966	50
1967	56
1968	124
1969	350

Enter name, drainage area and gage number of watershed.
East Branch Iowa River 7.94 sq. mi. Gage No. 5-4487
Any changes in identification input? Enter yes or no.
no
Enter number of years of record.
N
18
Any changes in value of N? Enter yes or no.
no
Enter values of maximum annual discharge.
Y(1)
122
Y(2)
172
Y(3)
457
Y(4)
51
Y(5)
60
Y(6)
69
Y(7)
187
Y(8)
357
Y(9)
34
Y(10)
260
Y(11)
166
Y(12)
173
Y(13)
220
Y(14)
370
Y(15)
50
Y(16)
56
Y(17)
124
Y(18)
350
Any changes in discharge input? Enter yes or no.
no

M= 2.141 S= 0.350 g= -0.220

Enter K value corresponding to recurrance
interval and value of g.
ayk
1.93[illegible]
An[illegible]anges in value [illegible] Enter yes or no.
[illegible]
[illegible]ecurrance int[illegible] in years.

```
RI
50
Any changes in value of recurrance interval?  Enter yes or no.
no


East Branch Iowa River   7.94 sq. mi.   Gage No. 5-4487


Q=    656 cfs

Recurrance Interval=     50 years


Do you want Q for a different recurrance interval?
Enter yes or no.
yes


Enter K value corresponding to recurrance
interval and value of g.
ayk
2.163
Any changes in value of K?  Enter yes or no.
no
Enter recurrance interval in years.
RI
100
Any changes in value of recurrance interval?  Enter yes or no.
no


East Branch Iowa River   7.94 sq. mi.   Gage No. 5-4487


Q=    789 cfs

Recurrance Interval=    100 years


Do you want Q for a different recurrance interval?
Enter yes or no.
no
Do you want to determine Q for another watershed?
Enter yes or no.
yes
```

5-4830. East Fork Hardin Creek near Churdan, Iowa 18

Location.--Lat 42 deg.06 min.25 sec., long 94 deg.22 min.10 sec., in SE¼SW¼ sec.5, T.84 N., R.30 W., on left bank 35 ft upstream from highway bridge, 4.4 miles upstream from mouth, and 6.5 miles southeast of Churdan.

Drainage area.--24.0 sq mi.

Gage.--Recording. Datum of gage is 1,050.90 ft above mean sea level, datum of 1929.

Stage-discharge relation.--Defined by current-meter measurements below 180 cfs and above by logarithmic plotting.

Remarks.--Base for partial-duration series, 200 cfs.

Peak stages and discharges

Water year	Date	Gage height (feet)	Discharge (cfs)
1952	July 14, 1952	4.33	79
1953	June 10, 1953	5.17	105
1954	Aug. 26, 1954	7.73	329
1955	Oct. 13, 1954	6.15	224
1955	July 10, 1955	6.60	252
1956	May 13, 1956	4.42	112
1957	June 14, 1957	6.57	216
	June 16, 1957	8.82	371
1958	July 19, 1958	6.10	186
1959	May 31, 1959	7.36	288
1960	Mar. 29, 1960	b7.63	a300
	Apr. 24, 1960	8.04	350
	May 5, 1960	8.92	413
	May 25, 1960	6.30	231
1961	Feb. 22, 1961	b5.41	a150
1962	Mar. 25, 1962	6.06	231
	July 14, 1962	7.46	315
1963	[illegible]. 29, 1963	7.78	a300

