

**ANNEX I-E**

**THE CHUTES HYDRO PROJECT EA HYDROLOGY MEMO**

## Project Memo

March 3, 2011

TO: Nava Pokharel

FROM: Mark Orton and Jim Law

cc: H337950

**Xeneca Power Development Inc.  
The Chutes Hydro Project****EA Hydrology Memo****1. Introduction**

This memorandum presents the information requested by the Ministry of the Environment (MOE), under Hydrological Analysis, items a) to g) of Table 1, for the proposed The Chutes Hydro Project on the Ivanhoe River. The Chutes is located in Chapleau District of the Northeast Region of Ontario. The Ivanhoe River flows north and drains 2723 km<sup>2</sup> at The Chutes.

Figure 1 shows details of the sub-basins draining to The Chutes, while Figure 2 shows the hydrometeorological and hydrological station networks in the region.

A full listing of the hydrology requirements and the location in this document where they can be found are given in Appendix A. The stepwise procedures used to synthesize a long term daily flow series at The Chutes and the software used to extract the information presented herein are listed in Appendix B.

Table 1 lists the information required by the MOE under Hydrological Analysis (as per project correspondence).

These analyses of existing data have been undertaken in support of the ongoing Environmental Assessment process and should not be used in the detailed engineering design without further review.

Seasons are defined as:

Winter	January 1 to March 31	Julian Day 1 to 90
Spring	April 1 to June 30	Julian Day 91 to 181
Summer	July 1 to September 30	Julian Day 182 to 273
Fall	October 1 to December 31	Julian Day 274 to 365

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If you disagree with any information contained herein, please advise immediately.

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**Table 1 Information Required under Hydrological Analysis**

a)	Descriptive flow statistics using all available daily flows for all years: mean, median, minimum, maximum, flow exceeded 20% time, flow exceeded 80% time.
b)	Extreme low flow statistics: 7Q2 (2 year return period 7-day-average-low flow), 7Q10 (10 year return period 7-day-average-low flow) and 7Q20 (20 year return period 7-day-average-low flow).
c)	Flow duration curves and tables using total daily average flow data for the entire period, for all four seasons and for all twelve months.
d)	Flow duration curves and tables using daily baseflow data for the entire period, for all four seasons and for all twelve months.
e)	Flow duration curves derived using both the percentile method and the median of percentiles method. Both methods are incorporated into the flow analysis tool, developed by Schmidt and Metcalfe (2009), which can be downloaded for free from <a href="http://trentu.ca/iws/software.php">http://trentu.ca/iws/software.php</a> .
f)	Flood frequency analysis using instantaneous maximum flow of each year for the entire period of records.
g)	Low flow frequency analysis using 7-day-average-low flow for the entire period of records.
h)	Altered flow of the bypass reach and the reach below tailrace, if applicable.
i)	Compensation flow for the bypass reach and the reach below tailrace, if applicable.

## 2. Descriptive Flow Statistics

Descriptive flow statistics for the Ivanhoe River at The Chutes have been prepared using the Streamflow Analysis and Assessment Software (SAAS) from the Ontario Ministry of Natural Resources (MNR). Synthesis of the long term daily flow series for 1971-1994 is described in *Ivanhoe Hydropower Sites – Hydrology Review*, Hatch (2009). An additional three years of data for 2007 to 2009 is now available at Water Survey of Canada (WSC) streamflow station 04LC003, Ivanhoe River at Foleyet. Inclusion of these additional three years has lowered the long term average flow estimate at The Chutes slightly, but does not affect previous energy assessments .

Figure 3 shows the superimposed daily hydrographs from the 24- year period 1971-94 as well as for the median of each day of the year.

Table 2 shows the descriptive flow statistics using all available daily flows for all years.

**Table 2 Descriptive Mean Daily Flow Statistics for The Chutes**

Parameter	Value	Units	Date of Occurrence
Mean Flow	29.7	m <sup>3</sup> /s	-
Median Flow	18.9	m <sup>3</sup> /s	-
Minimum Flow	1.71	m <sup>3</sup> /s	9/4/1975
Maximum Flow	293	m <sup>3</sup> /s	5/12/1979
Flow Exceeded 20% time	38.0	m <sup>3</sup> /s	-
Flow Exceeded 80% time	10.5	m <sup>3</sup> /s	-
Number of Zero Flow Days	0	-	-

### 3. Extreme Low Flow Statistics

Low flow frequency analysis of 7-day average low flows has been undertaken using the Engsoft Low Flow Frequency Analysis software ESLOFFAN. This software reads the full daily flow series for The Chutes and creates a 7-day (or 30-day) average flow series. The annual minima of this average flow series are then extracted for low flow frequency analysis using the 2-parameter Lognormal, 3-parameter Lognormal, Log Pearson III and Gumbel distributions.

Table 3 shows the annual 7-day average flow minima for the Ivanhoe River at The Chutes.

Table 4 shows  $7Q_{T\text{-year}}$  extreme low flow statistics from the frequency analyses.

The four frequency distributions shown in Table 4 give similar annual 7-day average flow minima for the  $7Q_2$ ,  $7Q_{10}$  and  $7Q_{20}$  extreme low flow statistics. The Log Pearson III distribution appears to give the best fit to the data in Table 3. The extreme low flow estimates from the Log Pearson III distribution are:

- $7Q_2$      $4.42 \text{ m}^3/\text{s}$
- $7Q_{10}$      $2.49 \text{ m}^3/\text{s}$
- $7Q_{20}$      $2.09 \text{ m}^3/\text{s}$

**Table 3 Annual 7-day Average Flow Minima – Ivanhoe River at The Chutes**

Year	Month	7-day Average Flow (m <sup>3</sup> /s)
1971	9	4.50
1972	9	8.91
1973	7	9.57
1974	9	5.47
1975	9	1.76
1976	9	2.27
1977	8	2.39
1978	4	6.84
1979	8	5.37
1980	9	3.56
1981	9	2.91
1982	8	3.36
1983	8	4.83
1984	9	3.29
1985	9	3.43
1986	7	5.33
1987	9	2.99
1988	7	4.03
1989	9	3.69
1990	9	4.59
1991	8	4.51
1992	3	7.47
1993	9	7.54
1994	9	6.56

**Table 4 7-day Average Extreme Low Flow Statistics – Ivanhoe River at The Chutes**

Return Period (years)	Minimum 7-day Average Low Flow (m <sup>3</sup> /s)			
	2 Parameter LogNormal	3 Parameter LogNormal	Log Pearson Type III	Gumbel
2	4.38	4.38	<b>4.42</b>	4.44
5	3.03	3.03	3.04	3.09
10	2.50	2.50	<b>2.49</b>	2.52
20	2.13	2.13	<b>2.09</b>	2.10
50	1.78	1.79	1.71	1.68
100	1.58	1.59	1.48	1.42

## 4. Total Daily Average Flow Duration Curves

SAAS v2.1.1 has been used to generate flow duration curves using total daily flow for the entire period of record, for all four seasons and for all twelve months. These flow duration curves are shown in Figures 4 to 6, respectively.

The flow duration analysis results used to prepare Figures 4 to 6 are given in Tables 5 and 6.

**Table 5 Total Daily Average Flow Duration Analysis for All Four Seasons and the Period of Record**

Percent of Time Exceeded	Total Daily Average Flow (m <sup>3</sup> /s)				Period of Record
	Winter	Spring	Summer	Fall	
0.01	41.4	293	91.9	157	290
0.1	41.1	283	85.4	152	264
1	30.7	240	54.8	110	174
2	27.9	206	45.3	90.2	146
3	25.7	185	42.4	81.2	131
4	24.5	174	39.6	70.0	116
5	23.6	165	36.4	64.2	102
6	23.2	157	33.3	58.9	91.9
7	22.7	150	31.5	54.6	83.0
8	22.3	145	29.6	51.4	73.9
9	22.1	142	28.3	49.4	65.5
10	21.7	140	26.6	47.5	60.0
11	21.5	135	25.6	46.0	55.8
12	21.3	128	24.7	44.9	52.5
13	21.1	123	24.0	43.8	49.7
14	20.8	120	23.2	43.1	46.9
15	20.5	116	22.6	42.3	44.6
16	20.3	112	21.8	41.5	42.9
17	20.0	110	21.3	41.1	41.3
18	19.9	105	20.5	40.6	40.4
19	19.7	102	19.9	40.2	39.2
20	19.4	98.3	19.5	39.7	38.0
21	19.2	94.7	18.9	39.2	37.0
22	18.9	92.1	18.7	38.8	36.0
23	18.7	89.4	18.1	38.3	34.9
24	18.5	85.9	17.7	37.9	33.8
25	18.3	83.5	17.3	37.5	32.9
26	18.0	80.2	16.9	37.1	31.9
27	17.8	76.8	16.6	36.6	30.8
28	17.6	74.0	16.3	36.2	29.9
29	17.5	71.0	15.9	35.8	29.1
30	17.3	67.5	15.6	35.5	28.4
31	17.1	65.3	15.2	35.1	27.9
32	16.9	63.8	14.9	34.5	27.2
33	16.7	61.1	14.7	34.0	26.5
34	16.6	59.4	14.3	33.7	25.9
35	16.3	57.8	14.1	33.4	25.2
36	16.2	56.1	13.8	33.2	24.6
37	16.1	55.2	13.6	32.8	24.1
38	16.0	54.1	13.4	32.3	23.6

Percent of Time Exceeded	Total Daily Average Flow (m³/s)				Period of Record
	Winter	Spring	Summer	Fall	
39	15.8	53.0	13.1	31.8	23.1
40	15.7	51.9	12.9	31.4	22.7
41	15.5	50.7	12.6	30.9	22.2
42	15.3	49.3	12.3	30.5	21.8
43	15.2	47.9	12.2	30.0	21.4
44	15.0	46.7	11.9	29.6	21.0
45	14.9	45.0	11.7	29.2	20.6
46	14.8	43.9	11.6	28.8	20.2
47	14.6	42.9	11.4	28.6	19.9
48	14.5	41.6	11.1	28.4	19.6
49	14.3	40.5	11.0	28.1	19.2
50	14.1	39.5	10.8	27.9	18.9
51	14.0	38.8	10.6	27.6	18.5
52	13.8	37.4	10.4	27.4	18.2
53	13.6	36.5	10.2	27.1	17.9
54	13.5	35.4	10.0	26.9	17.6
55	13.4	34.4	9.86	26.5	17.2
56	13.2	33.3	9.70	26.2	16.9
57	13.1	32.1	9.49	25.9	16.6
58	13.0	31.2	9.30	25.5	16.3
59	12.8	30.1	9.10	25.2	16.0
60	12.7	29.5	8.92	24.8	15.8
61	12.5	29.0	8.78	24.5	15.4
62	12.4	28.1	8.66	24.2	15.2
63	12.3	27.4	8.53	23.9	14.9
64	12.2	26.8	8.34	23.6	14.7
65	12.1	25.9	8.17	23.4	14.3
66	12.0	25.1	7.98	23.2	14.1
67	11.9	24.5	7.77	22.9	13.8
68	11.7	24.0	7.61	22.7	13.5
69	11.6	23.3	7.46	22.4	13.2
70	11.5	22.3	7.28	22.1	12.9
71	11.4	21.7	7.01	21.8	12.6
72	11.3	20.5	6.81	21.5	12.4
73	11.1	19.8	6.60	21.2	12.2
74	11.0	19.4	6.44	20.9	11.9
75	10.8	18.8	6.23	20.6	11.7
76	10.7	18.3	6.03	20.3	11.5
77	10.6	17.9	5.86	20.0	11.3
78	10.5	17.2	5.70	19.7	11.0
79	10.3	16.9	5.49	19.5	10.7
80	10.2	16.4	5.36	19.2	10.5
81	10.0	16.0	5.25	18.9	10.2
82	9.94	15.5	5.13	18.6	9.98
83	9.83	15.0	4.98	18.3	9.74
84	9.70	14.7	4.89	18.1	9.49
85	9.58	14.4	4.75	17.9	9.25
86	9.47	14.0	4.66	17.5	8.97
87	9.37	13.5	4.57	16.9	8.70

Percent of Time Exceeded	Total Daily Average Flow (m³/s)					Period of Record
	Winter	Spring	Summer	Fall		
88	9.25	13.1	4.43	16.3		8.46
89	9.13	12.7	4.28	16.0		8.19
90	9.01	12.3	4.14	15.4		7.81
91	8.85	12.0	4.05	15.0		7.39
92	8.68	11.8	3.84	14.5		6.76
93	8.52	11.4	3.67	13.8		6.22
94	8.38	11.1	3.45	12.2		5.62
95	8.30	10.7	3.24	10.9		5.22
96	8.13	10.4	2.98	9.10		4.82
97	7.88	9.99	2.73	7.72		4.40
98	7.41	9.40	2.53	5.62		3.83
99	6.68	8.38	2.29	5.15		2.97
99.9	5.41	6.59	1.72	4.30		2.02

Table 6 Total Daily Average Flow Duration Analysis for All Twelve Months of the Year

Percent of Time Exceeded	Total Daily Average Flow (m³/s)											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.01	41.4	23.8	41.1	285	293	142	91.9	65.4	39.6	157	137	138
0.1	41.3	23.8	40.9	284	290	141	91.8	63.3	39.6	157	137	137
1	34.0	22.1	34.8	262	223	97.6	72.3	44.7	36.8	132	90.3	99.0
2	30.5	21.2	27.3	241	201	79.3	59.5	41.7	32.7	106	82.8	69.5
3	28.6	20.8	25.7	235	188	73.6	51.8	35.2	29.7	94.3	75.0	52.3
4	27.8	20.4	24.9	213	179	66.9	48.5	31.6	26.4	88.5	67.2	49.4
5	26.6	20.2	22.6	191	175	64.7	45.2	28.2	24.8	82.2	62.8	47.0
6	25.2	20.0	21.8	183	170	61.7	44.4	25.5	23.6	74.8	59.6	45.9
7	24.7	19.9	21.5	172	164	59.5	42.4	24.5	22.7	68.1	57.3	44.7
8	24.3	19.8	21.1	166	160	58.0	41.0	24.1	21.2	64.3	55.1	43.8
9	24.0	19.7	20.5	159	156	56.6	40.2	23.5	20.0	60.1	53.5	43.2
10	23.6	19.4	19.2	151	152	56.0	37.9	22.9	19.3	53.3	51.7	42.9
11	23.4	19.3	18.7	147	149	55.3	36.4	22.3	18.7	51.1	50.1	42.2
12	23.2	19.0	18.4	145	147	54.3	35.6	21.8	18.1	49.2	47.8	41.5
13	23.0	18.7	18.0	143	144	53.4	33.1	21.3	17.6	47.6	46.2	41.3
14	22.8	18.3	17.6	141	140	52.5	32.0	20.5	17.2	46.0	45.1	41.1
15	22.7	18.0	17.4	140	137	52.0	30.9	20.0	16.9	45.3	43.8	41.0
16	22.5	17.8	16.9	138	135	51.3	29.7	19.5	16.3	43.7	43.3	40.6
17	22.4	17.5	16.3	131	131	50.6	29.4	18.9	15.6	42.6	42.3	40.5
18	22.2	17.3	16.0	124	128	49.9	28.9	18.6	15.2	41.7	41.1	40.3
19	22.1	17.1	15.8	121	124	48.7	28.3	18.0	15.0	40.8	40.4	39.7
20	21.9	17.0	15.4	116	123	47.2	26.9	17.6	14.8	39.8	39.9	39.5
21	21.8	16.8	15.1	114	121	46.5	26.2	16.9	14.5	38.9	39.1	39.3
22	21.6	16.7	14.9	110	120	45.3	25.9	16.8	14.1	38.3	38.4	39.1
23	21.5	16.6	14.7	105	119	44.8	25.2	16.5	13.9	37.6	38.0	38.8
24	21.5	16.4	14.4	99.7	116	43.9	24.6	16.3	13.5	36.7	37.5	38.5
25	21.3	16.3	14.3	96.2	113	43.4	24.0	16.0	13.1	36.0	37.0	38.1
26	21.2	16.2	14.0	93.7	112	42.0	23.3	15.7	13.0	35.6	36.6	37.9
27	21.1	16.2	13.9	91.1	111	41.2	22.8	15.5	12.7	34.8	36.4	37.7

