

# Magnitude and Frequency of 1993 Flood Volumes in Upper Mississippi River Basin

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Previous maximum flows on many streams and rivers were exceeded during the flood of 1993 in the upper Mississippi River Basin. Not only were peak discharges exceeded at many streamflow-gaging stations, but also flood volumes were significantly higher than previous maximums. Rainfall amounts that were greater than 127 cm (50 in.) were recorded in parts of Kansas, Missouri, and Iowa from April 1 through September 30, 1993. As a result of the excessive rainfall, 53 of the 60 stations discussed had flow volumes greater than twice the mean flow volume for April through September. The Mississippi River at St. Louis, Missouri, remained above flood stage for 144 days from April 1 to September 30, 1993, compared with 81 days during the spring and summer flood of 1973. Of the 60 stations, 24 recorded new maximum 3-day flood volumes, and 47 recorded new maximum 120-day flood volumes. This indicates that the flooding of 1993 is significant with respect to its long duration and magnitude of flow. The same aspect is indicated in the frequency analysis of the 1993 flood. During the 1993 flood, the 100-year 3-day flows were exceeded at 22 stations, and the 100-year 120-day flows were exceeded at 43 stations.

A common definition of the word "flood" is the temporary overflow of water from a river onto adjacent lands not normally covered by water. In 1993, millions of hectares of land in the upper Mississippi River Basin were flooded for weeks and months as persistent heavy rain fell over the Missouri and the Mississippi river basins. Record or near-record flood discharges were recorded at streamflow-gaging stations in North Dakota, South Dakota, Minnesota, Wisconsin, Nebraska, Iowa, Illinois, Kansas, and Missouri. The intense rainfall caused not only peak flood discharges but also sustained large flood volumes that resulted in more than 420 counties in the nine-state area declared federal disaster areas.

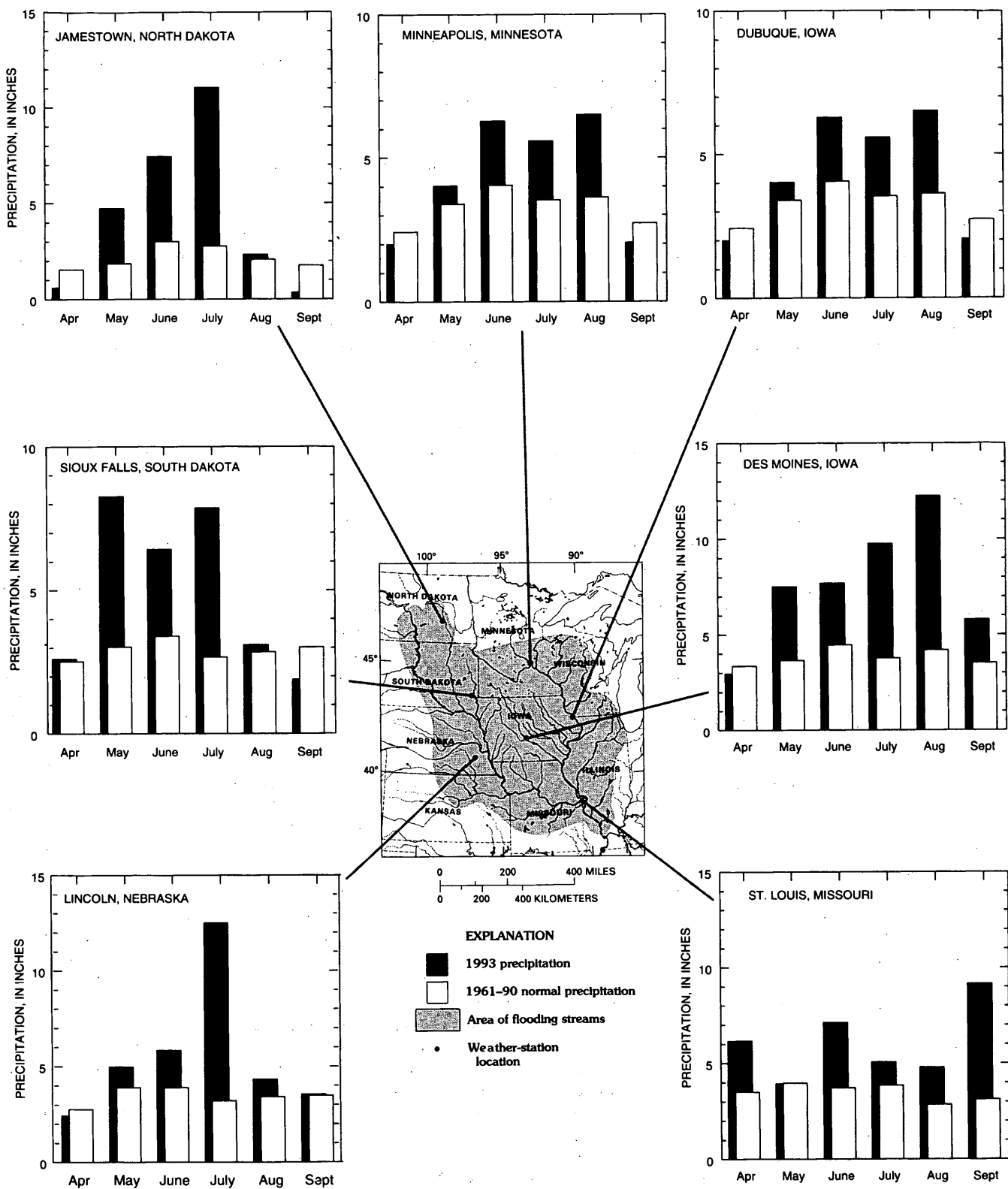
From April 1 through September 30, 1993, the sustained high flows transported enormous amounts of sediment and agricultural chemicals to the Gulf of Mexico, caused severe river bank erosion and instability, and resulted in scour of river channels at bridge crossings. The Missouri and Mississippi rivers upstream from St. Louis, Missouri, were closed to all barge traffic. Numerous Interstates and state highways also were closed for weeks until the flood waters finally receded. The Iowa River at Wapello, Iowa, (Site 19), was above flood stage for 164 days. The high flows contributed to severe scour problems at State Highway 99 crossing at Wapello, and the bridge was closed to traffic for weeks. Like the Iowa River, flood stage was exceeded 159 days at the Minnesota River near Jordan, Minnesota (Site 5). The duration of the flood on the Mississippi River at St. Louis, Missouri, (Site 59) was 144 days compared with 81 days during the spring and summer flood of 1973.

