Hydrologic Overview of the

Gwich'in and Sahtu Settlement Areas

Shawne A. Kokelj

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Water Resources Division
Indian and Northern Affairs Canada
Yellowknife, Northwest Territories
Canada

On the cover: Hare Indian River, Mackenzie River east bank tributary (Photo: S.A. Kokelj, INAC).

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Introduction

The purpose of this report is to provide a general overview of water quantity data collected in the Sahtu and Gwich'in Settlement Areas of the Mackenzie River basin, Northwest Territories (NWT). Beginning in 1933, Environment Canada's Water Survey Division has operated hydrometric stations on streams within these regions, six of which are currently operating in the Gwich'in Settlement Area (five continuous, one seasonal) and eight in the Sahtu Settlement Area (two continuous, six seasonal) (Figure 1). In this report, hydrometric data from 30 stations are presented using mean annual hydrographs, extreme-year hydrographs and basic statistics. Flood frequency analyses using the Pearson theoretical distribution were completed for stations with twenty or more years of data.

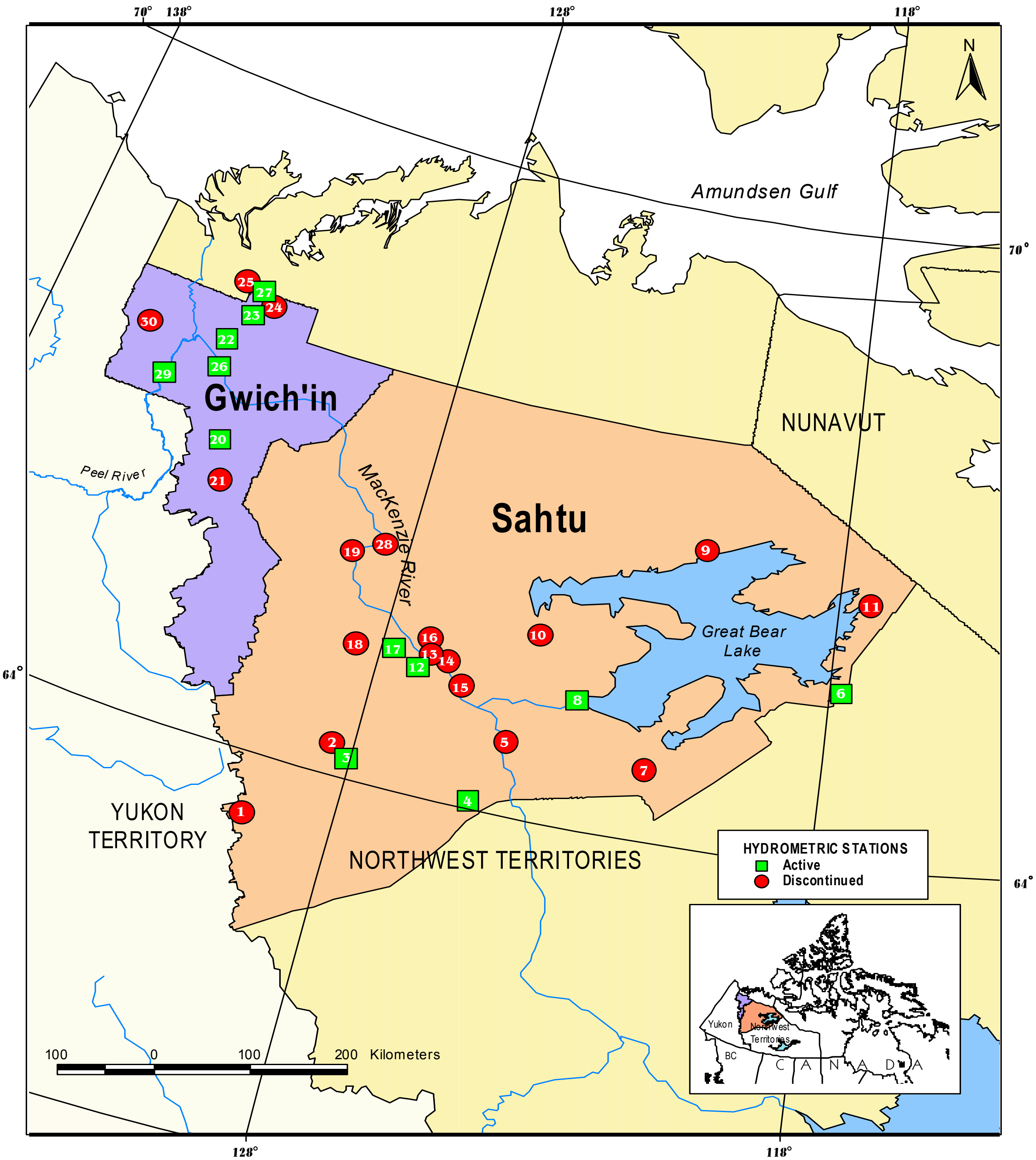
Gwich'in and Sahtu Settlement Areas

Geographic Boundaries

The majority of streams flowing through the Sahtu and Gwich'in Settlement Areas are nested within the Mackenzie River basin. Covering approximately 1.7 million km^2, the Mackenzie River system is the largest in Canada, flowing over 4000 km from tributaries in the Rocky Mountains in British Columbia to its Delta in the NWT, where it empties into the Beaufort Sea. From its outflow from Great Slave Lake, the Mackenzie River flows northward about 1750 km, passing through the Gwich'in and Sahtu Settlement Areas along the way. The river's mean annual discharge is approximately 9000 m^3/s, second in Canada only to the St. Lawrence River.

The Gwich'in Settlement Area in the Northwest Territories includes 56,935 km^2 of land, including the communities of Aklavik, Fort McPherson, Inuvik and Tsiigehtchic (Figure 1) (Gwich'in Renewable Resource Board, 2001). It extends in an irregular shape from approximately 68º13'N at its northern boundary to 64º20'N to the south (INAC, 1992). The western edge follows the Yukon border and extends as far as 136º26'W and to 129º43'W in the east (INAC, 1992).

Figure 1. Hydrometric Stations in the Gwich'in and Sahtu Settlement Areas of the NWT



Map ID #	Station Description (operating stations in bold)		
Sahtu Region Stations		**Gwich'in Region Stations**	
1	Tsichu River at Canol Road	20	**Arctic Red River near the mouth**
2	Twitya River near the mouth	21	Weldon Creek near the mouth
3	**Keele River above Twitya River**	22	**Rengleng River below Highway 8**
4	**Redstone River 63 km above the mouth**	23	**Caribou Creek above Highway 8**
5	Big Smith Creek near Highway 1	24	Cabin Creek above Highway 8
6	**Camsell River at outlet of Clut Lake**	25	Boot Creek near Inuvik
7	Johnny Hoe River above Lac Ste Therese	26	**Mackenzie River at Arctic Red River**
8	**Great Bear River at outlet of Great Bear Lake**	27	**Havikpak Creek near Inuvik**
9	Haldane River near the mouth	29	**Peel River above Fort McPherson**
10	Whitefish River near the mouth	30	Rat River near Fort McPherson
11	Sloan River near the mouth		
12	**Mackenzie River at Norman Wells**		
13	Bosworth Creek at Norman Wells		
14	Seepage Creek at Norman Wells		
15	Jungle Ridge Creek near the mouth		
16	Bosworth Creek near Norman Wells		
17	**Carcajou River below Imperial River**		
18	Mountain River below Cambrian Creek		
19	Ramparts River near Fort Good Hope		
28	Jackfish Creek near Fort Good Hope		

The Sahtu Settlement Area covers 280,238 km^2 in the NWT including Great Bear Lake (Figure 1) (Sahtu Land and Water Board, 2001). It extends from approximately 68º00'N at its northern boundary to 62º07'N at its southern boundary. The longitudinal boundaries are 131º04'W to the west and 115º55'W to the east (INAC, 1993). The communities in the region include Colville Lake, Deline, Fort Good Hope, Norman Wells and Tulita.

Hydrologic Regimes

Many factors combine to determine a hydrologic regime including geology, topography, elevation, climate, permafrost, drainage area and vegetation cover. Flowing roughly northward, the Mackenzie River divides streams of the Gwich'in and Sahtu Settlement Areas into two general areas: (1) eastern tributaries that flow from the Taiga Plains and Southern Arctic ecozones; and (2) western tributaries that originate from mountains within the Taiga Cordillera ecozone. The primary terrestrial ecozone in both regions is the Taiga Plains featuring broad lowlands and plateaus (Environment Canada, 2001b). The Southern Arctic ecozone is characterized by continuous permafrost, shrublands, meadows, eskers and numerous lakes and ponds, while the Taiga Cordillera features steep, mountainous terrain and narrow valleys (Environment Canada, 2001b).

In the northern portion of the Gwich'in region, the flat alluvial plains of the Mackenzie Delta are bordered to the west by the Richardson Mountains. The northeast and central areas of the region are characterized by a subdued relief of broad lowlands and plateaus, such as the Peel Plain and the Ramparts Plateau. The southern portion of the Gwich'in region falls within the range of the Mackenzie Mountains, as does the southwestern region of the Sahtu. The central portion of the Sahtu region is characterized by the Mackenzie Lowlands and the Franklin Mountains along a portion of the east bank of the Mackenzie River and the region surrounding Great Bear Lake. To the north of Great Bear Lake is the Southern Arctic ecozone, while to the east, the region encompasses a very small section of Taiga Shield where open, stunted forests grow between lakes and wetlands that dot the Precambrian Shield landscape (Environment Canada, 2001b). To south of Great Bear Lake lie the Taiga Plains.

There are two major sub-basins that contribute to the Mackenzie River drainage basin in these settlement regions: Peel River and Great Bear River. While the majority of the Peel River basin drains from the Selwyn, Ogilvie and Richardson mountains within the Yukon Territory, it empties into the Mackenzie Delta just north of Fort McPherson in the Gwich'in Settlement Area. Within the NWT portion of the river, the channel flows across the Peel Plateau and is relatively stable until just before its junction with Middle Channel of the Mackenzie Delta. Here, there is considerable bank erosion as a result of complex river currents, channel shifting and destabilization of ice-rich banks. Overall, the river is very responsive to input changes due to the topographic relief and lack of storage within the basin. In contrast, the Great Bear River basin drains an area of low relief and high storage capacity, resulting in relatively consistent flow rates both inter- and intra-annually. According to Church (1971), Great Bear Lake occupies approximately 22% of the Great Bear River watershed. Although there are a number of tributaries flowing into the lake, none are considered to be a major contributor.

The Gwich'in and Sahtu regions fall within the zones of continuous, extensive discontinuous and intermediate discontinuous permafrost (Heginbottom, 2000). Permafrost affects the hydrological cycle in many ways. For example, when ice-rich, it can act as a barrier to water infiltration, leaving more water available on the surface for various processes, such as evaporation, plant uptake or surface runoff to streams. This can result in extensive slope runoff (Woo, 1986) and rapid rises in stream water levels. Vegetation within the regions varies from boreal forest in the south, alpine in the mountains and arctic tundra in the north.

The climate of the Gwich'in and Sahtu regions can be categorized as a subarctic regime. Subarctic refers to those regions where the mean temperature of the warmest month is above 10ºC but no more than four months have a mean temperature exceeding 10ºC (Krauss, 1996). The climate of the area is characterized by cool summers and dry conditions, with mean temperatures at Inuvik of –28.8ºC in January, 13.8ºC in July and 257 mm of precipitation (Environment Canada, 2001c). Norman Wells experiences a mean temperature of –27.4ºC in January, 16.7ºC in July and 317 mm of precipitation (Environment Canada, 2001c). The Mackenzie Valley itself has a somewhat milder climate than adjacent areas to the east and west, while cooler temperatures remain longer over the more northerly and/or mountainous areas. A large portion of the annual precipitation is stored for several months in the form of snow and therefore snowmelt runoff in spring is a dominant feature of regional stream hydrographs.

Hydrometric Overview

Hydrometric Stations

A network of hydrometric stations with stream gauges quantifies the surface hydrology of the regions. There are currently 12 hydrometric gauges in operation in the Sahtu and Gwich'in Settlement Areas (Table 1). In addition, there are data from 18 other stations that are no longer operational. The stream flow data used in this report include up to and including 1999 from the Environment Canada HYDAT database (Environment Canada, 2001a).

There are four closed stations within the Sahtu that are not discussed in this report. Although the gauge itself is located within the Sahtu, the majority of the Lened Creek basin lies within the Deh

Cho region. Data gathered from the gauge located on the Redstone River near the mouth were considered unreliable and the station was relocated 63 km upstream in 1974. The gauges on the Mackenzie River at Sans Sault Rapids and Fort Good Hope are only operated seasonally, therefore data are only available from approximately late May to late October.