Percent of Time Exceeded	Total Daily Average Flow (m³/s)											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
28	21.0	16.0	13.7	87.0	109	40.5	22.1	15.2	12.3	34.0	36.1	37.4
29	20.8	15.9	13.5	84.3	107	39.6	21.6	15.0	12.2	33.7	35.8	37.2
30	20.7	15.8	13.5	82.0	105	39.0	21.3	14.8	11.9	33.5	35.6	37.0
31	20.6	15.6	13.4	76.9	103	37.9	20.7	14.7	11.7	33.2	35.5	36.4
32	20.5	15.5	13.2	74.3	102	37.3	20.0	14.2	11.5	32.7	35.3	36.0
33	20.3	15.4	13.0	68.8	101	36.9	19.7	13.9	11.4	32.4	34.8	35.4
34	20.2	15.3	12.9	63.9	98.8	36.3	19.4	13.8	11.0	32.0	34.4	34.7
35	20.0	15.2	12.8	59.8	96.5	35.4	19.1	13.6	10.9	31.4	34.1	34.3
36	19.9	15.2	12.6	56.3	94.7	34.8	18.8	13.5	10.7	30.6	33.8	33.9
37	19.7	15.0	12.5	54.0	92.6	34.3	18.5	13.3	10.6	30.4	33.6	33.6
38	19.6	14.9	12.5	52.3	91.9	33.4	18.1	13.1	10.5	30.0	33.3	33.3
39	19.5	14.9	12.4	49.7	90.4	32.7	17.7	12.9	10.2	29.3	33.0	33.0
40	19.3	14.7	12.3	45.1	89.4	31.7	17.3	12.6	9.96	28.9	32.8	32.3
41	19.2	14.5	12.2	43.7	86.6	31.3	17.1	12.5	9.81	28.6	32.3	32.0
42	19.0	14.3	12.1	41.5	85.6	30.8	16.7	12.3	9.67	28.3	31.3	31.7
43	18.9	14.1	12.1	40.2	84.1	30.1	16.5	12.0	9.38	28.0	30.6	31.5
44	18.7	13.9	12.0	39.3	82.8	29.8	16.1	11.8	9.15	27.7	30.0	31.1
45	18.6	13.7	11.9	37.5	80.1	29.5	15.8	11.7	8.98	27.4	29.7	30.9
46	18.5	13.6	11.9	34.6	78.3	29.3	15.3	11.5	8.81	27.1	29.1	30.5
47	18.3	13.4	11.7	33.2	76.0	29.0	14.8	11.3	8.71	26.8	28.8	30.1
48	18.2	13.3	11.7	32.3	74.2	28.4	14.4	11.1	8.61	26.2	28.5	29.7
49	18.0	13.1	11.6	30.9	72.5	28.0	14.1	10.9	8.49	25.9	28.2	29.4
50	17.8	13.1	11.6	29.3	71.1	27.5	14.0	10.8	8.19	25.6	27.9	29.1
51	17.7	13.0	11.5	28.0	69.8	27.2	13.7	10.7	8.01	25.4	27.7	28.8
52	17.6	12.8	11.4	27.4	68.8	26.3	13.6	10.5	7.78	24.9	27.6	28.7
53	17.5	12.7	11.3	26.5	67.3	26.0	13.3	10.3	7.59	24.6	27.1	28.5
54	17.4	12.6	11.2	25.6	65.8	25.6	13.0	10.2	7.48	24.2	26.8	28.3
55	17.3	12.5	11.1	24.8	64.5	25.1	12.5	9.99	7.12	24.0	26.4	28.2
56	17.2	12.4	10.9	24.4	63.6	24.7	12.3	9.85	6.82	23.7	26.1	27.9
57	17.1	12.3	10.7	24.2	62.3	24.2	12.1	9.67	6.61	23.2	25.7	27.7
58	16.9	12.1	10.6	23.3	60.7	23.7	11.9	9.53	6.55	22.3	25.0	27.4
59	16.8	12.1	10.5	22.3	59.3	23.1	11.8	9.39	6.45	21.8	24.7	27.3
60	16.7	12.0	10.4	21.6	58.0	22.5	11.6	9.24	6.29	21.2	24.4	27.2
61	16.6	11.9	10.2	19.7	56.4	21.7	11.5	9.07	6.15	20.9	24.3	26.9
62	16.4	11.8	10.1	19.3	55.7	21.1	11.2	8.89	5.96	20.6	24.0	26.9
63	16.3	11.7	10.1	18.5	55.0	20.5	11.0	8.73	5.89	20.4	23.6	26.6
64	16.1	11.6	9.99	18.2	54.1	20.1	10.8	8.58	5.80	20.1	23.2	26.2
65	16.1	11.5	9.96	17.8	52.9	19.7	10.5	8.45	5.61	19.6	23.0	26.0
66	16.0	11.4	9.89	17.2	51.8	19.5	10.2	8.25	5.47	19.4	22.5	25.7
67	15.9	11.3	9.82	17.0	50.2	19.2	10.0	8.06	5.34	19.1	22.1	25.4
68	15.8	11.1	9.74	16.6	49.1	18.8	9.87	7.86	5.27	18.8	21.7	25.0
69	15.7	11.0	9.68	16.3	48.4	18.2	9.67	7.72	5.16	18.4	21.4	24.8
70	15.5	11.0	9.63	16.2	47.2	18.0	9.46	7.65	5.07	18.2	21.1	24.5
71	15.4	10.9	9.55	15.7	46.4	17.6	9.26	7.44	4.96	18.0	20.9	24.0
72	15.2	10.8	9.49	15.3	44.2	17.2	8.94	7.25	4.91	17.8	20.7	23.7
73	15.0	10.8	9.45	15.0	43.5	16.9	8.86	6.98	4.82	17.7	20.5	23.6
74	15.0	10.7	9.39	14.8	42.0	16.4	8.74	6.79	4.71	17.2	20.3	23.5
75	14.8	10.6	9.35	14.5	40.9	16.2	8.60	6.52	4.67	17.1	20.1	23.4
76	14.7	10.5	9.28	14.2	40.0	15.9	8.48	6.42	4.60	16.8	20.0	23.2

Percent of Time Exceeded	Total Daily Average Flow (m³/s)											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
77	14.6	10.4	9.22	14.0	38.6	15.4	8.28	6.23	4.56	16.6	19.7	23.1
78	14.5	10.4	9.13	13.6	37.8	15.1	8.11	6.03	4.50	16.4	19.6	22.9
79	14.4	10.2	9.04	13.3	36.6	14.9	7.95	5.84	4.43	16.2	19.2	22.8
80	14.2	10.1	8.98	12.9	35.6	14.7	7.73	5.75	4.35	16.1	19.0	22.7
81	14.1	10.0	8.88	12.7	34.4	14.7	7.51	5.55	4.26	15.8	18.9	22.6
82	13.9	9.88	8.78	12.5	32.3	14.3	7.40	5.43	4.16	15.4	18.7	22.5
83	13.8	9.79	8.66	12.2	31.4	14.1	7.28	5.26	4.09	15.2	18.6	22.3
84	13.7	9.69	8.59	12.0	29.8	13.7	7.04	5.17	4.00	15.1	18.3	22.1
85	13.4	9.55	8.47	11.8	28.8	13.5	6.86	4.98	3.87	14.8	18.2	22.0
86	13.3	9.42	8.41	11.6	27.3	13.2	6.70	4.87	3.69	14.5	18.1	21.8
87	13.2	9.32	8.37	11.4	26.7	12.9	6.24	4.78	3.56	14.2	18.0	21.7
88	13.0	9.20	8.33	11.2	25.1	12.5	5.88	4.68	3.42	13.3	17.8	21.5
89	12.9	9.13	8.29	11.0	24.0	12.3	5.63	4.46	3.33	11.8	17.1	21.1
90	12.6	9.04	8.16	10.7	23.1	12.1	5.39	4.19	3.26	11.1	16.5	20.6
91	12.5	8.91	7.94	10.5	21.8	12.0	5.31	4.00	3.16	9.55	16.0	20.2
92	12.3	8.79	7.88	10.4	20.5	11.8	5.01	3.79	3.03	9.16	15.6	19.7
93	12.0	8.69	7.71	10.3	19.8	11.6	4.94	3.68	2.85	8.41	14.9	19.5
94	11.7	8.61	7.44	10.0	18.9	11.3	4.70	3.51	2.77	7.99	14.6	18.9
95	11.3	8.44	7.16	9.57	18.2	11.0	4.61	3.26	2.72	7.46	14.3	18.4
96	10.9	8.34	6.88	9.07	17.1	10.7	4.40	2.77	2.54	6.29	8.48	13.2
97	10.6	8.24	6.71	8.54	15.9	10.3	4.16	2.60	2.32	5.44	6.00	12.6
98	10.4	8.16	6.61	7.84	12.9	9.76	4.11	2.52	2.27	5.10	5.47	11.9
99	9.96	7.93	5.82	7.42	10.3	9.14	3.77	2.35	1.95	4.81	5.15	11.3
99.9	9.42	7.64	5.36	6.38	7.09	8.38	2.85	1.95	1.71	4.26	5.00	9.23
99.99	9.37	7.61	5.35	6.37	7.08	8.36	2.80	1.92	1.71	4.25	4.99	9.12

## 5. Daily Average Baseflow Flow Duration Curves

SAAS v2.1.1 separates baseflow using a recursive digital filtering procedure. The resulting daily average baseflow series is tabulated by SAAS and has been used to generate baseflow flow duration curves for the entire period of record, for all four seasons and for all twelve months. These baseflow flow duration curves are shown in Figures 7 to 9, respectively.

The flow duration analysis results used to prepare Figures 7 to 9 are given in Tables 7 and 8.

**Table 7 Daily Average Baseflow Flow Duration Analysis for All Four Seasons and the Period of Record**

Percent of Time Exceeded	Daily Average Baseflow (m <sup>3</sup> /s)				
	Winter	Spring	Summer	Fall	Period of Record
0.01	25.2	83.4	34.4	62.1	83.4
0.1	24.8	82.9	32.5	61.5	81.3
1	22.0	76.7	27.5	45.8	61.5
2	20.5	70.3	23.3	41.6	55.0
3	19.9	64.6	19.7	40.2	48.8
4	19.3	61.3	18.4	37.7	45.0
5	18.7	58.7	17.2	36.2	41.6
6	18.4	56.9	16.9	35.6	39.9
7	17.8	56.0	16.2	34.7	37.2
8	17.6	53.8	15.9	33.6	35.7
9	17.3	52.6	15.5	33.1	34.2
10	17.2	50.8	15.1	32.7	32.7
11	16.9	49.2	14.8	32.3	31.6
12	16.5	48.2	14.5	31.7	30.4
13	16.3	46.9	14.1	31.1	29.1
14	16.0	45.9	13.7	30.3	28.0
15	15.8	44.8	13.4	29.6	27.0
16	15.8	43.7	13.2	29.2	26.0
17	15.6	42.6	12.8	28.7	25.1
18	15.4	41.6	12.4	28.1	24.3
19	15.2	40.6	12.1	27.7	23.7
20	15.0	40.3	11.8	27.1	23.0
21	14.8	39.7	11.5	26.7	22.4
22	14.6	38.6	11.3	26.3	21.8
23	14.4	37.8	11.0	25.8	21.2
24	14.3	37.1	10.7	25.4	20.5
25	14.2	36.4	10.5	25.1	20.1
26	14.0	35.9	10.3	24.7	19.6
27	13.9	35.4	10.2	24.5	19.2
28	13.7	34.6	10.1	24.2	18.8
29	13.6	33.9	9.93	23.9	18.5
30	13.5	33.2	9.79	23.6	18.2
31	13.4	32.4	9.51	23.3	17.9
32	13.3	31.6	9.29	23.1	17.7
33	13.2	30.9	9.12	22.8	17.4
34	13.1	30.2	8.95	22.6	17.1
35	13.0	29.3	8.83	22.5	16.8
36	12.9	28.7	8.73	22.1	16.4
37	12.9	28.0	8.60	21.7	16.1
38	12.8	27.3	8.48	21.4	15.9
39	12.7	26.7	8.37	21.1	15.6
40	12.6	26.1	8.21	20.8	15.3
41	12.5	25.3	8.12	20.5	15.0
42	12.4	24.6	8.01	20.3	14.8
43	12.3	24.1	7.90	20.0	14.5
44	12.3	23.7	7.77	19.7	14.3

Percent of Time Exceeded	Daily Average Baseflow (m³/s)					Period of Record
	Winter	Spring	Summer	Fall		
45	12.2	22.9	7.64	19.5		14.1
46	12.1	22.4	7.56	19.3		13.8
47	12.1	22.0	7.48	19.1		13.6
48	12.0	21.5	7.42	18.9		13.4
49	11.9	21.1	7.39	18.7		13.2
50	11.8	20.4	7.28	18.6		13.0
51	11.7	20.1	7.19	18.5		12.8
52	11.6	19.6	7.05	18.3		12.6
53	11.6	19.2	6.92	18.2		12.5
54	11.5	18.8	6.80	18.0		12.3
55	11.4	18.4	6.72	18.0		12.1
56	11.3	18.1	6.53	17.9		12.0
57	11.3	17.8	6.43	17.8		11.8
58	11.2	17.4	6.33	17.7		11.7
59	11.1	17.0	6.26	17.5		11.5
60	11.0	16.5	6.18	17.3		11.3
61	10.8	16.2	6.06	17.1		11.2
62	10.7	15.8	5.92	16.9		11.0
63	10.5	15.4	5.73	16.7		10.7
64	10.4	15.0	5.55	16.5		10.5
65	10.3	14.6	5.42	16.2		10.3
66	10.1	14.2	5.34	16.0		10.1
67	10.0	14.0	5.26	15.7		9.95
68	9.96	13.6	5.16	15.4		9.80
69	9.90	13.3	5.06	15.2		9.62
70	9.80	13.0	5.00	14.9		9.48
71	9.72	12.8	4.89	14.6		9.31
72	9.62	12.5	4.79	14.4		9.15
73	9.54	12.3	4.74	14.2		9.02
74	9.49	12.1	4.66	14.1		8.87
75	9.41	12.0	4.61	14.0		8.71
76	9.29	11.9	4.52	13.7		8.56
77	9.21	11.7	4.44	13.5		8.39
78	9.13	11.6	4.38	13.1		8.30
79	9.03	11.4	4.29	12.8		8.16
80	8.96	11.2	4.22	12.3		8.00
81	8.91	11.1	4.15	12.0		7.81
82	8.80	10.9	4.10	11.6		7.56
83	8.69	10.6	3.98	11.1		7.41
84	8.60	10.3	3.85	10.6		7.17
85	8.51	10.1	3.73	10.1		6.87
86	8.43	9.91	3.57	9.58		6.62
87	8.36	9.75	3.45	9.19		6.37
88	8.32	9.58	3.35	8.71		6.07
89	8.29	9.46	3.28	8.23		5.61
90	8.26	9.30	3.21	7.61		5.33
91	8.19	9.13	3.15	6.97		5.02
92	8.05	9.03	3.10	6.50		4.75
93	7.97	8.82	2.92	5.94		4.53

Percent of Time Exceeded	Daily Average Baseflow (m³/s)					Period of Record
	Winter	Spring	Summer	Fall		
94	7.87	8.61	2.79	5.46		4.27
95	7.79	8.36	2.55	4.96		4.01
96	7.44	8.03	2.32	4.66		3.56
97	7.10	7.59	2.22	4.27		3.26
98	6.68	7.16	2.14	3.64		2.94
99	6.42	6.51	1.86	3.02		2.30
99.9	5.35	5.41	1.71	2.34		1.71

Table 8 Daily Average Baseflow Flow Duration Analysis for All Twelve Months of the Year

