Proceedings of the Iowa Academy of Science

Volume 56 | Annual Issue Article 28

1949

Hydrologic Comparisons for Floods of June 1947 in Iowa

L. C. Crawford
University of Iowa

Hydrologic Comparisons for Floods of June 1947 in Iowa [1]

By L. C. Crawford

Man has always been plagued by floods and it is reasonable to expect that he will continue to be faced with a variety of flood problems in the years to come. The great floods of June 1947 in Iowa were a tragic reminder of the continuing danger which Man faces from excess rainfall and runoff. Those floods were outstanding, not only with respect to the depths and intensities of the rainfall which produced them, but also with regard to the maximum rates and total amounts of runoff which resulted and the tremendous quantities of soil which were washed from the land. This paper has been prepared for the Geology Section of the Iowa Academy of Sciences to bring together certain pertinent data on three aspects — rainfall, runoff, and sediment loads — and to illustrate the extent and especially the comparative features of the technical data which are becoming available through the State and Federal cooperative program of the United States Geological Survey.

Rainfall

Great floods in Iowa are caused primarily by heavy rainfall, other hydrologic factors usually having little effect. The late Professor Floyd A. Nagler, first Director of the Iowa Institute of Hydraulic Research, once said that "Contrasted to the runoff that follows downfall of precipitation which is large in amount and great in intensity, the effect of most hydrologic factors seems relatively small indeed." The floods of June 1947 were no exception to Professor Nagler's pertinent observation.

The work of the United States Weather Bureau in Iowa, in cooperation with the Division of Weather, Iowa State Department of Agriculture, in forecasting and in collecting precipitation and temperature records, is well known and those records have been published for many years. The precipitation records that are presented have been taken from the official publications of the United States Weather Bureau for which agency C. E. Lamoureaux is present section director in Des Moines, Iowa.

The figures of annual precipitation are generally not indicative of the intensity and duration of flood-producing rainstorms that may have occurred during a year, or that can be anticipated in the

[1] Published with the approval of the Acting Director, Geological Survey, United States Department of Interior.

future. Nevertheless, a short resumé of the State-wide annual totals and extremes, which are available through the records of the United States Weather Bureau, affords an introductory basis for comparisons of interest with reference to the floods of June 1947. Considering the state of Iowa as a whole, the arithmetic mean annual precipitation is about 31.5 inches. The mean annual precipitation varies from slightly less than 26 inches in the Big Sioux River Valley in the extreme northwest section of the State to somewhat more than 36 inches in the extreme southeast corner and at points along the Mississippi River.

The year 1881 seems to have been the wettest calendar year on record in Iowa with an average depth over the State of 44.2 inches. Over a small area near Dubuque the total rainfall for the year exceeded 55 inches. The year 1910 appears to have been the driest with an average depth of 19.9 inches. Over some areas the rainfall for that year was less than 14 inches. A special study by the Iowa Institute of Hydraulic Research, however, shows that in the 12-month period ending May 31, 1934, the mean precipitation for the State as a whole was 19.5 inches or 0.4 inch less than that for the calendar year 1910. Mean figures of annual precipitation since 1930 over the State and mean annual temperatures are given in table 1.

Table 1

Mean Annual State-wide Precipitation and Temperature

Year	Mean Temp. Deg. Fahr.	Mean Annual Prec. Inches
1930	50.2	26.10
1931	53.2	35.37
1932	48.2	32.28
1933	50.8	24.94
1934	51.5	26.85
1935	48.6	33.16
1936	48.6	26.00
1937	47.5	27.60
1938	51.2	36.29
1939	51.1	25.16
1940	47.9	30.66
1941	51.1	36.84
1942	48.9	32.63
1943	47.9	31.20
1944	49.3	37.26
1945	47.7	34.60
1946	50.7	35.15
1947	48.9	35.23

For the month of June 1947, the average rainfall over the state of Iowa was 10.39 inches, which is the greatest total for any one month in the Weather Bureau's records. It exceeded previous monthly maxima of 9.76 inches in September 1926, 8.77 inches in May 1892, and 8.67 inches in July 1902. It also exceeded the normal for the month of June by 5.83 inches. Table 2 gives monthly totals for May to September, inclusive, and seasonal totals for all years since 1873 in which the monthly total for one or more of those months exceeded 7 inches; included also are the years 1918 and 1944, during which major floods occurred in Iowa.

Table 2

Total Monthly Average Precipitation, in Inches, for Selected Years and Months

Year	Month: May	June	July	August	September	Total
1875	2.94	7.81	6.05	4.04	5.02	25.86
1881	3.73	7.37	5.33	2.71	7.14	26.28
1882	5.42	7.48	3.66	1.61	0.87	19.04
1892	8.77	5.19	5.29	2.24	1.53	23.02
1902	5.39	7.16	8.67	6.58	4.35	32.15
1903	8.55	2.86	4.83	6.64	3.81	26.69
1907	3.48	5.35	7.27	4.33	2.75	23.18
1908	8.34	5.66	3.66	4.77	1.20	23.63
1914	3.31	5.57	2.27	2.19	7.88	21.22
1915	7.34	4.16	8.32	2.81	6.03	28.66
1918	6.87	5.29	3.17	3.61	1.87	20.81
1924	1.71	8.10	3.67	5.35	3.13	21.96
1926	2.76	4.52	3.72	3.80	9.76	24.56
1932	3.99	5.17	3.12	7.10	2.05	21.43
1935	4.84	7.00	3.35	2.42	3.46	21.07
1936	2.91	2.85	0.51	3.48	7.22	16.97
1941	3.26	6.20	2.24	1.94	7.74	21.38
1944	6.13	5.88	3.73	5.88	2.25	23.87
1947	4.26	10.39	1.72	1.49	2.10	19.96

The year 1902 affords a unique record in the fact that during the five-month period, there was heavy rainfall totaling 32.15 inches; and the total for the year was 43.82 inches — one of the highest in the period of record. The year 1947, on the other hand, strikingly enough had 35.23 inches for the year and less than 20 inches (19.96) in the five-month seasonal period. Only the years 1882 and 1936 show a lesser amount in this period in table 2. In fact, the extremely low amounts of State-wide average rainfall in July and August 1947 signifies the severe dry weather that set in after the floods and caused extensive crop shortages in addition to the damage resulting from the flooding. Particularly is it to be emphasized that the rainfall for only one August of record (1901) was less than that of August 1947.

The outstanding features of the rains that produced the great floods of June 1947 were their areal extent, duration, and accumulated monthly and bimonthly (May and June) totals over the entire State. That bears out the fact that major floods on the larger rivers of Iowa have generally been produced by widespread storms following a period of wet weather. The rainfall over the State for the month of June 1947 was in general from two to two and a half times normal, though that occurrence alone was not entirely responsible for the serious floods experienced. Contributing materially were the antecedent conditions of a saturated soil and rivers already swollen by a series of rains.

