

US Army Corps  
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Northwestern Division  
Missouri River Region  
Reservoir Control Center



Missouri River Main Stem Reservoirs

# Runoff Volumes for Annual Operating Plan Studies

RCC Technical Report O-98

*Missouri River Basin*



# RUNOFF VOLUMES FOR ANNUAL OPERATING PLAN STUDIES

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# **MISSOURI RIVER MAIN STEM RESERVOIRS**

## **RUNOFF VOLUMES FOR ANNUAL OPERATING PLAN STUDIES**

### **RCC TECHNICAL REPORT O-98**

#### **GENERAL**

This manual is an update to a similar report titled "MRD TECHNICAL REPORT A-75, MISSOURI RIVER MAIN STEM RESERVOIRS, RUNOFF VOLUMES APPROPRIATE FOR ANNUAL OPERATING PLAN STUDIES," dated April 1975 and unpublished studies completed in 1985 and 1993. The A-75 report should be referred to for a history of runoff volumes used for Annual Operating Plan (AOP) studies. The unpublished 1985 study was an update to the 1975 report, although there were several differences in the method of computing runoff volumes. The 1993 study and the current study were completed following essentially the same steps used in the 1975 study.

The AOP studies utilize statistically derived runoff volumes based on the 100-year historical record of runoff above Sioux City, Iowa during the period 1898 to 1997. The AOP studies are comprised of five runoff levels with statistical significance implied by their titles: upper decile, upper quartile, median, lower quartile and lower decile. All volumes discussed in this report are adjusted to the 1949 level of water resources development in the Missouri River basin.

The following sections outline the steps used to determine the runoff volumes for AOP studies. In this report the terms "runoff" and "inflow" are used interchangeably.

#### **BASIN ANNUAL RUNOFF VOLUMES**

The total annual runoff for the basin above Sioux City, Iowa for each of the five runoff levels, upper decile (UD), upper quartile (UQ), median (MED), lower quartile (LQ), and lower decile (LD), was determined using the steps outlined below.

- a. The computer program "FLOW" was used to rank the Summation of Inflow above Sioux City for the period of record (1898 - 1997).
- b. A duration curve of annual runoff volume for the basin above Sioux City is shown on Plate 1. The annual volume for each of the five runoff levels was determined based their statistical representation. For example, the LD is the annual runoff volume corresponding to a 10 percent non-exceedence (or conversely, an exceedence rate of 90 percent). Likewise, the UQ was the annual runoff volume with a non-exceedence rate of 75 percent (or exceedence rate of 25 percent.) Note the selected runoff volumes were not actual historical runoff volumes, but rather

were derived from the duration curve for total annual runoff volume above Sioux City. Table 1 shows the annual runoff volume in million acre-feet (MAF) for the basin above Sioux City for each of the runoff levels.

Runoff Level	Annual Volume in MAF
Lower Decile	15.5
Lower Quartile	19.5
Median	24.6
Upper Quartile	30.6
Upper Decile	34.5

**DISTRIBUTION OF RUNOFF BY REACH**

Six reaches are defined for use in the AOP studies: (1) the Fork Peck reach is the basin above Fort Peck dam, 57,500 square miles; (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, 39,080sq. mi..

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

a. The computer program "FLOW" was used to rank the annual runoff volume from each of the six reaches for the historic period of record (1898 - 1997).

b. An annual runoff volume duration curve was plotted for each reach using the results of the FLOW program. The curves are shown on Plates 2 through 7.

c. Due to the natural variation in the areal distribution of runoff, the sum of the incremental reach inflows for a specific runoff level is not equal the total basin runoff for that level. Therefore, the non-exceedence percentile of the reach runoffs was adjusted until the sum of incremental inflows was equal to the total basin runoff. For example, the sum of the 10 percent non-exceedence inflows for the six reaches was equal to 13.6 MAF, well below the 15.5 MAF determined for the lower decile runoff for the basin above Sioux City. By trial and error, it was determined that the sum of the reach inflows representing a 15 percent non-exceedence rate equaled the lower decile runoff for the basin as a whole. Adjusting the non-exceedence percentile

in this manner results in 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.

d. This procedure was repeated for the remaining runoff levels with the following outcomes: the sum of the 30 percent non-exceedence reach inflows equals the total basin LQ runoff, the sum of the 53 percentile reach inflows equals the total basin MED runoff, the sum of the 73 percentile reach inflows equals the UQ, and the sum of the 84 percentile reach inflows equals the UD. The resultant incremental reach runoff volumes in MAF 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	LD	LQ	MED	UQ	UD
Reach Percentile	15	30	53	73	84
Reach	Annual Volume in MAF				
Fort Peck	5.10	6.00	7.40	8.90	9.60
Garrison	7.30	9.40	11.00	12.90	14.20
Oahe	1.05	1.45	2.30	3.20	3.85
Fort Randall	0.30	0.50	0.90	1.20	1.50
Gavins Point	1.20	1.25	1.45	1.90	2.25
Sioux City	0.55	0.90	1.55	2.50	3.10
Total	15.50	19.50	24.60	30.60	34.50

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

Runoff Level	LD	LQ	MED	UQ	UD
Reach	Annual Runoff in Percent				
Fort Peck	32.9	30.8	30.1	29.1	27.8
Garrison	47.1	48.2	44.7	42.1	41.2
Oahe	6.8	7.4	9.3	10.5	11.2
Fort Randall	1.9	2.6	3.7	3.9	4.3
Gavins Point	7.7	6.4	5.9	6.2	6.5
Sioux City	3.6	4.6	6.3	8.2	9.0

## **DISTRIBUTION OF RUNOFF BY MONTH**

While the above gives the areal distribution of runoff, Annual Operating Plan studies require annual runoff to be distributed by month. A unique monthly distribution was computed for each reach for the upper decile, median and lower decile runoff levels. The upper decile runoff distribution was used for the upper quartile runoff. Likewise, the median runoff distribution was used for the lower quartile runoff. In order to maintain the character provided by specific years, the following procedure was used to distribute the annual runoff.

- a. The computer program "FLOW" was used to rank the annual runoff for the period of record for the six reaches.
- b. Using the ranked reach inflows, the ten individual years whose annual runoff was closest to the annual runoff for the lower decile, median and upper decile conditions were identified for each of the six reaches.
- c. Monthly runoff was expressed as a percentage of annual reach runoff for each year.
- d. 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 2nd largest runoff, 3rd largest runoff, etc. occurred.
- e. The monthly runoff percentages (as computed in c) were ranked from highest to lowest for each year. Then, 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 2nd highest month, 3rd highest month, etc.
- f. The distribution of annual runoff was accomplished by placing the average monthly runoff percentage (as determined in e) in the appropriate month (as determined in d). 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 three runoff levels (LD, MED and UD) for each of the 6 reaches for a total of 18 unique distributions. It was assumed that the upper decile distribution applies to the upper quartile flows and that the median distribution applied to the lower quartile flows.
- g. The resulting monthly distributions were multiplied by the annual runoff for the particular reach/runoff scenario to determine the monthly runoff.
- h. Using specific years to distribute the reach inflows by can create some inconsistencies. In particular, there are instances when monthly reach inflows 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. In these cases, monthly reach inflows were smoothed by

judgement to eliminate the inconsistencies while keeping the annual reach inflow the same. The resultant monthly reach inflow volumes in MAF are shown in Table 4 for the five runoff levels. After smoothing the flows, 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**