Table 1. Hydrometric stations with geographic coordinates and operating periods

Map ID #	Station ID	Station Description (operating stations in bold)	Group	Latitude	Longitude	Operating Period
Sahtu Region Stations						
1	10HA002	Tsichu River at Canol Road	Western	63.3039	-129.7900	1975-1992
2	10HA003	Twitya River near the mouth	Western	64.1606	-128.2992	1980-1990
3	10HA004	**Keele River above Twitya River**	Western	64.0997	-128.1500	**1995-2001**
4	10HB005	**Redstone River 63 km above the mouth**	Western	63.9253	-125.3006	**1974-2001**
5	10HC003	Big Smith Creek near Highway 1	Eastern	64.5925	-124.8128	1973-1994
6	10JA002	**Camsell River at outlet of Clut Lake**	GB Lake	65.6067	-117.7653	**1933-2001**
7	10JB001	Johnny Hoe River above Lac Ste Therese	GB Lake	64.5675	-121.7433	1969-1992
8	10JC003	**Great Bear River at outlet of Great Bear Lake**	Eastern	65.1347	-123.5181	**1961-2001**
9	10JD001	Haldane River near the mouth	GB Lake	66.8583	-121.2653	1975-1992
10	10JD002	Whitefish River near the mouth	GB Lake	65.7344	-124.6228	1977-1992
11	10JE001	Sloan River near the mouth	GB Lake	66.5219	-117.2739	1976-1991
12	10KA001	**Mackenzie River at Norman Wells**	Mackenzie R	65.2722	-126.8833	**1943-2001**
13	10KA003	Bosworth Creek at Norman Wells	Eastern	65.2906	-126.8744	1974-1979
14	10KA005	Seepage Creek at Norman Wells	Eastern	65.2639	-126.7222	1974-1978
15	10KA006	Jungle Ridge Creek near the mouth	Eastern	65.0642	-126.0678	1980-1994
16	10KA007	Bosworth Creek near Norman Wells	Eastern	65.3283	-126.8700	1980-1994
17	10KB001	**Carcajou River below Imperial River**	Western	65.2978	-127.6844	**1976-2001**
18	10KC001	Mountain River below Cambrian Creek	Western	65.2289	-128.5575	1975-1994
19	10KD004	Ramparts River near Fort Good Hope	Western	66.1122	-129.2753	1985-1996
28	10LD002	Jackfish Creek near Fort Good Hope	Eastern	66.2611	-128.5972	1980-1986
Gwich'in Region Stations						
20	10LA002	**Arctic Red River near the mouth**	Western	66.7883	-133.0794	**1968-2001**
21	10LA004	Weldon Creek near the mouth	Western	66.4119	-132.6942	1978-1990
22	10LC003	**Rengleng River below Highway 8**	Eastern	67.7558	-133.8442	**1973-2001**
23	10LC007	**Caribou Creek above Highway 8**	Eastern	68.0894	-133.4900	**1975-2001**
24	10LC009	Cabin Creek above Highway 8	Eastern	68.2614	-133.2614	1984-1996
25	10LC010	Boot Creek near Inuvik	Eastern	68.3611	-133.6439	1981-1990
26	10LC014	**Mackenzie River at Arctic Red River**	Mackenzie R	67.4581	-133.7444	**1972-2001**
27	10LC017	**Havikpak Creek near Inuvik**	Eastern	68.3144	-133.5208	**1995-2001**
29	10MC002	**Peel River above Fort McPherson**	Western	67.2361	-134.9075	**1969-2001**
30	10MC007	Rat River near Fort McPherson	Western	67.6769	-135.7181	1981-1990

Hydrometric Data

Basic hydrological statistics were calculated from daily flow data and are presented in Table 2. For each station, the total annual flow was determined for each year with a complete data record and mean total annual flow was calculated (Table 2). The annual basin yield (mm/year) is obtained by dividing the drainage area of the basin above the station gauge into the total annual flow at the gauge. The yield of a stream basin is the annual stream flow expressed as depth of water per unit area of the basin. It should be noted that all basin areas used in this report are based on the drainage area above the stream gauging site. The discharge, area and yield of a basin are useful summary statistics for comparison and classification of basins. With just a few years of data, mean annual hydrographs can clearly show patterns in yearly high and low flows. With several years of data, the annual high and low flow values can be extracted from these hydrographs and used in a frequency analysis of extremes (flood and drought events).

Annual hydrographs are included in the report as they are an effective way to illustrate the hydrology of a river basin. The area under a complete annual hydrograph gives the total annual flow or discharge volume. While the volume of flow can vary significantly between rivers (scale of the y-axis), the shape of the curve illustrates the major influences on river flow and can serve to characterize the flow regime.

A review of hydrometric data was completed for each of the stations in the Sahtu and Gwich'in settlement areas. Stations were divided into three major groups and one subgroup: (1) Mackenzie River stations; (2) Mackenzie east bank tributary stations; (2a) Great Bear Lake tributary stations; and (3) Mackenzie west bank tributary stations. From each group, one or two stations with regionally representative hydrographs were chosen and mean annual flows were graphed. Two annual hydrographs, representing the years with the highest (max) and lowest (min) recorded peaks, were also included. In addition, certain anomalous years were graphed and briefly discussed. Hydrographs for the remaining stations are included in Appendix A.

For most stations, the annual peak discharge occurs as a result of snow melt in the spring. However, peaks can occur at any time from late April to early September, depending largely on annual variability in precipitation (snow and rain). The response of a basin to rain events varies according to a number of factors, including basin topography, storage capacity, climate and antecedent moisture conditions (conditions prior to the rain event).

Table 2. Summary flow statistics

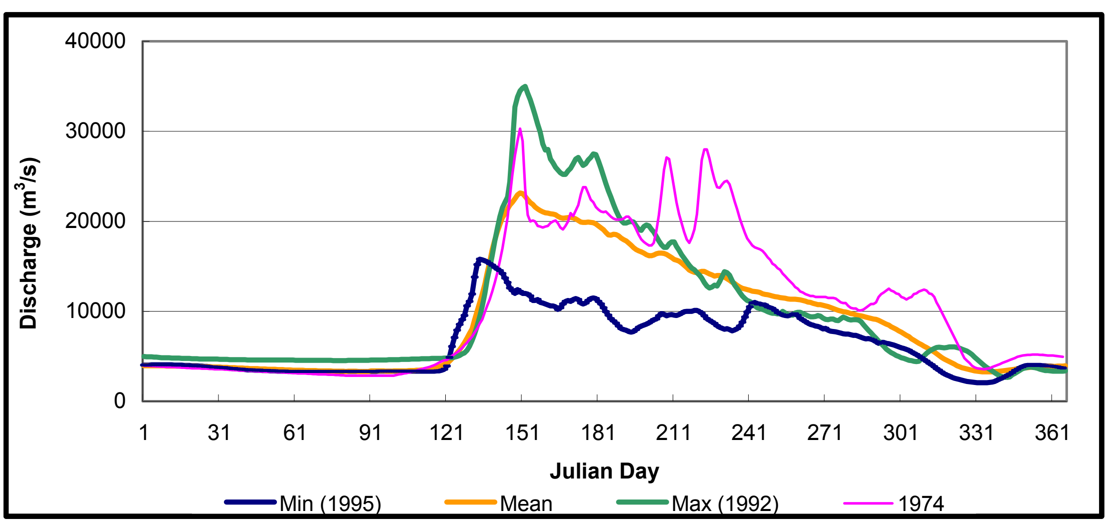
Station Description	Years of Record	Mean Annual Flow (m^3/s)	Mean Total Annual Flow ($10^6 m^3/yr$)	Basin Area (km^2)	Basin Yield (mm/yr)
Mackenzie River Stations					
Mackenzie River at Norman Wells	29	8541.1	269352	1570000	172
Mackenzie River at Arctic Red River	25	8969.3	282855	1660000	170
Mackenzie East Bank Tributaries					
Big Smith Creek near Highway 1	20	5.9	185	964	192
Great Bear River at outlet of Great Bear Lake	21	530.9	16744	145000	115
Bosworth Creek at Norman Wells	6	insufficient data	insufficient data	122	insufficient data
Seepage Creek at Norman Wells	4	0.1	2.0	31	60
Jungle Ridge Creek near the mouth	13	0.4	14	41	327
Bosworth Creek near Norman Wells	14	0.6	19	109	169
Jackfish Creek near Fort Good Hope	5	0.2	7	63	117
Rengleng River below Highway 8	19	2.8	87	1310	66
Caribou Creek above Highway 8	20	1.7	53	625	85
Cabin Creek above Highway 8	13	0.5	15	133	111
Boot Creek near Inuvik	9	0.1	3	28	98
Havikpak Creek near Inuvik	2	0.1	2	15	151
Great Bear Lake Tributaries					
Camsell River at outlet of Clut Lake	36	97.8	3083	31100	99
Johnny Hoe River above Lac Ste Therese	20	40.8	1287	17300	74
Haldane River near the mouth	13	11.4	361	3940	92
Whitefish River near the mouth	12	13.6	430	4740	91
Sloan River near the mouth	13	12.3	389	2040	191
Mackenzie West Bank Tributaries					
Tsichu River at Canol Road	17	3.6	113	219	515
Twitya River near the mouth	10	61.8	1950	5590	349
Keele River above Twitya River	1	115.7	3650	11200	326
Redstone River 63 km above the mouth	15	175.1	5522	15400	359
Carcajou River below Imperial River	18	70.0	2206	7400	298
Mountain River below Cambrian Creek	17	123.0	3879	11100	349
Ramparts River near Fort Good Hope	11	41.8	1319	7410	178
Arctic Red River near the mouth	22	157.8	4977	18600	268
Weldon Creek near the mouth	13	3.4	108	852	127
Peel River above Fort McPherson	22	675.9	21315	70600	302
Rat River near Fort McPherson	9	8.4	266	1260	211

In general, the basin yield of east bank tributaries (including tributaries to Great Bear Lake) is much less than that of west bank tributaries. The mean basin yield for eastern tributaries is approximately 130 mm/yr, while for western tributaries it is 316 mm/yr. This is likely as a result of lower storage capacity in western tributary basins, higher evaporative losses from storage areas in eastern tributaries and lower amounts of precipitation in eastern tributary basins.

Mackenzie River Stations

There are currently two gauges operating year-round on the Mackenzie River within the regions discussed in this report: (1) at Norman Wells and (2) near Tsiigehtchic (formerly known as Arctic Red River). The stream flow record for the Mackenzie at Arctic Red River station is 28 years long, with only three incomplete data years (Figure 2). Averaging the 28 years of data results in a considerable smoothing out of the annual variations. In addition, the Mackenzie River is not a river that responds rapidly to runoff events, given its extremely large size (1,660,000 km^2), the number of inflows and the volume of storage capacity within the basin. Nonetheless, the mean annual hydrograph is characterized by a relatively steep rising limb in May with a mean peak occurring in late May/early June. Throughout the remainder of the year, there is a gradual recession of flow volumes with a slightly steeper recession during freeze-up in November. Following freeze-up, there is a small increase in flow, after which there is a very gradual winter recession. This recession continues until just before spring melt.

Figure 2. Hydrographs for Mackenzie River at Arctic Red River (1972-1999)



The general shape of this mean annual hydrograph is characteristic of a subarctic nival regime (Church, 1974): the lowest production of runoff from drainage basins occurs in late winter, just before spring melt; the largest contribution to annual discharge comes from the melting of the winter snow pack during spring; and a transfer of in-stream water from discharge to ice storage occurs during freeze-up. The freshet (spring thaw) can be very dramatic and contributes to the annual break-up of ice cover on most rivers. The 1974 hydrograph for the Mackenzie River at Arctic Red River (Figure 2) demonstrates that flow can also be influenced by rainfall events (see peaks on Julian Days 209 (July 28), 224 (August 12), 298 (October 25) and 313 (November 9)).

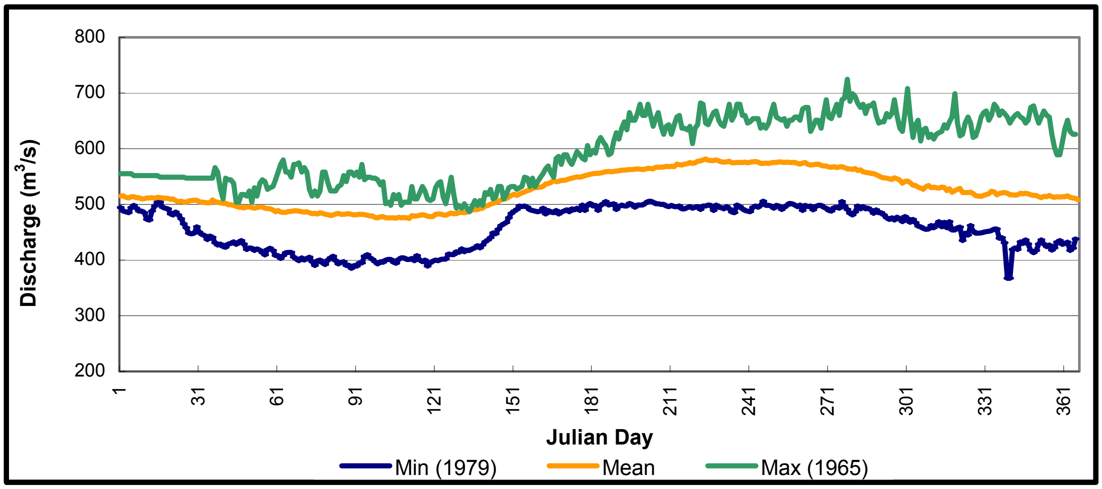
Photo 1. Mackenzie River at the Ramparts (Photo: B. Reid, INAC).

Eastern Tributary Stations

In operation since 1961, the gauge on Great Bear River has provided 21 full years of record and 18 partial years. Given its large basin size (145,000 km^2) and the gauge location at the outlet of Great Bear Lake, the mean annual hydrograph for Great Bear River is significantly different than that of other east bank tributary streams analyzed (Figure 3). Great Bear Lake is the largest freshwater lake entirely in Canada. Its drainage basin is characterized by a relatively subdued topography, with substantial storage capacity. In addition, the massive size of the lake provides a significant moderating effect on the river and supplies a steady flow of water throughout the year. Although small short-term fluctuations are evident in the minimum (1979) and maximum

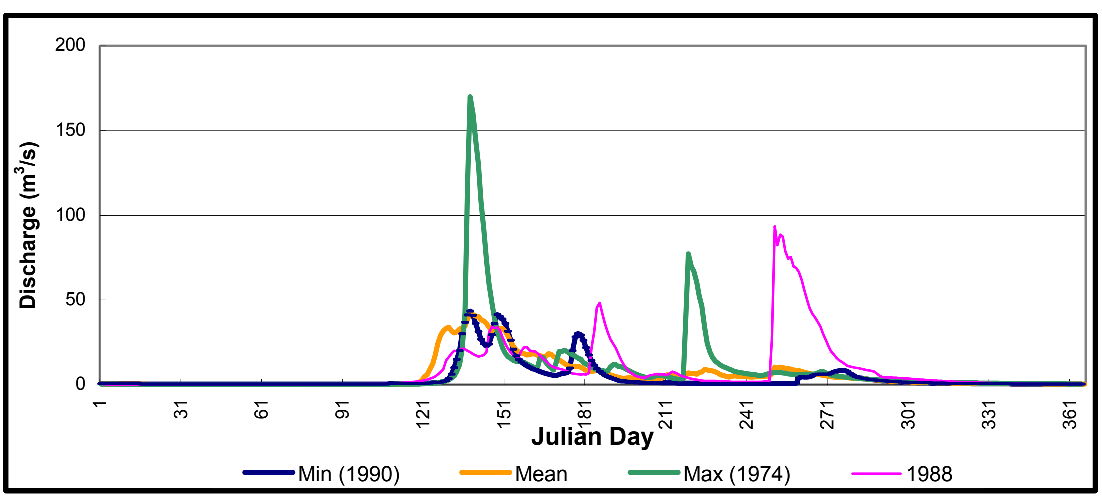
(1965) hydrographs, the mean annual hydrograph is characterized by a gentle rising limb that peaks approximately mid-August, before slowly falling until late the following April.

Figure 3. Hydrographs for Great Bear River at outlet of Great Bear Lake (1961-1999)



In contrast to Great Bear River, Big Smith Creek is responsive to spring freshet and rainfall events, as evidenced by the sharp peaks of its annual hydrographs (Figure 4). The upper portion of the basin east of the Franklin Mountains is characterized by areas with thermokarst lakes, while west of the mountains, the channel flows through a gorge and drops over several ledges. The mean annual hydrograph, composed of 20 full years of data and two partial years, indicates that although spring snow melt is the primary source of water to the stream, it is also somewhat affected by rain events in late summer/early fall. In some years, as highlighted by the 1988 hydrograph, the annual peak occurs as a result of a rainfall event.

