For the month of July (Plate 13), of the areas within the Rock Island District, Iowa had the highest totals. Eastern and central Iowa recorded up to 14 inches. The western part of the state had from 6 to 14 inches. Southern Minnesota and southern Wisconsin had from 6 to 10 inches and northern Missouri recorded between 6 and 14 inches of rain.

The rainfall totals for August are shown on Plate 14. In Iowa, the totals ranged from 4 to 14 inches, with the heaviest occurring in the northeastern part of the state. In Illinois, the totals ranged from 4 to 6 inches. Wisconsin's totals were about 4 inches. Minnesota recorded between 4 and 8 inches, and Missouri had from 4 to 8 inches.

IV. Mississippi River Basin

A. Main Stem Basin Description

The Mississippi River drains an area of 79,200 square miles at its upstream end of the Rock Island District at Guttenburg, Iowa, and has a total drainage area of 137,500 square miles at Lock and Dam 22, Saverton, Mo., the downstream limit of the District. Plate 1 shows the District's drainage area. Table 5 summarizes the drainage areas of the major tributaries and adjacent inflows contributing to each pool within the District. The slope of the Mississippi River between St. Anthony Falls at Minneapolis, Minn., downstream to its confluence with the Missouri River averages approximately 6 inches per mile except at the Rock Island-LeClaire Rapids in Pools 14-15 and the Des Moines Rapids in Pool 10, where the low water slope prior to construction of the pools was approximately 1.5 feet per mile. Topography near the pools is generally characterized by high bluffs and rolling hills.

The climate is variable at this junction where various air masses cross the continent. The weather is subject to change from cold, dry Arctic air masses in the winter to hot, dry air masses from the desert southwest in the summer. In addition, the area may be affected by mild Pacific Ocean air that has lost considerable moisture crossing the mountains, by cool Canadian air or by warm moist air from the Gulf of Mexico. The seasons also vary from year to year. The spring and fall seasons are more noted for the rapid changes from one type of air mass to another, and it is normally during these seasons, when most of the precipitation occurs. The summer of 1993 was an exception to this norm.

Major historical floods have resulted from a combination of snow melt and heavy general rains over the upper Mississippi River basin. The mean annual runoff of the Mississippi River at Lock and Dam 20 is 7.0 inches. This is equivalent to 49,279,000 acre-feet from 134,300 square miles of drainage area. The infiltration rate over the watershed is approximately 0.1 inch/hour. The mean annual runoff fluctuates from year to year.

B. Main Stem Hydrology/Hydraulics

1. Description of Flooding

The flooding on the Mississippi River was the most devastating in terms of property loss, disrupted businesses and personal trauma (Photo 7) of any flood in the history of the United States. Millions of acres of farmland were under water for weeks during the growing season. Damaged highways and roads disrupted overland transportation throughout the flooded region.

The river was closed to navigation for several weeks. The banks and channels of the Mississippi River were severely eroded in many reaches. In addition to the erosion of the river, erosion of valuable topsoil was a major problem. The extent and duration of the flooding caused numerous levees to fail. Every gaging station on the Mississippi below Lock and Dam 15 experienced a new flood of record. Above Lock and Dam 15, the 1993 Flood was surpassed by only one other event. A summary of the top five floods of record for the gaging stations along the Mississippi River main stem from Lock and Dam 11 downstream to Lock and Dam 22, is shown in Table 6.

Table 5
Drainage Area Inflows Into Mississippi River Pools

Pool Number	Stream Name	Mississippi River Mile above Ohio River	Drainage Area @ Gage (sqmi)	Drainage Area at L/D (sqmi)
10				79,600
11	Turkey	608.1	1,545	
11	Grant	593.2	267	
11	Platte	588.4	142	
11	Ungaged		546	
L & D 11	Mississippi River	583		82,100
12	Galena	563.4	125	
12	Ungaged		275	
L & D 12	Mississippi River	556.7		82,500
13	Maquoketa	548.6	1,553	
13	Apple	545.1	247	
13	Plum	536.8	230	
13	Ungaged		1,070	
L & D 13	Mississippi River	522.5		85,600
14	Wapsipinicon	506.8	2,330	
14	Ungaged		470	
L & D 14	Mississippi River	493.3		88,400
15	Ungaged Area		100	
L & D 15	Mississippi River	482.9		88,500
16	Rock	479.1	9,549	
16	Ungaged		1,451	

Table 5
Drainage Area Inflows Into Mississippi River Pools
(Continued)

