US Army Corps
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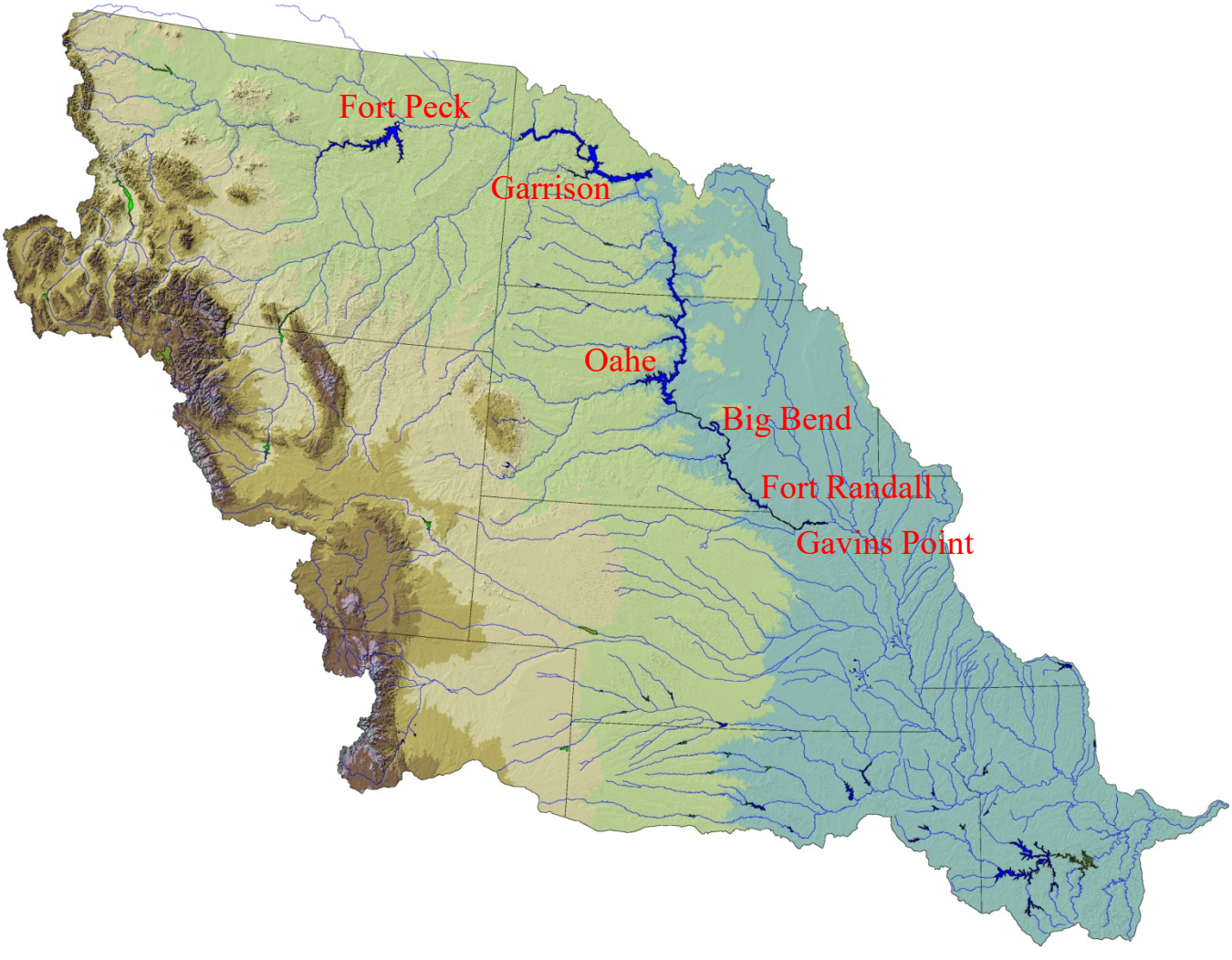
Northwestern Division

Runoff Volumes for AOP Studies

Technical Report



Missouri River Basin Water Management Division
Omaha, Nebraska

October 2020

Missouri River Basin Water Management Division

Technical Report

Runoff Volumes for Annual Operating Plan Studies, October 2020

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I. FOREWORD

A) Prior Studies

This report is an update to the report titled, *Missouri River Main Stem Reservoirs, Runoff Volumes for AOP Studies, Technical Report*, dated August 2013. The August 2013 report superseded several prior published and unpublished reports:

- *Missouri River Main Stem Reservoirs, Runoff Volumes for Annual Operating Plan Studies, RCC Technical Report Jy-08,* July 2008.

- *Addendum to RCC Technical Report O-98, Runoff Volumes for Annual Operation Plan Studies Upper Decile and Upper Quartile Runoff Extensions,* October 2004.

- *MRD Technical Report O-98, Missouri River Main Stem Reservoirs, Runoff Volumes Appropriate for Annual Operating Plan Studies*, October 1998.

Two unpublished updates in 1985 and 1993.

- *MRD Technical Report A-75, Missouri River Main Stem Reservoirs, Runoff Volumes Appropriate for Annual Operating Plan Studies*, August 1975.

The August 1975 report should be referred to for a history of how the runoff volumes were developed and used for Annual Operating Plan (AOP) studies. The unpublished 1985 report was an update to the 1975 report, although there were several differences in the method of computing runoff volumes. The 1993, October 1998, October 2004, July 2008, August 2013, and October 2020 reports were completed following essentially the same methodology used in the 1975 report. This report (October 2020) contains eight additional years of runoff from 2012-2019 since the publication of the August 2013 report.

B) Purpose

The purpose of this report is to describe the methodology, assumptions, data used, and results for developing the runoff volumes used in the AOP studies.

The AOP studies utilize statistically derived runoff volumes based on the 122-year historical record of runoff (1898-2019) above Sioux City, IA. The AOP studies are comprised of five runoff levels with statistical significance implied by their titles: upper decile (UD), upper quartile (UQ), median (MED), lower quartile (LQ), and lower decile (LD). These five runoff levels are derived from a volume-duration relationship which represents the cumulative distribution function for all data recorded at the site. Volume-duration relationships are used to define the percent of time that a given volume is equaled or exceeded. A duration relationship is not a probability relationship. It should not be interpreted on an annual event basis because it provides only the fraction of time that a given event was exceeded and not the annual probability of an event occurring.

Two additional runoff volume scenarios were developed for the August 2013 study. While the upper and lower decile runoff volumes cover 80 percent of the historic runoff record, these two additional scenarios, one on either side of the runoff spectrum, will encompass 96 percent of the historic annual runoff records. The annual runoff for the 2 percent non-exceedance (L2) is equaled or exceeded 98 percent of the time. The annual runoff for the 98 percent non-exceedance (U2) is equaled or exceeded 2 percent of the time. These annual runoff volumes are not part of the AOP scenarios but could be implemented for any given runoff season should the runoff forecast exceed the UD runoff scenario or be less than the LD runoff scenario.

All volumes discussed in this report are adjusted to the 1949 level of water resources development in the Missouri River basin. In this report, the terms "runoff" and "inflow" are used interchangeably.

II. DETERMINATION OF RUNOFF VOLUMES

A) Basin Annual Runoff Volumes above Sioux City, IA

The total annual runoff for the Missouri River basin above Sioux City, IA for each of the seven runoff levels -- U2, UD, UQ, MED, LQ, LD, and L2 -- was determined using the steps outlined below.

A volume-duration relationship, using total annual runoff for the period of record (1898-2019), was developed for the Missouri River above Sioux City, as shown on Plate 1. The eight additional years included in this update analysis are highlighted in red. The annual volume for each of the seven runoff levels were determined based on their statistical representation. For example, the LD is the annual runoff volume corresponding to a 10 percent non-exceedance (or conversely, an exceedance rate of 90 percent). Likewise, the UQ is the annual runoff volume with a non-exceedance rate of 75 percent (or exceedance rate of 25 percent). The seven runoff levels are not actual historical runoff volumes; they are derived from the volume-duration relationship for total annual runoff above Sioux City. Table 1 shows the annual runoff volume in thousand acre-feet (kAF) for the basin above Sioux City for each of the runoff levels for the 122-year period (1898-2019) as well as the August 2013 (1898-2011), July 2008 (1898-2006), and October 1998 (1898-1997) reports which had 114, 109, and 100 years of record, respectively.

The eight additional years (2012-2019) used in this study included two out of four years of above-normal runoff including the second (2019) and fourth (2018) largest runoff years in the 122 years of record for the Missouri River basin above Sioux City. As shown in Table 1, the eight additional years of record resulted in a slight increase in the L2, LD, LQ, and MED runoffs -- between 100 and 200 kAF -- and modest increases for the UQ and UD runoffs – 300 kAF and 700 kAF, respectively -- when compared to the August 2013 report (1898-2011). The biggest change was in the U2 runoff level. Due to the very high runoff experienced in 2018 and 2019, the U2 volume increased nearly 6,000 kAF. The runoff during this 8-year period in the upper portion of the basin (Fort Peck and Garrison reaches) is distributed fairly evenly across the period of record, as shown on Plates 2 and 3, respectively. The runoff during the 8-year period in the middle portion of the basin in the Oahe reach was generally above normal with the highest runoff year on record occurring in 2019, as shown on Plate 4. The runoff in the Fort Randall and

Gavins Point reaches, shown on Plates 5 and 6, respectively, was more evenly distributed during this 8-year period. The exception is the 2019 event, which was the highest runoff year in the 122 years of record for both reaches. The annual runoff during this 8-year period in the Sioux City reach, the lowest portion of the upper basin, was all located on the upper half of the curve, as shown on Plate 7. This includes 2019, the highest runoff year in 122 years of record.

B) Distribution of Runoff by Reach

Six reaches are defined for use in the AOP studies: (1) the Fort Peck reach is the basin above Fort Peck dam, 57,500 square miles (sq. mi.); (2) the Garrison reach includes the basin between Fort Peck and Garrison dams, 123,900 sq. mi.; (3) the Oahe reach includes the basin between Garrison and Oahe dams, 62,090 sq. mi.; (4) the Fort Randall reach includes the basin between Oahe and Fort Randall dams, 19,990 sq. mi.; (5) the Gavins Point reach includes the basin between Fort Randall and Gavins Point dams, 16,000 sq. mi.; and (6) the Sioux City reach includes the basin between Gavins Point Dam and Sioux City, IA, 39,080 sq. mi.

Table 1
Basin Annual Runoff Volumes above Sioux City, IA

Runoff Level	Annual Volume in kAF (1898-2019)	Annual Volume in kAF (1898-2011)	Annual Volume in kAF (1898-2006)	Annual Volume in kAF (1898-1997)
2nd Percentile (L2)	11,600	11,400	-----	-----
Lower Decile (LD)	16,200	16,100	16,200	15,500
Lower Quartile (LQ)	19,500	19,300	19,300	19,500
Median (MED)	24,700	24,600	24,400	24,600
Upper Quartile (UQ)	30,900	30,600	30,300	30,600
Upper Decile (UD)	35,200	34,500	34,300	34,500
98th Percentile (U2)	46,000	40,100	-----	-----

The following steps were used to distribute the total annual runoff for the Missouri River basin above Sioux City among the six reaches.

1. Volume-duration relationships were developed for each reach based on the annual reach runoff for the period of record (1898-2019) and are shown in Plates 2 through 7. The eight additional years included in this update are highlighted in red.

2. Due to the vast size of the Missouri River basin above Sioux City and its natural variation in the areal distribution of runoff, the sum of the six incremental reaches annual runoff for a specific non-exceedance level is not necessarily equal to the total annual basin runoff for that same non-exceedance level. In other words, the 10 percent non-exceedance annual runoff

volumes for each of the six individual reaches combined is 13,600 kAF which does not equal the 10 percent non-exceedance annual runoff of 16,200 kAF derived for the Missouri River basin above Sioux City. The two runoff values would only be equal if all reaches had identical annual rankings. For example, the Garrison reach had its 3rd highest annual runoff in 2018, but it was only the 7th highest runoff year for the Fort Peck reach, 48th highest for the Oahe reach, 24th highest for the Fort Randall reach, 13th highest for Gavins Point reach and 5th highest for the Sioux City reach. This compares to the 2018 annual runoff for the Missouri River basin above Sioux City, which was the 4th highest annual runoff on record.