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
<b><u>Lower Decile</u></b>													
Fort Peck	205	275	484	515	783	996	439	253	242	320	317	271	5100
Garrison	160	223	559	700	902	2020	1278	361	277	390	322	108	7300
Oahe	-12	41	408	183	100	215	82	21	64	6	-10	-48	1050
Fort Randall	-6	12	114	43	35	120	13	36	-10	-52	-5	0	300
Gavins Point	65	98	180	120	131	138	76	76	55	104	90	67	1200
Sioux City	-5	26	75	77	144	106	47	22	15	14	19	10	550
Total	407	675	1820	1638	2095	3595	1935	769	643	782	733	408	15500
<b><u>Lower Quartile</u></b>													
Fort Peck	212	283	500	525	925	1454	633	263	252	324	334	295	6000
Garrison	165	262	916	712	1197	2521	1765	496	417	400	327	222	9400
Oahe	-5	36	318	229	130	577	102	24	65	9	0	-35	1450
Fort Randall	-5	15	141	64	51	130	26	49	23	1	0	5	500
Gavins Point	68	100	189	124	138	143	81	80	58	105	94	70	1250
Sioux City	-3	48	238	90	174	125	76	55	35	24	25	13	900
Total	432	744	2302	1744	2615	4950	2683	967	850	863	780	570	19500
<b><u>Median</u></b>													
Fort Peck	261	349	546	628	1210	1851	829	324	319	398	375	310	7400
Garrison	237	326	970	853	1423	2958	2066	581	497	454	383	252	11000
Oahe	0	40	654	364	236	689	162	33	118	14	10	-20	2300
Fort Randall	0	19	253	115	140	185	74	57	42	2	3	10	900
Gavins Point	79	127	191	148	174	166	86	103	77	122	100	77	1450
Sioux City	5	82	350	199	310	224	129	96	60	42	32	21	1550
Total	582	943	2964	2307	3493	6073	3346	1194	1113	1032	903	650	24600
<b><u>Upper Quartile</u></b>													
Fort Peck	276	371	612	738	1487	2309	1130	423	351	492	390	321	8900
Garrison	316	394	995	1250	1723	3207	2405	763	522	593	472	260	12900
Oahe	5	49	950	394	285	749	246	103	135	85	181	18	3200
Fort Randall	5	39	293	239	150	195	89	65	64	38	5	18	1200
Gavins Point	89	161	193	207	257	237	178	144	114	132	102	86	1900
Sioux City	10	84	375	811	406	252	199	148	97	53	41	24	2500
Total	701	1098	3418	3639	4308	6949	4247	1646	1283	1393	1191	727	30600
<b><u>Upper Decile</u></b>													
Fort Peck	297	400	660	797	1604	2491	1219	456	379	531	420	346	9600
Garrison	348	434	1066	1376	1934	3530	2647	841	574	652	520	278	14200
Oahe	10	59	1154	474	347	881	297	123	163	102	218	22	3850
Fort Randall	10	49	393	297	159	224	111	72	92	60	10	23	1500
Gavins Point	106	191	221	246	319	280	211	169	135	157	120	95	2250
Sioux City	12	105	402	1006	553	318	246	184	127	66	51	30	3100
Total	783	1238	3896	4196	4916	7724	4731	1845	1470	1568	1339	794	34500

**Table 5**  
**Distribution of Runoff in Percent of Annual**

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
<b><u>Lower Decile</u></b>													
Fort Peck	4.0	5.4	9.5	10.1	15.4	19.5	8.6	5.0	4.7	6.3	6.2	5.3	100.0
Garrison	2.2	3.1	7.6	9.6	12.4	27.7	17.5	4.9	3.8	5.3	4.4	1.5	100.0
Oahe	-1.1	3.9	38.9	17.4	9.5	20.5	7.8	2.0	6.1	0.5	-1.0	-4.5	100.0
Fort Randall	-2.0	4.0	38.0	14.3	11.5	40.0	4.4	12.0	-3.3	-17.2	-1.7	0.0	100.0
Gavins Point	5.5	8.1	15.0	10.0	10.9	11.5	6.3	6.3	4.6	8.7	7.5	5.6	100.0
Sioux City	-0.9	4.8	13.7	14.0	26.1	19.2	8.6	4.0	2.7	2.5	3.5	1.8	100.0
Total	2.6	4.4	11.7	10.6	13.5	23.3	12.5	5.0	4.1	5.0	4.7	2.6	100.0
<b><u>Lower Quartile</u></b>													
Fort Peck	3.5	4.7	8.3	8.8	15.4	24.2	10.6	4.4	4.2	5.4	5.6	4.9	100.0
Garrison	1.8	2.8	9.7	7.6	12.7	26.7	18.8	5.3	4.4	4.3	3.5	2.4	100.0
Oahe	-0.4	2.5	21.9	15.8	9.0	39.7	7.1	1.7	4.5	0.6	0.0	-2.4	100.0
Fort Randall	-1.0	3.0	28.2	12.8	10.2	26.0	5.2	9.8	4.6	0.2	0.0	1.0	100.0
Gavins Point	5.5	8.0	15.1	9.9	11.1	11.4	6.5	6.4	4.6	8.4	7.5	5.6	100.0
Sioux City	-0.3	5.3	26.5	10.0	19.3	13.9	8.3	6.2	3.9	2.7	2.8	1.4	100.0
Total	2.2	3.8	11.8	8.9	13.4	25.4	13.8	5.0	4.4	4.4	4.0	2.9	100.0
<b><u>Median</u></b>													
Fort Peck	3.5	4.7	7.4	8.5	16.4	25.0	11.2	4.4	4.3	5.4	5.1	4.1	100.0
Garrison	2.1	3.0	8.8	7.8	12.9	26.9	18.8	5.3	4.5	4.1	3.5	2.3	100.0
Oahe	0.0	1.7	28.4	15.9	10.3	30.0	7.1	1.4	5.1	0.6	0.4	-0.9	100.0
Fort Randall	0.0	2.1	28.2	12.8	15.6	20.5	8.2	6.4	4.6	0.2	0.3	1.1	100.0
Gavins Point	5.4	8.8	13.2	10.2	12.0	11.4	5.9	7.1	5.3	8.5	6.9	5.3	100.0
Sioux City	0.3	5.3	22.6	12.7	20.0	14.5	8.3	6.2	3.9	2.7	2.1	1.4	100.0
Total	2.4	3.8	12.0	9.4	14.2	24.7	13.6	4.9	4.5	4.2	3.7	2.6	100.0
<b><u>Upper Quartile</u></b>													
Fort Peck	3.1	4.2	6.9	8.3	16.7	25.9	12.7	4.8	3.9	5.5	4.4	3.6	100.0
Garrison	2.5	3.1	7.7	9.7	13.4	24.9	18.5	5.9	4.0	4.6	3.7	2.0	100.0
Oahe	0.2	1.5	29.7	12.3	8.9	23.3	7.7	3.2	4.2	2.7	5.7	0.6	100.0
Fort Randall	0.4	3.2	24.4	19.9	12.5	16.3	7.5	5.4	5.3	3.2	0.4	1.5	100.0
Gavins Point	4.7	8.5	10.2	10.8	13.5	12.5	9.4	7.6	6.0	7.0	5.3	4.5	100.0
Sioux City	0.4	3.4	15.0	32.4	16.2	10.1	7.9	5.9	3.9	2.1	1.7	1.0	100.0
Total	2.3	3.6	11.2	11.8	14.1	22.7	13.9	5.3	4.2	4.6	3.9	2.4	100.0
<b><u>Upper Decile</u></b>													
Fort Peck	3.1	4.2	6.9	8.3	16.7	25.9	12.7	4.8	3.9	5.5	4.4	3.6	100.0
Garrison	2.5	3.1	7.5	9.7	13.6	24.9	18.6	5.8	4.0	4.6	3.7	2.0	100.0
Oahe	0.3	1.5	30.0	12.3	9.0	22.8	7.7	3.2	4.2	2.7	5.7	0.6	100.0
Fort Randall	0.7	3.2	26.2	19.9	10.6	14.9	7.4	4.8	6.1	4.0	0.7	1.5	100.0
Gavins Point	4.7	8.5	9.8	10.8	14.2	12.5	9.4	7.6	6.0	7.0	5.3	4.2	100.0
Sioux City	0.4	3.4	13.0	32.4	17.8	10.3	7.9	5.9	4.1	2.1	1.7	1.0	100.0
Total	2.3	3.6	11.3	12.2	14.3	22.3	13.7	5.3	4.3	4.5	3.9	2.3	100.0

## **DETERMINATION OF EXTENSION YEARS' RUNOFF**

In addition to an analysis of the effects of various levels of runoff upon system functions during the coming year, the Annual Operating plan presents a five-year extensions beyond the coming year to serve long-range planning purposes. Extensions are included for the median, lower quartile and lower decile runoff levels.

The median extension consists of a succession of five median years. However, if a similar procedure was used for the lower quartile and lower decile runoff levels, the probability of such a succession would be considerably more remote than the title indicates. Therefore a procedure was used which accounts for the probability of successive years of low runoff. The procedure and resulting runoff volumes for the lower quartile and lower decile extension years are outlined below.

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

b. The running averages were ranked and volume duration curves were plotted. The resulting curves are shown on Plates 8 through 12.

c. The 2-, 3-, 4-, 5- and 6-year average runoff volumes were determined from the curves for the lower decile (10%) and lower quartile (25%) levels.

d. The actual runoff for the 2nd, 3rd, 4th, 5th and 6th years was determined by working backward from the prior years' runoff. For example, the initial lower decile runoff volume was 15.5 MAF and the 2-year average for the lower decile condition was 16.2 MAF, so the 2nd year of a lower decile runoff period was calculated to be  $[(2 * 16.2) - 15.5] = 16.9$  MAF. The running averages were adjusted slightly to avoid having the runoff in the 2nd through 6th years vary greatly and to provide a smooth transition back toward normal runoff levels. The resultant annual runoff volumes for the 5-year extension period for the lower decile and lower quartile runoff levels are shown in Table 6.

