ESTIMATION OF STREAMFLOW CHARACTERISTICS AND ASSESSMENT OF TRENDS IN THE NIOBRARA RIVER AT MARIAVILLE, NEBRASKA

By Edward E. Fischer

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U.S. DEPARMENT OF THE INTERIOR
DONALD PAUL HODEL, Secretary
GEOLOGICAL SURVEY
Dallas L. Peck, Director

For additional information write:
District Chief
U.S. Geological Survey
406 Federal Building
100 Centennial Mall, North
Lincoln, Nebraska 68508

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CONVERSION FACTORS

Factors for converting inch-pound units used in this report to International System (SI) metric units are given below.

Multiply inch-pound units	By	To obtain SI units
foot	0.3048	meter
square foot per second	0.09294	square meter per second
cubic foot per second	0.02832	cubic meter per second
second-foot-day	2,447	cubic meter
mile	1.609	kilometer
square mile	2.590	square kilometer

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ABSTRACT

A computer model was used to synthesize a long-term streamflow record for the Niobrara River at Mariaville, Nebraska. The record was developed on the basis of 30-plus years of streamflow data from 3 upstream sites, and the U.S. Geological Survey's CONROUT model was calibrated using 294 days of measured flow at Mariaville; for the calibration period, 87 percent of the synthesized daily discharges were within 15 percent of the measured values. The synthesized record was analyzed for trends in streamflow characteristics. A marked decrease in the average consecutive-day low-flow discharges was detected after 1964, ranging between 162 cubic feet per second less for the 1-day low flow and 200 cubic feet per second less for the 14-day low flow. The decrease probably was caused by the startup of operations at Merritt Reservoir.

INTRODUCTION

The U.S. Geological Survey was requested by the U.S. Bureau of Reclamation to synthesize a long-term streamflow record of the Niobrara River at Mariaville, Nebraska (fig. 1), estimate selected streamflow statistics and probabilities, and estimate streamflow trends as part of a preliminary study for the Bureau's proposed O'Neill Alternative Project. This project, using recommendations made by the Nebraska Department of Water Resources (Becker, 1985), would withdraw water from the river for irrigation and ground-water recharge through a series of infiltration galleries buried near the streambed.

The method selected to synthesize the long-term discharge record was the flow-routing computer model, CONROUT (Doyle and others, 1983). A streamflow gaging station was established near the proposed withdrawal site in 1985 to facilitate calibration and verification of the model. Once calibrated, the model was used with the long-term records from the upstream gaging stations to synthesize a long-term record at the withdrawal site. This long-term, synthesized record was then used to compute streamflow statistics for the study site.

Interpretation of the synthesized streamflow record was complicated by existing upstream reservoirs, diversions and irrigation projects. Their cumulative effect on streamflow was investigated by analyzing trends of selected streamflow characteristics.

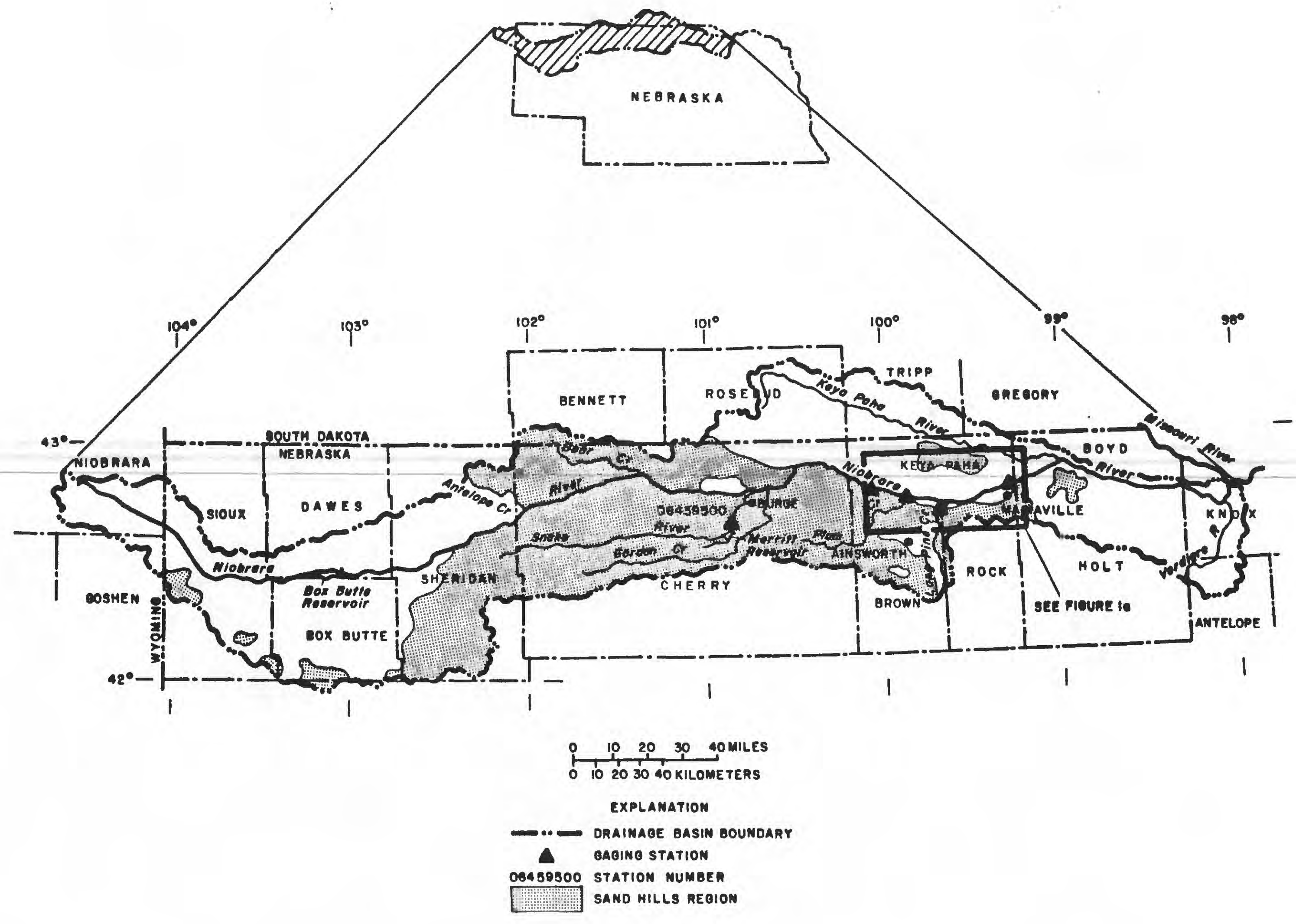

Figure 1.--Niobrara River drainage basin showing locations of streamflow gaging sites used in this study.