The annual runoff for each of the six reaches were individually ranked from lowest to highest and then combined to create a volume-duration relationship. The annual runoff for each of the specific non-exceedance levels for the Missouri River basin above Sioux City were then located on the combined reach volume-duration relationship to determine the incremental reach inflows that are equally likely to occur and which, when summed for the six reaches, equal the runoff for the basin as a whole. For example, the 16,200 kAF determined for the lower decile (i.e. not being exceeded 10 percent of the time) runoff for the basin above Sioux City was represented as a 20 percent non-exceedance rate on the duration relationship based on the sum of the reach inflows.

This procedure was repeated for the remaining runoff levels with the following outcomes: the sum of the 31 percent non-exceedance reach inflows equals the total upper basin LQ runoff; the sum of the 53 percentile reach inflows equals the total upper basin MED runoff; the sum of the 74 percentile reach inflows equals the UQ; and the sum of the 84 percentile reach inflows equals the UD. These percentiles with the additional eight years compared very closely to the 2013 study; the LD and MED volumes decreased about 1 percent, the UD volume increased 1 percent, and the LQ and UQ volumes did not change. For the two runoff scenarios, L2 and U2, the sum of the 95 percent equaled or exceeded reach inflow equals the total upper basin L2, an increase of 1 percent. The sum of the 4 percent equaled or exceeded reach inflow equals the total upper basin U2 runoff, an increase of 4 percent from the 2013 study. The resultant incremental reach runoff volumes in kAF are shown in Table 2 for the various runoff levels. The percent of runoff originating from each reach is shown in Table 3.

Table 2
Annual Incremental Reach Runoff Volumes

Runoff Level	L2	LD	LQ	MED	UQ	UD	U2
Reach Percentile	**5**	**20**	**31**	**53**	**74**	**84**	**96**
Reach	**Annual Volume in 1000 Acre-Feet (kAF)**						
Fort Peck	3,950	5,350	5,950	7,150	8,650	9,500	11,100
Garrison	5,700	7,450	9,200	10,850	12,850	14,250	16,350
Oahe	500	1,150	1,400	2,350	3,200	3,900	5,750
Fort Randall	100	350	450	900	1,200	1,500	2,200
Gavins Point	1,100	1,200	1,300	1,500	2,000	2,300	3,200
Sioux City	250	700	1,200	1,950	3,000	3,750	7,400
Total	11,600	16,200	19,500	24,700	30,900	35,200	46,000

Table 3
Distribution of Runoff by Reach
in Percent of Total Runoff above Sioux City, IA

Runoff Level	L2	LD	LQ	MED	UQ	UD	U2
Reach	**Annual Runoff in Percent**						
Fort Peck	34.1	33.0	30.5	29.0	28.0	27.0	24.1
Garrison	49.1	46.0	47.2	43.9	41.6	40.5	35.5
Oahe	4.3	7.1	7.2	9.5	10.3	11.1	12.5
Fort Randall	0.9	2.2	2.3	3.6	3.9	4.3	4.8
Gavins Point	9.5	7.4	6.7	6.1	6.5	6.5	7.0
Sioux City	2.1	4.3	6.1	7.9	9.7	10.6	16.1

C) Distribution of Runoff by Month

While the aforementioned procedure results in the areal distribution of runoff, AOP studies require annual runoff to be distributed by month. A monthly distribution was computed for each reach for the seven different runoff scenarios. An advantage of using a specific year's observed runoff is that such a selection provides for character or distinct variations in monthly runoff which may get masked when average values for particular months are used. To maintain the character provided by specific years, and to preserve the relationships which characteristically exist between adjacent reaches during particular runoff years, the following 8-step procedure was used to distribute the annual runoff by month:

1. Annual runoff for each reach was ranked for the period of record. Using the ranked reach inflows, the ten individual years whose annual runoff was closest to the annual runoff for the L2, LD, LQ, MED, UQ, UD, and U2 conditions were identified for each of the six reaches.

2. The historic monthly runoff for each of the 10 years, as chosen in step 1, was expressed as a percentage of annual reach runoff.

3. By analysis of each 10-year group of years, the month that usually has the maximum runoff was determined. Similar determinations were made of the usual month that the second largest runoff, third largest runoff, etc. occurred.

4. The monthly runoff percentages, as computed in step 2, were ranked from highest to lowest for each year. For each 10-year group, the average of the highest percentage from each year was computed, irrespective of what month in each particular year the maximum runoff occurred. The same process was used to compute the average runoff percentage for the second highest month, third highest month, etc.

5. The distribution of annual runoff was accomplished by placing the average monthly runoff percentage, as determined in step 4, in the appropriate month, as determined in step 3. For example, the highest average monthly runoff percentage was assigned to the month that the maximum runoff usually occurs, the second highest percentage to the month that the second highest runoff usually occurs, etc. This process was repeated for each reach/runoff level resulting in a monthly distribution for each of the seven runoff levels (L2, LD, LQ, MED, UQ, UD, and U2) for each of the 6 reaches for a total of 42 unique distributions.

7. The resulting monthly distributions were multiplied by the annual runoff for the particular reach/runoff scenario to determine the monthly runoff and were then plotted.

8. Using specific years to distribute the reach inflows can create some inconsistencies. There are instances when monthly reach runoff representing a lower runoff condition, such as the LD or LQ, are greater than the flows representing a higher runoff condition, such as the UD or UQ. If these inconsistencies were large, then the monthly distribution percentages for one runoff level that better represented the typical runoff pattern for that particular reach was applied to another runoff level to eliminate or reduce the inconsistencies. Occasionally, an inconsistency occurred where a particular month for a lower runoff level (for example, MED) had a higher monthly runoff than a higher runoff level (for example, UQ). To rectify this inconsistency, monthly reach inflows were smoothed by use of engineering judgment in a manner such that the annual reach inflow remained unchanged for both levels. The resultant monthly reach inflow volumes in kAF are shown in Table 4 for the seven runoff levels. After smoothing the runoff volumes, the monthly runoff distributions (in percent of annual reach inflow) were recomputed. Table 5 shows the monthly volumes as percentages of annual reach runoff.

Table 4
Monthly Reach Runoff Volumes
1000 Acre-Feet (kAF)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
2 Percentile (L2)													
Fort Peck	210	260	380	370	495	700	380	190	185	290	270	210	3,940
Garrison	160	205	550	430	700	1,450	945	300	235	335	270	120	5,700
Oahe	-25	30	200	120	80	100	30	10	25	5	-5	-70	500
Fort Randall	-30	15	80	25	40	35	5	10	0	-30	-25	-25	100
Gavins Point	70	90	140	110	120	125	70	60	70	95	85	65	1,100
Sioux City	0	15	100	35	20	45	65	30	0	-10	10	-50	260
Total	**385**	**615**	**1,450**	**1,090**	**1,455**	**2,455**	**1,495**	**600**	**515**	**685**	**605**	**250**	**11,600**
Lower Decile (LD)													
Fort Peck	230	300	400	450	865	1,180	600	260	230	310	300	225	5,350
Garrison	190	265	720	565	1,055	2,040	1,050	350	310	440	320	145	7,450
Oahe	-20	50	400	190	110	275	110	25	60	10	0	-60	1,150
Fort Randall	-25	35	135	60	75	90	10	30	5	-25	-20	-20	350
Gavins Point	75	95	155	120	130	135	80	65	75	105	90	75	1,200
Sioux City	15	20	180	90	120	65	75	40	35	30	50	-20	700
Total	**465**	**765**	**1,990**	**1,475**	**2,355**	**3,785**	**1,925**	**770**	**715**	**870**	**740**	**345**	**16,200**
Lower Quartile (LQ)													
Fort Peck	240	310	415	460	945	1,500	650	285	240	335	330	240	5,950
Garrison	220	280	835	640	1,180	2,525	1,700	475	395	455	335	160	9,200
Oahe	-15	60	440	250	140	310	130	35	70	15	10	-45	1,400
Fort Randall	-10	40	160	70	80	95	15	35	10	-20	-15	-10	450
Gavins Point	80	105	165	130	150	150	85	70	80	110	95	80	1,300
Sioux City	20	50	250	100	190	220	85	135	50	55	30	15	1,200
Total	**535**	**845**	**2,265**	**1,650**	**2,685**	**4,800**	**2,665**	**1,035**	**845**	**950**	**785**	**440**	**19,500**
Median (MED)													
Fort Peck	260	350	470	560	1,130	1,795	835	365	290	385	410	300	7,150
Garrison	255	350	940	765	1,240	3,150	2,070	570	475	500	355	180	10,850
Oahe	-10	100	625	390	225	600	170	65	80	30	90	-15	2,350
Fort Randall	15	45	260	170	110	135	65	45	50	10	-5	0	900
Gavins Point	90	120	170	145	175	215	95	85	85	115	110	95	1,500
Sioux City	35	110	400	320	270	300	160	130	90	65	50	20	1,950
Total	**645**	**1,075**	**2,865**	**2,350**	**3,150**	**6,195**	**3,395**	**1,260**	**1,070**	**1,105**	**1,010**	**580**	**24,700**
Upper Quartile (LQ)													
Fort Peck	285	380	640	780	1,345	2,155	1,100	405	350	440	450	320	8,650
Garrison	315	420	995	1,260	1,750	3,200	2,440	750	505	555	410	250	12,850
Oahe	0	155	1,090	410	315	680	240	75	90	40	115	-10	3,200
Fort Randall	30	50	320	275	135	160	80	55	70	15	0	10	1,200
Gavins Point	95	130	230	200	305	250	175	160	110	125	120	100	2,000
Sioux City	40	120	420	880	460	350	220	175	135	65	90	45	3,000
Total	**765**	**1,255**	**,3695**	**3,805**	**4,310**	**6,795**	**4,255**	**1,620**	**1,260**	**1,240**	**1,185**	**715**	**30,900**
Upper Decile (LD)													
Fort Peck	300	390	705	825	1,500	2,360	1,200	430	400	540	500	350	9,500
Garrison	325	455	1,100	1,410	1,945	3,570	2,700	840	560	640	420	285	14,250
Oahe	10	170	1,170	510	395	790	310	100	150	120	145	30	3,900
Fort Randall	40	55	440	310	150	210	100	70	80	20	5	20	1,500
Gavins Point	105	160	250	230	335	290	215	190	135	155	130	105	2,300
Sioux City	45	170	460	950	545	620	300	230	170	100	100	60	3,750
Total	**825**	**1,400**	**4,125**	**4,235**	**4,870**	**7,840**	**4,825**	**1,860**	**1,495**	**1,575**	**1,300**	**850**	**35,200**
98 Percentile (U2)													
Fort Peck	340	445	835	980	1,815	2,750	1,400	500	470	630	545	390	11,100
Garrison	340	505	1,245	2,150	2,000	3,995	3,020	975	710	660	440	310	16,350
Oahe	20	240	1,680	785	600	1,150	440	150	300	170	160	55	5,750
Fort Randall	80	70	835	390	185	250	135	100	90	25	10	30	2,200
Gavins Point	145	225	340	295	405	470	275	260	235	195	190	165	3,200
Sioux City	170	215	610	1,830	1,330	960	775	475	300	375	250	110	7,400
Total	**1,095**	**1,700**	**5,545**	**6,430**	**6,335**	**9,575**	**6,045**	**2,460**	**2,105**	**2,055**	**1,595**	**1,060**	**46,000**