**Table 6**  
**Annual Runoff Volumes for Extension Years**

<b>Lower Decile</b>			
Number of years (n)	n-year Average Flow (MAF)	Year	Runoff (MAF)
1	15.5	Initial	15.5
2	16.2	1st extension	16.9
3	16.7	2nd extension	17.7
4	17.1	3rd extension	18.3
5	17.5	4th extension	19.1
6	17.8	5th extension	19.3

<b>Lower Quartile</b>			
Number of years (n)	n-year Average Flow (MAF)	Year	Runoff (MAF)
1	19.5	Initial	19.5
2	20.5	1st extension	21.5
3	20.9	2nd extension	21.7
4	21.2	3rd extension	22.1
5	21.4	4th extension	22.2
6	21.7	5th extension	23.2

As with the initial year's runoff, it was necessary to distribute the extension years' runoff 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 basin runoff for the extension years varies widely, for example from 19.5 MAF to 23.2 MAF 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 percentages was used. The reach runoffs (in 1000 acre-feet) are shown in Table 7.

**Table 7**  
**Annual Incremental Reach Runoff Volumes for Extension Years**  
**1000 Acre-Feet**

<b>Lower Decile</b>					
Reach	1st Year	2nd Year	3rd Year	4th Year	5th Year
Total	5434	5616	5748	5918	5959
Garrison	8025	8444	8761	9186	9293
Oahe	1184	1263	1324	1408	1429
Fort Randall	364	404	435	478	489
Gavins Point	1230	1241	1246	1250	1250
Sioux City	663	732	786	860	880
<b>Total</b>	<b>16900</b>	<b>17700</b>	<b>18300</b>	<b>19100</b>	<b>19300</b>

<b>Lower Quartile</b>					
Reach	1st Year	2nd Year	3rd Year	4th Year	5th Year
Fort Peck	6557	6613	6722	6750	7023
Garrison	10070	10134	10260	10291	10596
Oahe	1760	1793	1859	1876	2047
Fort Randall	644	659	690	698	779
Gavins Point	1335	1343	1359	1362	1400
Sioux City	1134	1158	1210	1223	1355
<b>Total</b>	<b>21500</b>	<b>21700</b>	<b>22100</b>	<b>22200</b>	<b>23200</b>

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 and the LQ distribution was used for the five lower quartile extension years. The resulting monthly flows for each of the lower decile extension years are shown in Table 8. Table 9 shows the monthly flows for the lower quartile extension years.

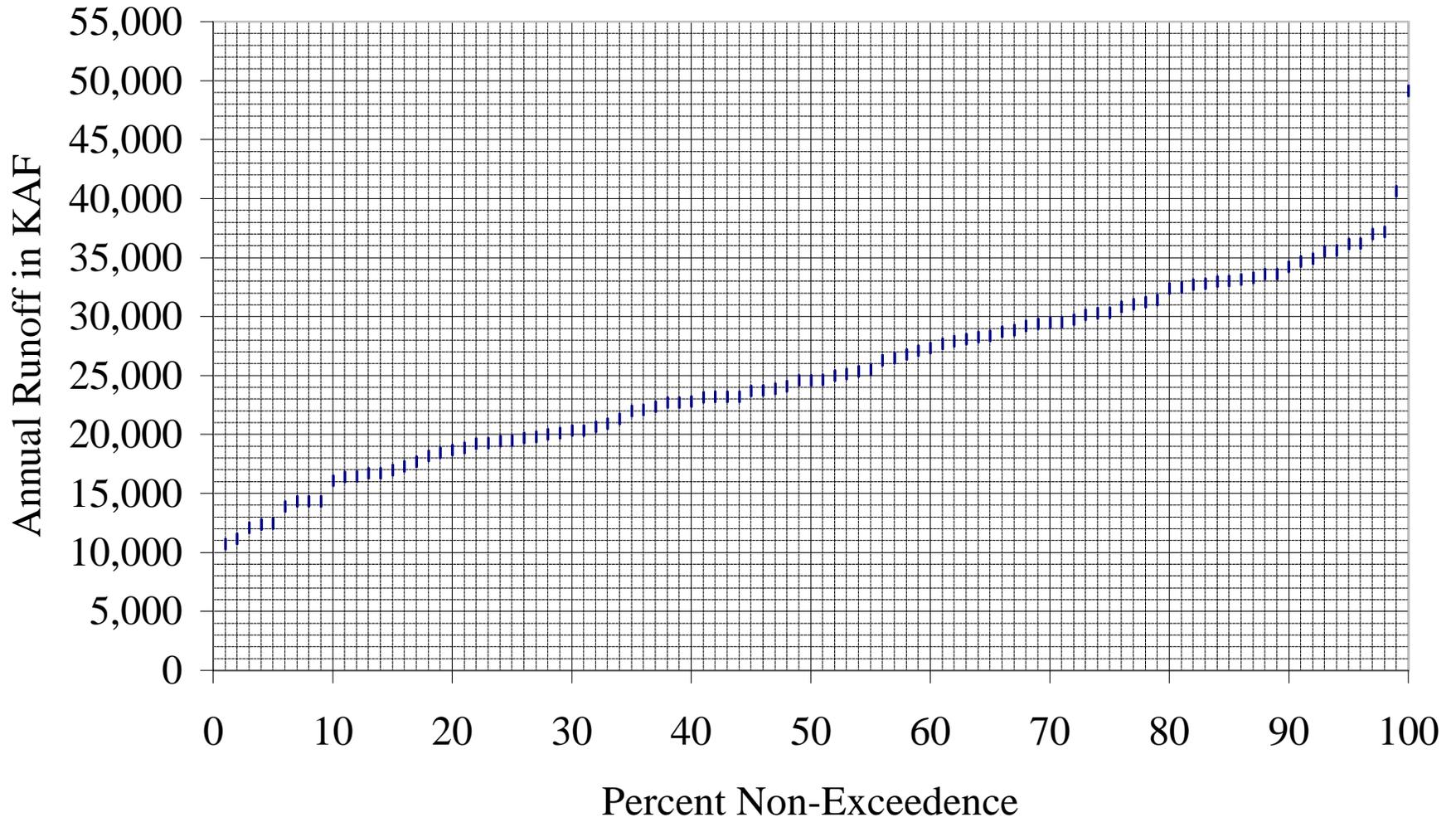
**Table 8**  
**Lower Decile**  
**Extension Years**  
**Monthly Reach Runoff Volumes**  
**1000 Acre-Feet**

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
<b><u>1st Extension Year</u></b>													
Fort Peck	217	293	516	549	834	1061	468	270	258	341	338	289	5434
Garrison	176	244	613	770	993	2221	1404	397	305	429	354	119	8025
Oahe	-13	47	460	206	113	242	92	24	72	6	-11	-54	1184
Fort Randall	-7	15	138	51	42	146	16	43	-12	-62	-6	0	364
Gavins Point	67	100	185	123	134	141	78	78	56	107	92	69	1230
Sioux City	-6	32	91	93	173	128	57	26	18	16	23	12	663
Total	434	731	2003	1792	2289	3939	2115	838	697	837	790	435	16900
<b><u>2nd Extension Year</u></b>													
Fort Peck	226	303	534	567	862	1097	483	279	266	352	349	298	5616
Garrison	185	258	645	810	1045	2337	1477	418	320	451	373	125	8444
Oahe	-14	50	491	220	120	259	99	25	77	6	-12	-58	1263
Fort Randall	-8	16	153	58	47	161	18	48	-13	-69	-7	0	404
Gavins Point	67	101	186	124	135	143	79	79	57	108	93	69	1241
Sioux City	-7	35	100	102	191	141	63	29	20	19	25	14	732
Total	449	763	2109	1881	2400	4138	2219	878	727	867	821	448	17700
<b><u>3rd Extension Year</u></b>													
Fort Peck	231	310	546	580	882	1123	495	285	273	361	357	305	5748
Garrison	192	268	670	840	1084	2425	1533	433	332	468	387	129	8761
Oahe	-15	52	515	231	127	271	103	26	81	7	-13	-61	1324
Fort Randall	-9	17	165	62	50	174	19	53	-15	-75	-7	1	435
Gavins Point	68	101	187	125	136	143	79	79	57	108	93	70	1246
Sioux City	-7	38	107	110	205	151	68	31	22	20	27	14	786
Total	460	786	2190	1948	2484	4287	2297	907	750	889	844	458	18300
<b><u>4th Extension Year</u></b>													
Fort Peck	238	318	562	598	909	1156	509	294	281	371	368	314	5918
Garrison	202	281	702	881	1136	2542	1607	454	349	491	405	136	9186
Oahe	-16	56	547	245	134	288	110	28	86	7	-13	-64	1408
Fort Randall	-10	19	181	68	55	191	22	58	-16	-82	-8	0	478
Gavins Point	68	102	188	125	137	144	79	79	57	108	93	70	1250
Sioux City	-8	41	118	121	225	166	74	34	23	22	30	14	860
Total	474	817	2298	2038	2596	4487	2401	947	780	917	875	470	19100
<b><u>5th Extension Year</u></b>													
Fort Peck	239	321	566	602	914	1164	513	296	283	374	370	317	5959
Garrison	204	284	710	891	1150	2572	1626	460	353	496	410	137	9293
Oahe	-16	56	555	249	136	293	112	29	87	7	-14	-65	1429
Fort Randall	-10	20	186	70	56	195	21	59	-16	-84	-8	0	489
Gavins Point	68	102	188	125	137	144	79	78	56	109	94	70	1250
Sioux City	-8	42	120	123	230	169	76	35	24	22	31	16	880
Total	477	825	2325	2060	2623	4537	2427	957	787	924	883	475	19300