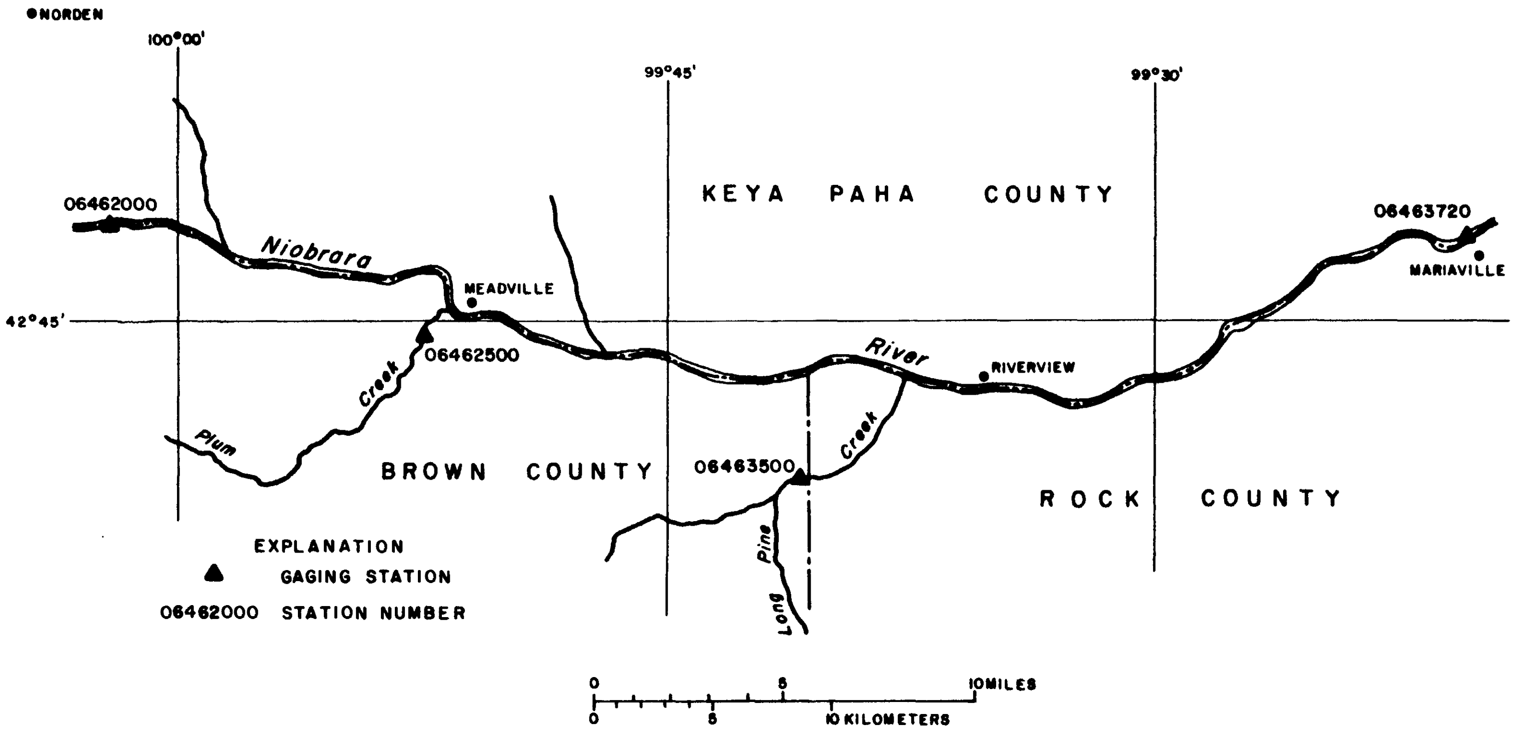

Figure 1a.--Enlargement from figure 1.

DESCRIPTION OF THE NIOBRARA RIVER AND BASIN

The Niobrara River basin includes parts of Wyoming, Nebraska, and South Dakota (fig. 1). The total basin area is 13,180 square miles. The basin area upstream from the proposed withdrawal site at Mariaville is about 9,810 square miles. The river is perennial throughout its eastward meandering path through Nebraska. In the vicinity of Mariaville, the average channel width is approximately 2,000 feet with an active channel width of about 1,000 feet (from topographic maps). The streambed is sand, and during periods of low flow the channel is braided.

A major part of the basin is comprised of the Sand Hills (fig. 1). Because of the high permeability of the sand, there is little overland runoff in this region except in areas adjacent to streams during heavy rains. Therefore, flooding seldom occurs, although occasionally ice jams cause local flooding in low areas bordering the main stem of the river (Newport, 1959, Shaffer, 1975).

Two major water projects in the Niobrara River basin directly affect flow in the river above the proposed withdrawal site--the Mirage Flats Project (Box Butte Reservoir) on the Niobrara River and the Ainsworth Irrigation Project (Merritt Reservoir) on the Snake River (fig. 1). Streamflow was first affected by the Mirage Flats Project when Box Butte Reservoir began storing water in 1945. Streamflow was affected by the Ainsworth Project when Merritt Reservoir began storing water in 1964 (Shaffer, 1975). A portion of the water diverted from the Snake River basin at Merritt Reservoir may re-enter the Niobrara River as return flow via Long Pine Creek. Any such return flow is included in the streamflow record collected at Long Pine Creek near Riverview (station No. 06463500).

Irrigation in the basin using ground water began in 1938 and has steadily increased (Shaffer, 1975). A sharp rise in the number of registered wells occurred in the mid 1950's, due to drought conditions. Another substantial increase started in the mid 1960's and was caused by a combination of drought, the availability of center-pivot irrigation systems, and favorable economic conditons. Despite the increased use of ground water, ground-water levels throughout most of the Niobrara River basin have remained largely unchanged (Ellis and Pederson, 1986).

DATA USED

The long-term streamflow record for the proposed infiltration gallery site on the Niobrara River at Mariaville was synthesized using existing records obtained at three upstream sites, Niobrara River near Norden (06462000), Plum Creek at Meadville (06462500), and Long Pine Creek near Riverview (06463500) (fig. 1a). A streamflow gaging station, Niobrara River at Mariaville (06463720), was installed during September 1985 near the proposed site in order to obtain a record of the actual streamflow for calibration and verification of streamflows routed to the site. The long-term record at Snake River River near Burge (06459500) was analyzed to determine the effects of the operation of Merritt Reservoir. A list of the stations and the period of record available at each site is given in table 1.