5-4830. East Fork Hardin Creek near Churdan, Iowa

Peak stages and discharges

Water year	Date	Gage height (feet)	Discharge (cfs)
1964	Apr. 13, 1964	5.36	172
1965	Mar. 31, 1965	b 8.28	a 300
	Apr. 5, 1965	6.13	214

a About
b Affected by ice

1966
367
1967
265
1968
77
1969
306

```
Enter name, drainage area and gage number of watershed.
East Fork Hardin Creek    24.0 sq. mi.    Gage No. 5-4830
Any changes in identification input? Enter yes or no.
no
Enter number of years of record.
N
18
Any changes in value of N?  Enter yes or no.
no
Enter values of maximum annual discharge.
Y(1)
79
Y(2)
105
Y(3)
329
Y(4)
252
Y(5)
112
Y(6)
371
Y(7)
186
Y(8)
288
Y(9)
413
Y(10)
150
Y(11)
315
Y(12)
300
Y(13)
172
Y(14)
300
Y(15)
367
Y(16)
265
Y(17)
77
Y(18)
306
Any changes in discharge input?  Enter yes or no.
no


M=  2.335            S=  0.236            g=   -0.817


Enter K value corresponding to recurrance
interval and value of g.
ayk
1.596
Any changes in value of K?  Enter yes or no.
```

no
Enter recurrance interval in years.
RI
50
Any changes in value of recurrance interval? Enter yes or no.
no

East Fork Hardin Creek 24.0 sq. mi. Gage No. 5-4830

Q= 515 cfs

Recurrance Interval= 50 years

Do you want Q for a different recurrance interval?
Enter yes or no.
yes

Enter K value corresponding to recurrance
interval and value of g.
ayk
1.721
Any changes in value of K? Enter yes or no.
no
Enter recurrance interval in years.
RI
100
Any changes in value of recurrance interval? Enter yes or no.
no

East Fork Hardin Creek 24.0 sq. mi. Gage No. 5-4830

Q= 551 cfs

Recurrance Interval= 100 years

Do you want Q for a different recurrance interval?
Enter yes or no.
no
Do you want to determine Q for another watershed?
Enter yes or no.
yes

5-4826. Hardin Creek at Farnhamville, Iowa 18

Location.--Near northeast corner sec.14, T.86 N., R.31.W., at bridge on State Highway 175 near west city limits of Farnhamville, Calhoun County.

Drainage area.--43.7 sq mi.

Gage.--Crest-stage gage. Datum is arbitrary.

Stage-discharge relation.--Defined by current-meter measurements.

Remarks.--Only annual peaks are shown.

Peak stages and discharges

Water year	Date	Gage height (feet)	Discharge (cfs)
1952	Mar. 29, 1952	8.09	318
1953	July 14, 1953	8.44	429
1954	Aug. 26, 1954	10.48	2,000
1955	Mar. 11, 1955	8.76	557
1956	Mar. 21, 1956	6.78	118
1957	June 16, 1957	7.90	270
1958	June 7, 1958	7.69	225
1959	June 1, 1959	9.06	700
1960	Mar. 29, 1960	9.75	840
1961	Sept. 30, 1961	7.91	272
1962	July 14, 1962	9.20	812
1963	May 13, 1963	9.55	995
1964	Apr. 13, 1964	8.54	466
1965	May 26, 1965	9.78	1,110
1966			277
1967			854
1968			570
1969			1960

```
Enter name, drainage area and gage number of watershed.
Hardin Creek    43.7 sq. mi.    Gage No. 5-4826
Any changes in identification input?  Enter yes or no.
no
Enter number of years of record.
N
18
Any changes in value of N?  Enter yes or no.
no
Enter values of maximum annual discharge.
Y(1)
318
Y(2)
429
Y(3)
2000
Y(4)
557
Y(5)
118
Y(6)
270
Y(7)
225
Y(8)
700
Y(9)
840
Y(10)
272
Y(11)
812
Y(12)
995
Y(13)
466
Y(14)
1110
Y(15)
277
Y(16)
854
Y(17)
570
Y(18)
1960
Any changes in discharge input?  Enter yes or no.
no

M=  2.738          S=  0.329          g=  -0.065

Enter K value corresponding to recurrance
interval and value of g.
ayk
2.019
Any changes in value of K?  Enter yes or no.
no
```

```
Enter recurrance interval in years.
RI
50
Any changes in value of recurrance interval?  Enter yes or no.
no


Hardin Creek   43.7 sq. mi.   Gage No. 5-4826


Q=   2522 cfs

Recurrance Interval=     50 years


Do you want Q for a different recurrance interval?
Enter yes or no.
yes


Enter K value corresponding to recurrance
interval and value of g.
ayk
2.278
Any changes in value of K?  Enter yes or no.
no
Enter recurrance interval in years.
RI
100
Any changes in value of recurrance interval?  Enter yes or no.
no


Hardin Creek   43.7 sq. mi.   Gage No. 5-4826


Q=   3068 cfs

Recurrance Interval=    100 years


Do you want Q for a different recurrance interval?
Enter yes or no.
no
Do you want to determine Q for another watershed?
Enter yes or no.
no


END OF JOB.
_


logout.
TIME 13:13:43; TIME USED: CPU 00:00:10; TERM 00:22:53; PAGE 00:44:5
```