Most of the rainfall records in Iowa that have been kept more than 20 years include figures for at least one measuring station that has experienced a monthly total of rainfall in excess of 10 inches sometime during the period June to September. During September 1926, for example, 18.57 inches of rain fell at Corydon. According to Weather Bureau records, monthly totals for June 1947 at individual stations varied from 4.24 inches at Merrill, to 18.12 inches at Van Meter, which depth was the greatest monthly total on record

Table 3

Total Monthly Precipitation at Selected Stations, June 1947

	Station	Precipitation Inches
Mississippi River Drainage Basin		
	Van Meter	18.12
	Traer	17.42
	Independence	15.67
	Earlham	15.50
	Winterset	15.48
	Indianola	15.26
	Grundy Center	14.78
	Rockwell City	14.48
	Toledo	14.39
	Des Moines (AP)	14.25
Missouri River Drainage Basin		
	Glenwood	16.59
	Melbourne	15.96
	Malvern	15.91
	Humeston	14.10
	Tabor	13.54

for that station. Table 3 gives the monthly total precipitation for June 1947 at selected stations of greatest amounts in Iowa.

In Des Moines, the month of June 1881 is recorded as the wettest month in the history of that city with a rainfall of 15.79 inches. The airport gage in Des Moines reported 14.25 inches in June 1947 and on June 12, 1947 measured 5.42 inches in a single twenty-four hour period, exceeding the previous record of 1878-1947 of 5.14 inches on June 19-20, 1881.

The greatest depths of rainfall recorded by the Weather Bureau in a twenty-four hour period during June 1947 were 6.65 inches at Rockwell City on June 22 and 5.69 inches at Indianola on June 5. The Weather Bureau also reported a fall of about 10 inches in the Lizard Creek Basin at a point a few miles upstream from the confluence of this stream and the Des Moines River at Fort Dodge. In this connection, it should be noted that a rainfall of over 6 inches in twenty-four hours at a single measuring station has often been considered to have a frequency or a recurrence interval of about once in 100 years.

To complete the consideration of such maximum monthly, twenty-four hour, and daily precipitations it should be mentioned that the greatest depths recorded for any one-day storms since the Weather Bureau has been keeping systematic records in Iowa are 13.00 inches at Primghar on July 15, 1900; 12.99 inches at Larrabee on June 24, 1891; and 12.10 inches at Bonaparte on June 10, 1905, during which time occurred the famous Devils Creek Flood near Fort Madison. The wettest September in Iowa history occurred in 1926 with a monthly total that was second only to June 1947. At Sioux Center on September 17-18, 1926, more than 11.5 inches of rain fell in fourteen hours and thirty minutes. More than 10 inches of rain within a twenty-four hour period have been officially measured at at least eight places in Iowa. In the storm of September 14, 1914, 3.24 inches of rain fell in Des Moines in 140 minutes, and 7.78 inches at Cedar Rapids in twenty-four consecutive hours. Such heavy downpours, which in twenty-four hours or less precipitate a third of that normally to be expected in a whole year, result in flash floods of devastating effect. Maximum floods on the smaller streams in Iowa usually result from such intense storms, which may be only a few hours in duration.

The accurate measurement of rainfall with the determination of hourly rates during intense storms requires automatic recording instruments. Until recent years the distribution of such instruments over the State has not been such as to give a reliable pattern, but some first-order stations of the Weather Bureau so equipped have recorded depths of rainfall of 2.6 inches and 3.5 inches in one- and two-hour intervals. There are, of course, other reports of excessive rates, the most striking perhaps being the affirmed belief of a resident of Des Moines County that more than 16 inches of rain fell in a 3-hour period over an area of about 50 square miles during the storm of August 15-16, 1898, that figure being reported in the proceedings of the Iowa Academy of Science for that year. Incidentally, while a rainfall of 13 to 16 inches in a twenty-four hour period is undoubtedly a cloudburst in Iowa, Texans like to emphasize the Thrall, Texas, storm of September 8-10, 1921, during which a depth of 38.2 inches was recorded during a twenty-four hour period.

Recently the Corps of Engineers and the United States Weather Bureau have developed some general estimates of the maximum possible precipitation that might occur in the United States east of the 100th meridian over areas of 10, 200, and 500 square miles. Those studies show, with justified admission of limitations in data and necessary assumptions in application, that for Iowa the maximum possible precipitation in twenty-four hours could be approximately 24 to 28 inches over a 10 square-mile area and 18 to 20 inches over a 500 square-mile area.

From the foregoing it may be seen that estimated possibilities for the future, coupled with factual records of the past, reveal that the rains and resultant floods of June 1947, in spite of their record-breaking character, may not be casually waved aside as the maximum possible to be expected. Through an intelligent use of the available rainfall data as previously outlined, together with that gathered by measurements of runoff and siltation over an extended period of years, modern engineering and technical skill should be able to do much to mitigate flood damages and loss of life and especially the distressing disruption of community and farming activities in the affected river and stream valleys.

Runoff

Rainfall is not usually the great destroyer of lives and property, but rather the runoff that heavy rainfall engenders. Although the depth of rainfall occurring over a watershed is the most important factor in determining the amount of runoff that will take place, the relationship between rainfall and either amount or rate of runoff is by no means direct or simple. For example, a certain quantity of rainfall will produce much higher maximum discharge and greater total runoff from saturated or frozen soil than from soil which is dry or cultivated. In fact, rainfall-runoff relationships are affected by many complex and variable factors, a few of which may be stated as follows:

1. Areal extent and intensity of the storm.
2. Direction of movement of the storm relative to the orientation of the stream basin.
3. Condition of soil and ground surface at the time of the storm.

Such being the case, it is essential that continuous records of stream flow be maintained as a fundamental part of the general hydrologic data in order that quantitative information relative to runoff may be available. The value of stream-flow records increases as the length of time over which they have been collected expands to cover years of both extreme flood and drought conditions. As is true with most natural phenomena, it is only through substantial length of record that reasonable predictions of occurrence and recurrence of extremes in discharge can be made.

Adequate information on the quantities of water available and ranges of stage to be expected, as well as quality of the water and the sediment loads that it carries, is essential in the consideration or construction and operation of hydraulic works of all kinds, including structures for flood protection, navigation developments, municipal supplies, power and industrial plants, drainage of lands, disease and pollution control, and conservation of water for various purposes. Such data are also necessary for the design of bridge and culvert openings, the establishment of highway and railroad elevations, and the maintenance and administration of all facilities and developments utilizing water resources. As amply demonstrated by the floods of June 1947, the lack of such information in the design and location of power plants, waterworks, sewage treatment plants, dams and bridges, and the industrial and residential areas of cities and towns will result in losses through flood damage far in excess of the slight relative cost of collecting and compiling stream-flow data.

There are three measures commonly used for the evaluation of flood discharges, each of which has a particular significance in the study of the problem. These are:

1. Maximum discharge in cubic feet per second per square mile of drainage area. — It is this figure that is a direct measure of the damaging effects of the flood. The greater the maximum flow the greater both the stage and velocity, each of which is a major contributor to property damage and loss of life.
2. *Flood runoff* in inches of depth over the drainage area. — This factor,

which is also an expression of total runoff, is of particular interest in the comparison of rainfall with runoff, the former being generally expressed in inches of depth also.

3. Total flood runoff in acre-feet. — This expresses the magnitude of the total runoff and is the most important figure in the design of reservoirs for the mitigation and control of damaging floods.

Table 4 presents maximum discharge in second-feet and in second-feet per square mile for the flood of June 1947 and for the greatest previous flood at 20 typical stream-gaging stations in Iowa. Included in that table also are the drainage area in square miles, the period of record, and the gage height or stage at which each maximum discharge occurred.