Pool Number	Stream Name	Mississippi River Mile above Ohio River	Drainage Area @ Gage (sqmi)	Drainage Area at L&D (sqmi)
L & D 16	Mississippi	457.2		99,500
17	Ungaged		100	
L & D 17	Mississippi	437.0		99,600
18	Iowa	433.4	12,500	
18	Edwards	431.2	445	
18	Pope Creek	427.8	183	
18	Ungaged		872	
L & D 18	Mississippi	410.5		113,600
19	Henderson	409.9	432	
19	Skunk	396.0	4,303	
19	Ungaged		665	
L & D 19	Mississippi	364.2		119,000
20	Des Moines	361.3	14,038	
20	Fox	353.6	400	
20	Ungaged		862	
L & D 20	Mississippi	343.2		135,200
21	Bear Creek	341.0	349	
21	Wyaconda	337.3	393	
21	Ungaged		158	
L & D 21	Mississippi	324.9		135,200
22	Fabius	323.4	1,465	
22	North	321.1	373	
22	Ungaged		462	
L & D 22	Mississippi	301.2		137,500

Table 6
Mississippi River Top 5 Floods of Record

Station	River Mile above Ohio River	Flood Stage Feet	Date 1	Stage 1	Date 2	Stage 2	Date 3	Stage 3	Date 4	Stage 4	Date 5	Stage 5
Cassville	606.3	18.00	4/25/65	24.12	6/30/93	21.01	4/23/69	20.52	4/21/51	20.30	4/24/52	20.18
Dam 11	583	13.80	4/26/65	25.69	7/01/93	22.32	4/23/69	21.72	4/22/51	21.63	4/25/52	21.57
Dubuque	579.3	17.00	4/26/65	26.81	7/01/93	23.84	4/24/69	23.09	5/06/75	22.78	4/25/52	22.70
Dam 12	556.7	NA	4/26/65	23.51	7/01/93	21.50	4/26/52	20.11	4/24/69	20.03	4/23/51	19.98
Sabula	535	16.00	4/27/65	22.90	7/07/93	21.30	4/25/69	20.00	4/27/52	19.90	4/26/51	19.60
Dam 13	522.5	16.00	4/28/65	25.03	7/08/93	22.17	4/26/69	21.37	4/27/52	21.23	4/26/51	21.00
Clinton	518	16.00	4/28/65	24.85	7/08/93	22.98	4/26/69	21.25	4/27/52	20.90	4/26/51	20.70
Camanche	512	17.00	4/28/65	24.65	7/08/93	22.98	4/26/69	21.53	4/27/52	21.20	10/6/86	20.85
Princeton	502	13.00	4/28/65	20.10	7/08/93	18.28	4/26/69	16.90	4/27/52	16.80	4/26/51	16.60
Dam 14	493.3	11.00	4/28/65	17.75	7/08/93	16.56	4/26/69	14.56	5/08/75	14.03	4/28/52	14.01
Dam 15	482.9	15.00	7/09/93	22.63	4/28/65	22.48	4/26/69	19.30	6/17 1892	19.30	10/7/86	19.22
Fairport	463.1	14.00	7/09/93	24.74	4/28/65	23.60	4/26/93	20.20	4/26/73	20.11	4/26/69	20.00
Dam 16	457.2	13.80	7/09/93	24.01	4/27/65	23.27	4/25/73	20.05	4/25/93	19.70	4/26/69	19.69
Muscatine	455.2	16.00	7/09/93	25.61	4/29/65	24.81	4/25/73	21.63	4/25/93	21.30	4/26/69	21.20
Dam 17	437.0	17.43	7/09/93	25.90	4/28/65	23.14	4/25/73	21.73	4/24/93	21.04	4/26/69	19.74
Keithsburg	428.0	13.00	7/09/93	24.15	4/27/65	20.36	4/22/93	19.66	4/25/73	19.35	10/7/86	17.46
Oquawka	415.9	15.00	7/10/93	28.30	4/28/65	24.20	4/25/73	24.02	4/24/93	23.50	10/7/86	21.90
Dam 18	410.5	9.00	7/10/93	21.54	4/25/73	17.90	4/27/65	17.10	4/30/93	16.58	10/6/86	14.72
Burlington	403.1	15.00	7/10/93	24.98	4/25/73	21.50	4/10/65	21.00	4/25/93	20.40	10/6/86	19.02
Dam 19 Keokuk	364.2	16.00	7/10/93	27.58	4/23/73	23.50	5/01/65	22.14	4/04/60	21.64	5/28/44	20.60
Gregory Landing	352.9	15.00	7/09/93	28.49	4/24/73	24.58	5/01/65	22.71	4/03/60	21.50	4/22/93	21.46
Dam 20	343.2	14.00	7/09/93	27.88	4/23/73	24.50	5/01/65	21.42	10/4/86	20.92	4/22/93	20.45
La Grange	336.0	16.00	7/13/93	28.30	4/25/73	25.30	4/27/93	23.35	5/1/65	22.40	10/4/86	22.20
Quincy	327.0	17.00	7/13/93	32.13	4/23/73	28.90	10/4/86	25.33	4/28/65	24.80	4/04/60	24.30
Dam 21	324.9	17.00	7/13/93	31.30	4/25/73	27.70	10/4/86	24.86	4/28/65	23.89	4/29/93	23.70
Hannibal	309.9	16.00	7/16/93	31.80	4/25/73	28.59	10/4/86	24.85	5/01/65	24.59	4/26/93	24.16
Dam 22	301.2	14.60	7/25/93	29.58	4/25/73	26.80	10/5/86	24.10	4/28/93	23.51	4/05/83	23.40

