ANNEX I

HYDROLOGY STUDIES AND PROPOSED OPERATING PLAN

ANNEX I-A

HYDROLOGY REVIEW FOR IVANHOE RIVER HYDROPOWER SITES

Xeneca Power Development Inc.

Hydrology Review

For

Ivanhoe River Hydropower Sites

H330922
Rev. 0
November 3, 2009

Project Report

November 3, 2009

Xeneca Power Development Inc.
Ivanhoe Hydropower Sites
Hydrology Review

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Xeneca Power Development Inc.
Ivanhoe Hydropower Sites

Hydrology Review

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1. Introduction

The objective of this report is to develop flow series for the Ivanhoe River that can be used to assess the hydroelectric generating potential of the following sites:

- The Chutes Rapids
- Three Falls

Flows in the Ivanhoe River have not been measured or monitored in the past at these sites; so long term flow series at each location must be synthesized from flow records at other gauge(s) on the Ivanhoe River and on other rivers in the region.

Figure 1 shows the Ivanhoe River watershed at the two project sites. Figure 2 shows the Ivanhoe River Basin, the locations of Water Survey of Canada (WSC) streamflow gauges and the annual average precipitation distribution in the region.

Flow synthesis generally follows these steps:

- Estimation of the expected mean annual runoff at the site
- Definition of the seasonal flow pattern
- Assessing the variability of runoff from year to year
- Synthesis of a long term daily flow record that meets the above parameters.

2. Mean Annual Runoff

Mean annual runoff (MAR) describes how much of the rainfall and snowmelt runoff in the basin drains past the site on average each year. MAR is usually expressed in units of mm over the drainage basin, for ease of comparison with precipitation (rain and snow) and evaporation, which are also expressed in mm.

The estimation of MAR for an ungauged site depends on the extent of regional information available and whether a water level monitoring gauge has been installed at the site. MAR estimation makes use of the following approaches, depending on the level of information available:

- A regional water balance analysis using precipitation and evapotranspiration data.
- Estimation of the long term average flow (LTAF) at a gauge on the same river.
- Regional runoff trends from a network of established streamflow stations.
- Flow synthesis from the gauged record on the same river.

2.1 Regional Water Balance

Where regional flow data is very limited MAR must be estimated from regional isohyets of equal precipitation and estimates of evapotranspiration, which tends to decrease from south to north across

Ontario. MAR is then estimated as the difference between long term average precipitation and evapotranspiration loss.

The streamflow station network in and around the Ivanhoe River basin is extensive and this simplistic approach was not used directly to estimate the MAR at the four sites. However, a calibrated water balance within the Ivanhoe River and Groundhog River basins has been used to model the variation in runoff between the sites and the Water Survey of Canada (WSC) gauges. This is described in Section 2.3.

2.2 Long Term Flow in the Ivanhoe River

Flows have been measured on the Ivanhoe River at Foleyet [04LC003], since 2001 and on the Groundhog River, to which the Ivanhoe River is a tributary, below Horwood Lake [04LC001] from 1933 to 1961, and at Fauquier [04LD001] from 1920 to 1995. Daily flow data for these streamflow stations are published by the Water Survey of Canada. At Foleyet the Ivanhoe River has a drainage area of 1,612 km^2 compared to 2,723 km^2 at The Chutes site and 3,242 km^2 at the Three Falls site. The mean annual flow for the six years of flow data at Foleyet was 17.8 m^3/s. The flows at this station are classified as "Natural" by WSC, but are naturally regulated by Ivanhoe Lake.

Six years of data are not sufficient to generate a reliable flow series so other flow records in the region have also been accessed to synthesize flows at the project sites.

2.3 Regional Runoff

The runoff at the three WSC streamflow gauges identified above is known, although the length of record used to generate runoff estimates varies widely from six years on the Ivanhoe River at Foleyet to 71 years on the Groundhog River at Fauquier.

Mean annual runoff estimates in the region are 339 mm below Horwood Lake (25 years), 348 mm at Foleyet (6 years) and 382 mm at Fauquier (71 years), with the runoff variation closely linked to the variation of annual average precipitation, as seen in Figure 2.

Regional runoff and precipitation, together with estimated evaporation loss have been used to calibrate a water balance model for the Groundhog River Basin, which includes the two project sites.

Long term runoff can be estimated as:

Runoff = Precipitation – Evaporation Loss

Annual average precipitation over each sub-basin can be estimated from Figure 2. Annual average lake evaporation loss in Ontario is well correlated with latitude, as shown in Appendix B, thus:

Annual average lake evaporation = -36.123*Latitude + 2296.6 mm

Basin wide actual evaporation loss is lower than lake evaporation and varies with land use and precipitation, but, in the long term, can be considered as a constant times lake evaporation for a defined region, i.e.