Flow volume is an important aspect in the analysis and description of flooding in the upper Mississippi River Basin. At streamflow-gaging stations throughout the upper Mississippi River Basin, record or near-record flow peaks and volumes were observed during the April 1 through September 30, 1993, flood. Record flow peaks at 154 selected streamflow-gaging stations were described in a work by Parrett et al. (1). Because flow volumes may be defined by several different characteristics, the flow-volume data require more extensive computations than do flow peak data. Only data for the 60 selected streamflow-gaging stations are presented in this report. The highest mean-daily discharge for selected consecutive  $n$ -day periods was computed at the 60 stations. At most stations, the volumes exceeded the previous maximums and the computed 100-year discharges for a given  $n$ -day period. For the 120-day consecutive period, the 1993 flow volumes exceeded the previous maximum volume at 47 of the 60 stations. The 100-year recurrence interval was exceeded at 43 of 60 stations for this same 120-day period.

## PRECIPITATION, APRIL 1 THROUGH SEPTEMBER 30, 1993

From April 1 through September 30, 1993, record or near-record precipitation was measured in the upper Mississippi River Basin. More than 127 cm of rain fell in parts of Iowa, Missouri, and Kansas from April to September. The heaviest rain fell in eastern Kansas; in Missouri, from southwest to northeast; and in the eastern two-thirds of Iowa. Rainfall totals of 76 cm or more were measured in most places; a maximum of 132.6 cm of rain fell in east-central Missouri. Rainfall during this period followed above-normal precipitation that had fallen during the winter and early spring.

An unusual characteristic of the chronological distribution of the extreme rainfall is that the heaviest rain at any particular location could have fallen in any month from April 1 through September 30, 1993. To illustrate the distribution of precipitation in the general area of flooding, the 1993 and normal (1961 to 1990) monthly precipitation totals of seven selected National Weather Service precipitation stations are shown in Figure 1. At Sioux Falls, South Dakota, the largest monthly recorded rainfall was 21.0 cm in May. However, near the mouth of the Missouri River at St. Louis, Missouri, the largest monthly rainfall total was in September. The rainfall total for July at Lincoln, Nebraska, was 31.8 cm, or 3.9 times the normal rainfall. This distribution and magnitude of rainfall in the flood area sustained the high stages and discharge volumes of runoff on many streams and rivers, especially on the Missouri and the Mississippi river main stems. A general overview of the excessive precipitation during spring and summer 1993 is provided in a work by Wahl et al. (2).



**FIGURE 1** Monthly precipitation for April through September 1993 and 30-year monthly normals (April through September 1961 to 1990) at seven weather stations in upper Mississippi River Basin (data supplied by National Weather Service).

## FLOOD VOLUMES, APRIL 1 THROUGH SEPTEMBER 30, 1993

One of the most significant aspects of the 1993 floods in the upper Mississippi River Basin was the volume of runoff in area streams and rivers. A summary of the flood volumes at selected streamflow-gaging stations from April 1 through September 30 is presented in this report. The magnitude, frequency, and duration of the volume of runoff are discussed.

### Magnitude and Duration of Volume of Runoff

The magnitude and duration of the 1993 flood volumes for April through September can be appreciated by comparing them with the mean runoff for the same period and with the previous maximum runoff for the period of record at each streamflow-gaging station. For informational purposes, the 1993 flows also may be compared with the mean-annual flows for the period at each station.

The runoff volumes from April through September 1993 were greater than the mean for the same period at the 60 stations. In fact, of the 60 stations, 53 had flow volumes that were greater than twice the mean. The ratio of the 1993 runoff volume to the mean flow volume at each station ranged from 1.18 for the Flambeau River near Bruce, Wisconsin, (Site 7) to 8.75 for the Rock River at Rock Valley, Iowa (Site 35). The location of these stations in the general flood area is shown in Figure 2.

The runoff volume from April through September also was compared with the period of record mean-annual runoff or the volume of runoff that would normally be expected in a year. Of the 60 stations, only 4 had runoff volumes that were less than the mean runoff volume for an entire year, and 9 had volumes of flow that were greater than four times the mean-annual runoff. Graphs of the monthly mean runoff from April through September 1993 and the mean monthly runoff for the period of record for seven streamflow-gaging stations are shown in Figure 3. During August, the flows on the James River near Scotland, South Dakota, (Site 33) were 18 times the August mean flow.

Excessive flow volumes also are reflected in the number of days the river remained above flood stage or at flood stage. Of a possible 183 days from April 1 through September 30, 1993, 17 stations were above flood stage for more than 90 days. In addition to the flood of 1993, the flood of 1973 was a significant event on the main stem of the Mississippi River at St. Louis. In a comparison of the floods of 1973 and 1993, the 1973 event had flows above flood stage for 81 days, and the flood of 1993 had flows above flood stage for 144 days.