Percent of Time Exceeded	Daily Average Baseflow (m³/s)											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.01	25.2	17.7	17.4	76.2	83.4	77.4	34.4	18.4	16.2	45.1	55.9	62.1
0.1	25.1	17.7	17.2	75.7	83.3	76.9	34.1	18.4	16.2	45.0	55.5	62.0
1	24.1	17.6	15.9	62.6	81.4	56.4	30.9	17.2	15.4	39.2	46.0	58.4
2	23.1	17.5	15.3	56.3	79.4	45.3	29.6	16.1	15.1	33.1	43.6	44.1
3	21.9	17.4	14.7	53.6	75.2	43.0	27.5	15.7	14.9	31.2	41.8	37.6
4	21.4	17.1	14.3	50.9	72.7	41.6	27.1	15.3	14.8	30.1	40.7	36.4
5	20.9	16.7	13.8	48.5	70.4	40.9	25.3	14.8	14.5	28.2	40.4	35.7
6	20.5	16.1	13.6	45.6	68.5	40.5	23.3	14.3	12.1	27.5	40.2	35.4
7	20.2	15.7	13.3	43.0	66.2	40.2	21.7	14.0	11.5	26.3	38.4	35.0
8	20.1	15.5	13.0	40.9	63.3	40.1	20.2	13.7	11.1	25.6	37.6	34.5
9	19.9	15.3	12.8	38.0	61.8	39.1	19.7	13.2	10.9	25.0	36.6	33.9
10	19.7	15.1	12.7	36.2	61.1	38.4	19.1	12.9	10.6	24.3	36.0	33.2
11	19.5	15.0	12.6	34.1	60.0	37.3	18.9	12.6	10.3	23.7	35.7	33.1
12	19.3	14.8	12.6	32.9	59.2	37.0	18.4	12.4	10.2	22.9	34.7	32.7
13	19.1	14.7	12.5	31.9	58.2	36.4	17.8	12.2	10.0	22.2	33.7	32.6
14	18.9	14.5	12.4	31.1	57.5	35.7	17.2	12.0	9.96	21.5	33.4	32.3
15	18.7	14.4	12.3	30.3	56.9	35.2	17.1	11.8	9.86	21.3	32.7	32.0
16	18.6	14.3	12.3	29.0	56.5	34.6	17.0	11.7	9.33	20.9	32.6	31.7
17	18.5	14.2	12.2	28.1	56.3	33.9	16.8	11.7	9.09	20.7	32.4	31.3
18	18.4	14.1	12.2	27.6	55.6	33.3	16.4	11.3	8.82	20.4	31.6	30.9
19	18.2	14.0	12.1	26.6	54.7	32.7	16.2	11.1	8.67	20.0	31.0	30.3
20	18.0	13.9	12.1	25.8	53.7	32.0	15.9	10.7	8.60	19.5	29.4	29.9
21	17.8	13.8	12.0	24.7	53.2	31.3	15.8	10.6	8.41	19.1	29.1	29.7
22	17.6	13.7	12.0	24.1	52.6	30.4	15.6	10.4	8.18	18.9	28.7	29.5
23	17.5	13.6	11.9	23.7	51.5	29.8	15.3	10.1	8.11	18.6	28.4	29.2
24	17.3	13.6	11.8	22.4	51.0	29.3	14.9	10.1	8.01	18.3	27.8	28.9
25	17.2	13.5	11.7	21.9	50.4	28.7	14.6	10.0	7.82	17.9	27.3	28.7
26	17.2	13.4	11.6	21.3	49.8	27.8	14.2	9.90	7.65	17.7	26.9	28.2
27	17.2	13.3	11.6	20.3	49.0	27.2	14.0	9.77	7.50	17.4	26.5	27.9
28	16.9	13.2	11.6	19.9	48.6	26.7	13.7	9.56	7.42	17.2	25.7	27.4
29	16.8	13.1	11.6	19.5	48.2	26.3	13.5	9.40	7.39	16.9	25.2	27.1
30	16.7	13.0	11.5	19.0	47.6	25.2	13.4	9.23	7.30	16.8	24.7	26.9
31	16.5	13.0	11.5	18.5	47.1	24.6	13.4	9.09	7.10	16.6	24.4	26.6
32	16.4	12.9	11.4	18.2	46.7	24.3	13.3	9.00	6.92	16.4	24.1	26.4
33	16.3	12.8	11.3	17.9	46.1	24.0	13.2	8.91	6.72	16.1	23.8	26.2
34	16.1	12.8	11.3	17.4	45.6	23.6	12.9	8.76	6.59	15.9	23.5	25.9

Percent of Time Exceeded	Daily Average Baseflow (m³/s)											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
35	16.0	12.7	11.3	17.0	45.2	23.2	12.6	8.58	6.50	15.6	23.3	25.6
36	16.0	12.6	11.3	16.6	44.8	22.7	12.4	8.50	6.43	15.3	23.2	25.4
37	15.9	12.5	11.2	16.2	44.0	22.4	12.1	8.35	6.41	15.1	23.0	25.1
38	15.8	12.4	11.2	15.9	43.7	22.0	11.6	8.22	6.33	14.9	22.7	24.9
39	15.8	12.3	11.1	15.5	42.9	21.8	11.4	8.14	6.27	14.6	21.9	24.8
40	15.8	12.2	11.0	15.2	42.5	21.4	11.2	7.99	6.20	14.4	21.4	24.6
41	15.7	12.2	10.8	14.8	41.9	21.1	11.0	7.87	6.11	14.2	20.8	24.5
42	15.6	12.1	10.6	14.4	41.0	20.7	10.7	7.80	6.00	14.1	20.4	24.4
43	15.6	12.0	10.4	14.2	40.6	20.4	10.5	7.68	5.95	13.9	20.1	24.2
44	15.4	12.0	10.3	13.9	40.3	20.1	10.4	7.62	5.76	13.8	19.8	24.0
45	15.3	11.9	10.2	13.6	39.7	19.5	10.2	7.56	5.56	13.7	19.6	23.8
46	15.1	11.8	10.1	13.4	38.9	19.4	10.1	7.49	5.41	13.6	19.5	23.6
47	15.0	11.7	10.0	13.2	38.3	19.1	9.85	7.45	5.33	13.4	19.3	23.5
48	14.9	11.6	9.94	13.1	38.0	18.8	9.65	7.31	5.26	13.2	19.1	23.2
49	14.7	11.5	9.92	12.9	37.6	18.6	9.36	7.22	5.21	13.0	18.9	23.0
50	14.6	11.5	9.88	12.8	37.2	18.3	9.23	7.07	5.07	12.8	18.8	22.8
51	14.4	11.4	9.73	12.6	36.5	18.1	9.07	6.99	4.90	12.6	18.7	22.7
52	14.3	11.3	9.64	12.5	36.2	18.0	8.92	6.89	4.80	12.4	18.5	22.6
53	14.2	11.1	9.54	12.3	35.9	17.7	8.83	6.79	4.74	12.2	18.4	22.5
54	14.1	11.0	9.50	12.3	35.6	17.4	8.79	6.69	4.68	12.1	18.2	22.5
55	14.0	10.8	9.49	12.1	35.3	17.0	8.71	6.53	4.66	11.9	18.2	22.5
56	13.9	10.8	9.45	12.1	34.8	16.5	8.52	6.46	4.59	11.7	18.1	22.4
57	13.8	10.6	9.29	11.9	34.2	16.2	8.44	6.31	4.54	11.6	18.0	22.1
58	13.7	10.5	9.20	11.9	33.7	15.8	8.38	6.24	4.48	11.4	18.0	21.9
59	13.6	10.4	9.13	11.7	33.3	15.4	8.33	6.20	4.45	11.2	18.0	21.7
60	13.5	10.3	9.06	11.7	32.5	15.0	8.16	6.12	4.41	11.1	18.0	21.5
61	13.4	10.2	9.02	11.6	31.7	14.7	8.07	6.02	4.40	10.9	17.9	21.3
62	13.4	10.1	8.97	11.6	31.3	14.4	8.00	5.89	4.37	10.8	17.9	21.1
63	13.3	10.0	8.90	11.4	30.5	14.1	7.90	5.76	4.30	10.5	17.8	20.9
64	13.2	9.91	8.82	11.2	29.9	13.9	7.73	5.64	4.24	10.4	17.7	20.7
65	13.1	9.82	8.76	11.1	29.1	13.6	7.61	5.48	4.15	10.2	17.7	20.5
66	13.1	9.76	8.69	11.1	28.5	13.4	7.56	5.44	4.07	9.96	17.7	20.3
67	13.0	9.69	8.64	11.0	28.0	13.1	7.47	5.35	4.04	9.85	17.5	20.1
68	13.0	9.62	8.61	10.9	27.2	12.8	7.42	5.29	3.93	9.68	17.5	19.8
69	12.9	9.56	8.55	10.7	26.7	12.6	7.41	5.22	3.82	9.43	17.4	19.7
70	12.9	9.52	8.51	10.4	26.1	12.3	7.35	5.14	3.72	9.27	17.2	19.6
71	12.8	9.45	8.45	10.3	25.5	12.2	7.28	5.05	3.65	9.03	16.9	19.4
72	12.7	9.38	8.41	10.1	25.1	12.0	7.21	4.99	3.56	8.83	16.7	19.2
73	12.6	9.30	8.37	9.92	24.2	12.0	7.13	4.92	3.50	8.66	16.5	19.1
74	12.5	9.28	8.34	9.79	24.0	11.9	7.05	4.82	3.44	8.39	16.2	18.9
75	12.4	9.21	8.32	9.63	23.1	11.9	6.86	4.77	3.39	8.24	15.9	18.8
76	12.4	9.19	8.31	9.55	22.4	11.8	6.79	4.67	3.35	7.96	15.7	18.7
77	12.3	9.12	8.31	9.44	22.0	11.7	6.75	4.61	3.32	7.76	15.5	18.6
78	12.2	9.07	8.29	9.34	21.3	11.5	6.47	4.56	3.30	7.38	15.3	18.5
79	12.1	9.01	8.27	9.23	20.7	11.4	6.28	4.47	3.28	7.15	15.1	18.4
80	12.0	8.94	8.27	9.16	20.2	11.2	6.08	4.35	3.26	6.89	14.8	18.3
81	11.9	8.92	8.20	9.10	19.8	11.1	5.77	4.28	3.22	6.69	14.7	18.1
82	11.7	8.90	8.12	9.04	19.1	10.9	5.49	4.23	3.18	6.48	14.5	17.9
83	11.6	8.80	8.03	9.03	18.5	10.7	5.36	4.17	3.16	6.30	14.3	17.7

Percent of Time Exceeded	Daily Average Baseflow (m³/s)											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
84	11.4	8.72	8.00	8.97	17.9	10.4	5.30	4.16	3.14	6.02	14.2	17.4
85	11.3	8.61	7.91	8.86	17.4	10.3	5.11	4.12	3.12	5.80	14.1	17.2
86	11.0	8.54	7.88	8.74	16.8	10.1	5.04	4.05	3.11	5.51	14.1	17.0
87	10.9	8.45	7.87	8.63	16.4	9.96	5.01	3.86	3.09	5.41	14.1	16.8
88	10.7	8.37	7.65	8.50	16.2	9.87	4.92	3.74	2.88	5.02	14.0	16.7
89	10.6	8.31	7.47	8.35	15.8	9.73	4.78	3.54	2.83	4.69	13.7	16.4
90	10.5	8.26	7.42	8.24	15.2	9.62	4.71	3.27	2.81	4.47	13.6	16.2
91	10.3	8.23	7.35	7.99	14.8	9.51	4.61	3.13	2.72	4.32	13.2	15.9
92	10.1	8.19	7.10	7.74	14.3	9.33	4.41	2.95	2.44	4.13	12.9	15.6
93	10.0	8.09	6.91	7.58	13.7	9.18	4.21	2.70	2.21	3.92	12.3	15.2
94	9.88	8.03	6.71	7.37	13.0	8.97	4.11	2.47	2.19	3.68	11.6	14.7
95	9.77	7.96	6.63	7.19	11.9	8.71	3.91	2.34	2.16	3.45	8.56	14.2
96	9.66	7.89	6.61	7.02	10.6	8.45	3.76	2.31	2.11	3.22	5.25	9.43
97	9.60	7.82	6.56	6.51	10.0	8.36	3.54	2.27	1.98	3.04	4.95	8.70
98	9.41	7.79	5.72	6.38	9.55	8.02	3.26	2.25	1.79	2.91	4.83	7.35
99	9.03	7.35	5.36	5.98	8.70	7.47	2.85	1.99	1.71	2.74	4.69	6.15
99.9	8.40	6.84	5.35	5.38	6.68	6.50	2.40	1.73	1.71	2.25	4.52	5.40
99.99	8.38	6.83	5.35	5.37	6.67	6.46	2.39	1.73	1.71	2.24	4.52	5.38

## 6. Median Annual Flow Duration Curves

SAAS v2.1.1 includes the option to generate median annual flow duration curves for the entire period of record, for all four seasons and for all twelve months. The median annual method calculates a flow duration curve (FDC) for each year (or month/season) of the period of record, records the value for each percent exceedance (0 to 100) on each year's FDC, calculates the median for each, and draws a FDC using the median values.

The median annual flow duration curves are shown in Figures 10 to 12, respectively.

The flow duration analysis results used to prepare Figures 10 to 12 are given in Tables 9 and 10.

**Table 9 Median Annual Flow Duration Analysis for All Four Seasons and the Period of Record**

Percent of Time Exceeded	Median Annual Flow (m³/s)					Period of Record
	Winter	Spring	Summer	Fall		
0.01	23.8	172	38.9	49.0		172
0.1	23.8	172	38.9	49.0		172
1	23.6	171	37.8	48.5		165
2	23.3	169	35.2	47.7		149
3	23.0	167	32.7	46.8		137
4	22.6	165	31.5	46.4		120
5	22.2	162	30.4	45.6		101
6	21.8	162	30.0	44.4		84.6
7	21.6	158	28.2	43.8		73.3
8	21.5	149	27.4	43.5		67.4
9	21.4	145	26.2	42.8		62.4
10	21.3	143	25.2	41.9		57.5
11	21.2	139	24.5	41.1		53.1

Percent of Time Exceeded	Median Annual Flow (m³/s)					Period of Record
	Winter	Spring	Summer	Fall		
12	21.1	133	23.3	40.3	50.5	
13	20.7	128	22.9	39.5	49.1	
14	20.7	123	22.6	39.4	45.8	
15	20.5	119	22.1	38.9	43.5	
16	20.4	115	21.6	37.8	42.2	
17	20.3	111	20.2	37.6	41.7	
18	20.3	109	19.9	37.5	40.7	
19	20.2	104	19.2	37.3	39.7	
20	20.0	100.0	17.9	35.6	38.6	
21	19.8	96.1	17.3	35.2	36.1	
22	19.6	92.4	17.0	34.8	35.3	
23	19.3	86.1	16.7	34.6	34.1	
24	19.1	80.8	16.0	34.4	33.3	
25	18.9	76.3	15.6	34.2	32.1	
26	18.6	72.7	15.5	33.9	31.0	
27	18.3	70.6	15.4	33.7	29.3	
28	18.2	69.9	15.3	33.6	28.7	
29	17.9	69.2	15.2	33.5	28.2	
30	17.6	66.5	15.0	33.3	27.6	
31	17.3	64.4	14.4	32.6	27.2	
32	17.1	62.5	14.0	32.5	26.9	
33	16.9	60.6	13.9	32.4	26.5	
34	16.8	58.4	13.8	32.1	25.9	
35	16.7	55.9	13.7	31.9	25.3	
36	16.5	54.0	13.4	31.7	24.8	
37	16.4	52.7	13.1	31.3	24.5	
38	16.2	52.1	12.9	31.0	24.2	
39	16.1	52.1	12.7	30.6	23.8	
40	16.0	51.0	12.6	30.3	23.0	
41	15.9	50.5	12.4	30.1	22.4	
42	15.8	50.2	12.1	30.0	22.0	
43	15.6	49.6	11.9	29.7	21.5	
44	15.5	48.2	11.8	29.5	21.1	
45	15.4	45.9	11.7	29.2	20.5	
46	15.2	44.6	11.7	28.9	20.1	
47	15.0	43.7	11.5	28.9	19.6	
48	14.8	42.1	11.4	28.9	19.3	
49	14.6	39.8	11.3	28.8	19.1	
50	14.5	37.1	11.2	28.7	18.8	
51	14.4	34.7	11.1	28.6	18.3	
52	14.1	32.3	10.9	28.6	17.9	
53	14.0	31.7	10.8	28.2	17.5	
54	14.0	30.7	10.7	28.0	17.3	
55	13.8	29.9	10.6	27.9	17.0	
56	13.6	29.6	10.5	27.5	16.9	
57	13.4	29.5	10.5	27.2	16.5	
58	13.2	29.2	10.3	27.2	16.2	
59	13.1	28.8	9.85	27.1	15.9	
60	13.0	28.7	9.51	26.5	15.7	