Hydrologists have recognized the possibilities of generalized correlations between the maximum discharge in second-feet per square mile and the size of the contributing area; the unit discharge decreasing with increasing area. In order to compare the 1947 flood data, a diagram, figure 1, has been prepared to demonstrate this relationship by utilizing the basic data in table 4. This diagram serves the useful purpose of comparing flood peaks for drainage areas of various sizes. The line of relation that is shown was drawn in 1941 generally through or slightly above the points of maximum unit discharge for the given drainage areas. This line, therefore, represents what at that time was the general upper limit or enveloping curve of flood-flow experience, based upon actual determinations in certain drainage basins in Iowa. A curve of this type, therefore, continually modified as a result of up-to-date flood data that are obtained on a continuing basis of operation, is of considerable assistance in the intelligent planning of any work which may require a knowledge of probable flood flows. It should be borne in mind, however, that such a curve is merely a record of past recorded experience and may be well below the maximum possible as was discussed previously.

It will be observed that only three flood peaks, those at Tracy, Ottumwa, and Keosauqua, exceeded the enveloping curve established with data available up to 1941. Nevertheless, it will be noted also that a considerable number of the 1947 flood-peak determinations plot very closely to the enveloping curve, indicating the magnitude of that flood. Moreover, an enveloping curve of values up to and including data for 1947 should apparently be somewhat higher for drainage areas of approximately 10,000 square miles than the curve drawn in 1941.

Table 4 illustrates also how stream-flow records of short duration, if used as the basis for estimates of maxima, are likely to lead to

Table 4

Summary of flood discharges in typical drainage basins in Iowa for the flood of June 1947

No.	Stream and Place of Determination	Drainage Area (Square miles)	Period of Record	Maximum Flood Previously Known: Date	Gage height (Feet)	Discharge: Second-feet	Discharge: Second-feet per square mile	Maximum During Present Flood: Time	Gage height (Feet)	Discharge: Second-feet	Discharge: Second-feet per square mile
1	L. Maquoketa R. near Durango	130	1934-	6-21-37	20.75	21,000	162.	6-13-47	21.23	23,000	177.
2	Maquoketa R. near Manchester	306	1903, 33-	9- 8-41	14.65	8,880	29.0	6-13-47	21.36	20,000	65.4
3	Iowa R. at Iowa City	3,230	1903-	6- 7-18	19.45	36,200	11.2	6-17-47	18.59	33,800	10.5
4	Iowa R. at Wapello	12,480	1915-	3-19-29	16.22	67,500	5.41	6-18-47	16.14	94,000	7.53
5	Salt Creek near Elberon	200	1945-	6-16-44	21.3	34,000	170.	6-13-47	17.6	*25,000	125.
6	Cedar R. at Waterloo	5,190	1941-	3-17-45	18.38	53,300	10.3	6-13-47	18.7	55,600	10.7
7	Des Moines R. near Boone	5,490	1920-27 33-	5-22-44	17.3	30,000	5.46	6-24-47	19.85	37,100	6.77
8	Des Moines R. at Tracy	12,400	1920-27 33-35, 40-	5-31-03	25.0	130,000	10.5	6-14-47	26.5	155,000	12.4
9	Des Moines R. at Ottumwa	13,200	1917-30 35-	5-24-44	17.5	73,200	5.54	6- 7-47	20.2	135,000	10.2
10	Des Moines R. at Keosauqua	13,900	1903-06 10-	6- 1-03	27.85	135,000	9.72	6-16-47	25.14	124,000	8.92
11	North Lizard Cr. near Clare	257	1940-	5-22-44	11.11	4,410	17.2	6-23-47	16.0	*10,000	38.9
12	North R. near Norwalk	348	1940-	8-26-46	21.87	7,050	20.3	6-13-47	25.3	32,000	92.0
13	Middle R. near Indianola	502	1940-	5-22-44	20.32	9,490	18.9	6-13-47	26.4	34,000	67.8
14	South R. near Ackworth	475	1940-	6- 9-41	20.56	12,100	25.5	6- 5-47	24.90	34,000	71.6
15	Nishnabotna R. above Hamburg	2,800	1922-23 28-	3-12-39	23.0	24,600	8.79	6-24-47	26.03	55,500	19.8
16	E. Nishnabotna R. at Red Oak	890	1918-25 36-	5-23-45	20.54	16,100	18.1	6-13-47	23.23	36,200	40.7
17	Nodaway R. at Clarinda	740	1918-25 36-	5-21-37	16.5	14,000	18.9	6-13-47	25.3	31,100	42.0
18	Thompson R. at Davis City	702	1918-25 41-	7-18-22	19.85	16,700	23.8	6-14-47	20.14	24,400	34.7
19	Chariton R. near Centerville	727	1938-	6-20-46	24.2	21,700	29.8	6- 7-47	23.94	20,300	28.0
20	Waubonsie Cr. near Bartlett	30	1946-	9- 4-46	27.7	13,500	450.	6- 4-47	24.0	*9,450	315.

* Estimated.