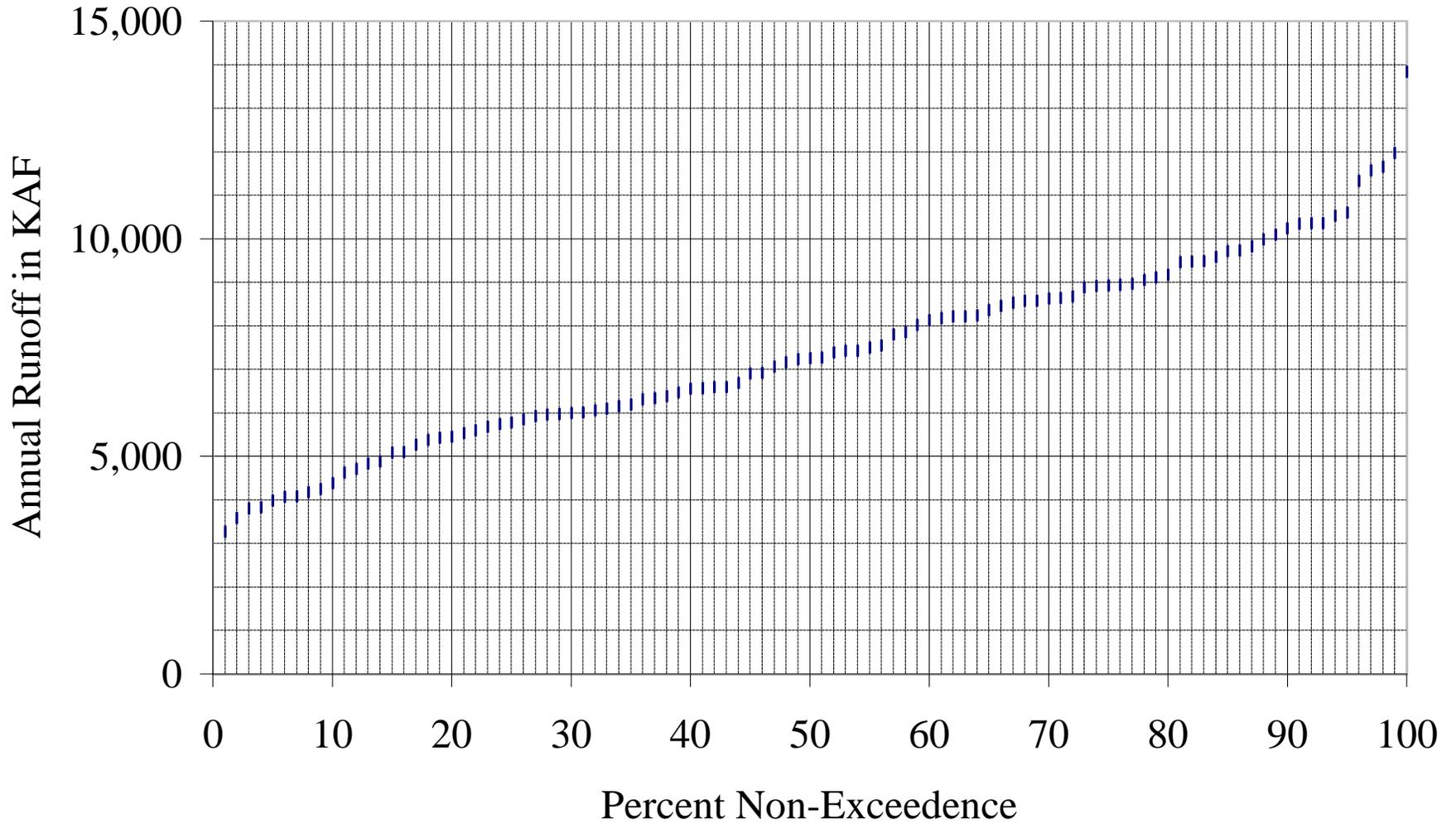
**Table 9**  
**Lower Quartile**  
**Extension Years**  
**Monthly Reach Runoff Volumes**  
**1000 Acre-Feet**

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
<b><u>1st Extension Year</u></b>													
Fort Peck	231	310	546	574	1011	1589	692	287	275	354	366	322	6557
Garrison	177	280	982	763	1282	2701	1891	532	446	428	350	238	10070
Oahe	-7	44	386	278	158	700	124	29	79	11	0	-42	1760
Fort Randall	-6	19	181	83	66	167	33	63	30	2	0	6	644
Gavins Point	73	107	202	132	147	153	87	85	62	112	100	75	1335
Sioux City	-3	60	300	113	219	158	95	70	44	31	31	16	1134
Total	465	820	2597	1943	2883	5468	2922	1066	936	938	847	615	21500
<b><u>2nd Extension Year</u></b>													
Fort Peck	233	312	551	579	1020	1603	698	288	278	357	369	325	6613
Garrison	178	282	988	768	1290	2718	1903	535	448	432	352	240	10134
Oahe	-7	45	393	283	161	714	126	30	80	11	0	-43	1793
Fort Randall	-7	20	185	84	67	171	34	65	31	2	0	7	659
Gavins Point	74	108	203	133	148	154	87	86	62	112	101	75	1343
Sioux City	-3	61	307	116	224	160	97	72	45	31	32	16	1158
Total	468	828	2627	1963	2910	5520	2945	1076	944	945	854	620	21700
<b><u>3rd Extension Year</u></b>													
Fort Peck	237	317	560	588	1037	1629	709	294	282	363	375	331	6722
Garrison	180	286	1000	777	1306	2752	1927	541	455	436	357	243	10260
Oahe	-7	46	408	294	167	740	131	31	83	11	0	-45	1859
Fort Randall	-7	21	194	88	70	179	36	68	32	2	0	7	690
Gavins Point	74	109	206	135	150	155	88	87	63	114	102	76	1359
Sioux City	-3	64	320	121	234	168	101	75	47	33	33	17	1210
Total	474	843	2688	2003	2964	5623	2992	1096	962	959	867	629	22100
<b><u>4th Extension Year</u></b>													
Fort Peck	237	318	563	591	1041	1636	712	295	284	365	376	332	6750
Garrison	181	287	1003	779	1311	2760	1932	543	456	438	358	243	10291
Oahe	-7	46	411	297	168	747	132	31	84	12	0	-45	1876
Fort Randall	-7	21	196	89	71	181	37	69	32	2	0	7	698
Gavins Point	75	110	206	135	150	155	89	87	63	114	102	76	1362
Sioux City	-3	65	324	122	236	170	102	76	47	32	34	18	1223
Total	476	847	2703	2013	2977	5649	3004	1101	966	963	870	631	22200
<b><u>5th Extension Year</u></b>													
Fort Peck	248	331	585	615	1083	1702	741	308	295	379	391	345	7023
Garrison	186	295	1033	802	1349	2841	1990	559	470	451	369	251	10596
Oahe	-8	51	449	324	183	815	143	34	92	13	0	-49	2047
Fort Randall	-8	23	219	100	79	203	41	76	36	2	0	8	779
Gavins Point	77	113	212	139	155	160	91	89	64	117	105	78	1400
Sioux City	-4	72	359	135	262	188	113	84	52	37	38	19	1355
Total	491	885	2857	2115	3111	5909	3119	1150	1009	999	903	652	23200

