

FLOW CHARACTERISTICS OF THE CLEARWATER RIVER  
AND TRIBUTARIES FROM CLEARBROOK TO PLUMMER,  
NORTHWESTERN MINNESOTA

Gregory A. Payne

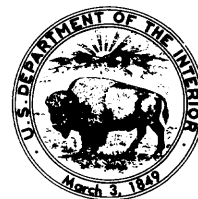
---

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations 89-4045

St. Paul, Minnesota

1989



DEPARTMENT OF THE INTERIOR  
MANUEL LUJAN, JR., Secretary  
U.S. GEOLOGICAL SURVEY  
Dallas L. Peck, Director

---

For information write to:

District Chief  
U.S. Geological Survey  
702 Post Office Building  
St. Paul, Minnesota 55101

Copies of this report can be purchased  
from:

U.S. Geological Survey  
Books and Open-File Reports Section  
Federal Center, Box 25425  
Denver, Colorado 80225

## CONTENTS

	Page
Abstract.....	1
Introduction.....	1
Purpose and scope.....	3
Approach.....	3
Flow in the Clearwater River.....	4
Daily streamflow, adjacent to the Red Lake Indian Reservation.....	4
Daily streamflow at Plummer, Minnesota.....	13
Results of periodic measurements.....	14
Water supply.....	16
Summary.....	24

## ILLUSTRATIONS

Figure 1.	Map showing location of the Clearwater River and tributaries near the Red Lake Indian Reservation.....	2
2.	Map showing location of gaging stations and discharge-measurement sites in the Clearwater River basin near the Red Lake Indian Reservation.....	6
3.	Hydrographs of daily mean flows in the Clearwater River and Ruffy Brook, March through October 1986.....	7
4.	Flow-duration curves for Ruffy Brook near Gonvick, March through October.....	18
5.	Flow-duration curves for Lost River at Oklee, March through October.....	20
6.	Flow-duration curve for Clearwater River near Clearbrook, March through October 1986.....	21

## TABLES

Table 1.	Discharge-measurement sites.....	5
2.	Total monthly flow for Clearwater River and Ruffy Brook, stream-gaging stations, 1986.....	8
3-6.	Daily mean discharges:	
3.	Station no. 05077600, Clearwater River near Clearbrook, Minnesota, 1986.....	9
4.	Station no. 05077700, Ruffy Brook near Gonvick, Minnesota, 1986.....	10
5.	Station no. 05077850, Clearwater River near Trail, Minnesota, 1986.....	11
6.	Station no. 05078000, Clearwater River near Plummer, Minnesota, 1986.....	12
7.	Discharge measurements made in 1986.....	15
8.	Ranked monthly mean discharges for water years 1960-78, 1986-87, Ruffy Brook near Gonvick .....	22
9.	Ranked monthly mean discharges for water years 1960-87, Lost River at Oklee.....	23

## CONVERSION FACTORS AND ABBREVIATIONS

Readers who prefer to use metric (International System) units rather than the inch-pound units in this report can make conversions using the following factors:

<u>Multiply Inch-Pound Unit</u>	<u>By</u>	<u>To obtain Metric Unit</u>
mile (mi)	1.609	kilometer (km)
acre-foot (acre-ft)	1,233	cubic meter (m <sup>3</sup> )
cubic foot per second (ft <sup>3</sup> /s)	0.02832	cubic meter per second (m <sup>3</sup> /s)

FLOW CHARACTERISTICS OF THE CLEARWATER RIVER  
AND TRIBUTARIES FROM CLEARBROOK TO  
PLUMMER, NORTHWESTERN MINNESOTA

By G. A. Payne

ABSTRACT

During March through October 1986, 52,560 acre-feet of water passed the continuous-record stream gaging station on the Clearwater River near Clearbrook, Minnesota, 4.8 river miles upstream from the Red Lake Indian Reservation. Flow at the downstream boundary of the Reservation totaled 93,770 acre-feet. The increase in Clearwater River flow in the reach bordering the Reservation equaled 32,950 acre-feet; 60 percent of the increase occurred during March, April, and May. During those months, flow in the Clearwater River was augmented by flow from Kiwosay Reservoir and Butcher Knife Creek, which are located on the Reservation. Daily streamflow records showed that flow in the river increased in the Reservation reach throughout the study except for 13 days during October when losses occurred. At the downstream Reservation boundary, all daily mean flows exceeded the 36 cubic feet per second minimum flow required by the Minnesota Department of Natural Resources for the gaging station at Plummer, Minnesota located 29.9 miles downstream from the Reservation boundary. Monthly flows generally followed expected seasonal trends, with the highest monthly totals occurring in April and May and the lowest monthly totals occurring during August, September, and October. Seasonal trends were modified by reservoir releases, withdrawals for irrigation, and return flows that resulted from drainage of adjacent wild-rice fields. A series of flow measurements showed that localized withdrawals and return flows at times exceeded 20 percent of total streamflow. Discharge measurements made during low flow indicated higher rates of groundwater discharge in the vicinity of the Kiwosay Reservoir than in other parts of the study reach. Measurements made during August indicated that groundwater discharge in the reach of the river bordering the Reservation resulted in a flow gain of about 20 percent. Analysis of long-term streamflow records showed that near-average hydrologic conditions prevailed during the study period.

INTRODUCTION

The Clearwater River flows along the southwestern boundary of the Red Lake Indian Reservation (fig. 1). Water is diverted from the river for irrigation of commercial wild-rice fields. Rice-growing activities are most intensive on riparian lands along the reach of river from immediately upstream from the south Reservation boundary and extending downstream to the city of Plummer, Minnesota, a distance of about 47 river miles (fig. 1).

Rice growing creates heavy demands for water from the Clearwater River. Growers start refilling rice fields during September, shortly after harvesting is completed, in preparation for the growing season that will commence the following spring. Once the fields are flooded, additional water is needed to compensate for evapotranspiration and leakage. Leakage losses are significant

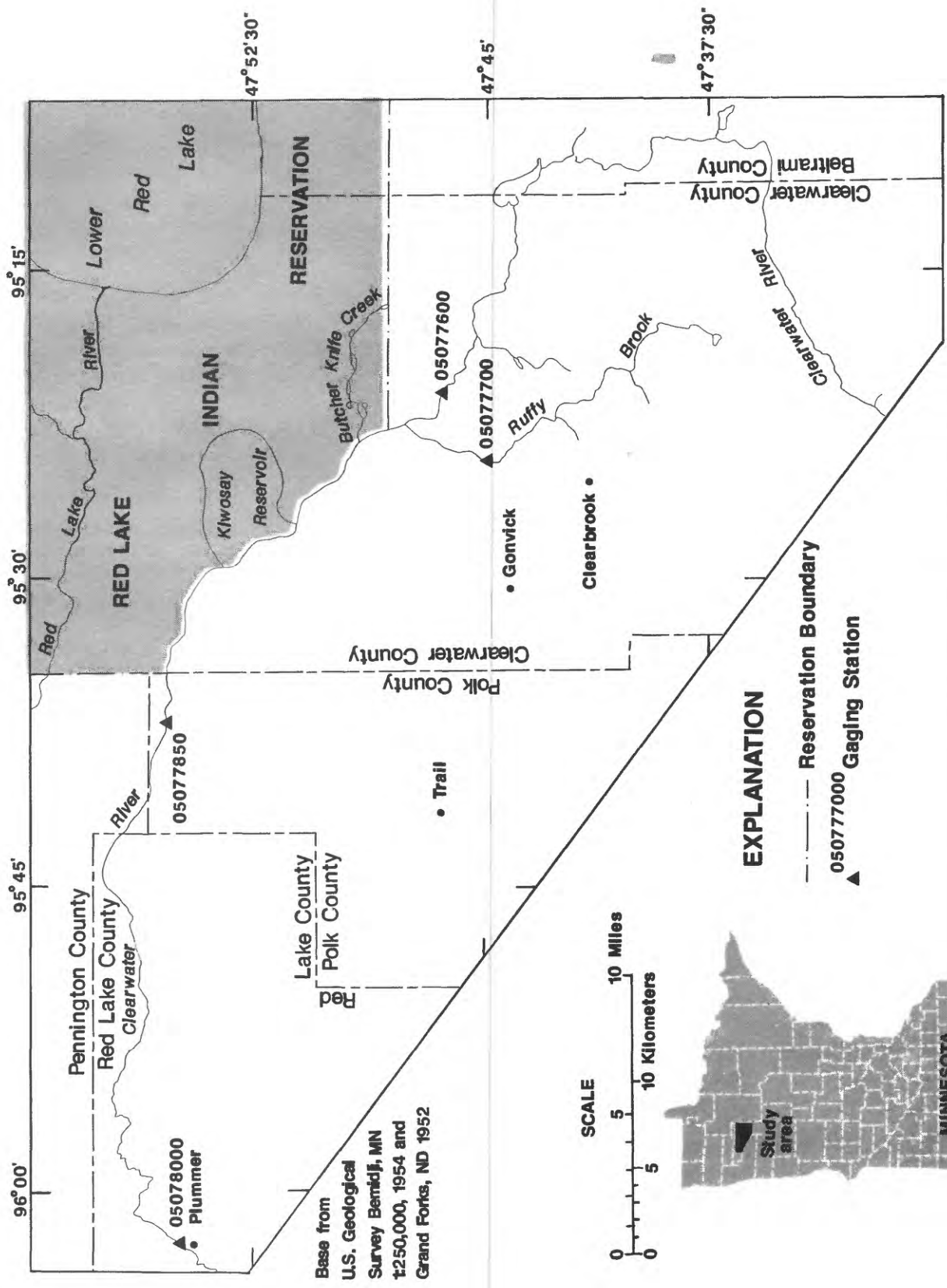


Figure 1. --- The Clearwater River and tributaries near the Red Lake Indian Reservation.

because of the organic soils of the area, which complicate dike construction, and excavation for dike construction, which may expose highly permeable sand and gravel underlying the beds of the fields.