5-4821.7 Big Cedar Creek near Varina, Iowa

Location.--Lat. 42 deg. 41 min. 21 sec., long 94 deg. 47 min. 55 sec., in NE¼NE¼ sec. 24, T.91 N., R.34W., on left bank 5 ft. downstream from county highway bridge, 3.1 miles upstream from Drainage ditch 74, and 5.5 miles northeast of Varina.

Drainage area.--80.0 sq. mi.

Gage.--Recording. Datum of gage is 1,225.12 ft above mean sea level, datum of 1929.

Stage-discharge relation.--Defined by current-meter measurements.

Remarks.--Base for partial-duration series, 400 cfs.

Peak stages and discharges

Water Year	Date	Gage height (feet)	Discharge (cfs)
1960	Mar. 27, 1960	11.42	1,020
	June 16, 1960	8.27	466
1961	Mar. 25, 1961	11.88	1,460
1962	Mar. 31, 1962	c	a 1,000
	July 2, 1962	8.91	665
	July 4, 1962	10,15	960
	July 28, 1962	7.89	452
	Aug. 31, 1962	13.68	2,080
1963	June 2, 1963	6.57	333
1964	May 6, 1964	6.23	291
1965	Apr. 8, 1965	10.17	1,060
	June 6, 1965	7.00	404

a About
c Maximum gage height 14.49 ft. Mar. 29 (ice jam)

1966 257

1967 852

1968 45

1969 992

```
login(bridge,bridge01)
GOOD AFTERNOON; USER 04; TIME  13:25:27  2/08/71;
load (lpear3)
xeq
Enter name, drainage area and gage number of watershed.
Big Cedar Creek   80.0 sq. mi.   Gage No. 5-4821.7
Any changes in identification input?  Enter yes or no.
no
Enter number of years of record.
N
10
Any changes in value of N?  Enter yes or no.
no
Enter values of maximum annual discharge.
Y(1)
1020
Y(2)
1460
Y(3)
2080
Y(4)
333
Y(5)
291
Y(6)
1060
Y(7)
257
Y(8)
852
Y(9)
45
Y(10)
992
Any changes in discharge input?  Enter yes or no.
no

M= 2.749          S= 0.492          g=   -1.251

Enter K value corresponding to recurrance
interval and value of g.
ayk
1.341
Any changes in value of K?  Enter yes or no.
no
Enter recurrance interval in years.
RI
50
Any changes in value of recurrance interval?  Enter yes or no.
no

Big Cedar Creek   80.0 sq. mi.   Gage No. 5-4821.7

Q=   2568 cfs
```

```
Recurrance Interval=     50 years

Do you want Q for a different recurrance interval?
Enter yes or no.
yes

Enter K value corresponding to recurrance
interval and value of g..
ayk
1.413
Any changes in value of K?  Enter yes or no.
no
Enter recurrance interval in years.
RI
100
Any changes in value of recurrance interval?  Enter yes or no.
no

Big Cedar Creek   80.0 sq. mi.   Gage No. 5-4821.7

Q=   2787 cfs

Recurrance Interval=    100 years

Do you want Q for a different recurrance interval?
Enter yes or no.
no
Do you want to determine Q for another watershed?
Enter yes or no.
yes
Enter name, drainage area and gage number of watershed.
_
```

5-4829. Hardin Creek near Farlin, Iowa

Location.--Near north quarter corner sec.14, T.84 N., R.31 W., at bridge, 1.5 miles northeast of Farlin, Greene County.