Annual average evaporation loss = C * Annual average lake evaporation

By accumulating annual average precipitation and evaporation loss for each sub-basin the runoff at each hydropower site and at the WSC streamflow stations can be calculated. In the Groundhog River basin the average runoff at the three WSC stations in the Groundhog River basin can be computed from the flow records, so the constant C is adjusted until the sum of the weighted[1] differences between runoff from the water balance equation and flow records is zero and the water balance equation is calibrated. Table 1 shows the water balance calibration for the Groundhog River basin.

Table 1 Water Balance Calibration for the Groundhog River

Precipitation		Latitude	Evap Et	PPT-Et	Area	Area*(PPT-Et)	∑Area	∑Area*(ppt-Et)	Location	Runoff
Sub-basin	mm	dec N	mm	mm	km^2	$mm.km^2$	km^2	mm.km2		mm
4LC1-1	830	47.5	463	367	371	136208	371	136208		367.1
4LC1-2	811	47.72	457	354	2359	836195	2730	972402		356.2
4LC1-3	787	48	448	339	573	193978	3303	1166381		353.1
4LC1-4	800	48.1	446	354	67	23745	3370	1190126	04LC001	353.2
4LC3-1	830	47.65	459	371	242	89892	242	89892		371.5
4LC3-2	811	47.85	453	358	725	259704	967	349596		361.5
4LC3-3	785	48.15	444	341	645	219848	1612	569444	04LC003	353.3
Chutes-1	800	48	448	352	55	19334	1667	588779		353.2
Chutes-2	785	48.25	441	344	833	286326	2500	875105		350.0
Chutes-3	800	48.15	444	356	56	19928	2556	895032		350.2
Chutes-4	795	48.25	441	354	167	59073	2723	954105	The Chutes	350.4
Three Falls-1	795	48.45	436	359	52	18693	2775	972798		350.6
Three Falls-1	810	48.5	434	376	467	175558	3242	1148356	Three Falls	354.2
4LD1-1	795	48.1	446	349	53	18519	6665	2357001		353.6
4LD1-2	815	48.5	434	381	2009	765281	8674	3122282		360.0
4LD1-3	852	48.35	438	414	53	21921	8727	3144203		360.3
4LD1-4	850	48.75	427	423	3173	1342572	11900	4486775	04LD001	377.0

The differences between the runoff estimates in Table 1 and from the runoff records are 4.1% at station 04LC001, 1.6% at station 04LC003 and 1.4% at station 04LD001. The estimated MAR at The Chutes is 350.4 mm and at Three Falls 354.2 mm. When combined with drainage areas this gives long term average flow (LTAF) estimates of 30.2 m^3/s at The Chutes and 36.4 m^3/s at Three Falls.

3. Seasonal Flow Pattern

A run-of-river hydroelectric project uses natural river flows, without the benefit of storage regulation through a reservoir. Thus it is important to know not only how much flow passes the dam, but also the distribution and timing of flows. This means that it is important to examine the seasonal flow pattern of streamflow stations that might be considered as a base for synthesizing a daily flow record at each project site.

The seasonal runoff patterns for the "Regulated" Groundhog River stations and Mattagami River at Timmins [04LA002] and the "Natural" Ivanhoe River station and Missinaibi River at Mattice [04LJ001] have been compared to examine the impacts of location, drainage area, dam operation and natural lake regulation. Figure 3 shows the seasonal flow pattern for the five streamflow records, with each month expressed as a ratio to the LTAF.

All five rivers exhibit similar seasonal patterns, with maximum flows of 200-400% LTAF occurring in the spring. However, the regulated flows in the Groundhog River at Horwood Lake [04LC001] and

[1] The differences are weighted by the years of record to recognize the greater accuracy of a runoff estimate from 71 years of data compared to one from 6 years of data.

the Mattagami River at Timmins [04LA002] are lowest in the summer whereas the natural flows in the Missinaibi River at Mattice [04LJ001] and the "regulated" flows in the Groundhog River at Fauquier [04LD001] experience lowest flows in winter. The short record for the Ivanhoe River at Foleyet [04LC003] shows similar low flow values in summer and winter.

This means that the "natural" flows in the Ivanhoe River above the project sites at Foleyet do include natural lake regulation and the seasonal pattern of "regulated" flows in the Groundhog River at Fauquier owes more to the unregulated 8,530 km^2 of the Groundhog River basin than the 3,370 km^2 controlled by Horwood Lake.

Seasonal flow patterns at the two project sites should lie between the Ivanhoe River at Foleyet [04LC003] and the Groundhog River at Fauquier [04LD001].

The lower maximum monthly spring runoff in the Ivanhoe River at Foleyet results from the occurrence of the peak flow in late April and the hydrograph recession in May. At the other streamflow stations both the peak and hydrograph recession occur in May.

4. Annual Flow Variability

The third component of a long term flow record required for generation analysis is flow variability from year to year. The LTAF and the seasonal flow pattern summarize the long term average characteristics of the flow series expected at the dam site. However, these flows will vary from year to year and will influence the generating potential of the site.