Table 1.--List of streamflow-gaging stations in the lower Niobrara River basin, Nebraska, used in this study

Station number	Station name	Period of record
06459500	Snake River near Burge	06/47 to current year
06462000	Niobrara River near Norden	10/52 to 9/83; 10/85 to current year
06462500	Plum Creek at Meadville	12/47 to 9/75; 10/76 to current year
06463500	Long Pine Creek near Riverview	4/48 to 1/54; 9/54 to current year
06463720	Niobrara River at Mariaville	10/85 to current year

SYNTHESIZING LONG-TERM STREAMFLOW RECORD AT MARIAVILLE

The long-term streamflow record for Niobrara River at Mariaville was synthesized using the Geological Survey's digital computer model, CONROUT, which is based on convolution methods of hydrologic routing. In this study, the model uses the streamflows at the upstream stations, streamflow at an index station adjusted to account for streamflow from the ungaged drainage area, and an optimized set of routing parameters that best duplicate the relationship between daily discharge at the upstream stations and the station at Mariaville.

The river was divided into three reaches: from Niobrara River near Norden to the mouth of Plum Creek, from the mouth of Plum Creek to the mouth of Long Pine Creek, and from the mouth of Long Pine Creek to Niobrara River at Mariaville. It was assumed that the inflow to the Niobrara from each tributary was the same as the discharges measured at the respective gaging stations, which are upstream of the mouths (fig. 1a).

The CONROUT model has the following three parameters: the routing distance (X, in units of miles), the flood wave celerity (C, in units of feet per second), and the wave dispersion coefficient (K, in units of feet squared per second). Only C and K require calibration. Initial values for C and K were computed for each reach of the river from the average channel slope, average channel width at average discharge, and approximate change in discharge with stage at average discharge. The model was run and the synthesized discharge compared with the observed discharge at Mariaville. Adjustments were made in C and K, the model was rerun, and the results were compared again. This optimization process was repeated until it was determined that a best fit was obtained.

The synthesized (routed) streamflow at Mariaville during the period used for model calibration compares favorably with the observed streamflow. The calibrated parameters are listed in table 2. The concurrent routed and observed daily mean discharges are compared in figure 2 and the comparison summarized in table 3. As shown in table 3, 87 percent of the total routed observations were within 15 percent of the respective observed discharge. In addition to modeling errors, differences between the routed and observed values can be attributed to variation in the pattern of precipitation across the basin in different runoff events and, to a lesser extent, the inaccuracies in measuring the streamflows at Niobrara River near Norden and Niobrara River at Mariaville. While only a short period of record (294 days) was available to calibrate the parameters, the values that were chosen were judged to be sufficiently accurate for estimating long-term flow characteristics.

Once the parameter values were calibrated, the model was used to synthesize the long-term streamflow record for Niobrara River at Mariaville based on the long-term records of the upstream gages. The concurrent period of record at the three upstream stations begins in October 1952 and continues through to the present (1986), with breaks in 1954 (Long Pine Creek), 1975-76 (Plum Creek), and 1983-85 (Niobrara River near Norden) (see table 1). Because the streamflows in Plum Creek and Long Pine Creek are fairly uniform and because both streams together contribute less than 25 percent to the total flow at Mariaville, the monthly mean values for the respective streams were substituted for missing daily values in 1954 and 1975-76. Hence, a continuous streamflow record at Mariaville was synthesized for the period October 1952 through September 1983.

STREAMFLOW STATISTICS AND PROBABILITIES

Streamflow statistics and probabilities were compiled for the period of record for each of the three upstream stations and on the synthesized period of record for Niobrara River at Mariaville. The statistics include the maximum and minimum monthly and annual mean discharges, and the mean monthly and mean annual discharges. Also tabulated are the corresponding standard deviation, skewness, and coefficient of variation, and duration of daily mean discharges. Probabilities were computed on annual consecutive-day high flows and annual consecutive-day low flows. The results are presented in tables 4 through 7.

Table 2.--Physical and calibrated model parameters for the Niobrara River study reaches

[Ft/ft, foot per foot; ft/s, foot per second; ft^2/s, square foot per second. "Ratio" is a factor governing the addition of flow at a node in the model. At the last node (06463720, Niobrara River at Mariaville), 1.42 times the daily flow at 06462500 (Plum Creek) was determined by calibration to account for the ungaged drainage area between 06462000 (Niorara near Norden) and Mariaville.]

Station number	Drainage area above station ($mile^2$)	Length of reach (mile)	Average width of reach (foot)	Average slope of reach (ft/ft)	Flood wave celerity, C (ft/s)	Wave dispersion coefficient, K (ft^2/s)	Ratio
06462000	8,390						--
		[1] 11.4	1,000	0.00126	3.2	396	
06462500	600						--
		[2] 12.6	1,000	.00155	3.2	323	
06463500	390						--
		[3] 17.0	1,000	.00143	3.2	350	
06463720	9,810						1.42

[1] From Niobrara River near Norden to mouth of Plum Creek.
[2] From mouth of Plum Creek to mouth of Long Pine Creek.
[3] From mouth of Long Pine Creek to Niobrara River at Mariaville.