Table 5
Monthly Distribution of Reach Runoff
in Percent of Annual Runoff

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
2 Percentile (L2)													
Fort Peck	5.3	6.6	9.6	9.4	12.6	17.8	9.6	4.8	4.7	7.4	6.9	5.3	100.0
Garrison	2.8	3.6	9.6	7.5	12.3	25.4	16.6	5.3	4.1	5.9	4.7	2.1	100.0
Oahe	-5.0	6.0	40.0	24.0	16.0	20.0	6.0	2.0	5.0	1.0	-1.0	-14.0	100.0
Fort Randall	-30.0	15.0	80.0	25.0	40.0	35.0	5.0	10.0	0.0	-30.0	-25.0	-25.0	100.0
Gavins Point	6.4	8.2	12.7	10.0	10.9	11.4	6.4	5.5	6.4	8.6	7.7	5.9	100.0
Sioux City	0.0	5.8	38.5	13.5	7.7	17.3	25.0	11.5	0.0	-3.8	3.8	-19.2	100.0
Basin Total	3.3	5.3	12.5	9.4	12.5	21.2	12.9	5.2	4.4	5.9	5.2	2.2	100.0
Lower Decile (LD)													
Fort Peck	4.3	5.6	7.5	8.4	16.2	22.1	11.2	4.9	4.3	5.8	5.6	4.2	100.0
Garrison	2.6	3.6	9.7	7.6	14.2	27.4	14.1	4.7	4.2	5.9	4.3	1.9	100.0
Oahe	-1.7	4.3	34.8	16.5	9.6	23.9	9.6	2.2	5.2	0.9	0.0	-5.2	100.0
Fort Randall	-7.1	10.0	38.6	17.1	21.4	25.7	2.9	8.6	1.4	-7.1	-5.7	-5.7	100.0
Gavins Point	6.3	7.9	12.9	10.0	10.8	11.3	6.7	5.4	6.3	8.8	7.5	6.3	100.0
Sioux City	2.1	2.9	25.7	12.9	17.1	9.3	10.7	5.7	5.0	4.3	7.1	-2.9	100.0
Basin Total	2.9	4.7	12.3	9.1	14.5	23.4	11.9	4.8	4.4	5.4	4.6	2.1	100.0
Lower Quartile (LQ)													
Fort Peck	4.0	5.2	7.0	7.7	15.9	25.2	10.9	4.8	4.0	5.6	5.5	4.0	100.0
Garrison	2.4	3.0	9.1	7.0	12.8	27.4	18.5	5.2	4.3	4.9	3.6	1.7	100.0
Oahe	-1.1	4.3	31.4	17.9	10.0	22.1	9.3	2.5	5.0	1.1	0.7	-3.2	100.0
Fort Randall	-2.2	8.9	35.6	15.6	17.8	21.1	3.3	7.8	2.2	-4.4	-3.3	-2.2	100.0
Gavins Point	6.2	8.1	12.7	10.0	11.5	11.5	6.5	5.4	6.2	8.5	7.3	6.2	100.0
Sioux City	1.7	4.2	20.8	8.3	15.8	18.3	7.1	11.3	4.2	4.6	2.5	1.3	100.0
Basin Total	2.7	4.3	11.6	8.5	13.8	24.6	13.7	5.3	4.3	4.9	4.0	2.3	100.0
Median (MED)													
Fort Peck	3.6	4.9	6.6	7.8	15.8	25.1	11.7	5.1	4.1	5.4	5.7	4.2	100.0
Garrison	2.4	3.2	8.7	7.1	11.4	29.0	19.1	5.3	4.4	4.6	3.3	1.7	100.0
Oahe	-0.4	4.3	26.6	16.6	9.6	25.5	7.2	2.8	3.4	1.3	3.8	-0.6	100.0
Fort Randall	1.7	5.0	28.9	18.9	12.2	15.0	7.2	5.0	5.6	1.1	-0.6	0.0	100.0
Gavins Point	6.0	8.0	11.3	9.7	11.7	14.3	6.3	5.7	5.7	7.7	7.3	6.3	100.0
Sioux City	1.8	5.6	20.5	16.4	13.8	15.4	8.2	6.7	4.6	3.3	2.6	1.0	100.0
Basin Total	2.6	4.4	11.6	9.5	12.8	25.1	13.7	5.1	4.3	4.5	4.1	2.3	100.0
Upper Quartile (UQ)													
Fort Peck	3.3	4.4	7.4	9.0	15.5	24.9	12.7	4.7	4.0	5.1	5.2	3.7	100.0
Garrison	2.5	3.3	7.7	9.8	13.6	24.9	19.0	5.8	3.9	4.3	3.2	1.9	100.0
Oahe	0.0	4.8	34.1	12.8	9.8	21.3	7.5	2.3	2.8	1.3	3.6	-0.3	100.0
Fort Randall	2.5	4.2	26.7	22.9	11.3	13.3	6.7	4.6	5.8	1.3	0.0	0.8	100.0
Gavins Point	4.8	6.5	11.5	10.0	15.3	12.5	8.8	8.0	5.5	6.3	6.0	5.0	100.0
Sioux City	1.3	4.0	14.0	29.3	15.3	11.7	7.3	5.8	4.5	2.2	3.0	1.5	100.0
Basin Total	2.5	4.1	12.0	12.3	13.9	22.0	13.8	5.2	4.1	4.0	3.8	2.3	100.0
Upper Decile (UD)													
Fort Peck	3.2	4.1	7.4	8.7	15.8	24.8	12.6	4.5	4.2	5.7	5.3	3.7	100.0
Garrison	2.3	3.2	7.7	9.9	13.6	25.1	18.9	5.9	3.9	4.5	2.9	2.0	100.0
Oahe	0.3	4.4	30.0	13.1	10.1	20.3	7.9	2.6	3.8	3.1	3.7	0.8	100.0
Fort Randall	2.7	3.7	29.3	20.7	10.0	14.0	6.7	4.7	5.3	1.3	0.3	1.3	100.0
Gavins Point	4.6	7.0	10.9	10.0	14.6	12.6	9.3	8.3	5.9	6.7	5.7	4.6	100.0
Sioux City	1.2	4.5	12.3	25.3	14.5	16.5	8.0	6.1	4.5	2.7	2.7	1.6	100.0
Basin Total	2.3	4.0	11.7	12.0	13.8	22.3	13.7	5.3	4.2	4.5	3.7	2.4	100.0
98 Percentile (U2)													
Fort Peck	3.1	4.0	7.5	8.8	16.4	24.8	12.6	4.5	4.2	5.7	4.9	3.5	100.0
Garrison	2.1	3.1	7.6	13.1	12.2	24.4	18.5	6.0	4.3	4.0	2.7	1.9	100.0
Oahe	0.3	4.2	29.2	13.7	10.4	20.0	7.7	2.6	5.2	3.0	2.8	1.0	100.0
Fort Randall	3.6	3.2	38.0	17.7	8.4	11.4	6.1	4.5	4.1	1.1	0.5	1.4	100.0
Gavins Point	4.5	7.0	10.6	9.2	12.7	14.7	8.6	8.1	7.3	6.1	5.9	5.2	100.0
Sioux City	2.3	2.9	8.2	24.7	18.0	13.0	10.5	6.4	4.1	5.1	3.4	1.5	100.0
Basin Total	2.4	3.7	12.1	14.0	13.8	20.8	13.1	5.3	4.6	4.5	3.5	2.3	100.0

III. DETERMINATION OF RUNOFF FOR EXTENSION YEARS

In addition to an analysis of the effects of various levels of runoff upon system functions during the coming year, the AOP presents 5-year extensions beyond the coming year to serve long-range planning purposes, primarily hydropower generation. Although the AOP typically only presents extension studies for median and lower runoff levels, extensions are included in this report for the UD, UQ, LQ, and LD runoff levels. Running extensions for the 2 percentile and 98 percentiles do not add significant value to the intended use of these extensions.

A) Distribution of Runoff for Extension Years by Reach

The median extension consists of a succession of five median years. However, if a similar procedure was used for the quartile and decile runoff levels, the probability of such a succession would be considerably more remote than the runoff description indicates. And yet, the five additional extension years should represent the significance level that their names imply. Therefore, to account for the probability of successive years of low or high runoff, the following procedure and resulting runoff volumes for the LD, LQ, UQ, and UD extension years are outlined below.

1. Running averages of annual runoff above Sioux City were computed for 2-, 3-, 4-, 5-, and 6-year periods.

2. The running averages were ranked, and volume duration relationships were derived. The resulting durations are shown on Plates 8 through 12.

3. The 2-, 3-, 4-, 5-, and 6-year average runoff volumes were determined from the durations for the LD (10%), LQ (25%), UQ (75%) and UD (90%) non-exceedance levels.

4. The actual runoff for the 2nd, 3rd, 4th, 5th, and 6th years were determined by working backward from the prior year's runoff. For example, the initial lower decile runoff volume was 16,200 kAF and the 2-year average for the lower decile condition was 16,800 kAF, so the 2nd year of a lower decile runoff period was calculated to be [(2 * 16,800) - 16,200] = 17,400 kAF. The running averages were adjusted slightly to avoid having the runoff in the 2nd through 6th years vary greatly from year to year. The resultant annual runoff volumes for the 5-year extension period for the LD and LQ runoff levels are shown in Table 6. The resultant annual runoff volumes for the 5-year extension period for the UQ and UD runoff levels are shown in Table 7.

Table 6
Annual Runoff Volumes for Extension Years, LD and LQ

Lower Decile (LD)

Number of years (n)	n-year Average Flow (kAF)	Year	Runoff (kAF)
1	16,200	Initial	16,200
2	16,800	1st extension	17,400
3	17,100	2nd extension	17,700
4	17,400	3rd extension	18,300
5	17,800	4th extension	19,400
6	18,100	5th extension	19,600

Lower Quartile (LQ)

Number of years (n)	n-year Average Flow (kAF)	Year	Runoff (kAF)
1	19,500	Initial	19,500
2	20,000	1st extension	20,500
3	20,700	2nd extension	22,100
4	21,100	3rd extension	22,300
5	21,500	4th extension	23,100
6	22,000	5th extension	24,500

Table 7
Annual Runoff Volumes for Extension Years, UQ and UD

Upper Quartile (UQ)			
Number of years (n)	n-year Average Flow (kAF)	Year	Runoff (kAF)
1	30,900	Initial	30,900
2	29,800	1st extension	28,700
3	29,300	2nd extension	28,300
4	29,000	3rd extension	28,100
5	28,700	4th extension	27,500
6	28,400	5th extension	26,900
Upper Decile (UD)			
Number of years (n)	n-year Average Flow (kAF)	Year	Runoff (kAF)
1	35,200	Initial	35,200
2	33,100	1st extension	31,000
3	32,100	2nd extension	30,100
4	31,500	3rd extension	29,700
5	31,100	4th extension	29,500
6	30,800	5th extension	29,300

B) Distribution of Runoff for Extension Years by Month

As with the initial year's runoff, it was necessary to distribute runoff for the extension years by reach and by month. The areal distribution of runoff for the extension years was based on the areal distribution of the initial year. Since the total upper basin runoff for the extension years varies widely, for example, from 19,500 kAF to 24,500 kAF for the lower quartile runoff condition, it was not appropriate to use the initial year's reach distribution percentages directly. Rather, a straight-line interpolation between the reach runoff percentages was used. In the case of the lower quartile example, the straight-line interpolation was between the lower quartile and median reach runoff percentages. The reach runoffs (in 1000 acre-feet) are shown in Table 8 for the lower decile and lower quartile runoffs. The reach runoffs (in 1000 acre-feet) are shown in Table 9 for the upper quartile and upper decile runoffs.

Table 8
Annual Incremental Reach Runoff Volumes
for Extension Years, LD and LQ
1000 Acre-Feet (kAF)

Lower Decile (LD)

Reach	1st Year	2nd Year	3rd Year	4th Year	5th Year
Fort Peck	5,588	5,643	5,751	5,934	5,966
Garrison	8,077	8,236	8,555	9,146	9,254
Oahe	1,240	1,263	1,308	1,392	1,408
Fort Randall	385	394	413	447	453
Gavins Point	1,242	1,252	1,269	1,298	1,302
Sioux City	868	912	1,004	1,183	1,217
Total	17,400	17,700	18,300	19,400	19,600

Lower Quartile (LQ)

Reach	1st Year	2nd Year	3rd Year	4th Year	5th Year
Fort Peck	6,193	6,570	6,616	6,798	7,107
Garrison	9,544	10,067	10,131	10,378	10,793
Oahe	1,564	1,845	1,882	2,032	2,309
Fort Randall	526	658	675	747	880
Gavins Point	1,343	1,408	1,415	1,445	1,493
Sioux City	1,330	1,552	1,581	1,700	1,918
Total	20,500	22,100	22,300	23,100	24,500

Table 9
Annual Incremental Reach Runoff Volumes
for Extension Years, UQ and UD
1000 Acre-Feet (kAF)

Upper Quartile (UQ)

Reach	1st Year	2nd Year	3rd Year	4th Year	5th Year
Fort Peck	8,131	8,035	7,987	7,842	7,696
Garrison	12,174	12,047	11,983	11,789	11,593
Oahe	2,886	2,831	2,803	2,721	2,639
Fort Randall	1,090	1,071	1,061	1,032	1,003
Gavins Point	1,817	1,784	1,768	1,720	1,672
Sioux City	2,602	2,532	2,498	2,396	2,297
Total	28,700	28,300	28,100	27,500	26,900

Upper Decile (UD)

Reach	1st Year	2nd Year	3rd Year	4th Year	5th Year
Fort Peck	8,673	8,463	8,369	8,321	8,274
Garrison	12,880	12,608	12,486	12,424	12,362
Oahe	3,215	3,084	3,027	2,999	2,971
Fort Randall	1,205	1,160	1,140	1,130	1,120
Gavins Point	2,008	1,933	1,899	1,883	1,866
Sioux City	3,019	2,852	2,779	2,743	2,707
Total	31,000	30,100	29,700	29,500	29,300

The monthly distributions of runoff developed for the initial year were used to distribute the reach runoff for the extension years. The LD distribution was used for the five lower decile extension years, the LQ distribution was used for the five lower quartile extension years, the UQ distribution was used for the five upper quartile years, and the UD distribution was used for the upper decile years. The resulting monthly flows for each of the lower decile extension years are shown in Table 10. Table 11 shows the monthly flows for the lower quartile extension years. Table 12 shows the monthly flows for the upper quartile extension years and Table 13 shows the monthly flows for the upper decile extension years.