Figure 4 shows the variation in long term annual flow for the five streamflow stations in Figure 3, expressed as ratios of the LTAF at each site. This figure demonstrates the importance of synthesizing a multi-year flow record to capture the full range of flow variation that could be expected over the life of the project. It is unfortunate that the period of record for the Ivanhoe River does not correspond to the period of record for the Groundhog River. However, comparisons to the Missinaibi River at Mattice [04LJ001], which spans all the other flows series, show similar annual variation of high and low years at all stations. The one slight exception to this is the Mattagami River at Timmins [04LA002], which stores flow from the spring of one year and releases it between January and March of the following year.

The complete records for the period show that sequences of up to seven years with below average flow could be expected in the future.

5. Turbinable Flow

The Run-of-River plants proposed for the two Ivanhoe hydropower sites must use river flows as they arrive, without the use of reservoir storage to regulate flows. The principal hydrological tool used to evaluate run-of-river plants is the flow duration curve. This curve ranks all flows from lowest to highest and plots them against the percent of time they are exceeded. This enables the analyst to compute the volume of flow on average that will pass through the turbine(s) for a given turbine discharge capacity.

Figure 5 shows the flow duration curves for the five streamflow stations compared above with flows expressed as ratios of the LTAF at each site.

The seasonal variation in flows seen at the selected streamflow stations is reflected in the flow duration curves. The strong regulation in the Mattagami River is reflected by the higher flows during the low flow period. The Groundhog River at Horwood Lake regulates flows, but at the expense of zero flow releases for 10% of the time. Both the Ivanhoe River and the Groundhog River at Fauquier exhibit more regulation and higher low flows than the natural flow in the Missinaibi River at Mattice [04LJ001].

The Ivanhoe River at the project sites should have flow duration curves that lie between stations 04LC003 and 04LD001, based on lake coverage and the mix of natural lake regulation and unregulated flow.

6. Long Term Daily Flow Synthesis

Synthesis of a long-term daily flow series at an ungauged site requires selection of an historic streamflow record that has the same characteristics as those expected at the dam to prorate to the site. Here the Ivanhoe River at Foleyet [04LC003] would be the best choice as the representative gauge, but its six years of record is considered too short. The Groundhog River at Fauquier [04LD001] is also a candidate for use as a representative gauge, but it includes the regulation effects of Horwood Lake.

The best solution to synthesize flow series at The Chutes and Three Falls is to use the long 04LD001 record adjusted to closer match the flow patterns at station 04LC003. This was done using 10-day running means of the average daily flow series[2] at the two stations shown in Figure 6. The ratio of the 10-day running means of average daily flow/LTAF at 04LC003 to 04LD001 was calculated for every day of the year. This ratio was then applied to the 24 year flow series for 04LD001 (1971-1994) to synthesize a 24-year flow series at 04LC003.

The daily flow ratio factors were adjusted, while maintaining the LTAF, to get the best fit for the 10-day running mean hydrograph for 04LC003. This best-fit hydrograph is shown in Figure 6 labelled "Project Sites".

This synthetic 24-year daily flow series for 04LC003 was then used to generate a flow duration curve to check that it lie between the curves for 04LD001 and 04LC003. Figure 7 shows the flow duration curve from synthetic flow series. This curve labelled "Sites" lies between the two station curves for most of its length and is considered a good representation of the sites for generation analysis.

Daily flows at each site have been prorated from the synthesized 24-year 04LC003 flow series by the ratios of LTAF values, i.e. 30.2 m^3/s and 36.4 m^3/s at The Chutes Rapids and Three Falls, respectively.

Monthly flows for the Ivanhoe River at Foleyet [04LC003] and the Groundhog River at Fauquier [04LD001] are shown in Tables 2 and 3.

[2] The continuous complete year period 1971-94 was used for station 04LD001 because a continuous recording station was in place during this period, giving the most accurate daily flows.

7. Results

The principal output of this hydrology review is two 24-year, daily flow series that can be used in the generation potential analysis of The Chutes Rapids and Three Falls hydropower sites on the Ivanhoe River. These datasets are too large to include in this report, but the following characteristics of the flow series are reproduced here to confirm their adherence to the objectives stated throughout the report:

- Tables 4-5 Monthly flow summary tables for each site
- Figure 6 Seasonal flow patterns for the two sites
- Figure 7 An annual flow variation diagram for the sites
- Figure 8 Daily flow duration curves for the sites.

In addition to the above Hatch has prepared Flow Metrics for each site using the synthesized 24-year daily flow series.

The Flow Metrics sheets have been attached as Appendix A. The relationship between average annual lake evaporation and latitude in Ontario is presented in Appendix B.

Note: The flow series derived for the two sites are intended for generation potential analysis and should not be used for final flood design or low flow evaluations. Detailed flood and low flow analyses should be undertaken at the project design stage.

8. Recommendations for Future Work

No additional analyses are recommended at this time in support of the energy generation analysis for the two sites on the Ivanhoe River.