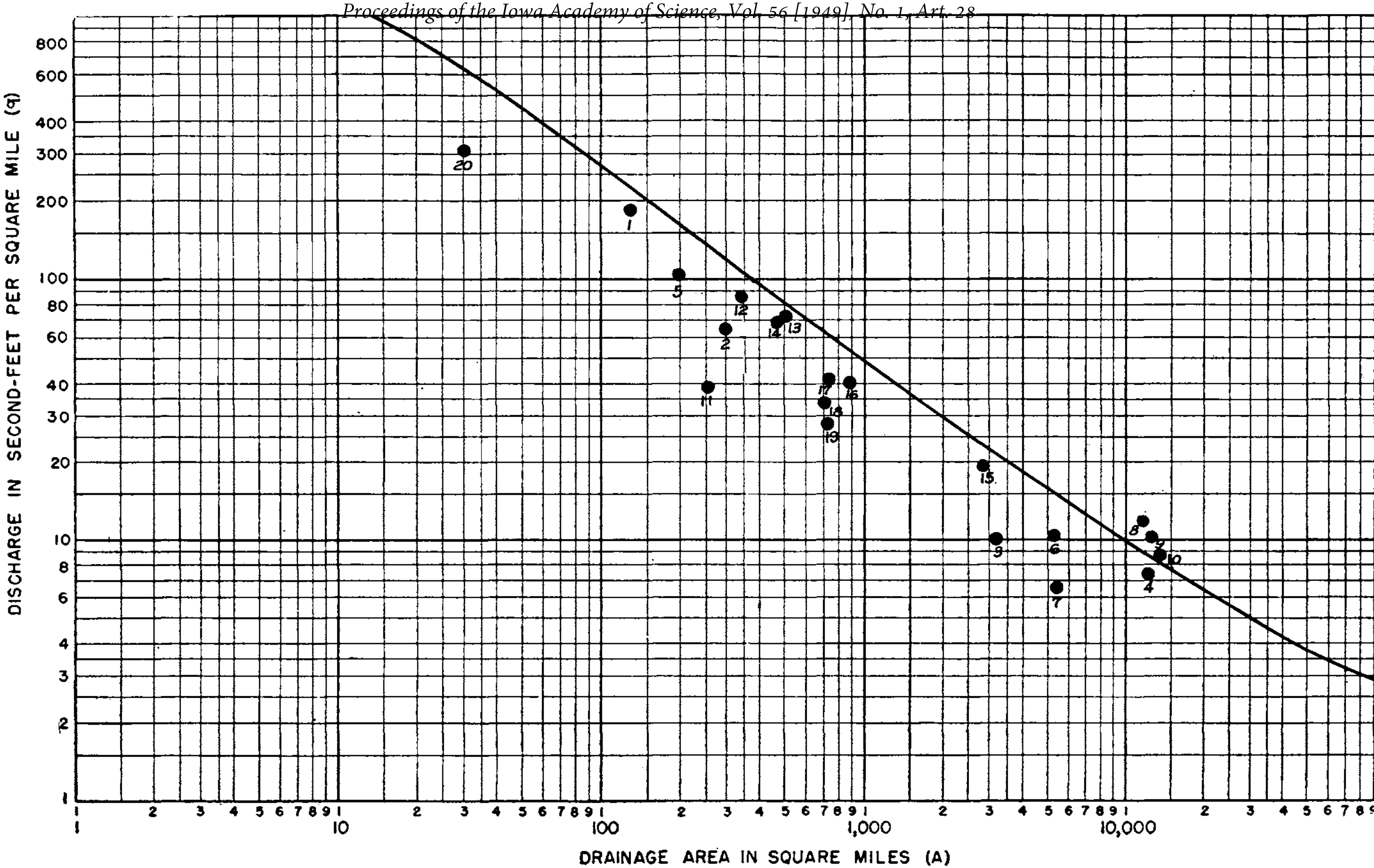

Figure 1. Chart showing maximum discharges determined for floods of June 1947 on typical Iowa streams in relation to enveloping curve established with data available prior to 1942. (See table 4 for 1947 data.)

conclusions that are grossly in error. For example, the table shows that the maximum discharge of the Nishnabotna River above Hamburg on June 24, 1947, was 225% of the previous highest peak observed during 22 years of record. A study of the dates of occurrence of the peak discharges as listed in table 4 will show that the June 1947 peaks in different areas were caused by storms on several different dates and in addition none of the streams in the extreme northwest or northeast sections of the state reached unusual stages during the month. This situation demonstrates the effect of the wide variaions in intensity and distribution of the several rain storms of June 1947.

Further illustration of the serious need for long-term records of stream flow is provided from an examination of the available stream-gaging records. The State and Federal cooperative program for the systematic collection of stream-flow records in Iowa was initiated in 1914, although a few records were obtained by special arrangements during earlier periods. Consequently, it has been reasonably well established that Iowa's greatest floods since Statehood was granted occurred in 1851 and 1881 with somewhat lesser and more localized floods occurring in such years as 1858 and 1903 according to historical accounts. Nevertheless, the records of the past, such as are available, impress one with the fact that in almost every year some small areas have been temporarily flooded. In almost a quarter of a century of record (1924-1948) on Ralston Creek at Iowa City, the maximum discharge occurred on June 27, 1941, although that year would not ordinarily be considered a time of general flood conditions. On the larger interior rivers a period of continuous and systematic record extends from 1903 to the present time at only three places; Cedar Rapids, Iowa City, and Keosauqua. These are the longest authentic records of stage and discharge and have been maintained by the cooperative effort of local, State, and Federal agencies.

A pertinent quantitative summary of the ten calendar months of highest total volume of runoff during the period of record for Cedar Rapids, Iowa City, and Keosauqua is given in table 5.

It will be noted that the years 1944-47 produced at least three of the ten highest months, including the highest since 1903. Furthermore, if no records had been kept for these stations for the period 1944-47, three of the highest months would not now be a matter of record, including the maximum.

Table 6 has been prepared from data on selected streams that were in the heavy-runoff areas and contains information on the

Table 5

Summary data for 10 calendar months of highest total runoff during period of record at Cedar Rapids, Iowa City, and Keosauqua

Order	Year	Month	Average Discharge (c. f. s.)	Runoff Inches
		Cedar Rapids		
1	1947	June	23,420	3.93
2	1929	March	18,400	3.19
3	1912	April	12,800	2.26
4	1945	March	12,670	2.20
5	1933	April	12,300	2.06
6	1936	March	12,080	2.10
7	1919	April	11,300	1.90
8	1946	March	11,020	1.91
9	1906	March	11,000	2.01
10	1937	March	10,940	1.90
		Iowa City		
1	1947	June	16,499	5.70
2	1918	June	11,000	3.80
3	1944	May	9,856	3.52
4	1913	April	9,520	3.29
5	1944	June	8,815	3.05
6	1929	March	8,800	3.14
7	1915	February	7,970	2.57
8	1903	June	7,490	2.59
9	1936	March	6,790	2.42
10	1937	March	6,401	2.28
		Keosauqua		
1	1947	June	58,890	4.73
2	1903	June	34,425	2.69
3	1944	May	32,370	2.68
4	1944	June	29,250	2.35
5	1917	June	26,800	2.15
6	1945	June	24,280	1.95
7	1945	May	23,480	1.95
8	1915	July	23,200	1.92
9	1929	March	22,230	1.85
10	1919	June	20,800	1.67

Note — It should be mentioned that reivsïon of earlier drainage areas where possible with better map data causes some relatively minor irregularities in the descending order of results in the runoff in inches as shown for these stations.

Table 6

Mean discharge and runoff comparisons for floods of June 1947 on selected Iowa streams

Stream and location	Drainage area (sq.miles)	Period of record: Years	Period of record: Mean disch. (c. f. s.)	Runoff during June 1947: Mean disch. (c. f s.)	Runoff during June 1947: Acre-feet	Runoff during June 1947: Depth in inches
Iowa River at Iowa City	3,230	1903-	1,508	16,500	981,700	5.70
Iowa River at Wapello	12,480	1915-	6,049	46,810	2,785,400	4.18
Cedar River near Conesville	7,840	1939-	4,369	25,680	1,528,300	3.65
Des Moines River near Boone	5,490	1920-27				
		1933-	1,598	11,340	674,800	2.30
Des Moines River at Des Moines	6,180	1915-27				
		1932-	2,081	15,780	939,100	2.85
Des Moines River below Raccoon River at Des Moines	9,770	1940-	4,735	32,070	1,908,000	3.66
Des Moines River at Tracy	12,400	1920-27				
		1933-35				
		1940-	4,434	51,550	3,067,000	4.64
Des Moines River at Ottumwa	13,200	1917-	4,478	54,020	3,214,000	4.57
Raccoon River near Jefferson	1,630	1940-	772	5,160	307,000	3.53
Raccoon River at Van Meter	3,410	1916-	1,134	13,560	807,000	4.44
South Raccoon River at Redfield	995	1940-	432	5,060	301,000	5.67
North River near Norwalk	348	1940-	220	2,990	178,000	9.58
Middle River near Indianola	502	1940-	313	4,670	278,000	10.38
South River near Ackworth	475	1940-	252	3,410	203,000	8.01
Whitebreast Creek near Knoxville	380	1945-	285	2,580	153,000	7.57
Nishnabotna River above Hamburg	2,800	1928-	794	16,430	977,900	6.55
Chariton River near Centerville	727	1938-	402	4,665	277,600	7.16

Table 7

Summary of yearly discharge, in second-feet, for Iowa River at Iowa City, Iowa
(Drainage area, 3,230 square miles)

