Flood Frequency Analysis for the Snare and Taltson Systems

Report

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Flood Frequency Analysis for the Snare and Taltson System
Snare and Taltson, NT

Northwest Territories Power Corporation

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Submitted by

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1.0 INTRODUCTION

1.1 Background

The NWT Power Corporation (NWTPC) operates two major hydroelectric generating systems in the North West Territories. The Snare system with four generating station on the Snare River (Rapids, Falls, Cascades, and Forks) is located north of Yellowknife, and the Taltson system is located south of Yellowknife and Great Slave Lake. A map of the area and the location of the two systems is shown in **Figure 1**.

Snare Rapids Powerhouse & Dam (constructed in 1948) is the first major station on the Snare cascade system located near the outlet of the Big Spruce Lake at an elevation of 222 m and has an approximate watershed area of 15,200 km^2. The Snare Ghost Generating System (G. S.) is located north east of Big Spruce lake and has a watershed of 13,300 km^2. Some of the other major lakes included in this watershed are Ghost, Snare, Indin, and Kwejinner Lakes.

The Taltson system consists of a single generating station at the Twin Gorges G.S. (constructed in 1965), which is located on the Taltson River some 56 km northeast of Fort Smith. It possesses a watershed area of approximately 42,121 km^2, and includes Nonacho Lake which is situated about 220 km further upstream on the Taltson River at an elevation of 320 m, with an approximate watershed area of 21,032 km^2. The Taltson River links a series of lakes that includes Gray, Hjalmar, Tronka Chua, Taltson, King, Lady Grey Tsu and the Nonacho Lakes.

1.2 Scope of Work

Canadian Dam Safety Guidelines recommend that flood hydrology be reviewed whenever the data base has increased by 50% from the data used in the previous analysis. Based on this criteria, the flood hydrology for the NWTPC hydro projects on the Snare and Taltson systems is overdue, and consequently this study was initiated to review the flood hydrology for these two systems. Specific tasks were to include the following:

- Collect and review the presently available sources of information and examine the consistency of the data and identify missing information;
- Search for additional candidate data sources to be used to supplement records, in-fill missing periods of records, or extend the periods of monitoring records;
- Identify and establish relationships and trends between gauging stations;
- Use appropriate results from the above to calculate and supplement the data records;
- Undertake frequency analysis of the historical records to return period peak flow estimates (i.e.,100 and 1000 return period events).

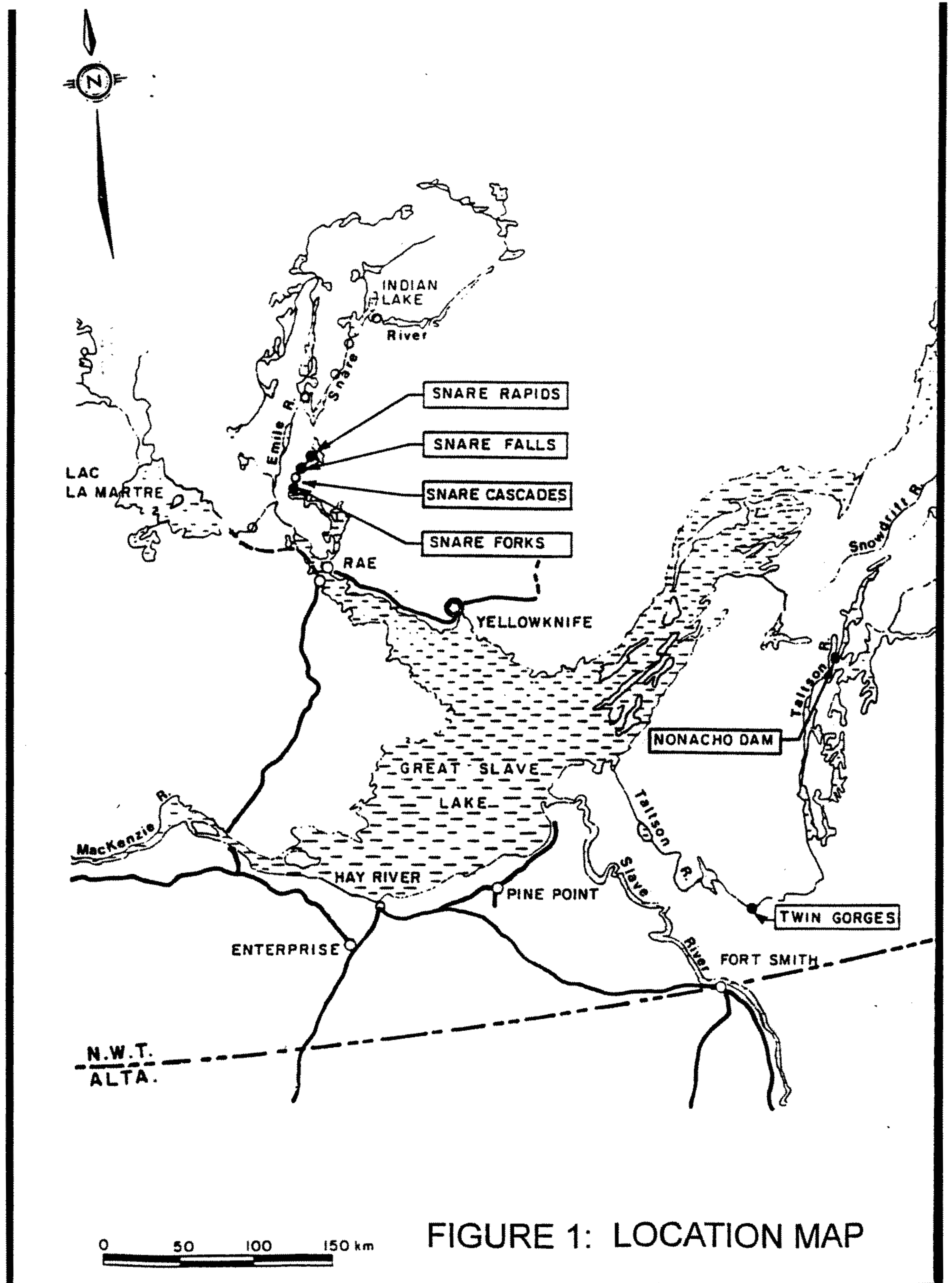


FIGURE 1: LOCATION MAP

1.3 Study Objectives

Specific study objectives of this report were to include the following:

- Estimate the 1000 year peak flow at the Snare Rapids.
- Estimate the 100 year peak flow at the outlet of Nonacho Lake.
- Estimate, approximately, the 1000 year peak flow at the outlet of Nonacho Lake.
- Estimate the 1000 year peak flow at the Twin Gorges facility.

These objectives are consistent with the Canadian Dam Safety Guidelines.

2.0 DATA SOURCES, COLLECTION, AND COMPILATION

The main sources of data for the Snare and Taltson systems were provided by Environment Canada and the NWTPC. Table 1 and Table 2 present a summary of the available data types, durations, and sources for both the Snare and Taltson River Systems.

TABLE 1
Available Data - Snare System

No.	Data Type	Data Duration	Data Source
1	Daily outflows and water level - Big Spruce Lake	1986-1997	NWTPC
2	Big Spruce Lake Stage Volume (Appendix A, Table A-2)	N/A	NWTPC
3	Mean monthly inflows to Big Spruce Lake (Appendix A, Table A-1)	1950-1996	Nishi-Khon/SNC Lavalin
4	Mean monthly inflows to Big Spruce Lake	1950-1976	Environment Canada
5	Mean monthly flows - Yellowknife River at inlet to Prosperous Lake	1950-1996	Environment Canada
6	Mean monthly flows - Lockhart River at outlet of Artillery Lake	1968-1996	Environment Canada
7	Mean monthly flows - Camsell River at outlet of Clut Lake	1964-1996	Environment Canada

It is noteworthy to mention that the mean monthly inflows to Big Spruce Lake (Appendix A, Table A-1) have been calculated by deregulation of the spillway and turbines discharges and water levels recorded at the Snare Rapids Generating Station (located at the outlet of Big Spruce Lake). The deregulation of the outflow records was previously undertaken by NWTPC.

Also noted in the above table are auxiliary streamflow gauging records from the Yellowknife, Lockhart and Camsell River stations which are not within the Snare River system, but which provide valuable information concerning local and regional runoff trends and statistics.

TABLE 2
Available Data - Taltson System

No.	Data Type	Data Duration	Data Source
1	Daily outflows and water levels - Nonacho Lake	1986-1997	NWTPC
2	Daily water level - Nonacho Lake	1962-1994	Environment Canada
3	Daily outflows and water levels - Twin Gorges Dam	1986-1997	NWTPC
4	Daily flows - Taltson River above Porter Lake	1978-1990	Environment Canada
5	Daily flows - Thoa River near inlet to Hill Island Lake	1970-1994	Environment Canada
6	Daily flows - Marten River above Thoa River	1977-1990	Environment Canada
7	Daily flows - Taltson River at outlet of Tsu Lake outflows	1964-1994	Environment Canada

As noted in Table 2 above, only relatively short periods of flow records are available for both the primary facilities of interest (Nonacho Lake and Twin Gorges dams). Extending these records using the auxiliary regional streamflow stations within the vicinity of these facilities (shown in the Table) represents the greatest challenge to confidently allow for subsequent frequency analysis.

3.0 DATA ANALYSIS

The major purpose of this study is to develop a long list of natural and statistically synthesized flow data for both Snare and Taltson systems which can then be used as an input into a frequency analysis. Different methods are used with each system to synthesize these new flow data as described in the following sections.

3.1 Snare System

3.1.1 Annual Runoff

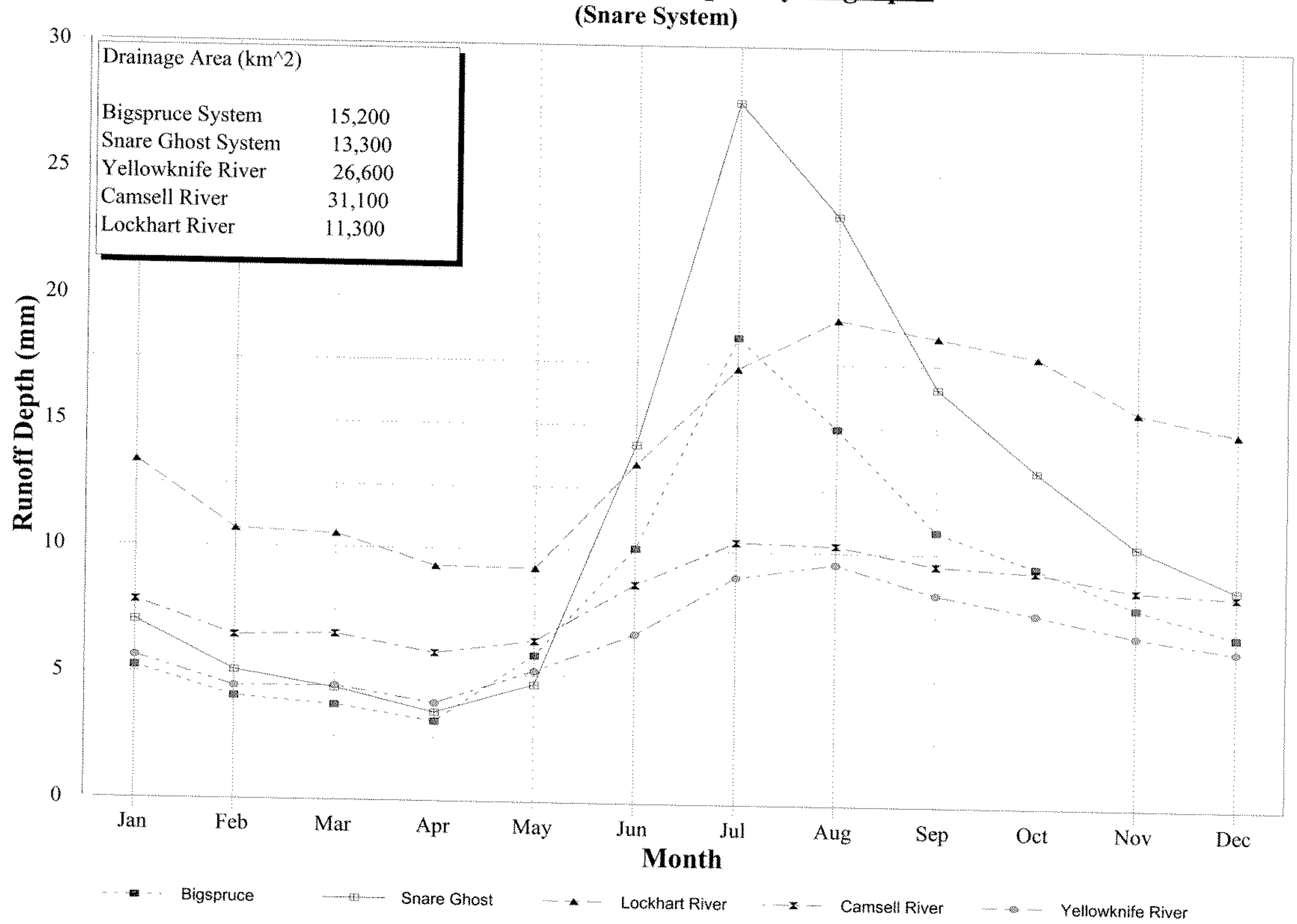
Annual runoff depth hydrographs for the Big Spruce inflows, Snare River below Snare Ghost (referred to hereafter as Snare Ghost), Lockhart River, Camsell River, and Yellowknife River have been constructed using historical mean monthly flows obtained from the available data sources described earlier and listed in Table 1 and unitized to facilitate comparison as shown in **Figure 2** . Both the Snare Ghost and Big Spruce hydrographs possess similar shaped rising and falling limbs and, most importantly, they both experience peak runoff conditions in the month of July. However, while the above hydrographs have been found to exhibit similar trends, it is noteworthy to mention that the Snare Ghost gauge yields approximately 27% more annual runoff per unit area than the Big Spruce gauge (139 mm versus 101 mm). As a result of these noted trends between the Big Spruce and Snare Ghost data sets, it was deemed appropriate to determine if a quality correlation exists between the two stations for daily and monthly flows as a means of extending the period of record at the two stations.