Figure 4. Hydrographs for Big Smith Creek near Highway 1 (1973-1994)



Rengleng River has 19 full years of record and eight partial years (Figure 5). The upper section of the basin is flat with poor drainage, while in the lower end, the channel meanders through relatively deep valley areas. The mean annual hydrograph has a steep rising limb, while the falling limb is only slightly less steep, indicating that the river is responsive to runoff but has limited storage capacity to sustain elevated flow volumes. According to the mean annual hydrograph, the river is not regularly affected by precipitation events later in the season, however the 1976 hydrograph demonstrates that if the appropriate conditions are in place, annual peak flow can occur late in the summer.

Figure 5. Hydrographs for Rengleng River below Highway 8 (1973-1999)

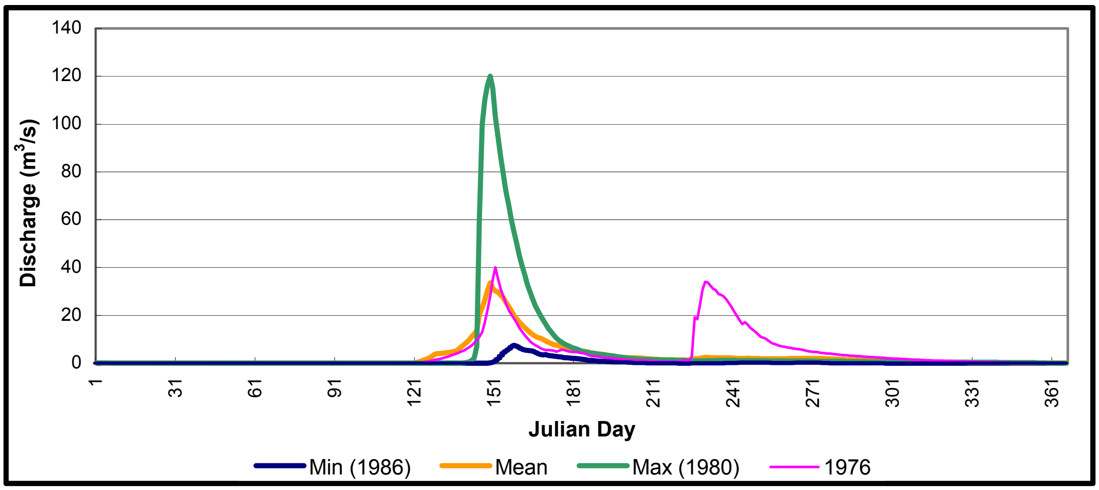


Photo 2. Typical drainage east of Mackenzie River, near Little Chicago (Photo: B. Reid, INAC).

Great Bear Lake Tributary Stations

The Camsell River has one of the longest data records in the north, with 35 full and three partial years. The river roughly marks the transition from Taiga Shield to the east and Taiga Plains to the west. Like Great Bear River, its mean annual hydrograph is very similar in appearance to that of individual year hydrographs (Figure 6). The primary reason for this is that the gauge is located at the outlet of a series of upstream lakes. The large amount of storage upstream and the size of the basin (31,100 km^2) serve to attenuate flows year-round, resulting in gently sloping, consistent hydrographs from one year to the next. The majority of precipitation events do not have sufficient impact on flow to be visible on annual hydrographs.

Figure 6. Hydrographs for Camsell River at outlet of Clut Lake (1933-1934, 1963-1999)

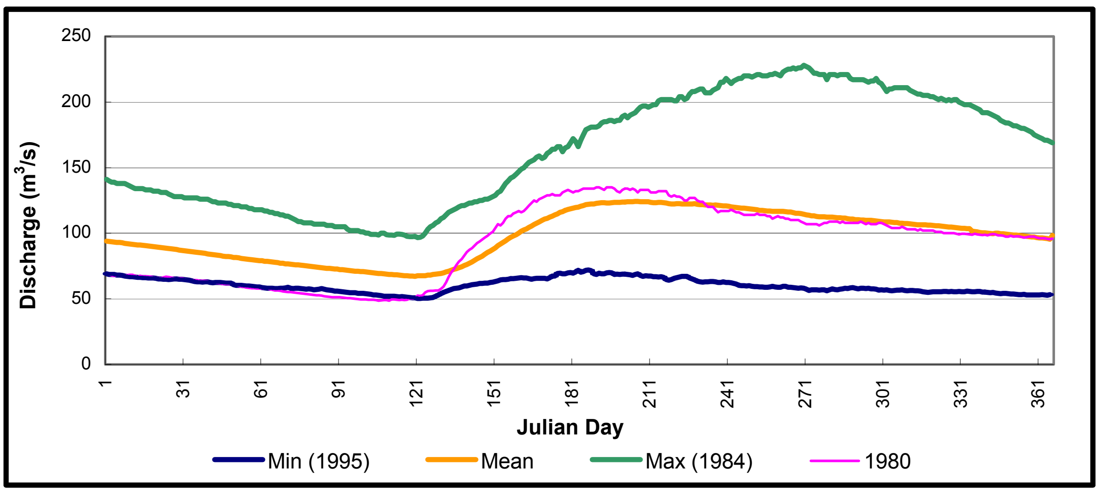
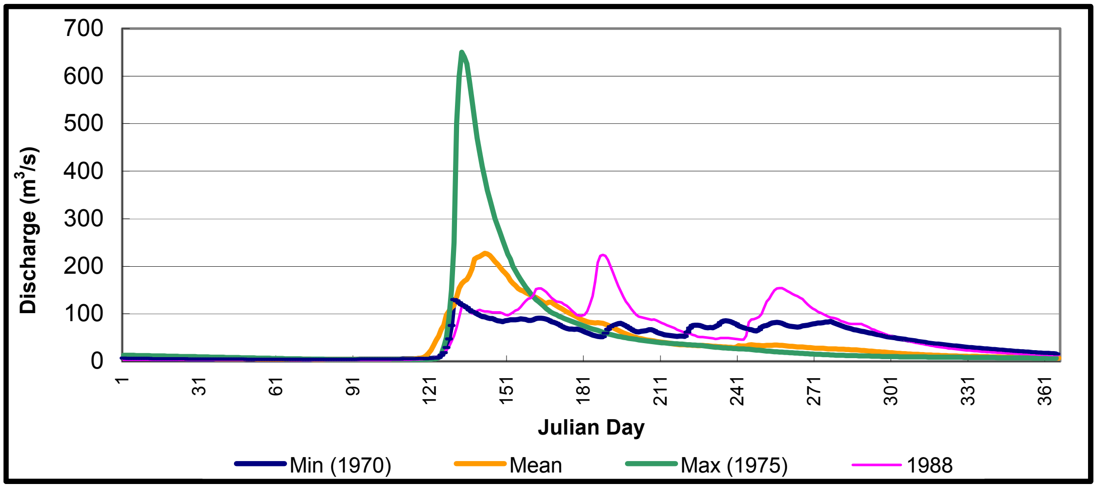


Photo 3. Clut Lake near outlet (Photo: S.A. Kokelj, INAC)

The Johnny Hoe River also flows north into Great Bear Lake and its 17,300 km^2 drainage basin is distributed between the Deh Cho, North Slave and Sahtu regions, all within the Taiga Plains. There are 20 full years and four partial years of data for this river (Figure 7). Unlike the Camsell River, however, flow of Johnny Hoe River is not regulated by large lakes. Like most other northern rivers, its flow regime is dominated by spring runoff, followed by a relatively rapid recession toward low flow volumes. There are, however, years when peaks occur much later in the season as a result of precipitation events (e.g., 1988).

Figure 7. Hydrographs for Johnny Hoe River above Lac Ste. Therese (1969-1992)



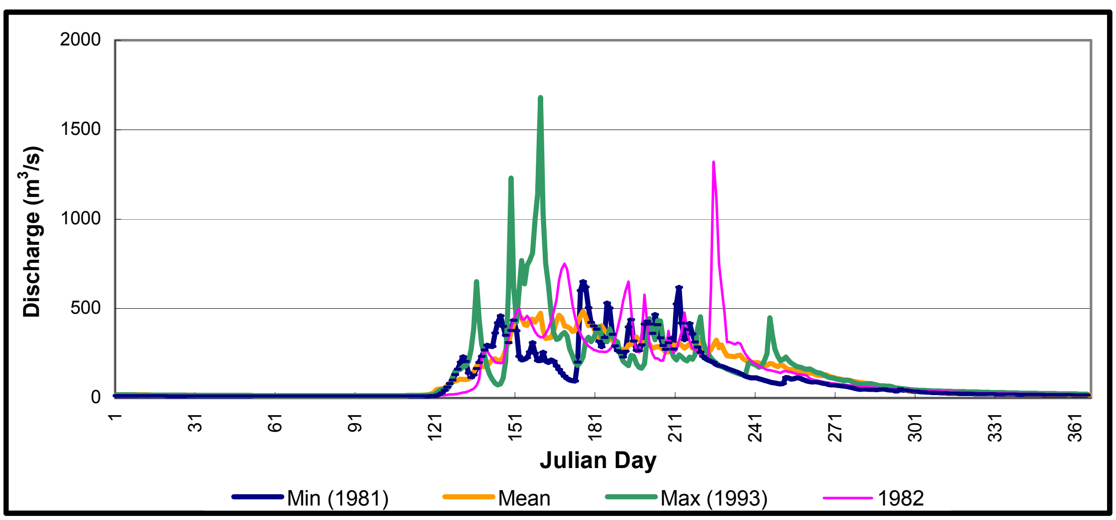
Western Tributary Stations

In general, tributary streams draining areas to the west of the Mackenzie River are more likely than eastern tributaries to have flow peaks resulting from rain events. Given that the timing of these events is scattered over several months as opposed to the single release of water during the spring, these peaks are not necessarily visible on mean annual hydrographs. They become evident when single year hydrographs are examined.

Photo 4. Keele River (Photo: A. Gibson, Sahtu Land and Water Board).

The shape of the mean annual hydrograph for the Mountain River indicates that during the 17 full years of record, peak flows are distributed over the period between June and August (Figure 8). Although the maximum peak recorded occurred during spring freshet (1993), the hydrograph for 1982 demonstrates that peak flow can also occur in mid-August. Both of these years are characterized by a series of smaller peaks and recessions. This is primarily due to the lack of storage capacity in mountain basins and steep bedrock topography, resulting in a responsive stream with water levels that fluctuate regularly with precipitation events.

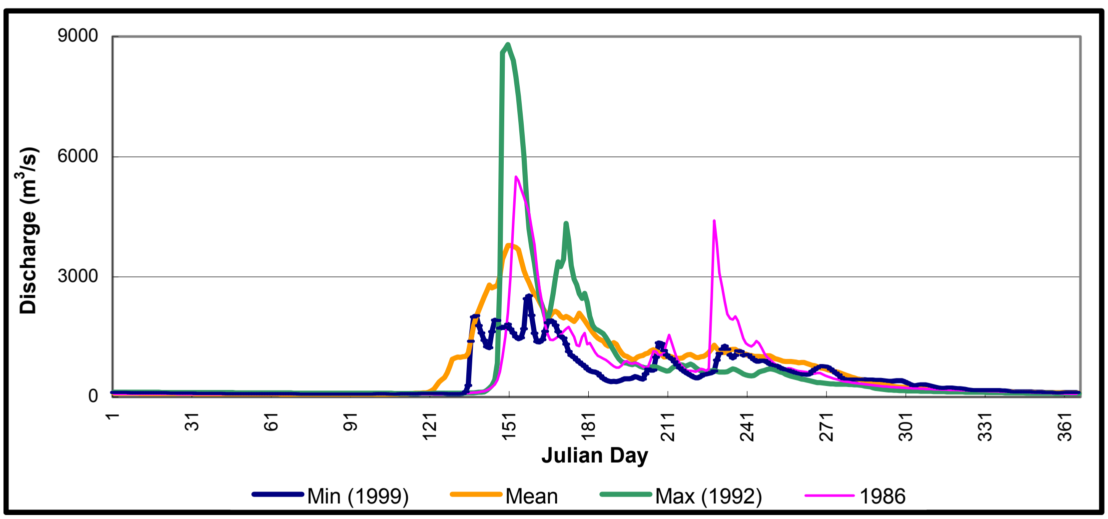
Figure 8. Hydrographs for Mountain River below Cambrian Creek (1978-1994)



The Peel River drains a basin area of 70,600 km^2, the majority of which is located in the Yukon Territory. The headwaters of most tributary streams lie within the Taiga Cordillera, and as a result, are very responsive to spring melt and rain events. The Peel River cuts through the Peel Plateau before reaching the Mackenzie Delta, north of Fort McPherson. During spring flood, flow of the lower Peel River can be reversed as a result of backwater flooding from the Mackenzie River. As a result, flow is diverted through Husky Channel to the west.

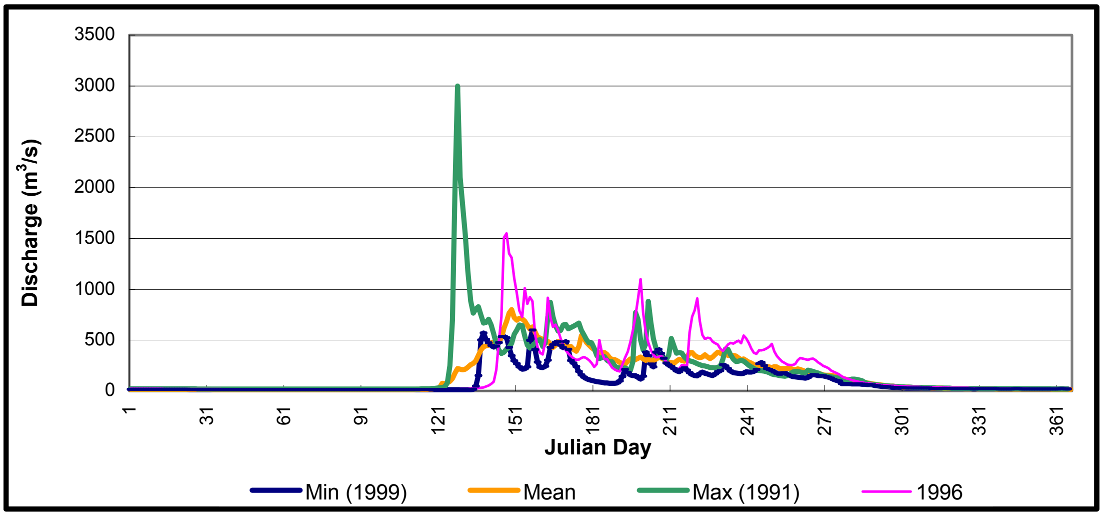
The mean annual hydrograph, composed of 22 full and eight partial years of record, indicates that annual peak flow occurs during spring freshet (Figure 9). Similar to the Mountain River, the river also responds to rain events later in the season, as evidenced by the slight increase of the mean annual hydrograph in August and the second peak in the 1986 hydrograph. The steepness of the hydrographs reflects the mountainous nature and lack of storage of the upper basin.