Large withdrawals and the concern of interests downstream of the rice-growing area led to a decision that gave the Minnesota Department of Natural Resources (DNR) authority to curtail withdrawals when flow at the Plummer, Minnesota gaging station decreases to a daily mean flow of 36 ft<sup>3</sup>/s (cubic feet per second) or less.

There is interest in further expansion of rice-growing operations, particularly on Reservation lands. Because flows at the U.S. Geological Survey continuous-record streamflow-gaging station at Plummer, Minnesota, have dropped below 36 ft<sup>3</sup>/s historically, and because withdrawals are frequently necessary during seasonal low-flow periods, it is essential that the flow of the Clearwater River in the vicinity of the Red Lake Indian Reservation be investigated.

### Purpose and Scope

This report presents the results of an investigation to gather information to (1) determine the natural flow characteristics of the Clearwater River, (2) determine the effect of withdrawals for irrigation on flow in the Clearwater River under present conditions, and (3) provide data to help assess the availability of water to maintain a minimum flow of 36 ft<sup>3</sup>/s in the Clearwater River at Plummer, in light of present use of water from the river.

Specifically, the report (1) describes the measured flow of the Clearwater River in the vicinity of the Red Lake Indian Reservation from March through October 1986, (2) discusses the impact of irrigation withdrawals and diversions during this period, and (3) briefly discusses the availability of water in the Clearwater River to maintain the minimum flow of 36 ft<sup>3</sup>/s at Plummer based on the 8 months of data collected in 1986.

### Approach

The continuous-record streamflow-gaging station at Plummer, Minnesota, (fig. 1, gaging station no. 05078000) has been operated since 1939. Most of the record is continuous, but only annual maximums were recorded from October 1979 to February 1982. Virtually all withdrawals occur upstream of the gaging station at Plummer, invalidating some of the normal analyses that can be performed on continuous streamflow records. Because of these upstream withdrawals, three additional gaging stations were established upstream of Plummer.

A gaging station was established on the Clearwater River near Clearbrook, Minnesota, (fig. 1, station no. 05077600). This station is located upstream of the rice-growing area and represents natural flow conditions. Another gaging station on Ruffy Brook near Gonvick (fig. 1, station no. 0507700), a tributary to the Clearwater River, was reactivated. The Ruffy Brook station is also

located upstream of the rice-growing area and was operated as a continuous record station from 1960 through 1978. The Ruffy Brook station was reactivated to provide additional information on flow entering the area and to provide a basis for comparing flow during the study period with historical flows. The third gaging station was established on the Clearwater River near Trail, Minnesota, (fig. 1, station no. 05077850) to measure flow where the river leaves the Reservation area.

The gaging-station network (fig. 1) provided a means of determining the amount of unaltered natural flow entering the study area (the gaging station near Clearbrook), a historical perspective (the Ruffy Brook gaging station), a means of determining the altered flow leaving the study area (the gaging station near Trail), and a means of determining the relation of flow in the upper watershed to flow at the gaging station at Plummer where the threshold flow of 36 ft<sup>3</sup>/s is officially monitored.

The distance between the gaging stations on the Clearwater River between Clearbrook and Trail is 21.2 river miles. Within this reach there are numerous irrigation pumps and several return flow ditches, Butcher Knife Creek, (a natural stream draining Reservation lands) and a major flow-diversion structure that directs flow into the Kiwosay reservoir, a fish-rearing pond. Because the gaging stations would only serve to document net gains and losses in the study reach, it was necessary to make periodic discharge measurements at selected points within the study reach. The purpose of these measurements was to identify areas of substantial gains and losses and to measure ground-water contribution during periods of no diversion or return flow activity. A listing of the additional measurement sites and a brief description of their specific purpose is given in table 1. The locations of the sites are shown in figure 2.

The continuous-record gaging stations were put into operation during February 1986. The series of discharge measurements commenced in late May 1986 and were continued at approximately 1-month intervals until late October, 1986.

## STREAMFLOW

### Daily Streamflow, adjacent to the Red Lake Indian Reservation

Records of daily mean flow were computed for the gaging stations on the Clearwater River near Clearwater, near Trail, at Plummer, and on Ruffy Brook near Gonvick. Hydrographs for these gaging stations are shown in figure 3. Table 2 is a summary of monthly flows expressed in acre-feet and tables 3-6 are listings of daily mean flows.



Table 1.--*Discharge-Measurement Sites*

Site	Purpose of Site
Ruffy Brook at Mouth (Site 1)	Determine the gain in flow in Ruffy Brook between the gaging station near Gonvik, and the mouth and determine if the discharge at the gaging station is representative of the total contribution of Ruffy Brook to the Clearwater River.
Clearwater River at the Southern Reservation Boundary (Site 2)	Determine the total flow of the Clearwater River at the upstream (southern) boundary of the Reservation.
Butcher Knife Creek at Mouth (Site 3)	Determine the amount of Clearwater River flow contributed by Butcher Knife Creek.
Clearwater River Diversion Channel (Site 4)	Determine the amount of flow diverted from the Clearwater River to the Kiwosay Reservoir.
Clearwater River at Highway 5 Bridge (Site 5)	Determine the effects of pumping, diversions, and return flows on the flow in the Clearwater River downstream from the Kiwosay diversion channel.
Clearwater River above Kiwosay Reservoir Outlet (Site 6)	Determine pumping, diversions, and return flows upstream from the Kiwosay return flow channel.
Kiwosay Dam Spillway (Site 7)	Determine the flow released from Kiwosay Reservoir to the Clearwater River.
Clearwater River at the Western Reservation Boundary (Site 8)	Determine flow in the Clearwater River at the downstream (western) boundary of the Reservation.