Table 10
Lower Decile (LD)
Extension Years
Monthly Reach Runoff Volumes
1000 Acre-Feet (kAF)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
1st Extension Year													
Fort Peck	240	313	418	470	903	1,232	627	272	240	325	313	235	5,588
Garrison	206	287	781	613	1,144	2,212	1,138	379	336	477	347	157	8,077
Oahe	-22	54	431	205	119	297	118	27	65	11	0	-65	1,240
Fort Randall	-28	39	149	65	83	99	11	33	6	-28	-22	-22	385
Gavins Point	78	98	160	124	135	140	83	67	78	108	93	78	1,242
Sioux City	19	25	223	112	149	80	93	50	43	37	62	-25	868
Total	493	816	2,162	1,589	2,533	4,060	2,070	828	768	930	793	358	17,400
2nd Extension Year													
Fort Peck	243	316	422	475	912	1,245	633	274	243	327	316	237	5,643
Garrison	210	293	796	625	1,166	2,255	1,161	387	343	486	354	160	8,236
Oahe	-22	55	439	209	121	302	121	27	66	11	0	-66	1,263
Fort Randall	-28	39	152	68	85	101	11	34	6	-28	-23	-23	394
Gavins Point	78	99	162	125	136	141	83	68	78	110	94	78	1,252
Sioux City	20	26	235	117	156	85	98	52	45	39	65	-26	912
Total	501	828	2,206	1,619	2,576	4,129	2,107	842	781	945	806	360	17,700
3rd Extension Year													
Fort Peck	247	322	430	485	930	1,268	645	280	247	333	322	242	5,751
Garrison	218	304	827	650	1,211	2,342	1,206	402	357	505	367	166	8,555
Oahe	-23	57	455	216	125	313	125	29	69	11	0	-68	1,309
Fort Randall	-29	41	159	71	88	106	12	35	6	-29	-24	-24	412
Gavins Point	79	100	164	127	138	143	85	69	79	111	95	79	1,269
Sioux City	22	29	258	129	172	93	108	57	50	43	72	-29	1,004
Total	514	853	2,293	1,678	2,664	4,265	2,181	872	808	974	832	366	18,300
4th Extension Year													
Fort Peck	255	333	444	499	959	1,309	665	288	255	344	333	250	5,934
Garrison	233	325	884	694	1,295	2,504	1,289	430	381	540	393	178	9,146
Oahe	-24	61	484	230	133	333	133	30	73	12	0	-73	1,392
Fort Randall	-32	45	172	77	96	115	13	38	6	-31	-26	-26	447
Gavins Point	81	103	168	130	141	146	87	70	80	114	97	81	1,298
Sioux City	25	34	304	152	203	110	127	68	59	50	85	-34	1,183
Total	538	901	2,456	1,782	2,827	4,517	2,314	924	854	1,029	882	376	19,400
5th Extension Year													
Fort Peck	256	335	446	502	965	1,315	669	290	256	346	335	251	5,966
Garrison	236	329	894	702	1,311	2,534	1,304	435	385	547	397	180	9,254
Oahe	-24	61	490	233	135	337	135	30	72	12	0	-73	1,408
Fort Randall	-32	45	175	78	97	117	13	38	6	-32	-26	-26	453
Gavins Point	81	103	168	130	141	147	87	71	81	114	98	81	1,302
Sioux City	26	35	313	156	209	113	130	70	61	52	87	-35	1,217
Total	543	908	2,486	1,801	2,858	4,563	2,338	934	861	1,039	891	378	19,600

Table 11
Lower Quartile (LQ)
Extension Years
Monthly Reach Runoff Volumes
1000 Acre-Feet (kAF)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
1st Extension Year													
Fort Peck	250	323	432	479	984	1,560	676	296	250	349	344	250	6,193
Garrison	228	290	866	664	1,224	2,620	1,763	493	410	472	348	166	9,544
Oahe	-17	67	491	280	156	346	145	40	78	17	11	-50	1,564
Fort Randall	-12	47	187	82	93	111	18	41	12	-23	-18	-12	526
Gavins Point	83	108	170	134	155	155	88	72	83	114	98	83	1,343
Sioux City	22	55	277	111	211	244	94	150	55	61	33	17	1,330
Total	554	890	2,423	1,750	2,823	5,036	2,784	1,092	888	990	816	454	20,500
2nd Extension Year													
Fort Peck	265	342	458	508	1,044	1,656	718	315	265	370	364	265	6,570
Garrison	241	306	914	700	1,291	2,763	1,860	520	432	498	367	175	10,067
Oahe	-20	80	580	330	184	408	171	46	92	20	13	-59	1,845
Fort Randall	-15	58	234	102	117	139	22	51	15	-28	-22	-15	658
Gavins Point	87	114	179	141	162	162	92	75	87	119	103	87	1,408
Sioux City	26	65	323	129	246	285	110	175	65	70	39	19	1,552
Total	584	965	2,688	1,910	3,044	5,413	2,973	1,182	956	1,049	864	472	22,100
3rd Extension Year													
Fort Peck	267	345	461	512	1,050	1,668	723	316	267	373	367	267	6,616
Garrison	242	308	920	705	1,300	2,780	1,872	523	435	501	369	176	10,131
Oahe	-20	81	591	336	188	417	175	47	94	20	13	-60	1,882
Fort Randall	-15	60	240	105	120	143	23	52	15	-30	-23	-15	675
Gavins Point	87	114	180	142	163	163	93	76	87	120	103	87	1,415
Sioux City	26	66	329	132	250	290	112	178	66	72	40	20	1,581
Total	587	974	2,721	1,932	3,071	5,461	2,998	1,192	964	1,056	869	475	22,300
4th Extension Year													
Fort Peck	274	354	474	526	1,080	1,714	743	325	274	383	377	274	6,798
Garrison	248	316	942	722	1,331	2,848	1,918	536	446	513	378	180	10,378
Oahe	-22	87	639	363	203	450	189	50	101	22	15	-65	2,032
Fort Randall	-17	66	266	116	133	158	25	58	17	-33	-25	-17	747
Gavins Point	89	117	183	145	167	167	94	78	89	122	105	89	1,445
Sioux City	28	71	355	142	269	312	120	191	71	78	42	21	1,700
Total	600	1,011	2,859	2,014	3,183	5,649	3,089	1,238	998	1,085	892	482	23,100
5th Extension Year													
Fort Peck	287	370	496	549	1,129	1,792	776	340	287	400	394	287	7,107
Garrison	258	328	980	751	1,385	2,962	1,994	557	463	534	393	188	10,793
Oahe	-25	99	726	412	231	511	215	58	115	25	16	-74	2,309
Fort Randall	-20	78	313	137	156	186	30	68	20	-39	-29	-20	880
Gavins Point	92	121	190	149	172	172	98	80	92	126	109	92	1,493
Sioux City	32	80	400	160	304	352	135	215	80	88	48	24	1,918
Total	624	1,076	3,105	2,158	3,377	5,975	3,248	1,318	1,057	1,134	931	497	24,500

Table 12
Upper Quartile (UQ)
Extension Years
Monthly Reach Runoff Volumes
1000 Acre-Feet (kAF)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
1st Extension Year													
Fort Peck	268	357	602	733	1,264	2,025	1,034	381	329	414	423	301	8,131
Garrison	298	398	943	1,194	1,658	3,032	,2312	710	478	526	388	237	12,174
Oahe	0	140	983	370	284	613	216	68	81	36	104	-9	2,886
Fort Randall	27	45	290	250	123	145	73	50	64	14	0	9	1,090
Gavins Point	86	118	209	182	277	227	159	145	100	114	109	91	1,817
Sioux City	35	104	364	763	399	304	191	152	117	56	78	39	2,602
Total	714	1,162	3,391	3,492	4,005	6,346	3,985	1,506	1,169	1,160	1,102	668	28,700
2nd Extension Year													
Fort Peck	265	353	595	725	1,249	2,002	1,022	375	325	409	418	297	8,035
Garrison	295	395	933	1,181	1,641	3,000	2,287	703	473	520	385	234	12,047
Oahe	0	137	964	363	279	602	212	66	80	35	102	-9	2,831
Fort Randall	27	45	285	245	120	143	71	50	62	13	1	9	1,071
Gavins Point	85	116	205	178	272	223	156	143	98	112	107	89	1,784
Sioux City	34	101	355	743	388	295	185	148	114	55	76	38	2,532
Total	706	1,147	3,337	3,435	3,949	6,265	3,933	1,485	1,152	1,144	1,089	658	28,300
3rd Extension Year													
Fort Peck	263	351	591	720	1,242	1,990	1,016	374	323	406	416	295	7,987
Garrison	294	392	928	1,175	1,632	2,984	2,275	699	471	518	382	233	11,983
Oahe	0	136	955	359	275	596	210	65	79	35	101	-8	2,803
Fort Randall	27	44	283	243	119	141	71	49	62	13	0	9	1,061
Gavins Point	84	115	203	177	270	221	155	141	97	111	106	88	1,768
Sioux City	33	100	350	733	383	291	183	146	112	55	75	37	2,498
Total	701	1,138	3,310	3,407	3,921	6,223	3,910	1,474	1,144	1,138	1,080	654	28,100
4th Extension Year													
Fort Peck	258	345	580	707	1,219	1,955	997	367	317	399	408	290	7,842
Garrison	289	385	913	1,156	1,606	2,936	2,239	688	463	509	376	229	11,789
Oahe	0	132	927	349	268	578	204	64	76	34	98	-9	2,721
Fort Randall	26	43	275	236	116	138	69	47	60	13	0	9	1,032
Gavins Point	82	112	198	172	262	215	150	138	95	107	103	86	1,720
Sioux City	32	96	335	703	367	280	175	140	108	52	72	36	2,396
Total	687	1,113	3,228	3,323	3,838	6,102	3,834	1,444	1,119	1,114	1,057	641	27,500
5th Extension Year													
Fort Peck	254	338	569	694	1,197	1,917	980	360	311	391	400	285	7,696
Garrison	284	379	898	1,137	1,579	2,887	2,200	677	455	501	370	226	11,593
Oahe	0	128	899	338	260	561	198	62	74	33	95	-8	2,640
Fort Randall	25	42	267	230	113	134	67	46	58	13	0	8	1,003
Gavins Point	79	109	192	167	255	209	146	134	92	104	100	84	1,671
Sioux City	31	92	322	674	352	268	168	134	103	50	69	34	2,297
Total	673	1,088	3,147	3,240	3,756	5,976	3,759	1,413	1,093	1,092	1,034	629	26,900