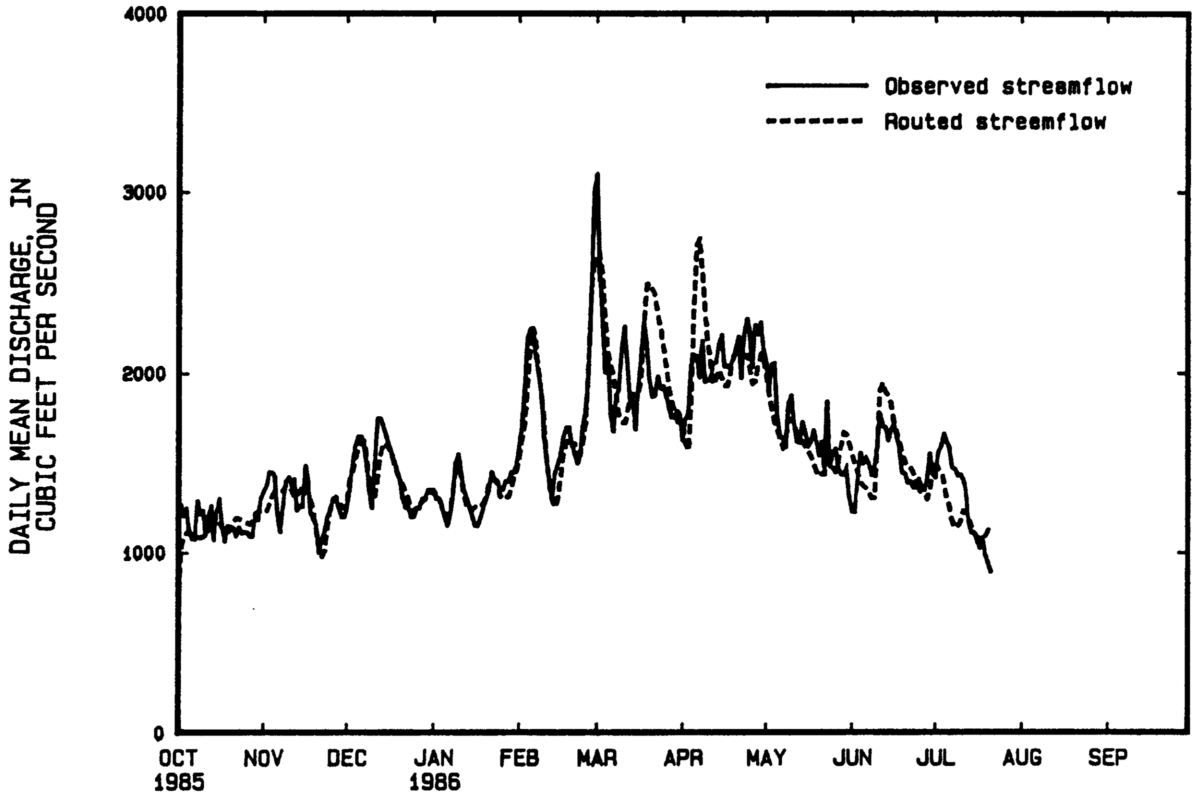

Figure 2.--Comparison of routed streamflow with observed streamflow, Niobrara River at Mariaville.

Table 3.-- Summary of the comparison of routed and observed daily mean discharges for Niobrara River at Mariaville

Unit of comparison:	Daily mean discharge (cubic feet per second)
Number of comparisons:	294 values (1 per day)
Mean negative error:	7.04 percent for 162 days
Mean positive error:	7.36 percent for 132 days
Mean error:	7.18 percent for 294 days
Routed streamflow volume:	454,774 second-foot-days
Observed volume:	458,538 second-foot-days
Volume error:	-0.82 percent

Percentage of total observations (percent)	Upper limit of percentage error (percent)
47	5
74	10
87	15
93	20
97	25

(Example: 74 percent of the routed daily values differed from the corresponding observed daily value by 10 percent or less.)

Table 4.--Selected streamflow statistics , Niobrara River near Norden, Nebraska (06462000)

Monthly and annual mean discharges

Month	Maximum (ft^3/s)	Minimum (ft^3/s)	Mean (ft^3/s)	Standard deviation (ft^3/s)	Skewness	Coefficient of variation (percent)
Monthly mean discharge, 10/53 to 9/83, 10/85 to 7/86:						
October	1020	571	763	120	0.06	0.16
November	961	588	855	97.1	-1.47	0.11
December	1020	563	867	103	-0.76	0.12
January	1030	588	859	105	-0.46	0.12
February	1220	622	980	115	-0.65	0.12
March	1640	714	1090	223	0.30	0.20
April	1400	704	1020	170	0.59	0.17
May	1560	693	986	204	0.76	0.21
June	1540	593	899	221	1.41	0.25
July	1360	407	710	195	1.43	0.28
August	938	458	654	141	0.17	0.22
September	985	489	687	139	0.33	0.20
Annual mean discharge, water years 1953-83:						
	1051	708	861	91.5	-0.06	0.11

Duration of daily mean discharges, water years 1953-83

Daily mean discharge (ft^3/s)	Percentage of days discharge was equaled or exceeded	Daily mean discharge (ft^3/s)	Percentage of days discharge was equaled or exceeded
130	100.0	910	37.3
330	99.9	1000	24.1
360	99.8	1100	14.1
400	99.5	1200	8.5
450	98.5	1400	3.2
490	95.9	1500	2.2
550	90.8	1700	1.0
610	84.0	1900	0.5
670	76.9	2100	0.3
740	67.4	2300	0.2
830	52.4	2800	0.1

Table 4.--Selected streamflow statistics, Niobrara River near Norden, Nebraska (06462000) --continued

Probability of annual high flows, water years 1953-83

Exceedence probability (percent)	Recurrence interval (years)	Highest average flow (ft^3/s)					
		Consecutive days					
		1	3	7	15	30	60
99	1.01	1190	1130	997	917	852	824
50	2	1820	1650	1540	1410	1280	1150
10	10	3010	2550	2170	1810	1550	1360
4	25	3840	3140	2520	1990	1640	1450
2	50	4580	3640	2790	2110	1710	1500
1	100	5420	4200	3070	2240	1770	1550

Probability of annual low flows, climatic years 1954-83

Non-exceedence probability (percent)	Recurrence interval, in years	Lowest average flow (ft^3/s)					
		Consecutive days					
		1	3	7	14	30	60
1	100	134	215	355	357	371	390
2	50	163	241	369	375	390	411
5	20	212	283	391	404	421	445
10	10	258	321	413	432	450	478
20	5	316	368	443	470	490	520
50	2	414	454	511	554	578	613

Table 5.--Selected streamflow statistics, Plum Creek at Meadville, Nebraska (06462500)

Monthly and annual mean discharges

Month	Maximum (ft^3/s)	Minimum (ft^3/s)	Mean (ft^3/s)	Standard deviation (ft^3/s)	Skewness	Coefficient of variation (percent)
Monthly mean discharge, 1/48 to 7/86:						
October	145	78.8	97.8	12.9	1.66	0.13
November	167	79.9	99.1	16.4	2.32	0.17
December	132	78.5	96.9	10.8	0.96	0.11
January	141	73.4	96.6	14.4	1.20	0.15
February	248	80.0	108	30.3	3.08	0.28
March	246	82.6	130	37.9	1.54	0.29
April	399	91.4	146	58.6	2.54	0.40
May	356	83.7	145	56.0	1.93	0.39
June	276	85.9	130	42.0	1.55	0.32
July	390	73.2	114	64.4	3.55	0.56
August	164	73.3	98.4	21.2	1.74	0.22
September	144	76.7	96.4	16.2	1.40	0.17
Annual mean discharge, water years 1949-85:						
	188	91.6	113	21.6	2.04	0.19