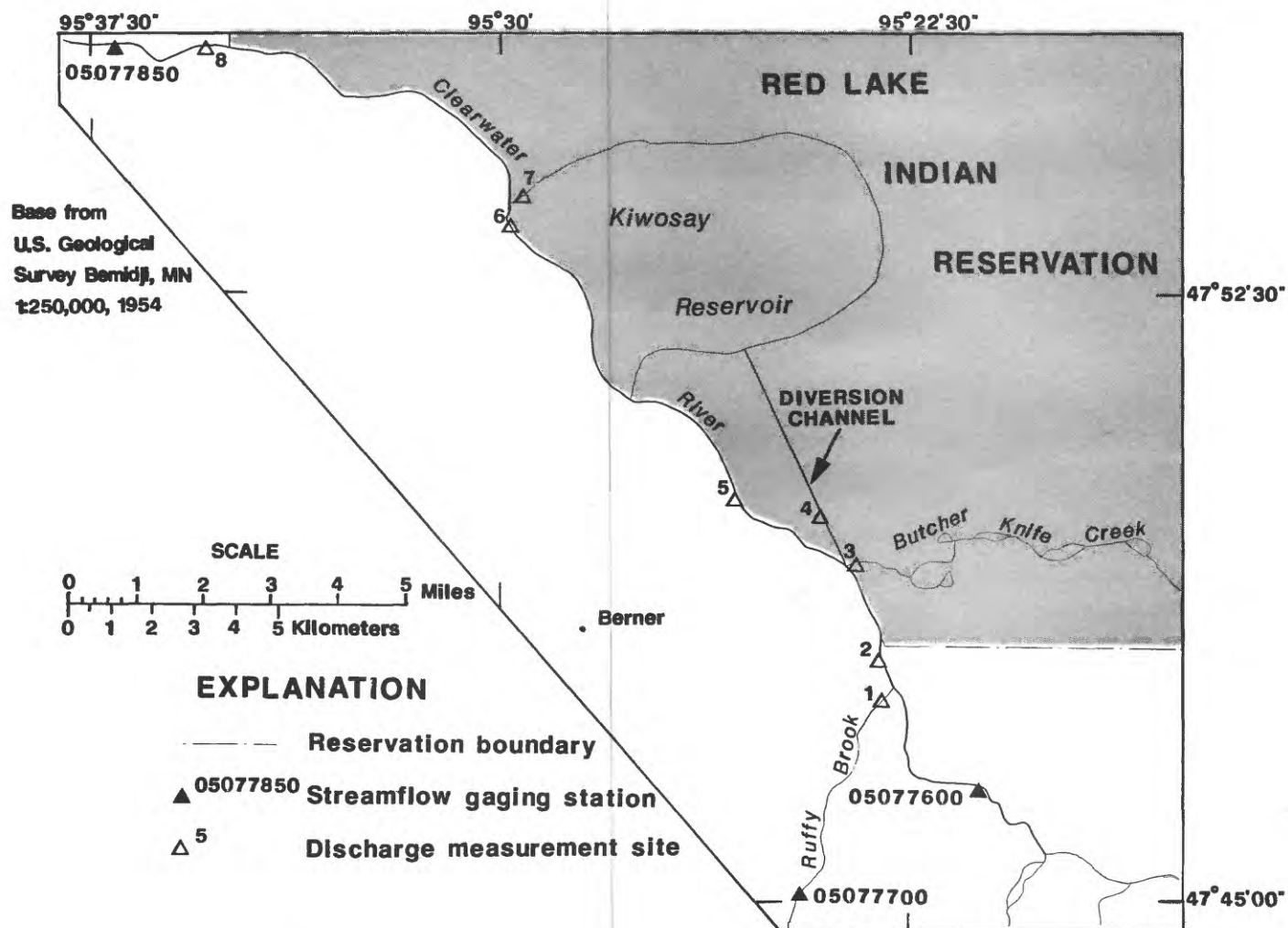
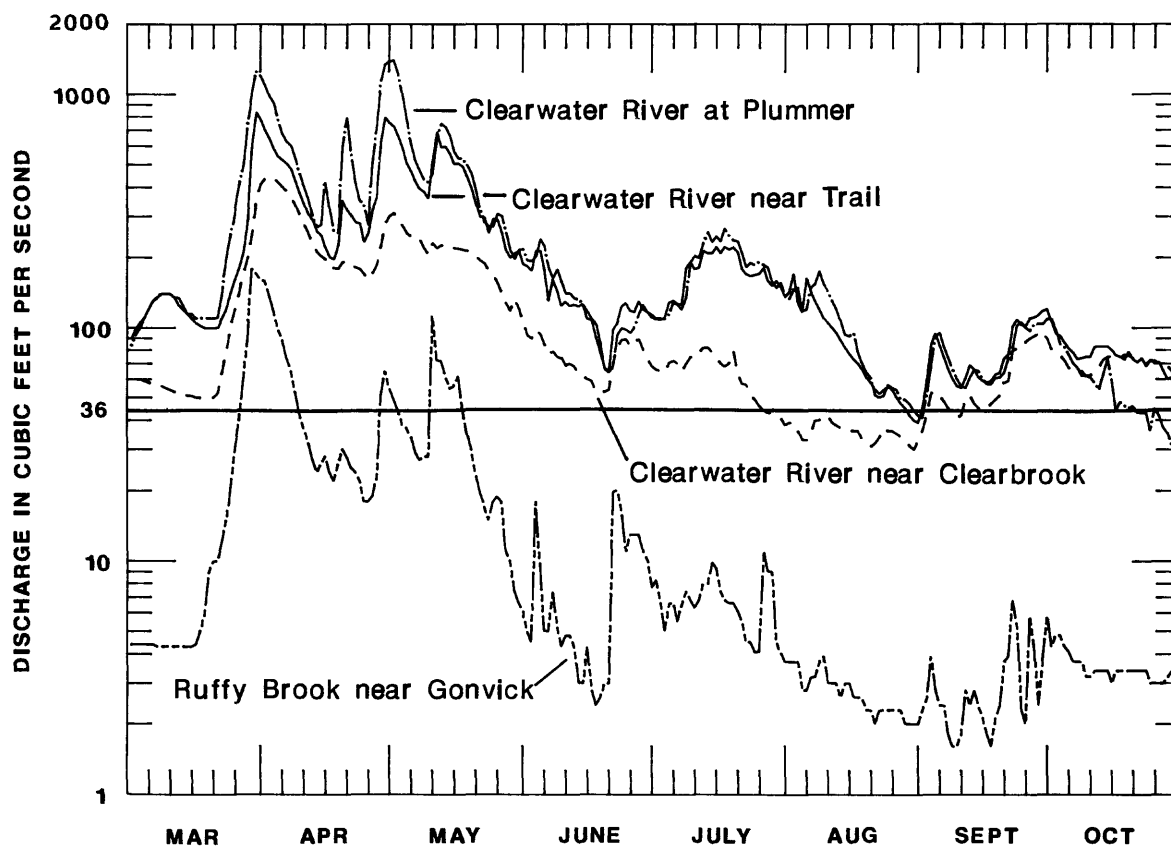


Figure 2. -- Location of gaging stations and discharge measurement sites in the Clearwater River basin near the Red Lake Indian Reservation.



**Figure 3. -- Hydrographs of daily mean flow in the Clearwater River and Ruffy Brook, March through October, 1986.**

**Table 2.--Total monthly flows for Clearwater River and Ruffy Brook,  
stream-gaging stations, 1986**

[Values are in acre-feet except for those in parenthesis, which are percent increase or decrease]

	March	April	May	June	July	August	September	October	Total
Clearwater River near Clearbrook, Minn.	5,990	15,640	12,600	4,440	3,860	2,190	3,540	4,300	52,560
Ruffy Brook near Gonvick, Minn.	1,770	2,900	2,150	470	407	168	178	216	8,260
Clearwater River near Trail, Minn.	11,630	23,790	25,580	7,620	10,510	5,230	4,710	4,700	93,770
Clearwater River at Plummer, Minn.	16,790	35,680	31,640	7,900	11,230	5,760	4,510	3,430	116,900
Flow increase, Clearwater River from south Reservation boundary to west Reservation <sup>1</sup>	3,870 (50)	5,250 (28)	10,830 (73)	2,710 (55)	6,240 (146)	2,870 (122)	992 (27)	184 (4.1)	32,950 (54)
Flow increase, Clearwater River from gaging station near Trail, Minn. to gaging station at Plummer, Minn.	5,160 (44)	11,890 (50)	6,060 (24)	280 (3.7)	720 (6.9)	530 (10)	-200 (-4.2)	-1,270 (-27)	23,170 (25)
Flow in excess of 36 cubic feet per second Clearwater River near Clearbrook, Minn.	3,780	13,500	10,390	2,300	1,650	0.00	1,400	2,090	35,110
Flow in excess of 36 cubic feet per second Clearwater River near Trail, Minn.	9,420	21,650	23,370	5,480	8,300	3,020	2,570	2,490	76,300
Flow in excess of 36 cubic feet per second Clearwater River at Plummer, Minn.	14,580	33,540	29,430	5,760	9,020	3,550	2,370	1,220	99,470

NOTE: Totals may not be exact because of rounding.

<sup>1</sup> Calculated by adding the flow at Ruffy Brook near Gonvick to flow at Clearwater River near Clearbrook and subtracting the result from flow at Clearwater River near Trail.

**Table 3.--Daily mean discharge, station no. 05077600, Clearwater River near Clearbrook, Minnesota, 1986**

[Values are discharges in cubic feet per second except where noted. In the monthly summary below the daily table, the line beginning with "Total" gives the sum of the daily figures. The line beginning with "Mean" gives the average flow in cubic feet per second during the month. The lines beginning with "Max" and "Min" give the maximum and minimum daily discharges, respectively, for the month. The line beginning with "Acre-ft." gives the discharge for the month in acre-feet.]

Day	March	April	May	June	July	August	September	October
1	61	434	311	93	66	39	36	81
2	60	440	296	90	65	39	42	77
3	60	439	274	98	64	36	52	76
4	59	423	254	94	71	33	53	72
5	58	405	247	85	72	33	51	67
6	58	387	250	77	70	35	48	64
7	57	366	240	79	65	40	45	64
8	56	339	220	75	70	40	43	65
9	55	308	206	74	75	41	41	62
10	54	280	231	69	74	42	42	62
11	53	254	220	70	78	39	49	65
12	52	234	226	68	82	38	51	67
13	52	212	228	63	82	37	46	73
14	51	204	226	62	78	36	45	75
15	51	198	220	60	74	36	44	75
16	50	182	219	59	70	36	45	74
17	50	181	217	53	68	36	47	74
18	50	179	214	53	70	33	49	77
19	50	191	210	53	79	32	51	76
20	50	193	204	54	63	31	58	74
21	52	185	195	70	57	32	59	72
22	65	182	190	82	57	34	80	70
23	80	179	177	89	51	37	81	70
24	100	171	170	89	49	36	81	72
25	120	161	157	83	46	36	87	72
26	140	171	142	88	44	35	90	70
27	170	185	129	89	43	34	92	68
28	200	224	118	80	43	33	94	68
29	251	278	133	73	42	31	96	65
30	344	302	122	68	41	30	89	61
31	412		107		38	33		60
Total	3,021	7,887	6,353	2,240	1,947	1,103	1,787	2,168
Mean	97.5	263	205	74.7	62.8	35.6	59.6	69.9
Max.	412	440	311	98	82	42	96	81
Min.	50	161	107	53	38	30	36	60
Acre-ft.	5,990	15,640	12,600	4,440	3,860	2,190	3,540	4,300

**Table 4.-- Daily mean discharge, station no. 05077700,  
Ruffy Brook near Convik, Minnesota, 1986**

[Values are discharges in cubic feet per second except where noted. In the monthly summary below the daily table, the line beginning with "Total" gives the sum of the daily figures. The line beginning with "Mean" gives the average flow in cubic feet per second during the month. The lines beginning with "Max" and "Min" give the maximum and minimum daily discharges, respectively, for the month. The line beginning with "Acre-ft." gives the discharge for the month in acre-feet.]