Figure 9. Hydrographs for Peel River above Fort McPherson (1969-1999)



Although its basin is smaller (18,600 km^2), the regime of the Arctic Red River is very similar to that of the Peel River (Figure 10). The river's headwaters lie within the Mackenzie Mountains and attain the second highest altitudes of a river basin north of 60°. The presence of numerous silt bars in its lower reaches are an indication of the river's heavy sediment load. Arctic Red River is the last tributary to the Mackenzie River before it branches out to the Delta area. Like the Peel River, the mean annual hydrograph, composed of 21 full and 11 partial years of record, shows a peak during spring freshet, while individual year hydrographs highlight peaks later in the summer, generally as a result of rain events.

Figure 10. Hydrographs for Arctic Red River near the mouth (1968-1999)



Frequency Analyses of Extremes

Management of water resources often requires a frequency analysis of extreme hydrological events. The accuracy of such an analysis increases with the length of the data record, and the accepted guideline for effective analysis is a minimum of 30 years of flow data from a gauged station. Operating periods of the stations examined in this report vary considerably, from seven to 41 years (Table 1), reflecting changes in the cost of logistics, priorities and budgets over the years. Given that so few stations provide 30 or more years of flow data, the minimum acceptable time line for the purposes of frequency analysis was lowered to 20 years. Only years with a complete data record during the break-up and subsequent open water period were used in the frequency analysis to be certain that the maximum annual flow was recorded. The analysis has been applied to 12 station data sets (Table 3).

Table 3. Results of frequency analyses using Pearson Theoretical Distribution (stations with ≥ 20 years of data)

Station description	Basin yield (mm/yr)	Number of high-flow data years	10-year high flow (m^3/s)	25-year high flow (m^3/s)	100-year high flow (m^3/s)	Maximum daily flow recorded (m^3/s)
Redstone River 63 km above the mouth	359	21	2738	3321	4142	3750 1991/07/28
Big Smith Creek near Highway 1	192	21	143	159	179	170 E 1974/05/18
Camsell River at outlet of Clut Lake	99	37	180	201	228	228 1984/09/26
Johnny Hoe River above Lac Ste. Therese	74	20	523	596	688	650 B 1975/05/13
Great Bear River at outlet of Great Bear Lake	115	32	712	773	861	852 1962/08/12
Mackenzie River at Norman Wells	172	32	29175	30698	32410	33300 1988/07/04
Carcajou River below Imperial River	298	20	1296	1576	1980	1930 1990/06/25
Arctic Red River near the mouth	268	24	2208	2634	3248	3000 B 1991/05/08
Rengleng River below Highway 8	66	24	75	97	130	120 E 1980/05/29
Caribou Creek above Highway 8	85	25	50	61	76	65 B 1980/05/26
Mackenzie River at Arctic Red River	170	27	32749	33715	34625	35000 B 1992/05/31
Peel River above Fort McPherson	302	24	7339	8013	8841	8800 B 1992/05/29

B – backwater   E - estimated

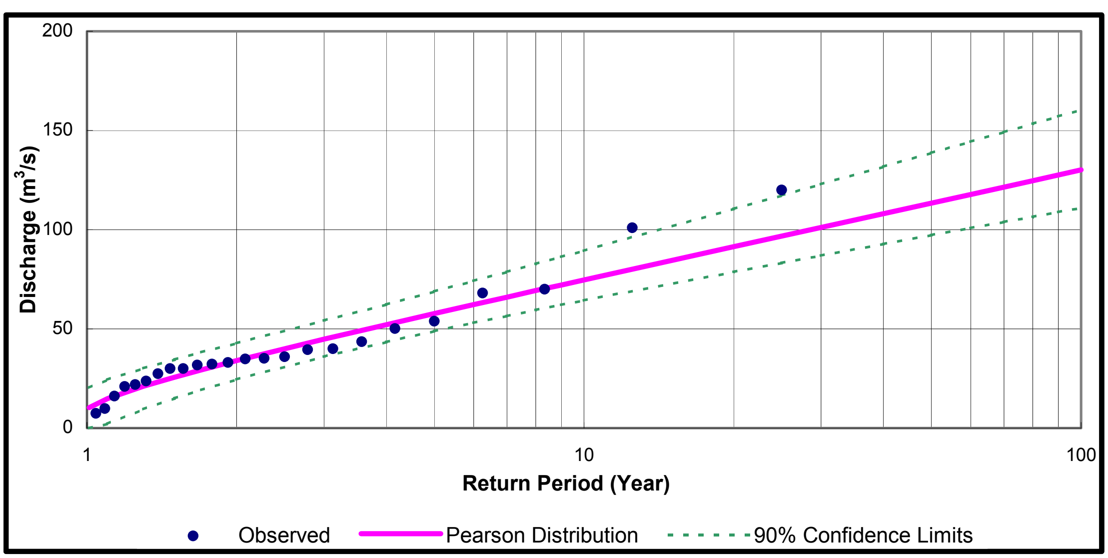
Extremes of high flow (flood) events can have significant impact on ecosystem and human activities. Historical records of annual extremes can be used to predict the likelihood or probability of similar events by the technique of frequency analysis. The probability of a given flow magnitude is expressed as a return period, which is the time interval in which a given flow magnitude should be exceeded one time. Given that the length of data records is relatively brief, a theoretical distribution was used to calculate flood probabilities. Theoretical distribution techniques use the mean, standard deviation and skewness of the observed annual maximum flow to evaluate the return period of annual maximum flows. The theoretical distribution and the 90%

confidence limits were calculated using the Pearson theoretical distribution, widely used in hydrology as a statistical model to describe extreme events (Chow, 1964; Maidment, 1993).

Though estimates of return period can be useful in planning activities and developments near streams, one limitation in the application of the technique is worth noting - the magnitudes of the annual extremes and their corresponding return periods generally follow a characteristic distribution for each stream, but two events of equal magnitude with a given return period can and do occur within less time than expected.

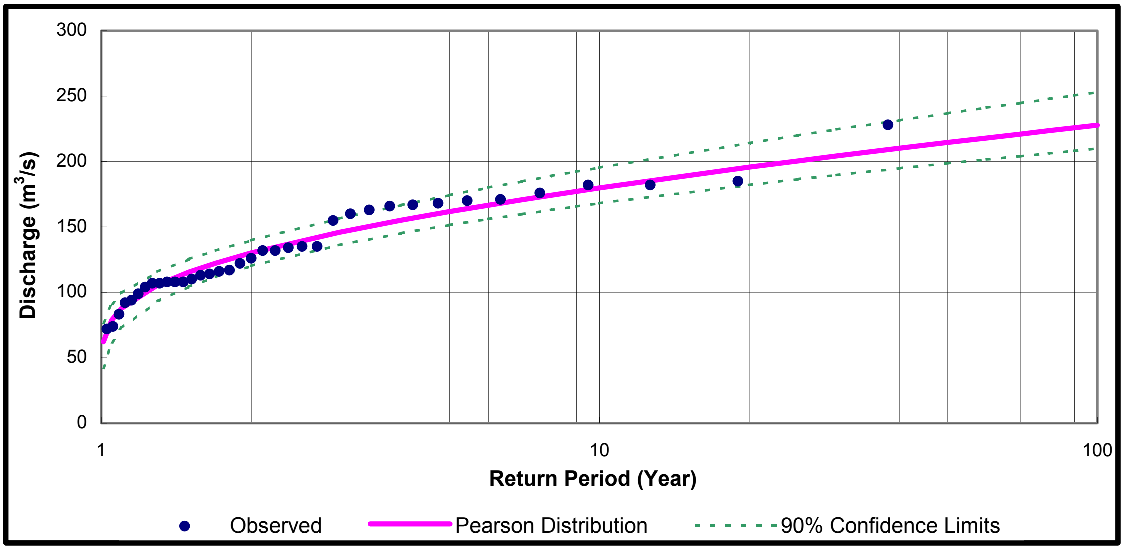
In general, the Pearson Theoretical Distribution fits the distribution of observed values better near the small and medium-sized observed flows than at high flows (Figures 11 and 12, Appendix B). The maximum recorded flow (in years with a complete record) at 11 of the 12 stations analyzed falls substantially above the Pearson theoretical distribution. As a result, the highest daily flow ever recorded at several stations is close to or greater than the predicted 100-year high flow (Table 3). Although, in theory, this is not impossible, it is highly unlikely, given the short length of the station records. For example, at Rengleng River, the theoretical distribution predicts a return period of approximately 70 years for a flow magnitude of 120 m^3/s, whereas it was observed within the 24-year data set (Figure 11). As more data are received, the fit between observed data and theoretical distribution should improve. Although two observed

Figure 11. Flood frequency distribution for Rengleng River below Highway 8 (1976-1999)



discharge values fall just outside of the 90% confidence limits between the three to four year return period, the 37-year data set for the Camsell River provides a good fit between theoretical and observed return frequency values (Figure 12).

Figure 12. Flood frequency distribution for Camsell River at outlet of Clut Lake (1934, 1964-1999)



Conclusion

The information in this report is based on data recorded at 30 hydrometric stations located across the Gwich'in and Sahtu Settlement Areas. The operating period of the gauges ranges from seven to 59 years. Both of the regions feature a diverse landscape, which helps to contribute to a variety of hydrological conditions. The majority of streams, however, are characterized by a nival flow regime. This means that the spring snowmelt is the primary source of water, generally resulting in springtime peak flows. The tributaries flowing from the west of the Mackenzie River, however, are also significantly influenced by precipitation events during the summer months, primarily due to the lack of storage capacity in the mountainous topography. As a result, peak flows may occur over the summer months or into early autumn.

In general, the basin yield of east bank tributaries (including tributaries to Great Bear Lake) is less than half of that of west bank tributaries, likely as a result of lower storage capacity in western tributary basins, higher evaporative losses from storage areas in eastern tributaries and lower amounts of precipitation in eastern tributary basins.

A flood frequency analysis was performed on gauges having a minimum of 20 years of continuous record during break-up and open water conditions. Although overall, the Pearson Theoretical Distribution curve calculated for each stream fits the observed data quite well, it is not as effective at determining the return period of higher flow events. Its performance would improve with an increased period of record.

Acknowledgements

The author would like to acknowledge the initial work of Martin Lacroix and Jennifer Dougherty in making preparations for this report and of Moise Coulombe-Pontbriand for preparing initial flood frequency analyses for the streams described in this report. Discussions with Bob Reid and Derek Faria were essential for the report's completion. Digital map updates were completed by Denise Bicknell. The assistance of members of Environment Canada's Water Survey Division (Yellowknife) with data clarifications is gratefully acknowledged. Thanks are also extended to Al Gibson and Bob Reid for the use of their photographs.