Duration of daily mean discharges, water years 1949-75, 1977-85

Daily mean discharge (ft^3/s)	Percentage of days discharge was equaled or exceeded	Daily mean discharge (ft^3/s)	Percentage of days discharge was equaled or exceeded
15.0	100.0	180	6.2
53	99.9	210	4.0
61	99.7	240	2.7
70	99.1	280	1.8
80	94.0	320	1.2
92	70.4	370	0.8
110	32.1	430	0.5
120	23.1	490	0.3
140	13.2	560	0.2
160	9.1	750	0.1

Table 5.--Selected streamflow statistics, Plum Creek at Meadville, Nebraska (06462500)--continued

Probability of annual high flows, water years 1949-75, 1977-85

Exceedence probability (percent)	Recurrence interval (years)	Highest average flow (ft^3/s)					
		Consecutive days					
		1	3	7	15	30	60
99	1.01	119	117	113	105	102	97.6
50	2	334	296	248	210	176	152
10	10	793	676	512	383	295	239
4	25	1160	976	708	497	373	294
2	50	1500	1260	889	597	440	341
1	100	1920	1610	1100	709	514	392

Probability of annual low flows, climatic years 1949-75, 1978-86

Non-exceedence probability (percent)	Recurrence interval (years)	Lowest average flow (ft^3/s)					
		Consecutive days					
		1	3	7	14	30	60
1	100	15.7	38.8	54.6	64.3	69.1	75.3
2	50	20.3	42.3	56.7	65.5	70.0	75.9
5	20	28.4	48.0	60.0	67.4	71.7	77.0
10	10	36.7	53.2	63.1	69.5	73.6	78.4
20	5	47.4	59.5	67.1	72.3	76.3	80.5
50	2	66.7	71.5	75.6	79.2	83.3	86.8

Table 6.--Selected streamflow statistics, Long Pine Creek near Riverview, Nebraska (06463500)

Monthly and annual mean discharges

Month	Maximum (ft^3/s)	Minimum (ft^3/s)	Mean (ft^3/s)	Standard deviation (ft^3/s)	Skewness	Coefficient of variation (percent)
Monthly mean discharge, 5/48 to 12/54, 10/55 to 6/86:						
October	164	100	128	15.8	0.70	0.12
November	165	101	130	15.9	0.41	0.12
December	166	102	129	16.4	0.49	0.13
January	172	103	126	17.7	1.12	0.14
February	203	96.5	134	19.6	1.51	0.15
March	212	106	155	28.9	0.39	0.19
April	309	114	154	34.3	2.68	0.22
May	246	103	161	38.7	0.80	0.24
June	396	105	160	49.3	3.09	0.31
July	368	99.0	149	53.0	2.40	0.36
August	236	92.9	144	35.4	0.87	0.10
September	187	88.1	139	25.9	0.10	0.19
Annual mean discharge, water years 1949-53, 1955-85:						
	202	111	142	19.9	0.86	0.14

Duration of daily mean discharges, water years 1949-53, 1955-85

Daily mean discharge (ft^3/s)	Percentage of days discharge was equaled or exceeded	Daily mean discharge (ft^3/s)	Percentage of days discharge was equaled or exceeded
44	100.0	260	2.2
76	99.9	280	1.8
85	99.7	320	1.2
95	98.6	350	1.0
110	89.1	400	0.8
120	71.0	440	0.6
130	52.9	490	0.5
150	27.7	550	0.4
160	18.2	610	0.3
180	8.3	690	0.2
200	5.3	950	0.1
230	3.2		

Table 6.--Selected streamflow statistics, Long Pine Creek near Riverview, Nebraska (06463500) --continued

Probability of annual high flows, water years 1949-53, 1955-85

Exceedence probability (percent)	Recurrence interval (years)	Highest average flow (ft^3/s)					
		Consecutive days					
		1	3	7	15	30	60
99	1.01	131	130	129	129	128	124
50	2	467	348	265	220	189	170
10	10	1220	767	488	366	284	240
4	25	1800	1070	636	461	344	282
2	50	2350	1350	765	541	393	317
1	100	3020	1670	911	632	447	355

Probability of annual low flows, climatic years 1950-53, 1956-86

Non-exceedence probability (percent)	Recurrence interval (years)	Lowest average flow (ft^3/s)					
		Consecutive days					
		1	3	7	14	30	60
1	100	49.2	64.8	74.5	81.6	90.1	93.3
2	50	54.6	68.4	77.1	83.8	91.9	95.4
5	20	63.2	74.0	81.5	87.5	95.0	99.0
10	10	71.1	79.4	85.7	91.2	98.2	103
20	5	80.8	86.3	91.4	96.2	103	107
50	2	98.8	101	104	108	114	119

Table 7.--Selected streamflow statistics of the synthesized record, Niobrara River at Mariaville, Nebraska (06463720)

Monthly and annual mean discharges

Month	Maximum (ft^3/s)	Minimum (ft^3/s)	Mean (ft^3/s)	Standard deviation (ft^3/s)	Skewness	Coefficient of variation (percent)
Monthly mean discharge, 10/53 to 9/83, 10/85 to 6/86:						
October	1380	901	1120	121	-0.06	0.11
November	1390	942	1220	108	-0.95	0.09
December	1420	878	1230	118	-0.76	0.10
January	1400	921	1210	119	-0.23	0.10
February	1740	969	1360	139	0.01	0.10
March	2110	1060	1550	274	0.16	0.18
April	2240	1050	1500	267	1.07	0.18
May	2620	1040	1490	334	1.42	0.22
June	2180	1000	1370	300	1.30	0.22
July	2670	752	1140	385	2.98	0.34
August	1440	772	1030	167	0.73	0.16
September	1370	823	1050	144	0.29	0.14
Annual mean discharge, water years 1953-83:						
	1580	1090	1270	118	0.73	0.09

Duration of daily mean discharges, water years 1953-83

Daily mean discharge (ft^3/s)	Percentage of days discharge was equaled or exceeded	Daily mean discharge (ft^3/s)	Percentage of days discharge was equaled or exceeded
447	100.0	1800	5.7
670	99.9	1900	4.3
790	98.1	2100	2.6
850	95.7	2300	1.8
930	89.2	2400	1.5
1000	81.1	2600	1.0
1100	68.5	2900	0.7
1200	53.9	3100	0.4
1300	37.2	3400	0.3
1400	24.5	3700	0.2
1500	16.3	4000	0.1
1600	11.1		

Table 7.--Selected streamflow statistics of the synthesized record, Niobrara River at Mariaville, Nebraska (06463720) --continued