Drainage area.--101 sq mi.

Gage.--Crest-stage gage. Datum is arbitrary.

Stage-discharge relation.--Defined by current-meter and indirect measurements.

Remarks.--Only annual peaks are shown.

Peak stages and discharges

Water year	Date	Gage height (feet)	Discharge (cfs)
1951	Mar. 29, 1951	12.97	2,270
1952	Mar. 29, 1952	9.11	472
1953	July 14, 1953	7.96	300
1954	Aug. 27, 1954	12.57	1,810
1955	July 10, 1955	10.03	631
1956		c	200
1957	June 17, 1957	10.59	743
1958		c	150
1959	June 1, 1959	11.40	980
1960	Mar. 29, 1960	13.32	1,960
1961	Mar. 27, 1961	8.86	324
1962	Mar. 26, 1962	12.48	2,000
1963	May 13, 1963	10.87	930
1964	Apr. 13, 1964	9.39	615
1965	Sept. 27, 1965	9.79	703

c Peak stage did not reach bottom of gage

1966	474
1967	1,020
1968	250
1969	1,950

```
Hardin Creek   101 sq. mi.   Gage No. 5-4829
Any changes in identification input?  Enter yes or no.
no
Enter number of years of record.
N
19
Any changes in value of N?  Enter yes or no.
no
Enter values of maximum annual discharge.
Y(1)
2270
Y(2)
472
Y(3)
300
Y(4)
1810
Y(5)
631
Y(6)
200
Y(7)
743
Y(8)
150
Y(9)
980
Y(10)
1960
Y(11)
324
Y(12)
2000
Y(13)
930
Y(14)
615
Y(15)
703
Y(16)
474
Y(17)
1020
Y(18)
250
Y(19)
1950
Any changes in discharge input?  Enter yes or no.
no

M=  2.841          S=  0.362          g=   -0.177

Enter K value corresponding to recurrance
interval and value of g.
ayk
1.957
```

no
Enter recurrance interval in years:
RI
50
Any changes in value of recurrance interval? Enter yes or no.
no

Hardin Creek 101 sq. mi. Gage No. 5-4829

Q= 3541 cfs

Recurrance Interval= 50 years

Do you want Q for a different recurrance interval?
Enter yes or no.
yes

Enter K value corresponding to recurrance
interval and value of g.
ayk
2.194
Any changes in value of K? Enter yes or no.
no
Enter recurrance interval in years.
RI
100
Any changes in value of recurrance interval? Enter yes or no.
no

Hardin Creek 101 sq. mi. Gage No. 5-4829

Q= 4314 cfs

Recurrance Interval= 100 years

Do you want Q for a different recurrance interval?
Enter yes or no.
no
Do you want to determine Q for another watershed?
Enter yes or no.
yes

5-4490. East Branch Iowa River near Klemme, Iowa
(Published as "East Fork Iowa River near Klemme". 1948-58)

Location.--Lat 43 deg.00 min.30 sec., long 93 deg.37 min.35 sec., in NE¼NW¼ sec. 36, T.95 N., R.24 W., on left bank 15 feet downstream from highway bridge, 1.0 mile west of Klemme, and 18.2 miles upstream from confluence with West Branch Iowa River, and at mile 345.3 above mouth of Iowa River.

Drainage area.--133 sq mi.

Gage.--Recording. Datum of gage is 1,179.02 ft above mean sea level, datum of 1929. Prior to Oct. 1, 1955, nonrecording gage at site 0.6 mile upstream at datum 1.11 ft higher.

Stage-discharge relation.--Defined by current-meter measurements.