As noted above, the flow series derived for the Ivanhoe sites are intended for generation potential analysis and should not be used for final flood design or low flow estimates. Detailed flood and low flow estimates should be undertaken during the Environmental Assessment and Project Design phases.

Table 2 Mean Monthly Flows in the Ivanhoe River at Foleyet [04LC003]

Year	January	February	March	April	May	June	July	August	September	October	November	December	Year
2001	6.5	6.2	6.4	37.9	31.7	15.8	6.6	3.3	11.1	28.8	31.9	35.0	18.5
2002	15.2	9.7	10.3	53.7	61.4	27.8	10.5	7.5	5.9	24.0	15.0	11.6	21.1
2003	8.7	6.5	6.1	27.7	54.7	20.4	15.4	14.3	8.3	15.8	22.1	22.0	18.6
2004	11.9	8.6	10.3	50.4	45.5	14.0	10.6	5.9	7.7	9.1	15.3	11.6	16.7
2005	8.2	7.0	6.1	31.1	24.5	12.0	4.0	2.1	2.2	14.2	20.5	16.9	12.4
2006													
2007													
2008	11.2	10.3	7.6	53.7	63.3	25.0	19.9	12.7	5.4	4.9	8.7	9.1	19.3
Mean	10.3	8.1	7.8	42.4	46.8	19.2	11.2	7.6	6.8	16.1	18.9	17.7	17.8

Table 3 Mean Monthly Flows in the Groundhog River at Fauquier [04LD001]