The significance of the 1993 flow volumes also may be indicated by determining the period of  $n$  consecutive days in 1993 that had the highest accumulated flow and by comparing this flow (the 1993 annual  $n$ -day flow) with the previous maximum  $n$ -day flow for the period of record. This comparison for the 1993 flow volume and the previous maximum for the period of record for 3-, 7-, and 30-day periods are listed in Table 1. Comparisons of the 60-, 90-, and 120-day periods for 1993 flow volumes and previous maximums are listed in Table 2. In general, the longer the  $n$ -day period, the more significant the 1993 flow was when compared with previous maximums, except along rivers downstream of reservoirs that were below normal pool elevation and where floodwater was stored intentionally. For example, the streamflow-gaging station on the Blue Earth River near Rapidan, Minnesota, (Site 3) had a 3-day flow

of slightly less than one-half the previous 3-day maximum; but for the 120-day period, the 1993 flow was 1.69 times the previous maximum. Of the 60 stations analyzed in this report, 24 had new maximum 3-day flows (Table 1), and 47 had new maximum 120-day flows (Table 2).

### Frequency of Volume of Runoff

Recurrence interval or probability of exceedance also can be used to quantify the magnitude of a specific flood event (Tables 1 and 2). The statistical procedure used here to compute recurrence intervals for peak discharges also is applicable to flow analysis for any specific highest mean-daily discharge for  $n$ -day consecutive periods. The 100-year recurrence interval was exceeded at 22 stations for a 3-day duration (Table 1) and at 43 stations for a 120-day duration (Table 2). Comparison of the 1993  $n$ -day flow with respect to the computed 100-year value for each  $n$ -day period is shown in Figure 4 for selected stations. In most cases, the 1993 flows exceeded the 100-year flows. The Missouri River at Kansas City, Missouri, (Site 50) 3-day duration flow and the Iowa River at Wapello, Iowa, (Site 19) 120-day duration flow were 1.8 times the 100-year flow.

### EFFECTS OF RESERVOIRS ON FLOODS

The effect of the main-stem reservoirs on the Missouri River in reducing flows is apparent when comparing the recurrence intervals for the 120-day duration at the Nebraska City, Nebraska, (Site 40) streamflow-gaging station to a station farther downstream, such as that at St. Joseph, Missouri, (Site 45). The 120-day flow at Nebraska City has a recurrence interval of 16 years compared with a recurrence interval of 80 years at St. Joseph; this indicates that the less severe flood at Nebraska City was the result of storage of flood waters in upstream reservoirs. However, because of the tremendous amount of inflow below the main-stem reservoirs, the shorter duration 3-day flow at Nebraska City has a 60-year recurrence interval, which is significantly higher than the 16-year recurrence interval for the 120-day value at Nebraska City. The main-stem reservoirs on the Missouri River stored a significant amount of flow from April through September, thus reducing the long duration of flooding downstream from the reservoirs. However, as a result of the magnitude and intensity of storms downstream of the reservoirs, shorter duration flow events were still pronounced and had high recurrence intervals.

An important aspect of the flood of 1993 was the role played by flood-control reservoirs in the upper Mississippi River Basin. Most of reservoirs are on the main stem of the Missouri River and in the Kansas River Basin, which is a major tributary to the Missouri River. Because of storage in the reservoirs in the Kansas River Basin, peak flows from below Tuttle Creek Lake downstream to the mouth of the Kansas River were reduced by 30 percent or more (3).

### SUMMARY

Record high flood flows were observed in nine states in the upper Mississippi River Basin from April 1 through September 30, 1993. In the upper Midwest, sustained high flows caused the halting of barge traffic, closing of highways, and flooding of farmland, which resulted in billions of dollars in damage. The high flows were sustained by storms that produced more than 76.2 cm of rain in Kansas,