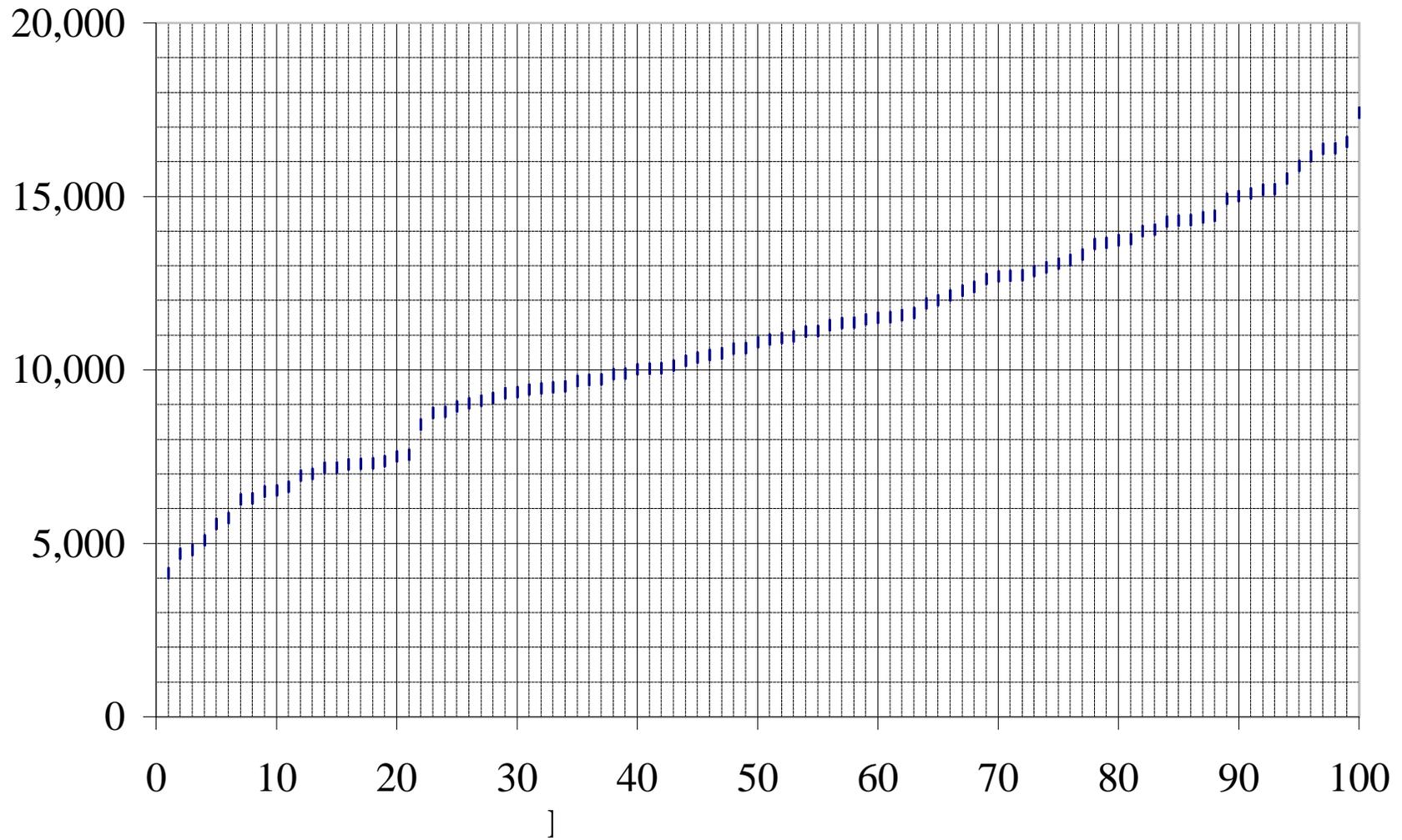
# Missouri River above Sioux City Annual Runoff, 1898 - 1997



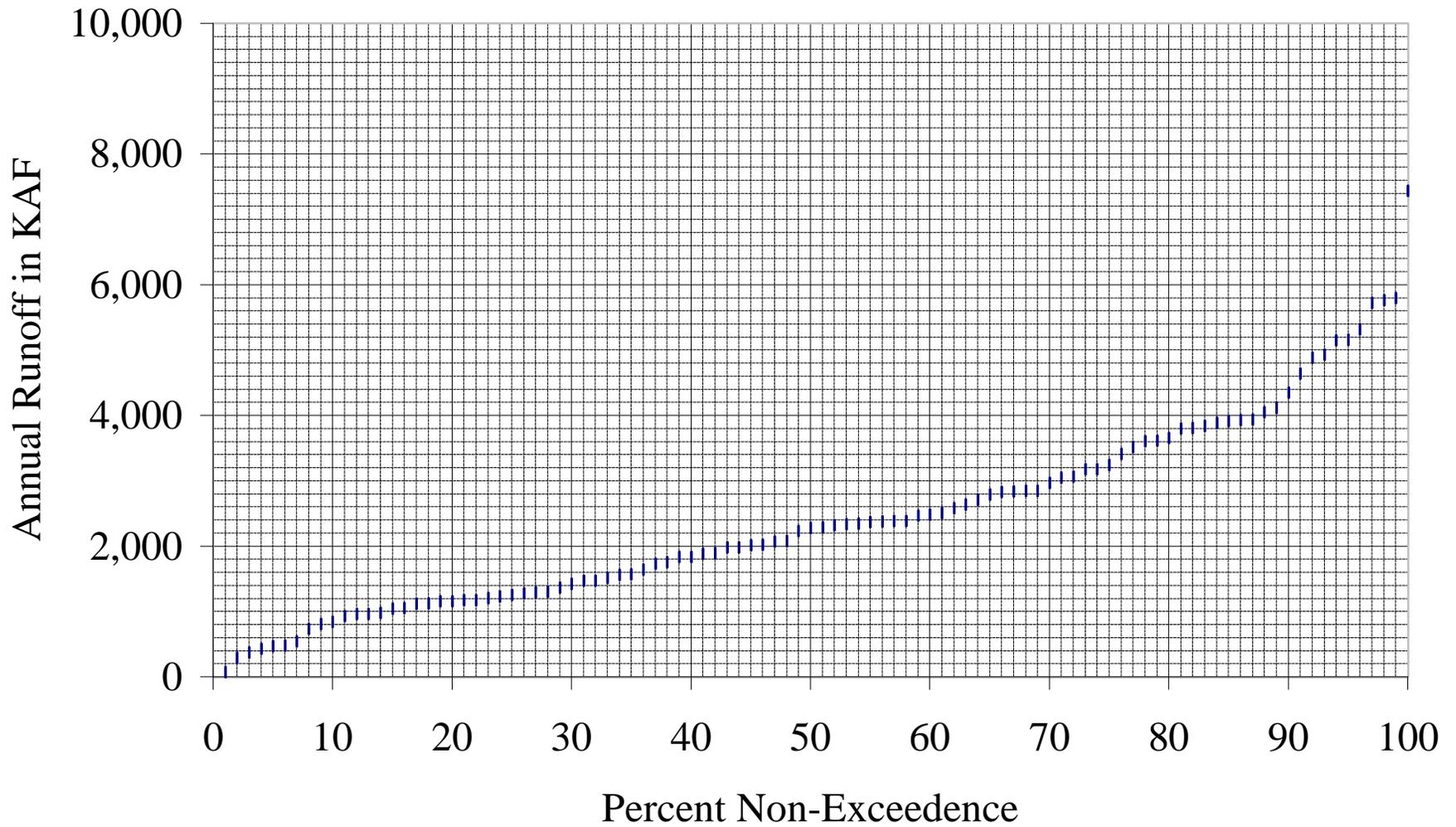
# Missouri River above Fort Peck Annual Runoff, 1898 - 1997