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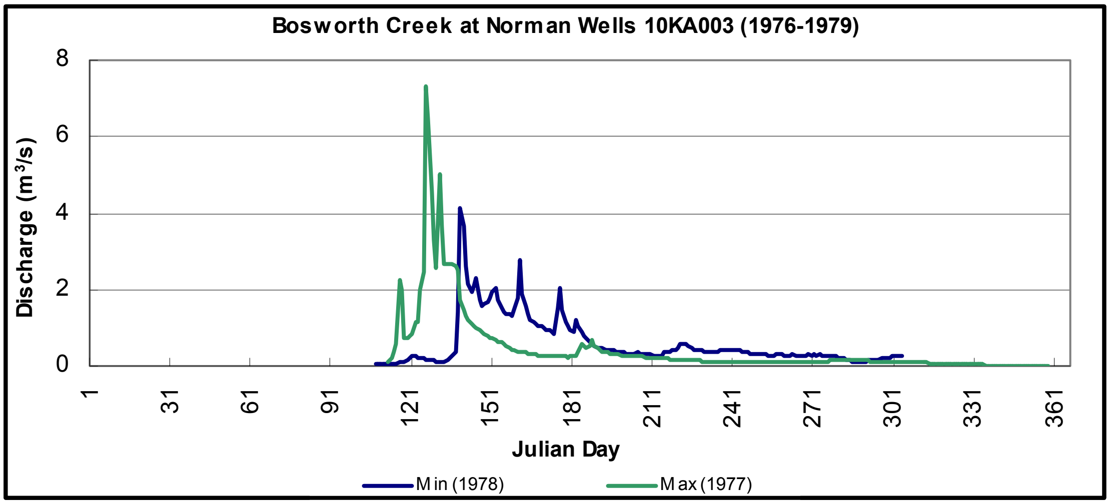
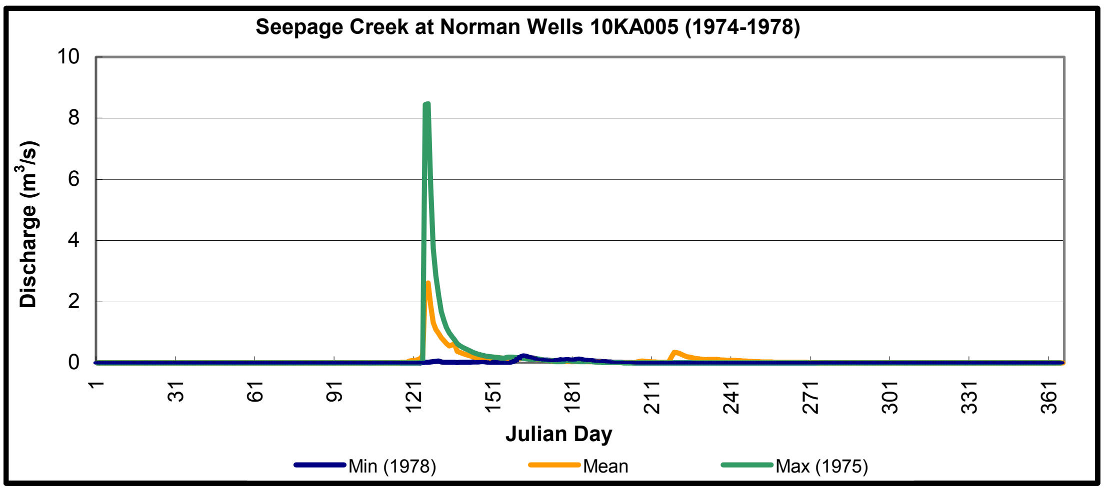
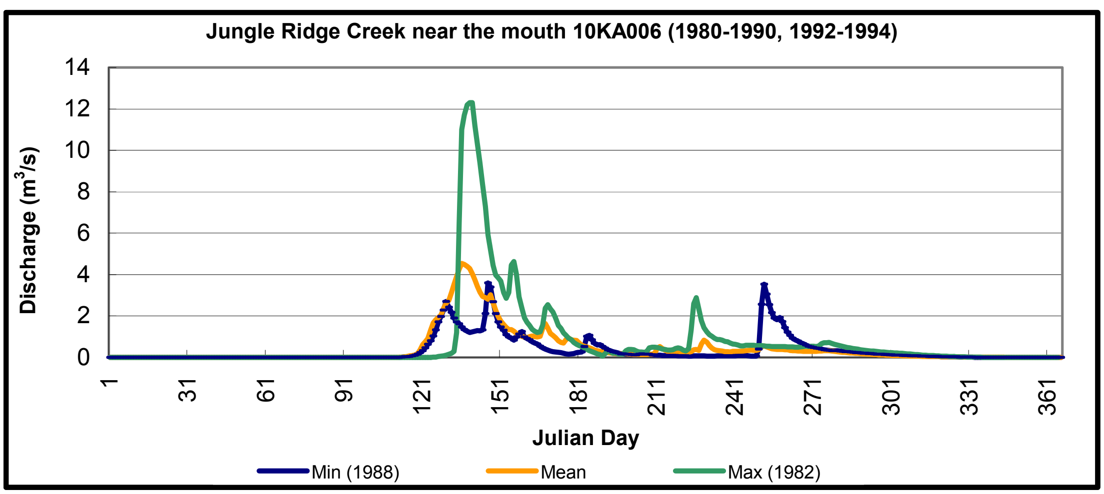
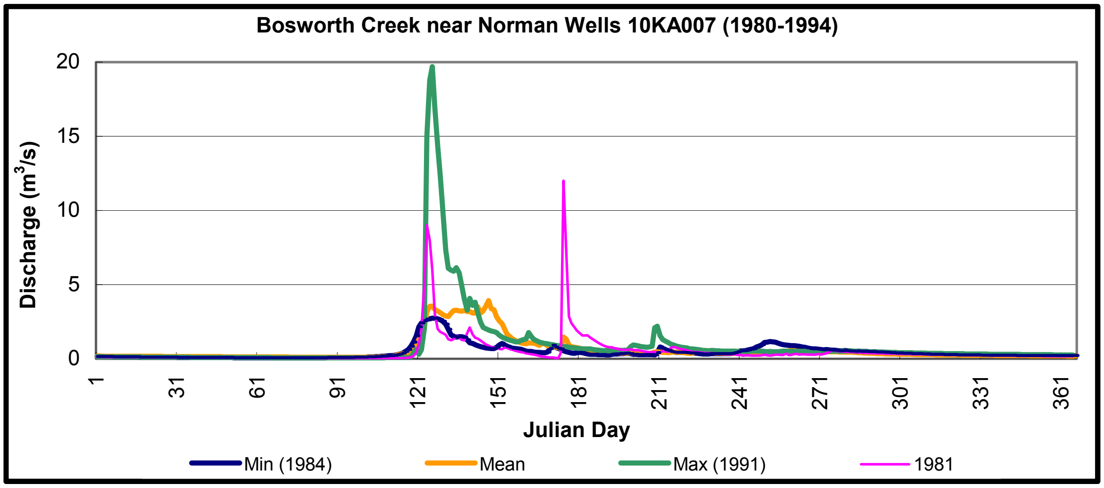
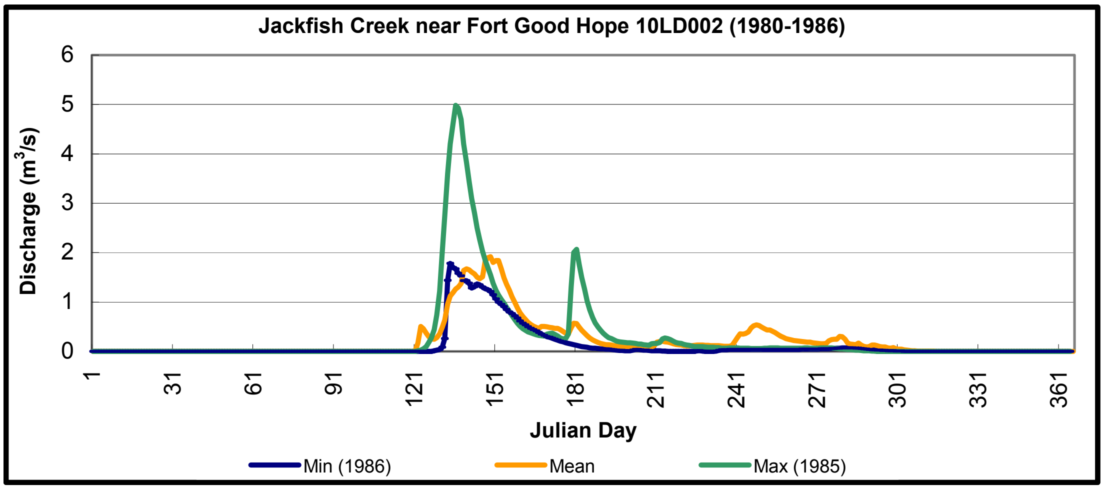
Appendix A. Hydrometric Station Hydrographs

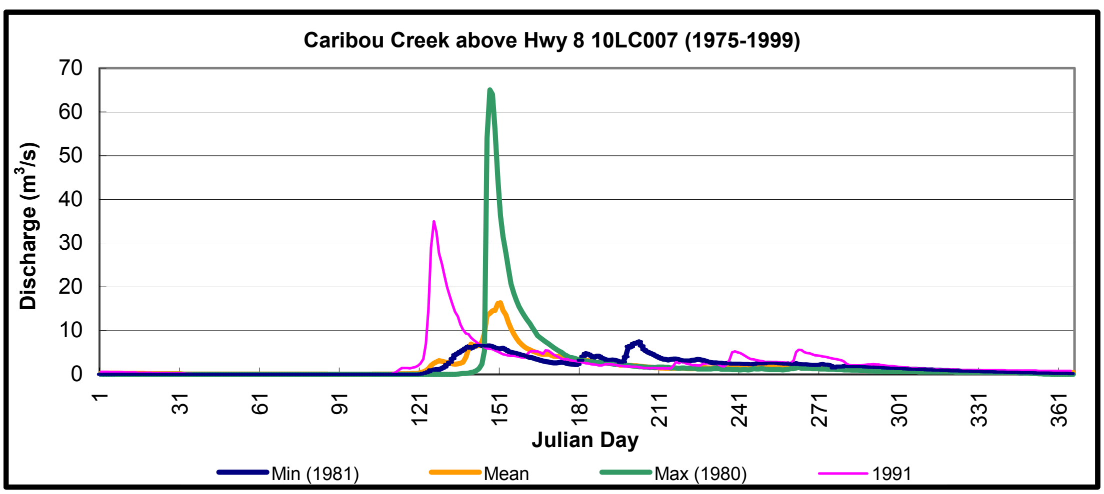


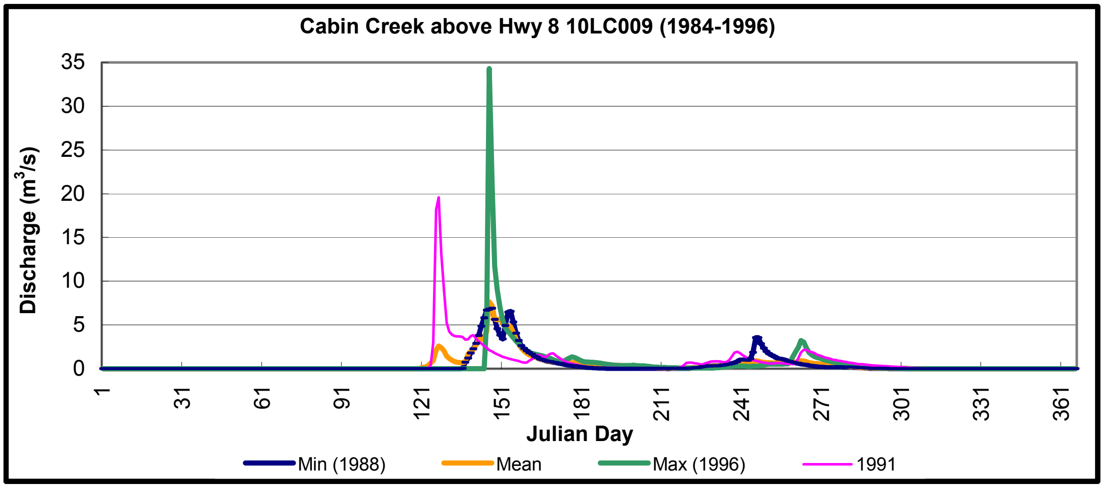


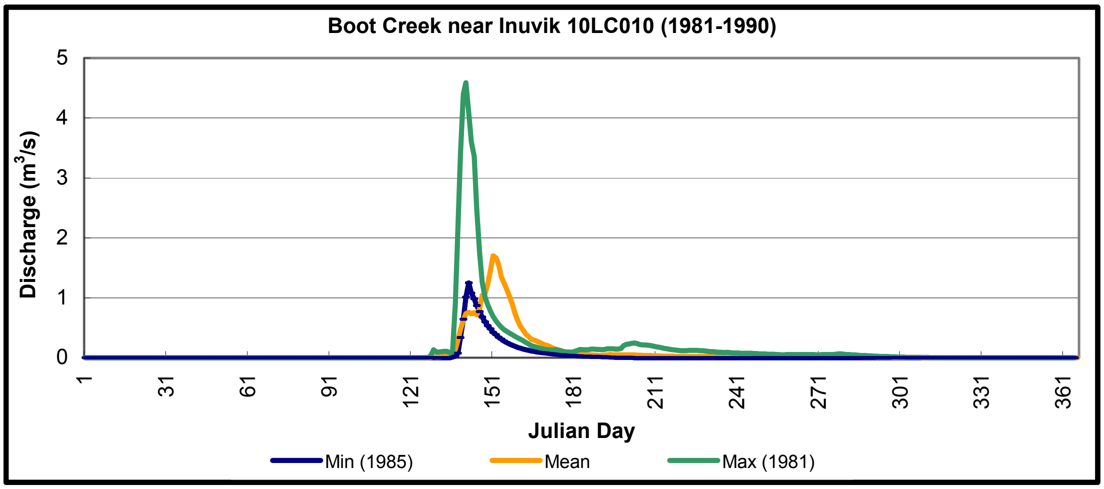


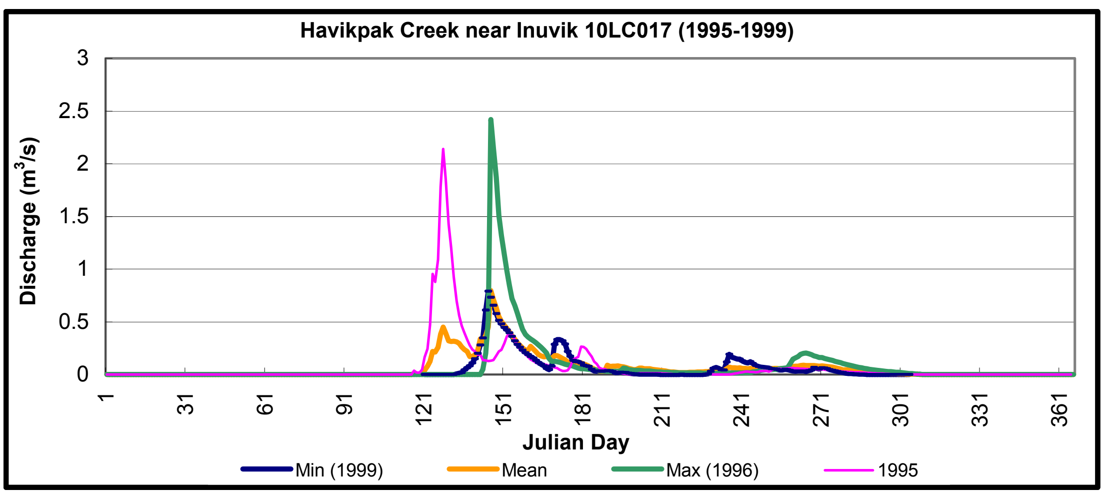

Bosworth Creek near Norman Wells 10KA007 (1980-1994)
Discharge (m^3/s)
0
5
10
15
20
1
31
61
91
121
151
181
211
241
271
301
331
361
Julian Day
Min (1984)
Mean
Max (1991)
1981

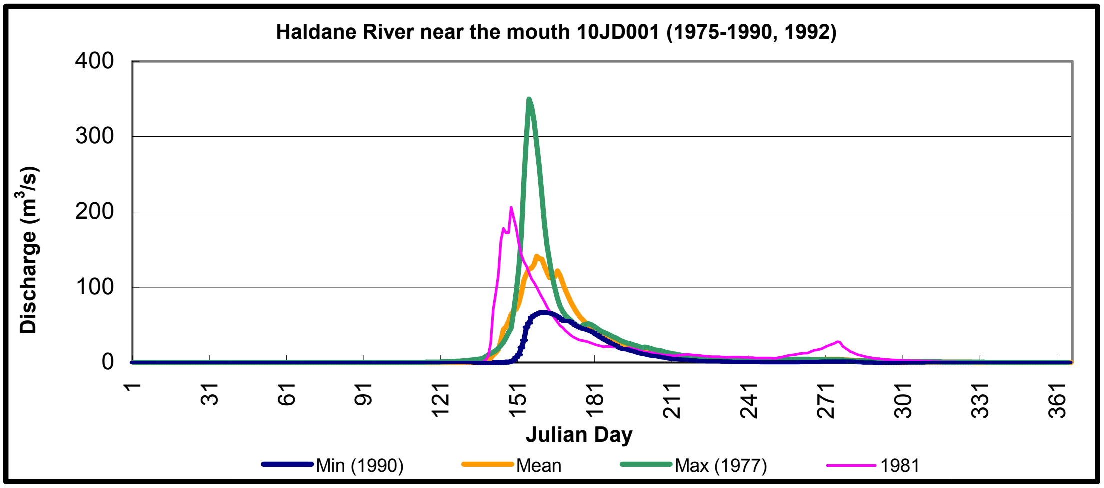

Jackfish Creek near Fort Good Hope 10LD002 (1980-1986)
Discharge (m^3/s)
0
1
2
3
4
5
6
1
31
61
91
121
151
181
211
241
271
301
331
361
Julian Day
Min (1986)
Mean
Max (1985)


Caribou Creek above Hwy 8 10LC007 (1975-1999)
Discharge (m^3/s)
0
10
20
30
40
50
60
70
1
31
61
91
121
151
181
211
241
271
301
331
361
Julian Day
Min (1981)
Mean
Max (1980)
1991