Probability of annual high flows, water years 1953-83

Exceedence probability (percent)	Recurrence interval (years)	Highest average flow (ft^3/s)					
		Consecutive days					
		1	3	7	15	30	60
99	1.01	1560	1520	1400	1300	1260	1250
50	2	2540	2430	2250	2020	1810	1640
10	10	4370	4060	3380	2730	2330	2060
4	25	5660	5160	4040	3080	2590	2280
2	50	6810	6130	4570	3330	2770	2440
1	100	8140	7240	5140	3590	2960	2600

Probability of annual low flows, climatic years 1954-83

Non-exceedence probability (percent)	Recurrence interval (years)	Lowest average flow (ft^3/s)					
		Consecutive days					
		1	3	7	14	30	60
1	100	459	520	662	668	691	731
2	50	498	552	678	692	716	755
5	20	556	602	704	728	755	794
10	10	608	646	729	762	790	830
20	5	668	700	764	806	836	875
50	2	772	798	843	898	929	970

ANALYSIS OF THE SYNTHESIZED STREAMFLOW RECORD

Streamflow characteristics that are of greatest importance in the planning for diversions are those that reflect the availability of water during low-flow periods. Therefore, the synthesized streamflow record was analyzed for any trends in the low-flow parameters that might be attributed to or initiated by the building of water projects in the basin or to other changes in basin parameters. Box Butte Reservoir was completed before records were kept at the gaging stations used in this study, and the reservoir's effect on streamflow is difficult to assess. The other project that might affect low-flow parameters is the Ainsworth Irrigation Project and Merritt Reservoir, which was completed in 1964. Only the ice-free period April through November (8 months) of each year of record was evaluated.

Trends in the streamflow record of the Niobrara River at Mariaville were partially evaluated by comparing mean annual 1-, 3-, 7-, 14-, 30-, and 60-day low flows. These low-flow statistics were computed for the period April 1 through November 30 of each year of synthesized streamflow record and are plotted as bar graphs in figure 3. The solid line is a 15-year weighted moving average of the yearly values, and the dotted lines represent 1 weighted moving standard deviation from this line. In all figures, there is a decrease in the weighted average that is centered approximately on 1964, and there is a small increase near the end of the record. The annual rainfall at Ainsworth (fig. 4) does not show the decline in the mid 1960's, but does show an increase in the most recent years. The decrease in discharge may be attributed to the filling of Merritt Reservoir in 1964 and to the subsequent interception of low flows in the Snake River since then. The weighted average begins to decrease before 1964 because the moving average algorithm computes the weighted average for a particular year from the 7 years before through the 7 years after that year. The increase in the weighted average after 1975 is probably due to the increase in precipitation during the last few years (see fig. 4); it also may include the effects of a new equilibrium being established with return flow from the project.

Values in each of the low-flow categories were determined for the period prior to and following completion of Merritt Reservoir, 1953-63 and 1964-82, and a regression analysis performed on each period. No significant trends were detected within either of the periods for any of the low-flow categories; that is, the best "predictor" for a particular period was its average (fig. 5). However, there is a marked difference between the averages of the two periods in each category. Examination of the streamflow record for Snake River near Burge (06459500), which is 2 miles downstream from Merritt Reservoir, and for Niobrara River near Norden yields a similar pattern (table 8). Therefore, the difference as computed for Niobrara River at Mariaville is probably a result of the regulation by Merritt Reservoir.

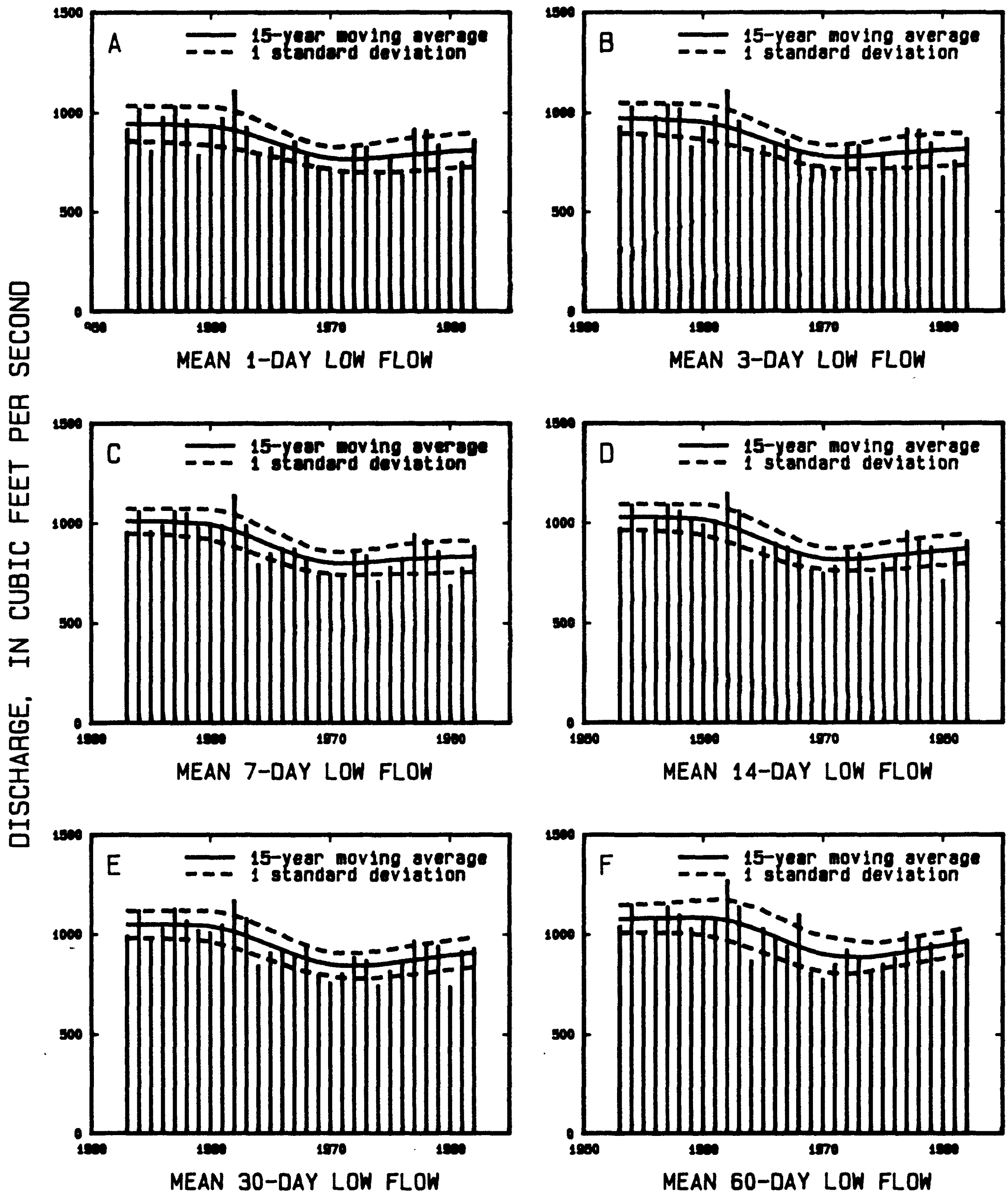

Figure 3.--Yearly mean 1-, 3-, 7-, 14-, 30-, and 60-day low flows during the period April through November for the synthesized streamflow record, Niobrara River at Mariaville.