It is also important to note that the features described above are in contrast to what is illustrated by the Lockhart, Camsell and Yellowknife River gauges. Specifically, they do not illustrate as pronounced an annual freshet period and therefore it was determined that these stations should not be used to compare the timing and magnitude of the critical peak periods of runoff. However, in view of the fact that these stations are geographically within close proximity to the study area, these stations can at least be enlisted as indicators of relative annual climatic conditions within the region. The Double Mass Curve approach was used as a mean of testing consistency of Big Spruce mean monthly inflow data with each of Camsell, Yellowknife, and Lockhart Rivers. The results are presented in following sections of the report.

3.1.2 Double Mass Curve

The value of the Double Mass Curve Approach is to assist in determining the consistency of the Big Spruce flow records. Specifically, this method will help in identifying whether non-natural influences have created a bias or affected the quality of the data set (i.e., operational changes, turbine efficiencies, flow measurement techniques, etc.,). By preparing graphs of accumulated runoff volume for Big Spruce Lake and the regional streamflow gauges, it would be expected that over the comparable periods of record near-linear relationships would exist. This of course assumes that the climatic conditions would be relatively uniform throughout the region, and that the runoff yield from the gauged watersheds

Fig 2: Annual Runoff Depth Hydrographs
(Snare System)



has not been altered or biased. It should be noted that Mr. P. Helwig, a Senior Hydro Engineer with the NWTPC, indicated that a new turbine was installed at the Snare Rapids Dam in 1985 and that the change in the efficiency of the turbine was not considered in the calculation of the daily outflows from this new turbine.

The major regulating structure along the Snare River is Big Spruce Lake. At this station 44 years of deregulated inflow data to Big Spruce Lake were provided by the NWTPC and Environment Canada (Appendix A, Table A-1). An examination of the double mass curve for this data has been undertaken with a comparison to mass curves from the Lockhart, Camsell, and Yellowknife River flow records.

Big Spruce vs Lockhart River: Double mass curve on mean monthly flow basis for Big Spruce Lake vs Lockhart River for the period of 1968-1996.

Double mass curve of the mean monthly flows for Big Spruce vs Lockhart River for the period of 1968-1996 is shown in **Figure 3**. This curve shows a consistency in the slope for the period 1968-1976, which indicates a consistency in the Big Spruce data for this period. Figure 3 also shows a change in the slope moving downward from 1976 to 1984 and upward from 1984 to 1985. This change in the slope could be due to a variety of factors such as operational change, turbine efficiencies, flow measurement techniques, or a change between dry and wet periods for the above mentioned periods. Table 3 shows annual mean flows for the periods for Big Spruce Lake and Lockhart River and the percentage change in the annual mean flows between each two periods.

TABLE 3
Percentage Change in Annual Mean flows
Big Spruce vs Lockhart River

Period	Big Spruce Lake		Lockhart River	
	Annual Mean Flow (m^3/s)	Percentage Change* (%)	Annual Mean Flow (m^3/s)	Percentage Change* (%)
1968-1976	52		119	
1976-1985	33	-38	106	-11
1985-1993	54	+3	143	+17
1993-1996	53	+2	101	-15

* Percentage change of a period is relative to the period 1968-1976

As shown in Table 3 and Figure 3, the decrease in the percentage annual mean flow for Big Spruce between periods 1968-1976 and 1976-1985 is much larger (-38%) than Lockhart River (-11%) which causes the curve to slope downward. Similarly, the rate of change in the percentage annual mean between the period 1985-1993 is grater at Lockhart (+17%) than at Big Spruce(+3%), and therefore the

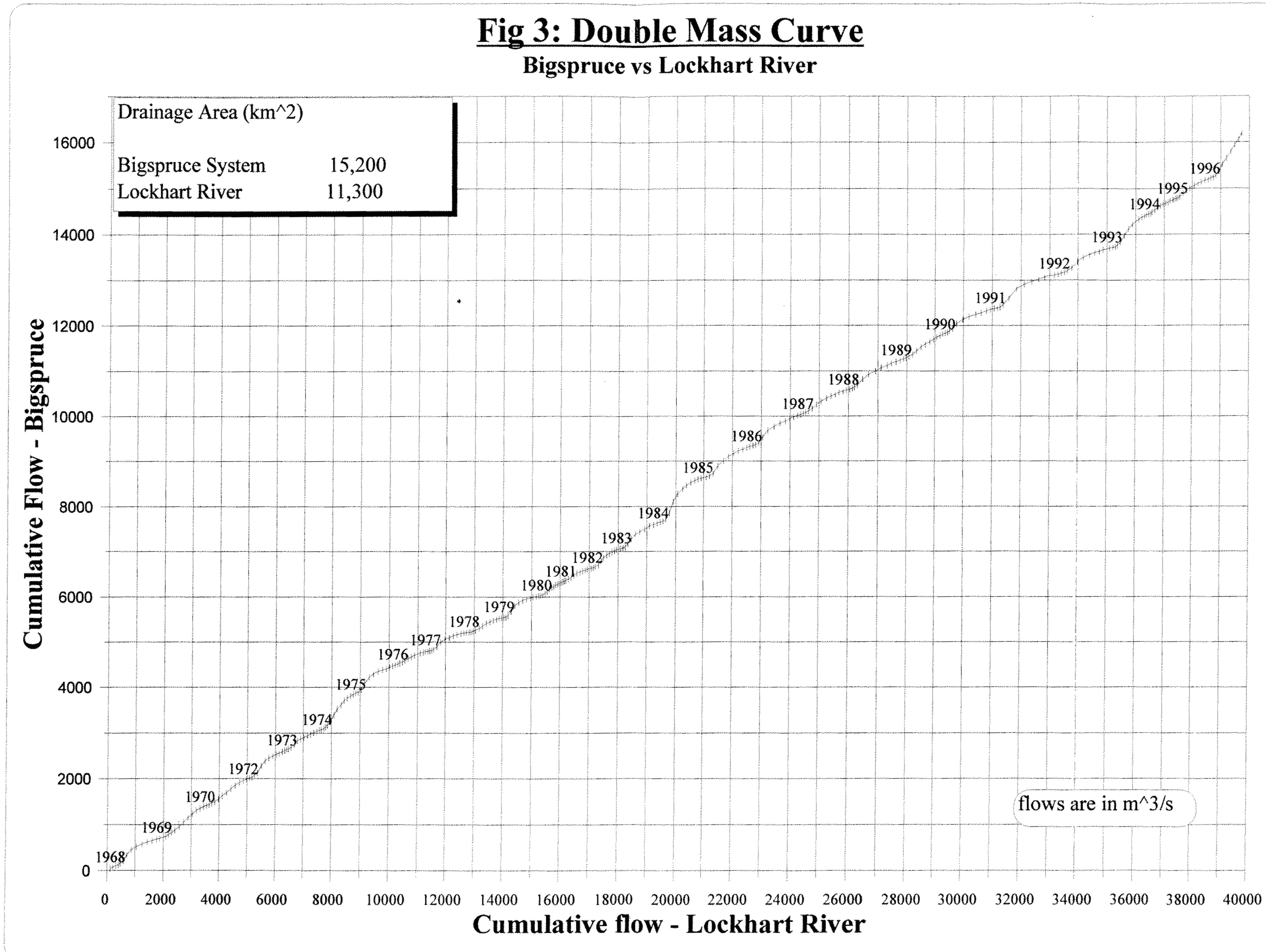


Fig 3: Double Mass Curve
Bigspruce vs Lockhart River
Drainage Area (km^2)
Bigspruce System 15,200
Lockhart River 11,300
Cumulative Flow - Bigspruce
Cumulative flow - Lockhart River
flows are in m^3/s
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
20000
22000
24000
26000
28000
30000
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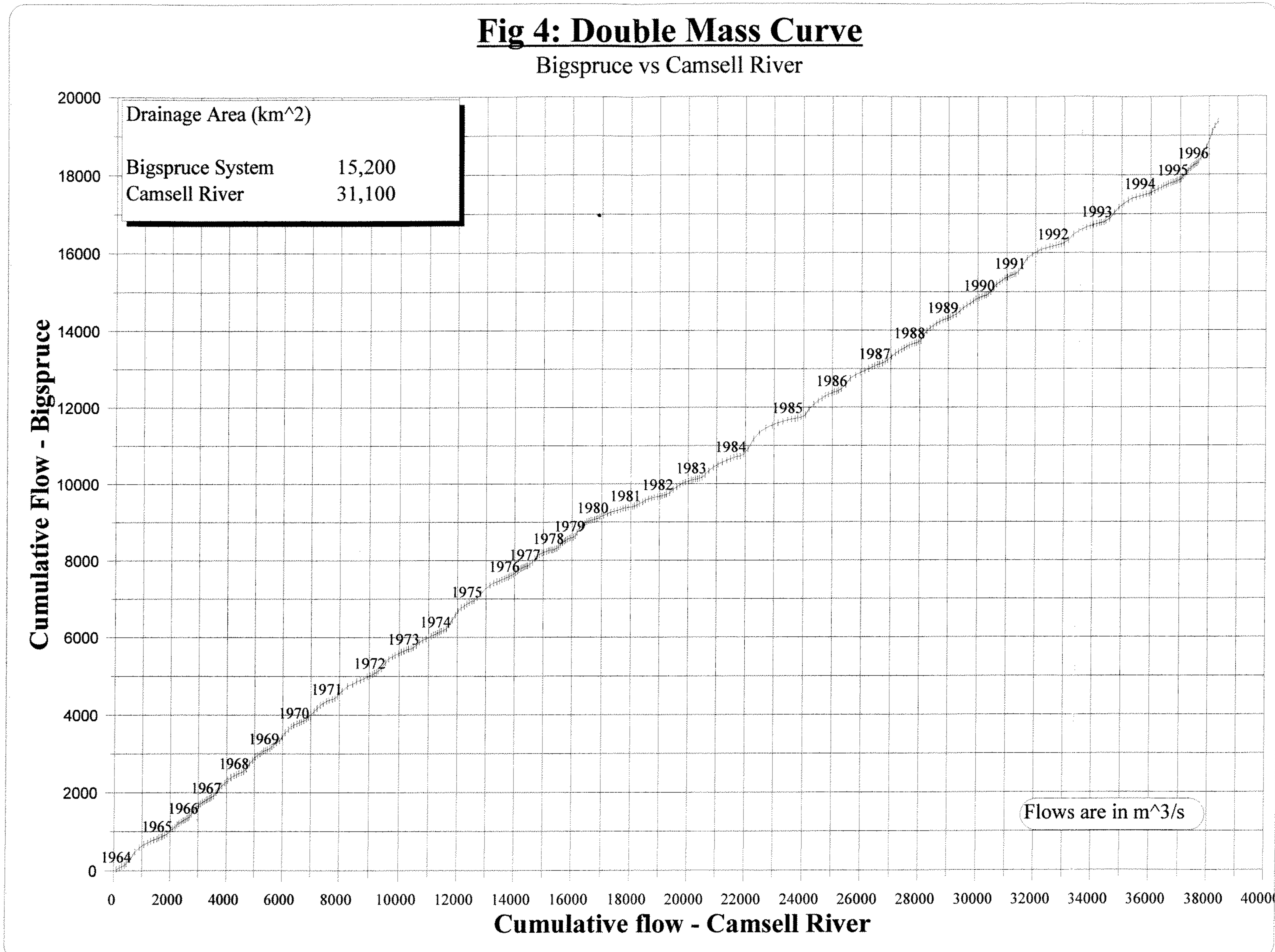
Fig 4: Double Mass Curve
Bigspruce vs Camsell River
Drainage Area (km^2)
Bigspruce System 15,200
Camsell River 31,100
Cumulative Flow - Bigspruce
Cumulative flow - Camsell River
Flows are in m^3/s
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
20000
22000
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slope of the curve moves downward for that period. The slope of the graph then increases for the period from 1993-1996 because there is an increase in the percentage annual mean flows at Big Spruce (+2%) and a large decrease at Lockhart River (-15%).