a. Flood of 1952

Historically notable floods on the Upper Mississippi River prior to 1952 include the floods of 1851, 1880, 1881, 1868, 1888, 1892 and 1951. The fall of 1951 was cooler and wetter than normal and the 1951-1952 winter produced abnormally heavy accumulations of snow. November of 1951 was the coldest November in forty years at Minneapolis, Minn.

The prime characteristic of the 1952 flood was that it came from rapid snowmelt. In late March 1952, the water equivalent exceeded 5 inches in the upper Minnesota, Rum and St. Croix River basins. Major warming trends occurred from March 29 - April 1 and April 6 - 9. This resulted in the flooding that occurred in the Upper Mississippi River basin.

b. Flood of 1965

The Spring Flood of 1965 was one of the most severe on record from the headwaters of the Mississippi River to its confluence with the Illinois and Missouri Rivers. Flood stages higher than ever recorded prior to 1965 were set at each gaging station along the Mississippi River within the Rock Island District during the months of April and May. Above average precipitation during August and September 1964 resulted in wet ground when the winter freeze-up occurred. Deep frost penetration resulted from the cold temperatures of December. Although average snowfall fell over most of the Upper Mississippi River basin during December and January, above average snowfall occurred in March. These factors, in addition to the unseasonably cold temperatures of March, resulted in very little snowmelt. This was followed by warm temperatures which caused the record 1965 Flood.

Although record maximum discharges were set on the main stem of the Mississippi River between Dubuque, Iowa, and Hannibal, Mo., the Iowa streams tributary to the Mississippi River did not exceed any previous discharge records. Flooding on Illinois tributaries was confined principally to the lower reaches and was due mostly to backwater from the Mississippi River. Flood duration at various locations along the Mississippi River varied from 26 days at Dubuque to 43 days at Hannibal.

c. Flood of 1969

The Flood of 1969 that occurred in the upper midwestern states was in the spring of that year. It was attributed primarily to an exceptionally heavy blanket of snow which accumulated during the period of December 1968 through February 1969. The precipitation in March was light however at the end of the month water content of snow on the ground was up to 8 inches in some areas. Unusually heavy rain in the Fall of 1968 throughout the area produced saturated soil conditions and as much as 3 inches of additional precipitation of localized spring rainfall in the Red River basin during the period April 7-10, 1969 accentuated the flooding. The snowmelt flooding affected the six states of North Dakota, South Dakota, Minnesota, Iowa, Wisconsin and Illinois.

d. Flood of 1973

Rainfall was above average in the Upper Mississippi River basin in the Fall of 1972. This resulted in discharges of as much as three times the normal amounts at some of the gaging stations in December 1972. Although the winter snowfall was fairly light, temperatures were variable causing snow to melt and rain to fall rather than snow. These factors lead to high runoff and high stream flow levels. On many tributaries and on the Mississippi River primarily between Keokuk and Fort Madison, Iowa, ice jams were prevalent in January and February 1973. In March and April, rainfall was well above average which then brought the Mississippi River and its tributaries above flood levels in late March. The crest at Hannibal, Mo., and Quincy, Ill., was 4 feet higher than in 1965. The river was above flood stage at Hannibal for 106 days.