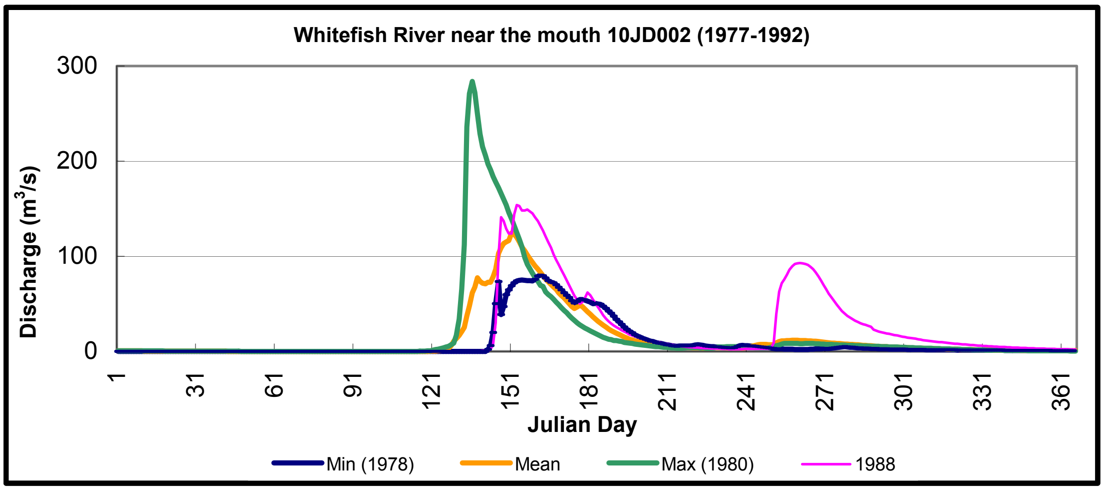

Cabin Creek above Hwy 8 10LC009 (1984-1996)
Discharge (m3/s)
Julian Day
Min (1988)
Mean
Max (1996)
1991


Boot Creek near Inuvik 10LC010 (1981-1990)
Discharge (m3/s)
Julian Day
Min (1985)
Mean
Max (1981)

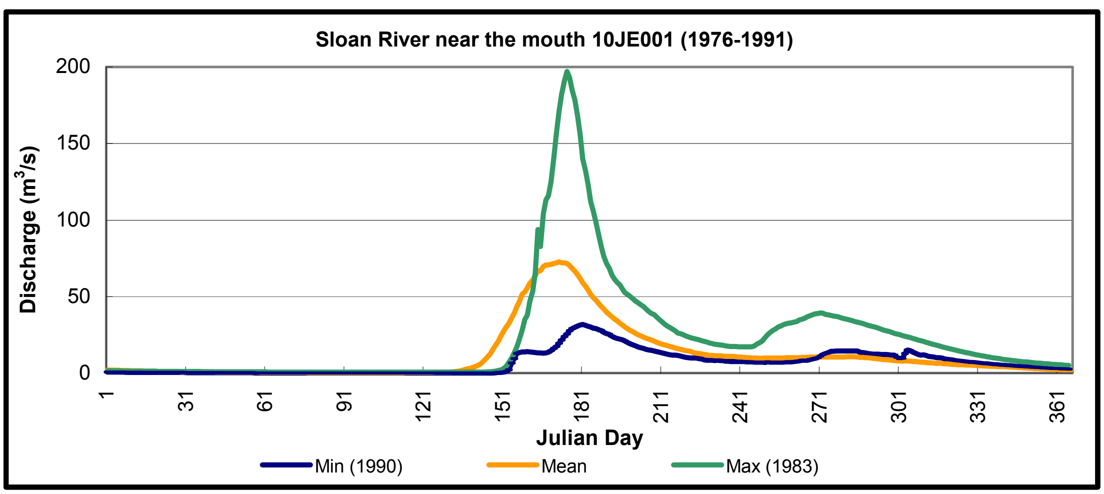

Havikpak Creek near Inuvik 10LC017 (1995-1999)
Discharge (m3/s)
Julian Day
Min (1999)
Mean
Max (1996)
1995



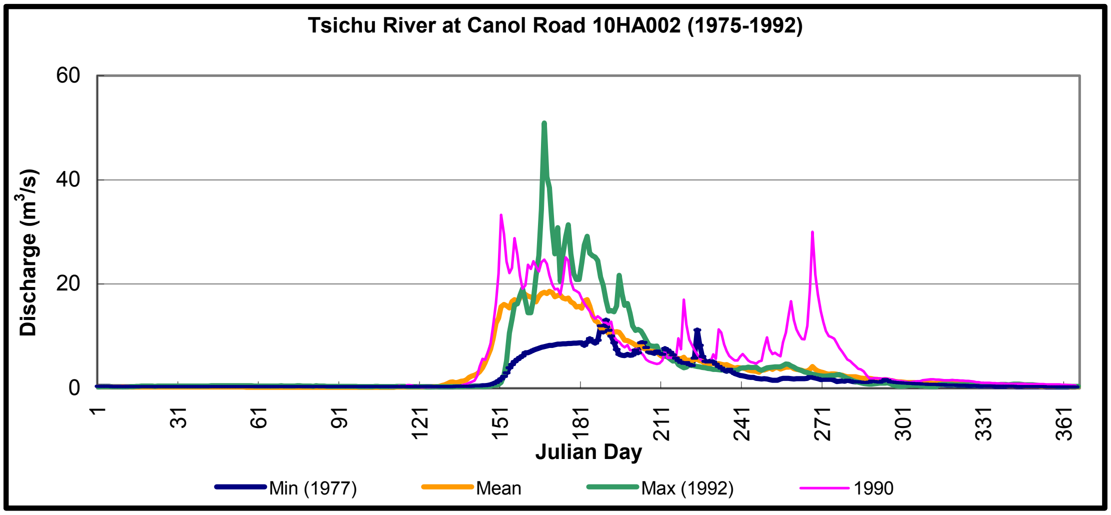
Haldane River near the mouth 10JD001 (1975-1990, 1992)
Discharge (m3/s)
400
300
200
100
0
1
31
61
91
121
151
181
211
241
271
301
331
361
Julian Day
Min (1990)
Mean
Max (1977)
1981

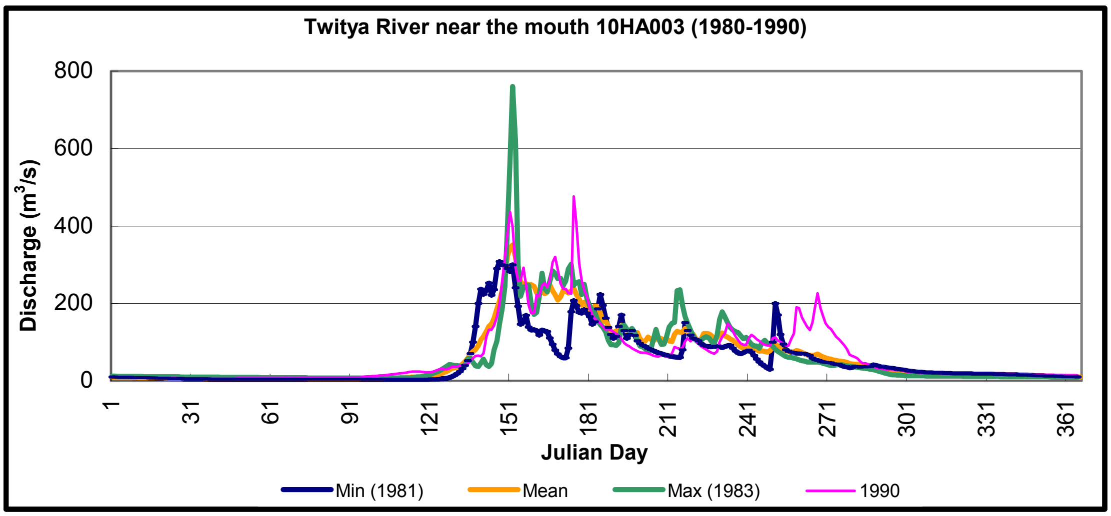


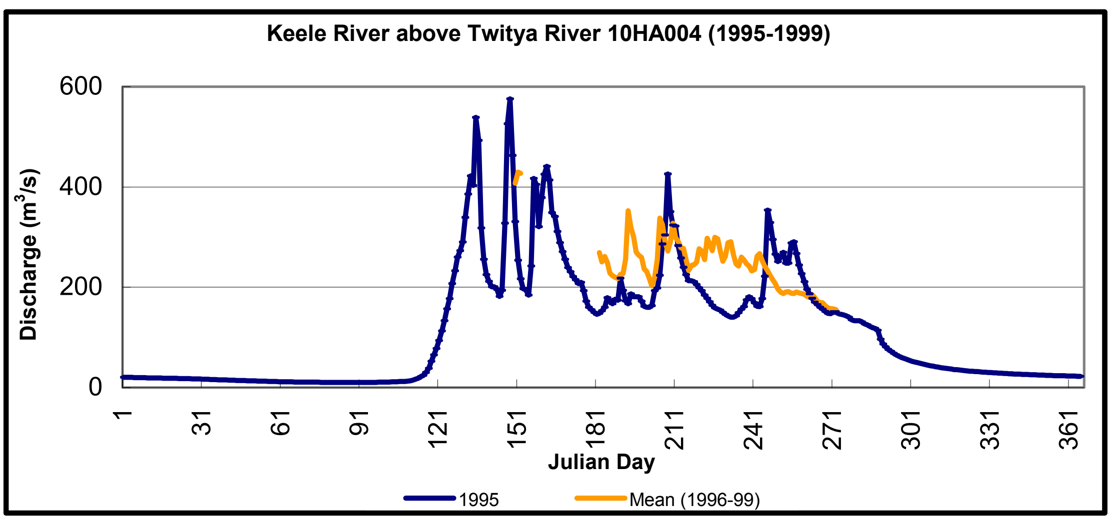
Whitefish River near the mouth 10JD002 (1977-1992)
Discharge (m3/s)
300
200
100
0
1
31
61
91
121
151
181
211
241
271
301
331
361
Julian Day
Min (1978)
Mean
Max (1980)
1988

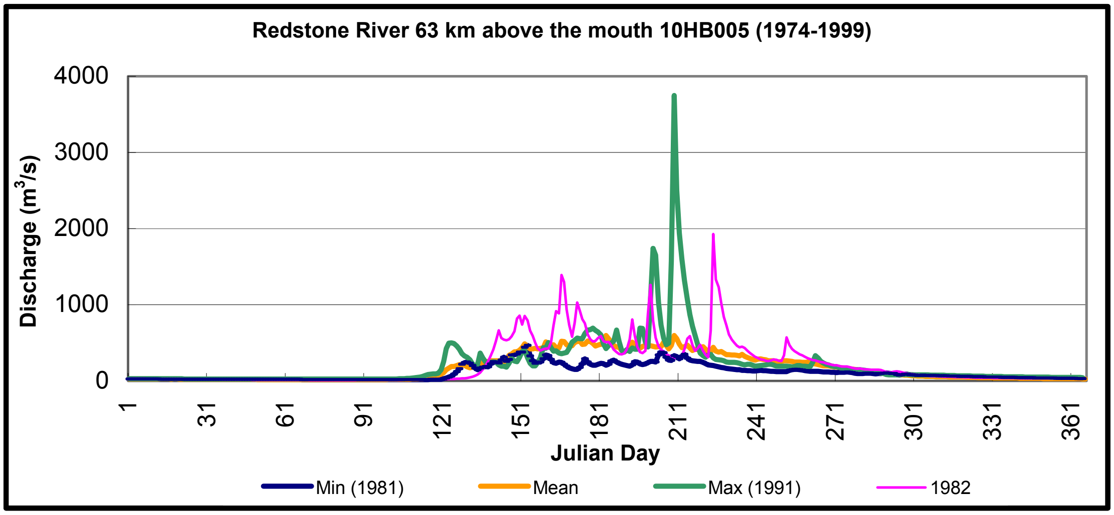


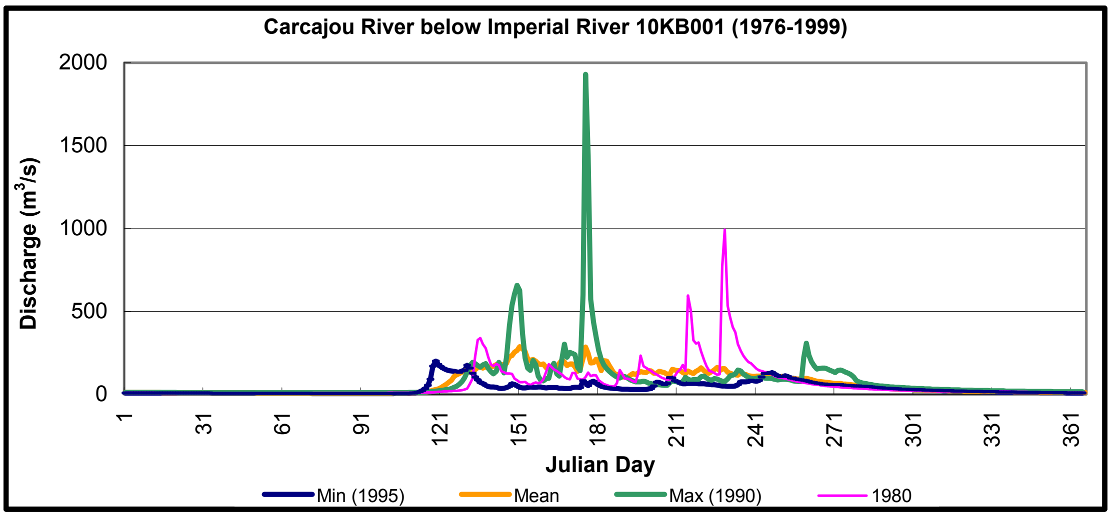
Sloan River near the mouth 10JE001 (1976-1991)
Discharge (m3/s)
200
150
100
50
0
1
31
61
91
121
151
181
211
241
271
301
331
361
Julian Day
Min (1990)
Mean
Max (1983)