Day	March	April	May	June	July	August	September	October
1	4.4	159	49	5.0	8.3	3.7	2.3	4.8
2	4.4	138	44	4.5	6.6	3.7	2.6	4.8
3	4.4	119	38	18	5.0	3.7	3.9	4.8
4	4.4	99	37	9.6	6.6	2.8	2.8	4.3
5	4.4	89	34	5.0	6.6	2.8	2.4	4.1
6	4.4	74	29	5.0	5.5	3.2	2.4	3.7
7	4.3	66	27	7.4	6.6	3.2	1.8	3.7
8	4.3	53	28	5.3	7.4	3.7	1.6	3.7
9	4.3	43	28	4.3	6.8	3.9	1.6	3.2
10	4.3	37	113	4.8	6.3	3.0	1.8	3.2
11	4.3	32	72	4.8	6.8	3.0	2.8	3.4
12	4.3	27	72	4.3	8.0	3.0	2.4	3.4
13	4.3	24	62	3.0	8.0	2.6	2.8	3.4
14	4.3	26	55	3.0	9.9	3.0	2.4	3.4
15	4.3	28	56	4.3	9.3	3.0	2.1	3.0
16	4.4	24	62	2.8	7.4	2.6	1.8	3.4
17	5.0	22	44	2.4	6.8	2.6	1.6	3.4
18	6.0	26	35	2.6	6.6	2.6	2.1	3.4
19	9.0	30	30	3.0	6.6	2.3	2.4	3.4
20	10	28	23	3.0	6.1	2.3	3.7	3.4
21	10	25	20	20	5.5	2.0	3.9	3.4
22	12	24	17	20	4.5	2.3	6.8	3.4
23	15	22	15	16	4.5	2.3	5.3	3.4
24	20	18	18	11	4.1	2.3	2.3	3.0
25	30	18	19	13	4.1	2.3	2.0	3.0
26	40	19	18	13	11	2.3	5.8	3.0
27	60	23	11	13	9.0	2.3	4.3	3.0
28	93	51	9.9	11	9.0	2.0	2.4	3.2
29	180	65	7.4	10	4.5	2.0	3.9	3.4
30	171	55	6.6	7.7	4.1	2.0	5.8	3.0
31	161		6.1		3.7	2.0		3.4
Total	891.5	1,464	1,086.0	236.8	205.2	84.5	89.8	109.1
Mean	28.8	48.8	35.0	7.89	6.62	2.73	2.99	3.52
Max.	180	159	113	20	11	3.9	6.8	4.8
Min.	4.3	18	6.1	2.4	3.7	2.0	1.6	3.0
Acre-ft.	1,770	2,900	2,150	470	407	168	178	216

**Table 5.-- Daily mean discharge, station no. 05077850,  
Clearwater River near Trail, Minnesota, 1986**

[Values are discharges in cubic feet per second except where noted. In the monthly summary below the daily table, the line beginning with "Total" gives the sum of the daily figures. The line beginning with "Mean" gives the average flow in cubic feet per second during the month. The lines beginning with "Max" and "Min" give the maximum and minimum daily discharges, respectively, for the month. The line beginning with "Acre-ft." gives the discharge for the month in acre-feet.]

Day	March	April	May	June	July	August	September	October
1	90	701	730	184	109	143	45	106
2	100	648	662	175	109	172	59	94
3	105	585	591	214	110	128	85	92
4	110	544	507	215	129	117	95	86
5	120	526	470	177	131	165	83	81
6	130	509	425	132	127	143	74	78
7	135	484	395	160	126	130	66	73
8	140	431	385	145	182	120	60	74
9	140	383	357	124	192	110	56	75
10	140	344	514	130	178	105	55	75
11	135	309	689	124	181	100	61	83
12	135	292	594	126	214	95	69	83
13	125	259	597	124	209	88	66	83
14	115	252	559	126	209	82	61	83
15	110	223	506	109	222	77	59	80
16	105	202	507	108	209	73	58	76
17	102	196	494	90	222	70	59	75
18	100	225	446	78	217	66	63	73
19	100	353	401	67	221	61	64	79
20	100	322	345	65	211	58	74	73
21	100	305	300	99	177	54	77	71
22	110	284	298	105	170	52	102	74
23	120	283	255	124	167	54	109	68
24	140	233	293	128	169	56	103	73
25	160	253	293	118	171	54	102	70
26	180	321	258	117	181	50	110	71
27	210	356	215	130	159	47	111	65
28	290	623	200	120	152	45	113	60
29	600	796	209	117	159	42	118	61
30	840	754	214	111	150	40	120	65
31	778		188		136	39		69
Total	5,865	11,996	12,897	3,842	5,299	2,636	2,377	2,369
Mean	189	400	416	128	171	85.0	79.2	76.4
Max.	840	796	730	215	222	172	120	106
Min.	90	196	188	65	109	39	45	60
Acre-ft.	11,630	23,790	25,580	7,620	10,510	5,230	4,710	4,700

**Table 6.-- Daily mean discharge, station no. 05078000,  
Clearwater River near Plummer, Minnesota, 1986**

[Values are discharges in cubic feet per second except where noted. In the monthly summary below the daily table, the line beginning with "Total" gives the sum of the daily figures. The line beginning with "Mean" gives the average flow in cubic feet per second during the month. The lines beginning with "Max" and "Min" give the maximum and minimum daily discharges, respectively, for the month. The line beginning with "Acre-ft." gives the discharge for the month in acre-feet.]

Day	March	April	May	June	July	August	September	October
1	84	1100	1400	195	110	133	41	109
2	94	980	1230	193	110	146	51	97
3	100	920	988	201	109	149	68	85
4	110	781	767	241	114	118	92	81
5	120	677	610	225	129	120	95	76
6	130	628	519	181	126	149	82	70
7	135	607	472	163	120	154	74	68
8	140	537	433	179	134	175	66	62
9	140	467	421	158	192	154	60	61
10	140	407	455	141	204	144	56	61
11	135	361	650	141	199	131	55	59
12	125	302	747	134	231	121	61	55
13	120	271	724	133	257	107	66	62
14	115	275	666	126	233	93	65	74
15	115	426	570	118	247	92	60	59
16	110	326	534	110	235	95	57	44
17	110	261	532	104	267	78	57	49
18	110	255	499	85	247	70	61	47
19	110	594	462	66	237	64	61	45
20	110	799	398	64	235	61	64	45
21	110	562	328	68	208	51	74	44
22	140	421	284	94	182	50	82	42
23	200	352	273	100	190	51	103	43
24	250	341	271	98	186	57	106	36
25	310	275	309	95	192	55	100	47
26	410	509	304	101	186	54	97	42
27	490	724	259	114	182	49	104	38
28	750	1110	216	126	158	49	104	36
29	1000	1340	197	117	149	47	104	31
30	1250	1380	216	114	156	44	109	32
31	1200		218		139	42		31
Total	8,463	17988	15952	3985	5664	2903	2275	1731
Mean	273	600	515	133	183	93.6	75.8	55.8
Max.	1,250	1,380	1,400	241	267	175	109	109
Min.	84	255	197	64	109	42	41	31
Acre-ft.	16,790	35,680	31,640	7,900	11,230	5,760	4,510	3,430



Comparison of total flow in the Clearwater River entering the study reach at the station near Clearbrook (table 2) with flow leaving the area at the station near Trail shows an increase of 41,210 acre-feet within the reach for the period March through October, and at least 8,260 acre-feet of the increase entered from Ruffy Brook. The remaining increase, 32,950 acre-feet, occurred in the reach adjacent to the reservation. The monthly data show that flow was consistently increasing through the study reach throughout the period of data collection. An inspection of the daily records, however, reveals that net decreases in flow occurred during 13 days in October. The percent increase in flow through the reach is shown in table 2. The large range in monthly percentages (4.1 to 146 percent) reflect periods of heavy withdrawals (October) as well as periods of flow releases (July and August).