2. Stream Data

Stage hydrographs have been prepared for selected stations along the Mississippi River to show the 1993 river stages from March 1 through September 30. The Mississippi River stage hydrographs (Plates 15 through 21) show the spring flood peaks which occurred in March and the record flood peaks that occurred in July. These hydrographs also show the short duration of the spring flood and the much longer duration of the summer flood. Flood stage for each station is shown at the top of the plate.

The stage hydrograph for the Dubuque, Iowa, gage is shown on Plate 15. Dubuque is located at river mile 579.3. Plate 16 shows river stage fluctuations at Clinton, Iowa. Clinton is located at river mile 518. The heavy precipitation that occurred in early July brought the peak stage to 22.98 feet on July 8. At Clinton, Iowa, the 1993 water year runoff depth was 14.64 inches compared to the mean annual runoff depth for the period of record (119 years) of 7.62 inches.

Plate 17 shows the stage hydrograph at Davenport, Iowa. The first flood that occurred in Davenport was in early April and it remained at or above flood stage until the middle of May. Again in mid-June the river stage rose above flood stage and remained above flood stage until the end of July. Parts of downtown Davenport (Photo 8) were under several feet of flood water during this period. The record peak stage of 22.63 feet at Davenport occurred on July 9.

The stage hydrograph at Keithsburg, Ill., is shown on Plate 18. This station is located near river mile 428.0. As shown on this hydrograph, the water levels remained above flood stage for over five months. From early June until the middle of September, the levels at Keithsburg remained above flood stage. The City of Keithsburg was inundated with flood water on July 7 when the non-federal levee failed. The flood of record occurred on July 9 with the peak stage of 24.15 feet.

The river stages at Burlington, Iowa are shown on Plate 19. The Burlington gage is located at river mile 403.1. On April 25, the river stage reached 20.40 feet which was the fourth highest flood of record. The heavy rains of June and July brought the stage above flood stage again in early June, and it remained there until the middle of September. The flood of record occurred on July 10 and was 24.98 feet. At Keokuk, Iowa, located at river mile 364.2, the 1993 water year runoff depth was 18.55 inches, compared to the mean annual runoff depth for the period of record (114 years) of 7.36 inches.

The hydrograph for the station at Quincy, Ill., is shown on Plate 20. Quincy is located at river mile 327.0. Flood waters began to rise in early to mid-June and remained high until the middle of September. The flood of record occurred at Quincy July 13 with a river stage of 32.13 feet. The fluctuations shown on the hydrograph in July are the result of levee failures and overtoppings that also occurred at that time.

The stage hydrograph at Hannibal, Mo., is shown on Plate 21. Hannibal is located at river mile 309.9. Hannibal experienced the longest duration of flooding. On July 16, the flood of record was 31.8 feet. The river remained above flood stage until the end of September. The rapid fluctuations observed in July are the result of the levee failures and overtoppings that occurred at the same time.

3. Main Stem Hydraulics

Flooding on the main stem Mississippi River was reduced downstream of the confluence of the Des Moines River due to the reservoir regulation at the Saylorville and the Lake Red Rock dams. Flooding was also reduced downstream of the Iowa River due to the operation of the Coralville Dam. The comparison of stages with and without the control structures is summarized in Table 7. A detailed discussion of the reservoir regulation is found in Sections V (Des Moines River Basin) and VI (Iowa/Cedar River Basins).

The Mississippi River profiles on Plates 22 through 27 show the elevation of the 1993 Flood compared to other historical events. The stages that are shown on these plates were developed in 1979 for the Upper Mississippi River Basin Commission by the U.S. Army Corps of Engineers. Plate 22 originates at the upstream limit of the Rock Island District. From Lock and Dam 10 to Lock and Dam 11, the 1993 Flood ranked between a 10-year and 50-year event. The flood of 1965 far exceeded the 1993 event along this reach of the river. Downstream of Lock and Dam 11 to Lock and Dam 12, the 1993 Flood was very close to the 50-year event. The 1965 Flood remains the flood of record along this entire reach.

The Mississippi River profile on Plate 23 extends from Lock and Dam 13 to Lock and Dam 14. Between Bellevue, Iowa, and the confluence of the Maquoketa River, the 1993 Flood remained at the 50-year recurrence interval. From the confluence of the Maquoketa River to Camanche, Iowa, the frequency dropped to between the 10-year and the 50-year event. From Camanche to LeClaire, Iowa, the 1993 event was close to the 50-year event. Along this reach of the river, the 1965 Flood remains the highest on record with the 1993 event ranking second.