Big Spruce vs Camsell River: Double mass curve on mean monthly flow bases for Big Spruce Lake vs Camsell River for the period of 1964-1996.

As shown in **Figure 4**, the curve shows a consistency in the slope for the period 1964-1979, which indicates a consistency in the Big Spruce data for this period. Figure 4 also shows a change in the slope, moving downward from 1979 to 1983, and keeping constant from 1983-1995 . As mentioned earlier this change in the slope could be due to a variety of factors such as operational change, turbine efficiencies, flow measurement techniques, or a change between dry and wet periods for the above-mentioned periods. Table 4 below shows the annual mean flows for the periods for Big Spruce Lake and Camsell River and the percentage change in the annual mean flows between each two periods.

TABLE 4
Percentage Change in Annual Mean Flows
Big Spruce vs Camsell River

Period	Big Spruce Lake		Camsell River	
	Annual Mean Flow (m^3/s)	Percentage Change* (%)	Annual Mean Flow (m^3/s)	Percentage Change* (%)
1964-1979	48		88	
1979-1984	88	-33	87	-1
1984-1995	54	+11	116	+24
1995-1996	65	+26	68	-23

* Percentage change of a period is relative to the period 1964-1979

As shown in Table 4 and Figure 4, the percentage decrease in the annual mean flow for Big Spruce between periods 1964-1979 and 1979-1983 is much larger (-33%) than Camsell River (-1%), which leads to a decrease in the slope of the curve in Figure 4. The increase in the percentage of annual mean flow between 1984-1995 is larger at Camsell River (+24%) than Big Spruce (+11%) and the curve is slightly sloping downward compared to the slope for the period 1964-1979. Again, the slope of the graph increases for the period from 1995-1996 because there is an increase in the percentage annual mean flows at Big Spruce (+26%) and a large decrease at Lockhart River (-23%).

Big Spruce vs Yellowknife River: Double mass curve on mean monthly flow basis for Big Spruce Lake vs Yellowknife River for the period of 1950-1996.

As shown in **Figure 5**, the curve shows a consistency in the slope for the period 1950-1968 and a change in the slope, moving downward from 1968-1976 and 1985-1993 and moving upward from 1976-1985 and 1993-1996. This change in the slope could be due to a variety of factors such as operational change, turbine efficiencies, flow measurement techniques, or a change between dry and wet periods for the above-mentioned periods. Table 5 shows the annual mean flows for the periods for Big Spruce Lake and Yellowknife River and the percentage change in the mean monthly flows between each of the two periods.

TABLE 5
Percentage Change in Mean Monthly Flow
Big Spruce vs Yellowknife River

Period	Big Spruce Lake		Yellowknife River	
	Mean Monthly Flow (m^3/s)	Percentage Change* (%)	Mean Monthly Flow (m^3/s)	Percentage* Change (%)
1950-1968	47		29	
1968-1976	53	+11	40	+28
1976-1985	38	-19	20	-31
1985-1993	56	+16	43	+33
1993-1996	41	-13	21	-28

* Percentage change of a period is relative to the period 1950-1968

As shown in Table 5, the percentage increase in the annual mean flow for Big Spruce between periods 1950-1968 and 1968-1976 is much smaller (+11%) than for Yellowknife River (+28%), and therefore the slope of the graph moves downward. In contrast, the rate of decrease for the period 1976-1985 is much greater at Yellowknife River (-31%) than at Big Spruce (-19%), and the slope of the graph moves upward for that period. Period 1985-1993 showed a greater increase in the annual mean flows at Yellowknife (+33%) than Big Spruce (+16%), and the slope of the graph moves upward for that period. Similarly, for the period 1993-1996 the slope of the graph moves further upward and Yellowknife experiences a larger decrease in the annual mean flows then Big Spruce.

From the analysis above, it is apparent that there is a variability in the annual mean flows between Big Spruce and the other three stations. Many factors such as operational changes, turbine efficiencies, flow measurement techniques, and climatic influences between dry and wet periods may contribute to these changes and fluctuations. It should be noted that watersheds with large lakes could be more sensitive to climatic changes compared to watersheds with smaller lakes. However, in general, all three graphs exhibit two similar characters. The first is the consistency in the slope of all three graphs for different

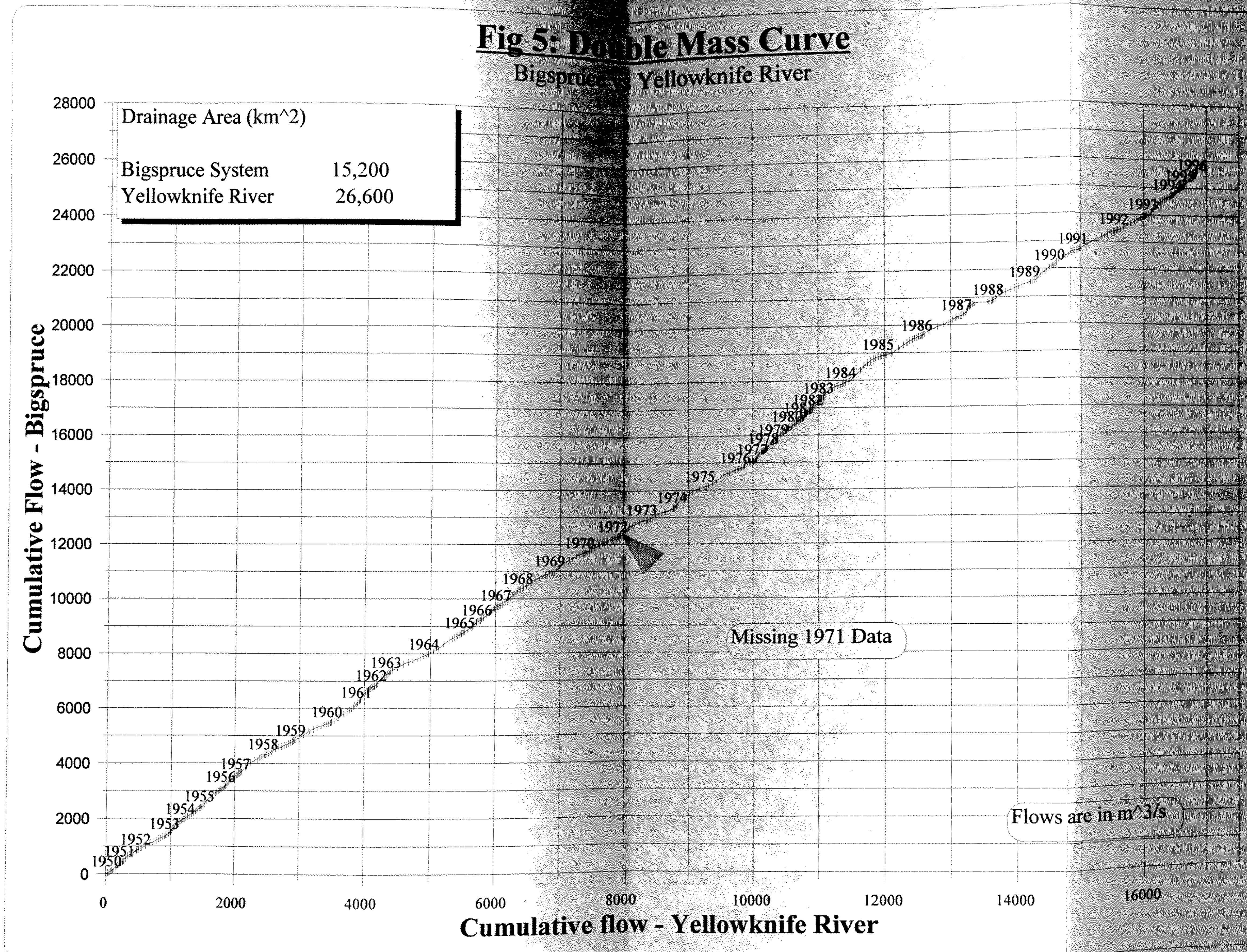


Fig 5: Double Mass Curve
Bigspruce vs Yellowknife River
Drainage Area (km^2)
Bigspruce System 15,200
Yellowknife River 26,600
Missing 1971 Data
Flows are in m^3/s
Cumulative Flow - Bigspruce
Cumulative flow - Yellowknife River

periods, which may indicate a consistency in the Big Spruce data for these periods. Secondly, an approximate 15% decrease in the slope of all three graphs for the period 1985-1996 which could be resulted from a change in the efficiency of the new turbine and consequently the calculated outflow from this turbine. Therefore, additional statistical and sensitivity analysis is to be undertaken to further evaluate the consistency of the 47 years Big Spruce flow data.

3.1.3 Ratios and Trends

An appropriate method used to validate the consistency of the Big Spruce data set is to examine the peak flow statistics of the station in view of its own trends (daily, monthly and annually) and the trends of the nearby regional flow monitoring stations. Specifically, this approach is to firstly identify if trends do in fact exist, and secondly, to develop relationships between these data sets. This technique also lends itself to ultimately allow for a technique to both in-fill missing periods of record, and extend the existing periods of record.

This approach was initially undertaken by simply determining peak daily and monthly flow ratios for the Big Spruce Lake station and the nearby regional monitoring stations that presumably experience reasonably similar historic climatic conditions. It was already noted in the unit runoff hydrograph discussions that the Snare Ghost station exhibited similar runoff trends and therefore this station was the focus of this comparison technique.

As requested by P. Helwig of NWTPC, the following four ratios have been considered for the analysis of trends and ratios between Snare Ghost and Big Spruce systems. The validity of these trends has been further strengthened by an evaluation of best fit equations and resulting correlation coefficients exhibited between the data sets. Table 6 below and the following **Figures (6-1 to 6-4)** summarize and outline the results of this examination.

TABLE 6
Regional Trend Analysis
(Snare System)

Symbol	Parameter	Period	Mean Ratio	R^2
R1	$\frac{\textit{Peak Day (Big Spruce)}}{\textit{Max. 30 Day (Big Spruce)}}$	1950-1977	1.116	0.922
R2	$\frac{\textit{Max. 30 Day (Snare Ghost)}}{\textit{Max. Mean Month (Big Spruce}}$	1985-1996	0.864	0.932
R3*	$\frac{\textit{Peak Day (Snare Ghost)}}{\textit{Peak Day (Big Spruce)}}$	1985-1996	1.118	0.923
R4	$\frac{\textit{Peak Day (Snare Ghost)}}{\textit{Max. Mean Month (Big Spruce}}$	1985-1996	1.296	0.903

* Synthesized data are used to calculate this ratio.

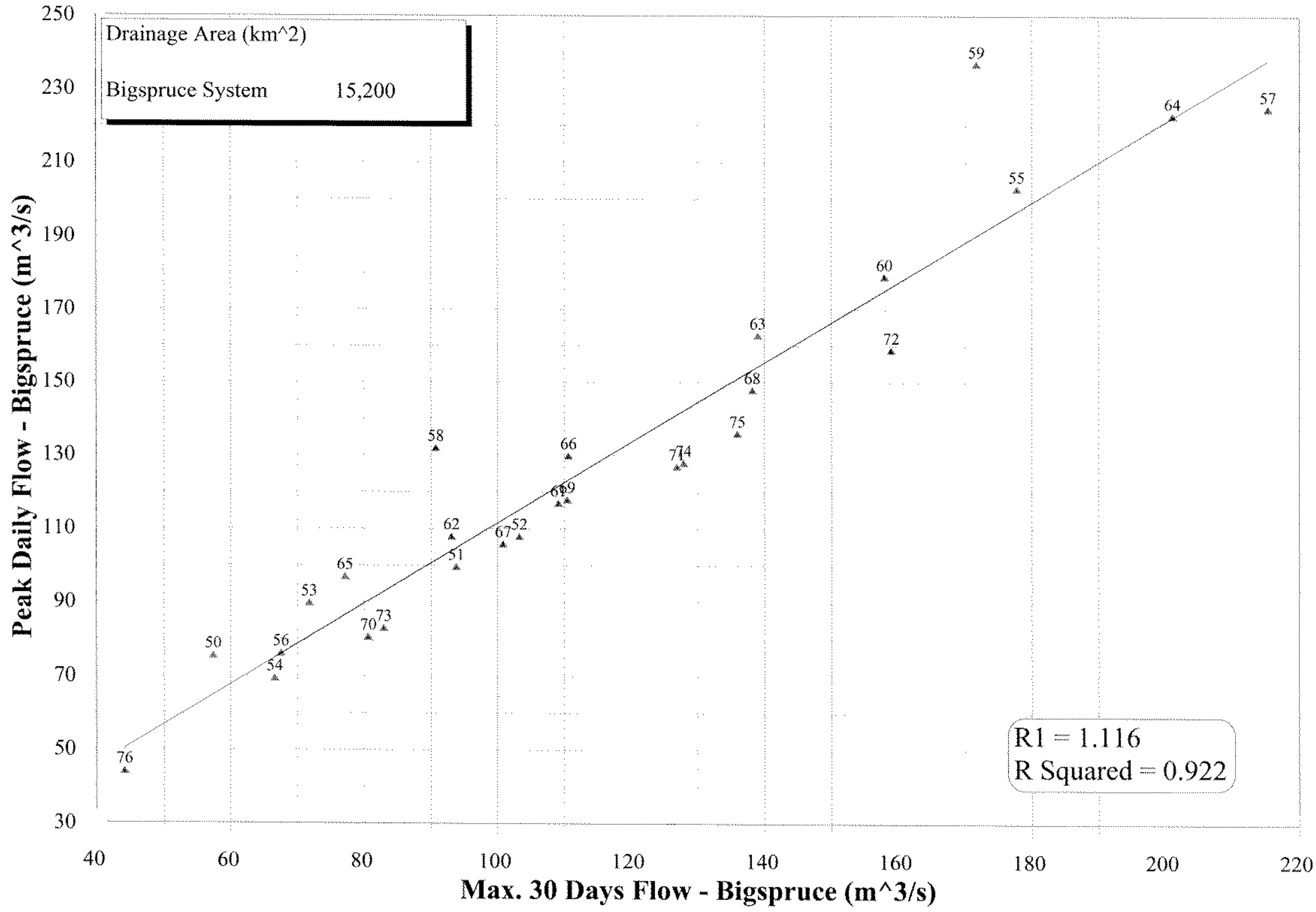
As shown in Table 6 and **Figure 6-1**, the R1 parameter shows a strong trend between peak daily and maximum 30 day moving window for Big Spruce Lake. Note that the maximum 30 day "moving window" showed a stronger trend compared to the mean calendar monthly statistics, and therefore it was deemed to be a more appropriate technique to examine peak daily flow rate relationships for the Big Spruce station. Noticeably, two outliers are apparent. Both the 1958 and 1959 peak events demonstrate relatively higher than normal daily peak discharges (132 m^3/s for 5 days in 1958 and 237 m^3/s for 7 days in 1959). With the exception of these two data points the relationship shown in the Figure represents an appropriate technique to estimate peak daily flows at Big Spruce in absence of detailed streamflow records. The established ratio of R1 is then used with the mean monthly flows of Big Spruce to synthesize new population of peak daily flows for the periods 1977-1996 as shown in Table 7.