The largest monthly increase through the study reach was observed during May (10,830 acre-feet). Much of this increase can be attributed to release of water from the Kiwosay Reservoir. Daily flow record was not obtained at the Kiwosay Reservoir outlet, but a discharge measurement made May 21 indicated that 69.0 ft<sup>3</sup>/s, or 22 percent, of the total flow at the gaging station near Trail was from the Kiwosay Reservoir. Comparison of the hydrographs of flow at the gaging stations (fig 3) near Clearbrook and Trail gives further evidence of the contribution of the Kiwosay Reservoir to flow in the Clearwater River, particularly for the periods April 18-24, May 10-20, and May 23-28. During these periods, peaks occurred in the discharge hydrograph for the gaging station near Trail, while the discharge hydrograph for the gaging station near Clearbrook shows steady or declining flow.

The data show that withdrawals and return flows alter the natural flow of the Clearwater River. For example, the natural flow at the gaging station near Clearbrook decreased 13 percent for July compared to June, while flow at the gaging station near Trail increased 38 percent as a result of return flows. Similarly, comparing August and September flow at the gaging station near Clearbrook, flow increased 62 percent, while flow at the gaging station near Trail decreased 10 percent as a result of withdrawals. These variable flows were also observed for the periods April-May and September-October (table 2).

#### Daily Streamflow at Plummer, Minnesota

The effects of withdrawals were more pronounced in the reach of the Clearwater between the gaging station near Trail and the gaging station at Plummer than they were in the reach of the Clearwater adjacent to the Reservation. As shown by the monthly values in table 2, the gain between the gaging stations near Trail and at Plummer was less than the gain between the gaging stations near Clearbrook and Trail during May through October and totaled only 23,170 acre-feet during the study period compared to a gain of 32,950 acre-feet in the Reservation area. The reach from the gaging station near Trail to the gaging station at Plummer was a losing reach during the months of September and October. The loss of flow became more acute after October 15 as shown in figure 3 and the discharge declined below 36 ft<sup>3</sup>/s during October 29, 30, and 31.

During the period, October 15-31, flow at the gaging station near Trail remained at 60 ft<sup>3</sup>/s or greater, indicating that more than enough flow was leaving the Reservation area to maintain the required 36 ft<sup>3</sup>/s threshold flow at Plummer.

The river reach from the gaging station near Trail to the gaging station at Plummer is 29.9 miles in length, whereas the reach from the gaging station near Clearbrook to the gaging station near Trail is 21.2 miles in length. Despite the fact that the reach from Trail to Plummer is longer and has a larger drainage area, the relative lack of flow gain compared to the upper reach suggests that the reach from Trail to Plummer may have lower rates of runoff and groundwater discharge in addition to being affected by withdrawals.

### Results of Periodic Measurements

The series of periodic discharge measurements in the primary study area provided much additional information about flow conditions in and near the Reservation boundary. All sites were measured on the same day during each run of measurements, providing an overview of conditions throughout the reach on that day. The results of the measurements are shown in table 7.

When the study was initiated, it was expected that flow in the Clearwater River at the gaging station near Clearbrook would be representative of the flow in the river at the upstream boundary of the Reservation. It was not practical to locate a gaging station at the Reservation boundary, but it was expected that daily discharge at the boundary could be closely estimated by correlating the periodic measurements at the boundary with the continuous flow record at the gaging station near Clearbrook. The periodic measurements indicated, however, that a satisfactory correlation could not be developed between the two sites. Withdrawals in this part of the reach probably are responsible for the lack of a close correlation. On May 21, for example, a quantity of water equal to the entire flow (53.2 ft<sup>3</sup>/s) of Ruffy Brook at the mouth (site 1) was apparently withdrawn before it reached the Reservation's southern boundary. A similar situation was apparent when attempts were made to correlate flow at the gaging station on Ruffy Brook with discharge measurements at the mouth of Ruffy Brook.

The periodic measurements indicated that Butcher Knife Creek contributed substantial flow to the Clearwater River during spring (33.2 ft<sup>3</sup>/s on May 21), but by June 23 flow decreased to only 3.46 ft<sup>3</sup>/s and continued in a gradual recession throughout the summer, reaching zero flow by August 27. Flow resumed following fall rains but the measurements suggest that the flow during fall may not have exceeded 1.0 ft<sup>3</sup>/s. It was expected that daily flow record in Butcher Knife Creek could be estimated by correlation with daily record from Ruffy Brook or the Clearwater River near Clearbrook, but a satisfactory correlation could not be established. The lack of correlation may be caused by the fact that virtually all of Butcher Knife Creek's drainage area is a bog which would have response characteristics unlike those of the more upland drainage basins of Ruffy Brook and the Clearwater River.

**Table 7.--Discharge measurements made in 1986**

[Values are discharge in cubic feet per second. e, estimated discharge]

	May 21	June 23	July 22	August 27	September 30	October 14	October 28
Clearwater River near Clearbrook	202	90.0	57.4	33.2	89.9	73.9	67.8
Ruffy Brook near Gonvick	20.6	16.6	4.98	2.23	5.54	3.36	2.93
Ruffy Brook at mouth (site 1)	53.2	14.8	20.9	3.91	8.57	5.66	4.53
Clearwater River at south Reservation boundary (site 2)	201	85.4	83.8	38.6	103	78.2	69.8
Butcher Knife at mouth (site 3)	33.2	3.46	2.03	.00	.50e	.90e	.80
Kiwoyay Reservoir diversion channel (site 4)	.00	.5e	.05e	.00	.02e	.00	.10e
Clearwater River at Highway 5 bridge (site 5)	270	98.9	102	39.0	107	73.7	67.7
Clearwater River above Kiwoyay Reservoir outlet (site 6)	234	108	102	44.2	104	77.3	73.2
Kiwoyay Dam spillway (site 7)	69.0	1.0e	.00	.50	.10e	.00	.50
Clearwater River at west Reservation boundary (site 8)	317	121	138	46.8	98.0	80.2	64.2
Clearwater River near Trail	316	128	177	47.0	108	84.9	58.6
Clearwater River near Plummer	398	107	180	53.0	112	78.5	30.5

No flow was diverted from the Clearwater River to the Kiwosay Reservoir (site 4) during the period of study (Floyd W. Jorgensen, Natural Resources Specialist, Red Lake Tribal Council, oral commun., 1988). The flows indicated in table 7 for the diversion channel are the result of leakage from the diversion channel into the Clearwater River.

Discharge at the Kiwosay Reservoir outlet (site 7) was substantial during spring as indicated by a discharge of 69.0 ft<sup>3</sup>/s measured on May 21. Releases from the Kiwosay Reservoir were reduced during June and remained at low levels through October as indicated by the measurements shown in table 7.

The periodic measurement site (site 8) on the Clearwater River at the western Reservation boundary is located 2.2 river miles upstream from the gaging station near Trail. Comparison of flow measurements indicates that the amount of flow recorded at the gaging station near Trail reasonably approximates the flow at the western Reservation boundary. A notable exception was observed on July 22 when there was a 39.0 ft<sup>3</sup>/s (28 percent) increase in flow between the two sites. That increase demonstrates the effect that irrigation return flows can have over relatively short reaches of the river.

One set of measurements, made on August 27, provided flow information representative of conditions not influenced by withdrawals or return flows. The personnel making the measurements reported that all the rice fields were dewatered and that no pumps were operating. In addition to the lack of activity related to rice growing, this run of measurements coincided with the minimum flows for the study period. The results, therefore, provide an opportunity to examine conditions at a time when virtually all changes in flow between the gaging stations near Clearbrook and near Trail can be attributed to ground-water discharge except for 3.91 ft<sup>3</sup>/s contributed by Ruffy Brook. In the reach encompassing the Reservation boundary, streamflow increased about 20 percent. The average increase in flow (after subtracting out Ruffy Brook's flow) was 0.47 (ft<sup>3</sup>/s)/mi (cubic feet per second per mile). The rate of increase rose markedly from 0.20 (ft<sup>3</sup>/s)/mi to 1.04 (ft<sup>3</sup>/s)/mi, in the portion of the reach between the Highway 5 bridge and the Kiwosay outlet. This subreach flows past the dike that forms the Kiwosay Reservoir. The impounded water adjacent to the stream may be inducing additional ground-water discharge to the Clearwater River.

## WATER SUPPLY

The total amount of water available during the study period is shown by the values expressed in acre-feet in table 2. Table 2 shows that 52,560 acre-feet entered the Reservation area at the gaging station near Clearbrook and 93,770 acre-feet left the Reservation at the gaging station near Trail. The monthly values shown for the gaging station near Trail represent water that potentially is available for expansion of rice irrigation. As mentioned in the introduction, however, the Minnesota Department of Natural Resources has authority to curtail withdrawals when the flow in the Clearwater River at Plummer drops to 36 ft<sup>3</sup>/s. Because of this restriction, only the amount in excess of 36 ft<sup>3</sup>/s (2,142 acre-feet in a 30-day period) can reasonably be considered available for additional rice production. These values are shown in table 2 for the gaging stations near Clearbrook and Trail. Full utilization of

these amounts of water would necessarily mean that virtually no water would be available to rice growers downstream from the gaging station near Trail because of the observed lack of recharge and runoff in the downstream reach and the 36-ft<sup>3</sup>/s threshold level for permitted irrigation.