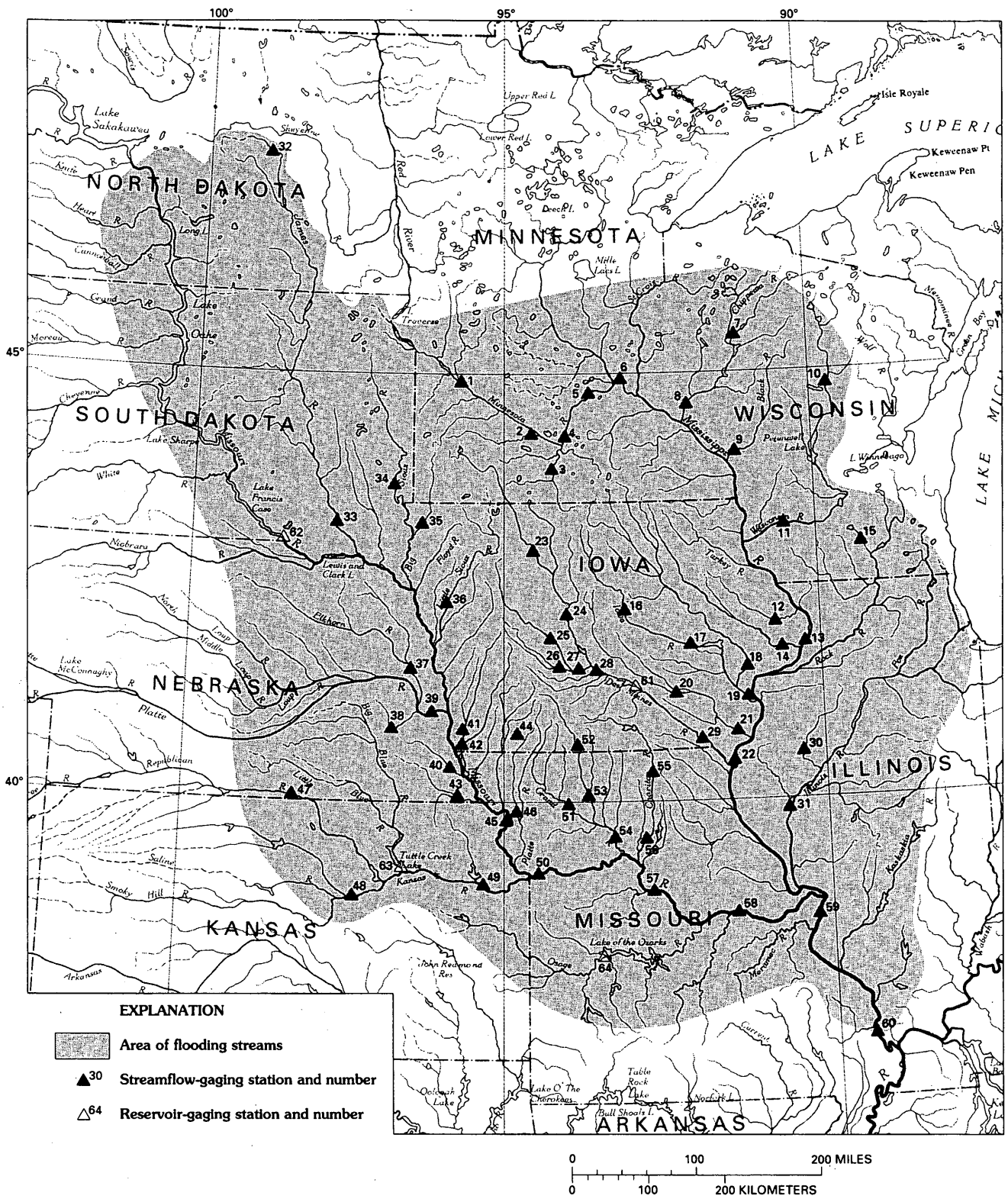
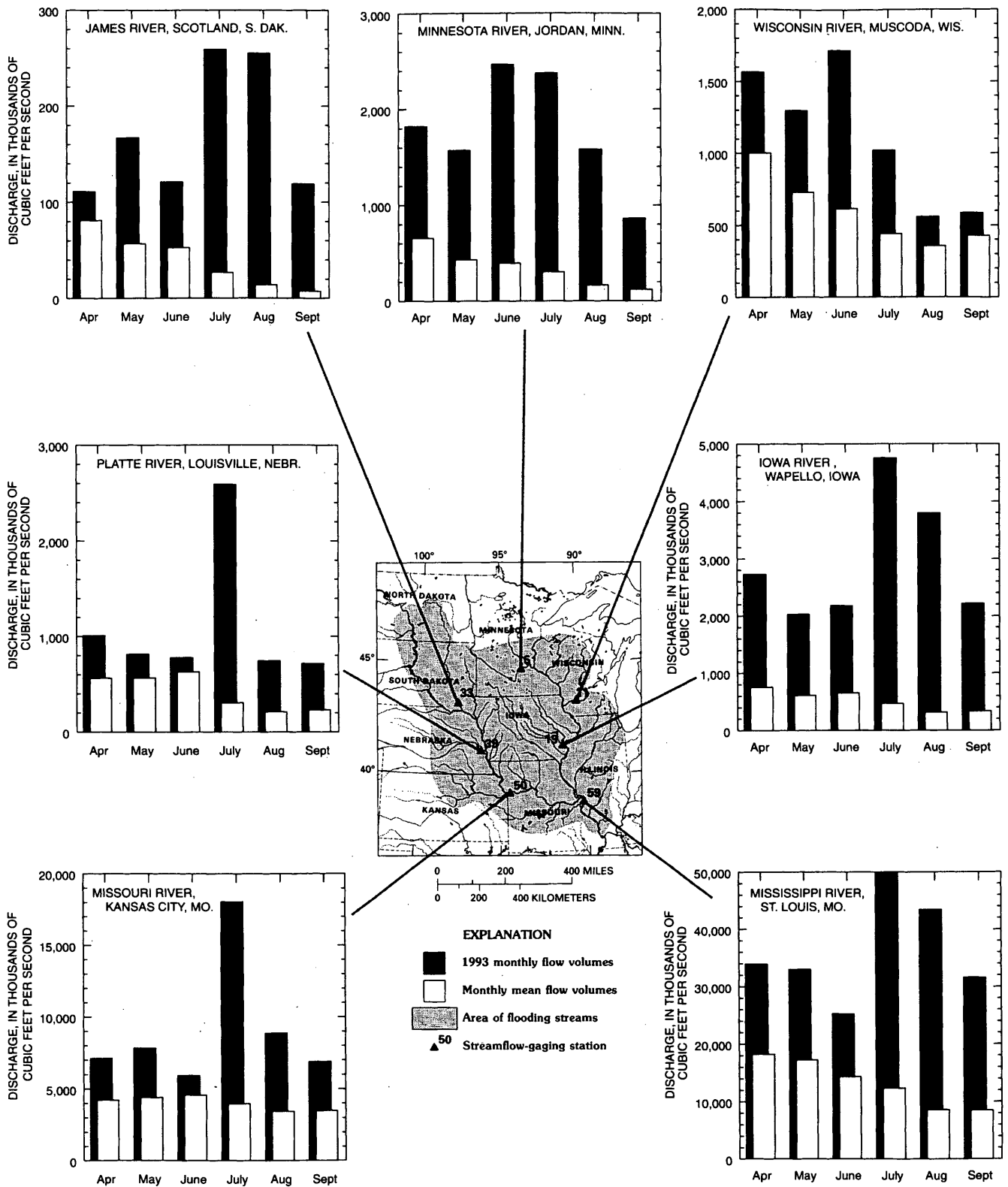
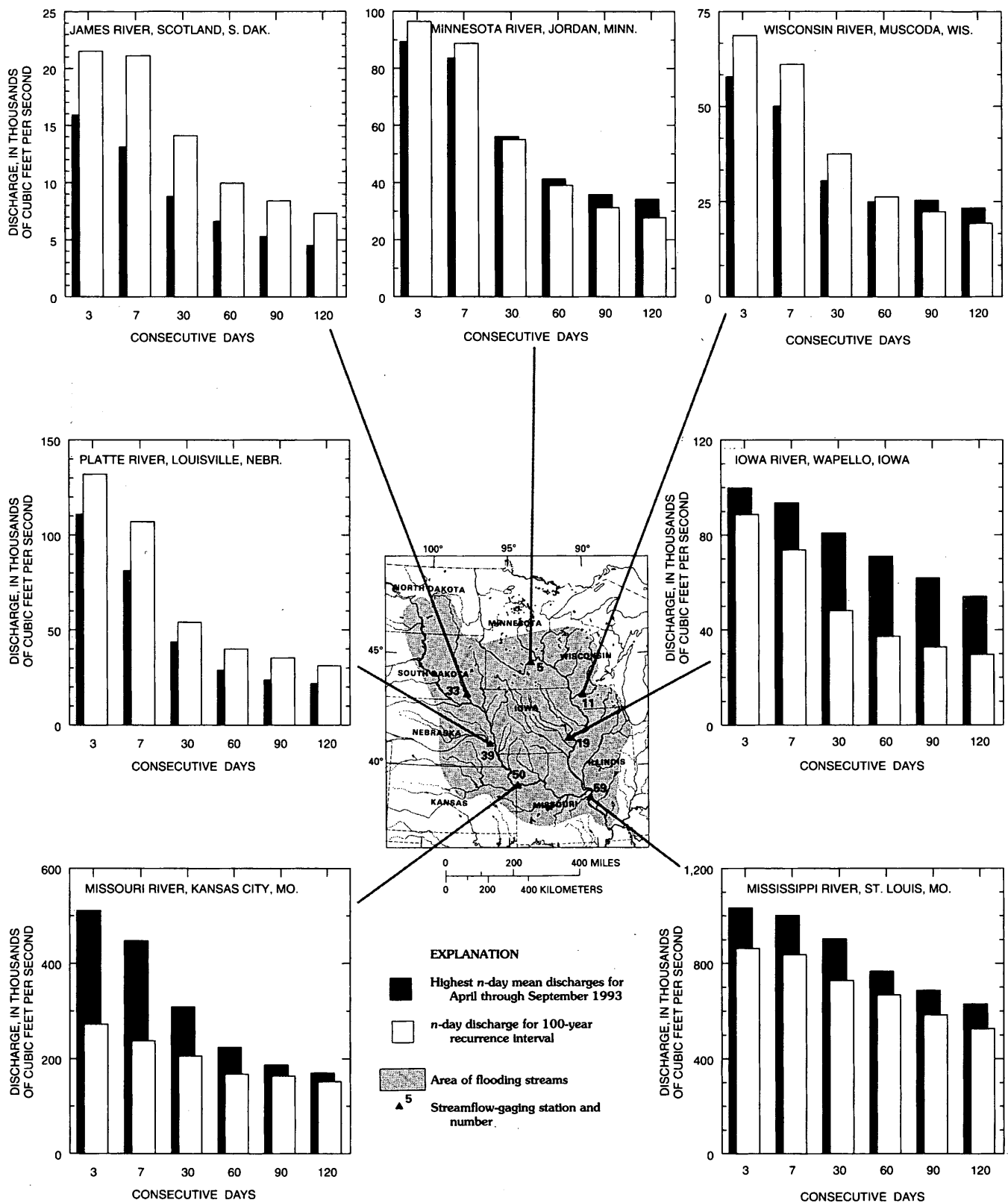