Year	W. S. P. (no. and page)	Water year ending Sept. 30					Calendar year				
		Maximum day	Minimum day	Mean	Per square mile	Runoff in inches	Maximum day	Minimum day	Mean	Per square mile	Runoff in inches
1904	*130- 59	8,410	150	1,230	0.381	5.17	8,410	150	1,090	0.337	4.62
1905	*171- 83	8,710	170	1,520	.471	6.42	8,710	250	1,700	.526	7.17
1906	*207- 71	—	—	1,970	.610	8.25	—	—	2,000	.619	8.40
1907	*	—	—	2,490	.771	10.42	—	—	2,410	.746	10.13
1908	*	—	—	1,200	.368	5.05	5,850	85	1,040	.322	4.41
1909	*	12,400	58	1,740	.539	7.32	12,400	58	1,950	.604	8.20
1910	*	9,520	70	1,010	.313	4.24	9,520	48	773	.239	3.25
1911	*	9,680	43	564	.175	2.37	9,680	43	755	.234	3.19
1912	*	20,000	64	1,390	.430	5.84	20,000	64	1,220	.378	5.13
1913	*	7,030	70	944	.292	3.99	7,030	70	963	.298	4.07
1914	*385-212	8,000	100	834	.258	3.51	8,000	181	1,050	.325	4.42
1915	405-162	20,000	300	2,960	.916	12.44	20,000	300	3,010	.932	13.93
1916	*435-162	10,900	38	2,250	.697	9.46	10,500	10	1,650	.511	6.93
1917	*455-144	17,500	10	1,290	.399	5.44	17,500	80	1,300	.402	5.48
1918	*475-106	35,300	38	1,950	.604	8.19	35,300	38	2,060	.638	8.64
1919	505-193	12,800	79	2,070	.641	8.71	12,800	79	2,430	.752	10.23
1920	505-193	8,130	280	2,130	.659	8.98	8,130	264	1,830	.567	7.71
1921	525-117	14,300	190	1,390	.430	5.86	14,300	190	1,470	.455	6.16
1922	545-116	5,780	158	1,320	.409	5.58	5,780	158	1,130	.350	4.74
1923	565-104	8,420	—	800	.248	3.36	8,420	153	877	.272	3.69
1924	585-107	19,100	61	2,000	.619	8.29	19,100	61	1,960	.607	8.26
1925	605-102	1,510	48	514	.159	2.18	3,160	48	564	.175	2.37
1926	625- 97	17,400	111	1,210	.375	5.05	17,400	111	1,430	.443	6.00
1927	645- 66	9,310	274	1,720	.533	7.26	9,310	258	1,630	.505	6.85
1928	665- 75	8,820	258	1,550	.480	6.51	8,820	290	1,790	.554	7.52
1929	685-111	21,900	512	2,710	.839	11.40	21,900	320	2,280	.706	9.59

1930	700-110	11,300	92	1,020	.316	4.29	11,300	92	932	.289	3.91
1931	730-133	2,790	48	312	.097	1.32	7,750	48	811	.251	3.42
1932	730-133	7,750	200	2,090	.647	8.82	5,400	83	1,690	.523	7.14
1933	745-151	8,700	83	1,180	.365	4.95	8,700	88	1,050	.325	4.41
1934	760-188	1,840	30	204	.063	.86	1,840	30	246	.076	1.04
1935	785-186	8,550	73	1,474	.456	6.20	8,550	179	1,631	.505	6.85
1936	805-205	12,900	59	1,388	.430	5.83	12,900	59	1,282	.397	5.39
1937	825-241	16,800	88	1,581	.489	6.64	16,800	56	1,494	.463	6.27
1938	855-252	4,600	56	1,260	.390	5.29	4,600	126	1,398	.433	5.87
1939	875-261	8,860	74	1,056	.327	4.45	8,860	74	912	.282	3.85
1940	895-226	2,800	32	352	.109	1.49	2,800	32	391	.121	1.66
1941	925-266	5,510	74	863	.267	3.64	6,320	126	1,466	.454	6.16
1942	955-268	7,590	621	2,314	.716	9.71	7,590	384	1,924	.596	8.07
1943	975-	8,730	384	2,260	.700	9.50	8,730	335	2,147	.665	9.03
1944	1005-283	30,100	234	2,796	.866	11.79	30,100	234	2,740	.848	11.56
1945	1035-	9,270	223	2,033	.629	8.56	9,270	200	2,050	.635	8.63
1946		14,500	200	1,905	.590	8.02	14,500	200	2,140	.663	9.00
1947		32,600	218	3,399	1.05	14.29					

* Computed from report "Stream Flow Records of Iowa — 1873-1932"; records in water-supply papers incomplete.
Note: Drainage area revised in 1934.

average flow in cubic feet per second for June 1947 and the mean discharge for the period of available record to serve as a comparison.

Within the factual records of discharge in Iowa, a yearly yield of as much as 10 inches of runoff from a basin, regardless of size, is indeed unusual. For illustrative purposes, a summary of yearly discharge for the gaging station on Iowa River at Iowa City is given in table 7 during the period of record to Sept. 30, 1947. That year, it will be noted, had the highest runoff, 14.29 inches. The significant effect that the floods of May and June 1947 had upon the total yearly runoff of Iowa streams — in spite of the dry weather in July and August 1947 — is illustrated in table 8. Typical stations are listed for which the runoff volume was more than 10 inches and also the highest for any water year in the period of record ending Sept. 30, 1947 at that station.

As a result of these facts and the vivid experience of flood waters of 1947 in Iowa, the people of the State, especially those who suffered from inundation, are taking a keen interest in the cause, frequency, and prevention of floods.

The foregoing are but a few of the many basic facts about natural

Table 8

Yearly Runoff at Typical Stations, 1947

Station	Yearly Amount
Mississippi Basin	
North River near Norwalk, Iowa	20.60
Middle River near Indianola, Iowa	18.35
Bear Creek at Ladora, Iowa	17.93
Maquoketa River near Maquoketa, Iowa	16.73
L. Maquoketa River near Durango, Iowa	16.34
South River near Ackworth, Iowa	15.98
Wapsipinicon River near Dewitt, Iowa	15.09
Whitebreast Creek near Knoxville, Iowa	15.02
Iowa River near Belle Plaine, Iowa	14.79
English River at Kalona, Iowa	13.96
Wapsipinicon River at Independence, Iowa	11.75
South Raccoon River at Redfield, Iowa	11.38
Des Moines River at Ottumwa, Iowa	10.74
Des Moines River at Tracy, Iowa	10.57
Missouri Basin	
Chariton River near Centerville, Iowa	15.07
Thompson River at Davis City, Iowa	14.37
E. Nishnabotna River at Red Oak, Iowa	12.77
Nishnabotna River above Hamburg, Iowa	12.48
Nodaway River at Clarinda, Iowa	11.89

stream flow which become apparent as the period of record lengthens and includes unusual floods. Based on these experiences, the legendary highwater marks passed down through several generations seem less improbable. As the period of years over which a continuous adequate record of stream flow is obtained increases to include more and more of the infrequent extremes, both maximums and minimums, it becomes increasingly possible to base the design of bridges, dams, water plants and other hydraulic structures on sound economic premises. The amount of public funds expended for the purpose of collecting records is a relatively small per cent of the total cost of such structures. Loss of a single structure due to lack of adequate provision for handling flood flows will often equal or exceed the cost of obtaining many years of adequate record.