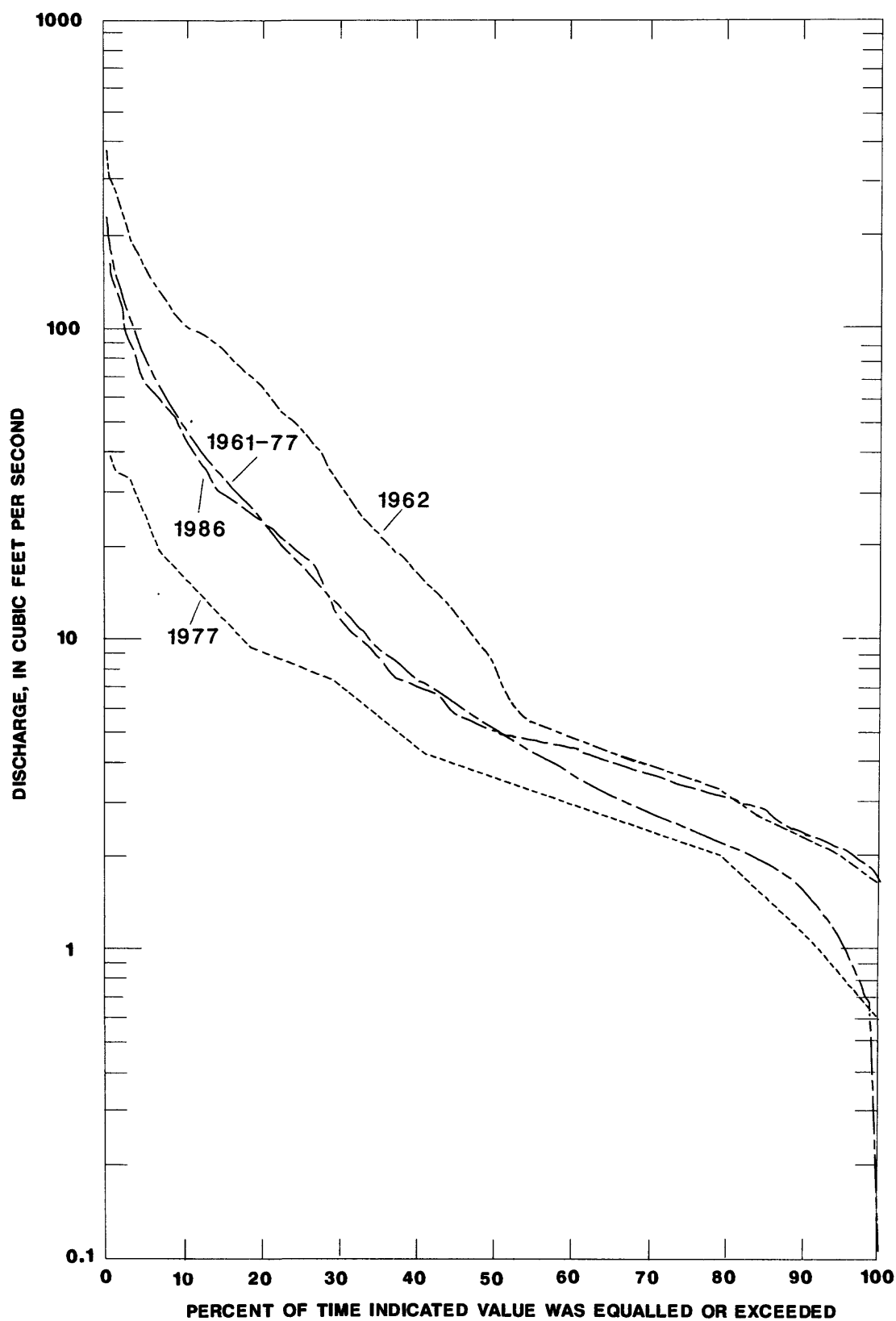
Examining the data for the study period (table 2), 35,110 acre-feet was available for additional use at the gaging station near Clearbrook and 76,300 acre-feet were available at the gaging station near Trail. The monthly distribution of these amounts was very uneven, however. Note that during June, when the need for irrigation water can be critical, only 2,300 acre-feet was available at the gaging station near Clearbrook and only 5,480 acre-feet was available at the gaging station near Trail. Similarly, even less water was available in September and October to refill the fields after harvest. Relatively larger quantities of water were available during April and May, but much of this flow (at the gaging station near Trail) was derived from stored water released from the Kiwosay Reservoir.

The preceding discussion is based entirely on conditions observed during March through October 1986 encompassing only a single growing season. Although the data provide an adequate accounting of water supply during 1986, there remains the question of whether conditions observed during 1986 are an adequate representation of normal flow--that is, can one expect the average water supply to be different from that measured during 1986.

Conditions observed during 1986 can be put in perspective by comparing them with longer-term flow records. Two of the gaging-stations in the study area, Clearwater River at Plummer and Ruffy Brook near Gonvick, have longer-term records. A third gaging station, Lost River at Oklee, is located in a drainage basin adjacent to the Clearwater basin. The record from the gaging station at Plummer was not analyzed because it is affected by irrigation withdrawals and therefore not representative of natural conditions. Flow at the Ruffy Brook gaging station is not affected by withdrawals but analysis requires the assumption that, as a tributary, it responds to climatic variables in a manner similar to the Clearwater main stem. The drainage area of the Lost River at Oklee is 266 mi<sup>2</sup> and is similar in size to the drainage area of the Clearwater River near Clearbrook.

Figure 4 shows flow-duration curves for Ruffy Brook, for the 8-month period ending October 31. The duration curve for the longer-term period of record, 1961-77, is shown along with curves for the study year (1986), a dry year (1977) and a wet year (1962). A comparison of the curves shows that flow duration in 1986 closely follows the duration curve from the longer-term record except at low flow (less than 5.0 ft<sup>3</sup>/s). One can conclude that flow in Ruffy Brook during 1986 was near normal with above-normal low flow. The total amount of water available during a similar 8-month period, therefore, cannot be expected on the average to exceed the amount available in 1986.

The flow-duration curves for the Lost River for the 8-month period ending October 31 are shown in figure 5. Flow duration for March through October 1986 did not follow the long-term duration curve as closely as it did at Ruffy Brook. High flow and low flow were both slightly greater than the long-term average, but flows in the interquartile range (exceeded 25-75 percent of the time) were nearly all below the long-term average.



**Figure 4. -- Flow-duration curves for Ruffy Brook near Gonvick, March through October.**

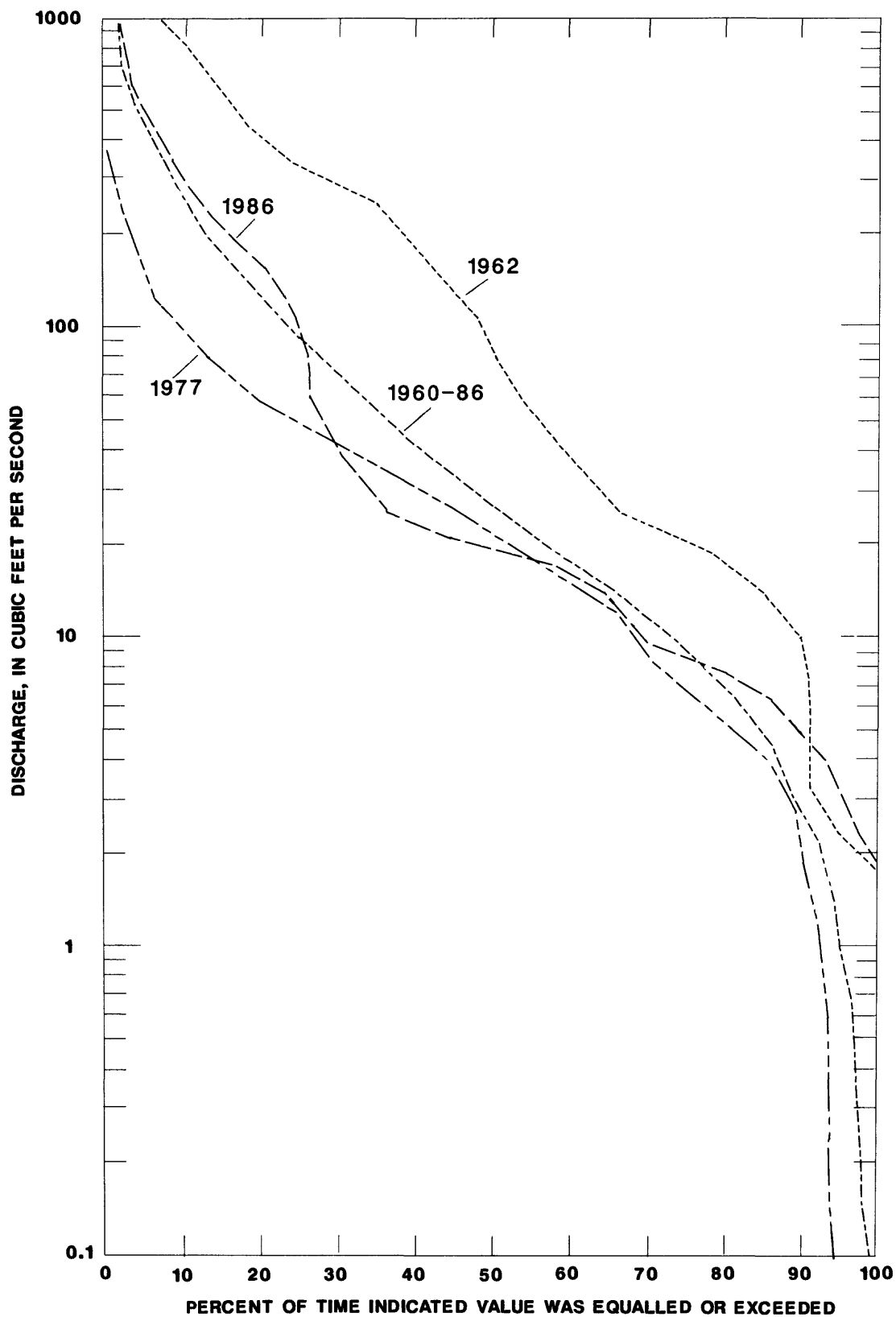
The flow duration curve for the Clearwater River near Clearbrook is shown in figure 6. Long-term records have not been obtained at this gaging station so a direct comparison with average flow duration cannot be made. The curve shows an abrupt change in slope at higher flows that is similar to the change in slope shown in figure 5 for Lost River at Oklee, indicating that the Clearwater River may also have had above-average high flow during the study period. The curve for the Clearwater River lacks the break in slope that occurs at low flow in the long-term curves for both Ruffy Brook and Lost River, indicating that low flows were above average in the Clearwater River near Clearbrook during the study period.