FIGURE 2 Location of selected streamflow-gaging stations and reservoirs in upper Mississippi River Basin.



**FIGURE 3** Monthly mean runoff, April through September 1993, and mean monthly runoff at selected streamflow-gaging stations in upper Mississippi River Basin.



**FIGURE 4** Highest *n*-day mean discharges for indicated number of consecutive days for April through September 1993 and 100-year *n*-day annual discharges at selected streamflow-gaging stations in upper Mississippi River Basin.

**TABLE 1 Magnitude and Frequency of Highest Mean Daily Discharges from 3, 7, and 30 Consecutive Days at Selected Streamflow-Gaging Stations in Upper Mississippi River Basin (POR = Period of Record; RI = Recurrence Interval, Rounded to Nearest 5 Years for 20- to 50-Year RIs and to Nearest 10 Years for 55- to 100-Year RI)**

Site number	Station name and number	3-day values			7-day values			30-day values		
		1993 (m <sup>3</sup> /s)	RI for 1993 (years)	Previous maximum for POR (m <sup>3</sup> /s)	1993 (m <sup>3</sup> /s)	RI for 1993 (years)	Previous maximum for POR (m <sup>3</sup> /s)	1993 (m <sup>3</sup> /s)	RI for 1993 (years)	Previous maximum for POR (m <sup>3</sup> /s)
1	Minnesota River at Montevideo, MN 05311000	305	10	924	286	10	781	238	15	392
2	Cottonwood River near New Ulm, MN 05317000	552	60	683	423	70	515	209	>100	199
3	Blue Earth River near Rapidan, MN 05320000	526	16	1,130	476	17	1,060	344	40	381
4	Minnesota River at Mankato, MN 05325000	2,020	35	2,580	1,880	30	2,410	1,310	60	1,260
5	Minnesota River near Jordan, MN 05330000	2,500	80	3,110	2,340	80	2,800	1,570	>100	1,360
6	Mississippi River at St. Paul, MN 05331000	2,880	30	4,730	2,770	25	4,540	2,380	50	2,830
7	Flambeau River near Bruce, WI 05360500	372	13	440	280	7	384	136	3	232
8	Chippewa River at Durand, WI 05369500	2,090	20	2,910	1,520	14	2,200	689	5	1,070
9	Black River near Galesville, WI 05382000	1,240	>100	1,430	834	80	974	336	80	342
10	Wisconsin River at Rothschild, WI 05398000	1,020	18	1,190	725	13	874	336	7	428
11	Wisconsin River at Muscoda, WI 05407000	1,620	16	2,108	1,400	16	1,810	854	15	1,070
12	Maquoketa River near Maquoketa, IA 05418500	571	15	641	493	>100	414	258	>100	191
13	Mississippi River at Clinton, IA 05420500	6,580	25	8,510	6,520	30	8,290	5,820	65	6,270
14	Wapsipinicon River near DeWitt, IA 05422000	560	25	602	549	70	482	409	>100	308
15	Yahara River near McFarland, WI 05429500	18.8	30	23.6	18.1	25	23.1	16.5	45	20.1