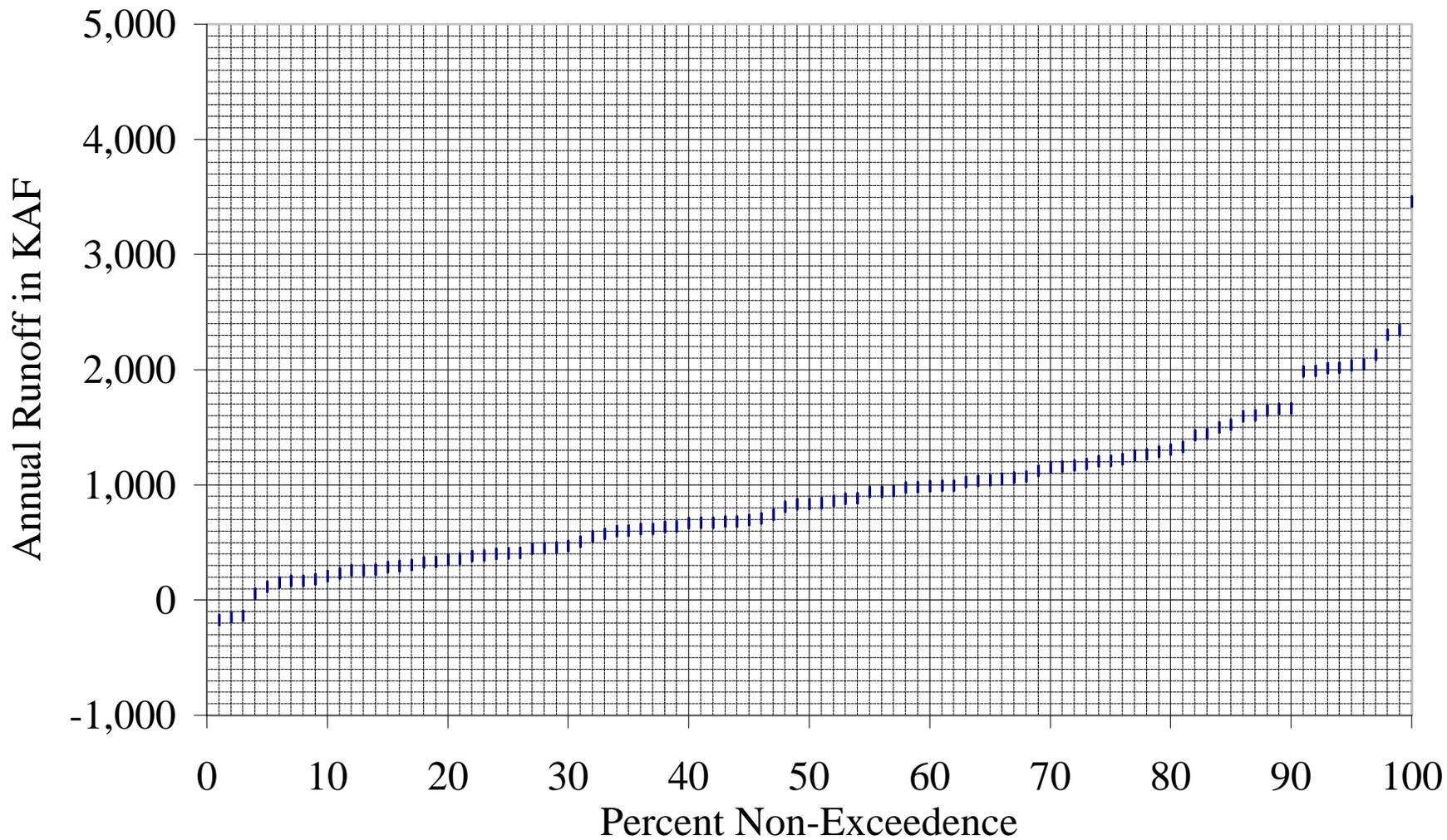
# Fort Peck to Garrison Annual Runoff, 1898 - 1997



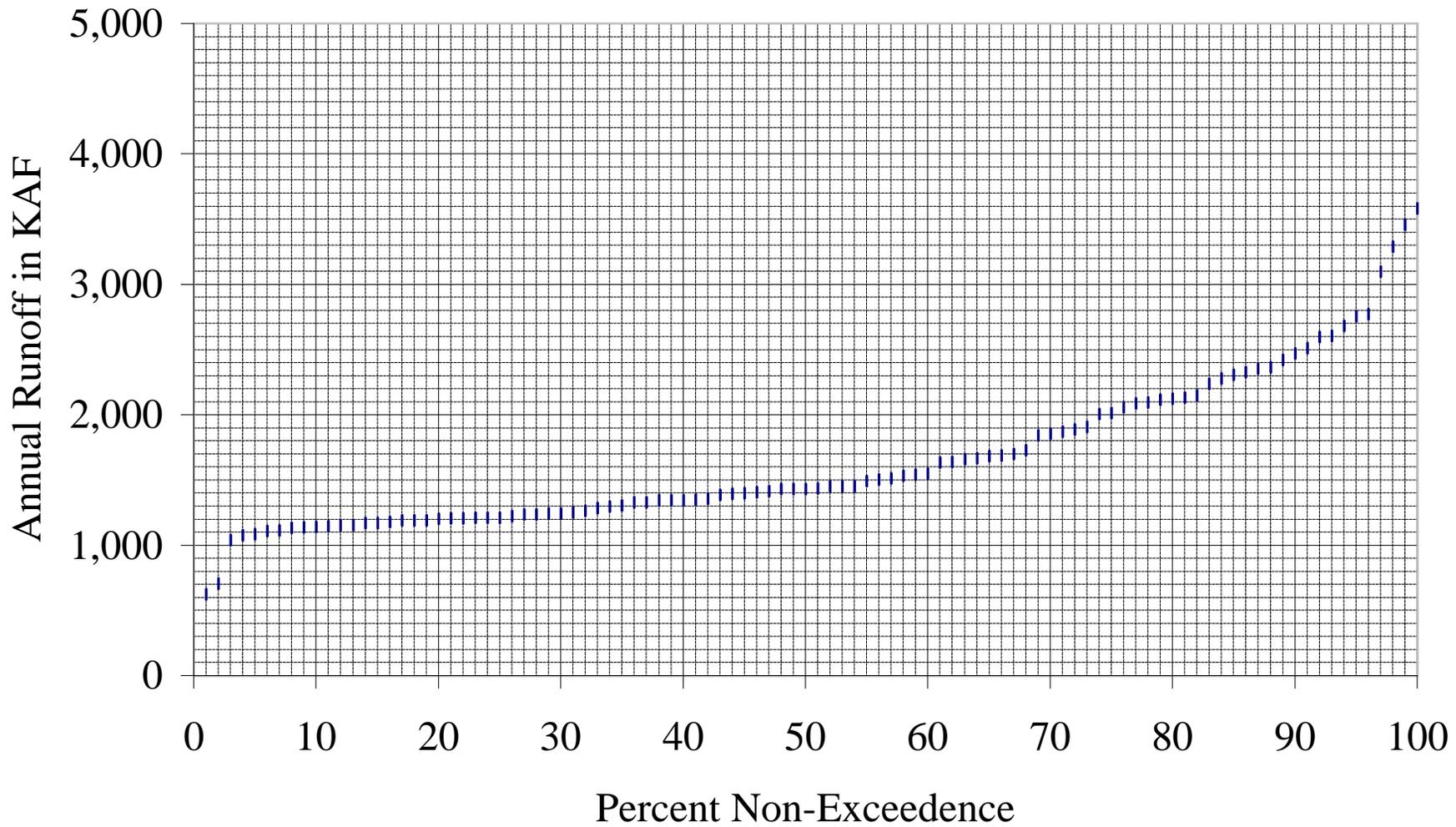
# Garrison to Oahe Annual Runoff, 1898 - 1997



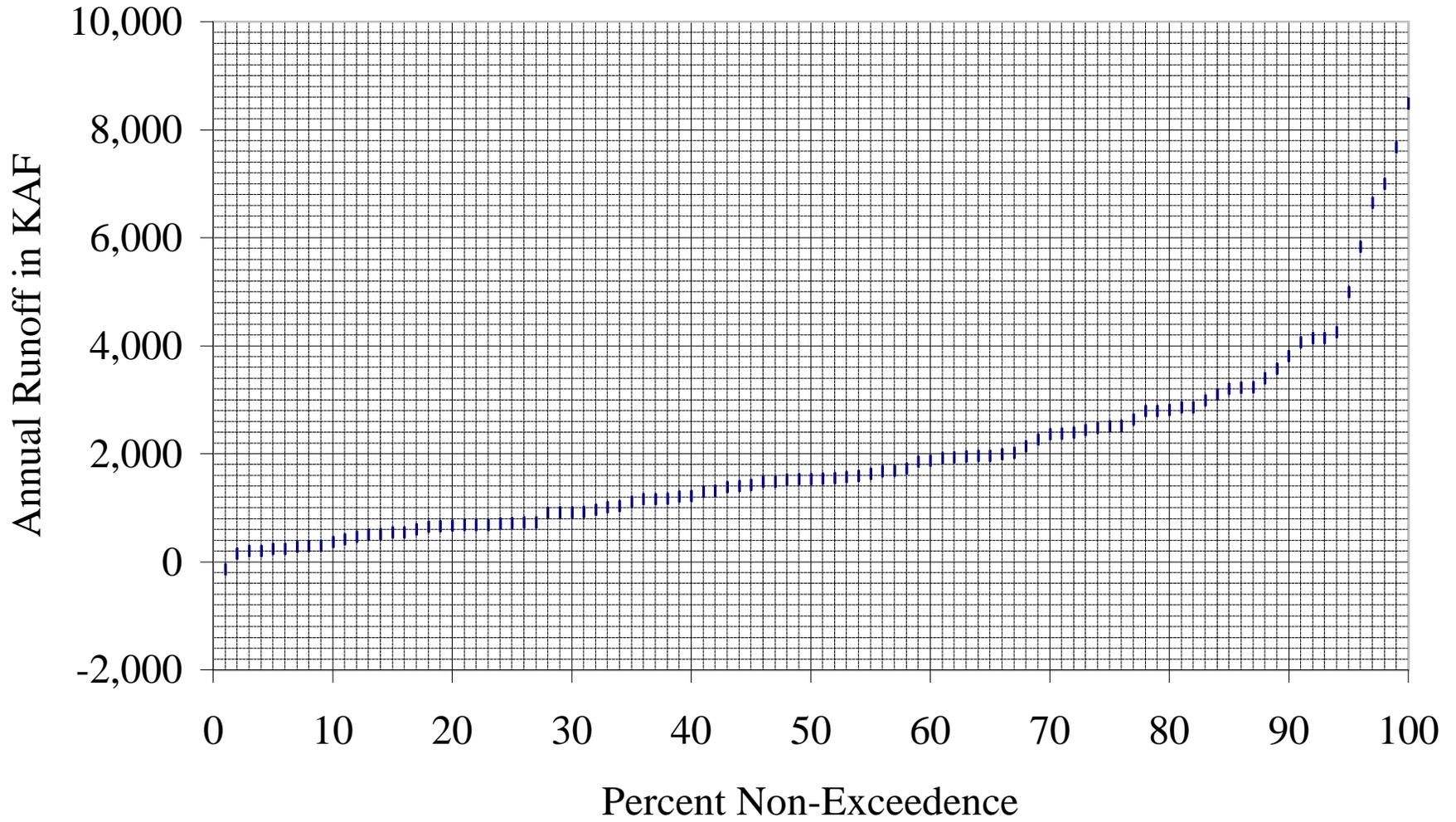
# Oahe to Fort Randall Annual Runoff, 1898 - 1997