TABLE 7
Synthesized Peak Daily Flows
(Snare System)

Year	Max. Monthly Flow (m^3/s)	Peak Daily Flow (m^3/s)	Year	Max. Monthly Flow (m^3/s)	Peak Daily Flow (m^3/s)
1977	97.50	108.80	1987	89.40	99.76
1978	57.50	64.16	1988	134.50	150.08
1979	137.30	153.21	1989	52.70	92.28
1980	49.50	55.24	1990	111.30	124.20
1981	47.90	53.45	1991	209.40	233.66
1982	84.40	94.18	1992	137.80	153.77
1983	112.60	125.65	1993	159.80	178.32
1984	257.50	287.34	1994	53.10	59.25
1985	168.40	187.91	1995	63.70	71.08
1986	154.50	172.40	1996	155.80	173.85

Similarly, **Figure 6-2** shows the result of an analysis of the maximum 30 days at the Snare Ghost facility vs maximum mean monthly flows at Big Spruce. As shown in the Figure, a high correlation was achieved ($R^2 = 0.93$). Unfortunately, a mixed population of monthly calendar and moving 30 day window data sets was required for this examination. This was attributed to detailed daily digital records not being available for the Big Spruce Station for the period 1985 - 1997, and consequently the analysis was limited to monthly calendar statistics at Big Spruce. However, to illustrate the benefits of enlisting the 30 day moving window by strictly applying monthly calendar flow estimates, the trend was examined and was found to be weaker as illustrated by a correlation coefficient of only 0.86.

Fig 6-1: R1-Peak Daily Flow vs. Max.
30 Days Flow at Big Spruce (50-76)



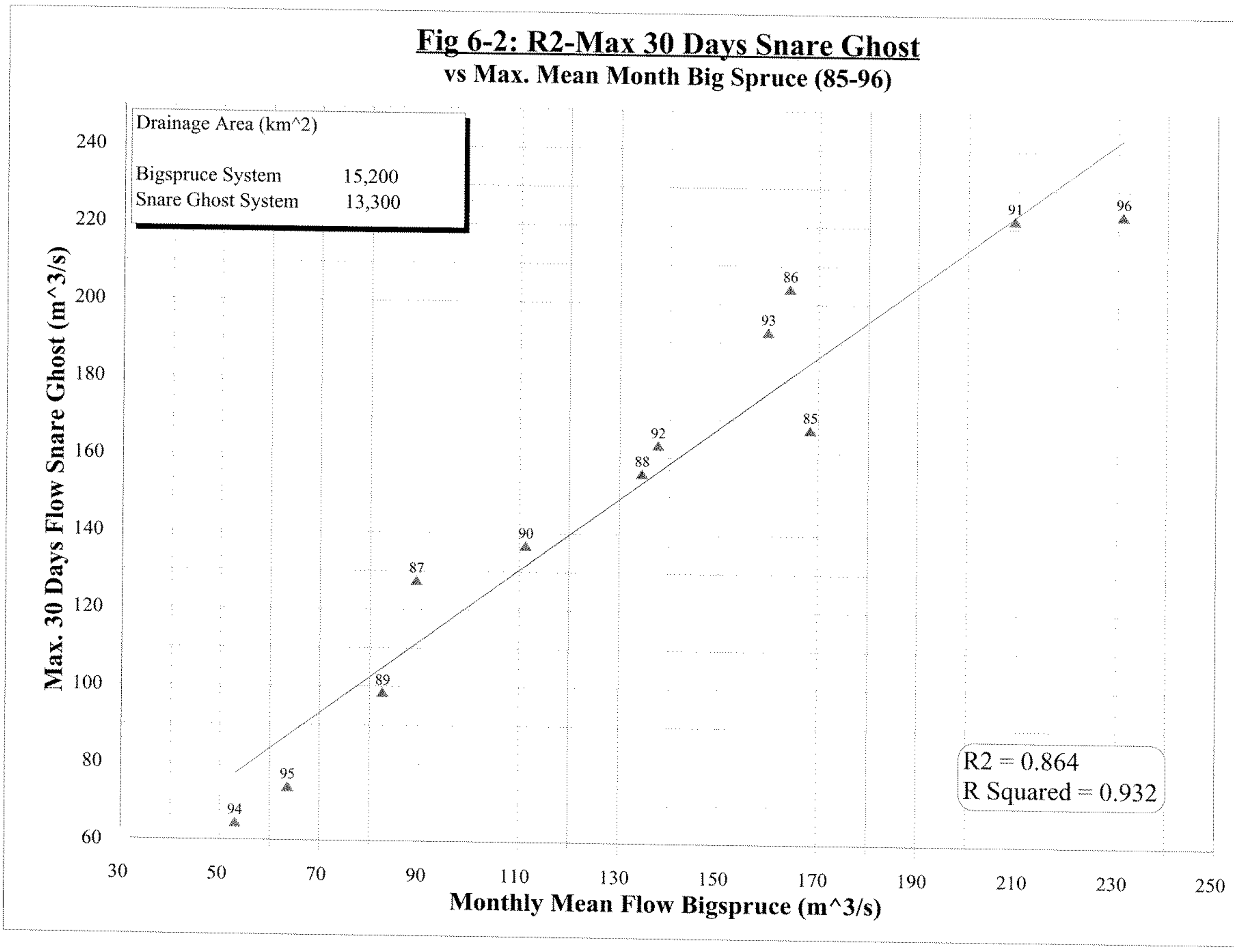


Fig 6-2: R2-Max 30 Days Snare Ghost
vs Max. Mean Month Big Spruce (85-96)
Drainage Area (km^2)
Bigspruce System 15,200
Snare Ghost System 13,300
R2 = 0.864
R Squared = 0.932
Max. 30 Days Flow Snare Ghost (m^3/s)
Monthly Mean Flow Bigspruce (m^3/s)
60
80
100
120
140
160
180
200
220
240
30
50
70
90
110
130
150
170
190
210
230
250
85
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Fig 6-3: R3-Peak Daily Flow

Snare Ghost vs Big Spruce (85-96)

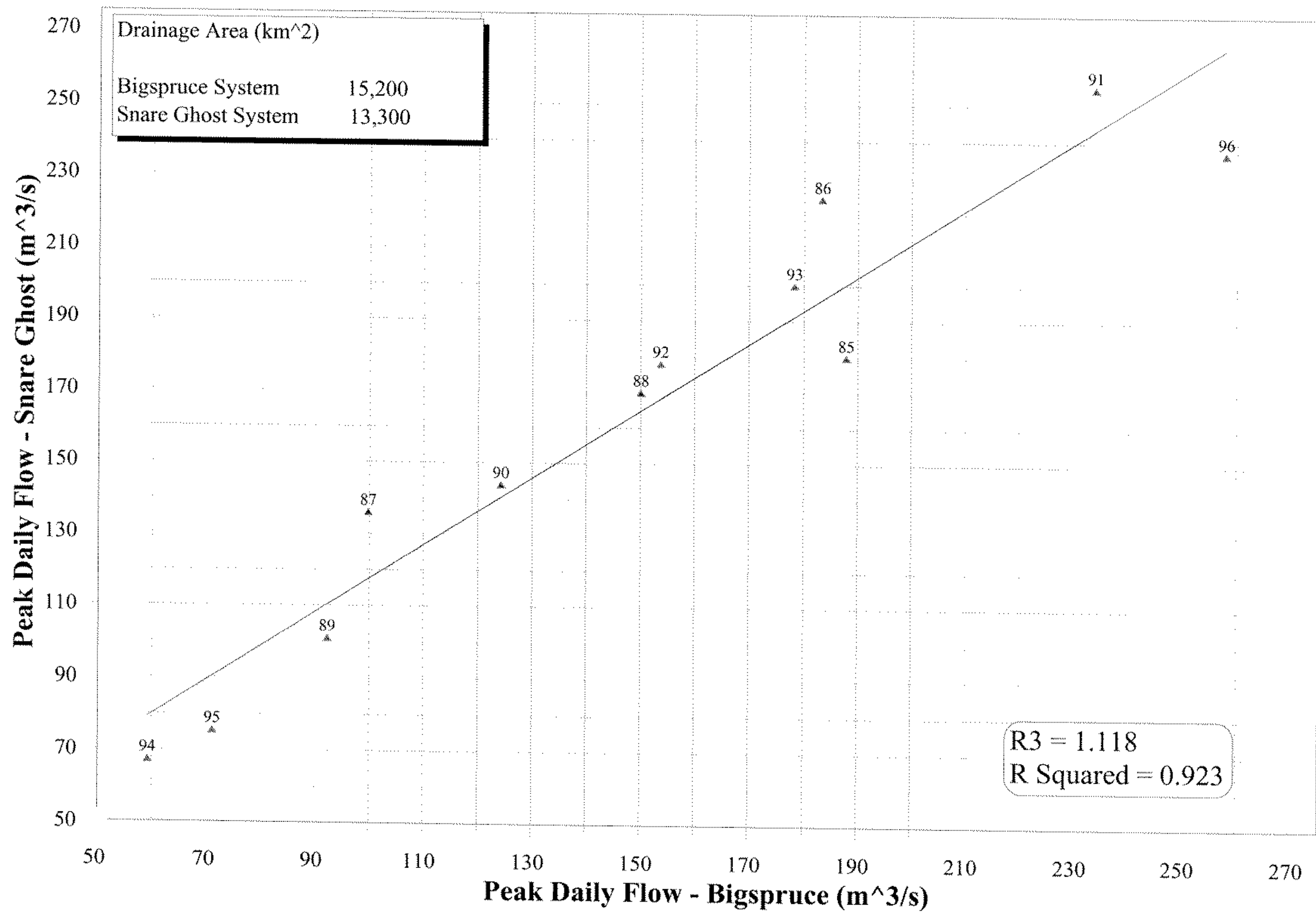
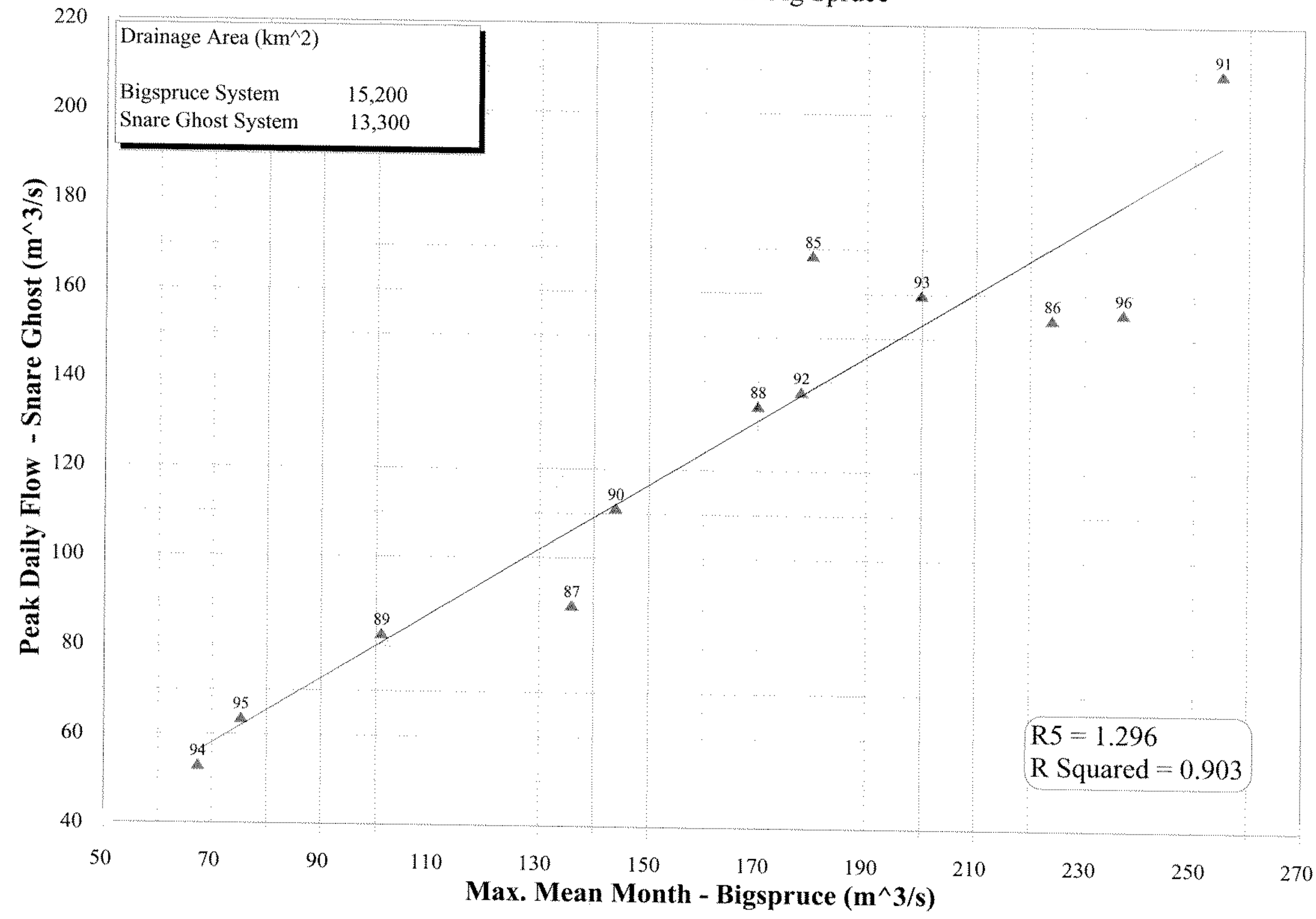