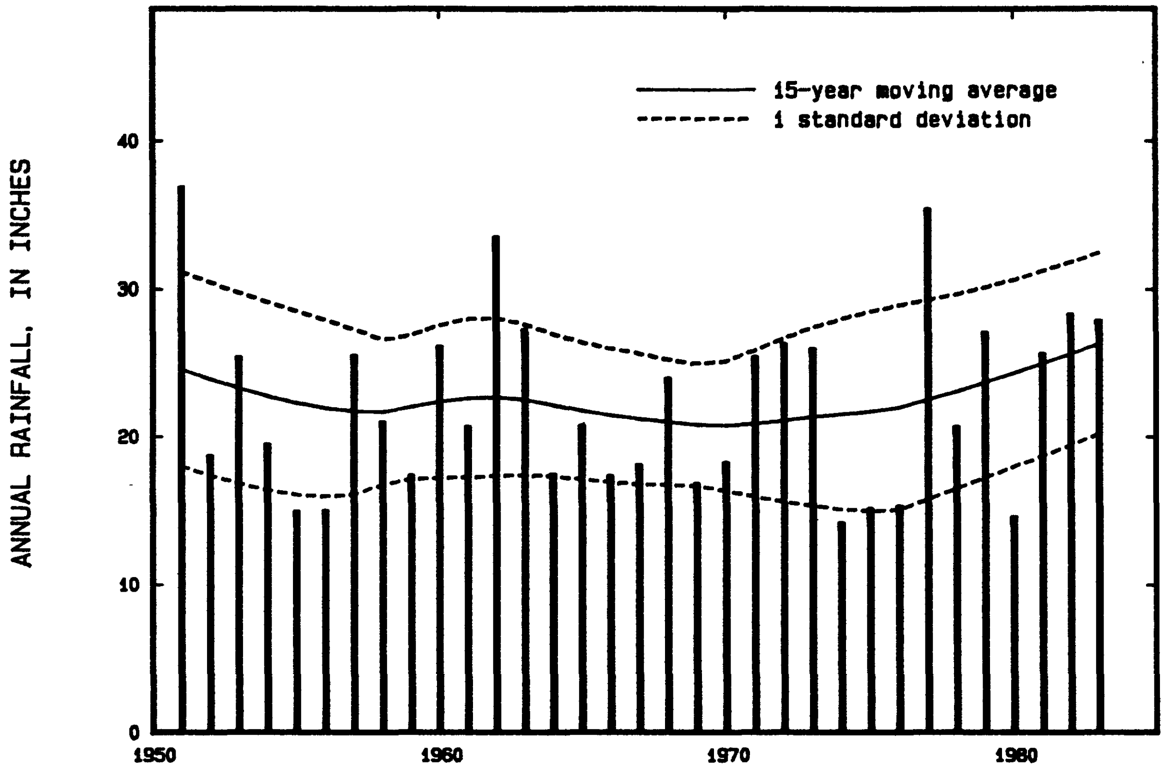

Figure 4.--Annual rainfall at Ainsworth, Nebraska.