Remarks.--Base for partial-duration in series, 700 cfs.

Peak stages and discharges

Water year	Date	Gage height (feet)	Discharge (cfs)
1944	June 1944	9.96	2,550
1948	Mar. 15, 1948	4.68	[c]238
1949	Mar. 7, 1949	[b]7.3	[a]685
1950	Mar. 26, 1950	[b]7.02	[a]500
1951	Mar. 29, 1951	[b]8.59	1,000
	Apr. 7, 1951	8.61	1,940
	June 26, 1951	10.80	3,440
1952	Mar. 30, 1952	7.60	900
1953	June 8, 1953	5.70	385
1954	June 19, 1954	[d]11.2	5,960
	June 21, 1954	10.74	4,820
1955	July 5, 1955	5.47	348
1956	Mar. 26, 1956	[b]4.91	[a]150
1957	June 23, 1957	4.75	176
1958	June 4, 1958	6.08	355
1959	May 21, 1959	8.25	1,100

East Branch Iowa River near Klemme, Iowa--(Continued)

Peak stages and discharges

Water year	Date	Gage height (feet)	Discharge (cfs)
1959	May 31, 1959	8.12	1,020
1960	Mar. 28, 1960	8.25	1,100
1961	Mar. 26, 1961	9.40	3,250
1962	Mar. 30, 1962	[b]9.05	[a]1,600
	July 5, 1962	8.53	1,420
	July 20, 1962	8.20	1,090
	Aug. 31, 1962	8.84	1,830
1963	July 6, 1963	8.48	950
	July 20, 1963	8.44	922
1964	Sept. 9, 1964	8.09	972
1965	Apr. 8, 1965	9.94	4,090
	June 6, 1965	7.63	728
	Sept. 19, 1965	9.39	2,080
	Sept. 29, 1965	8.48	1,090

a About
b Affected by ice
c Maximum for period April to September 1948
d Maximum stage known

1966	812
1967	532
1968	351
1969	2270

```
Enter name, drainage area and gage number of watershed.
East Branch Iowa River    133 sq. mi.    Gage No. 5-4490
Any changes in identification input?  Enter yes or no.
no
Enter number of years of record.
N
23
Any changes in value of N?  Enter yes or no.
no
Enter values of maximum annual discharge.
Y(1)
238
Y(2)
685
Y(3)
500
Y(4)
3440
Y(5)
900
Y(6)
385
Y(7)
5960
Y(8)
348
Y(9)
150
Y(10)
176
Y(11)
355
Y(12)
1100
Y(13)
1020
Y(14)
1100
Y(15)
3250
Y(16)
1830
Y(17)
950
Y(18)
972
Y(19)
4090
Y(20)
812
Y(21)
582
Y(22)
351
Y(23)
2770
Any changes in discharge input?  Enter yes or no.
no
```

M= 2.930   S= 0.442   g= 0.216

Enter K value corresponding to recurrance
interval and value of g.
ayk
2.167
Any changes in value of K? Enter yes or no.
no
Enter recurrance interval in years.
RI
50
Any changes in value of recurrance interval? Enter yes or no.
no

East Branch Iowa River . 133 sq. mi. Gage No. 5-4490

Q= 7703 cfs

Recurrance Interval= 50 years

Do you want Q for a different recurrance interval?
Enter yes or no.
yes

Enter K value corresponding to recurrance
interval and value of g.
ayk
2.484
Any changes in value of K? Enter yes or no.
no
Enter recurrance interval in years.
RI
100
Any changes in value of recurrance interval? Enter yes or no.
no

East Branch Iowa River 133 sq. mi. Gage No. 5-4490

Q= 10633 cfs

Recurrance Interval= 100 years

Do you want Q for a different recurrance interval?
Enter yes or no.
no
Do you want to determine Q for another watershed?
Enter yes or no.
yes

E

5-4800. Lizard Creek near Clare, Iowa 30
(Published as "North Lizard Creek nr. Clare, 1940-54)

Location.--Lat 42 deg.32 min.40 sec., long 94 deg.20 min.45 sec., in NE¼NE¼ sec.11, T.89 N., R.30 W., on right bank 20 ft downstream from highway bridge, 3 miles south of Clare, 8 miles northwest of Fort Dodge, and 8.9 miles upstream from South Lizard Creek.