SEDIMENT

To the layman a river is a stream of water. To the engineer it is a stream of sediment as well. Sediment — the material formed by decomposition and disintegration of the earth's rock mantle — has been transported to the sea by running water in all eons past and will continue to be so transported as long as the land masses rise above the seas and the earth's crust is subject to the erosive effects of the atmosphere.

Failure to recognize the capabilities of certain streams to transport sediment has resulted in costly losses and geologists and engineers have long recognized the importance of determining the sediment loads of streams together with records of water discharge, for such knowledge is fundamental to the design of any works for the development and use of stream flow. Particularly is that knowledge important in the planning of reservoirs in which space must be allotted for the deposition of sediment. The soil conservationist, too, is deeply interested in sediment transportation, for to him the material in transport is soil that is forever lost. Particularly is this true in Iowa, which is so intensively cultivated that the fertile fields that comprise practically the whole State are the source of much of the sediment loads of the streams.

In recognition of the needs for general information on the sediment loads in streams, a project was inaugurated in 1939 under the sponsorship of a Federal Interdepartmental Committee composed of representatives of the United States Geological Survey, the Corps of Engineers, the Bureau of Reclamation, the Office of Indian Affairs, the Department of Agriculture, and the Tennessee Valley Authority, in cooperation with the Iowa Institute of Hydraulic Research, at which place most of the experimental work was performed. Various devices for collecting samples of stream flow and its analysis for sediment content were tried out and improved instruments perfected. In addition, nine reports were prepared on the work of the committee, covering the subject of sediment transportation in a comprehensive manner.

The United States Geological Survey and the Corps of Engineers are actively engaged at the present time in the collection of daily samples from sediment-bearing streams and from these computing the quantities of sediment which these streams are transporting. In Iowa these agencies together with the Iowa Geological Survey and the Iowa Institute of Hydraulic Research cooperate and consolidate their efforts in this work, collecting continuous records at stations on the Iowa, Des Moines, and Cedar Rivers as well as many spot samples during floods on other streams throughout the State.

The analysis of sediment samples is such that the results are determined in parts per million, e.g., the number of pounds, dry weight, of sediment that are contained in one million pounds of the water-sediment mixture. The stream discharge is measured in cubic feet per second, which by a simple conversion can be changed into tons per day. That figure, when multiplied by the parts per million of the sediment that the water contains as measured for that day will give the number of tons of sediment that the stream transported in that period.

As a matter of general interest, the U. S. Geological Survey has made in Iowa numerous spot determinations of flood discharge and sediment load during the high waters of 1944 and 1945 and the outstanding and disastrous floods of 1947. The figures thus obtained are of interest both from the standpoint of the rates of sediment movement indicated and the rates at which that sediment was being removed from the watershed of the stream. Table 9 contains the pertinent information. It will be noted that a column headed "Tons per day per square mile" is included. This, of course, is a measure of the rate at which the material is being removed from the drainage area. A word of caution in examining this table — the figures contained therein are *rates at the time of measurement only*. The figures are not indicative of average conditions over any extended period.

Floods are not only disastrous in the water damage that they inflict; they are also tremendous robbers of soil. The excessive rainfalls that produce them wash enormous quantities of soil into

Table 9

Instantaneous sediment discharge of some Iowa streams

Stream and location	Drainage area (sq. mi.)	Date of observ.	Discharge† (sec.-ft.)	Sediment concent. (ppm.)	Sediment discharge§ Tons per day	Tons per day per sq. mi.
MISSISSIPPI RIVER BASIN						
Mississippi R. at Keokuk	119,000	July 1, 1944	209,000	765	432,000	3.6
		April 6, 1945	180,500	311	152,000	1.3
Mississippi R. at McGregor	67,500	Oct. 22, 1946	30,800	40	3,387*	.05
Northeastern Iowa						
L. Maquoketa R. near Durango	130	June 26, 1944	6,120	18,800	311,000	2,390
Maquoketa R. near Maquoketa	1,550	June 27, 1944	43,700	5,440	642,000	414
Wapsipinicon R. at Independence	1,060	June 14, 1947	19,300	536	27,900	26.3
Wapsipinicon R. at Central City	1,270	June 18, 1944	9,270	431	10,800	8.50
Wapsipinicon R. near Dewitt	2,300	June 27, 1944	23,100	1,580	99,000	43.0
		June 29, 1944	17,000	856	39,300	17.1
Iowa — Cedar River Basin						
English R. near Kalona	580	May 3, 1946	985	2,530	6,730	11.6
		June 13, 1946	1,700	7,620	35,000	60.3
Iowa R. near Belle Plaine	2,420	June 17, 1944	16,500‡	860	38,300	15.8
Iowa R. above Coralville	3,035	May 22, 1944	22,000	1,730	103,000	33.9
Iowa R. at Iowa City	3,230	May 22, 1944	23,000	3,030	188,000	58.2
		May 24, 1944	30,600	1,840	152,000	47.1
		Jan. 5, 1946	9,740‡	2,230	58,600	18.1
		Mar. 7, 1946	4,370‡	6,410	75,600	23.4
		June 5, 1947	17,700	1,260	60,200	18.6
		June 16, 1947	32,200‡	2,270	197,000	60.9
Iowa R. at Wapello	12,480	May 29, 1944	45,900	309	38,300	3.07
		June 21, 1944	51,600	440	61,300	4.91
		Mar. 22, 1945	57,700	270	42,100	3.37
		June 6, 1947	58,200	563	88,500	7.09
Cedar R. at Waterloo	5,190	June 15, 1944	18,800	150	7,610	1.47
		Mar. 17, 1945	54,300	365	53,500	10.3
Cedar R. at Cedar Rapids	6,640	June 18, 1944	28,100	955	72,500	10.9
		Mar. 19, 1945	52,000	512	71,900	10.8
		June 3, 1947	35,200	1,450	138,000	20.8
Cedar R. at Rochester	7,280	Sept. 28, 1943	1,700	112	514	.07
		June 19, 1944	30,900	684	57,100	7.84
		Mar. 21, 1945	48,800	330	43,500	5.98
Cedar R. near Conesville	7,840	May 29, 1944	19,800	178	9,520	1.21
		June 20, 1944	30,400	524	43,000	5.48
		Mar. 21, 1945	49,100	384	50,900	6.49
Lime Cr. at Mason City	535	June 12, 1944	6,510	826	14,500	27.1
Ralston Cr. at Iowa City		June 1, 1947		3,570	898	
Shell Rock R. at Marble Rock	1,330	June 13, 1944	13,000	463	16,300	12.3
Skunk River Basin						
Skunk R. near Sigourney	850	June 13, 1946	2,620	2,840	20,100	23.6
Skunk R. near Oskaloosa	1,640	May 23, 1946	1,300	3,780	13,300	8.1
		June 13, 1946	2,730	10,400	76,700	46.8
		June 3, 1947	5,260	1,240	17,600	10.7
Skunk R. at Coppock	2,890	May 25, 1944	35,300	1,210	115,000	39.8
Skunk R. at Augusta	4,290	May 26, 1944	43,700	1,750	206,000	48.0
Des Moines River Basin						
Des Moines R. near Boone	5,490	June 17, 1944	17,700‡	212	10,100	1.84
Des Moines R. at Des Moines	6,180	June 17, 1944	29,100	409	32,100	5.19
		May 17, 1945	6,370	240	4,130	.67
		May 24, 1945	13,530	473	17,300	2.80