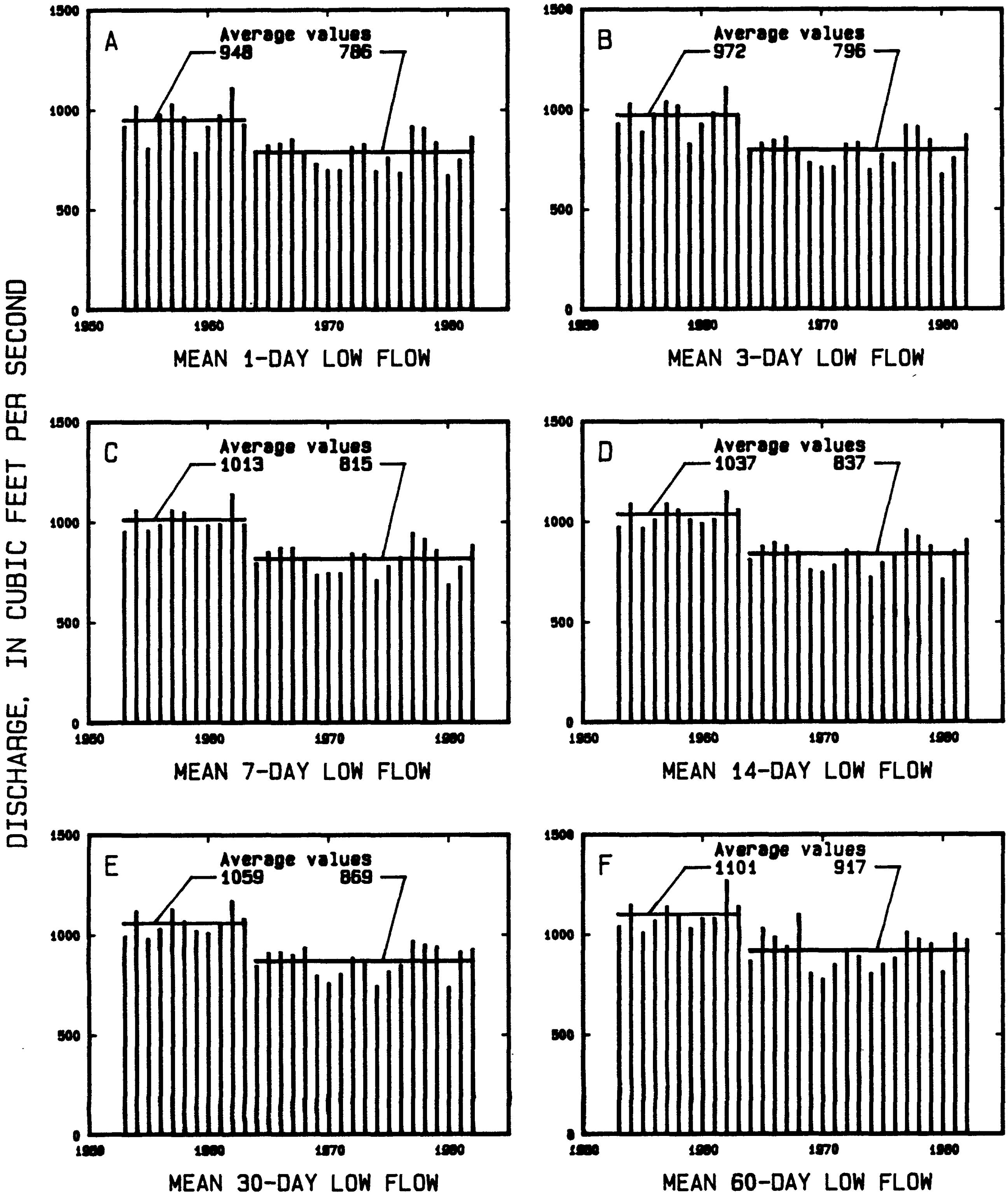

Figure 5.--Yearly mean 1-, 3-, 7-, 14-, 30-, and 60-day low flows during the period April through November and the average values for 1953-63 and 1964-82 synthesized streamflow record, Niobrara River at Mariaville.

Table 8.--Average April through November low flows, 1953-63 and 1964-82, Snake River near Burge (06459500), Niobrara River near Norden (06462000), and synthesized streamflow record Niobrara River at Mariaville (06463720)

Low-flow duration (days)	Average low flow, 1953-63 (ft^3/s)	Average low flow, 1964-82 (ft^3/s)	Difference between the averages (ft^3/s)
Snake River near Burge:			
1	194	11.7	-182
3	200	12.1	-188
7	212	13.9	-198
14	217	17.4	-200
30	222	22.4	-200
60	228	31.8	-196
Niobrara River near Norden:			
1	592	435	-157
3	629	454	-175
7	683	473	-210
14	708	490	-218
30	729	514	-215
60	759	555	-204
Niobrara River at Mariaville:			
1	948	786	-162
3	972	796	-176
7	1013	815	-198
14	1037	837	-200
30	1059	869	-190
60	1101	917	-184

Since there is no significant trend in the synthesized streamflow data other than a marked decrease in low-flow values since 1964, the synthesized streamflow record can be accepted as repesenting flow in the Niobrara River at Mariaville until there is a marked change in basin conditions. Streamflow statistics and probabilities were recompiled from the synthesized record for Niobrara River at Mariaville for the period 1964-83. They are presented in table 9.

REFERENCES CITED

Becker, H.L., 1985, Nebraska state-led O'Neill unit alternatives study: Nebraska Department of Water Resources, Lincoln, Nebraska, 31 p.

Doyle, W.H., Jr., Shearman, J.O., Stiltner, G.J., and Krug, W.R., 1983, A digital model for streamflow routing by convolution methods: U.S. Geological Survey Water-Resources Investigations Report 83-4160, 130 p.

Ellis, M.J., and Pederson, D.T., 1986, Groundwater levels in Nebraska, 1985: The University of Nebraska-Lincoln, Conservation and Survey Division, Nebraska Water Survey Paper Number 61, 65 p.

Newport, T.G., 1959, Ground-water resources of the lower Niobrara and Ponca Creek basins, Nebraska and South Dakota: U.S. Geological Survey Water-Supply Paper 1460-G, 51 p.

Shaffer, F.B., 1975, History of irrigation and characteristics of streamflow in northern Nebraska: U.S. Geological Survey Open-File Report 7501, 114 p.

Table 9.--Selected streamflow statistics of the synthesized record, Niobrara River at Mariaville, Nebraska (06463720), since 1964

Monthly and annual mean discharges

Month	Maximum (ft^3/s)	Minimum (ft^3/s)	Mean (ft^3/s)	Standard deviation (ft^3/s)	Skewness	Coefficient of variation (percent)
Monthly mean discharge, 10/64 to 9/83, 10/85 to 6/86:						
October	1380	901	1070	115	0.86	0.11
November	1390	942	1190	126	-0.36	0.11
December	1420	878	1200	132	-0.43	0.11
January	1400	921	1200	138	-0.14	0.11
February	1740	969	1350	164	0.02	0.12
March	2090	1060	1480	287	0.47	0.19
April	2090	1050	1480	275	0.84	0.19
May	2620	1040	1450	384	1.73	0.26
June	2160	1000	1340	299	1.46	0.22
July	2250	752	1060	321	3.04	0.30
August	1170	772	970	161	1.51	0.17
September	1300	823	1010	135	0.65	0.13
Annual mean discharge, water years 1965-83:						
	1580	1090	1220	116	1.59	0.09

Duration of daily mean discharges, water years 1965-83

Daily mean discharge (ft^3/s)	Percentage of days discharge was equaled or exceeded	Daily mean discharge (ft^3/s)	Percentage of days discharge was equaled or exceeded
580	100.0	1600	9.8
660	99.9	1700	6.8
710	99.6	1800	5.2
760	98.6	1900	4.0
810	96.2	2100	2.4
860	92.7	2200	2.0
920	85.5	2300	1.6
990	75.1	2500	1.1
1100	60.4	2700	0.8
1200	45.8	2900	0.6
1300	31.3	3100	0.3
1400	21.1	3300	0.2
1500	14.3	3700	0.1

Table 9.--Selected streamflow statistics of the synthesized record, Niobrara River at Mariaville, Nebraska (06463720), since 1964--continued

Probability of annual high flows, water years 1965-83

Exceedence probability (percent)	Recurrence interval (years)	Highest average flow (ft^3/s)					
		Consecutive days					
		1	3	7	15	30	60
99	1.01	1570	1540	1410	1250	1180	1180
50	2	2460	2340	2140	1950	1760	1590
10	10	3860	3600	3130	2600	2260	1980
4	25	4750	4390	3700	2900	2490	2170
2	50	5510	5060	4160	3130	2660	2320
1	100	6350	5790	4660	3350	2830	2460

Probability of annual low flows, climatic years 1965-83

Non-exceedence probability (percent)	Recurrence interval (years)	Lowest average flow (ft^3/s)					
		Consecutive days					
		1	3	7	14	30	60
1	100	556	603	664	674	691	733
2	50	577	620	678	693	712	753
5	20	610	645	700	721	744	782
10	10	639	669	720	746	771	809
20	5	675	700	746	777	804	842
50	2	745	762	799	833	866	906