Plate 24 shows the reach of the Mississippi River from Lock and Dam 14 to Lock and Dam 16. From LeClaire to Lock and Dam 14, the 1993 Flood was close to the 50-year event. Downstream of Lock and Dam 14, the 1993 Flood was above the 50-year event and below Moline, Ill., the 1993 Flood reached the 100-year level. From Davenport, Iowa, to Fairport, Iowa, the 1993 high water exceeded the 1965 level, ranked between a 50-year and 100-year event, and has the distinction of being the flood of record.

The Mississippi River profile shown on Plate 25 extends from Fairport, Iowa, to Lock and Dam 19. Between Fairport and Muscatine, the 1993 event remained above the 50-year and below the 100-year recurrence interval; however, it ranks the highest on record. From Muscatine to Dam 17, the 1993 level exceeds the 100-year recurrence interval. From Lock and Dam 17 downstream to Dam 18, the 1993 level exceeds the 200-year recurrence interval.

As shown on Plate 26, from Lock and Dam 18 to the Burlington Bridge, the 1993 level was between the 200-year and the 500-year recurrence interval. Downstream from the Burlington Bridge, the 1993 level exceeds the 500-year frequency event to river mile 364.

The Mississippi River profile shown on Plate 27 shows the 1993 event from Lock and Dam 20 to Lock and Dam 22, the downstream limit of the District. The 1993 event exceeds the 500-year level and is the flood of record for this reach of the Mississippi River. In summary, 1993 was the flood of record from Davenport, Iowa, (river mile 482.9) to Saverton, Mo., (river mile 301.2) on the Mississippi River.

Table 7
Stage Reduction on the Mississippi River Main Stem
From the Operation of Saylorville, Red Rock and Coralville Dams

	Observed		Reconstituted		
Station	**Stage (feet)**	**Flow (cfs)**	**Stage (feet)**	**Flow (cfs)**	**Reduction (feet)**
Burlington, Iowa	25.0	400,000	25.0	400,000	0.0*
Quincy, Illinois	32.1	#	#	#	0.9*
Hannibal, Missouri	31.8	#	#	#	0.2*

The peak discharges for this reach of the Mississippi River (Quincy,Il., to St. Louis, Mo.) will be re-evaluated by the USGS.
*Estimated

C. Sedimentation

1. Changes to Channel

A preliminary assessment was made of the navigation channel along the main stem of the Mississippi River to determine the impact the 1993 Flood had on sedimentation. Generally there is a correlation between the descending limb of the flood hydrograph and the amount of sediment deposited in the channel. The 1993 flood receded slowly and hence the amount of deposition in the channel was not significant. Typical cross sections from each pool within the Rock Island District were selected from 1992 and 1993 soundings. These cross sections were compared to determine whether deposition or scour had occurred as a result of the flooding. An attempt was made to evaluate the impact on sedimentation due to the magnitude and duration of the flooding.

Cross sections at the same locations taken in 1991 were compared to 1992 to assess if the deposition and scour were significantly greater or less than between 1992 and 1993. The sounding data for 1991 was very limited, and of the cross sections that were used to compare 1992 and 1993, only two cross sections were available for 1991.

Based upon the 26 selected cross sections that compared 1992 with 1993, it was determined that 13 of the 26 sections showed sediment deposition. Only four of the cross sections showed degradation across the entire channel. The remaining nine sections either had little to no change or had equal amounts of degradation and aggradation across the section. Plate 28 shows the cross section located at river mile 610.0 within Pool 11 where a significant amount of scour occurred across most of the channel. Up to 5 feet of scour occurred in one year. Plate 29 shows the cross section located at river mile 424 within Pool 18 where a significant amount of deposition occurred. As much as 9 feet of sediments was deposited at this cross section in one year. These two cross sections show the extreme cases of erosion and deposition as a result of the 1993 Flood event.

A more comprehensive study of 1993 Flood changes to the Mississippi River channel is beyond the scope of this report.

2. Sedimentation Data

In an effort to assess the impact of flooding on suspended sediment transport of the Mississippi River within the Rock Island District, data from two stations were evaluated. The two stations chosen were the Mississippi River at East Dubuque, Ill. (river mile 579.9) and the Mississippi River at Keokuk, Iowa (river mile 363.9). These stations have been operated by the Rock Island District since 1968 and 1981, respectively. At each station, daily depth integrated samples were collected from a bridge at a single location. These samples were analyzed for suspended sediment concentration by the USGS in Iowa City, Iowa. Preliminary mean daily discharges were computed by the USGS at Clinton, Iowa (just downstream from East Dubuque) and at Keokuk. Daily suspended sediment loads were computed using a computer program developed by the Corps of Engineers. This program computes daily suspended sediment loads using an interpolation procedure, which is comparable to those computed by hand (using graphical techniques) and has been routinely in use since 1970.