Stream and location	Drainage area (sq. mi)	Date of observ.	Discharge† (sec.-ft.)	Sediment concent. (ppm.)	Sediment discharge§ Tons per day	Tons per day per sq. mi.
Des Moines R. below Raccoon R. at Des Moines	9,770	June 17, 1944	43,800	553	65,400	6.69
		Apr. 27, 1945	24,600	731	48,600	4.97
		Apr. 30, 1947	12,500	5,900	199,000	20.4
		June 2, 1947	19,100‡	3,960	204,000	20.9
		June 3, 1947	24,300‡	2,720	178,000	18.2
		June 25, 1947	61,500‡	2,720	452,000	46.3
		June 26, 1947	73,800	1,430	285,000	29.2
Des Moines R. at Tracy	12,400	May 25, 1944	61,400	960	159,000	12.8
		May 29, 1944	44,700	474	57,200	4.61
Des Moines R. at Ottumwa	13,200	May 26, 1944	63,200	1,030	176,000	13.3
		May 29, 1944	52,800	671	95,700	7.25
		Apr. 20, 1945	34,100	564	51,900	3.93
Des Moines R. at Keosauqua	13,900	May 26, 1944	67,200‡	1,110	201,000	14.5
		June 29, 1947	78,800	970	206,000	14.8
Raccoon R. at Van Meter	3,410	June 17, 1944	14,200‡	388	14,900	4.37
		Apr. 27, 1945	9,740	671	17,600	5.16
		May 23, 1945	11,900	2,300	73,900	21.7
		June 3, 1947	19,100	2,280	118,000	34.6
		June 25, 1947	39,700	2,760	296,000	86.8
So. Raccoon R. at Redfield	995	Apr. 25, 1945	3,690	2,880	28,700	28.8
		May 22, 1945	8,790	4,210	99,900	100
		May 23, 1945	5,150	4,050	56,300	56.6
		June 2, 1947	13,300	5,730	206,000	207
North R. near Norwalk	348	Apr. 17, 1945	2,530	1,400	9,560	27.5
Middle R. near Indianola	502	Apr. 17, 1945	3,640	6,820	67,000	133
		June 20, 1946	2,270	8,820	54,100	108
South R. near Ackworth	475	Apr. 17, 1945	4,720	9,080	116,000	244
		June 18, 1946	5,660	8,700	133,000	280
Whitebreast Cr. near Knoxville	380	June 20, 1946	6,500	2,920	51,200	135
		June 5, 1947	11,200	7,870	238,000	626
MISSOURI RIVER BASIN						
Boyer R. at Logan	810	Apr. 23, 1945	11,600	23,100	723,000	893
		July 18, 1945	6,850	13,100	242,000	299
Waubonsie Cr. near Bartlett	30	May 28, 1947	40.4	37,900	41,300	1,380
		June 4, 1947	446	276,000	332,000	11,100
Nishnabotna R. above Hamburg	2,800	Apr. 19, 1945	2,240	3,330	20,100	7.2
		May 23, 1945	20,000	5,720	309,000	110
		June 27, 1945	7,160	23,500	454,000	16.2
		May 29, 1947	5,660	16,600	254,000	90.7
		June 3, 1947	9,290	7,330	184,000	65.7
East Nishnabotna R. at Red Oak	890	May 22, 1945	15,700	8,020	340,000	382
		May 22, 1945	11,320	9,600	293,000	329
		May 23, 1945	5,480	3,880	57,400	64.5
		May 29, 1947	3,440	9,920	92,100	103
		June 2, 1947	13,900	6,880	258,000	290
Nodaway R. at Clarinda	740	June 5, 1947	14,700	10,400	413,000	558
Chariton R. near Centerville	727	Apr. 18, 1945	7,040	920	17,500	24.1
		June 20, 1946	18,000	880	42,800	58.9
Thompson R. at Davis City	702	Apr. 17, 1945	8,840	4,110	98,100	140
Maple R. at Mapleton	661	July 18, 1945	4,350	7,030	82,600	125

* Incl. slough.

† Determined by current-meter measurement, except as noted.

‡ Discharge determined from stage-discharge relation.

§ Sediment discharge at time of sampling only, not indicative of average conditions.

the stream channels where it is picked up and transported to the sea, being irretrievably lost from the land. Examination of the column giving sediment discharge in tons per day well illustrates the volumes of sediment that streams in flood are capable of transporting.

The average rate at which sediment is removed from a watershed may be regarded as a measure of the need for soil conservation in that area and the last column in Table 9 gives this rate. It will be noted that the figures are not large throughout the Iowa-Cedar, Skunk, and Des Moines River Basins, except for North, Middle, and South Rivers and Whitebreast Creek, tributaries to Des Moines River. On the other hand, the rates are much larger generally for streams tributary to Missouri River, reaching the astounding figure of 11,100 tons per square mile for Waubonsie Creek near Bartlett. It is believed that this figure is exceptional and possibly due to the collapse of a portion of the material that forms the stream banks above the gage.

Of more general interest to the soil conservationist and others are the figures of annual sediment discharge, for they are an index of both the yearly soil losses and the rates at which reservoirs on the stream would silt up. Table 10 presents data on the sediment loads carried by the Des Moines, Cedar, and Iowa Rivers. These figures are given for water years (October 1 to September 30), with averages where two or more years of record are available. Figures are also included for the month of June 1947 to show the extremely large quantities of sediment that flood waters can remove in a short space of time.

The figures of annual sediment discharge are given in tons. They are converted into acre-feet of space that the sediment would occupy if it were to settle in a reservoir and into equivalent uniform depth in inches of soil removed from the watershed; the first by using the assumption that sediment deposited under water will weigh 60 pounds per cubic foot in place, a figure arrived at on the basis of several experiments by the Iowa Institute of Hydraulic Research; the second on the assumption that the soil in place weighs 100 pounds per cubic foot. The figure of acre-feet deposited under water is a measure of the rate at which a reservoir may be expected to fill with sediment, reducing and finally destroying its usefulness for the storage of water. The depth of soil removed from a watershed is an indication of the rate at which degradation of the area is occurring and a measure of soil loss.

Simply as a matter of general interest, figures are given also

Table 10

Some sediment loads in midwestern and other rivers

Stream	Water Year (Oct. to Sept.)	Mean Flow (cfs)	Sediment load (million tons)	Parts per million (by wt.)	Equivalent acre-feet	Equivalent Inches over Drain. Area	Fall (ft./mile)
Iowa River at Iowa City, Iowa	1943-44	2,796	2.618	960	2,000	0.0069	
(3,230 sq. mi.)	1944-45	2,033	1.026	504	783	.0027	
	1945-46	1,905	1.252	658	955	.0033	2.16
Three year average		2,245	1.632	750	1,250	.0043	
Month of June	1947	16,500	1.3857	1,150	1,060	.0037	
Cedar River at Cedar Rapids, Iowa	1943-44	3,666	1.000	273	763	.0013	
(6,640 sq. mi.)	1944-45	4,682	.962	205	734	.0012	
	1945-46	3,568	.812	228	620	.0010	1.65
Three year average		3,972	.925	232	706	.0012	
Des Moines River below Raccoon River	1944-45	6,406	5.181	810	3,960	.0045	
(9,770 sq. mi.)	1945-46	4,083	3.329	815	2,540	.0029	1.5
Three year average		5,245	4.255	812	3,250	.0037	
Month of June	1947	32,070	3.267	1,020	2,490	.0028	
Colorado River at Grand Canyon (137,800 sq. mi.)	Mean — 16 years	17,400	200.0	11,500	153,000	.0123	4.05
Missouri River at Omaha, Nebr. (322,800 sq. mi.)	Mean — 14 years	23,470	100.0	4,260	76,300	.0027	1.44
Mississippi River at Dubuque, Iowa (81,600 sq. mi.)	Mean — 1943-45	58,000	7.67	132	5,850	.0008	.35
Yellow River, in China	Mean —	68,000	1,470	21,600	1,120,000	.043	1.11
Flood of Aug.	1934	494,000		105,000			1.40