Year	January	February	March	April	May	June	July	August	September	October	November	December	Year
1921	17.5	14.7	19.0	297.0	342.1	122.4	78.8	58.6	63.1	162.5	61.9	51.3	107.9
1922	47.7	40.0	34.2	233.1	989.3	159.8	111.6	67.3	25.3	26.9	47.6	38.5	153.1
1923	30.3	23.6	21.1	72.5	353.6	119.1	96.2	50.1	138.4	68.4	78.4	46.1	91.9
1924	28.5	26.9	26.2	90.0	350.5	184.6	66.9	62.9	86.6	39.7	33.7	40.2	86.6
1925	25.5	23.6	24.5	163.2	286.2	337.9	215.8	127.0	45.4	84.3	83.1	66.8	124.1
1926	37.6	26.3	18.6	27.9	396.2	212.2	297.9	103.0	91.6	101.3	113.8	83.0	126.8
1927	52.9	42.7	51.4	346.9	556.7	207.3	108.4	72.8	39.7	141.2	85.3	54.3	147.2
1928	49.6	42.1	36.3	117.2	910.3	431.5	282.1	148.7	327.3	493.7	306.8	118.1	273.0
1929	72.1	28.0	43.3	257.6	477.1	314.4	143.4	61.6	85.2	180.6	242.2	76.9	165.7
1930	35.1	49.5	61.5	112.3	638.2	305.0	208.2	66.6	54.8	100.0	74.0	42.8	146.6
1931	45.9	39.6	51.0	219.0	427.4	114.8	47.4	29.3	43.0	109.9	214.5	129.1	123.0
1932	73.0	72.2	75.8	85.4	456.6	102.7	115.2	87.4	123.9	174.1	188.0	78.2	136.5
1933	64.8	64.0	38.7	279.4	546.0	196.9	67.9	52.9	61.0	29.1	49.8	22.8	123.0
1934	13.6	48.1	47.9	40.2	674.7	222.7	70.8	53.5	110.0	74.6	140.5	112.8	134.9
1935	43.0	50.0	59.0	161.1	471.6	203.9	136.5	79.1	65.3	148.6	104.7	44.2	131.2
1936	32.0	45.9	41.9	68.5	744.5	245.7	77.0	35.8	40.0	45.0	47.0	27.9	121.6
1937	28.2	43.6	45.3	134.3	467.1	101.6	164.3	179.3	91.3	177.1	150.3	91.1	140.5
1938	45.9	54.8	54.8	441.3	601.1	422.2	114.3	134.7	52.3	31.2	66.1	46.4	172.3
1939	43.4	45.3	52.7	72.9	795.3	298.4	156.4	48.9	82.4	123.8	85.9	37.3	154.7
1940	44.7	46.2	46.6	57.6	484.1	350.6	183.9	58.3	110.8	78.2	139.2	66.8	139.1
1941	31.5	50.5	54.6	321.0	531.4	157.6	94.5	137.0	276.8	397.3	234.3	196.1	207.7
1942	88.4	74.4	81.5	331.6	475.5	110.1	48.4	36.1	117.7	218.1	120.9	54.0	146.7
1943	43.8	49.4	52.4	83.9	407.4	370.6	154.7	58.3	45.0	44.8	69.6	40.7	118.7
1944	38.0	54.3	59.6	97.4	430.2	149.0	47.0	77.9	167.1	164.6	88.5	51.1	119.0
1945	53.0	55.1	108.6	338.7	244.3	266.0	134.9	45.0	46.3	69.6	135.0	62.3	129.8
1946	48.1	54.9	94.7	289.1	419.6	247.6	110.0	63.3	81.1	56.1	145.6	106.7	143.3
1947	54.5	56.6	67.4	68.7	762.7	609.9	151.8	64.0	63.6	24.0	34.8	25.9	165.9
1948	24.2	26.2	29.8	220.3	333.0	104.0	93.0	98.9	59.7	52.0	112.2	91.4	103.9
1949	53.5	66.8	68.6	183.6	505.2	172.1	65.0	33.9	29.6	30.7	47.5	35.7	108.0
1950	43.0	49.6	57.8	64.6	731.3	481.1	256.9	70.1	54.1	103.3	118.0	87.9	177.5
1951	62.3	64.7	71.9	551.3	474.5	163.0	118.2	70.5	70.4	183.3	243.0	138.3	184.5
1952	68.9	76.3	74.4	270.1	444.9	292.1	177.2	108.1	64.6	55.1	105.0	139.2	156.5
1953	69.6	77.9	91.9	204.5	684.5	284.9	131.9	58.7	133.2	96.0	75.7	138.8	171.4
1954	67.9	72.5	77.9	238.6	601.0	250.0	134.1	66.9	64.6	270.6	209.8	81.9	178.7
1955	63.6	61.5	66.6	316.8	294.1	123.4	33.8	29.3	23.8	81.4	85.7	53.1	102.7
1956	53.6	54.1	58.3	72.8	547.4	323.3	135.4	67.5	129.7	64.1	48.1	42.7	133.4
1957	44.7	49.0	54.5	288.0	406.7	171.8	194.7	48.4	72.0	79.8	220.7	99.9	144.5
1958	66.9	55.4	74.2	187.5	182.5	209.5	97.6	48.8	99.4	141.4	161.5	74.4	116.6
1959	54.0	48.5	54.3	86.9	483.2	174.3	33.5	51.9	69.8	106.9	135.1	61.0	113.8
1960	56.6	51.8	65.0	189.4	1155.4	235.3	64.5	88.2	70.6	72.9	127.9	61.2	187.6
1961	52.3	38.8	48.9	204.4	495.5	349.1	300.3	131.9	339.7	236.1	173.0	114.1	207.7
1962	71.8	74.1	69.5	110.4	681.7	167.7	54.5	116.7	240.1	77.2	56.1	59.0	148.9
1963	48.9	51.6	66.8	187.9	351.5	289.5	124.7	85.1	88.1	70.9	68.1	73.5	125.8
1964	76.7	77.6	48.1	315.0	559.2	335.1	142.7	78.8	114.9	222.5	181.4	90.2	186.9
1965	78.4	80.3	52.7	89.9	667.8	121.5	79.2	109.7	172.8	236.6	116.4	78.2	157.9
1966	75.1	78.5	72.2	216.4	524.2	268.0	77.0	79.0	45.6	257.8	157.4	107.0	163.8
1967	90.6	93.2	69.6	392.2	707.3	281.1	116.4	95.0	45.5	52.4	62.0	50.7	171.7
1968	45.2	53.7	89.3	470.2	229.6	372.7	217.1	65.7		177.0		63.9	
1969	67.0	88.6	54.8	249.0	566.4	198.0	167.0	54.8	66.7	110.3			
1970					387.6	301.5	173.9		55.1	71.1	69.5	64.5	
1971	60.2	65.0	54.2	100.1	637.5	220.1	94.6	50.4	63.6	85.3	147.1	81.7	139.0
1972	68.1	57.9	68.0	54.5	565.4	327.8	159.0	100.2	104.7	142.8	76.8	49.0	148.4
1973	51.7	70.9	81.2	358.6	464.1	198.3	147.6	146.3	154.6	119.0	95.2	65.4	163.1
1974	53.9	75.4	73.5	59.9	562.1	296.9	126.7	84.9	82.3	179.6	126.6	56.4	148.9
1975	79.5	60.2	41.7	70.4	431.7	300.9	47.2	19.2	27.5	40.1	116.5	83.6	110.1
1976	45.7	46.4	91.0	483.0	489.0	129.6	77.3	59.8	21.0	25.4	22.5	25.8	126.4
1977	42.0	38.8	41.2	461.9	262.4	92.8	49.0	27.2	125.1	88.5	149.5	70.8	120.5
1978	51.3	46.8	50.8	33.4	597.2	339.5	237.5	70.4	88.5	203.3	80.8	56.2	155.7
1979	37.7	40.2	34.4	205.9	714.9	354.4	110.9	62.3	83.2	215.5	182.3	80.5	177.7
1980	48.5	51.8	53.6	251.8	358.5	190.8	88.1	42.2	54.8	135.9	64.8	44.7	115.5
1981	47.1	57.9	62.0	384.4	478.3	172.6	75.9	27.5	29.7	61.5	82.7	46.7	127.3
1982	43.1	42.7	41.2	105.1	425.4	91.1	147.1	45.2	126.7	310.4	195.8	84.6	139.1
1983	47.6	38.7	78.6	142.2	766.6	474.6	111.9	56.8	89.5	155.8	84.6	57.8	176.3
1984	59.7	63.3	56.2	319.5	248.9	210.5	301.5	72.8	38.5	68.7	129.1	90.3	138.3
1985	72.3	58.6	61.8	267.1	471.5	175.4	146.5	87.7	38.6	89.9	116.6	64.3	138.0
1986	47.1	49.1	43.0	367.8	351.1	85.2	53.2	135.4	144.6	216.6	142.9	80.6	143.4
1987	48.6	44.1	81.1	232.2	114.3	104.4	107.9	87.1	30.9	82.5	68.0	49.8	87.7
1988	48.1	67.7	34.5	265.2	435.3	116.7	48.5	132.4	85.9	99.3	285.1	167.1	148.8
1989	65.7	87.1	52.2	104.1	640.2	310.6	95.2	60.8	44.9	63.7	135.4	59.2	143.6
1990	64.5	61.4	96.1	339.9	573.6	242.1	207.4	68.9	94.3	290.2	196.4	92.2	194.7
1991	59.9	84.6	56.3	372.2	244.6	102.9	43.1	38.6	60.9	118.0	95.2	80.6	112.8
1992	67.5	69.8	40.1	199.1	441.4	119.5	76.2	86.4	103.7	153.6	133.3	91.5	132.1
1993	71.1	63.1	41.2	169.7	546.7	322.2	196.5	140.9	120.1	163.8	104.8	57.8	167.2
1994	55.9	42.8	43.6	148.2	323.2	188.5	118.8	113.6	66.3	78.6	82.1	54.1	110.1
Mean	52.8	54.9	57.2	209.8	504.8	234.5	124.1	75.6	88.9	125.1	118.5	72.1	144.2