During 1993, 250 suspended sediment samples were taken at the East Dubuque station and 184 samples were taken at the Keokuk station. These numbers of suspended sediment samples have typically been taken each year at these stations for the period of record. Based on these data, monthly and annual suspended sediment loads for each year were computed. Average annual loads for the period of record were also computed. Tables 8 and 9 list the monthly suspended sediment transport results by year, for East Dubuque and Keokuk respectively. The notation "N/A" indicates data were not available for the time period in question.

From the data it can be seen that suspended sediment transport during 1993 exceeded the period of record average for most months for which data are available at both stations. Particularly dramatic were the months of May through August at East Dubuque and April through September at Keokuk. For the water year 1993, the Mississippi River at East Dubuque, transported 6,700,000 tons of suspended sediment, which represents about 167% of the average annual load for the period of record. At Keokuk the Mississippi River transported 33,700,000 tons of suspended sediment, which represents 308% of the average annual load for the period of record. While the annual suspended sediment load at East Dubuque for 1993 was less than that observed during 1973, the annual load at Keokuk for 1993 exceeded the highest annual load for the period of record, also observed in 1973.

						TABLE 8							
			SUSPENDED SEDIMENT LOAD (TONS) AT EAST DUBUQUE, IL										
WATER													
YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANNUAL
1968	3492	28614	43802	19,316	37,022	55,130	202,027	372,709	605,918	866,171	206,975	189,930	2,631,106
1969	417,410	240,899	167,727	N/A	2,913	393,885	1,547,506	962,516	965,686	1,068,898	109,895	88,396	5,965,731
1970	86,312	56,145	37,837	663	3,643	69,544	344,231	655,081	788,453	72,298	66,197	81,884	2,262,288
1971	135,519	312,566	115,993	1,970	N/A	705,718	1,820,611	444,505	703,235	283,584	76,614	73,307	4,673,622
1972	102,629	383,385	41,935	15,594	56,318	666,022	1,298,534	769,506	266,570	210,538	996,108	534,753	5,341,892
1973	566,954	245,430	136,768	384,487	295,162	1,564,903	1,440,533	1,106,286	1,032,409	170,432	268,908	111,479	7,323,751
1974	235,714	103,362	74,320	N/A	16,076	319,432	1,234,160	887,960	2,749,585	183,832	66,809	43,541	5,914,791
1975	42,390	135,618	38,876	42,739	4,207	645,177	869,080	1,575,473	479,433	357,215	81,958	79,764	4,351,930
1976	50,679	134,272	57,905	18,191	115,391	742,153	1,747,203	168,203	60,024	53,495	32,594	24,098	3,204,208
1977	49,427	11,599	14,051	N/A	21,775	99,331	131,635	47,328	40,659	80,339	30,190	105,117	631,451
1978	217,016	130,752	19,815	N/A	N/A	99,443	1,142,109	436,909	943,834	1,312,320	143,847	422,305	4,868,350
1979	133,428	87,041	20,612	N/A	N/A	1,305,953	1,661,381	1,211,065	723,885	507,334	377,830	369,604	6,398,133
1980	121,365	136,586	43,861	89,187	N/A	274,745	527,348	88,668	847,090	66,445	191,744	620,604	3,007,643
1981	229,547	74,908	25,951	N/A	N/A	92,616	525,648	308,371	355,251	307,532	175,541	263,124	2,358,489
1982	248,961	104,806	N/A	N/A	N/A	N/A	930,693	971,291	497,429	133,136	88,833	127,714	3,102,863
1983	392,169	548,660	251,676	161,230	182,250	1,083,889	611,351	884,098	260,786	567,220	162,265	230,561	5,336,155
1984	218,935	198,112	N/A	N/A	178,097	344,365	732,617	1,450,206	1,079,423	555,699	120,879	102,273	4,980,606
1985	269,331	346,717	184,350	N/A	N/A	616,836	866,604	657,210	243,008	382,567	85,362	180,715	3,832,700
1986	546,167	245,749	N/A	3,442	22,825	371,690	1,245,784	886,492	299,662	301,973	241,507	542,090	4,707,381
1987	709,367	181,479	57,216	148,104	33,225	117,271	120,576	78,534	93,925	74,424	89,408	79,860	1,783,389
1988	51,903	49,466	26,783	N/A	N/A	133,065	249,067	79,978	25,784	28,697	31,643	42,273	718,659
AVG	229,939	178,865	75,527	80,448	74,531	485,058	916,605	668,685	622,002	361,150	173,577	205,400	3,971,197
1993	118,179	175,143	N/A	N/A	N/A	185,241	1,304,531	1,176,219	1,118,667	1,327,439	924,871	320,610	6,650,900