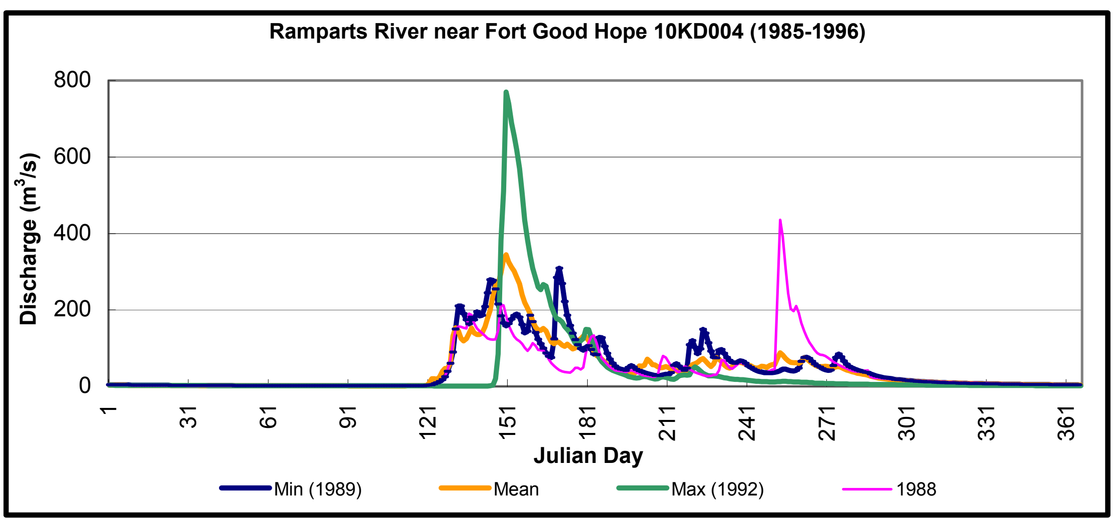

Tsichu River at Canol Road 10HA002 (1975-1992)
60
40
20
0
Discharge (m3/s)
1
31
61
91
121
151
181
211
241
271
301
331
361
Julian Day
Min (1977)
Mean
Max (1992)
1990

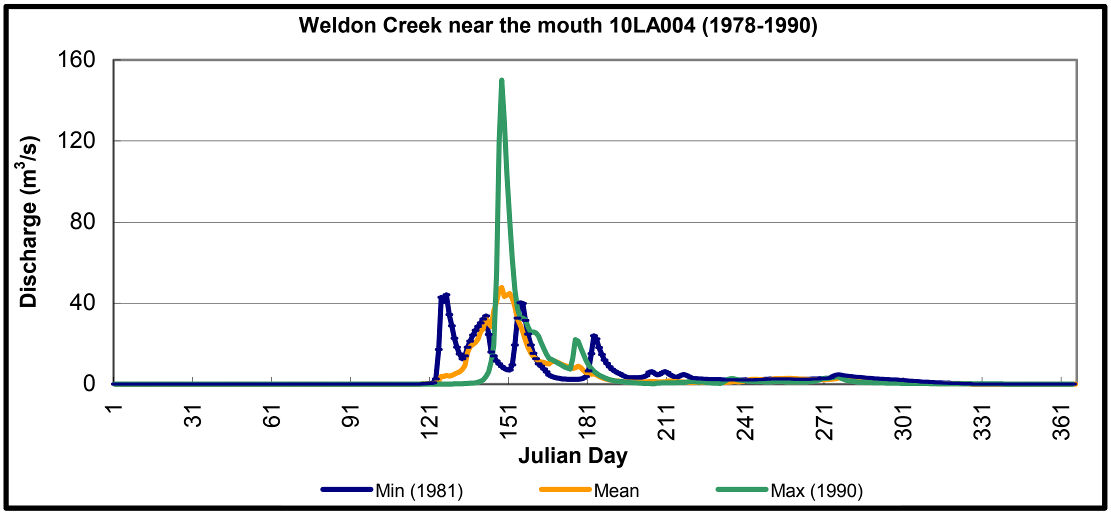

Twitya River near the mouth 10HA003 (1980-1990)
800
600
400
200
0
Discharge (m3/s)
1
31
61
91
121
151
181
211
241
271
301
331
361
Julian Day
Min (1981)
Mean
Max (1983)
1990

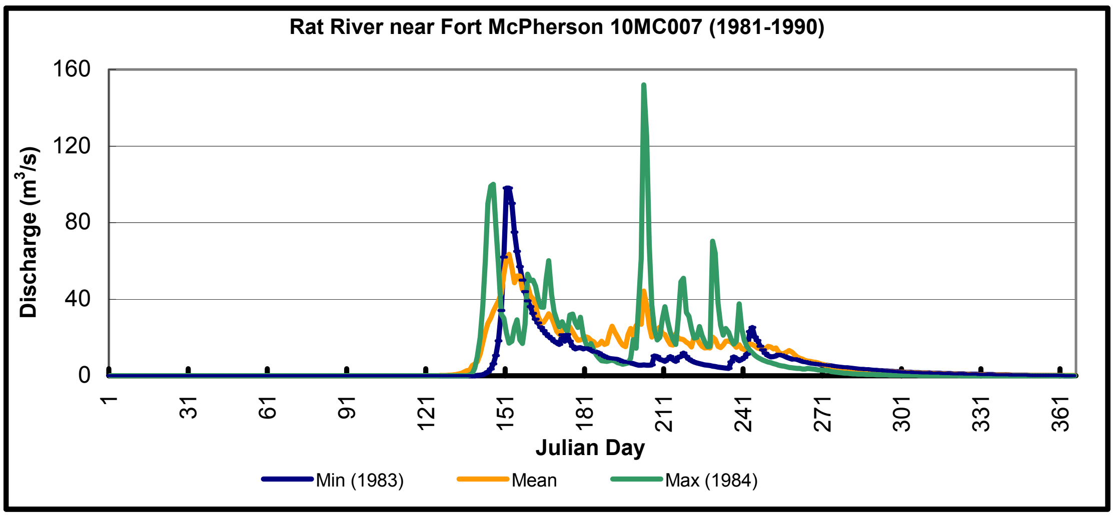

Keele River above Twitya River 10HA004 (1995-1999)
600
400
200
0
Discharge (m3/s)
1
31
61
91
121
151
181
211
241
271
301
331
361
Julian Day
1995
Mean (1996-99)

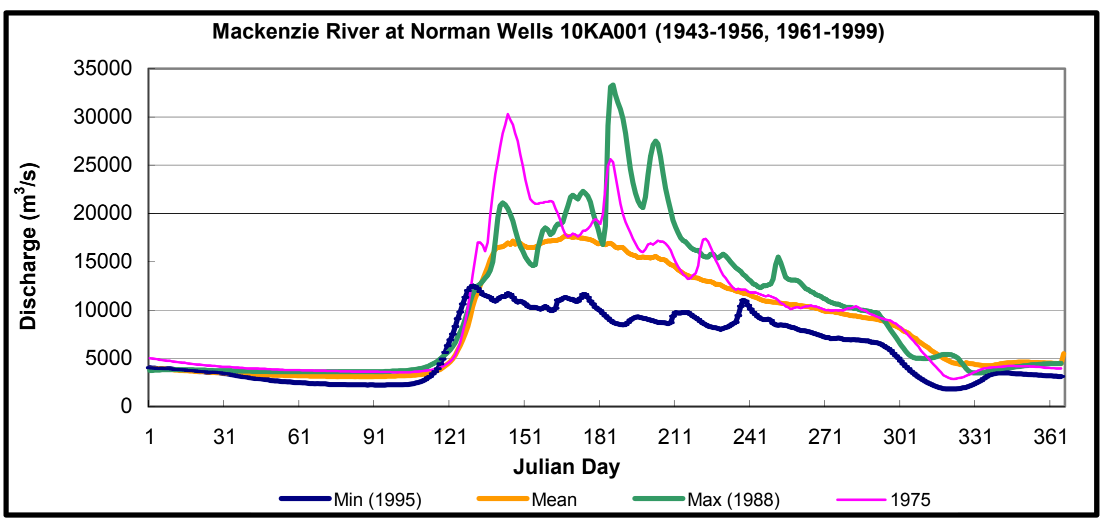

Redstone River 63 km above the mouth 10HB005 (1974-1999)
Discharge (m³/s)
4000
3000
2000
1000
0
1
31
61
91
121
151
181
211
241
271
301
331
361
Julian Day
Min (1981)
Mean
Max (1991)
1982


Carcajou River below Imperial River 10KB001 (1976-1999)
Discharge (m³/s)
2000
1500
1000
500
0
1
31
61
91
121
151
181
211
241
271
301
331
361
Julian Day
Min (1995)
Mean
Max (1990)
1980

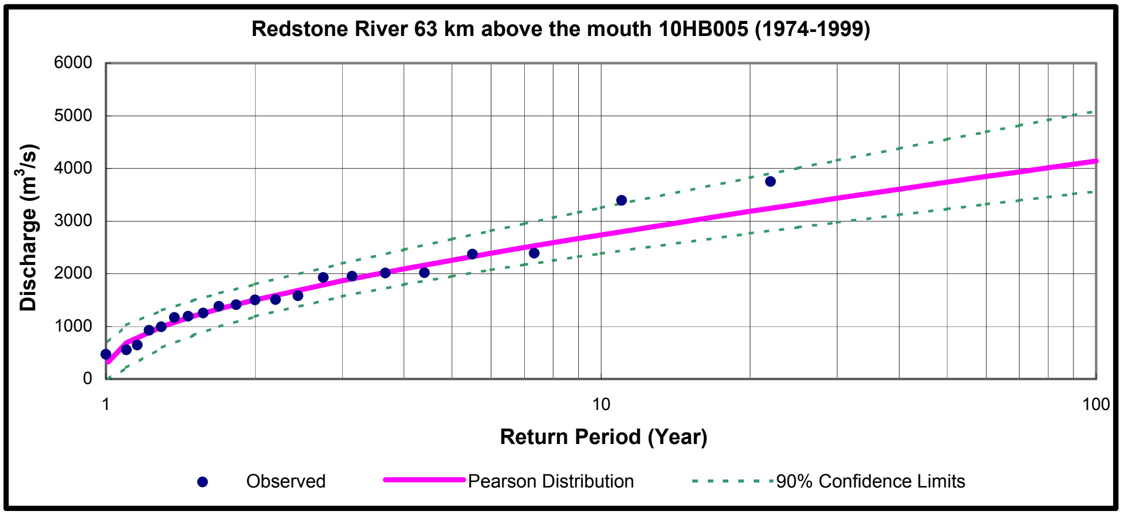

Ramparts River near Fort Good Hope 10KD004 (1985-1996)
Discharge (m³/s)
800
600
400
200
0
1
31
61
91
121
151
181
211
241
271
301
331
361
Julian Day
Min (1989)
Mean
Max (1992)
1988

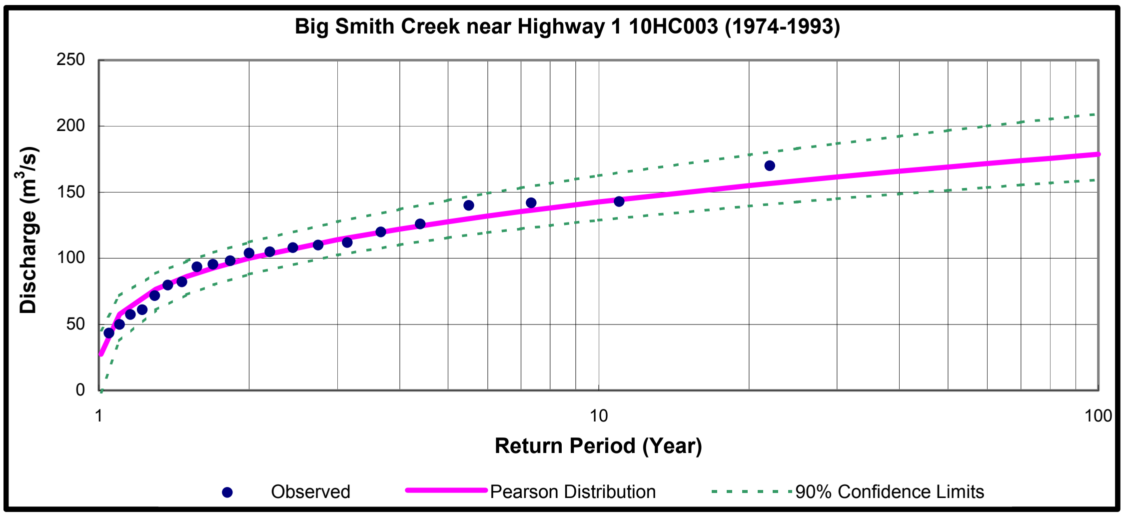

Weldon Creek near the mouth 10LA004 (1978-1990)
160
120
80
40
0
Discharge (m3/s)
1
31
61
91
121
151
181
211
241
271
301
331
361
Julian Day
Min (1981)
Mean
Max (1990)

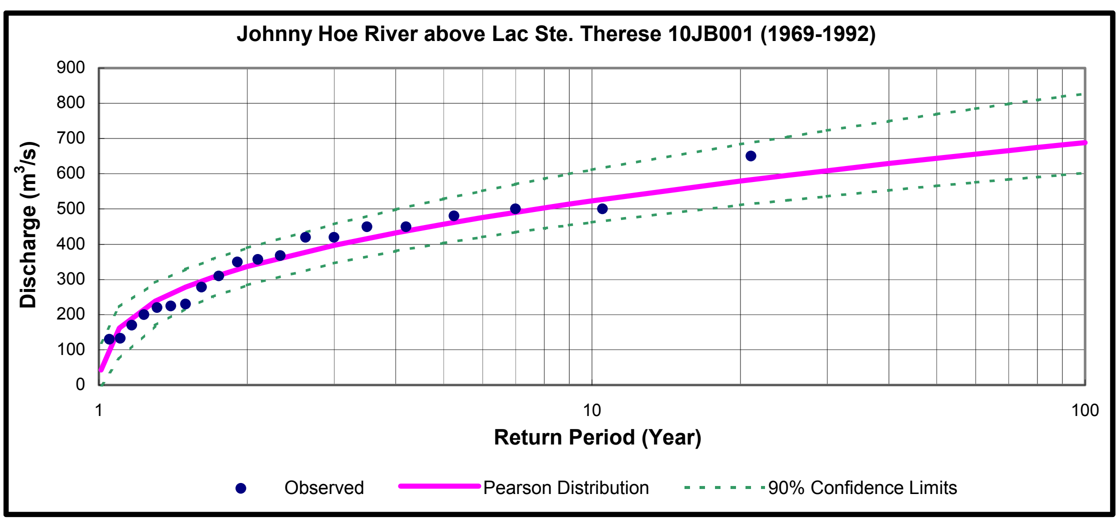

Rat River near Fort McPherson 10MC007 (1981-1990)
160
120
80
40
0
Discharge (m3/s)
1
31
61
91
121
151
181
211
241
271
301
331
361
Julian Day
Min (1983)
Mean
Max (1984)