Drainage area.--257 sq mi.

Gage.--Nonrecording prior to May 6, 1953; recording thereafter. Datum of gage is 1,079.30 ft above mean sea level, datum of 1929.

Stage-discharge relation.--Defined by current-meter measurements below 4,500 cfs and by logarithmic plotting above 4,500 cfs.

Remarks.--Base for partial-duration series, 1,000 cfs.

Peak stages and discharges

Water year	Date	Gage height (feet)	Discharge (cfs)
1940	Aug. 26, 1940	4.8	374
1941	June 14, 1941	5.1	442
1942	June 5, 1942	6.65	1,060
1943	Feb. 22, 1943	7.4	1,440
1944	May 20, 1944	11.11	4,410
	June 13, 1944	9.2	2,640
1945	Mar. 11, 1945	7.42	1,570
	Apr. 24, 1945	6.7	1,270
	May 22, 1945	6.7	1,310
	June 1, 1945	6.8	1,310
1946	May 25, 1946	9.18	2,750
1947	June 19, 1947	6.1	1,030
	June 23, 1947	16.0	10,000
	June 30, 1947	8.5	2,170
1948	Feb. 28, 1948	7.2	1,370
	Mar. 18, 1948	7.5	1,550
1949	Mar. 5, 1949		1,700

5-4800. Lizard Creek near Clare, Iowa--(Continued)

Peak stages and discharges

Water year	Date	Gage height (feet)	Discharge (cfs)
1950	June 25, 1950	5.7	870
1951	Mar. 28, 1951	10.42	3,620
	May 2, 1951	8.79	2,390
	June 18, 1951	7.1	1,430
1952	Mar. 30, 1952	7.15	1,470
	July 8, 1952	7.11	1,430
1953	June 28, 1953	6.54	1,190
1954	June 11, 1954	11.06	4,150
	June 20, 1954	13.21	6,210
	Aug. 27, 1954	7.29	1,530
1955	Apr. 25, 1955	5.29	660
1956	May 31, 1956	3.74	147
1957	May 21, 1957	4.75	399
1958	June 3, 1958	7.71	1,740
1959	June 1, 1959	7.67	1,740
1960	Mar. 29, 1960	10.01	3,650
1961	Mar. 26, 1961	9.08	2,900
1962	Mar. 28, 1962	9.55	3,360
	July 3, 1962	6.27	1,080
	July 5, 1962	7.22	1,630
	Sept. 1, 1962	11.90	5,400
1963	June 6, 1963	6.15	995
1964	May 24, 1964	5.29	560
1965	Apr. 7, 1965	11.10	4,670
	Sept. 29, 1965	6.19	1,020
1966			870
1967			3350
1968			120
1969			1600