						TABLE 9							
				SUSPENDED SEDIMENT LOAD (TONS) AT KEOKUK, IA									
WATER													
YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANNUAL
1968	52098	241576	43802	21020	55879	98880	196511	293378	337586	816785	234520	202894	2594929
1969	53213	241576	43799	194680	65195	650153	3517245	2193525	1182530	4605436	207578	137883	13092813
1970	538127	526494	99320	118325	26012	585429	561214	1445686	1618913	79329	194793	807908	6601550
1971	153499	161641	78277	17980	1228402	1987993	2430604	623872	833517	281473	59727	91164	7948149
1972	352291	540771	180516	83298	116221	1066218	2229979	2671011	1031858	185763	1010754	710975	10179655
1973	172838	453941	679038	1198289	1059225	5563007	9242163	5782339	3041989	459656	257537	254085	28164107
1974	820246	845506	173568	729187	658760	1723555	2015094	9848613	8556885	1295997	301012	87558	27055981
1975	664849	349718	484527	99744	130545	2589811	2032767	3874700	951925	513786	76377	95945	11864694
1976	67308	95774	142646	19010	73998	1669575	3464753	1328049	92746	59894	21965	23542	7059260
1977	49041	92930	194177	21568	43639	128421	156078	64267	20807	66698	100544	182593	1120763
1978	30993	39686	31969	87926	24515	754812	2487706	1389234	884484	2446931	208976	874340	9261572
1979	411581	361082	245777	13067	59401	4733121	4963702	2785512	895788	427820	666979	547791	16111621
1980	396765	211427	110260	278788	212055	554003	788059	128866	1727927	108569	330033	733256	5580008
1981	271686	548831	268969	45830	211337	289943	1368003	680919	1007320	733981	307908	370409	6105136
1982	516589	176719	144222	64956	1981	N/A	4100872	2736896	1930720	2125117	569408	303738	12671218
1983	594371	389817	462082	523509	1034902	2910493	4187782	2506254	1645104	1639049	267251	264410	16425024
1984	639984	1558293	3046301	313620	179231	369930	2248451	3967716	2740262	1791102	176519	165409	17196818
1985	508366	969608	1354332	457508	1745682	4278679	1883742	1002230	133847	74507	69014	97914	12575429
1986	463218	1342130	488976	141228	164966	2050046	2283344	3899320	1358947	1204819	206025	795914	14398933
1987	699164	1004753	602970	127899	61511	231937	357096	179203	244079	136748	187655	144065	3977080
1988	3672357	484938	139772	304033	195809	622430	750425	124301	83280	58089	90748	67013	6593195
1989	97303	72534	261641	131036	66965	212250	525749	177643	232374	120954	70722	159140	2128311
1990	59546	50764	79562	115451	96360	1298351	289389	790630	5849857	1821092	1205770	807999	12464771
AVE	490671	467848	406804	222085	326634	1582229	2264379.5	2108441.9	1582728	915373.7	296601	344606	10920479
1993	149547	1099629	1294172	591843	278298	1809161	5510725	3074828	5371762	9800130	2858588	1848019	33886702

D. Tributary Hydrology/Hydraulics

1. Description of Flooding

a. Maquoketa River

The Maquoketa River enters the Mississippi River at river mile 548.6 and has a drainage area of 1,553 square miles at Maquoketa, Iowa. June 27, 1993, the Maquoketa River the flood of record peak stage was 34.86 feet. Flood stage is at 24.0 feet. The period of record for the Maquoketa River gage at Maquoketa is from 1913 to current year. Other notable events recorded at this gage are as follows: 32.59 feet on July 6, 1993; 30.63 feet in 1975; 29.6 feet in 1981; and 29.18 feet in 1947. For the months of April through September 1993, the runoff depth at Maquoketa was 17.4 inches. The mean runoff depth for the months of April through September for the period of record (79 years) was 4.8 inches.