for Colorado River at Grand Canyon, above Lake Mead; Missouri River at Omaha, Nebr.; Mississippi River at Dubuque, Iowa; and Yellow River in China. The Colorado River is definitely the champion in matters of sediment transportation in North America, but far surpassed by "China's Sorrow." The Colorado is plowing off its watershed over a hundredth of an inch of soil per year. Probably only a small part of that loss, however, is soil of present value to man, for little of the basin is cultivated. The Missouri River is removing about one-fifth as much soil per year as the Colorado, but a considerably greater portion of that soil is lost from cultivated areas. The Iowa River at Iowa City and the Des Moines River at Des Moines are removing considerably more soil per year from each square mile of their watersheds than is the Missouri River at Omaha and the soil in Iowa comes from a highly cultivated region and represents a real loss to agriculture.

Conclusion

The available history of floods in Iowa during the years of Statehood reflects most interesting information and lessons of value. Those floods have cost Iowa many casualties and many millions of dollars. Floods of greater intensity seem to have been more numerous in recent years than formerly. Such a seeming increase in flood conditions, however, may be more apparent than real. Nevertheless, the people of Iowa are becoming increasingly flood conscious and with this an awareness of not only the existence of the flood menace but of the suggested methods of alleviating and controlling flood damages insofar as humanly possible.

In June 1948, the President of the United States signed a Civil Functions appropriation bill carrying $573,000,000 which had been appropriated by the 80th Congress, Second Session, for the Department of the Army to work on flood control and navigation projects in the United States. In accordance with flood control acts, funds for soil conservation work are provided in other appropriations to the Department of Agriculture. These acts came almost exactly one year after the floods of June 1947 in Iowa and the appropriations included for the Corps of Engineers alone $3,888,100 for flood control of rivers in Iowa or bordering the State. In addition to these appropriations, Iowa will benefit by $12,000,000 in appropriations that were made on a regional basis to the Department of the Army for levee and channel improvement work on the Mississippi and Missouri Rivers.

In reporting on the comparisons of hydrologic facts and recognition of the associated problems through expenditures of public funds, it is emphasized that industrial as well as agricultural expansion and progress in Iowa during and since World War II provides ample proof that water in general, and water courses in particular, are of strategic importance. The waters of this State along with the land are the most valuable resources to be conserved for most beneficial use. The waters are, at times, a destructive agent against which protection is needed. Stream-flow records serve the same purpose for orderly development with respect to water resources that mapping, land-line surveys, and recording the transfer of title have accomplished for private and public benefit with respect to land resources. Records of stream flow and siltation should be looked upon in the same light as the title records of land which are maintained and kept in every county courthouse in Iowa. Unfortunately, it has been in only relatively recent years that comprehensive and systematic inventories of the water resources of Iowa have been initiated and the records preserved in a form for ready practical use.

As further measurements in each succeeding year may be expected to throw new light on data previously published, it should be borne in mind that some of the results of measurements of runoff and suspended sediment loads as presented herein are obtained from preliminary computations and are, therefore, subject to possible revision. Furthermore, hydrological records, especially those of short duration, are usually not to be considered final or conclusive — each additional year's record when used in conjunction with previous records adds new information and new value to the total record and the proper evaluation of the flood-producing potentialities of a basin or a state.

In any event, the present situation with respect to erosion and flood damage presents a challenge and calls for the full cooperation of the people and the best efforts of all agencies, local, state, and federal, the combined efforts of which are needed in an adequate and proper program of land and water management.

Acknowledgment

The principal data from which this paper was prepared were obtained from the official files of the State and Federal cooperative facilities of the United States Geological Survey district office in Iowa City and from information gathered from a number of sources as cited, such as the Weather Bureau. The writer is also indebted to the Survey office staff and many individuals engaged in the collection of or interested in hydrologic records in Iowa. Special acknowledgment is due M. C. Boyer, research engineer, Iowa Institute of Hydraulic Research, and H. G. Hershey, Director and State Geologist of Iowa, for their valuable assistance.

Bibliography

1. "A Survey of Iowa Floods," by Floyd A. Nagler, Bull. of the Assoc. State Eng. Societies, Vol. 3, No. 4, October 1928.
2. The Monthly Review of Iowa Weather and Crop Service, later Climatological Data, United States Weather Bureau.
3. "An Analysis of Unusual Precipitation Records in Iowa," by F. T. Mavis, and J. W. Howe, Journ. of the Amer. Water Works Assoc., Vol. 27, No. 2, February 1935.
4. "Generalized Estimates of Maximum Possible Precipitation over the United States East of the 10th Meridian," Hydrometeorological Rept. No. 23, United States Weather Bureau.
5. "Floods in Iowa," by Jacob A. Swisher, Iowa Journ. of History and Politics, Vol. XLV, No. 4, October 1947.
6. "Rainfall and Runoff on Small Areas," by Quincy C. Ayres, Bull. of Assoc. State Eng. Soc., Vol. 15, No. 4, October 1940.
7. "Iowa: The Rivers of Her Valleys," by William J. Petersen, published by the State Historical Society of Iowa, 1941.
8. "Maximum Discharge at Stream-Measurement Stations Through December 31, 1941," by Gordon R. Williams and Lawrence C. Crawford, Water-Supply Paper No. 847, U. S. Geological Survey, 1940.
9. "Possible and Probable Future Floods," by W. P. Creager, Civil Engineering, Vol. 39, No. 11, November 1939.
10. "Unusual Events and Their Relation to Federal Water Policies," by W. G. Hoyt, Proc. Am. Soc. C. E., Vol. 88, No. 2, 1942.
11. "Drainage and Control by Erosion," by Thomas Radford Agg, The Construction of Roads and Pavements, Chapt. 3, 1940.
12. Surface Water Supply Papers; U. S. Geological Survey.
13. "Summaries of Yearly and Flood Flow Relating to Iowa Streams, 1873-1940," Water-Supply Bull. No. 1, Iowa Geological Survey, 1942.
14. "A Study of Methods Used in Measurement and Analysis of Sediment Loads in Streams, Reports 1-9," prepared jointly by U. S. Geological Survey, Corps of Engineers, Bureau of Reclamation, Office of Indian Affairs, Tennessee Valley Authority, Department of Agriculture, and Iowa Institute of Hydraulic Research: published by U. S. Army Engineers District Office, St. Paul, Minnesota.

U. S. GEOLOGICAL SURVEY
HYDRAULICS LABORATORY
UNIVERSITY OF IOWA
IOWA CITY, IOWA