Fig 6-4: R4-Peak Daily Flows Snare

Ghost vs Max. Mean Month Big Spruce



Peak daily flows for the same period for Big Spruce and Snare Ghost were then examined as shown in Table 6 and **Figure 6-3** with a ratio (R3) of 1.118 and a correlation ($R^2 = 0.923$). Again this graph shows a good trend and a good correlation between the two stations based on daily peak flows. R3 was not used in any further manipulation.

The fourth ratio, R4, compares the peak daily flows at Snare Ghost vs maximum mean monthly flows at Big Spruce as shown in Table 6 and **Figure 6-4**. With a ratio of R4 of 1.296 and three outliers for the years 1985, 1991, and 1996, the graph shows a weak correlation between the two stations. R4 was not used in any further manipulations.

3.1.4 Summary of Results

The result of the mass curve analysis provided a closer look at the 47 years of available inflow data to the Big Spruce Lake (Snare System). Each mass curve showed a consistency in the slope of the graph for a specific period of time, demonstrating a consistency in the data used (Big Spruce inflow data) for that same period. Meanwhile, all three mass curves showed an average decrease of 15% in the slope of their graphs for the period 1985-1996, and this could be due to the fact that a change in the efficiency of the new turbine (installed in 1985) was not considered in the calculation of the daily outflows from the turbine. Furthermore, by comparing the annual mean flows for different periods it was determined that the stations examined possessed relatively different percentage changes in their annual mean flows (Table 3, 4 and 5) compared to Big Spruce. This difference in the annual mean flows between Big Spruce and the other three stations could be due to a variety of factors such as operational change, turbine efficiencies, flow measurement techniques, or a change between dry and wet periods. It is also apparent that a dry period was experienced for the period 1978-1985 and that all three mass curves, in general, possess similar shape for that same period.

A further analysis of the 47 years of data from Big Spruce, using ratios and trends between Big Spruce and Snare Ghost, has shown a good correlation between peak daily flows and maximum 30 days flow (R1). Similarly, a good correlation was found between the two stations based on daily and monthly flows (R2 and R3). The use of 30 days (moving windows) method provided a step further in the analysis for better fit and better value of R1 and R2. The ratio R1 was further used to synthesize peak daily inflows to the Big Spruce Lake for the period 1977-1985. Both ratios, R2 and R4, can be further improved with the use of daily flow data and the use of maximum 30 days "moving windows" for Big Spruce. The ratio R4 hsowed a weak correlation between the two stations and was not used further in any calculations.

3.2 Taltson System

3.2.1 Annual Runoff

Annual runoff depth hydrographs for the Nonacho, Twin Gorges, Taltson at outlet of Tsu Lake (referred to as Tsu Lake hereafter), Thoa near Hill Island (Thoa hereafter), and Marten above Thoa River (Marten hereafter) have been calculated based on mean monthly flows for the available data shown in Table 2. **Figure 7** shows the unit hydrograph for the four stations: Marten with the smallest drainage area (738 km^2) has the highest peak runoff, and Tsu Lake with the largest drainage area (58,700 km^2) has the lowest peak runoff. The graph also shows similar hydrographs for the Twin Gorges and Tsu Lake, both having similar rising and falling limps and both peaking around the month of July. From the graph it was noticed that the Nonacho hydrograph is also similar to the Twin Gorges and Tsu Lake hydrographs with a relatively higher peak in the month of July and a steeper rising and falling limps (smaller drainage area of 21,032 km^2). As a result, a good correlation between Twin Gorges and Tsu Lake is conceivable, and further analysis should be attempted to determine if a good correlation does exist between these two stations.

3.2.2 Ratios and Trends

3.2.2.1 Nonacho System

The NWTPC provided daily flow and water level data for the Nonacho system for the periods 1986-1997. Water level data for the period of 1970-1994 was also available from the Environment Canada library, but with a different water level datum then the NWTPC. Daily and monthly flows can be calculated for the period 1970-1985 by first adjusting the water level datum provided by Environment Canada for that same period to match the water level datum provided by the NWTPC, and secondly by using total outflows and water level data provided by the NWTPC. Using a common period of water level records (1985-1994) from these two sources, water level datum from Environment Canada was adjusted to match the water level datum provided by the NWTPC. These adjusted water levels were then used with the daily outflow and water level data provided by NWTPC to calculate maximum daily peak flows for the period 1970-1985 with the assumption of 2 gates open (shown in bolded fonts in Table 8). Table 8 summarizes the result of this calculation.

Fig 7: Annual Runoff Depth Hydrographs

(Taltson System)

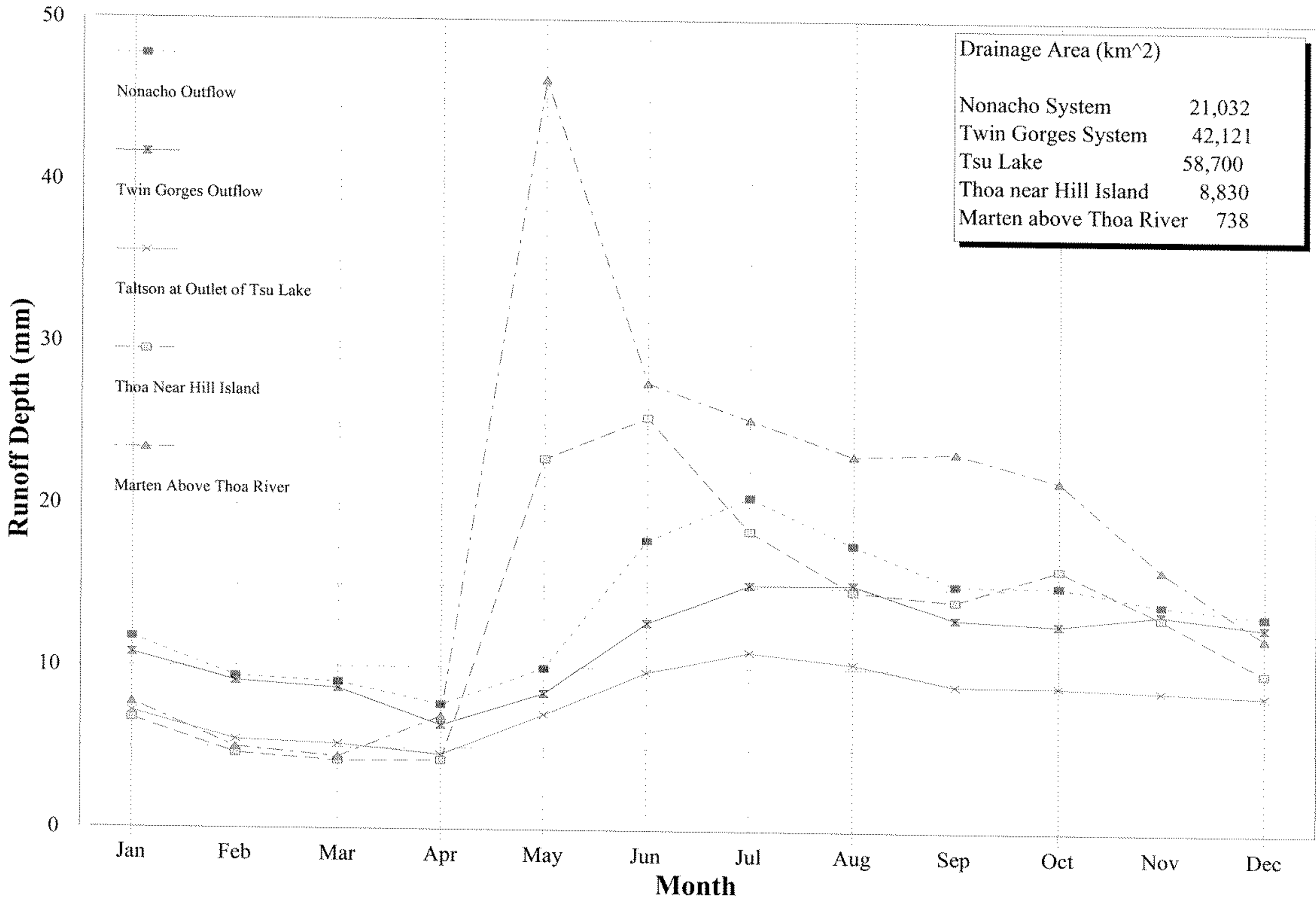


TABLE 8
Max. Daily Peak - Nonacho System
(1970-1997)

Year	Max. Daily Peak (m3/s)	Max. Water Level (m)	Recorded/Calculated Water Level (m)	No. of Gates Open
1970	117.7	6.18	320.80	2
1971	113.0	6.12	320.74	2
1972	153.7	6.37	320.99	2
1973	140.3	6.3	320.92	2
1974	176.3	6.48	321.10	2
1975	239.5	6.75	321.37	2
1976	189.2	6.54	321.16	2
1977	99.91	6.04	320.66	2
1978	101.1	6.08	320.70	2
1979	125.0	6.22	320.84	2
1980	63.2	5.80	320.42	2
1981	177.9	6.49	321.11	2
1982	274.4	6.88	321.50	2
1983	153.7	6.37	320.99	2
1984	149.1	6.35	320.97	2
1985	234.4	6.73	321.35	2
1986	101.7		320.89	0
1987	125.5		321.02	0
1988	315.3		321.59	3
1989	229.2		321.26	3
1990	115.6		320.96	0
1991	293.9		321.57	2
1992	250.0		321.41	2
1993	142.4		321.02	1
1994	171.5		321.17	1
1995	168.8		321.13	1
1996	205.9		321.16	3
1997	128.7		320.93	1

Data provided by NWTPC
Data provided by Environment Canada
Data calculated from tables

3.2.2.2 Twin Gorges System

The only available data provided by the NWTPC with daily outflows and water level at the Twin Gorges dam data was for the period of 1986-1997 (shaded area in Table 9). In order to apply the frequency analysis to this system, data had to be extended further. As a result, a search for correlation between the Twin Gorges system and other stations in the same region was examined. The Nonacho system and three other stations: Thoa, Tsu Lake, and Marten were selected for this analysis (Table 9). The need for a common period of records between Twin Gorges and the other four stations has added a greater limitation to the analysis by reducing the available data for comparison. With this limitation, different stations showed different correlations to the Twin Gorges System. Table 10 shows the ratios, range, and the mean of each ratio between the Twin Gorge system and each of the four stations. The ratio between Twin Gorges and Tsu Lake (D/B in Table 10) showed the lowest range, 0.298 with a mean value of 0.811. It was also shown earlier (in Section 3.2.1) that both Tsu Lake and Twin Gorges produce similar annual runoff depth hydrographs (Figure 7). As a result, the ratio D/B (shown in bolded fonts in Table 10) was used to extract further peak daily flows data for theTwin Gorges system by dividing the ratio 0.811 by peak daily flows of Tsu Lake for the period 1964-1985. Table 11 summarizes and outlines the result of this calculation.