Percent of Time Exceeded	Median Annual Flow (m³/s)					Period of Record
	Winter	Spring	Summer	Fall		
61	12.8	28.6	8.87	26.0		15.5
62	12.6	28.3	8.64	25.7		15.1
63	12.4	25.9	8.45	25.6		14.8
64	12.2	25.5	8.19	25.4		14.5
65	12.2	25.4	8.01	25.2		14.2
66	12.0	25.1	7.90	24.6		13.9
67	11.9	24.7	7.86	24.4		13.7
68	11.6	24.4	7.78	24.3		13.2
69	11.4	23.9	7.50	24.2		13.1
70	11.3	23.5	7.45	23.9		12.8
71	11.2	22.6	7.31	23.7		12.5
72	11.1	21.8	7.19	23.5		12.4
73	11.0	20.6	7.12	23.0		12.1
74	10.9	19.7	7.08	22.4		11.9
75	10.9	18.3	7.04	21.8		11.8
76	10.8	17.8	6.83	21.3		11.6
77	10.7	17.3	6.52	20.9		11.2
78	10.5	16.7	6.32	20.6		11.0
79	10.3	16.2	6.25	20.4		10.8
80	10.3	15.7	6.19	20.1		10.7
81	10.2	15.5	5.91	19.8		10.3
82	10.1	15.5	5.77	19.5		10.1
83	10.0	15.4	5.51	19.4		9.96
84	9.96	15.3	5.42	19.2		9.82
85	9.89	15.1	5.33	19.1		9.63
86	9.82	14.7	5.27	18.8		9.42
87	9.74	14.3	5.21	18.7		9.27
88	9.68	13.8	5.14	18.6		9.00
89	9.63	13.5	5.06	18.5		8.61
90	9.59	13.1	4.88	18.4		8.27
91	9.52	12.9	4.69	18.3		7.45
92	9.42	12.6	4.63	18.2		6.88
93	9.31	12.4	4.56	18.1		6.64
94	9.15	11.8	4.53	18.1		6.48
95	9.11	11.4	4.44	17.7		6.13
96	8.99	11.3	4.35	17.4		5.41
97	8.93	10.9	4.25	17.0		5.14
98	8.87	10.5	4.18	16.7		4.62
99	8.79	10.2	4.13	15.8		4.35
99.9	8.76	10.2	4.11	15.3		4.11

**Table 10 Median Annual Flow Duration Analysis for All Twelve Months of the Year**

Percent of Time Exceeded	Median Annual Flow (m³/s)											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.01	23.6	17.1	15.5	148	166	47.6	30.8	19.1	21.6	41.1	38.4	34.3
0.1	23.6	17.1	15.5	148	166	47.6	30.8	19.1	21.6	41.1	38.4	34.3
1	23.6	17.1	15.5	148	166	47.6	30.8	19.1	21.6	41.1	38.4	34.3
2	23.6	17.1	15.4	147	165	47.3	30.8	19.0	21.6	41.1	38.4	34.3
3	23.5	17.1	15.4	146	163	46.5	30.6	18.9	21.6	41.1	38.3	34.2
4	23.4	17.0	15.3	145	160	45.7	30.4	18.7	21.5	41.1	38.2	34.1
5	23.3	17.0	15.2	144	159	44.8	30.2	18.5	20.8	41.0	38.1	34.0
6	23.2	16.9	15.1	144	157	43.8	29.9	18.3	20.0	40.5	37.9	34.0
7	23.0	16.8	15.0	144	155	42.9	29.6	18.0	18.9	40.1	37.7	33.9
8	22.9	16.7	14.9	144	154	41.9	29.3	17.7	17.8	39.8	37.5	33.8
9	22.7	16.6	14.9	144	151	41.2	29.0	17.5	17.1	39.6	37.3	33.8
10	22.5	16.6	14.8	144	149	40.8	28.7	17.3	16.5	39.5	37.2	33.7
11	22.4	16.5	14.7	144	147	40.3	28.4	17.1	15.9	39.0	37.0	33.7
12	22.2	16.1	14.6	144	143	39.9	27.9	16.9	15.8	38.0	36.8	33.6
13	22.0	16.1	14.5	143	139	39.7	27.3	16.8	15.5	36.9	36.7	33.3
14	21.8	16.1	14.4	143	137	39.4	26.7	16.6	15.2	35.8	36.5	32.7
15	21.7	16.1	14.3	143	134	39.1	26.3	16.5	14.8	35.2	36.4	32.1
16	21.6	16.1	14.2	142	132	39.1	26.1	16.2	14.6	35.0	36.3	32.0
17	21.5	16.0	14.1	140	131	39.0	25.8	15.9	14.3	34.8	36.2	31.9
18	21.4	15.9	14.1	138	129	38.9	25.1	15.7	14.1	34.6	36.1	31.8
19	21.3	15.9	14.0	134	126	38.7	24.2	15.4	14.0	34.5	36.1	31.8
20	21.2	15.8	13.9	129	122	38.6	23.5	15.2	13.5	34.4	36.0	31.7
21	21.0	15.8	13.6	125	120	38.4	22.6	15.1	13.5	34.2	35.9	31.7
22	20.9	15.7	13.4	120	116	38.2	22.3	14.9	13.4	33.9	35.8	31.7
23	20.8	15.7	13.3	116	115	38.0	22.1	14.8	13.4	33.6	35.8	31.6
24	20.7	15.7	13.1	109	113	37.8	21.8	14.6	13.1	33.3	35.7	31.6
25	20.5	15.6	12.9	92.5	112	37.6	21.4	14.4	12.9	32.7	35.7	31.6
26	20.3	15.5	12.7	88.6	111	37.4	21.0	14.2	12.8	32.2	35.6	31.5
27	20.1	15.5	12.5	82.7	111	37.1	20.6	14.1	12.7	31.6	35.5	31.5
28	19.9	15.4	12.4	71.0	110	36.4	20.2	13.9	12.6	31.3	35.4	31.5
29	19.7	15.4	12.3	64.1	108	36.0	19.8	13.8	12.4	31.2	35.3	31.5
30	19.5	15.3	12.3	59.5	104	35.3	19.4	13.7	12.3	31.2	35.3	31.4
31	19.4	15.3	12.2	55.3	102	34.3	19.2	13.6	12.2	31.1	35.3	31.4
32	19.2	15.2	12.2	52.3	101	33.5	19.1	13.5	12.0	31.0	35.2	31.3
33	19.0	15.1	12.2	50.9	99.6	33.0	19.0	13.4	11.9	31.0	35.0	31.2
34	18.9	15.1	12.2	49.6	98.3	32.5	18.8	13.3	11.8	30.8	34.9	31.2
35	18.8	15.0	12.1	48.3	96.5	32.0	18.5	13.2	11.7	30.5	34.7	31.1
36	18.6	14.9	12.1	46.9	94.8	31.4	18.2	13.1	11.5	30.1	34.6	31.1
37	18.5	14.9	12.1	45.5	93.0	30.8	17.9	13.0	11.0	29.1	34.4	31.1
38	18.4	14.8	12.1	42.4	90.5	30.5	17.8	12.9	10.5	28.8	34.1	31.0
39	18.3	14.7	12.0	40.5	87.9	30.3	17.7	12.9	10.3	28.6	33.9	30.9
40	18.2	14.6	12.0	39.7	85.3	30.1	17.6	12.8	10.2	28.3	33.8	30.7
41	18.0	14.5	12.0	38.8	82.3	29.9	17.5	12.5	10.2	28.2	33.7	30.7
42	17.9	14.4	12.0	38.0	79.7	29.8	17.3	12.3	10.1	28.1	32.3	30.6
43	17.8	14.3	12.0	37.0	77.3	29.8	17.2	12.0	9.89	28.1	31.9	30.5
44	17.7	14.2	11.9	36.0	75.3	29.7	17.1	11.8	9.65	28.0	31.4	30.5
45	17.6	14.1	11.9	35.1	73.9	29.5	16.9	11.6	9.41	27.9	31.0	30.4

Percent of Time Exceeded	Median Annual Flow (m³/s)											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
46	17.5	14.0	11.9	34.2	72.6	29.4	16.8	11.3	9.20	27.8	30.8	30.4
47	17.4	13.9	11.9	33.4	71.5	28.3	16.4	11.2	9.13	27.3	30.6	30.4
48	17.3	13.8	11.9	32.6	70.7	27.7	16.0	11.1	9.06	27.0	30.4	30.3
49	17.2	13.8	11.8	31.8	70.1	27.4	15.6	11.0	8.99	26.6	30.3	30.2
50	17.1	13.7	11.8	30.4	68.9	26.8	15.1	10.9	8.90	26.3	30.0	30.2
51	17.0	13.6	11.7	28.2	68.0	26.2	14.6	10.9	8.82	26.1	29.4	30.0
52	16.9	13.6	11.6	27.1	67.2	25.7	14.0	10.8	8.71	25.9	29.0	29.9
53	16.9	13.5	11.6	26.9	66.6	25.5	13.4	10.8	8.55	25.7	28.9	29.7
54	16.8	13.5	11.5	26.6	66.1	25.3	13.0	10.8	7.72	25.5	28.8	29.6
55	16.7	13.4	11.5	26.3	65.6	25.1	12.6	10.8	7.28	25.4	28.7	29.5
56	16.6	13.3	11.4	26.1	64.8	25.0	12.2	10.8	7.01	25.2	28.4	29.4
57	16.6	13.3	11.2	25.9	64.0	24.9	11.9	10.7	6.75	25.1	28.0	29.3
58	16.5	13.2	11.0	25.2	63.8	24.8	11.7	10.5	6.50	25.0	27.7	29.2
59	16.5	13.1	10.9	23.9	62.9	24.8	11.5	10.3	6.41	24.9	27.7	29.1
60	16.4	13.0	10.9	23.2	61.9	24.8	11.3	10.1	6.34	24.8	27.7	29.0
61	16.4	13.0	10.9	22.4	60.6	24.8	11.2	10.0	6.29	24.6	27.7	28.9
62	16.3	13.0	10.8	21.6	58.9	24.7	11.0	9.93	6.23	24.5	27.6	28.8
63	16.2	12.9	10.8	21.1	57.2	24.7	10.8	9.82	6.15	24.3	27.5	28.6
64	16.2	12.8	10.7	20.6	55.6	24.6	10.4	9.67	6.08	24.2	27.4	28.5
65	16.2	12.8	10.6	20.1	54.0	24.4	10.1	9.52	6.02	24.0	27.4	28.4
66	16.1	12.7	10.6	19.7	52.8	24.1	9.97	9.37	5.97	23.9	27.3	28.3
67	16.0	12.6	10.5	19.4	51.6	23.7	9.85	9.28	5.93	23.6	27.2	28.2
68	16.0	12.6	10.4	19.1	50.4	23.4	9.74	9.20	5.88	23.4	26.7	28.0
69	15.9	12.6	10.3	18.7	49.2	23.0	9.62	9.10	5.84	23.1	26.4	27.9
70	15.9	12.5	10.2	18.4	48.0	22.7	9.49	8.96	5.81	22.9	26.3	27.8
71	15.8	12.5	10.1	18.1	46.8	22.3	9.34	8.79	5.77	22.8	26.1	27.7
72	15.6	12.4	10.1	17.3	45.6	21.9	9.27	8.66	5.74	22.7	25.9	27.6
73	15.5	12.4	10.1	16.8	44.4	21.7	9.22	8.49	5.71	22.4	25.8	27.5
74	15.3	12.4	10.0	16.6	43.2	21.7	9.17	8.31	5.68	21.9	25.6	27.4
75	15.2	12.3	10.0	16.5	42.3	21.7	9.13	8.15	5.65	21.4	25.5	27.3
76	15.1	12.3	10.0	16.3	41.6	21.4	9.08	8.01	5.62	21.0	25.3	27.1
77	15.0	12.2	10.00	16.2	40.8	21.2	9.02	7.91	5.59	20.8	25.0	27.0
78	14.9	12.1	9.98	16.0	39.9	20.9	8.96	7.81	5.56	20.6	24.7	26.9
79	14.8	12.0	9.97	15.8	39.4	20.6	8.90	7.71	5.53	20.4	24.5	26.8
80	14.6	12.0	9.96	15.7	39.3	20.4	8.84	7.61	5.50	20.3	24.4	26.7
81	14.5	11.9	9.95	15.5	39.3	20.2	8.79	7.50	5.27	20.1	24.2	26.5
82	14.3	11.9	9.91	15.3	39.2	20.0	8.73	7.40	5.11	19.9	24.1	26.4
83	14.2	11.9	9.89	15.1	38.3	19.9	8.68	7.27	5.10	19.7	24.0	26.3
84	14.1	11.8	9.88	14.9	36.7	19.7	8.63	7.11	5.09	19.6	23.9	26.1
85	14.0	11.8	9.86	14.3	35.1	19.6	8.58	6.95	5.08	19.5	23.6	26.0
86	14.0	11.7	9.83	13.9	34.1	19.5	8.54	6.84	5.04	19.1	23.2	25.9
87	13.9	11.6	9.78	13.7	33.8	19.4	8.41	6.76	4.99	18.9	22.5	25.8
88	13.8	11.6	9.73	13.5	33.5	19.0	8.27	6.67	4.95	18.6	22.0	25.7
89	13.7	11.5	9.68	13.3	33.2	18.8	8.13	6.40	4.90	18.4	21.4	25.6
90	13.7	11.4	9.66	13.2	32.4	18.4	7.94	6.02	4.85	18.3	21.2	25.4
91	13.6	11.3	9.64	13.0	31.8	17.9	7.75	5.87	4.81	18.1	20.9	25.1
92	13.6	11.2	9.61	12.9	31.2	17.4	7.63	5.77	4.76	17.9	20.6	24.9
93	13.5	11.1	9.58	12.8	30.7	17.0	7.59	5.68	4.72	17.8	20.0	24.7
94	13.4	11.0	9.55	12.7	30.2	16.6	7.55	5.60	4.67	17.6	19.4	24.6

Percent of Time Exceeded	Median Annual Flow (m³/s)											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
95	13.3	11.0	9.52	12.6	29.7	16.2	7.51	5.51	4.63	17.0	18.8	24.5
96	13.3	10.9	9.51	12.5	29.3	15.8	7.46	5.44	4.60	16.7	18.3	24.3
97	13.2	10.9	9.49	12.4	28.9	15.4	7.41	5.36	4.58	16.6	17.9	24.2
98	13.0	10.8	9.48	12.3	28.6	15.0	7.36	5.29	4.56	16.5	17.9	24.1
99	13.0	10.8	9.48	12.3	28.5	14.9	7.35	5.26	4.55	16.5	17.9	24.0
99.9	13.0	10.8	9.48	12.3	28.5	14.9	7.35	5.26	4.55	16.5	17.9	24.0
99.99	13.0	10.8	9.48	12.3	28.5	14.9	7.35	5.26	4.55	16.5	17.9	24.0

## 7. Flood Frequency Analysis

The foregoing flow analyses for the Ivanhoe River at The Chutes has been based on a daily flow series synthesized from the Groundhog River at Fauquier [04LD001] for 1971 to 1994, when a continuous recorder based flow record is available. The flood frequency analysis has been based on the full 1921 to 1994 (not 1970) annual maximum total daily average flow data for the Groundhog River at Fauquier and the nine year record from 2001 to 2009 for the Ivanhoe River at Foleyet [04LC003]. The mean annual flood from these two streamflow stations, and other adjacent streamflow stations, were used to establish a simple relationship between drainage area and mean annual flood, which was used to pro-rate the annual maximum flood series at Fauquier and Foleyet to The Chutes.

Instantaneous maximum flows are available for nineteen years at 04LD001 and eight years at 04LC003. This means that, to make use of the full period of flood record, the instantaneous flow maxima must be estimated from the daily average flow maxima.

Figure 13 shows the instantaneous flood peaks plotted against the daily peaks. Linear regression lines fitted to these data points give the following relationships:

$$04LC003 \text{ Instantaneous Flood Peak} = 1.029 \times \text{Daily Flood} \quad R^2 = 0.999$$

$$04LD001 \text{ Instantaneous Flood Peak} = 1.018 \times \text{Daily Flood} \quad R^2 = 0.997$$

An instantaneous flood maxima series can be estimated for the Ivanhoe River at The Chutes by interpolating between these two regression equations on the basis of drainage area. This meant increasing the daily maxima series by 2.6% to get the instantaneous flood maxima series.