The flow-duration curves described above indicate that total flows at gaging stations in and adjacent to the study area were near normal to above normal during March-October 1986. The dip in the flow duration curve for Lost River, however, suggests that a part of the study period was dryer than normal.

Long-term monthly flow records were examined to determine which part of the study period may have experienced below-normal flow. Table 8 shows ranked monthly mean discharges for Ruffy Brook. During the study period monthly discharges exceeded the 50th percentile except during April, June, and October. The April, June, and October discharges exceeded the 25th percentile, however, placing them in the normal range. Only one monthly discharge (March) exceeded the 75th percentile, placing it in the above-normal range.

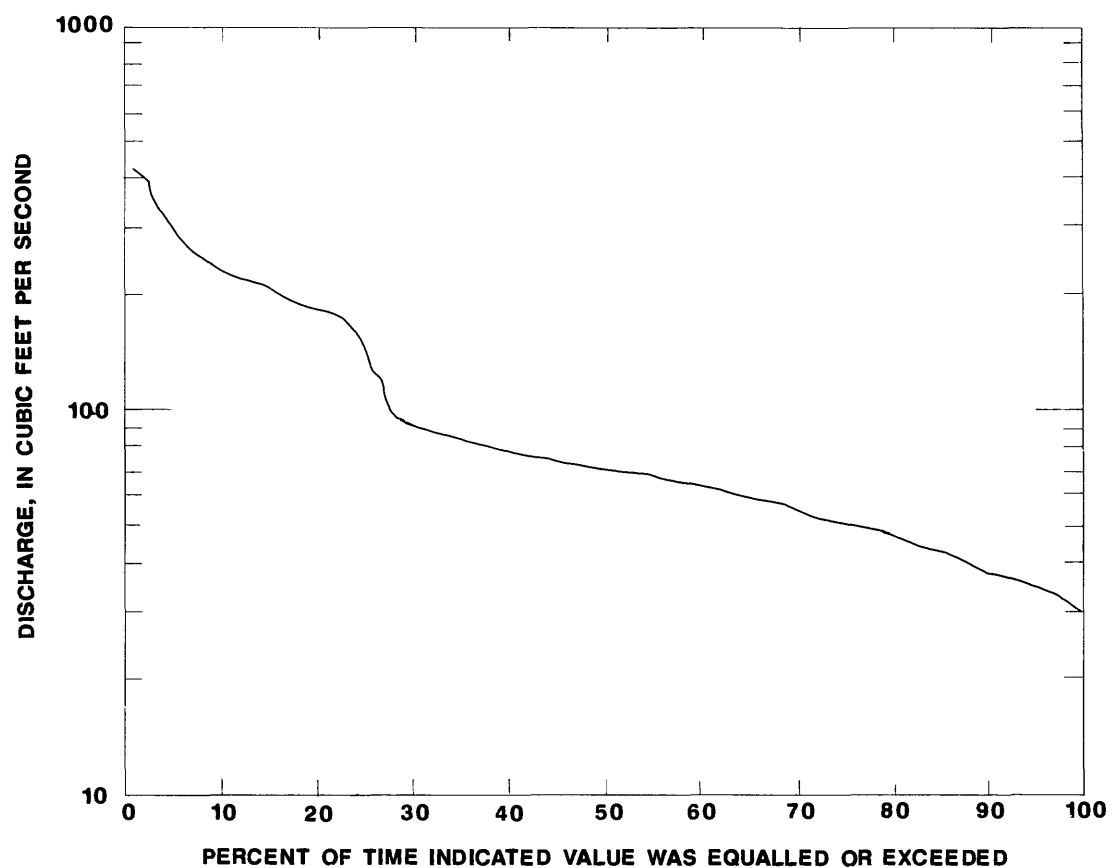
Table 9 shows ranked monthly mean discharges for Lost River at Oklee. March 1986 discharges were above normal as they were at Ruffy Brook. Discharges were below the 50th percentile during June, July, August, September, and October 1986, but remained in the normal range except during June when the mean discharge was below the normal range.

\*The analysis of monthly mean flows in Ruffy Brook and the adjacent Lost River basin indicates that, during the 1986 study period, flow in and adjacent to the Clearwater River basin was within the normal range except for March which was above normal and June which was below normal.



**Figure 5. -- Flow-duration curves for Lost River at Oklee, March through October.**





**Figure 6. -- Flow-duration curve for Clearwater River near Clearbrook, March through October 1986.**

Table 8.--*Ranked monthly mean discharges for water years 1960-78, 1986-87, Ruffy Brook near Gonvick*

[Values are in cubic feet per second.--, no monthly mean discharge; \*\*, monthly mean discharge for 1986. Note: A water year is October 1 through September 30, for example, October 1, 1986 is in Water Year 1987.]

March	April	May	June	July	August	September	October
Discharge Year	Discharge Year	Discharge Year	Discharge Year	Discharge Year	Discharge Year	Discharge Year	Discharge Year
-- 1960	-- 1960	-- 1960	-- 1960	-- 1960	-- 1960	-- 1960	-- 1960
-- 1987	-- 1987	-- 1987	-- 1987	-- 1987	-- 1987	-- 1987	-- 1987
2.07 1971	6.91 1977	4.61 1977	2.29 1961	2.10 1961	1.09 1976	.62 1967	-- 1986
2.32 1964	12.80 1973	5.42 1976	2.52 1973	2.87 1974	1.17 1961	.69 1976	1.15 1968
2.56 1965	22.40 1968	8.74 1973	2.60 1976	3.22 1973	1.41 1970	1.56 1970	1.21 1977
2.68 1962	26.30 1961	10.60 1968	3.39 1977	3.55 1969	1.58 1964	2.15 1974	1.60 1961
3.10 1969	31.90 1963	10.90 1978	5.61 1978	3.88 1977	1.82 1968	2.17 1963	1.97 1964
3.79 1977	35.20 1976	16.80 1971	6.83 1966	3.96 1970	1.89 1977	2.25 1960	3.19 1975
3.99 1978	48.80 1986**	22.40 1964	7.71 1971	4.33 1966	1.94 1967	2.53 1969	3.22 1962
4.66 1970	50.10 1964	26.80 1961	7.89 1986**	4.45 1964	2.14 1971	2.54 1972	3.52 1987**
5.73 1975	54.20 1971	27.20 1975	9.50 1972	4.73 1960	2.45 1965	2.62 1968	4.26 1963
5.81 1974	60.90 1962	28.70 1967	12.30 1974	4.85 1971	2.70 1978	2.94 1966	4.48 1971
6.44 1961	71.30 1967	29.90 1972	12.70 1964	5.23 1978	2.73 1986**	2.99 1986**	5.08 1967
10.90 1963	74.10 1972	33.60 1966	13.80 1975	5.26 1965	2.93 1975	3.18 1971	5.09 1969
14.20 1968	74.10 1969	34.10 1969	16.10 1969	6.19 1967	3.12 1973	3.78 1978	5.13 1976
17.80 1972	85.20 1974	35.00 1986**	23.90 1968	6.62 1986**	3.20 1974	4.10 1961	5.54 1973
18.50 1976	85.80 1970	38.20 1963	25.70 1970	7.62 1968	3.38 1960	4.75 1965	5.92 1965
28.80 1986**	89.60 1975	38.50 1970	29.40 1967	7.98 1963	3.62 1962	5.67 1964	10.20 1966
30.30 1967	91.70 1978	43.90 1974	49.20 1965	11.80 1972	5.04 1969	6.44 1975	12.40 1970
33.90 1973	92.90 1965	51.60 1965	53.20 1963	38.20 1975	6.89 1963	7.28 1962	13.10 1978
37.50 1966	118.00 1966	105.00 1962	54.40 1962	57.30 1962	8.38 1972	13.90 1977	28.90 1964
					18.69 1966	59.30 1973	34.70 1972
Percentile values for the monthly mean discharge, water years 1960-87							
25th percentile							
3.10	31.90	10.90	5.61	3.63	1.84	2.19	3.19
50th percentile							
5.81	60.90	28.70	12.30	4.79	2.71	2.96	5.08
75th percentile							
18.50	85.80	38.20	25.70	7.37	3.35	5.44	10.20