Table 13
Upper Decile (UD)
Extension Years
Monthly Reach Runoff Volumes
1000 Acre-Feet (kAF)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
1st Extension Year													
Fort Peck	274	356	644	753	1,369	2,155	1,095	392	365	493	456	320	8,672
Garrison	303	415	1,116	908	1,472	3,739	2,457	677	564	594	421	214	12,880
Oahe	8	140	964	420	326	651	256	82	124	99	120	25	3,215
Fort Randall	32	44	353	250	121	169	80	56	64	16	4	16	1,205
Gavins Point	92	140	218	201	293	253	188	165	118	135	114	92	2,009
Sioux City	36	137	370	765	439	499	242	185	137	80	81	48	3,019
Total	745	1,232	3,665	,3297	4,020	7,466	4,318	1,557	1,372	1,417	1,196	715	31,000
2nd Extension Year													
Fort Peck	267	347	628	735	1,336	2,102	1,070	384	356	481	445	312	8,463
Garrison	296	407	1,092	890	1,441	3,660	2,405	662	552	581	413	209	12,608
Oahe	8	134	925	403	312	625	245	79	119	95	115	24	3,084
Fort Randall	31	43	340	240	116	162	77	55	62	15	4	15	1,160
Gavins Point	88	134	210	193	282	245	181	160	113	130	109	88	1,933
Sioux City	34	129	350	722	415	472	228	175	129	76	76	46	2,852
Total	724	1,194	3,545	3,183	3,902	7,266	4,206	1,515	1,331	1,378	1,162	694	30,100
3rd Extension Year													
Fort Peck	264	344	621	727	1,321	2,080	1,057	379	352	476	440	308	8,369
Garrison	293	403	1,082	880	1,427	3,625	2,382	656	547	575	409	207	12,486
Oahe	8	132	908	396	307	613	241	78	116	93	113	23	3,028
Fort Randall	30	42	334	236	114	160	76	53	61	15	4	15	1,140
Gavins Point	87	132	206	190	277	239	178	157	110	128	107	87	1,898
Sioux City	33	126	341	704	404	460	222	170	126	75	74	44	2,779
Total	715	1,179	3,492	3,133	3,850	7,177	4,156	1,493	1,312	1,362	1,147	684	29,700
4th Extension Year													
Fort Peck	263	342	618	723	1,314	2,067	1,050	376	350	473	438	307	8,321
Garrison	292	401	1,076	876	1,420	3,607	2,370	653	544	573	406	206	12,424
Oahe	8	131	900	392	305	607	238	77	115	92	111	23	2,999
Fort Randall	30	41	331	233	113	159	75	54	60	15	4	15	1,130
Gavins Point	86	131	205	188	274	237	176	156	111	127	106	86	1,883
Sioux City	33	124	337	695	399	454	219	168	124	73	73	44	2,743
Total	712	1,170	3,467	3,107	3,825	7,131	4,128	1,484	1,304	1,353	1,138	681	29,500
5th Extension Year													
Fort Peck	261	340	615	719	1,306	2,055	1,045	375	348	470	435	305	8,274
Garrison	291	399	1,071	872	1,413	3,589	2,358	649	541	570	404	205	12,362
Oahe	8	129	891	388	301	603	236	76	115	91	110	23	2,971
Fort Randall	30	41	328	231	112	157	75	52	60	15	4	15	1,120
Gavins Point	85	130	203	187	272	235	174	154	110	126	105	85	1,866
Sioux City	32	123	332	686	393	448	217	166	123	72	72	43	2,707
Total	707	1,162	3,440	3,083	3,797	7,087	4,105	1,472	1,297	1,344	1,130	676	29,300