The estimated instantaneous flood maxima at The Chutes are shown in Table 11.

This 82-year instantaneous flood maxima series was entered into the SAAS model and also into Environment Canada's Consolidated Frequency Analysis software CFA3.1. In CFA3.1 the data set was tested for independence, trend, homogeneity and randomness and was found to be free of any statistical inconsistencies.

The data set was then subjected to parametric flood frequency analysis using the following frequency distributions:

- General Extreme Value (GEV)
- 3 parameter Lognormal
- Log Pearson Type III

- Wakeby.

Table 12 shows the flood frequency analysis results at The Chutes.

Figure 14 shows the GEV distribution, which was found to give the best fit to the data.

**Table 11 Estimated Instantaneous Flood Maxima for the Ivanhoe River at The Chutes**

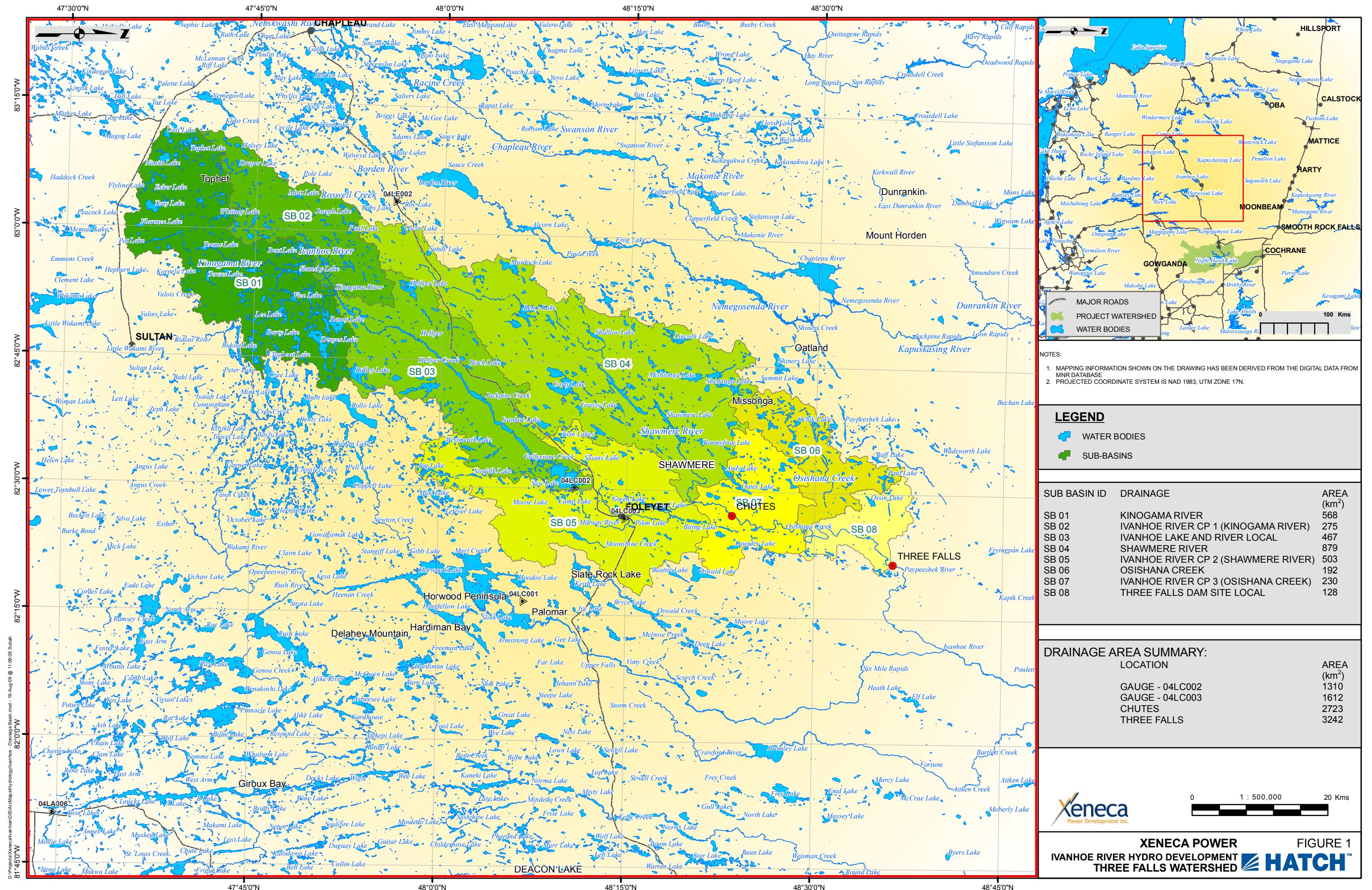
Year	Peak (m <sup>3</sup> /s)	Year	Peak (m <sup>3</sup> /s)
1921	168	1962	226
1922	353	1963	149
1923	137	1964	241
1924	91	1965	220
1925	122	1966	150
1926	135	1967	262
1927	205	1968	191
1928	286	1969	188
1929	158	1971	173
1930	224	1972	162
1931	122	1973	174
1932	146	1974	162
1933	181	1975	144
1934	206	1976	292
1935	136	1977	252
1936	279	1978	246
1937	214	1979	301
1938	256	1980	196
1939	279	1981	183
1940	143	1982	179
1941	237	1983	212
1942	220	1984	121
1943	156	1985	248
1944	173	1986	150
1945	116	1987	90.2
1946	206	1988	153
1947	315	1989	184
1948	175	1990	235
1949	187	1991	148
1950	284	1992	159
1951	197	1993	193
1952	159	1994	100
1953	218	2001	190
1954	212	2002	259
1955	143	2003	175
1956	207	2004	192
1957	260	2005	80.3
1958	89.3	2006	228
1959	214	2007	143
1960	383	2008	284
1961	159	2009	154

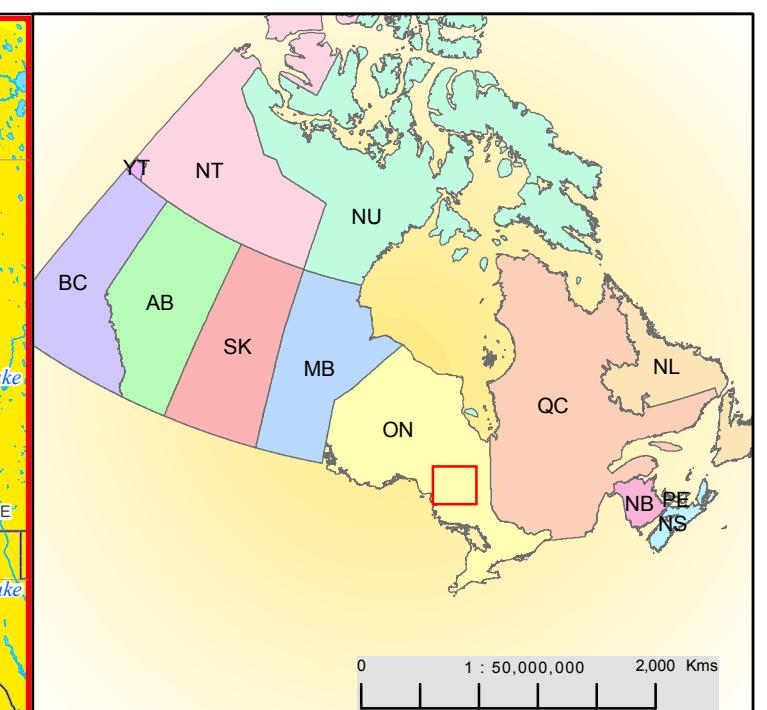
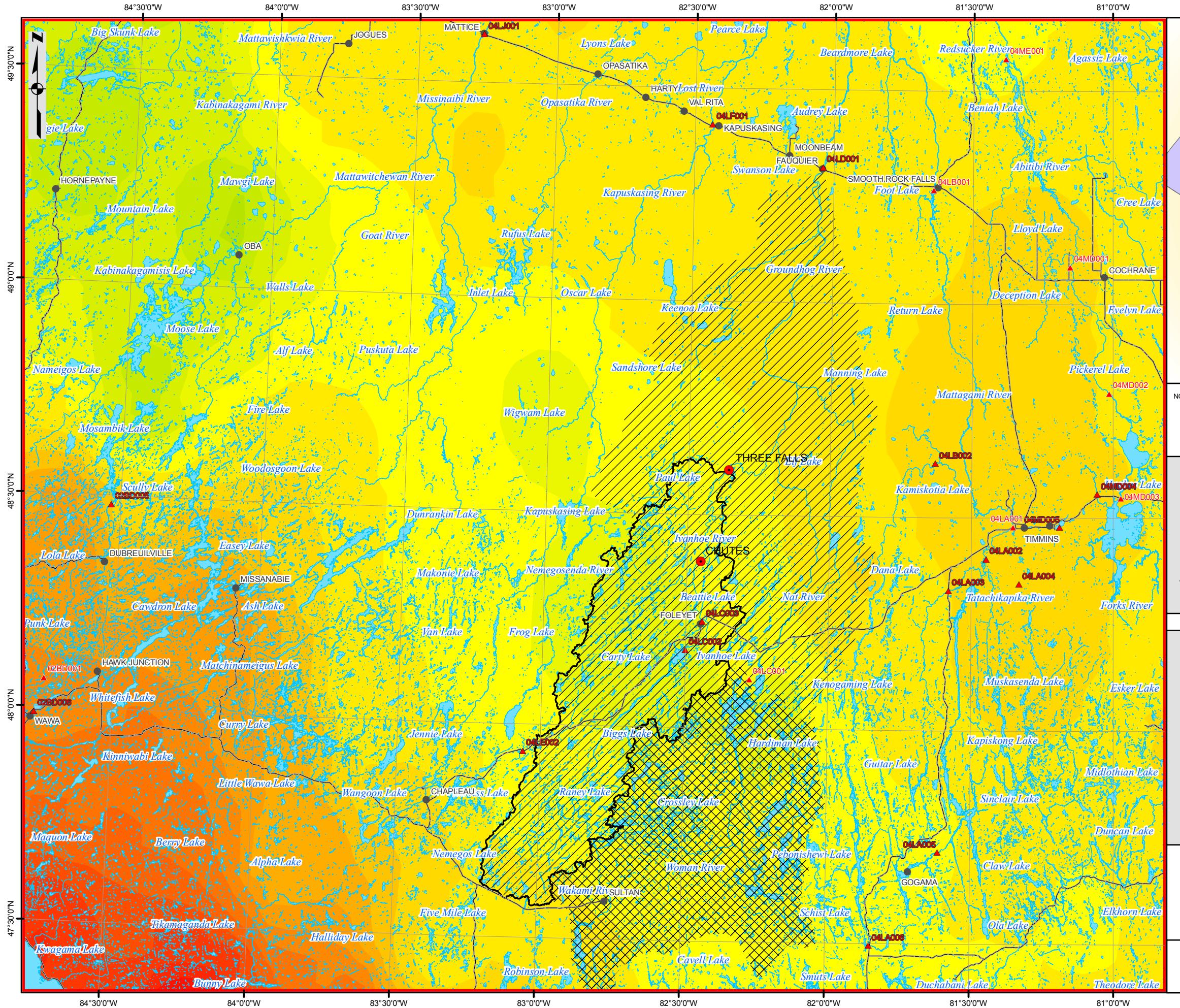
**Table 13 Flood Frequency Analysis for the Ivanhoe River at The Chutes**

Return Period Years	Instantaneous Flood Peak in m <sup>3</sup> /s			
	GEV	3 para Lognormal	Log Pearson III	Wakeby
1.003	67.3	66.6	69.4	76.5
1.050	106	106	106	101
1.250	142	143	143	145
2	187	188	188	186
5	243	242	243	242
10	277	275	275	278
20	307	304	303	310
50	344	340	336	346
100	370	365	360	369
200 <sup>(1)</sup>	394	390	382	389
500 <sup>(1)</sup>	424	422	410	412
1000 <sup>(1)</sup>	445	446	431	427

Note: <sup>(1)</sup> Flood estimates with a return period of greater than 100 year should be used with caution.

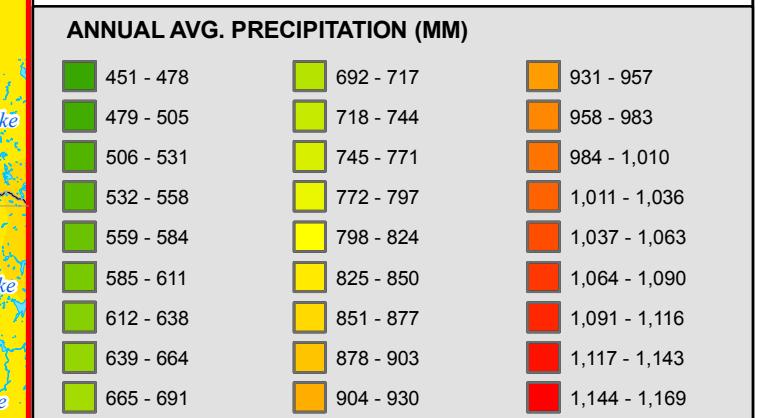
The Flood flows are intended for use in the EA and shall not be used for engineering design without further review.