Table 9: Measured Peak Daily Flows - Twin Gorges system

	Area (km^2)				
	A	B	C	D	E
	21,032.00	42121	8,830.00	58,700.00	738.00
Year	Nonacho	Twin Gorges	Thoa near *Hill Island inlet*	Taltson Outlet of Tsu Lake	Marten above Thoa River
64				413.00	
65				362.00	
66				326.00	
67				340.00	
68				238.00	
69				264.00	
70			47.00	156.00	
71			56.90	154.00	
72			117.00	204.00	
73			96.00	218.00	
74			96.60	311.00	
75			145.00	479.00	
76			142.00	368.00	
77			73.10	198.00	9.43
78			52.40	187.00	7.28
79			100.00	165.00	12.30
80			90.70	151.00	11.90
81			108.00	228.00	13.00
82			264.00	409.00	31.60
83			77.60	271.00	11.90
84			133.00	340.00	23.30
85			240.00	431.00	42.90
86	101.70	183.00	85.10	221.00	17.90
87	125.50	300.00		257.00	4.58
88	315.30	440.00	151.00	543.00	20.10
89	229.20	319.00	164.00	392.00	16.80
90	115.60	187.00		215.00	28.10
91	293.90	439.00	219.00	521.00	
92	250.00	404.00	221.00	514.00	
93	142.40	213.60	102.00	230.00	
94	171.50	309.50	200.00	329.00	
95	168.80	252.50			
96	205.90	350.70			
97	128.70	324.40			

Table 10: Ratios Between Twing Gorges (B) and Each of:

Nonacho Lake (A), Tsu Lake (D), Thoa River(C), and Marten River(E)

Year	B/A	D/B	C/A	B/D	B/C
86		**0.867**	1.993	0.179	0.451
87	0.898	**0.615**		1.148	
88	1.194	**0.886**	1.141	0.384	0.611
89	0.697		1.704	0.333	0.408
90	0.695	**0.825**			
91	0.808	**0.852**	1.775		0.420
92	0.746	**0.913**	2.106		0.383
93	0.807	**0.773**	1.706		0.439
94	0.749	**0.763**	2.778		0.324
95	0.901				
96	0.747				
97	0.850				
Range	0.499	**0.298**	1.637	0.815	0.286
Mean	0.827	**0.811**	1.886	0.511	0.434

TABLE 11
Calculated Daily Peak Flows - Twin Gorges System

Year	Peak Daily Flow (m^3/s)	Year	Peak Daily Flow (m^3/s)
1964	365.20	1975	423.60
1965	320.10	1976	325.40
1966	288.30	1977	175.10
1967	300.70	1978	165.40
1968	N/A	1979	145.90
1969	233.40	1980	133.50
1970	137.90	1981	201.6
1971	136.20	1982	361.70
1972	180.40	1983	239.6
1973	192.80	1984	300.70
1974	275.00	1985	381.10

3.2.3 Summary of Results

3.2.3.1 Nonacho System

With the result of the previous analysis for Nonacho system (Table 8), daily peak flow data were extended further by 16 years, making the total period of record 28 years (1970-1997). These data were used as an input into the frequency analysis to determine the 100 and the 1000 years peak daily flows at the Nonacho Dam. Table 12 provides a summary of the results for the Nonacho System showing the synthesized data in bolded fonts.

3.2.3.2 Twin Gorges System

Annual runoff depth hydrographs have provided the first step in the analysis of the Twin Gorges system. As shown in Figure 8, both the Twin Gorges and Tsu Lake hydrographs displayed similarity in their shape. Further, a second step was undertaken to examine the correlation between the Twin Gorge and Tsu Lake daily and monthly flows. With the limitation of available data at these two sites, a common period of record of 8 years was used to evaluate the range and the mean ratio between these two stations. The ratio between Twin Gorges and Tsu Lake had a range of 0.298 and a mean ratio of 0.811. As a result of these findings, Tsu Lake was used to synthesize further peak daily flows for the Twin Gorges system.

The result shown in Table 11 further extended the period of record for the Twin Gorges system to 33 years of data, and frequency analysis was then applied to determine the 1000 year return period flow estimates at the dam. Table 12 provides a summary of the results for the Twin Gorges System showing the calculated data in bolded fonts.

TABLE 12
Summary of Available And Synthesized Data for Nonacho and Twin Gorges Systems

Year	Peak Daily (m3/s)	Peak Daily (m3/s)	Year	Peak Daily (m3/s)	Peak Daily (m3/s)
	Nonacho System	Twin Gorges System		Nonacho System	Twin Gorges System
1964	N/A	**365.2**	1981	**177.9**	**201.6**
1965	N/A	**320.1**	1982	**274.4**	**361.7**
1966	N/A	**288.3**	1983	**153.7**	**239.6**
1967	N/A	**300.7**	1984	**149.1**	**300.7**
1968	N/A	**N/A**	1985	234.4	381.1
1969	N/A	**233.4**	1986	101.7	183.0
1970	**117.7**	**137.9**	1987	125.5	300.0
1971	**113.0**	**136.2**	1988	315.3	440.0
1972	**153.7**	**180.4**	1989	229.2	319.0
1973	**140.3**	**192.8**	1990	115.6	187.0
1974	**176.25**	**275.0**	1991	293.9	439.0
1975	**239.50**	**423.6**	1992	250.0	404.0
1976	**198.2**	**325.4**	1993	142.4	213.6
1977	**99.9**	**175.1**	1994	171.5	309.5
1978	**101.1**	**165.4**	1995	168.8	252.5
1979	**125.0**	**145.9**	1996	205.9	350.7
1980	**63.2**	**133.5**	1997	128.7	324.4

4.0 FREQUENCY ANALYSIS

As noted earlier, the principal objective of this investigation is to provide estimates of return period peak daily flows and design hydrographs at the Nonacho, Snare Rapids, and Twin Gorge Dams. By compiling the observed and estimated peak flow rates into a sequence of historical long term annual events, statistical analysis of the data can be undertaken to yield the probability-based flow estimates. The analysis of the data was undertaken using Environment Canada's FDRPFFA computer program. This software estimates return period flood flow estimates using the Gumbel, Lognormal (LNML), Three Parameter Lognormal (3PLNML, and Log Pearson Type Three distribution (LPIII) using moments and maximum likelihood distributions. It was observed that, in general, the 3PLNML and the LPIII distributions tended to not yield statistically valid solutions, whereas the Gumbel and LNML distributions tended to respectively yield the lower and higher peak flow estimates. As the Lognormal distribution tends to provide conservatively higher estimates, and in view of the fact that the earlier investigations examining the statistics of these systems also applied the Lognormal technique, it has been selected as a preferred indicator of the return period flood flow estimates.

Table 13 below presents the return period estimates for the Q1000 and Q100 inflows to the Big Spruce Lake using the Lognormal distribution.

TABLE 13
Return Period Peak Flow
(Snare-Rapids)

Return Period	Peak Flow (m^3/s)
100 Year Flood	328
1000 Year Flood	458

By subsequently scanning the historical record at the Snare Rapids, the peak runoff volume for selected durations ranging from one day up to 6 months were compiled (Table 14). These historical volumes were then subjected to frequency analysis and the resulting Lognormal distribution volume estimates (shown in **Figure 8**) were converted into a cumulative mass curve and compared with historical representative high runoff events (shown in **Figure 9**). This derived Q1000 event mass curve can be considered to be a threshold or upper limit of a theoretical design event.

TABLE 14
1-6 Month Cumulative Volume for
Q1000 and Four Years of High Records (Snare Rapids)

	Total Volume (m^3)					
Year	1 Month	2 Month	3 Month	4 Month	5 Month	6 Month
1955	146188800	764640000	982627200	1124928000	1238457600	1339545600
1959	393984000	689472000	1124928000	1049760000	1156550400	1240012800
1984	667440000	1096934400	1238457600	1759190400	1956441600	2059084800
1991	542764800	921974400	1339545600	1341360000	1484179200	1612224000
Q1000*	1040000000	1920000000	2280000000	2510000000	2760000000	2860000000
Peak Daily volume for Q1000			39600000			

* 1000 year flood

As also shown in Figure 9, from the selected historical events, the mass curve for the 1984 event best represents the shape of the 1000 year threshold volume curve and was therefore selected as the basis for deriving and distributing the theoretical event. Through close examination of these two mass curves, it was determined that the ordinates of the 1984 event (mass curve and hydrograph) could be factored or pro-rated by a factor of 1.55 to provide a quality comparable alignment with the Q1000 year theoretical threshold event. Based on this, and assuming that the large floods have the same hydrograph shape as the 1984 flood (the largest recorded so far), the hydrograph for the 1000 years flood (inflow to Big Spruce lake) would be as shown in **Figure 10**.

Figure 8: Frequency Analysis of 1-6 Months Volume (Snare Rapids)