Table 4 Mean Monthly Flows in the Ivanhoe River at The Chutes

Year	January	February	March	April	May	June	July	August	September	October	November	December	Year
1971	19.7	15.4	12.0	31.3	103.7	31.9	14.7	8.4	8.5	20.2	40.3	36.8	28.7
1972	22.2	13.7	15.1	16.2	94.8	47.8	24.1	16.3	13.5	34.3	19.6	22.3	28.4
1973	16.8	16.9	18.0	108.8	81.0	29.6	22.8	24.0	20.1	28.6	24.8	29.7	35.1
1974	17.9	17.8	16.3	17.6	88.8	44.0	20.0	14.3	10.6	42.6	31.7	25.7	29.1
1975	26.6	14.4	9.2	21.7	75.3	44.4	7.3	3.2	3.6	9.2	30.9	37.9	23.7
1976	15.4	10.8	20.1	151.4	87.5	18.9	11.7	10.2	2.7	6.0	5.9	11.8	29.3
1977	13.6	9.2	9.1	143.0	48.7	13.8	7.6	4.2	15.8	21.3	39.3	32.0	29.7
1978	17.1	11.1	11.3	9.4	91.9	50.2	37.1	11.7	11.2	50.4	20.7	25.5	29.2
1979	12.5	9.6	7.6	65.2	117.1	52.5	17.2	10.6	11.0	47.3	45.3	36.4	36.2
1980	16.0	12.3	11.9	80.3	67.9	27.9	14.0	7.0	7.5	32.0	16.4	20.4	26.1
1981	15.4	13.7	13.7	113.6	83.0	25.5	11.8	4.6	3.7	14.5	21.1	21.2	28.5
1982	14.1	10.1	9.1	32.3	80.1	13.3	21.8	7.5	16.1	70.1	49.8	38.0	30.4
1983	15.9	9.2	17.5	42.6	127.3	68.9	17.4	9.6	11.6	37.2	22.0	26.1	33.9
1984	19.4	15.0	12.4	96.9	45.8	31.4	46.8	12.1	5.2	16.0	33.0	41.2	31.2
1985	23.9	13.9	13.7	86.5	84.5	25.8	21.8	14.9	5.0	21.6	30.4	29.0	31.0
1986	15.5	11.7	9.5	111.5	65.3	12.5	8.2	23.2	18.4	52.4	36.5	36.5	33.5
1987	16.4	10.4	18.0	68.5	19.9	15.5	16.0	14.5	4.0	19.5	17.7	22.8	20.3
1988	15.6	16.0	7.6	80.6	78.5	17.0	7.5	23.0	11.4	23.4	77.3	73.7	36.0
1989	21.4	20.7	11.5	32.0	106.4	45.9	14.8	10.2	5.9	14.6	35.0	26.7	28.8
1990	21.1	14.6	21.4	106.6	98.0	35.8	32.4	11.4	12.1	64.1	49.2	41.5	42.5
1991	19.6	20.0	12.4	111.1	44.8	15.1	6.6	6.2	7.4	26.9	23.9	36.7	27.5
1992	22.1	16.6	8.9	64.7	77.6	17.8	11.8	14.2	13.3	35.8	35.1	41.6	30.0
1993	23.7	15.0	9.1	52.8	94.8	47.3	30.1	23.3	14.6	37.5	26.8	26.2	33.6
1994	18.3	10.2	9.7	45.7	55.2	27.8	18.0	19.0	8.5	18.6	21.7	24.5	23.2
Mean	18.3	13.7	12.7	70.4	79.9	31.7	18.4	12.7	10.1	31.0	31.4	31.8	30.2