Table 9.--Ranked monthly mean discharges for water years 1960-87, Lost River at Oklee

[Values are in cubic feet per second.--, no monthly mean discharge; \*\*, monthly mean discharge for 1986. Note: A water year is October 1 through September 30, for example, October 1, 1986 is in Water Year 1987.]

March	April	May	June	July	August	September	October
Discharge Year	Discharge Year	Discharge Year	Discharge Year	Discharge Year	Discharge Year	Discharge Year	Discharge Year
--	--	--	--	1.99	1.17	.83	--
1960	1960	1960	1960	1961	1961	1976	1982
1964	29.60	10.50	8.20	3.49	1.85	1.27	2.22
1965	48.90	16.69	9.82	7.55	2.30	1.52	2.50
1966	66.40	16.89	10.60	8.68	2.99	1.74	2.71
1967	97.20	21.90	17.00	8.78	3.14	3.16	2.93
1968	103.00	22.00	19.60	9.46	4.44	5.22	7.71
1969	110.00	42.50	22.50	14.60	4.48	7.08	7.71
1970	120.00	57.50	23.30	16.00	6.32	7.46	7.71
1971	148.00	62.00	25.30	20.00	6.93	8.43	9.29
1972	148.00	64.70	25.40	22.30	7.10	8.54	12.11
1973	186.00	68.30	36.80	22.50	7.34	11.40	12.90
1974	214.00	71.60	39.90	22.90	8.42	13.40	14.60
1975	223.00	87.20	45.70	23.19	8.43	14.60	16.80
1976	265.00	128.00	66.30	26.30	10.30	15.40	18.80
1977	343.00	133.00	66.80	32.80	10.90	16.60	20.40
1978	346.00	153.00	80.20	40.10	14.10	17.39	21.19
1979	370.00	175.00	91.80	41.80	21.19	18.19	22.10
1980	503.00	190.00	94.00	60.00	28.90	18.69	24.50
1981	513.00	210.00	94.20	66.90	30.40	19.00	30.10
1982	538.00	217.00	98.70	75.40	31.20	19.19	51.10
1983	571.00	218.00	113.00	79.20	31.30	39.70	65.80
1984	591.00	235.00	114.00	98.00	36.00	45.40	73.70
1985	677.00	237.00	131.00	125.00	39.30	57.10	77.20
1986	677.00	239.00	134.00	148.00	72.50	61.90	82.90
1987	678.00	271.00	141.00	205.00	72.90	83.50	86.40
1988	726.00	272.00	250.00	275.00	281.00	171.00	101.00
1989	745.00	622.00	657.00	442.00	351.00	330.00	146.00
1990							470.00
1991							
1992							
1993							
1994							
1995							
1996							
1997							
1998							
1999							
2000							
2001							
2002							
2003							
2004							
2005							
2006							
2007							
2008							
2009							
2010							
2011							
2012							
2013							
2014							
2015							
2016							
2017							
2018							
2019							
2020							
2021							
2022							
2023							
2024							
2025							
2026							
2027							
2028							
2029							
2030							
2031							
2032							
2033							
2034							
2035							
2036							
2037							
2038							
2039							
2040							
2041							
2042							
2043							
2044							
2045							
2046							
2047							
2048							
2049							
2050							
2051							
2052							
2053							
2054							
2055							
2056							
2057							
2058							
2059							
2060							
2061							
2062							
2063							
2064							
2065							
2066							
2067							
2068							
2069							
2070							
2071							
2072							
2073							
2074							
2075							
2076							
2077							
2078							
2079							
2080							
2081							
2082							
2083							
2084							
2085							
2086							
2087							
2088							
2089							
2090							
2091							
2092							
2093							
2094							
2095							
2096							
2097							
2098							
2099							
2100							
2101							
2102							
2103							
2104							
2105							
2106							
2107							
2108							
2109							
2110							
2111							
2112							
2113							
2114							
2115							
2116							
2117							
2118							
2119							
2120							
2121							
2122							
2123							
2124							
2125							
2126							
2127							
2128							
2129							
2130							
2131							
2132							
2133							
2134							
2135							
2136							
2137							
2138							
2139							
2140							
2141							
2142							
2143							
2144							
2145							
2146							
2147							
2148							
2149							
2150							
2151							
2152							
2153							
2154							
2155							
2156							
2157							
2158							
2159							
2160							
2161							
2162							
2163							
2164							
2165							
2166							
2167							
2168							
2169							
2170							
2171							
2172							
2173							
2174							
2175							
2176							
2177							
2178							
2179							
2180							
2181							
2182							
2183							
2184							
2185							
2186							
2187							
2188							
2189							
2190							
2191							
2192							
2193							
2194							
2195							
2196							
2197							
2198							
2199							
2200							
2201							
2202							
2203							
2204							
2205							
2206							
2207							
2208							
2209							
2210							
2211							
2212							
2213							
2214							
2215				</			

## SUMMARY

During March through October 1986, 52,560 acre-feet of water passed the gaging station on the Clearwater River near Clearbrook located 4.8 miles upstream from the Red Lake Indian Reservation boundary. Tributary inflow, groundwater discharge, and release of water from the Kiwosay Reservoir contributed to a total discharge of 93,770 acre-feet at the downstream boundary. The total gain was 41,210 acre-feet, of which 32,950 acre-feet occurred along the boundary of the Reservation.

Daily streamflow records showed that the reach of the Clearwater River along the Reservation gained flow throughout the study period except for 13 days in October when there were small net losses. Flow at the downstream boundary of the Reservation remained above the 36-ft<sup>3</sup>/s minimum required at the City of Plummer 29.9 miles downstream from the Reservation. The amount of flow leaving the Reservation area in excess of the 36-ft<sup>3</sup>/s minimum totaled 76,300 acre-feet. The monthly distribution of flow was uneven, generally following seasonal trends with the highest monthly discharge totals occurring in April and May and the lowest monthly discharge totals occurring during August, September, and October. Seasonal trends were modified by withdrawals, reservoir releases, and rice-field drawdowns. These activities affected flows at the downstream Reservation boundary and caused wide fluctuations in percent net-flow gains on a month-to-month basis that, at times, ran counter to natural seasonal trends observed upstream from the Reservation.

Downstream from the Reservation, in the reach between the gaging station near Trail and the gaging station at Plummer, the effect of withdrawals was more severe than in the reach flowing past the Reservation. Despite its greater length, flow gains in the downstream reach fell short of gains in the upstream reach from May through August and there was a net loss of flow in the downstream reach during September and October. The loss caused flows at Plummer to decline below the 36-ft<sup>3</sup>/s regulatory level on October 29, 30, and 31.

Periodic discharge measurements at various locations along the Reservation boundary showed that flow in Butcher Knife Creek and releases from the Kiwosay Reservoir made significant contributions to the total flow of the Clearwater River during spring, but declined in significance during summer and fall. The discharge measurements also verified effects of localized withdrawals and return flows that were inferred from the record obtained at the more widely-spaced continuous-record gaging stations. Some of the localized effects involved significant amounts of flow such as the withdrawal of 53 ft<sup>3</sup>/s within a short reach of the Clearwater immediately upstream from the Reservation during May and the return of 39 ft<sup>3</sup>/s within a 2-mile reach immediately downstream from the Reservation during July. Discharge measurements made during August in the absence of withdrawals and releases indicated that ground-water discharge increased flow in the Clearwater by about 20 percent within the reach flowing past the Reservation. The August measurements also showed that ground-water discharge increased along the reach that is adjacent to the Kiwosay Reservoir, suggesting that the reservoir may induce ground-water discharge to the Clearwater River.

Analysis of longer-term records for Ruffy Brook and an adjacent-basin gaging station, Lost River at Oklee, indicate that discharge during the 8-month study period was within the normal range except during March when it was above normal and during June when it was below normal. On this basis, the flow and water supply characteristics of the Clearwater River that were observed during 1986 appear to be representative of those that can be expected over the long term.