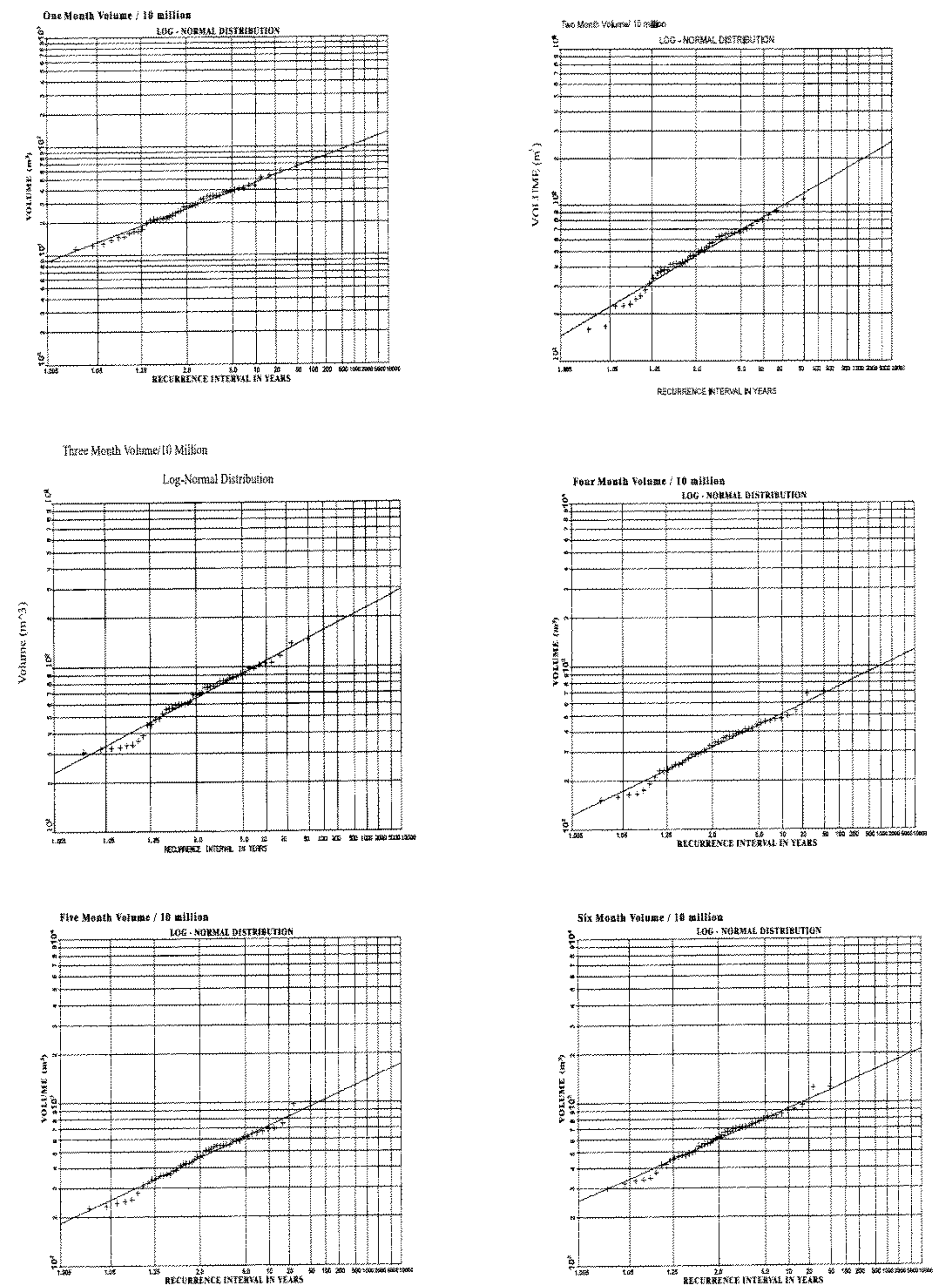


Fig 9:Mass Curves of Q1000 and Four Years of High Record

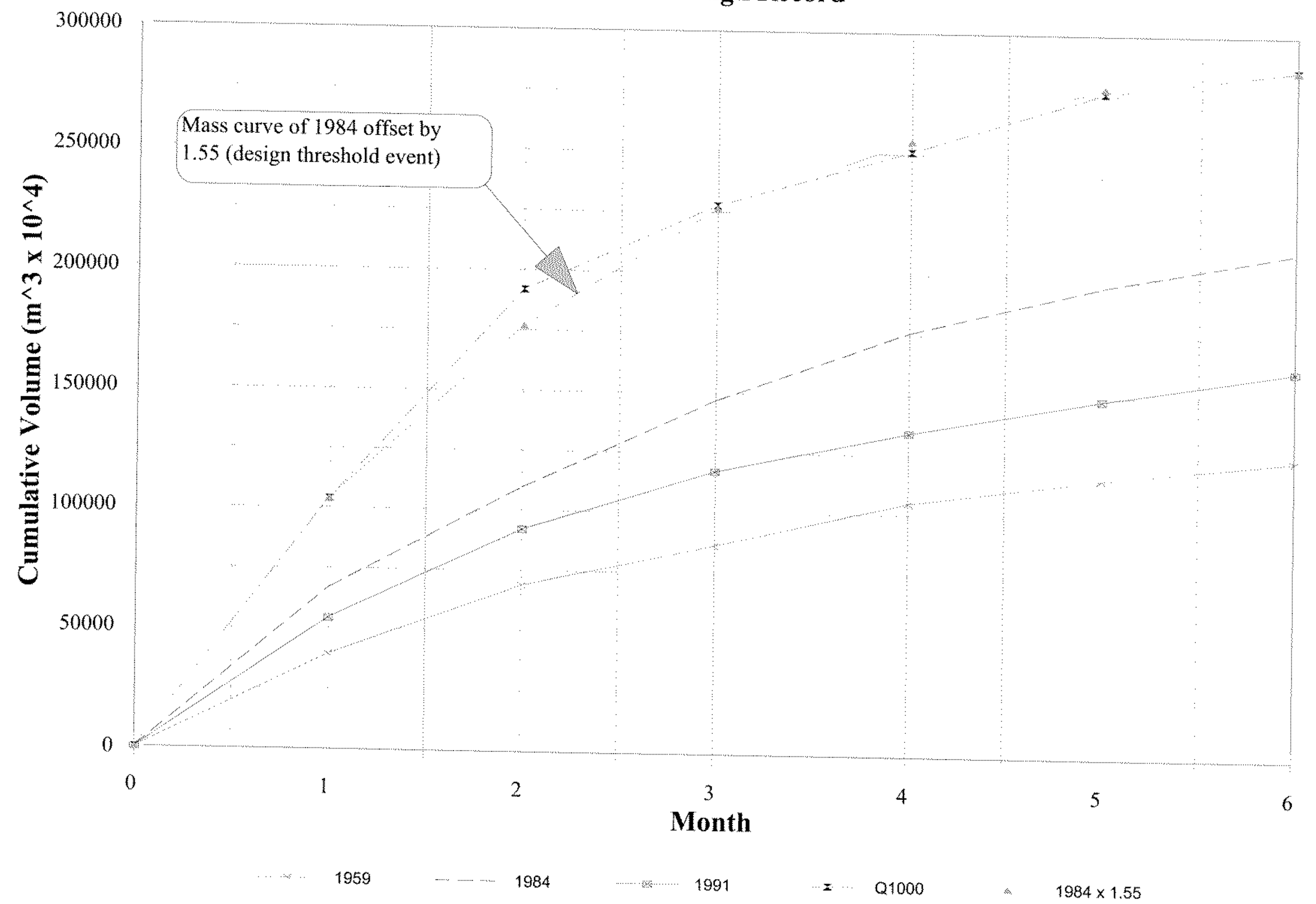
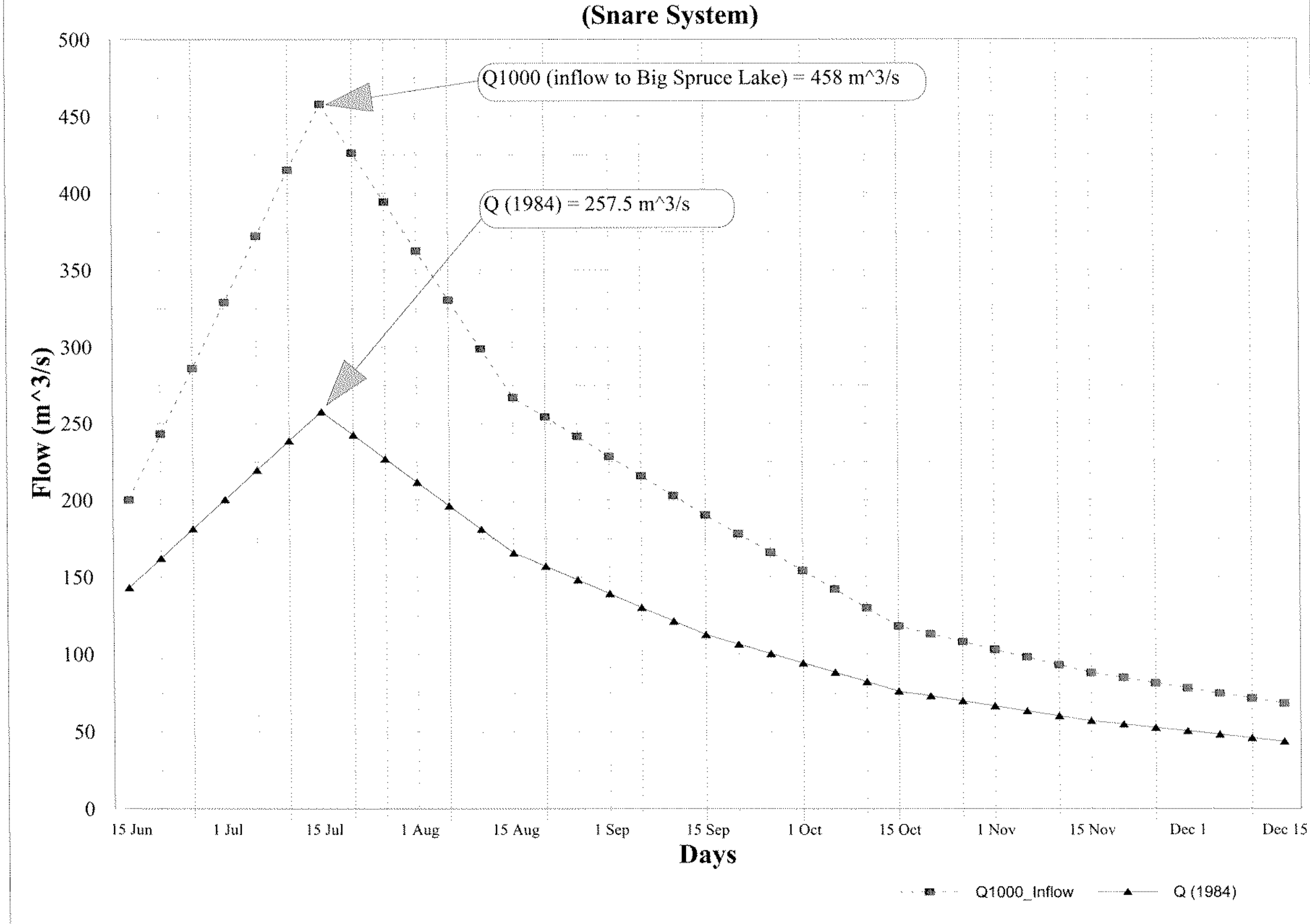
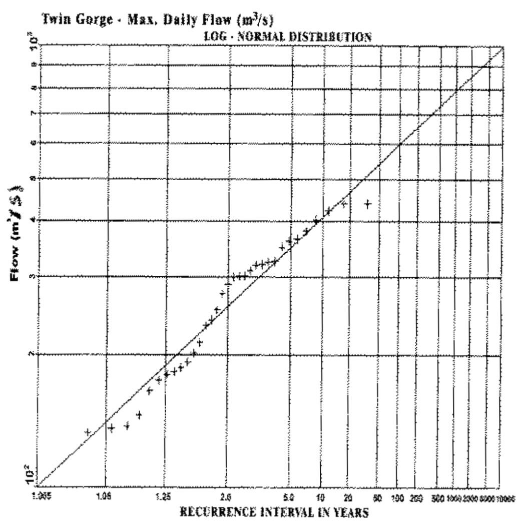


Fig 10: 1984 and Q1000 Hydrographs
(Snare System)



Two other Frequency analysis were conducted to estimate the 1000 and 100 years return period flood for each of the Twin Gorge and Nonacho systems using the Lognormal Distribution . Table 15 and **Figure 11** below presents the result of these two frequency analysis.

Figure 11
Frequency Analysis
(Taltson System)



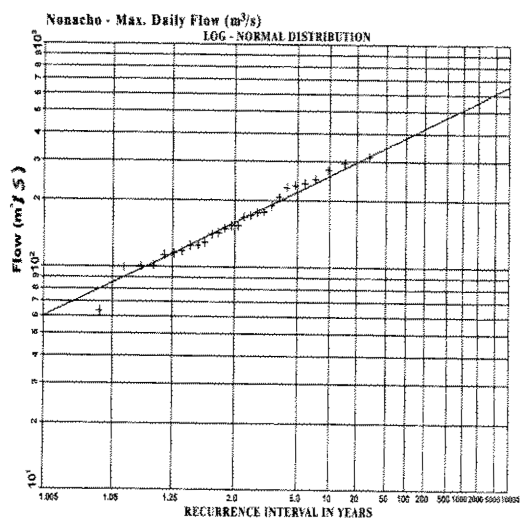


TABLE 15
Return Period Peak Flow
(Taltson System)

System	100 Years Peak Flow (m^3/s)	1000 Years Peak Flow (m^3/s)
Twin Gorge Dam	N/A	795
Nonacho Dam	384	515

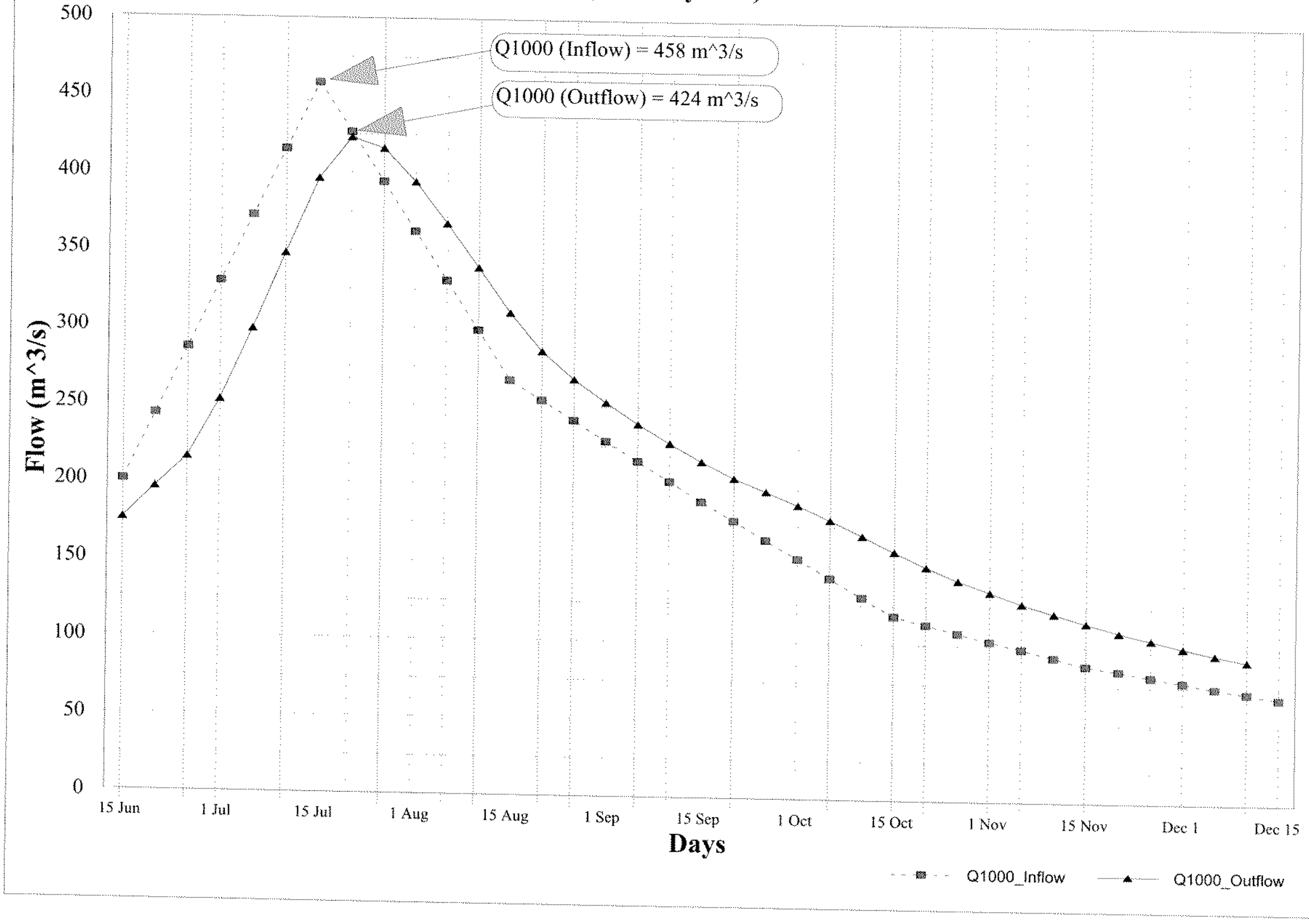
5.0 FLOOD ROUTING (SNARE SYSTEM)

Flood routing of the estimated 1000 years event through Big Spruce reservoir was carried out to determine the reduction in the peak flow of this event at the Snare Rapids. Because of the lack of certain required data, or in order to facilitate the routing analysis, some assumptions were mad. No outflow rating curves for the stoplog-controlled gates at 5B and the generator-controlled outlet were provided by the NWTPC. Therefore, and assumption of a 30 m^3/s outflow from the generator-controlled outlet was assumed. Two rating curves were calculated for the stoplog-controlled gates. The first rating curve was calculated for the two centered stoplog-controlled gates with an opining of 7.62m x 5.94m and an invert elevation of 217.32m for each with the assumption that no stoplogs are present (both gates are fully open). The second rating curve was calculated for the other six stoplog-controlled gates with an opining of 7.32m x 3.51m and an invert elevation of 219.76m for each with the assumption that no stoplogs are present (all six gates are fully open). A stage-volume table was provided by the NWTPC (appendix A-2) and was used in the process of the routing.