nter name, drainage area and gage number of watershed.
Lizard Creek 257 sq. mi. Gage No. 5-4800
Any changes in identification input? Enter yes or no.
no
Enter number of years of record.
N
30
Any changes in value of N? Enter yes or no.
no
Enter values of maximum annual disclarge.
Y(1)
374
Y(2)
442
Y(3)
1060
Y(4)
1440
Y(5)
4410
Y(6)
1570
Y(7)
2750
Y(8)
10000
Y(9)
1550
Y(10)
1700
Y(11)
870
Y(12)
3620
Y(13)
1470
Y(14)
1190
Y(15)
6210
Y(16)
660
Y(17)
147
Y(18)
399
Y(19)
1740
Y(20)
1740
Y(21)
3650
Y(22)
2900
Y(23)
5400
Y(24)
995
Y(25)
560
Y(26)
4670
Y(27)
870
Y(28)

```
Y(29)
120
Y(30)
1600
Any changes in discharge input?  Enter yes or no.
no

M=  3.154          S=  0.458          g=   -0.492

Enter K value corresponding to recurrance
interval and value of g.
ayk
1.782
Any changes in value of K?  Enter yes or no.
no
Enter recurrance interval in years.
RI
500
Any changes in value of recurrance interval?  Enter yes or no.
yes
Enter recurrance interval in years.
RI
50
Any changes in value of recurrance interval?  Enter yes or no.
no

Lizard Creek   257 sq. mi.   Gage No. 5-4800

Q=   9339 cfs

Recurrance Interval=     50 years

Do you want Q for a different recurrance interval?
Enter yes or no.
yes

Enter K value corresponding to recurrance
interval and value of g.
ayk
1.961
Any changes in value of K?  Enter yes or no.
no
Enter recurrance interval in years.
RI
100
Any changes in value of recurrance interval?  Enter yes or no.
no_

Lizard Creek   257 sq. mi.   Gage No. 5-4800

Q=  11280 cfs

Recurrance Interval=    100 years

Do you want Q for a different recurrance interval?
Enter yes or no.
no
```

5-4810. Boone River near Webster City, Iowa 30

Location.--Lat 42 deg.26 min.00 sec., long 93 deg.48 min.15 sec., in NW¼SE¼ sec.18, T.88 N., R.25 W., on right bank 10 ft upstream from bridge on State Highway 60, 2 miles south of Webster City, and 4.5 miles downstream from White Fox Creek.

Drainage area.--844 sq mi.

Gage.--Nonrecording prior to June 26, 1940; recording thereafter. Datum of gage is 989.57 ft above mean sea level, datum of 1929.

Stage-discharge relation.--Defined by current-meter measurements.

Remarks.--Base for partial-duration series, 2,500 cfs.

Peak stages and discharges

Water year	Date	Gage height (feet)	Discharge (cfs)
1918	June 10, 1918	[c]19.1	21,500
1932	June 18, 1932	16.0	15,000
1940	Aug. 15, 1940	4.40	[a]740
1941	June 3, 1941	5.4	1,500
1942	June 7, 1942	6.7	2,620
	June 30, 1942	7.52	3,060
1943	Mar. 16, 1943	6.71	2,410
1944	May 20, 1944	11.4	7,090
	June 14, 1944	13.70	10,200
1945	Mar. 13, 1945	9.26	4,820
	Apr. 17, 1945	7.42	3,130
	Apr. 24, 1945	9.18	4,730
	May 24, 1945	7.44	3,220
	June 2, 1945	9.21	4,810
	June 10, 1945	7.0	2,810
	Aug. 16, 1945	11.51	7,200
1946	Feb. 1946	[a]10.1	5,340
	Mar. 13, 1946	7.47	3,150
	May 26, 1946	10.67	6,730
1947	June 13, 1947	8.02	3,780
	June 18, 1947	8.05	3,800

5-4810. Boone River near Webster City, Iowa--(Continued)

Peak stages and discharges

Water year	Date	Gage height (feet)	Discharge (cfs)
1947	June 25, 1947	12.75	9,340
	July 1, 1947	9.52	5,250
1948	Feb. 28, 1948	[b]8.4	[a]2,600
	Mar. 19, 1948	8.40	4,160
1949	Mar. 7, 1949	8.24	3,980
	Mar. 28, 1949	6.90	2,820
1950	Mar. 7, 1950	9.25	5,000
	June 18, 1950	8.10	3,890
	June 24, 1950	7.10	2,990
1951	Feb. 27, 1951	[b]9.2	[a]4,950
	Mar. 6, 1951	6.60	2,580
	Mar. 29, 1951	13.00	9,800
	Apr. 7, 1951	11.00	7,070
	Apr. 25, 1951	6.70	2,510
	May 2, 1951	9.85	5,630
	June 3, 1951	7.30	3,030
	June 15, 1951	8.08	3,830
	June 28, 1951	13.37	10,400
1952	Apr. 1, 1952	7.65	3,330
	July 9, 1952	8.10	3,830
	July 15, 1952	7.10	2,840
1953	May 1, 1953	5.72	1,760
1954	June 10, 1954	7.72	3,450
	June 22, 1954	18.55	20,300
	Aug. 27, 1954	7.04	2,790
1955	July 6, 1955	11.14	7,190
1956	May 30, 1956	4.32	890
1957	June 16, 1957	7.52	3,230
1958	July 15, 1958	9.47	5,300
1959	May 24, 1959	7.50	3,300
	June 1, 1959	7.40	3,210