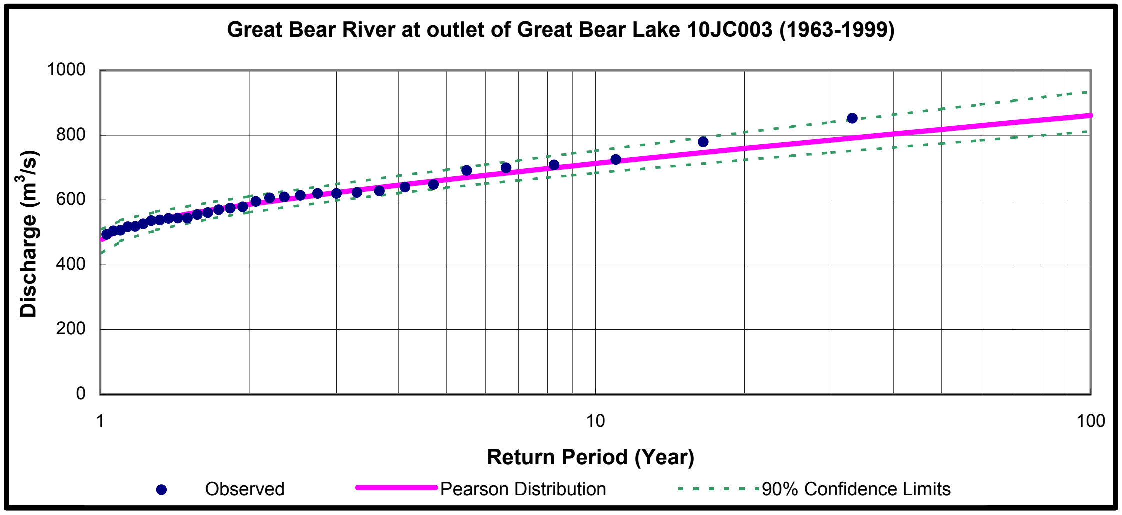

Mackenzie River at Norman Wells 10KA001 (1943-1956, 1961-1999)
35000
30000
25000
20000
15000
10000
5000
0
Discharge (m3/s)
1
31
61
91
121
151
181
211
241
271
301
331
361
Julian Day
Min (1995)
Mean
Max (1988)
1975

Appendix B. Flood Frequency Graphs

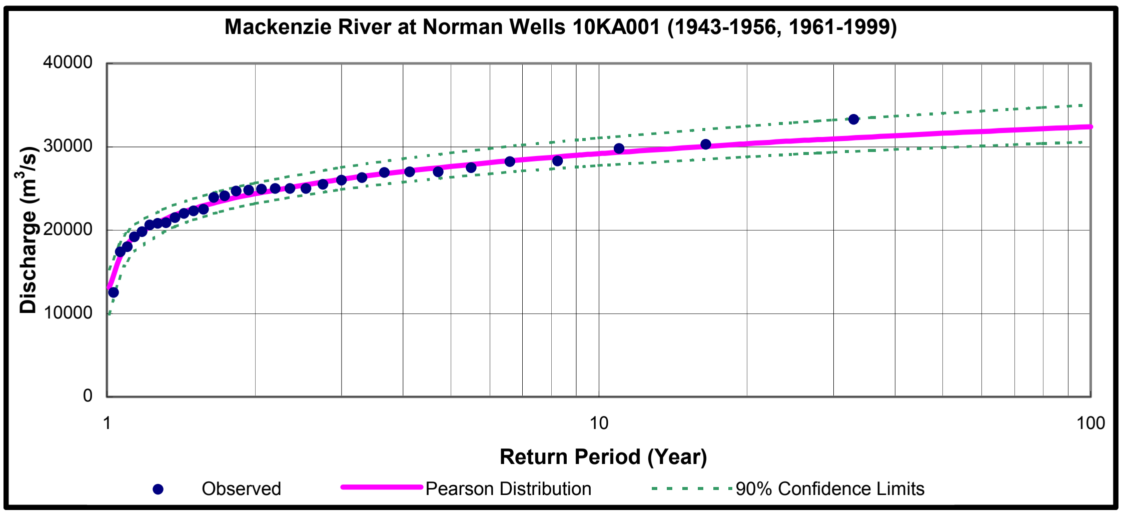




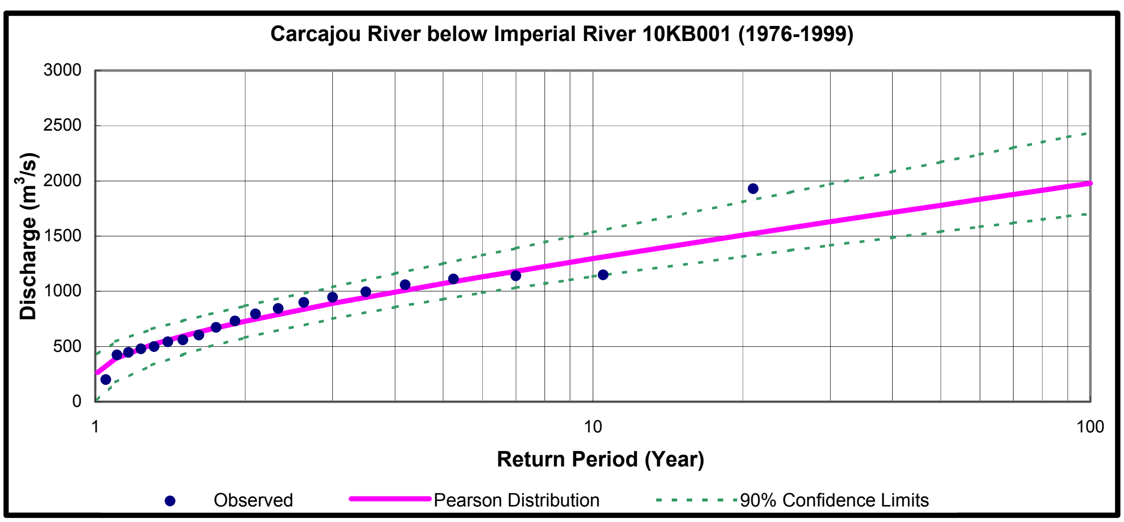




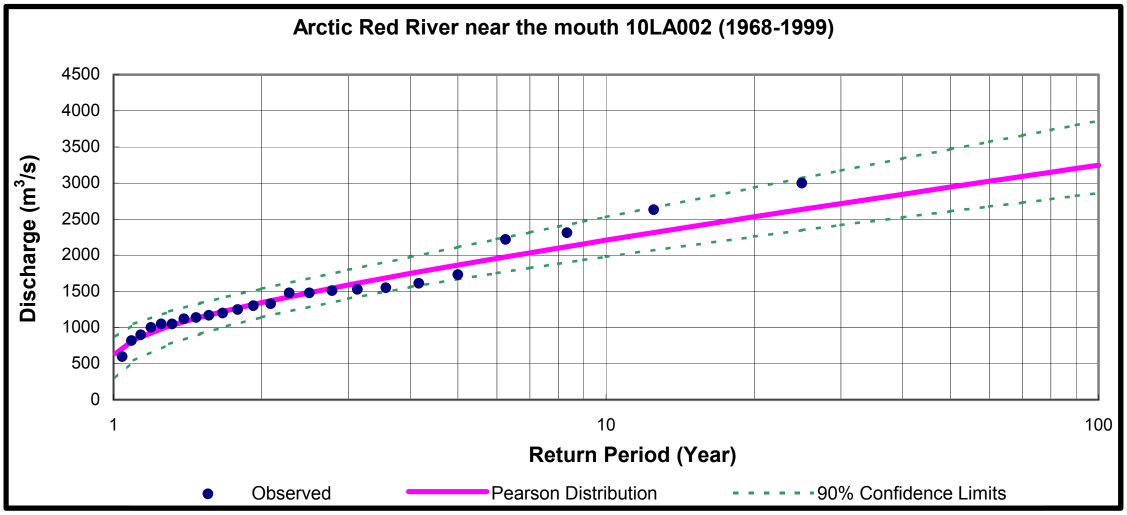
Great Bear River at outlet of Great Bear Lake 10JC003 (1963-1999)
1000
800
600
400
200
0
Discharge (m3/s)
1
10
100
Return Period (Year)
Observed
Pearson Distribution
90% Confidence Limits

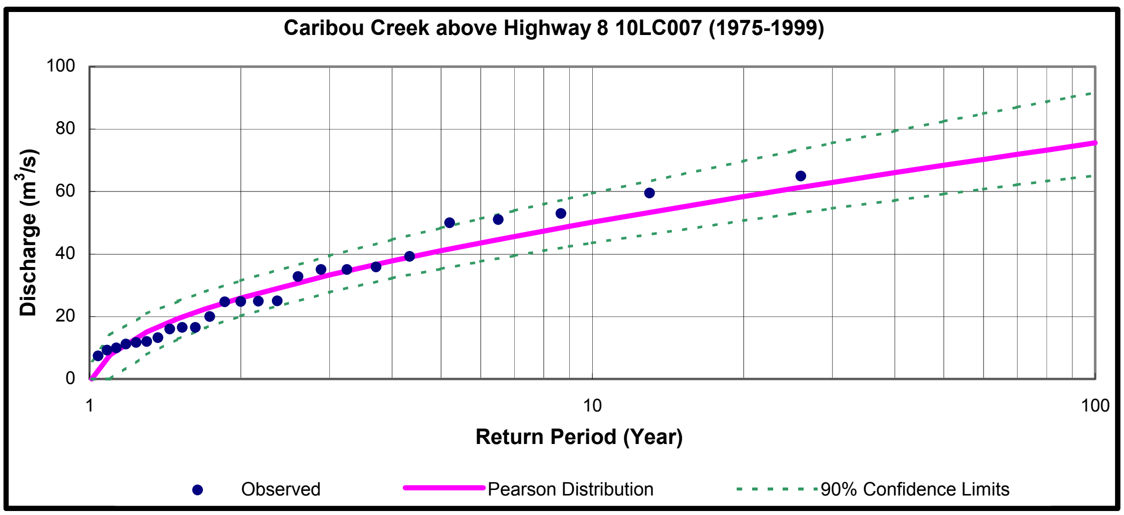


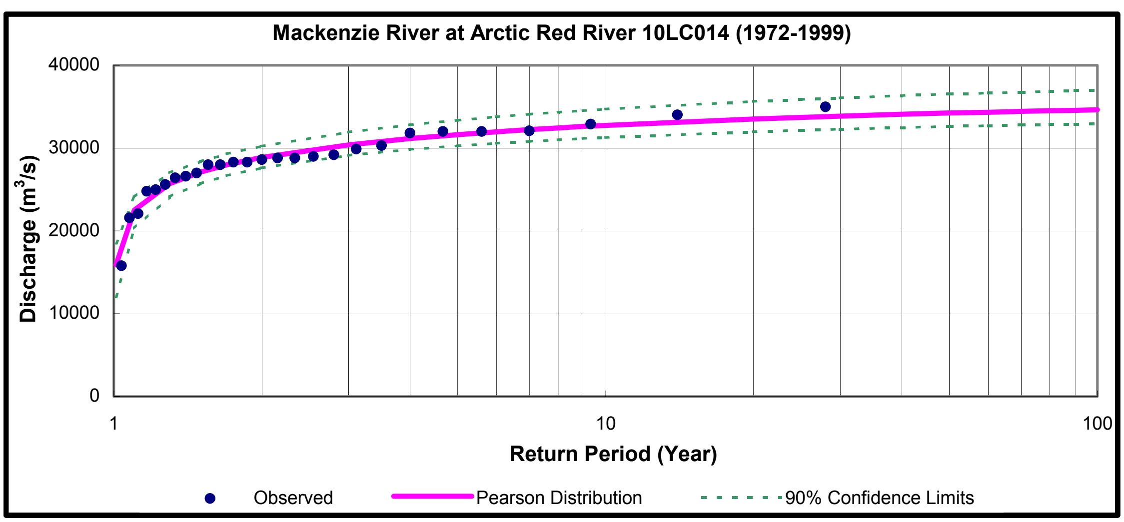
Mackenzie River at Norman Wells 10KA001 (1943-1956, 1961-1999)
40000
30000
20000
10000
0
Discharge (m3/s)
1
10
100
Return Period (Year)
Observed
Pearson Distribution
90% Confidence Limits

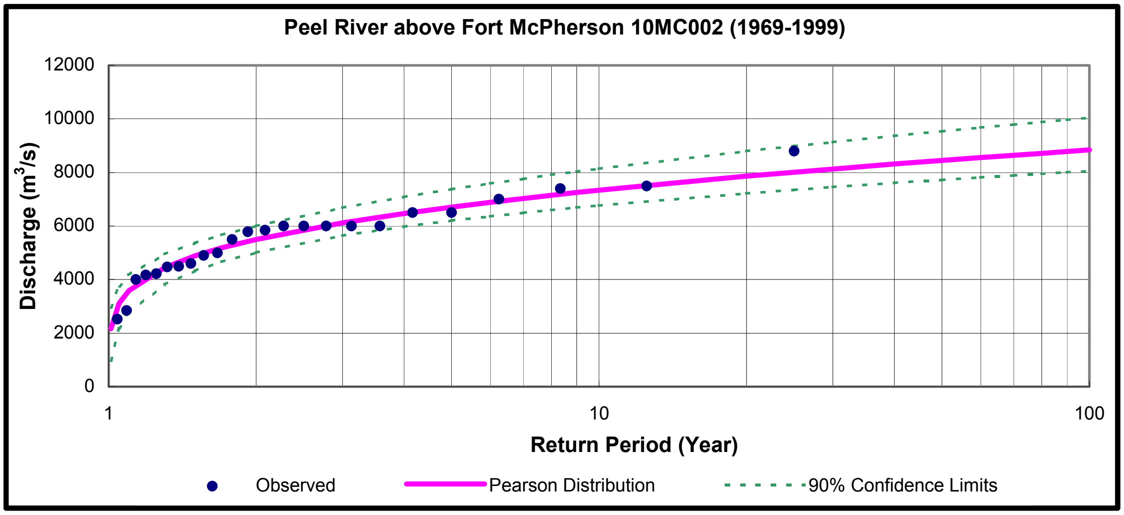


Carcajou River below Imperial River 10KB001 (1976-1999)
3000
2500
2000
1500
1000
500
0
Discharge (m3/s)
1
10
100
Return Period (Year)
Observed
Pearson Distribution
90% Confidence Limits


Arctic Red River near the mouth 10LA002 (1968-1999)
Discharge (m3/s)
4500
4000
3500
3000
2500
2000
1500
1000
500
0
1
10
100
Return Period (Year)
Observed
Pearson Distribution
90% Confidence Limits


Caribou Creek above Highway 8 10LC007 (1975-1999)
Discharge (m3/s)
100
80
60
40
20
0
1
10
100
Return Period (Year)
Observed
Pearson Distribution
90% Confidence Limits


Mackenzie River at Arctic Red River 10LC014 (1972-1999)
Discharge (m3/s)
40000
30000
20000
10000
0
1
10
100
Return Period (Year)
Observed
Pearson Distribution
90% Confidence Limits


Peel River above Fort McPherson 10MC002 (1969-1999)
12000
10000
8000
6000
4000
2000
0
Discharge (m3/s)
1
10
100
Return Period (Year)
Observed
Pearson Distribution
90% Confidence Limits