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TABLE 1 (continued)

Site number	Station name and number	3-day values			7-day values			30-day values		
		1993 (m <sup>3</sup> /s)	RI for 1993 (years)	Previous maximum for POR (m <sup>3</sup> /s)	1993 (m <sup>3</sup> /s)	RI for 1993 (years)	Previous maximum for POR (m <sup>3</sup> /s)	1993 (m <sup>3</sup> /s)	RI for 1993 (years)	Previous maximum for POR (m <sup>3</sup> /s)
16	Iowa River at Marshalltown, IA 05451500	448	20	927	384	100	613	251	>100	232
17	Iowa River at Marengo, IA 05453100	913	>100	644	792	>100	546	566	>100	325
18	Cedar River near Conesville, IA 05465500	1,790	40	1,780	1,470	50	1,530	1,210	>100	955
19	Iowa River at Wapello, IA 05465500	2,790	>100	2,260	2,620	>100	1,800	2,260	>100	1,370
20	South Skunk River near Oskaloosa, IA 05471500	538	>100	459	479	>100	375	333	>100	260
21	Skunk River at Augusta, IA 05474000	1,230	>100	1,600	1,030	>100	1,120	762	>100	588
22	Mississippi River at Keokuk, IA 05474500	11,900	>100	9,550	11,700	>100	9,040	10,900	>100	7,450
23	Des Moines River at Humboldt, IA 05474500	454	60	484	426	55	437	347	>100	241
24	Des Moines River near Stratford, IA 054813000	1,070	25	1,450	1,000	40	1,220	795	>100	613
25	North Raccoon River near Jefferson, IA 05482500	412	13	501	361	20	378	217	45	224
26	South Raccoon River at Redfield, IA 05484000	655	>100	423	431	>100	280	161	>100	141
27	Raccoon River at Van Meter, IA 05484500	1,340	>100	907	983	>100	801	496	>100	392
28	Des Moines River below Raccoon River at Des Moines, IA 05485500	2,830	>100	1,550	2,460	>100	1,520	1,590	>100	1,040
29	Des Moines River at Keosauqua, IA 05490500	3,000	>100	1,410	2,940	>100	1,140	2,510	>100	1,020
30	Spoon River at Seville, IL 05570000	773	60	773	599	90	546	258	90	245
31	Illinois River at Valley City, IL 05586100	2,430	5	3,420	2,370	5	3,390	2,040	6	2,770
32	James River near Grace City, ND 064678170	82.6	35	77.6	65.0	25	64.4	27.2	18	22.4

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TABLE 1 (continued)

Site number	Station name and number	3-day values			7-day values			30-day values		
		1993 (m <sup>3</sup> /s)	RI for 1993 (years)	Previous maximum for POR (m <sup>3</sup> /s)	1993 (m <sup>3</sup> /s)	RI for 1993 (years)	Previous maximum for POR (m <sup>3</sup> /s)	1993 (m <sup>3</sup> /s)	RI for 1993 (years)	Previous maximum for POR (m <sup>3</sup> /s)
33	James River near Scotland, SD 06478500	445	45	717	367	30	554	246	30	261
34	Big Sioux River near Dell Rapids, SD 06481000	361	14	865	294	17	577	198	40	194
35	Rock River near Rock Valley, IA 06483500	487	15	840	386	20	602	286	>100	182
36	Little Sioux River at Correctionville, IA 06606600	529	25	717	476	25	596	347	>100	275
37	Elkhorn River at Waterloo, NE 06800500	661	9	1,950	510	11	1,060	330	30	336
38	Salt Creek at Lincoln, NE 06803500	484	60	325	286	80	174	98.0	40	86.8
39	Platte River at Louisville, NE 06805500	3,110	50	2,860	2,270	35	2,320	1,220	40	1,180
40	Missouri River at Nebraska City, NE 06807000	5,100	60	4,760	4,340	45	4,700	3,300	60	3,440
41	West Nishnabotna River at Randolph, IA 06808500	356	10	462	254	40	266	186	>100	135
42	Nishnabotna River above Hamburg, IA 06810000	980	>100	1,070	790	>100	692	504	>100	462
43	Big Nemaha River at Falls City, NE 06815000	1,090	80	1,110	778	>100	552	456	>100	221
44	Nodaway River at Clarinda, IA 06817000	454	>100	532	347	>100	300	195	>100	139
45	Missouri River at St. Joseph, MO 06818000	8,710	>100	5,400	7,640	>100	5,350	5,540	>100	4,450
46	Platte River near Agency, MO 06820500	1,360	>100	1,110	969	>100	860	613	>100	395
47	Republican River at Guide Rock, ME 06853020	200	20	400	146	25	247	67.2	13	133
48	Kansas River at Fort Riley, KS 06879100	2,260	>100	1,390	2,030	>100	1,170	1,210	>100	745

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TABLE 1 (continued)