Missouri River above Sioux City
Annual Runoff, 1898-2019

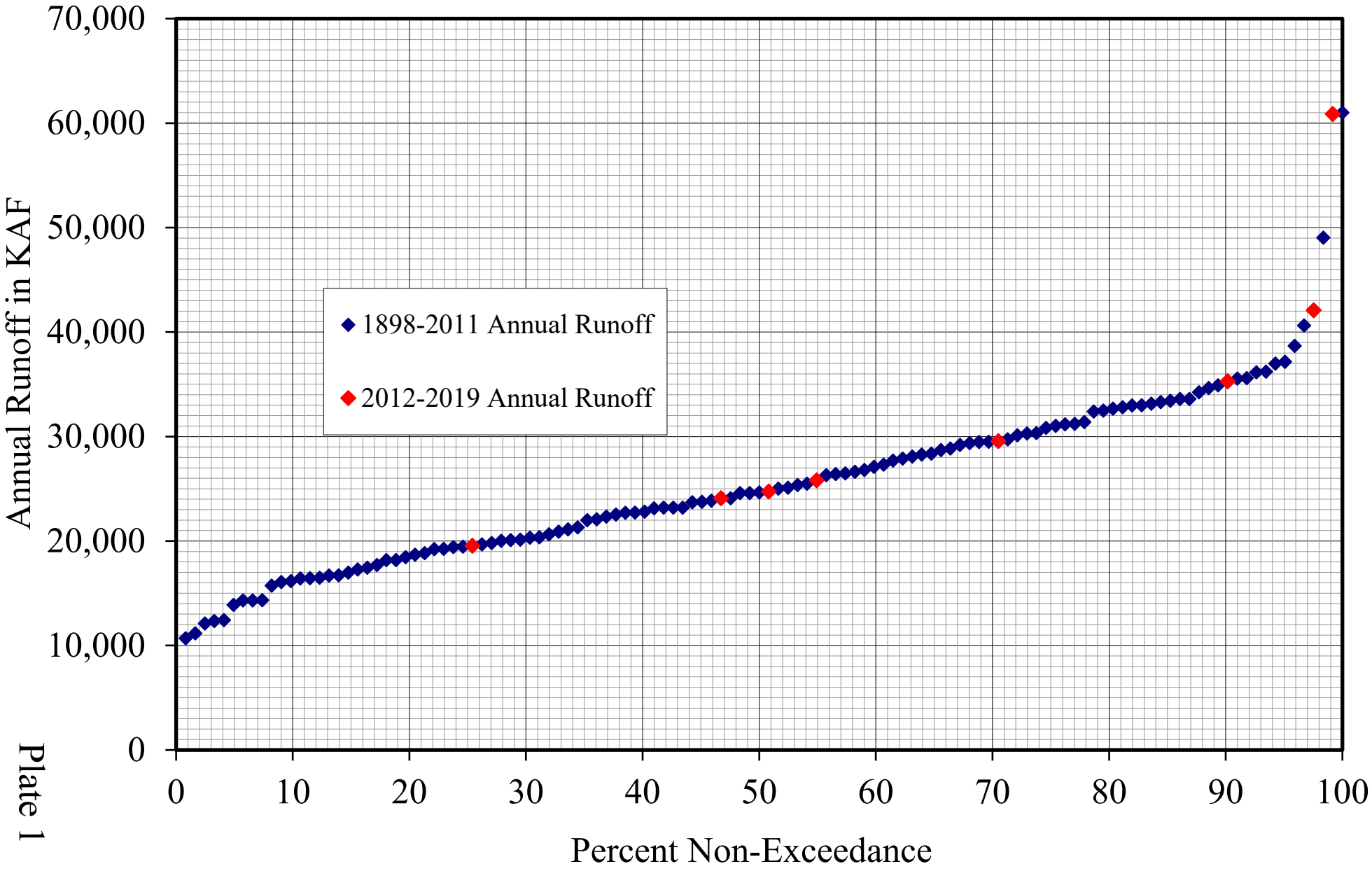

Plate 1

Missouri River above Fort Peck
Annual Runoff, 1898-2019

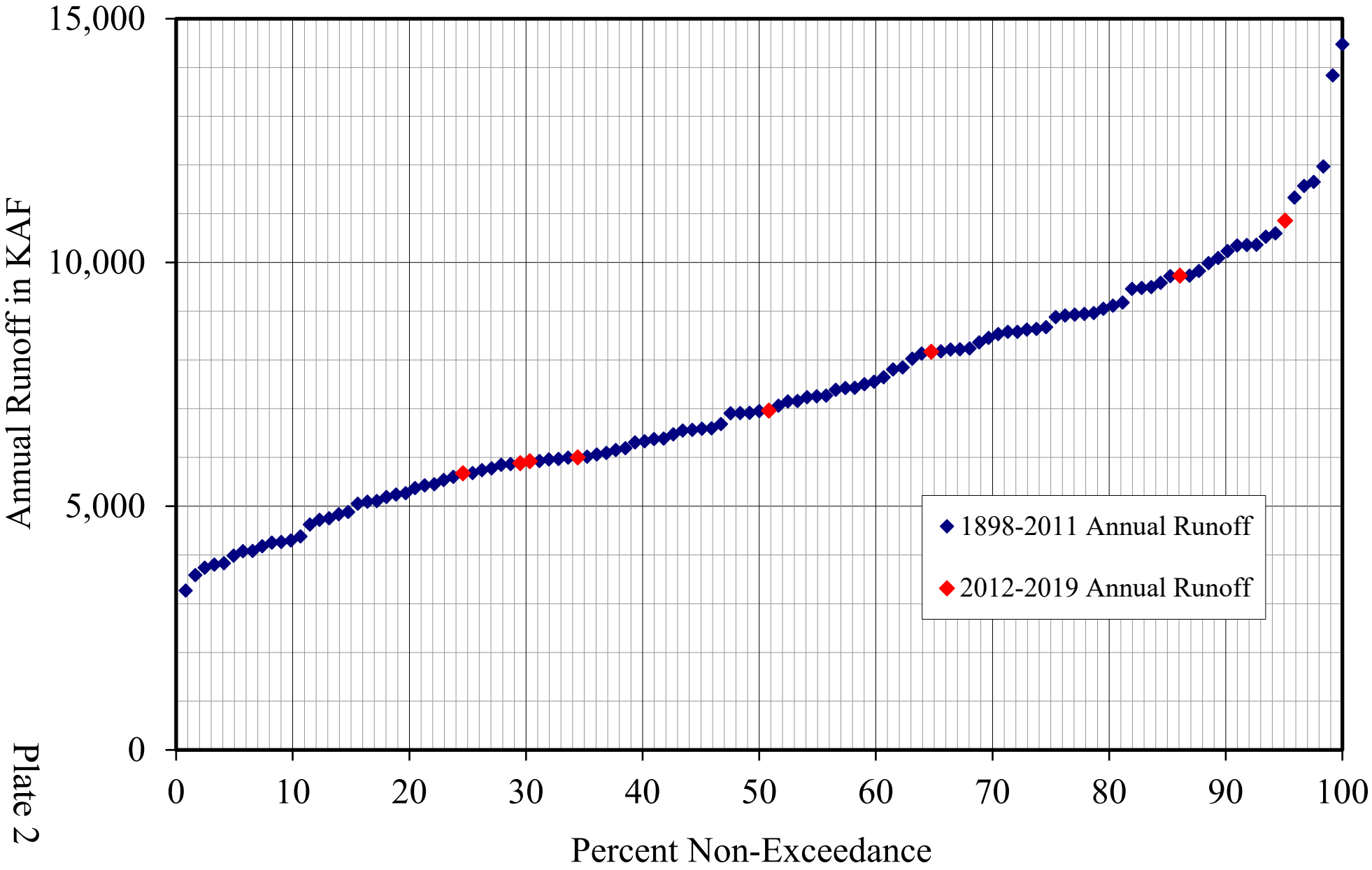

Plate 2

Fort Peck to Garrison
Annual Runoff, 1898-2019

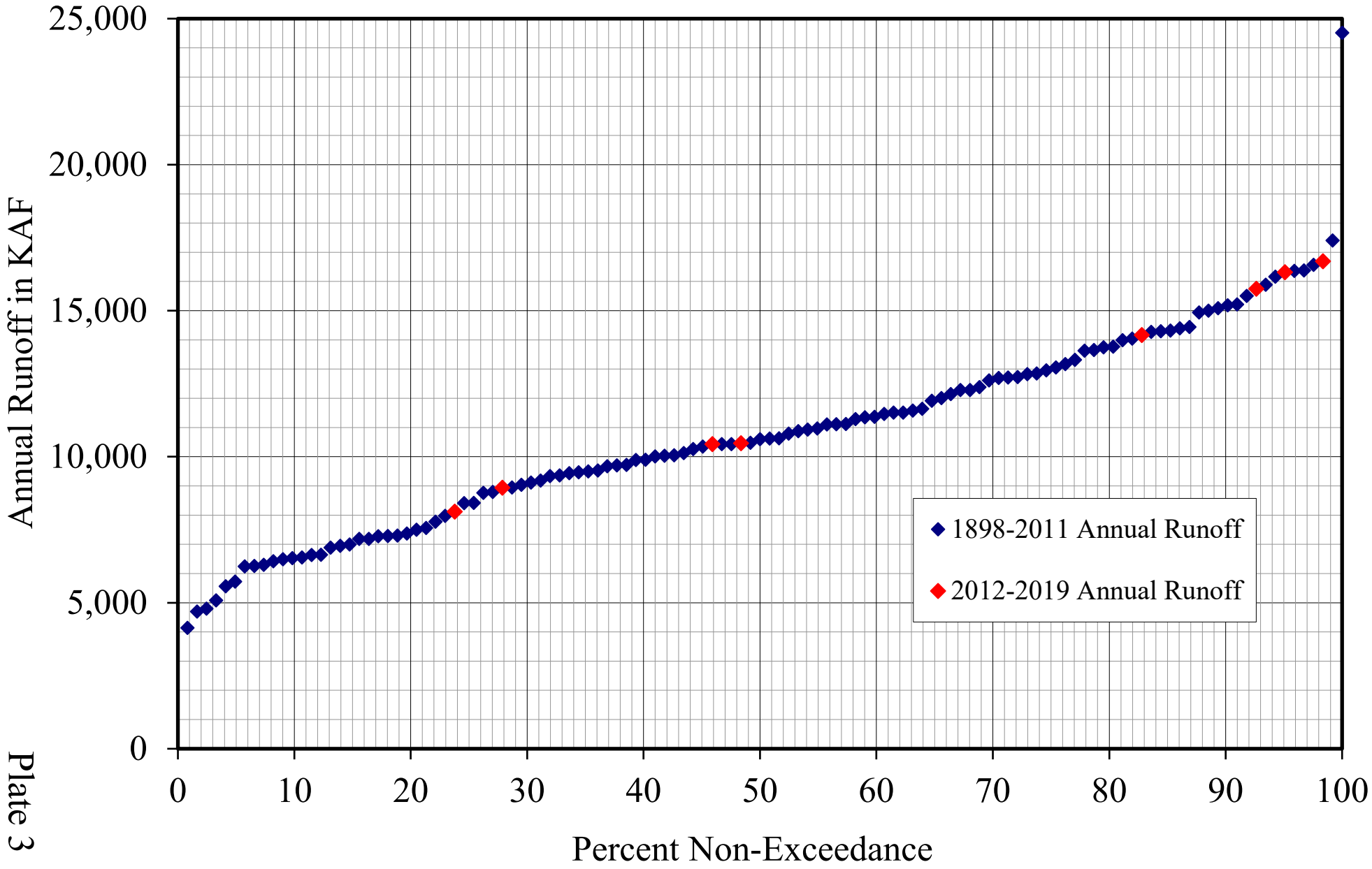

Plate 3

Garrison to Oahe
Annual Runoff, 1898-2019

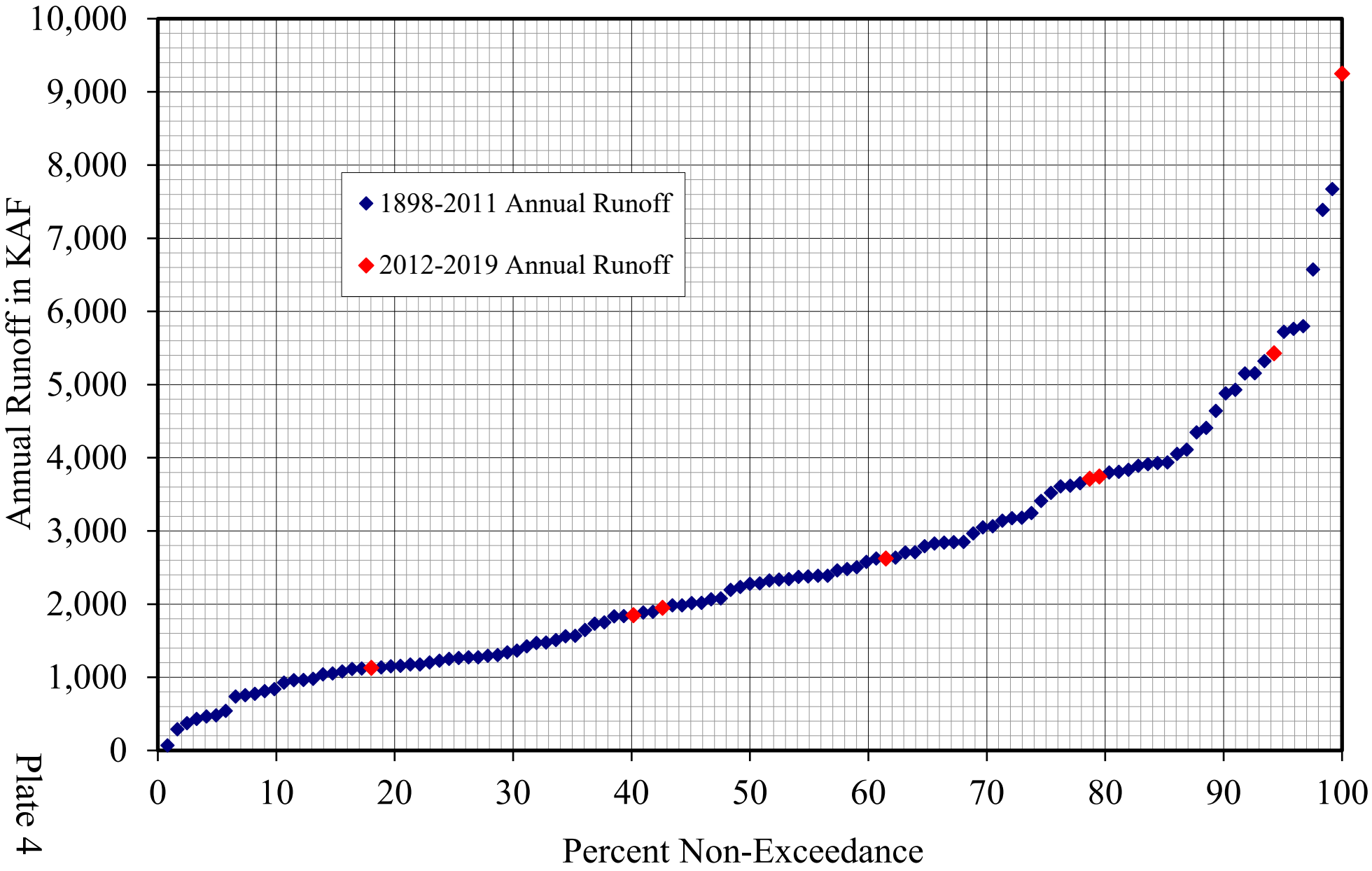

Plate 4

Oahe to Fort Randall
Annual Runoff, 1898-2019