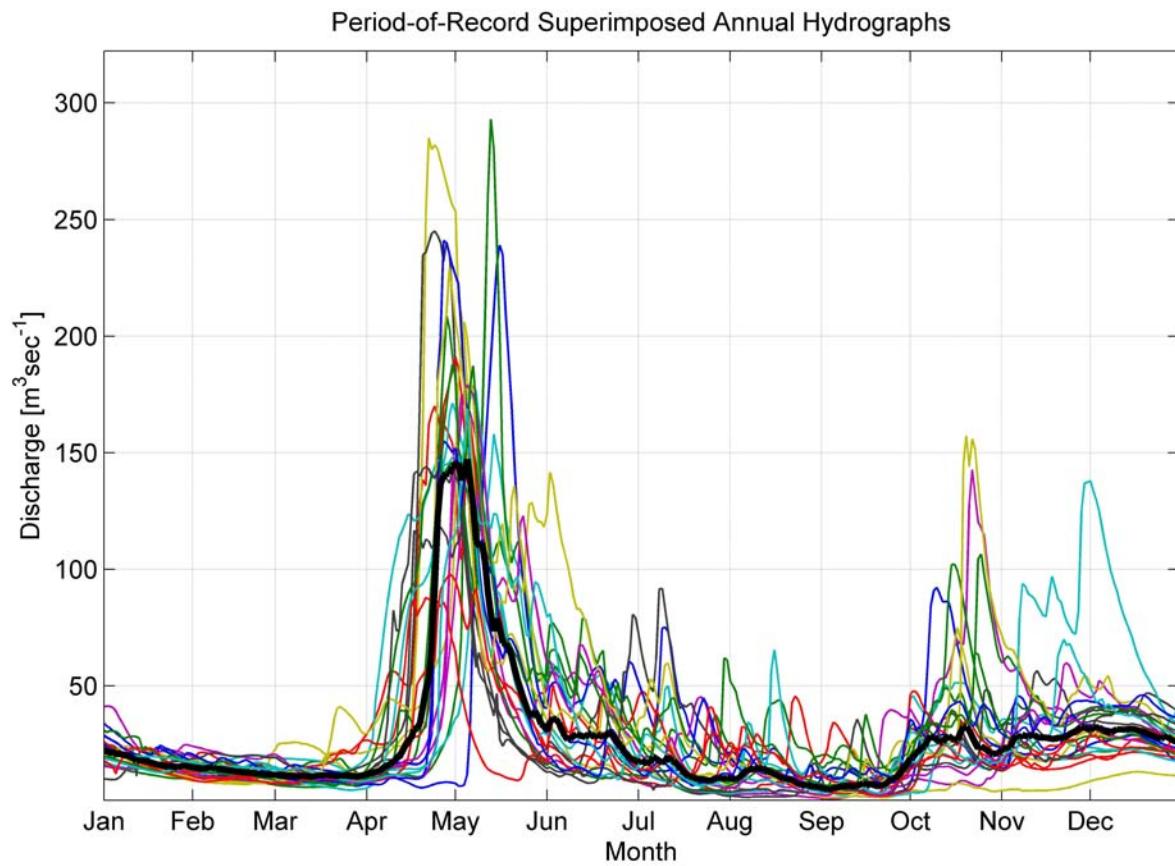




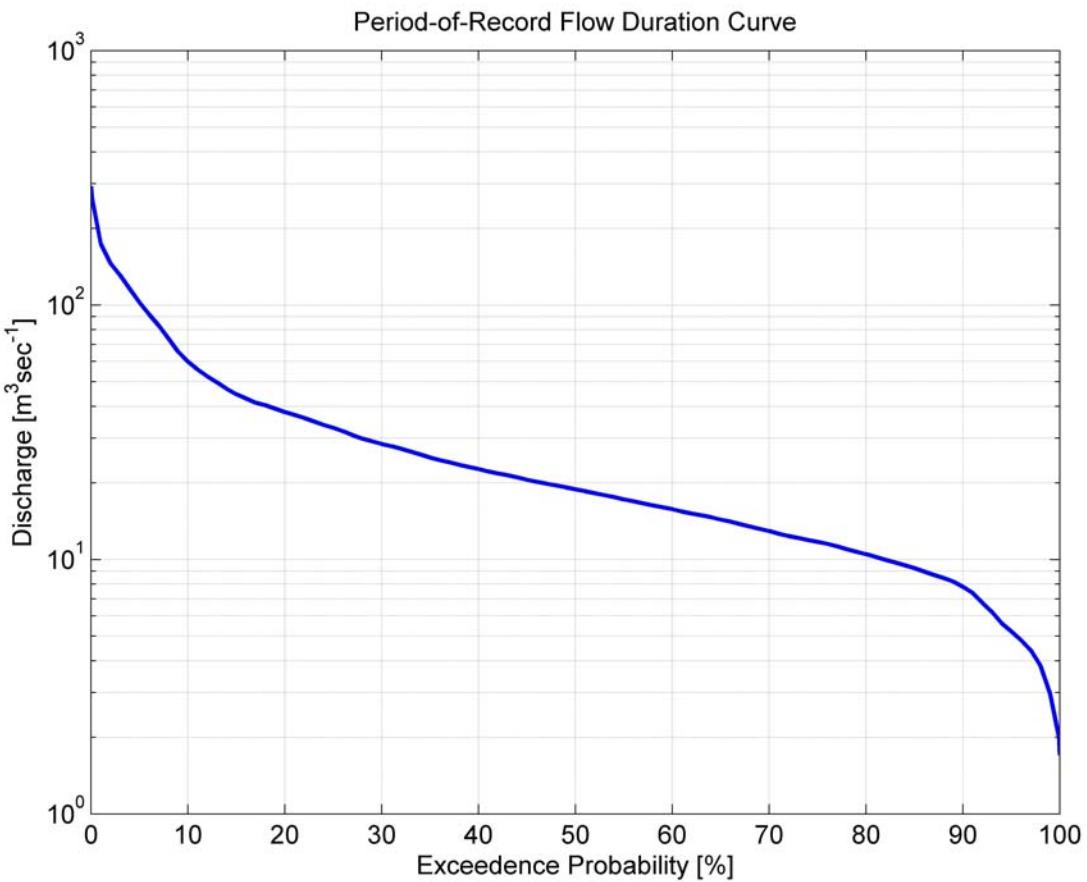
**NOTES:**

- MAPPING INFORMATION SHOWN ON THE DRAWING HAS BEEN DERIVED FROM THE DIGITAL DATA FROM MNR DATABASE
- PROJECTED COORDINATE SYSTEM IS NAD 1983, UTM ZONE 17N.
- PRECIPITATION DERIVED USES MONTHLY CLIMATE DATA (1961-1990)
- SOURCE: CANADA GRIDDED CLIMATE DATA, RON HOPKINSON  
[HTTP://WWW.CICS.UVIC.CA/CLIMATE/DATA.HTM](http://WWW.CICS.UVIC.CA/CLIMATE/DATA.HTM)

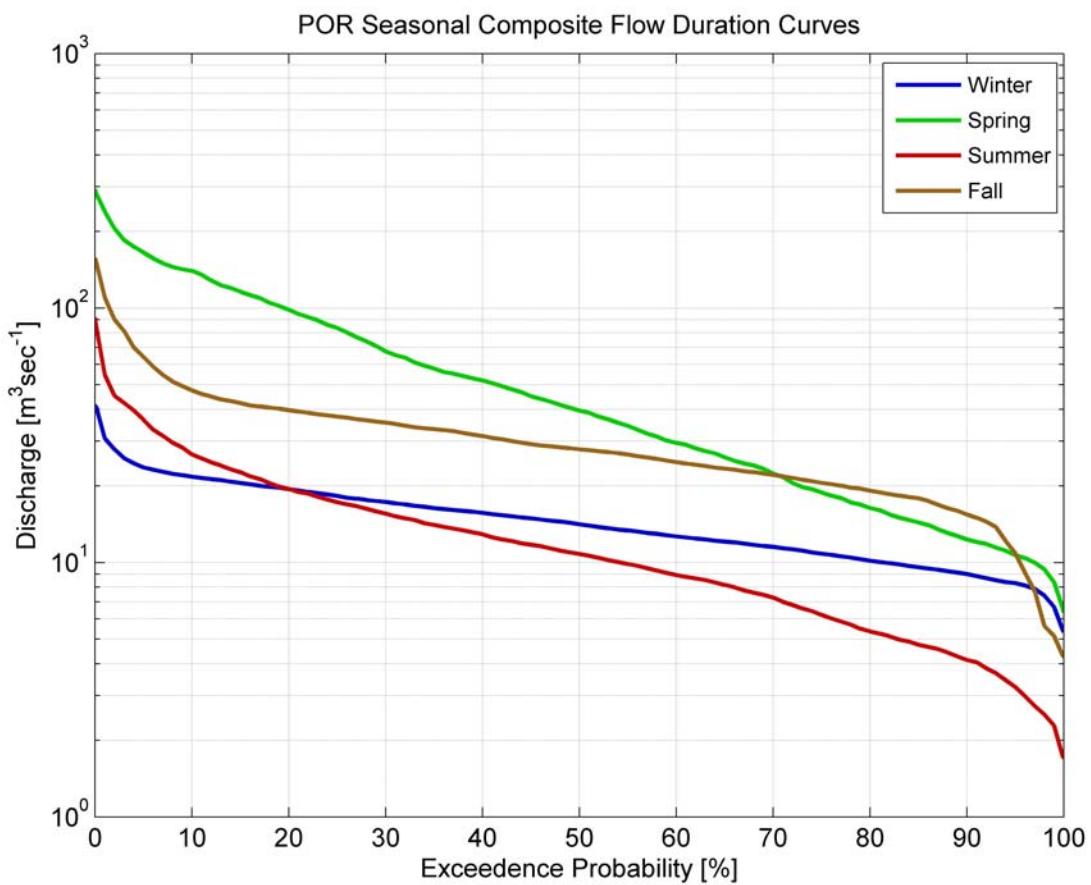




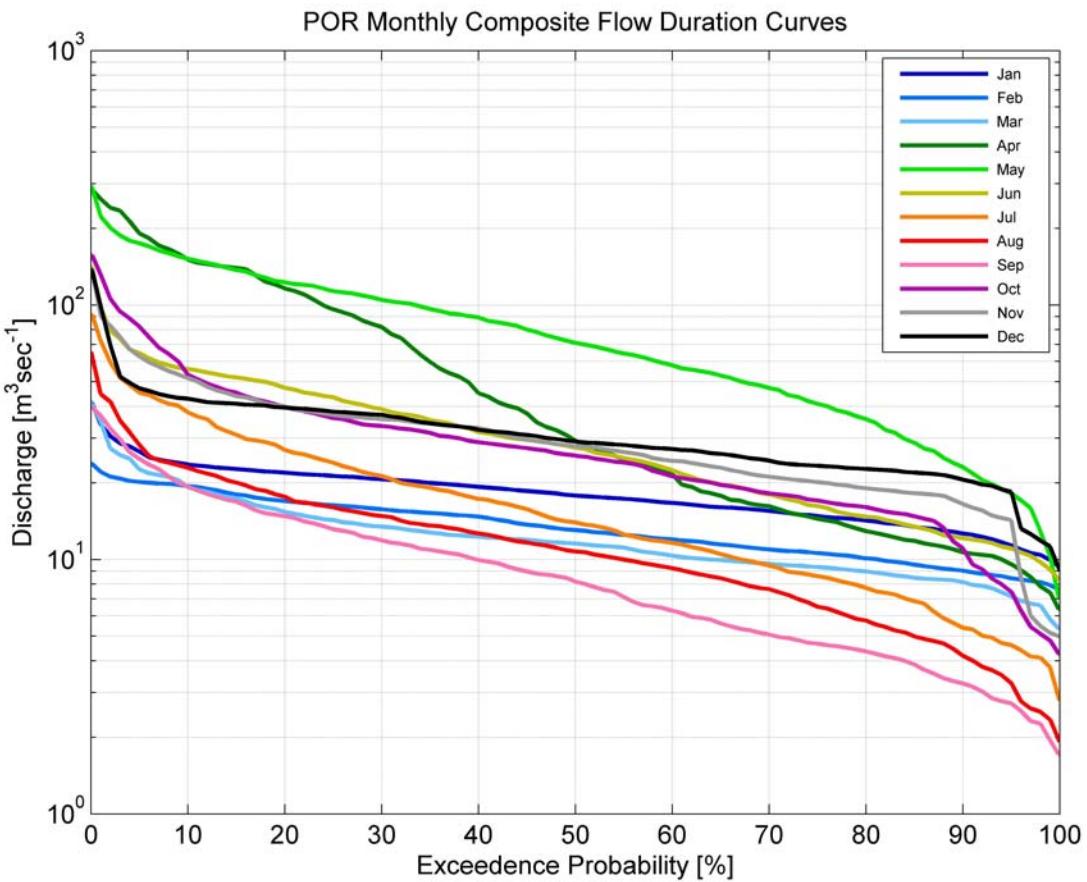
**Figure 3** (SAAS) Superimposed Daily Hydrographs at The Chutes



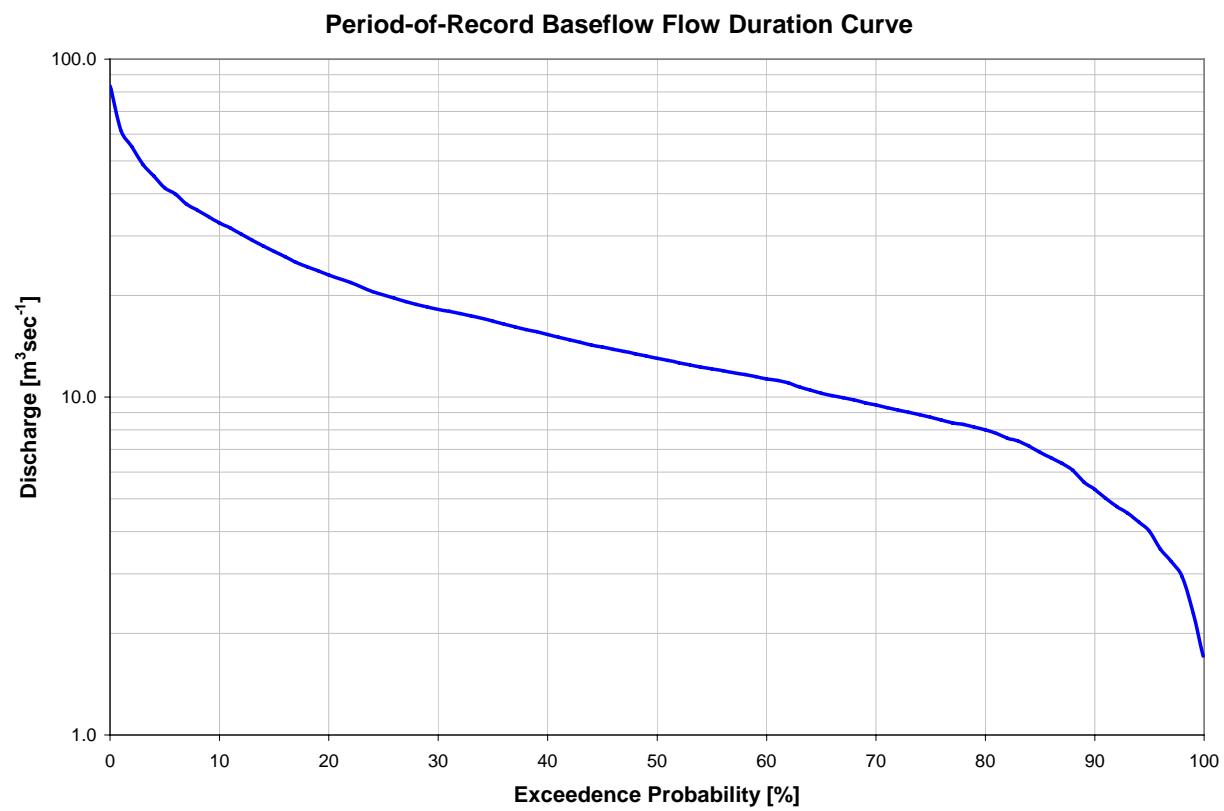
**Figure 4 (SAAS) Period of Record Total Daily Average Flow Duration Curve**



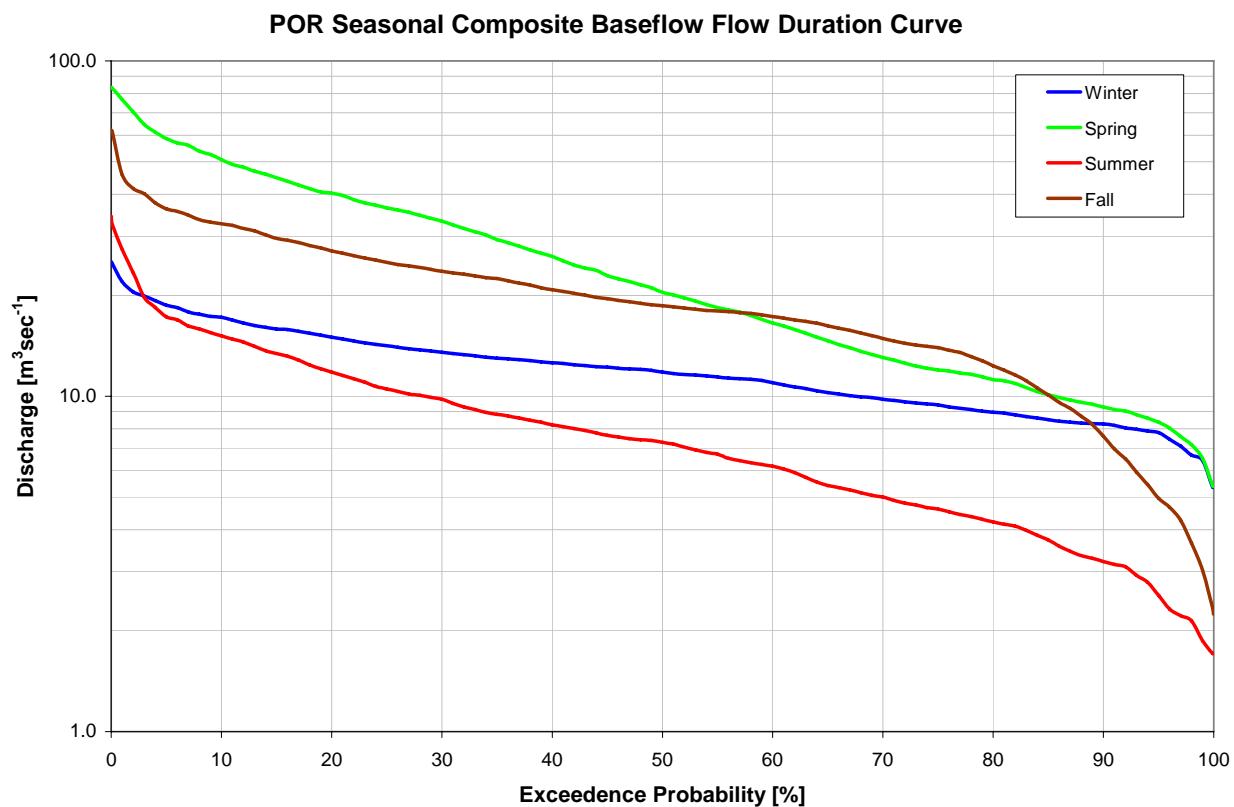
**Figure 5 (SAAS) Period of Record Seasonal Composite Flow Duration Curves**