Site number	Station name and number	3-day values			7-day values			30-day values		
		1993 (m <sup>3</sup> /s)	RI for 1993 (years)	Previous maximum for POR (m <sup>3</sup> /s)	1993 (m <sup>3</sup> /s)	RI for 1993 (years)	Previous maximum for POR (m <sup>3</sup> /s)	1993 (m <sup>3</sup> /s)	RI for 1993 (years)	Previous maximum for POR (m <sup>3</sup> /s)
49	Kansas River at LeCompton, KS 06891000	4,700	40	11,100	4,280	80	8,540	2,860	>100	4,370
50	Missouri River at Kansas City, MO 06893000	14,300	>100	7,980	12,500	>100	6,720	8,650	>100	5,400
51	Grand River near Gallatin, MO 06897500	2,210	>100	169	1,650	>100	1,190	980	>100	647
52	Thompson river at Davis City, IA 06898000	588	50	1,000	386	70	577	211	>100	145
53	Thompson River at Trenton, MO 06899500	1,300	80	1,490	1,060	>100	862	543	>100	473
54	Grand River near Sumner, MO 06902000	4,400	>100	4,120	4,060	>100	2,750	2,520	>100	1,930
55	Chariton River at Novinger, MO 06904500	543	35	543	493	50	454	283	100	274
56	Chariton River near Prairie Hill, MO 06905500	818	100	778	756	>100	554	459	>100	420
57	Missouri River at Booneville, MO 06909000	19,500	>100	8,990	17,000	>100	8,370	11,600	>100	6,410
58	Missouri River at Hermann, MO 06934500	19,700	>100	13,900	17,400	>100	12,400	12,200	>100	9,550
59	Mississippi River at St. Louis, MO 07010000	28,900	>100	23,600	28,000	>100	23,000	25,300	>100	19,500
60	Mississippi River at Thebes, IL 07022000	27,100	>100	24,300	26,500	>100	23,700	24,900	>100	20,800

**TABLE 2 Magnitude and Frequency of Highest Mean Daily Discharges from 60, 90, and 120 Consecutive Days at Selected Streamflow-Gaging Stations in Upper Mississippi River Basin (POR = Period of Record; RI = Recurrence Interval, Rounded to Nearest 5 Years for 20- to 50-Year RIs and to Nearest 10 Years for 55- to 100-Year RI)**

Site number	Station name and number	60-day values			90-day values			120-day values		
		1993 (m <sup>3</sup> /s)	RI for 1993 (years)	Previous maximum for POR (m <sup>3</sup> /s)	1993 (m <sup>3</sup> /s)	RI for 1993 (years)	Previous maximum for POR (m <sup>3</sup> /s)	1993 (m <sup>3</sup> /s)	RI for 1993 (years)	Previous maximum for POR (m <sup>3</sup> /s)
1	Minnesota River at Montevideo, MN 05311000	221	25	274	180	30	213	160	50	175
2	Cottonwood River near New Ulm, MN 05317000	144	>100	113	124	>100	81.5	112	>100	68.6
3	Blue Earth River near Rapidan, MN 05320000	286	>100	239	256	>100	183	255	>100	151
4	Minnesota River at Mankato, MN 05325000	988	>100	840	857	>100	641	840	>100	557
5	Minnesota River near Jordan, MN 05330000	1,160	>100	913	1,000	>100	694	958	>100	602
6	Mississippi River at St. Paul, MN 05331000	1,830	45	2,030	1,630	60	1,680	1,560	90	1,450
7	Flambeau River near Bruce, WI 05360500	110	4	169	104	5	146	91.6	5	120
8	Chippewa River at Durand, WI 05369500	538	6	720	510	11	652	451	14	577
9	Black River near Galesville, WI 05382000	224	>100	206	229	>100	161	195	>100	132
10	Wisconsin River at Rothschild, WI 05398000	277	12	325	263	40	259	222	40	212
11	Wisconsin River at Muscoda, WI 05407000	700	40	860	711	>100	720	652	>100	591
12	Maquoketa River near Maquoketa, IA 05418500	181	>100	135	148	>100	114	132	>100	106
13	Mississippi River at Clinton, IA 05420500	4,840	80	5,350	4,510	>100	4,590	4,450	>100	3,980
14	Wapsipinicon River near DeWitt, IA 05422000	328	>100	209	291	>100	186	249	>100	169
15	Yahara River near McFarland, WI 05429500	14.7	80	14.0	13.3	>100	12.8	13.5	>100	11.2

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TABLE 2 (continued)

Site number	Station name and number	60-day values			90-day values			120-day values		
		1993 (m <sup>3</sup> /s)	RI for 1993 (years)	Previous maximum for POR (m <sup>3</sup> /s)	1993 (m <sup>3</sup> /s)	RI for 1993 (years)	Previous maximum for POR (m <sup>3</sup> /s)	1993 (m <sup>3</sup> /s)	RI for 1993 (years)	Previous maximum for POR (m <sup>3</sup> /s)
16	Iowa River at Marshalltown, IA 05451500	225	>100	163	211	>100	144	181	>100	123
17	Iowa River at Marengo, IA 05453100	501	>100	277	437	>100	246	370	>100	215
18	Cedar River near Conesville, IA 05465500	1,080	>100	650	1,010	>100	568	907	>100	498
19	Iowa River at Wapello, IA 05465500	1,990	>100	946	1,730	>100	868	1,510	>100	781
20	South Skunk River near Oskaloosa, IA 05471500	278	>100	179	244	>100	139	210	>100	117
21	Skunk River at Augusta, IA 05474000	644	>100	451	560	>100	398	490	>100	339
22	Mississippi River at Keokuk, IA 05474500	8,760	>100	6,720	7,840	>100	6,240	7,530	>100	5,600
23	Des Moines River at Humboldt, IA 05474500	291	>100	163	254	>100	171	246	>100	151
24	Des Moines River near Stratford, IA 054813000	689	>100	476	588	>100	448	594	>100	392
25	North Raccoon River near Jefferson, IA 05482500	158	50	167	141	60	153	140	>100	131
26	South Raccoon River at Redfield, IA 05484000	117	>100	84.3	97.2	>100	66.9	84.6	>100	64.4
27	Raccoon River at Van Meter, IA 05484500	353	>100	300	311	>100	276	286	>100	234
28	Des Moines River below Raccoon River at Des Moines, IA 05485500	1,210	60	848	1,050	35	812	983	40	731
29	Des Moines River at Keosauqua, IA 05490500	1,900	>100	868	1,600	>100	773	1,410	>100	736
30	Spoon River at Seville, IL 05570000	181	>100	162	152	>100	138	129	>100	125
31	Illinois River at Valley City, IL 05586100	1,860	8	2,540	1,630	8	2,160	1,600	14	1,840