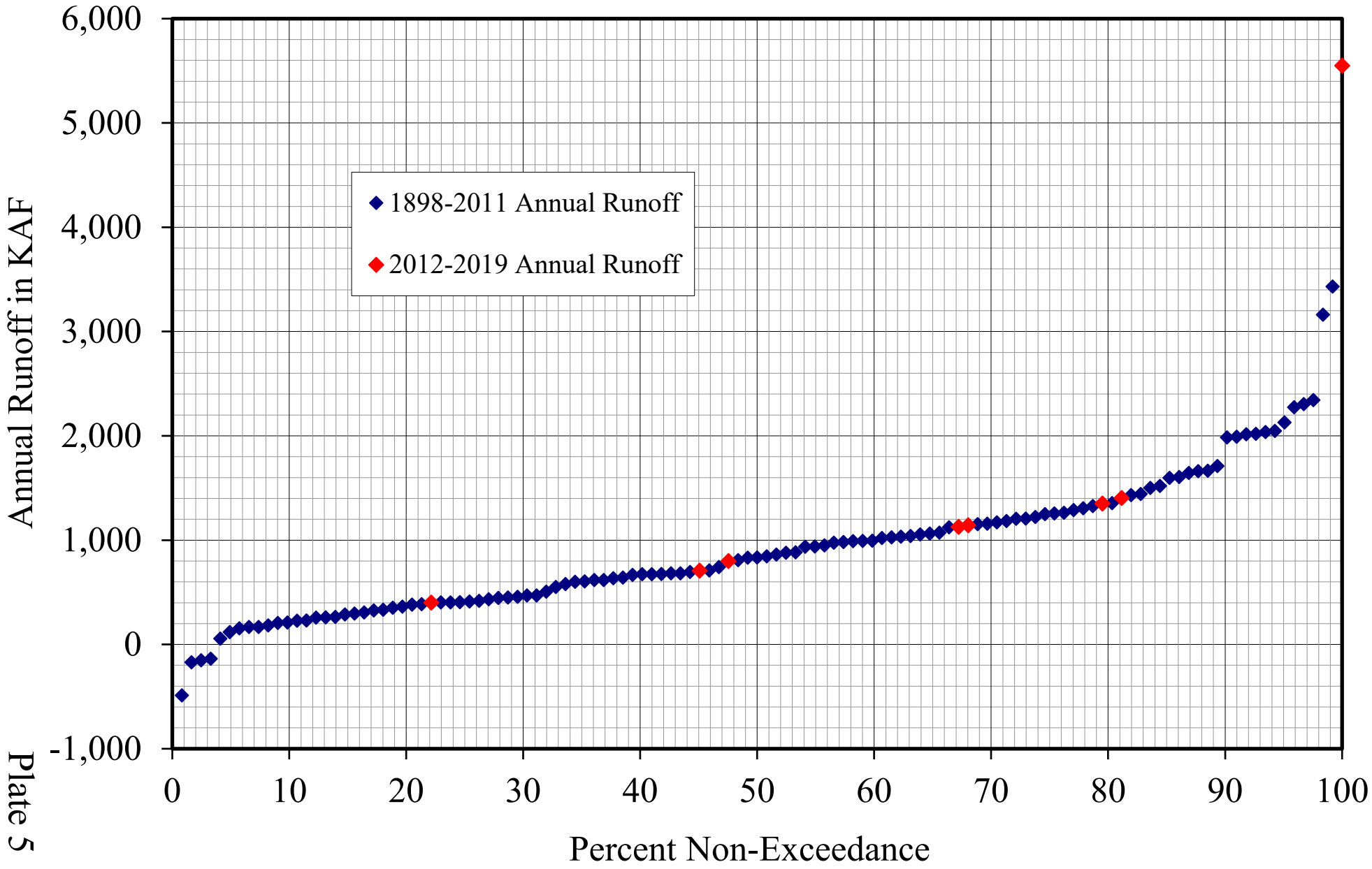

Plate 5

Fort Randall to Gavins Point
Annual Runoff, 1898-2019

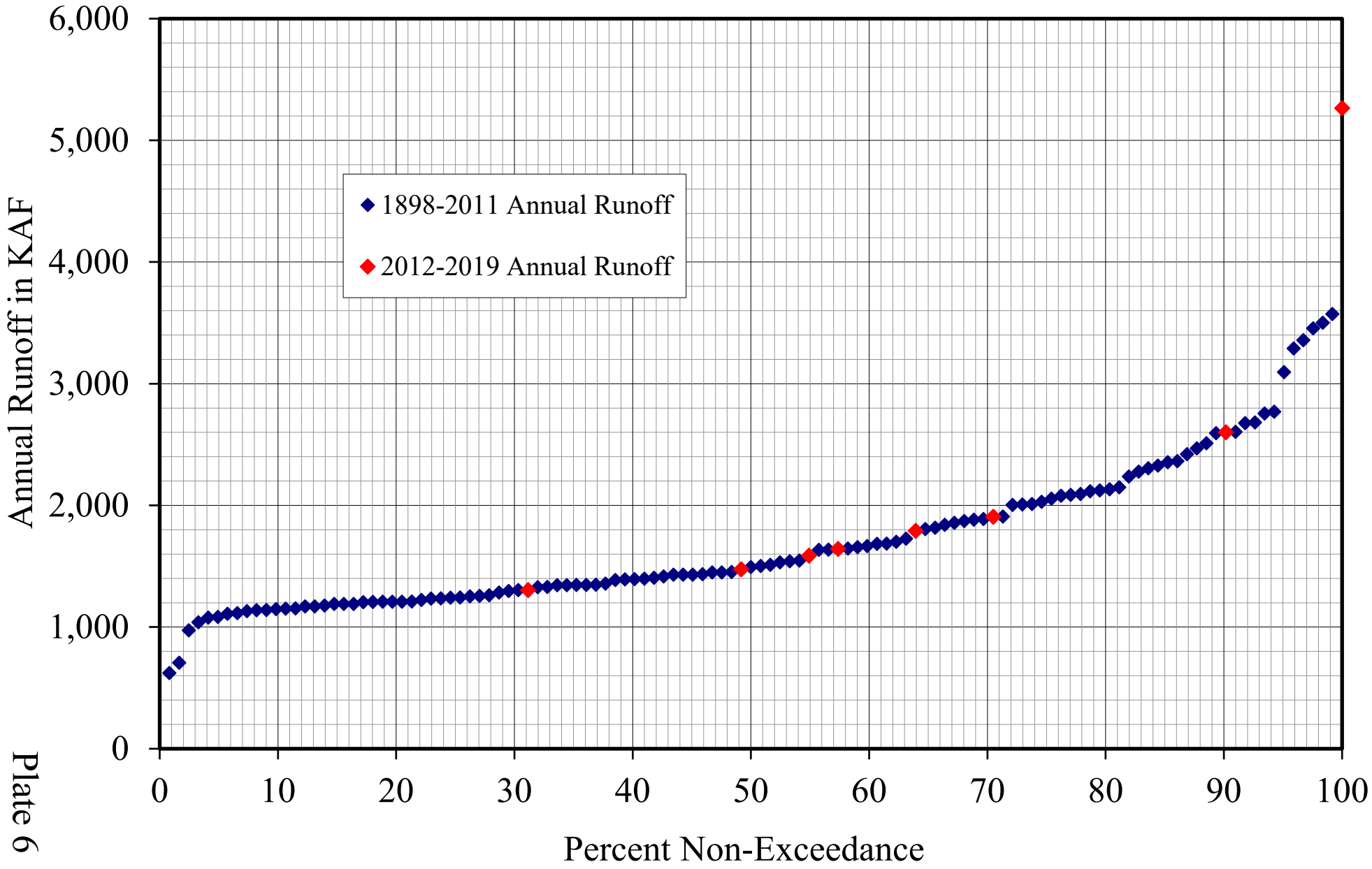

Plate 6

Gavins Point to Sioux City
Annual Runoff, 1898-2019

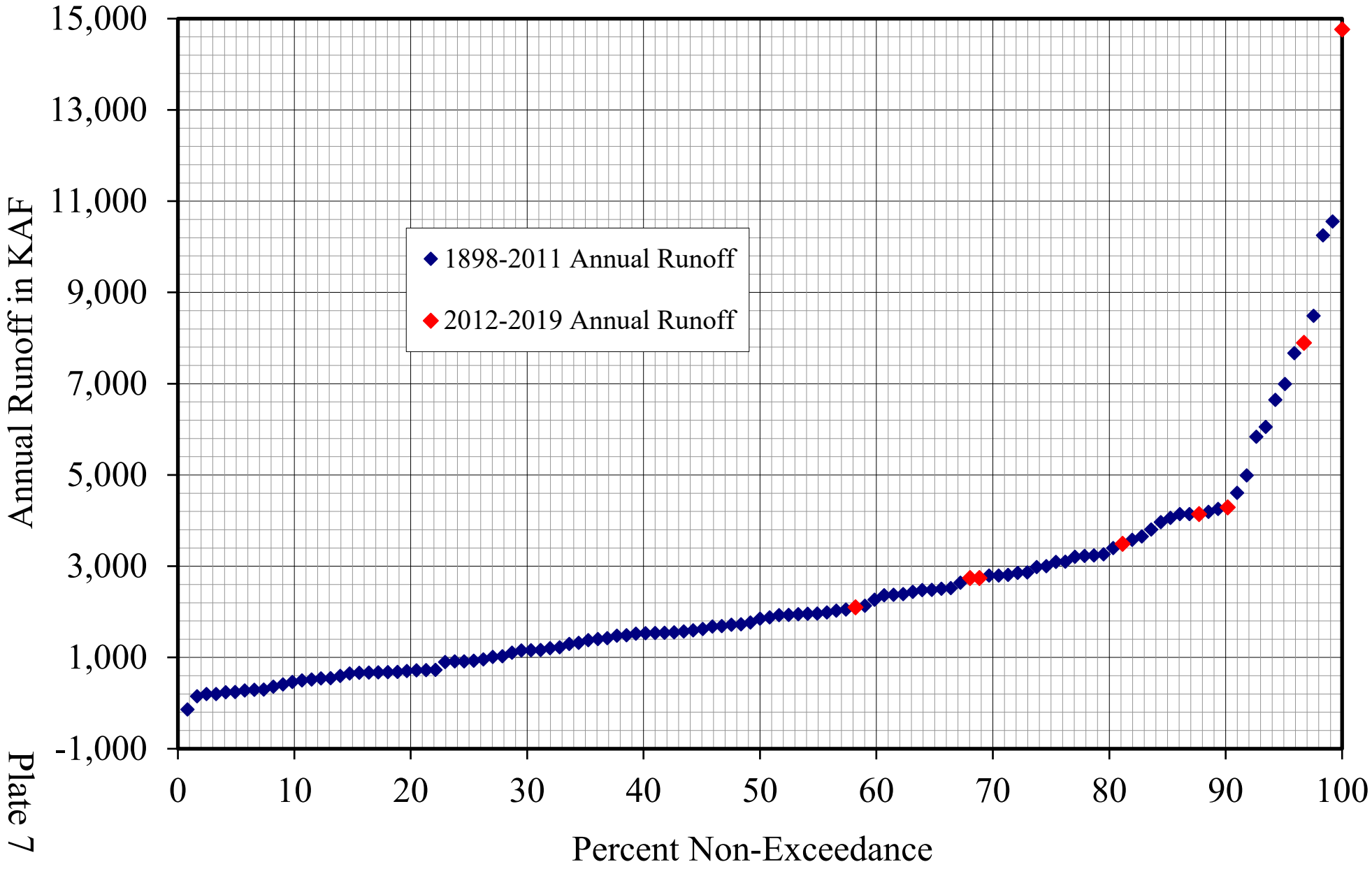

Plate 7

Missouri River above Sioux City
2-Year Average - Annual Runoff, 1898-2019

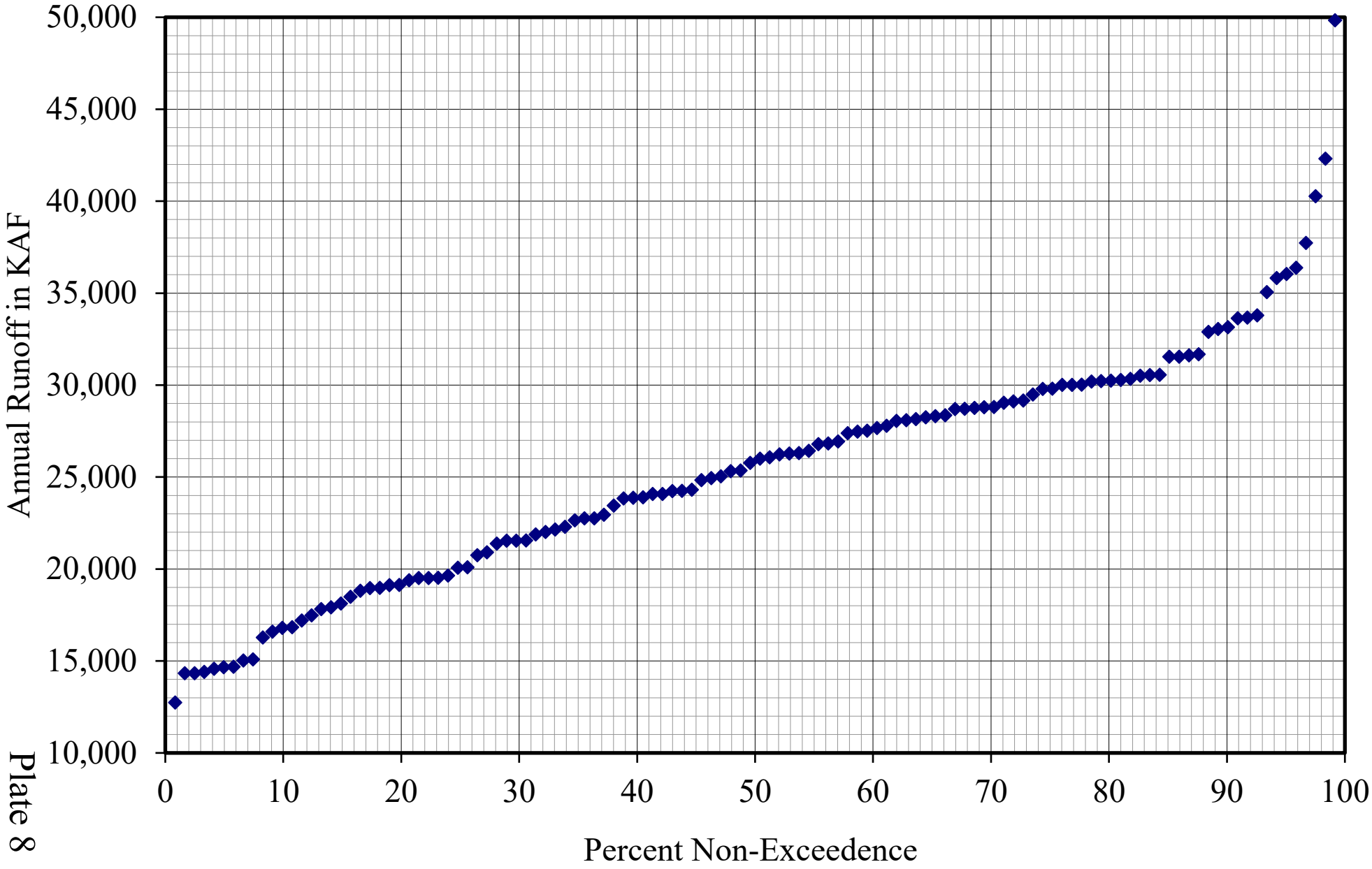

Plate 8

Missouri River above Sioux City
3-Year Average - Annual Runoff, 1898-2019