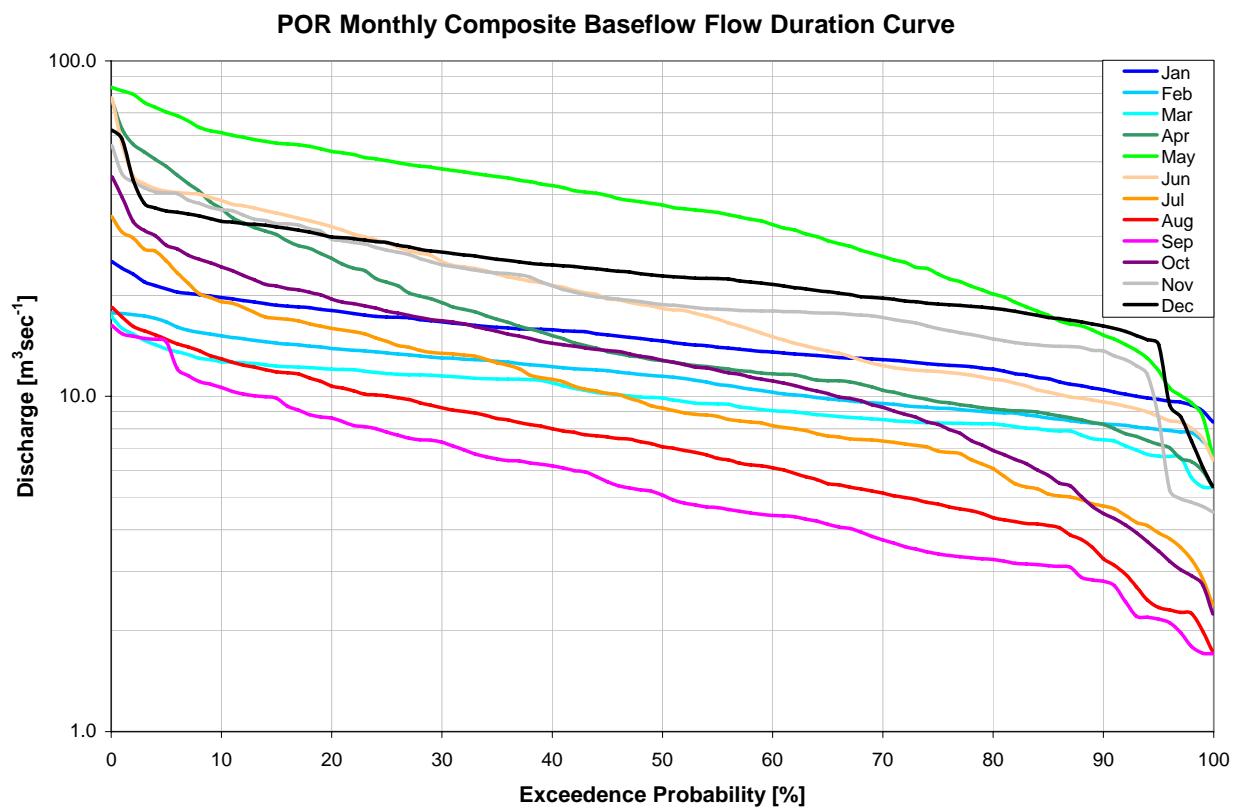
**Figure 6 (SAAS) Period of Record Monthly Composite Flow Duration Curves**



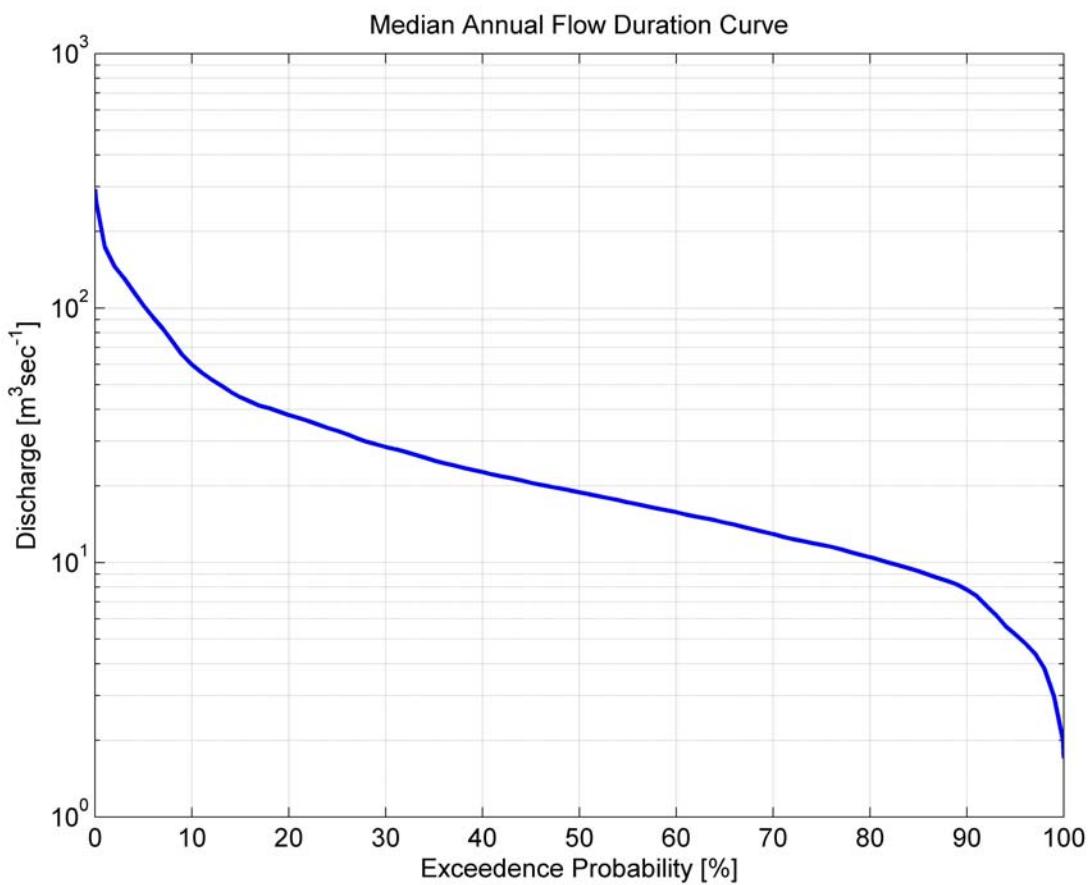
**Figure 7 (SAAS) Period of Record Baseflow Flow Duration Curve**



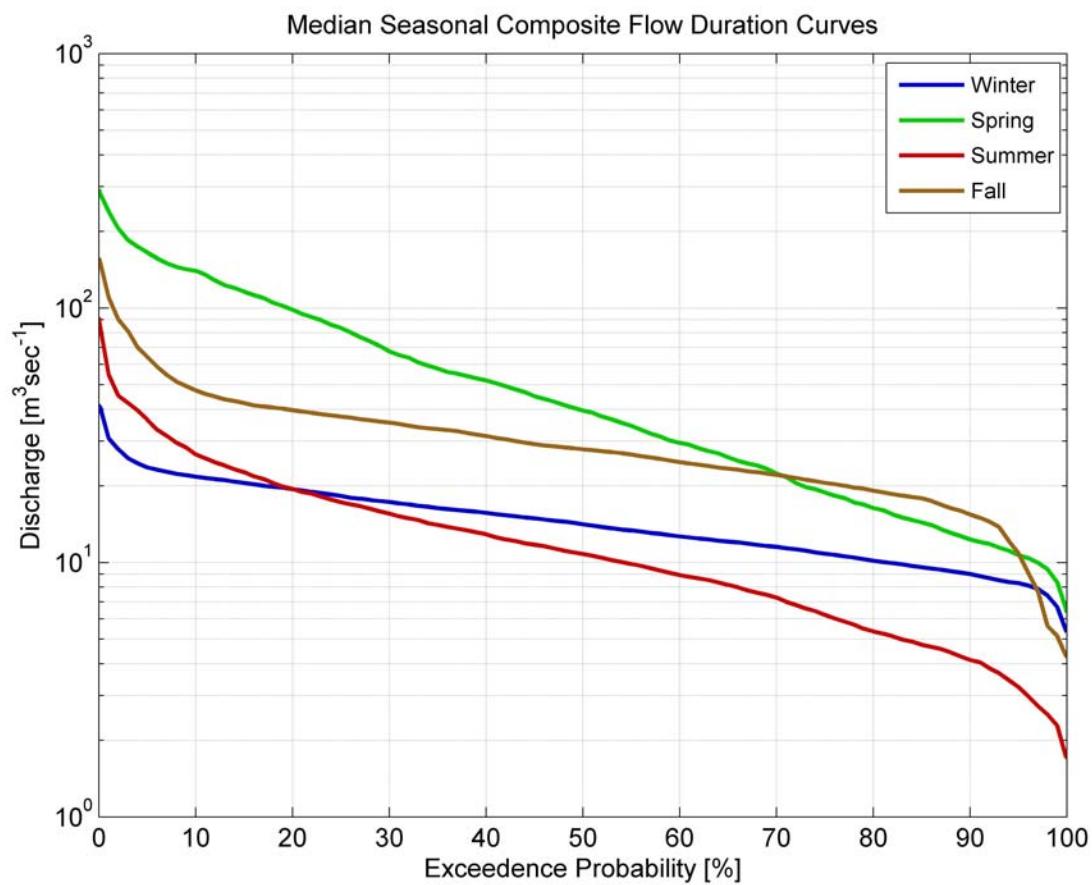
**Figure 8 (SAAS) Period of Record Seasonal Composite Baseflow Flow Duration Curves**



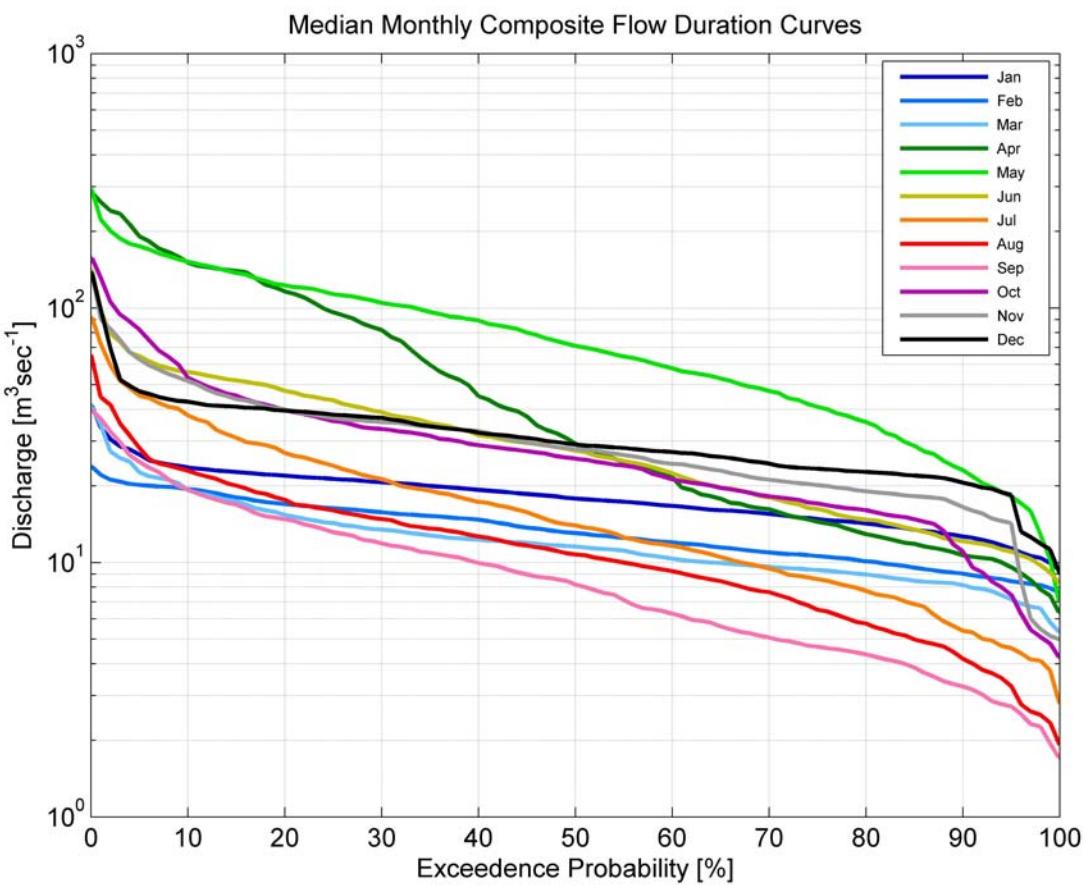
**Figure 9 (SAAS) Period of Record Monthly Composite Baseflow Flow Duration Curves**



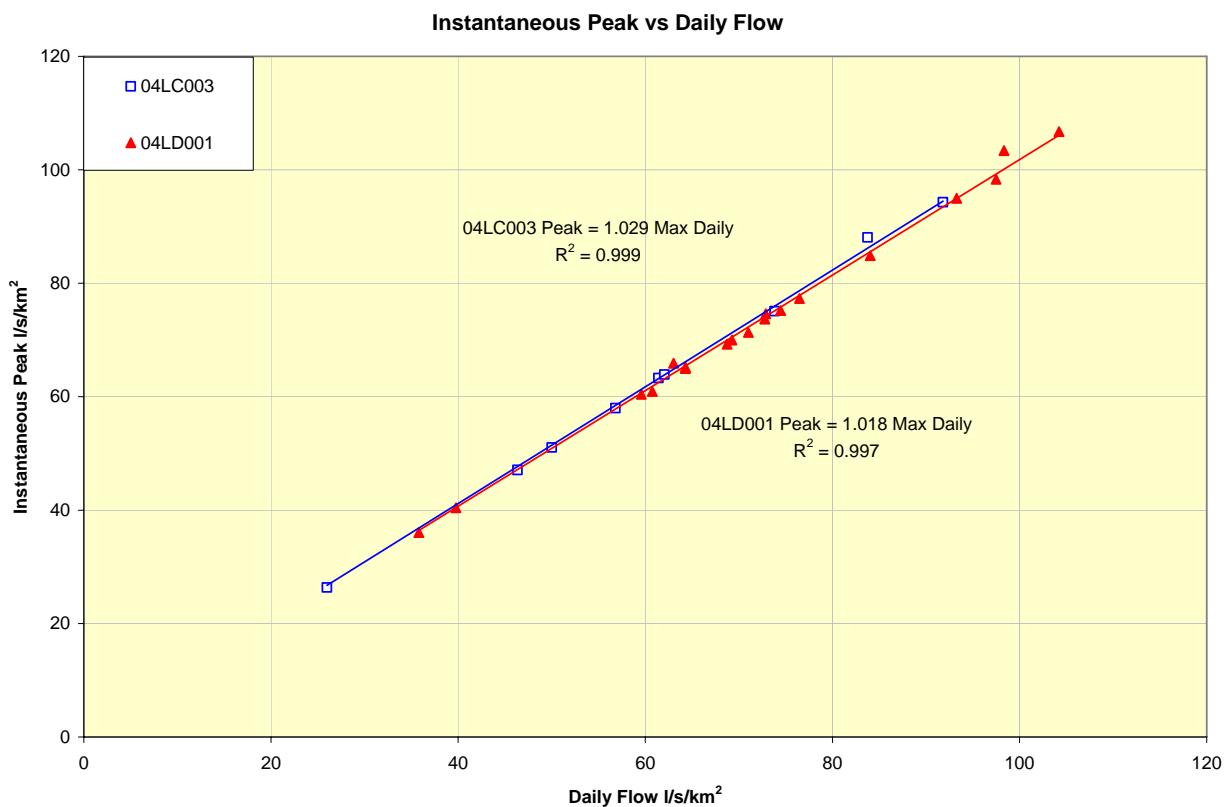
**Figure 10 (SAAS) Median Annual Flow Duration Curve**