b. Wapsipinicon River

The Wapsipinicon River enters the Mississippi River at river mile 506.8. The area of the drainage basin is 2,563 square miles. The 1993 Flood stage ranked the fourth highest for this river. Plate 30 shows the water surface profile for the Wapsipinicon River near DeWitt, Iowa. The period of record for the Wapsipinicon River gage at DeWitt is 1934 to current year. On July 8, the river rose to 12.88 feet. Flood stage is 10 feet. The four other events that ranked in the top five are as follows: 14.19 feet in 1990; 13.07 feet in 1974; 13.06 feet in 1990; and 12.76 feet in 1973. For the months of April through September 1993, the runoff depth near Dewitt was 24.2 inches. The mean runoff depth for the months of April through September for the period of record (58 years) was 5.24 inches.

c. Edwards River

The Edwards River enters the Mississippi River at river mile 431.2. The watershed has an area of 446 square miles. The period of record for the Edwards River gage at New Boston, Ill., is from 1934 to current year. The 1993 Flood was the flood of record for the Edwards River at New Boston. The peak stage was 24.53 feet, reached March 5, 1993. Flood stage is 17.0 feet. Again July 16,1993, the river reached its fifth highest crest at New Boston. The stage was 22.35 feet. In 1973 the river crested at 23.33 feet in 1974, it crested at 22.51 feet, and in 1990, it crested at 22.39 feet.

d. Pope Creek

Pope Creek enters the Mississippi River at river mile 427.2 near Keithsburg, Ill. The watershed area is 183 square miles. Of the top five floods that occurred at the Keithsburg gage, three of them occurred in 1993. The flood of record occurred on July 24, 1993. The peak stage was 29.08 feet. Flood stage is 20.0 feet. For this gage, the period of record is from 1934 to current year. Other notable events are 28.56 feet in 1990; 28.47 feet on March 4, 1993; 28.17 feet on June 8, 1993; and 28.0 feet in 1937.

e. Henderson Creek

Henderson Creek enters the Mississippi River at river mile 409.9. The area of the watershed is 598 square miles. The gaging station, located at Oquawka, Ill., has a period of record extending from 1938 to current year. Flood stage is 21.5 feet. The Flood of 1993 had two peaks that ranked in the top five for this station. The flood of record occurred on July 25, 1993 and had a peak stage of 32.48 feet. The second highest event occurred in 1982 and reached 31.05 feet. June 9, 1993 had a stage of 29.40 feet. The two other notable events occurred in 1982 with a stage of 28.88 feet and in 1950 with a stage of 28.17 feet.

V. Des Moines River Basin

A. Basin Description

The Des Moines River basin extends across central Iowa to the southeastern part of the state (Plate 31). The watershed has an area of 14,802 square miles. Des Moines, Ottumwa and Fort Dodge are the largest population centers. This basin contains 9.4 million acres of land and 42,000 acres of lake surface. The Des Moines River has numerous tributaries, many of which are very short with small drainage areas. The major tributaries include the East Fork, the Boone River, the Raccoon River, Middle River and the South River.

The Des Moines River basin has an average width of 40 miles and extends 360 miles from its headwaters north of Slayton, Minn., to its confluence with the Mississippi River near Keokuk, Iowa. Downstream of its confluence with the Raccoon River near Des Moines, Iowa, the river valley changes both in direction and character. North of this point, the valley topography is shallow, with steep walls and a narrow flood plain. South of this point the river flows southeasterly in a broader, more mature flood plain in which the valley becomes wider and deeper and the bluffs become more rounded.

B. Main Stem Hydrology/Hydraulics

1. Description of Flooding

The flooding on the Des Moines River was the most severe and had the greatest impact on the City of Des Moines. Plate 32 shows the total monthly precipitation for May, June, July and August in 1993 vs. the average total precipitation for the same period at the Des Moines National Weather Service rainfall gage. The record rainfall that persisted in the basin resulted in overtopping the levees and inundating the city's water treatment plant. The residents were without drinking water for three weeks. The storm that was responsible for this event began at 9 p.m. on July 8 and ended on July 9 at 1 a.m. During that five-hour period, 6.5 inches of rain fell on an already swollen Des Moines River basin. Flash flooding occurred on the Raccoon River, a tributary to the Des Moines River that has its confluence in the City of Des Moines. This compounded the severity of the flooding in Des Moines. The operation of the two reservoirs that are located on the Des Moines River and the impact that they had on the flooding are discussed in detail in Sections D and E, Reservoir Regulation.