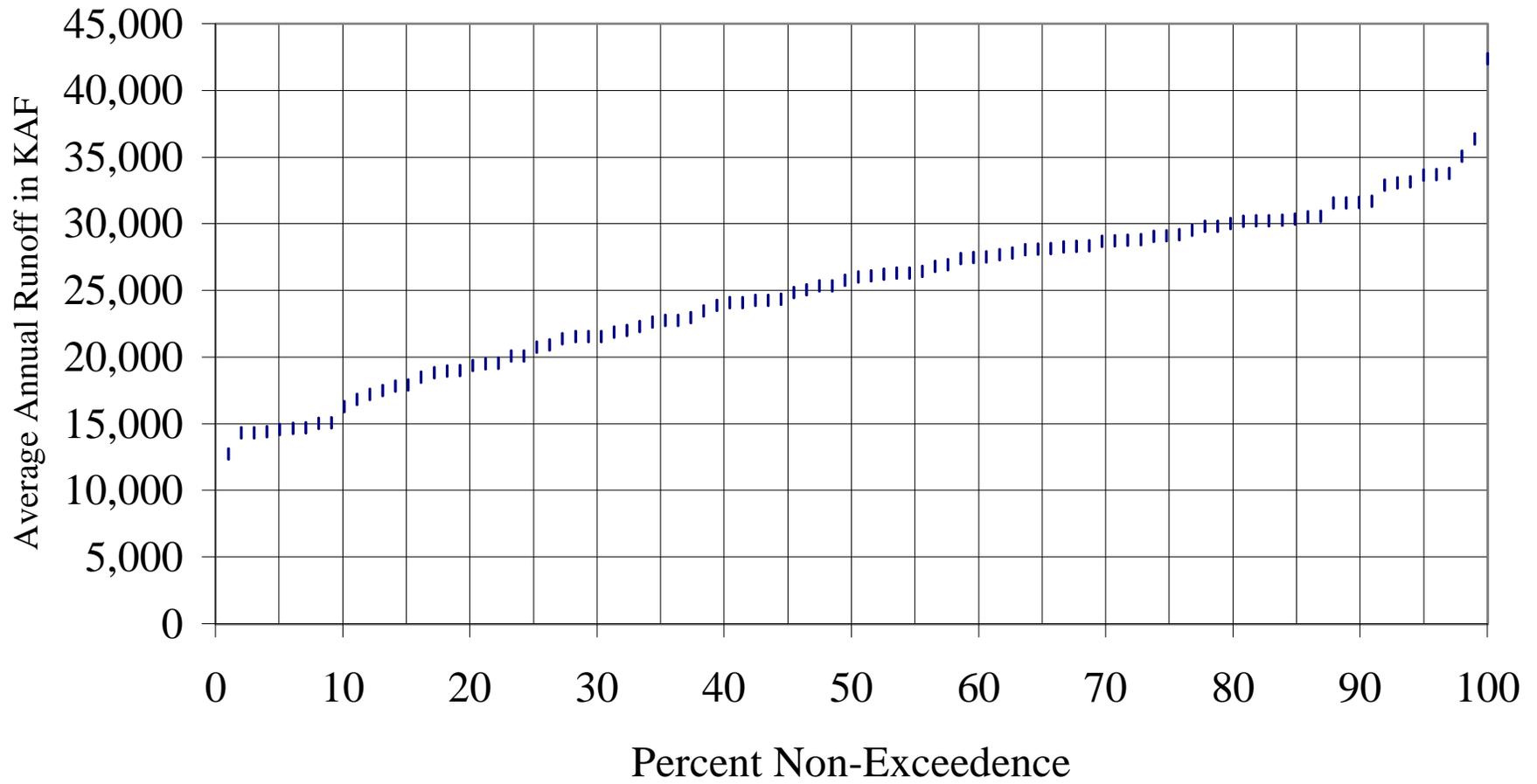
# Fort Randall to Gavins Point Annual Runoff, 1898 - 1997



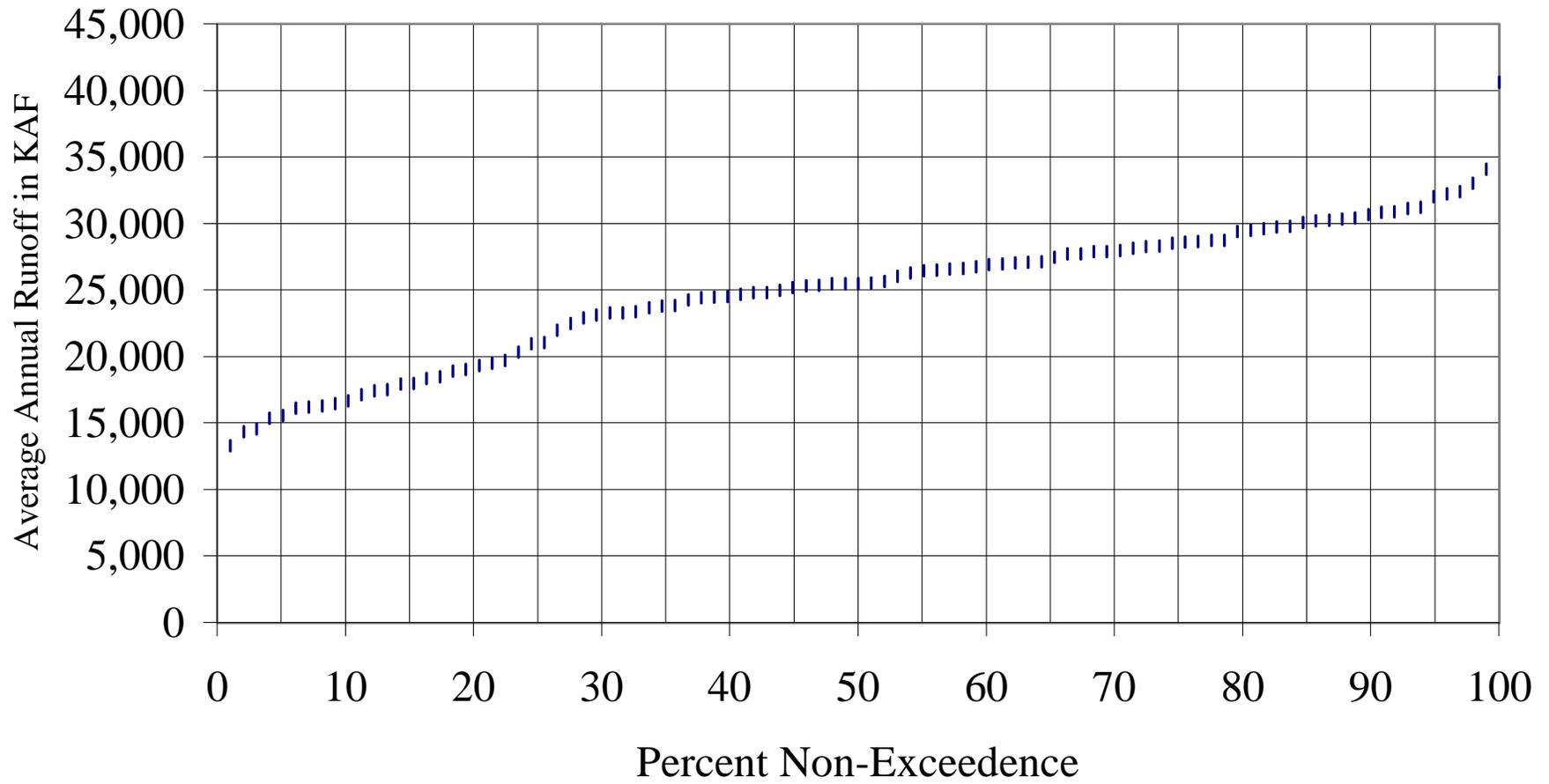
# Gavins Point to Sioux City Annual Runoff, 1898 - 1997