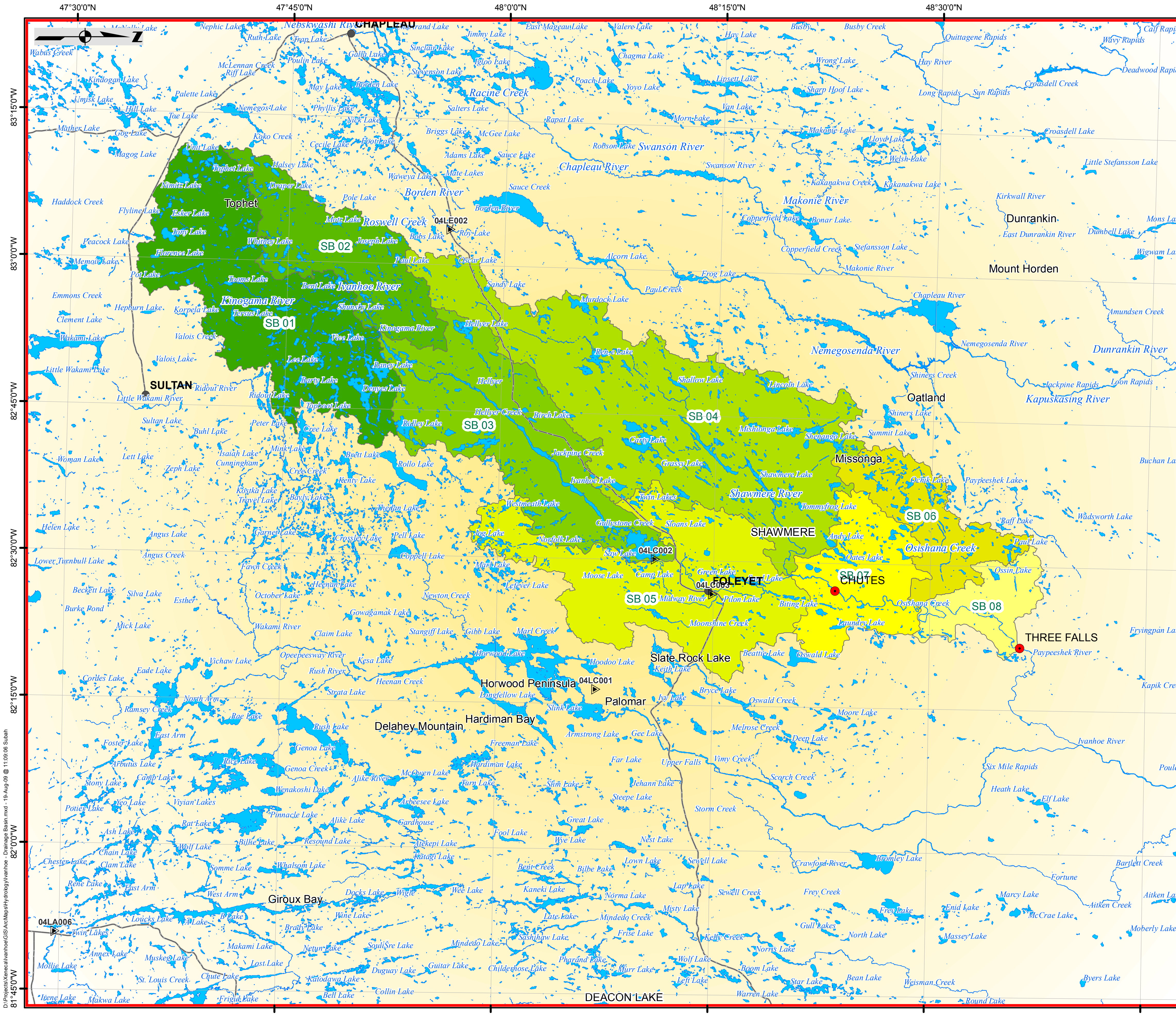
Table 5 Mean Monthly Flows in the Ivanhoe River at Three Falls