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TABLE 2 (continued)

Site number	Station name and number	60-day values			90-day values			120-day values		
		1993 (m <sup>3</sup> /s)	RI for 1993 (years)	Previous maximum for POR (m <sup>3</sup> /s)	1993 (m <sup>3</sup> /s)	RI for 1993 (years)	Previous maximum for POR (m <sup>3</sup> /s)	1993 (m <sup>3</sup> /s)	RI for 1993 (years)	Previous maximum for POR (m <sup>3</sup> /s)
32	James River near Grace City, ND 064678170	15.8	17	11.6	11.0	16	7.90	8.37	15	5.96
33	James River near Scotland, SD 06478500	186	35	217	148	30	180	126	30	152
34	Big Sioux River near Dell Rapids, SD 06481000	131	40	134	109	45	110	105	60	91.6
35	Rock River near Rock Valley, IA 06483500	226	>100	129	183	>100	129	157	>100	113
36	Little Sioux River at Correctionville, IA 06606600	308	>100	226	252	>100	191	242	>100	181
37	Elkhorn River at Waterloo, NE 06800500	228	35	279	187	25	286	174	30	243
38	Salt Creek at Lincoln, NE 06803500	60.8	45	56.0	45.1	40	48.2	38.1	40	41.2
39	Platte River at Louisville, NE 06805500	806	30	1,090	661	20	1,040	605	25	913
40	Missouri River at Nebraska City, NE 06807000	2,600	45	2,830	2,260	20	2,800	2,060	16	2,600
41	West Nishnabotna River at Randolph, IA 06808500	133	>100	98.0	112	>100	84.3	102	>100	75.9
42	Nishnabotna River above Hamburg, IA 06810000	358	>100	276	308	>100	206	271	>100	169
43	Big Nemaha River at Falls City, NE 06815000	251	>100	177	203	>100	151	170	>100	124
44	Nodaway River at Clarinda, IA 06817000	116	>100	75.6	97.4	>100	59.9	83.7	>100	57.7
45	Missouri River at St. Joseph, MO 06818000	4,060	>100	3,530	3,440	90	3,470	3,050	80	3,220
46	Platte River near Agency, MO 06820500	356	>100	209	270	>100	170	226	>100	161
47	Republican River at Guide Rock, ME 06853020	45.1	9	116	38.1	9	99.1	29.4	8	99.1

(continued on next page)

TABLE 2 (continued)

Site number	Station name and number	60-day values			90-day values			120-day values		
		1993 (m <sup>3</sup> /s)	RI for 1993 (years)	Previous maximum for POR (m <sup>3</sup> /s)	1993 (m <sup>3</sup> /s)	RI for 1993 (years)	Previous maximum for POR (m <sup>3</sup> /s)	1993 (m <sup>3</sup> /s)	RI for 1993 (years)	Previous maximum for POR (m <sup>3</sup> /s)
48	Kansas River at Fort Riley, KS 06879100	935	>100	610	778	>100	501	664	>100	423
49	Kansas River at LeCompton, KS 06891000	2,100	>100	2,830	1,740	>100	2,130	1,490	>100	1,820
50	Missouri River at Kansas City, MO 06893000	6,270	>100	4,400	5,240	>100	4,400	4,760	>100	4,170
51	Grand River near Gallatin, MO 06897500	554	>100	344	409	>100	272	342	>100	215
52	Thompson river at Davis City, IA 06898000	122	>100	78.4	92.1	>100	70.8	77.3	>100	59.1
53	Thompson River at Trenton, MO 06899500	311	>100	251	240	>100	214	202	>100	174
54	Grand River near Sumner, MO 06902000	1,470	>100	1,090	1,110	>100	890	938	>100	725
55	Chariton River at Novinger, MO 06904500	181	50	163	151	60	147	130	>100	124
56	Chariton River near Prairie Hill, MO 06905500	278	80	263	233	80	227	191	80	193
57	Missouri River at Booneville, MO 06909000	8,540	>100	5,680	7,170	>100	5,100	6,360	>100	4,930
58	Missouri River at Hermann, MO 06934500	9,770	>100	8,650	8,740	>100	7,500	7,810	>100	6,640
59	Mississippi River at St. Louis, MO 07010000	21,400	>100	18,800	19,200	>100	17,200	17,600	>100	15,300
60	Mississippi River at Thebes, IL 07022000	21,700	>100	20,100	19,500	>100	18,600	17,900	>100	16,700

Missouri, and Iowa; some places received more than 127 cm from April through September. In July, Lincoln, Nebraska, recorded 31.8 cm of rain, or 3.9 times its normal rainfall for the month.

The flood runoff or volume that resulted from the excessive rainfall can be quantified by comparing the 1993 flood volumes at selected streamflow-gaging stations with the mean runoff for the period of record of each station. Comparisons also may be made by determining the highest mean discharges or accumulated flows for periods of  $n$  consecutive days ( $n$ -day values) and by comparing these values with previous maximums or by determining recurrence intervals for the 1993  $n$ -day values from station records. For the 60 stations included in this report, 53 recorded flow volumes that were greater than twice the mean for the April to September period. In fact, 9 of the 60 stations had flow volumes that were four times the mean-annual flow. At 47 of the 60 stations, the magnitude of the 1993 flood volumes was significantly greater than the previously

recorded maximums for 120-day volumes. Frequency analysis of the historical or period of record flows also indicated that the 100-year flood volume for the 120-day period was exceeded at 43 of the 60 stations in 1993. At the Iowa River streamflow-gaging station at Wapello, Iowa, the 1993 flood volume was 1.8 times the 100-year flood volume.

## REFERENCES

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3. Perry, C. A. *Effects of Reservoirs on Flood Discharges in the Kansas and Missouri River Basins*. U.S. Geological Survey Circular 1120-E, 1994.