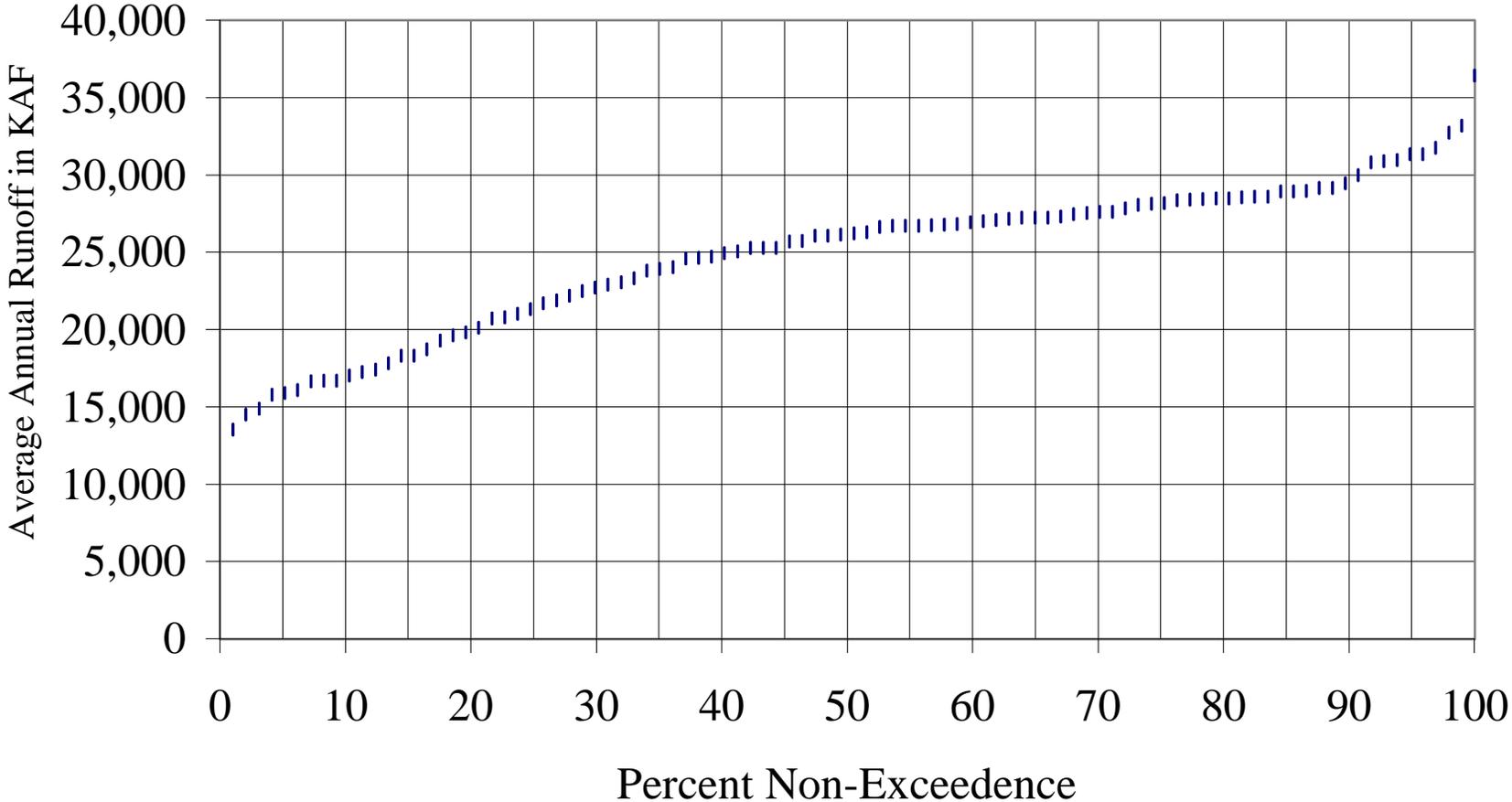
**Missouri River above Sioux City  
2-year Average  
Annual Runoff**



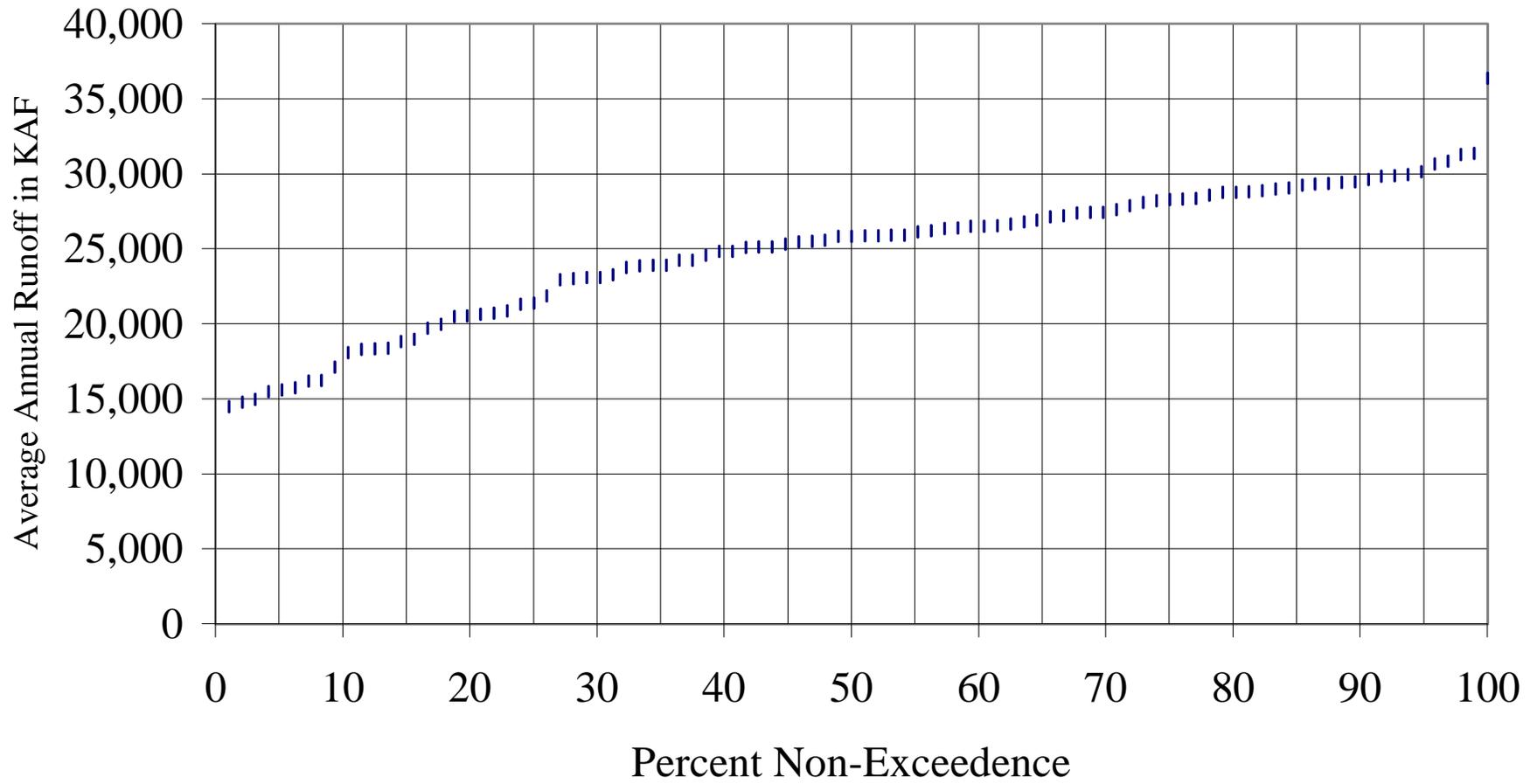
# Missouri River above Sioux City 3-year Average Annual Runoff



**Missouri River above Sioux City  
4-year Average  
Annual Runoff**



**Missouri River above Sioux City  
5-year Average  
Annual Runoff**



**Missouri River above Sioux City  
6-year Average  
Annual Runoff**