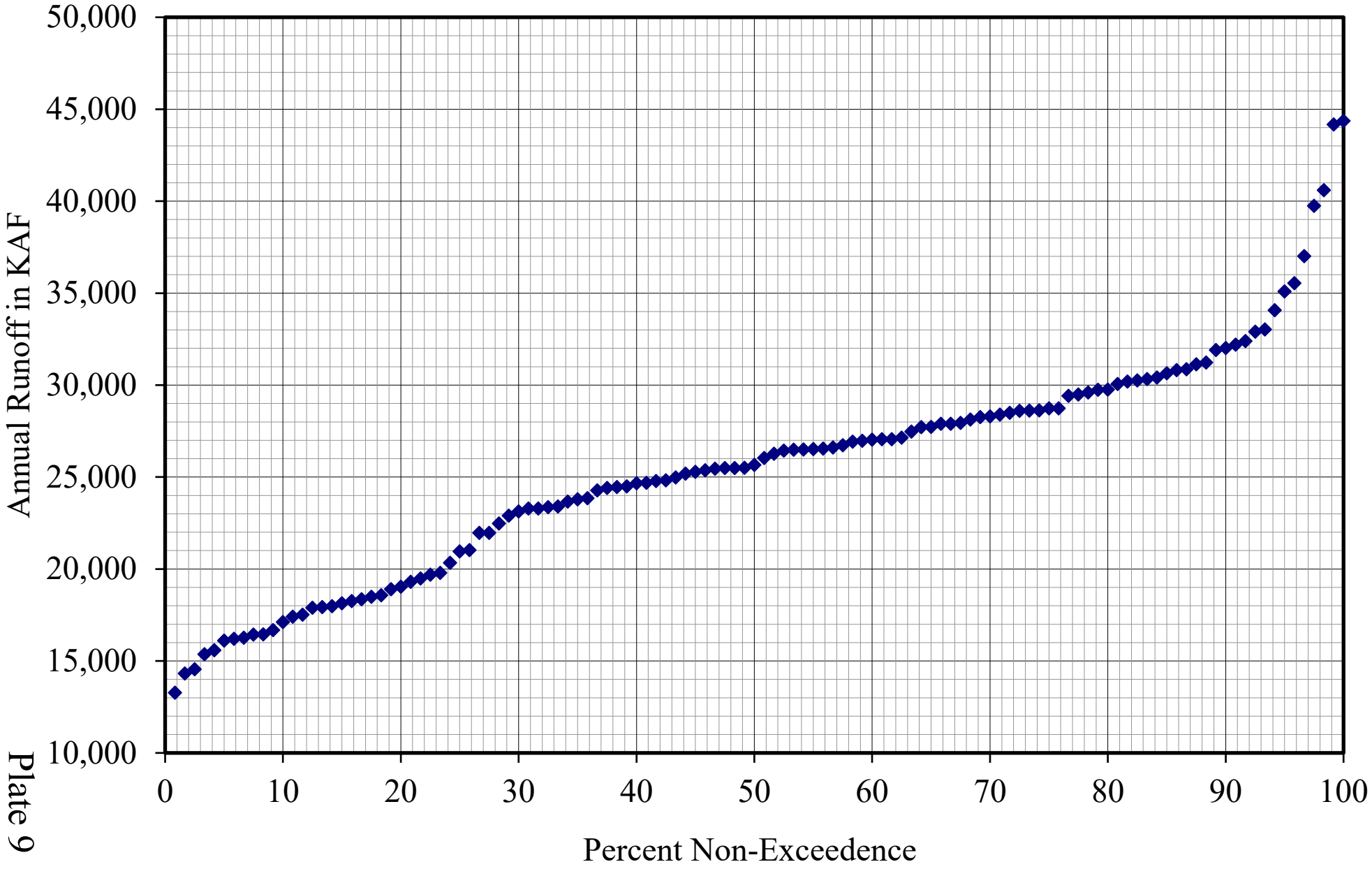

Plate 9

Missouri River above Sioux City
4-Year Average - Annual Runoff, 1898-2019

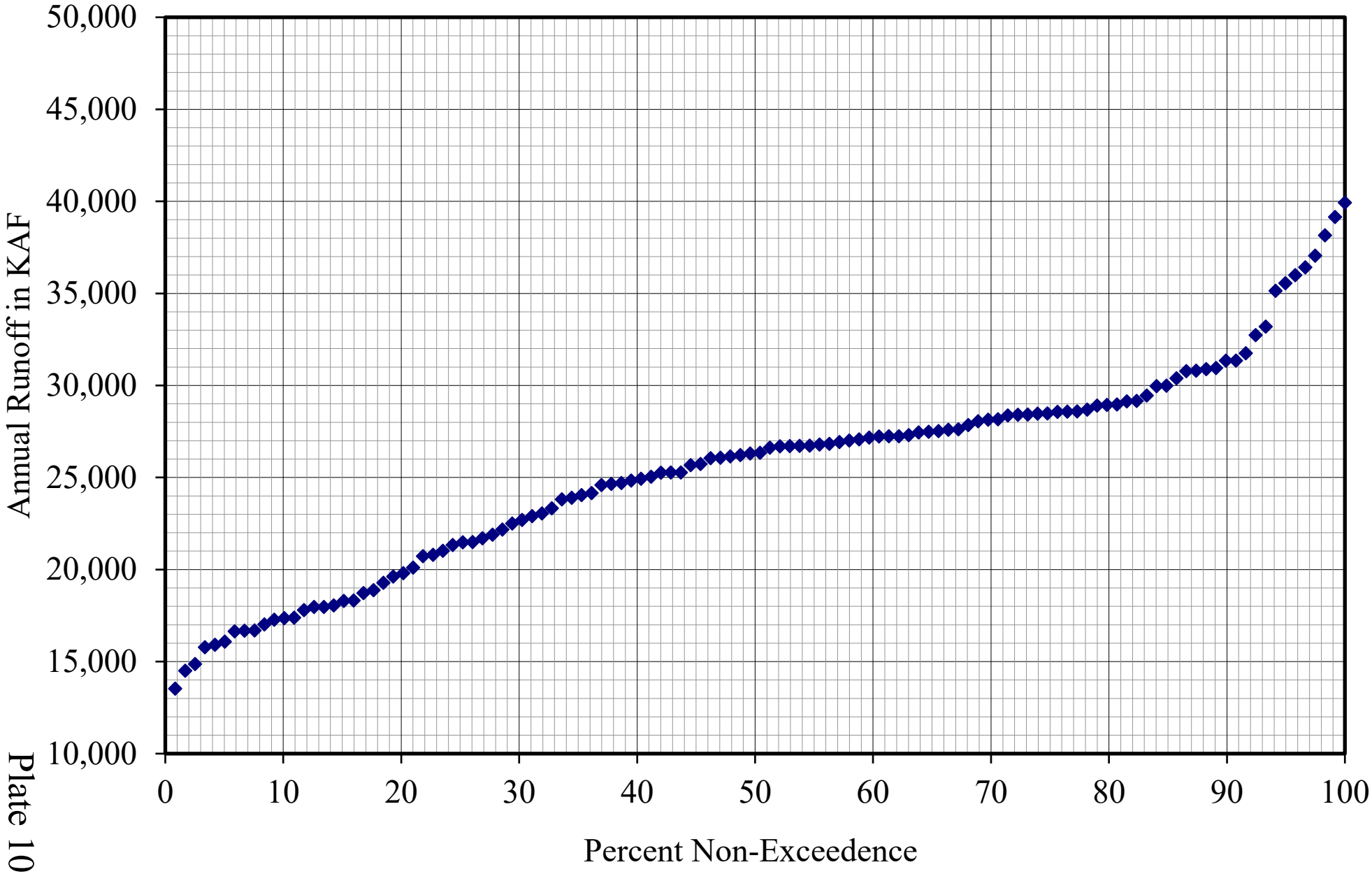

Plate 10

Missouri River above Sioux City
5-Year Average - Annual Runoff, 1898-2019

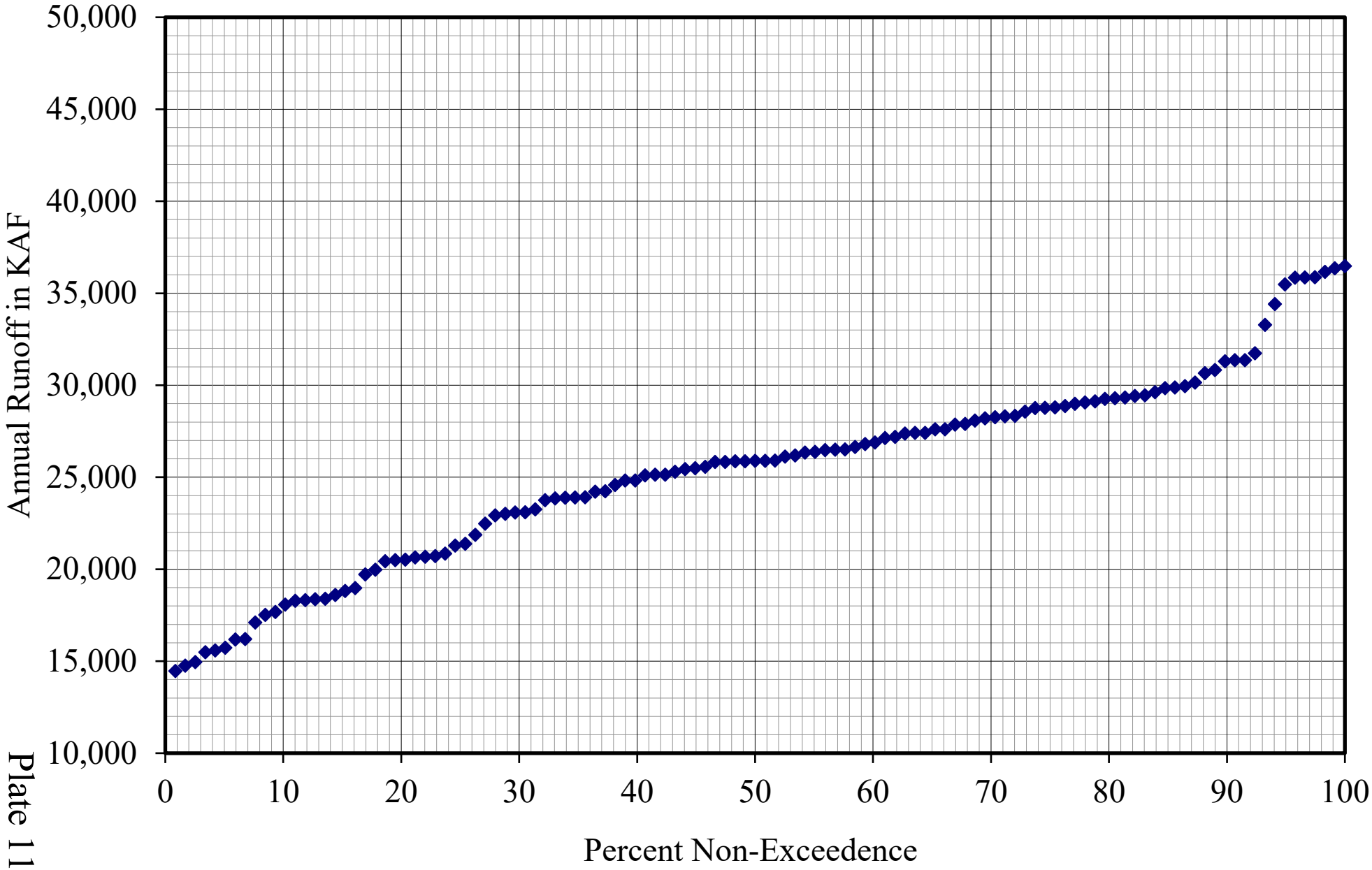

Plate 11

Missouri River above Sioux City
6-Year Average - Annual Runoff, 1898-2019

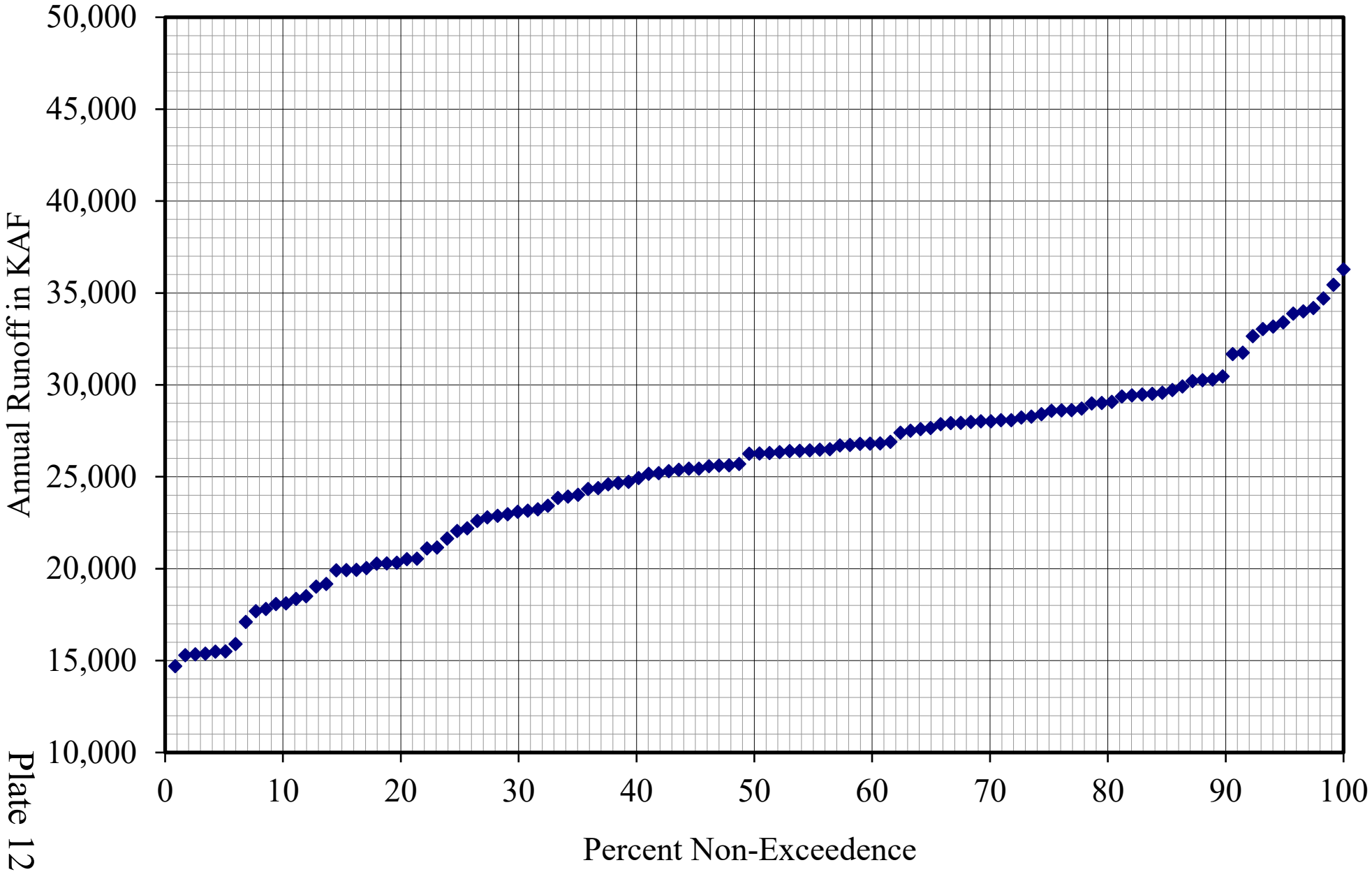

Plate 12