**Figure 11** (SASS) Median Seasonal Composite Flow Duration Curves

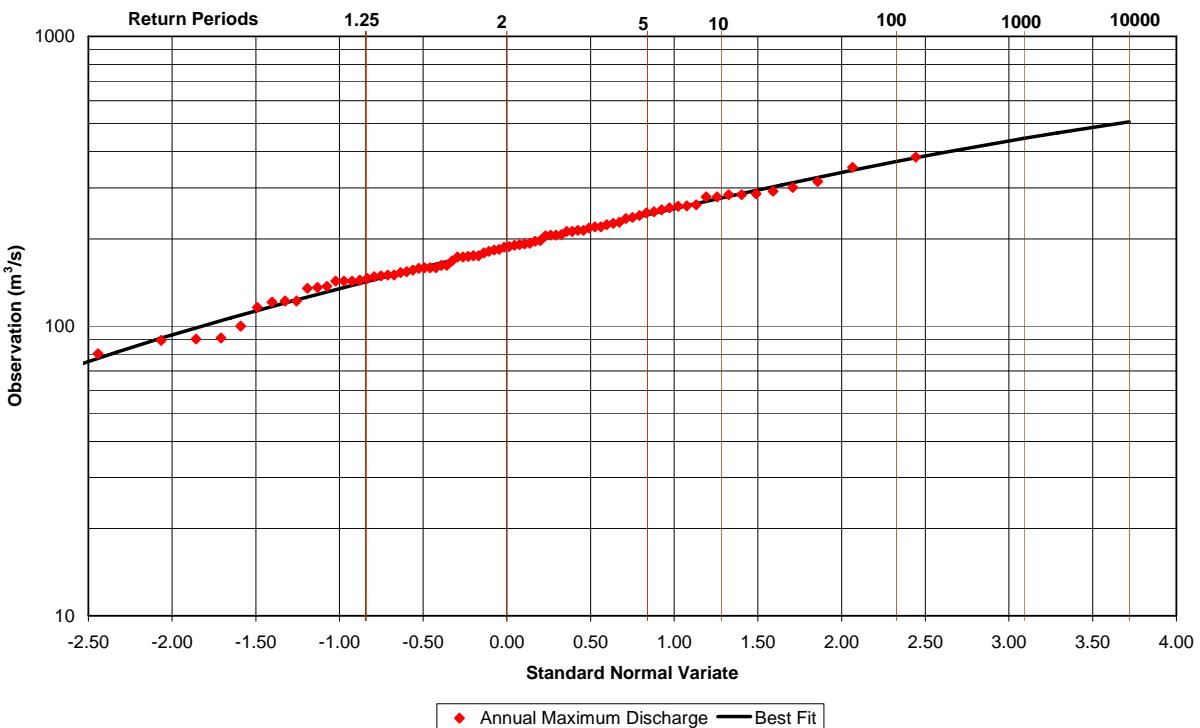


**Figure 12** (SAAS) Median Monthly Composite Flow Duration Curves



**Figure 13      Instantaneous Peaks vs Daily Flow for the Groundhog and Ivanhoe Rivers**

**Ivanhoe River at The Chutes - Synthesized Instantaneous Maxima  
GEV Distribution**



**Figure 14 (CFA3.1) Instantaneous Flood Frequency Analyses for The Chutes**

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## **Appendix A**

# **MOE Hydrology Requirements**

What information is required under hydrological analysis?	Location
a) Descriptive flow statistics using all available daily flows for all years: mean, median, minimum, maximum, flow exceeded 20% time, flow exceeded 80% time.	Hydrology Report
b) Extreme low flow statistics: $7Q_2$ (2 year return period 7-day-average-low flow), $7Q_{10}$ (10 year return period 7-day-average-low flow) and $7Q_{20}$ (20 year return period 7-day-average-low flow).	Section 3
c) Flow duration curves and tables using total daily average flow data for the entire period, for all four seasons and for all twelve months.	Section 4
d) Flow duration curves and tables using daily baseflow data for the entire period, for all four seasons and for all twelve months.	Section 5
e) Flow duration curves derived using both the percentile method and the median of percentiles method. Both methods are incorporated into the flow analysis tool, developed by Schmidt and Metcalfe (2009), which can be downloaded for free from <a href="http://trentu.ca/iws/software.php">http://trentu.ca/iws/software.php</a> .	Section 6
f) Flood frequency analysis using instantaneous maximum flow of each year for the entire period of records.	Section 7
g) Low flow frequency analysis using 7-day-average-low flow for the entire period of records.	Section 3
h) Altered flow of the bypass reach and the reach below tailrace, if applicable.	n/a
i) Compensation flow for the bypass reach and the reach below tailrace, if applicable.	n/a

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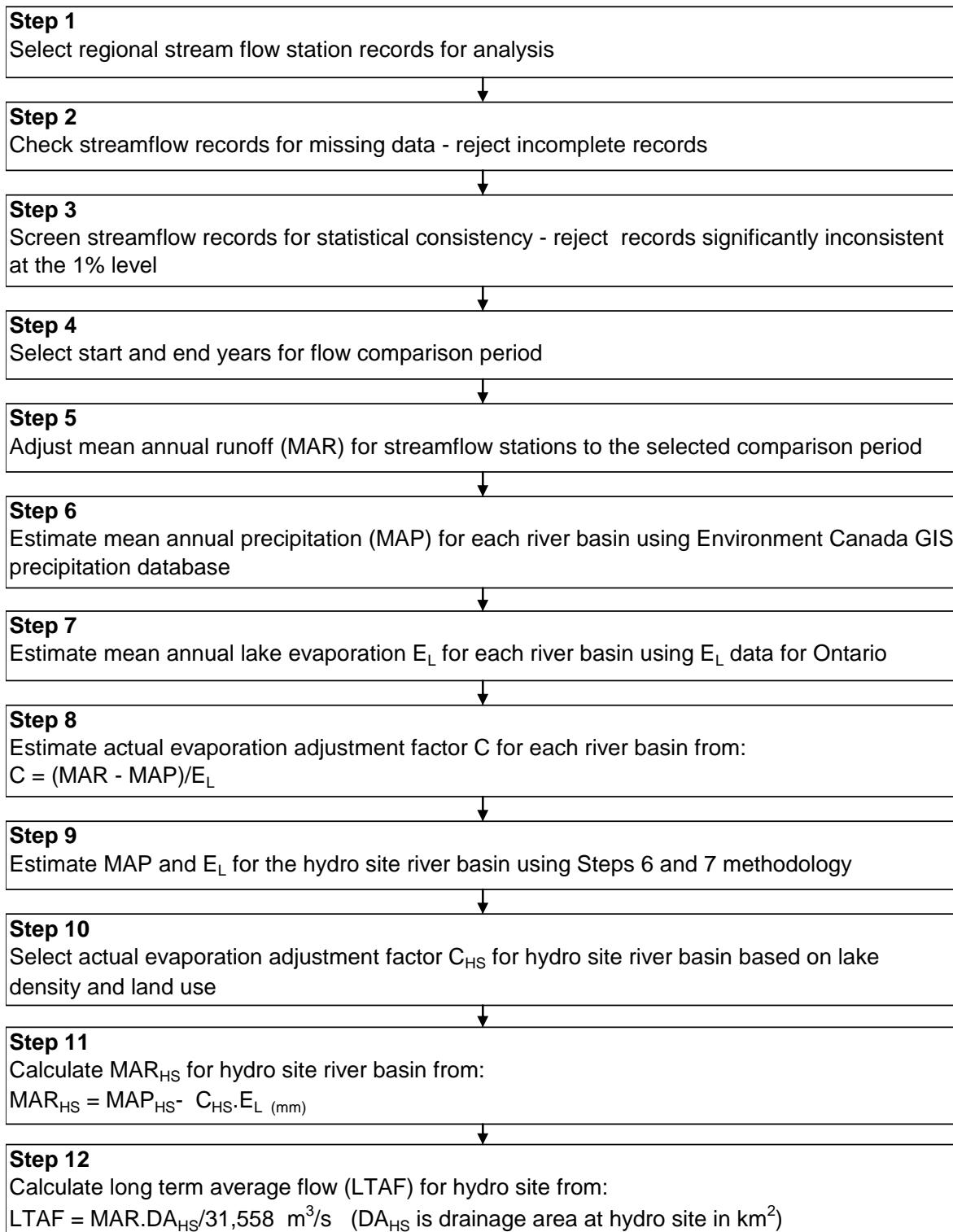
## **Appendix B**

# **MOE Hydrology Requirement Calculation Procedures**

# Hydro Site Hydrology in Ontario

## Daily Flow Series Synthesis

### Long Term Average Flow



## Hydro Site Hydrology in Ontario

### Daily Flow Series Synthesis

#### Representative Streamflow Record

##### **Step 1**

Select regional stream flow station records to convert the LTAF for the hydro site to a daily flow series



##### **Step 2**

Qualitatively assess the characteristics of each river basin:

- degree of regulation, natural or man-made
- drainage area and direction
- latitude and orientation
- drainage density
- lake coverage and land use



##### **Step 3**

The representative streamflow record should have a similar:

- seasonal flow pattern
- temporal flow distribution
- annual variability

as the ungauged hydro site



##### **Step 4**

For each streamflow record divide long term average monthly flow by the LTAF to get a dimensionless seasonal flow pattern



##### **Step 5**

For each streamflow record note the maximum month of the year and % LTAF and minimum month of the year and % LTAF



##### **Step 6**

For each streamflow record prepare a dimensionless daily flow/LTAF duration curve



##### **Step 7**

For each streamflow record note the shape of the curve at the percent exceedance values at the extremes of the curve



##### **Step 8**

For each streamflow record plot the dimensionless historic histogram of mean annual flow/LTAF - patterns should be similar for rivers in the same region



##### **Step 9**

Qualitatively assess the characteristics of the river basin at the hydro site - see Step 2



##### **Step 10**

Select representative streamflow record that best fits the characteristics of the river basin at the hydro site



##### **Step 11**

If more than one streamflow record meets the criteria above select a record with the best measurement method from (best to worst):

1. Continuous (river section)
2. Continuous (at dam)
3. Manual
4. Powerplant



##### **Step 12**

Calculate daily flows for hydro site from daily flows at the selected representative streamflow station (RSS):

$$\text{Flow}_{\text{HS}} = \text{Flow}_{\text{RSS}} \cdot \frac{\text{LTAF}_{\text{HS}}}{\text{LTAF}_{\text{RSS}}}$$

## Hydro Site Hydrology in Ontario

Ontario Ministry of the Environment Requirements	Input Data Source	Software	Comments
a) Descriptive flow statistics using all available daily flows for all years: mean, median, minimum, maximum, flow exceeded 20% time, flow exceeded 80% time.	Long term daily flow series synthesized for hydro site. Must be > 20 years.	SAASv2.1.1	The Hydrograph Explorer (Basic Table) and Flow Analysis (Flow Duration Curves) applications.
b) Extreme low flow statistics: $7Q_2$ (2 year return period 7-day-average-low flow), $7Q_{10}$ (10 year return period 7-day-average-low flow) and $7Q_{20}$ (20 year return period 7-day-average-low flow).	Long term daily flow series synthesized for hydro site. Must be > 20 years.	ENGSOFT/ESLOFFAN	7-day average low flow frequency analysis application; 2LN, 3LN, Log Pearson and Gumbel distributions.
c) Flow duration curves and tables using total daily average flow data for the entire period, for all four seasons and for all twelve months.	Long term daily flow series synthesized for hydro site. Must be > 20 years.	SAASv2.1.1	Flow Analysis (Flow Duration Curves); period of record, seasonal and monthly applications.
d) Flow duration curves and tables using daily baseflow data for the entire period, for all four seasons and for all twelve months.	Long term daily flow series synthesized for hydro site. Must be > 20 years.	SAASv2.1.1	Flow Analysis (Baseflow analysis table); 1, 5, 25, 50, 75, 95 and 99% baseflow exceedance values for: period of record, seasonal and monthly applications.
e) Flow duration curves derived using both the percentile method and the median of percentiles method. Both methods are incorporated into the flow analysis tool, developed by Schmidt and Metcalfe (2009), which can be downloaded for free from <a href="http://trentu.ca/iws/software.php">http://trentu.ca/iws/software.php</a> .	Long term daily flow series synthesized for hydro site. Must be > 20 years.	SAASv2.1.1	Flow Analysis (Flow Duration Curves); percentile and median of percentiles methods for; period of record, seasonal and monthly applications.
f) Flood frequency analysis using instantaneous maximum flow of each year for the entire period of records.	Long term instantaneous flood series synthesized for hydro site. Must be > 20 years.	CFA3.1	See Flood Frequency Analysis sheet
g) Low flow frequency analysis using 7-day-average-low flow for the entire period of records.	Long term daily flow series synthesized for hydro site. Must be > 20 years.	ENGSOFT/ESLOFFAN	7-day average low flow frequency analysis application; 2LN, 3LN, Log Pearson and Gumbel distributions.
h) Altered flow of the bypass reach and the reach below tailrace, if applicable.	Design flow series.		To be defined in design phase
i) Compensation flow for the bypass reach and the reach below tailrace, if applicable.	Design flow series.		To be defined in design phase

# Hydro Site Hydrology in Ontario

## Flood Frequency Analysis

### Step 1

Pre-process instantaneous annual flood peak series from synthesized daily flow series at the hydro site:

1. Select instantaneous and daily annual flood peaks from regional streamflow stations
2. Compare peaking factors (instantaneous/daily peaks) with:
  - Drainage area
  - Season
  - Regulation (natural and man-made)
  - Flood magnitude (divided by drainage area)
  - previous and following day flows
3. Derive function to estimate instantaneous flood peaks from daily flood peaks
4. Use function to estimate instantaneous annual flood peak series from synthesized daily flow series at hydro site



### Step 2

Input the synthesized instantaneous flood peak series to the CFA3.1 software



### Step 3

Screen synthesized instantaneous flood peak series for statistical consistency, including:

- Independence
- Trend
- Homogeneity
- General Randomness



### Step 4

Test for high and low outliers and adjust accordingly



### Step 5

Perform parametric frequency analysis using:

- The General Extreme Value (GEV) Distribution
- The Three-Parameter Lognormal (3LN) Distribution
- The Log Pearson Type III Distribution
- The Wakeby Distribution



### Step 6

Select best fit frequency distribution



### Step 7

Plot and tabulate instantaneous flood peak estimates for hydro site

## Hydro Site Hydrology in Ontario

### Hydrological Software used in Analysis

Software	Title	Source	Year	Description
SAASv2.1.1	Streamflow Analysis and Assessment Software	Ontario Ministry of Natural Resources	2010	SAAS is a MATLAB application to analyze an annual maxima flow series, daily streamflow time-series and hourly streamflow time-series. The software produces tabular and graphic reports on: <ul style="list-style-type: none"> <li>- flow hydrographs</li> <li>- flood frequency analysis</li> <li>- flow duration curves</li> <li>- baseflow</li> <li>- rate of change</li> </ul>
ESLOFFAN	EngSoft LOw Flow Frequency ANalysis	ENGSOFT	1995	ESLOFFAN extracts the annual minimum 7-day or 30-day average flows from a HYDAT formatted daily flow series and undertakes low flow frequency analysis using the 2LN, 3LN, Log Pearson III and Gumbel distributions. The software produces tabular and graphic output for each distribution.
CFA 3.1	Consolidated Frequency Analysis	Environment Canada	2000	CFA 3.1 imports an annual maxima flow series and stores it in a direct access file. The software performs the following tests on the data series: <ul style="list-style-type: none"> <li>- Spearman rank order serial correlation coefficient test for independence</li> <li>- Spearman rank order correlation coefficient test for trend</li> <li>- Mann-Whitney split sample test for homogeneity</li> <li>- Runs above and below the median for general randomness</li> </ul> <p>Flood estimates are computed using the following distributions:</p> <ul style="list-style-type: none"> <li>- The General Extreme Value (GEV) Distribution</li> <li>- The Three-Parameter Lognormal (3LN) Distribution</li> <li>- The Log Pearson Type III Distribution</li> <li>- The Wakeby Distribution</li> </ul> <p>The software produces tabular and graphic output for each distribution.</p>