The result of the flood routing analysis are presented in **Figure 12.** It is worth to mention that different gate sizes and different invert elevation of each gate has a clear effect on the routing calculation and consequently on the 1000 years outflow curve. As a result, peak flow of 424 was estimated at the Snare Rapids which is a 7.4% reduction in the peak discharge.

Fig 12: Flood Routing

(Snare System)



6.0 CONCLUSION AND RECOMMENDATIONS

A flood frequency analysis study was requested by the NWTPC to estimate the 100 and 1000 year flood at the Snare Rapids and the 1000 year flood at the Twin Gorges dam. Because of the lack of requierd data in the area, new data had to be statistically introduced and synthesized. Different methods were used to introduce these new population of data and a different method was also used to test these new data.

6.1 Snare System

As a first step in the analysis, the annual runoff depth hydrograph provided a clear similarity and the possibility of a good correlation between Big Spruce and Snare Ghost mean monthly flows. A better annual runoff depth hydrograph can be produced using daily flow data, which then can explain further the similarities and differences in the shape of the two hydrographs on the daily bases. The three double mass curves between Big Spruce and each of Camsell, Yellowknife, and Lockhart Rivers provided a closer look at the consistency of the Big Spruce flow data. However, a detailed analysis of these three double mass curves was impossible at the time of this study because of the lack of information. The calculation of the percentage changes in the flow rates between different periods was performed only to explain the changes in the slope of the 3 graphs (Figures 3, 4, and 5).

Four ratios: R1, R2, R3, and R4 were selected for the examination of any correlation between Big Spruce and Snare Ghost station. R1 showed a strong correlation between daily and maximum 30 days flow for the Big Spruce. This ratio was used to synthesize a new population of daily peak flow data that was not originally available. R2 and R3 also showed a good correlation between the two stations. A weak correlation was found with R4 and the ratio was not used in any further analysis.

The pro-rated mass curve of the 1984 by a factor of 1.55 has produced a similar mass curve to the estimated 1000 years mass curve. The 1000 years inflow hydrograph was produced using this 1000 years mass curve and based on assumption that the 1000 years flood will produce a similar hydrograph to the 1984 hydrograph. The Lognormal distribution used in the frequency analysis produced a conservative estimate of the peak flood. The 1000 years inflow hydrograph with a peak of 458 m^3/s was routed through Big Spruce reservoir and a 7.4% reduction was accomplished producing a 1000 years return peak flow of 424 m^3/s at the Snare Rapids.

6.2 Taltson System

As a first step in the analysis, the annual runoff depth hydrograph provided a clear similarity and the possibility of a good correlation between Twin Gorges and Tsu Lake mean monthly flows. A better annual runoff depth hydrograph can be produced using daily flow data, which then can explain further the similarities and differences in the shape of the two hydrographs on the daily bases. The availability of water level data at Nonacho Lake and the possibility of back-converting these water levels into daily peak flows has extended the period of record and made the frequency analysis of the Nonacho system more acceptable.

The use of ratios between Twin Gorges and Tsu Lake was an effective second step in the analysis to show that a good correlation dos exist between these two stations (Twin Gorges and Tsu Lake, share approximately the same drainage area). Using this correlation enabled us to further extend available data to 34 years. The frequency analysis using the Lognormal distribution has produced a conservative estimate of the 1000 years flood for the Twin Gorges system with a peak of 795 m^3/s and for the Nonacho system with a peak of 515 m^3/s.

In conclusion, further detailed analysis needs to be done and other possibilities should be investigated to find better correlations. Indin Lake flow data should be investigated because of its proximity to Big Spruce Lake and the availability of data for this station. The use of "moving window" to produce maximum 30 days flow can be used to improve the value of R2 and R3. This can be accomplished if digital daily flow data are provided.

APPENDIX A

Table A-1 : Big Spruce Lake Mean Monthly Inflows (m^3/s)

YEAR	JAN	FEB	MAR	APRIL	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC	MEAN
1950	19.7	20.8	17.7	17.3	30.8	27.1	28.1	43.8	56.4	38.4	30.8	26.1	29.8
1951	23.0	22.3	19.5	16.5	26.1	33.0	84.6	75.7	53.2	35.4	29.2	25.7	37.0
1952	25.8	23.0	20.3	22.7	47.6	93.8	87.7	51.1	47.2	48.2	40.5	37.0	45.4
1953	31.7	27.6	23.7	21.0	25.5	34.0	67.8	63.2	60.6	51.2	64.3	52.8	43.6
1954	41.1	32.3	26.2	23.2	31.3	36.1	64.5	58.7	41.8	38.0	39.5	41.8	39.5
1955	35.1	33.1	28.5	24.4	39.0	147.0	148.0	84.1	54.9	43.8	36.7	33.4	59.0
1956	28.5	25.9	21.8	18.9	20.2	25.3	43.7	56.3	52.0	61.2	61.9	46.7	38.5
1957	35.9	30.7	26.5	22.3	28.9	46.1	171.0	161.0	76.4	50.8	40.6	36.0	60.5
1958	32.5	27.8	22.7	21.5	36.1	60.9	87.0	54.2	39.8	38.0	44.7	35.2	41.7
1959	33.3	31.9	30.3	29.9	29.1	32.2	114.0	152.0	67.5	71.5	41.2	36.7	55.8
1960	32.2	27.6	24.0	21.2	54.2	105.0	147.0	85.4	60.0	45.0	63.7	41.6	58.9
1961	42.7	57.9	54.5	53.3	274.0	83.0	109.0	80.7	45.0	31.6	27.8	24.4	53.1
1962	22.1	19.1	16.1	13.6	23.8	26.1	61.6	82.8	83.3	50.9	38.5	31.5	39.1
1963	28.2	23.8	32.2	30.0	32.8	36.3	105.0	116.0	74.9	64.4	61.3	56.5	55.1
1964	46.8	38.2	29.4	25.9	51.6	101.0	200.0	110.0	69.4	46.7	37.9	33.2	65.8
1965	28.0	24.2	21.3	19.3	24.4	33.4	67.6	76.7	43.7	45.3	40.3	36.4	38.4
1966	33.0	30.8	22.4	17.8	32.0	56.2	107.0	76.4	55.8	38.8	33.7	29.5	44.5
1967	25.0	22.6	20.0	16.5	20.4	31.0	81.1	99.7	81.4	68.8	70.0	65.6	50.2
1968	48.9	34.9	28.5	21.8	31.8	53.0	135.0	106.0	65.7	54.0	42.2	33.8	54.6
1969	29.1	23.7	21.2	19.2	46.7	40.3	54.0	65.0	95.9	110.0	85.8	66.9	54.8
1970	47.9	33.1	26.6	22.7	28.6	35.4	59.2	63.1	73.6	80.7	80.7	62.0	51.1
1971	41.6	30.3	25.5	26.2	54.4	122.0	127.0	68.5	49.6	43.9	40.5	43.3	56.1
1972	36.2	33.1	27.7	18.3	33.7	59.7	159.0	100.0	64.6	41.3	36.0	31.1	53.4
1973	28.9	30.3	16.4	10.7	36.0	58.0	83.3	47.3	34.8	38.2	34.3	30.6	37.4
1974	25.0	25.7	20.8	23.2	27.4	39.6	95.7	128.0	127.0	96.6	87.8	57.5	62.9
1975	49.6	34.0	28.6	23.6	63.7	120.0	136.0	79.6	48.7	35.1	33.1	30.0	56.8
1976	32.3	17.3	20.8	21.3	23.2	28.1	42.5	44.2	31.7	27.8	18.4	18.4	27.2
1977	14.2	10.8	7.8	6.3	27.5	58.6	97.5	63.1	47.9	31.7	24.7	20.0	34.2
1978	14.4	11.5	6.1	3.7	19.5	25.0	35.4	57.5	52.0	39.2	31.9	25.0	26.8
1979	14.7	12.0	8.3	12.3	33.3	81.0	137.3	73.9	41.1	32.5	23.2	16.7	40.5
1980	11.7	15.1	7.8	15.7	37.7	39.6	49.5	32.4	28.9	26.2	22.6	19.2	25.5
1981	17.0	13.6	12.1	9.3	16.1	26.7	37.5	47.9	39.2	28.4	26.2	21.0	24.6
1982	17.5	12.8	12.1	8.3	23.4	38.2	84.4	77.5	56.3	39.9	31.4	27.5	35.8
1983	18.9	13.2	14.3	7.7	8.1	24.9	67.8	112.6	85.7	69.5	62.9	55.7	45.1
1984	36.0	32.3	23.6	20.1	39.6	142.9	257.5	165.7	112.6	76.1	57.0	43.6	83.9
1985	31.5	25.0	13.1	10.4	29.0	54.6	168.4	116.6	94.0	66.0	51.6	39.8	58.3
1986	34.0	24.7	20.9	16.7	48.7	117.8	154.5	86.6	66.5	52.5	50.4	42.1	59.6
1987	31.1	27.6	21.7	18.9	32.4	50.6	89.4	82.1	60.4	44.0	41.0	36.3	44.6
1988	31.4	24.5	21.0	16.7	21.1	45.0	134.5	109.7	74.6	63.5	57.0	48.5	54.0
1989	36.7	32.8	25.5	19.3	34.3	42.6	82.7	81.9	64.3	56.6	54.3	46.3	48.1
1990	37.4	28.7	23.5	18.7	27.8	51.8	111.3	87.1	64.4	45.9	44.7	36.6	48.2
1991	29.2	22.8	17.5	12.4	55.1	146.3	209.4	96.7	65.1	49.4	38.2	32.1	64.5
1992	14.7	23.8	19.4	14.3	37.3	64.7	137.8	93.5	56.7	40.2	34.5	27.7	47.1
1993	22.5	21.4	16.0	11.6	37.8	50.3	159.8	142.1	95.2	66.4	49.7	40.7	59.5
1994	31.0	25.0	23.0	14.1	30.5	34.8	53.1	42.5	30.6	26.7	21.5	22.6	29.6
1995	18.4	15.7	14.2	10.9	24.1	23.5	52.5	63.7	57.4	49.0	42.8	39.7	34.3
1996	31.8	27.1	23.0	18.7	35.1	97.0	155.8	123.4	150.1	231.1	154.2	114.0	96.8
Mean	29.7	25.6	21.4	18.5	32.9	59.1	105.2	84.8	63.8	53.8	46.4	38.7	48.3
Max.	49.6	57.9	54.5	53.3	63.7	147.0	257.5	165.7	150.1	231.1	154.2	114.0	96.8
Min.	11.7	10.8	6.1	3.7	8.1	23.5	28.1	32.4	28.9	26.2	18.4	16.7	24.6

Table A-2 : Big Spruce Stage - Volume (Snare System)

Water Elevation (ft)	Water Elevation (m)	Reservoir Area (Acre)	Reservoir Area (m^2)	Cumulative Volume Above 217.9ft (m^3)
728.5	222.05	32006	129,556,223	509,504,457
728	221.89	31901	129,131,197	489,791,859
727	221.59	31691	128,281,143	450,560,985
726	221.28	31481	127,431,090	411,589,207
725	220.98	31271	126,581,037	372,876,525
724	220.68	31062	125,735,031	334,428,491
723	220.37	30852	124,884,978	296,233,385
722	220.07	30642	124,034,924	258,297,375
721	219.76	30432	123,184,871	220,620,461
720	219.46	30222	122,334,818	183,202,644
719	219.15	30012	121,484,764	146,043,922
718	218.85	29803	120,638,759	109,146,148
717	218.54	29593	119,788,706	72,505,002
716	218.24	29383	118,938,652	36,122,953
715	217.93	29173	118,088,599	0