5-4810. Boone River near Webster City, Iowa--(Continued)

Peak stages and discharges

Water year	Date	Gage height (feet)	Discharge (cfs)
1960	Mar. 29, 1960	12.10	8,960
1961	Mar. 28, 1961	9.80	5,860
1962	Mar. 31, 1962	13.15	10,600
	Sept. 3, 1962	9.56	5,620
1963	Apr. 29, 1963	7.52	3,520
1964	Aug. 1, 1964	7.77	3,820
1965	Mar. 1, 1965	e	[a]6,600
	Apr. 6, 1965	15.91	15,200
	May 27, 1965	7.91	4,010
	June 3, 1965	8.02	4,100
	June 6, 1965	8.12	4,060
	Sept.22, 1965	11.48	8,060
	Sept.29, 1965	10.11	6,240

a About.
b Affected by ice
c Maximum stage known since 1896, from floodmarks, from information by local resident
d Maximum for period Mar. to Sept. 1940
e Unknown

1966 5610

1967 9840

1968 3040

1969 8170

```
xeq
Enter name, drainage area and gage number of watershed.
Boone River   844 sq. mi.   Gage No. 5-4810.
Any changes in identification input?  Enter yes or no.
no
Enter number of years of record.
N
30
Any changes in value of N?  Enter yes or no.
yes
Enter number of years of record.
N
30
Any changes in value of N?  Enter yes or no.
no
Enter values of maximum annual discharge.
Y(1)
740
Y(2)
1500
Y(3)
3060
Y(4)
2410
Y(5)
10200
Y(6)
7200
Y(7)
6730
Y(8)
9340
Y(9)
4160
Y(10)
3980
Y(11)
5000
Y(12)
10400
Y(13)
3830
Y(14)
1760
Y(15)
20300
Y(16)
7190
Y(17)
890
Y(18)
3230
Y(19)
5300
Y(20)
3300
Y(21)
8960
Y(22)
5860
```

10600
Y(24)
3520
Y(25)
3820
Y(26)
15200
Y(27)
5610
Y(28)
9840
Y(29)
3040
Y(30)
8170
Any changes in discharge input? Enter yes or no.
no

M= 3.680 S= 0.337 g= -0.575

Enter K value corresponding to recurrance
interval and value of g.
ayk
1.734
Any changes in value of K? Enter yes or no.
no
Enter recurrance interval in years.
RI
50
Any changes in value of recurrance interval? Enter yes or no.
no

Boone River 844 sq. mi. Gage No. 5-4810

Q= 18395 cfs

Recurrance Interval= 50 years

Do you want Q for a different recurrance interval?
Enter yes or no.
yes

Enter K value corresponding to recurrance
interval and value of g.
ayk
1.899
Any changes in value of K? Enter yes or no.
no
Enter recurrance interval in years.
RI
100
Any changes in value of recurrance interval? Enter yes or no.
no

Boone River 844 sq. mi. Gage No. 5-4810

Q= 20909 cfs

```
Recurrance Interval=     100 years

Do you want Q for a different recurrance interval?
Enter yes or no.
no
Do you want to determine Q for another watershed?
Enter yes or no.
no

END OF JOB.
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logout
TIME 13:58:08; TIME USED: CPU 00:00:18; TERM 00:32:40; PAGE 01:04:32;
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