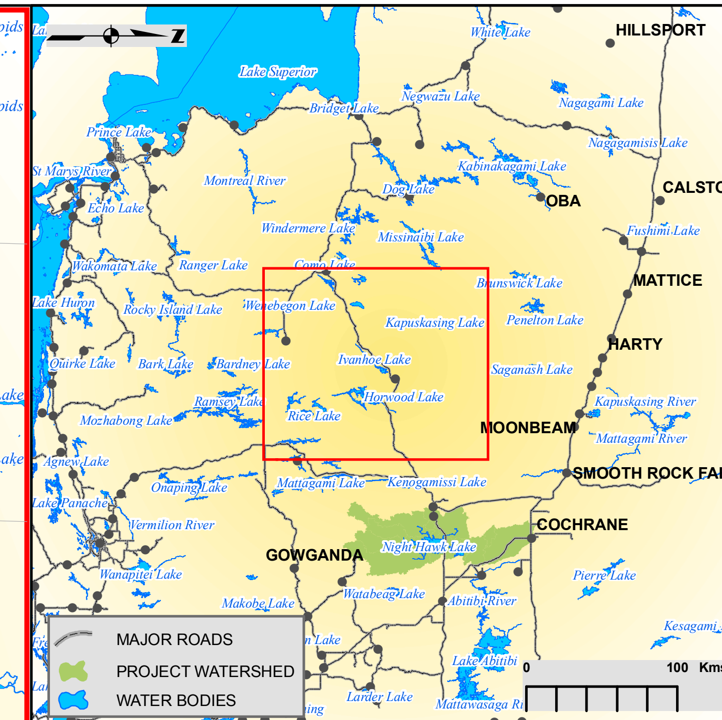
Year	January	February	March	April	May	June	July	August	September	October	November	December	Year
1971	23.7	18.6	14.4	37.7	124.9	38.3	17.7	10.1	10.2	24.4	48.6	44.3	34.5
1972	26.7	16.5	18.2	19.5	114.1	57.5	29.0	19.6	16.2	41.3	23.6	26.9	34.2
1973	20.2	20.3	21.7	130.9	97.5	35.7	27.4	28.9	24.2	34.4	29.9	35.8	42.3
1974	21.5	21.4	19.6	21.2	106.9	53.0	24.1	17.3	12.7	51.3	38.1	31.0	35.0
1975	32.0	17.3	11.1	26.1	90.7	53.4	8.7	3.9	4.3	11.1	37.2	45.6	28.5
1976	18.6	13.0	24.2	182.2	105.4	22.8	14.1	12.3	3.3	7.2	7.1	14.2	35.3
1977	16.3	11.1	11.0	172.1	58.7	16.6	9.1	5.0	19.0	25.7	47.3	38.6	35.8
1978	20.6	13.3	13.6	11.3	110.6	60.5	44.6	14.0	13.5	60.6	24.9	30.7	35.1
1979	15.0	11.5	9.2	78.5	141.0	63.2	20.7	12.8	13.2	57.0	54.5	43.8	43.5
1980	19.2	14.7	14.3	96.6	81.7	33.6	16.9	8.4	9.0	38.5	19.8	24.5	31.4
1981	18.5	16.5	16.5	136.8	100.0	30.7	14.2	5.5	4.5	17.5	25.4	25.5	34.3
1982	16.9	12.2	11.0	38.9	96.5	16.1	26.3	9.1	19.4	84.4	59.9	45.7	36.6
1983	19.2	11.0	21.0	51.3	153.2	82.9	20.9	11.5	13.9	44.8	26.5	31.4	40.9
1984	23.4	18.0	15.0	116.6	55.1	37.7	56.4	14.6	6.2	19.3	39.7	49.5	37.6
1985	28.8	16.8	16.5	104.2	101.7	31.1	26.3	18.0	6.0	26.0	36.6	35.0	37.3
1986	18.7	14.0	11.5	134.2	78.6	15.0	9.9	28.0	22.2	63.1	44.0	44.0	40.3
1987	19.8	12.5	21.7	82.4	23.9	18.6	19.3	17.4	4.8	23.4	21.3	27.4	24.4
1988	18.8	19.3	9.2	97.0	94.5	20.4	9.0	27.7	13.8	28.2	93.1	88.7	43.3
1989	25.8	24.9	13.9	38.5	128.0	55.2	17.8	12.3	7.1	17.6	42.1	32.2	34.7
1990	25.4	17.6	25.8	128.3	117.9	43.1	39.0	13.8	14.5	77.1	59.2	50.0	51.1
1991	23.6	24.1	15.0	133.8	53.9	18.1	8.0	7.4	9.0	32.4	28.7	44.2	33.1
1992	26.6	19.9	10.7	77.9	93.4	21.4	14.1	17.1	16.0	43.1	42.2	50.0	36.1
1993	28.5	18.1	10.9	63.5	114.1	56.9	36.3	28.0	17.6	45.1	32.3	31.5	40.4
1994	22.0	12.2	11.6	55.0	66.4	33.5	21.7	22.9	10.2	22.4	26.1	29.5	27.9
Mean	22.1	16.5	15.3	84.8	96.2	38.1	22.1	15.2	12.1	37.3	37.8	38.3	36.4

Mark Orton

MO:ll

FIGURES





NOTES:

1. MAPPING INFORMATION SHOWN ON THE DRAWING HAS BEEN DERIVED FROM THE DIGITAL DATA FROM MNR DATABASE
2. PROJECTED COORDINATE SYSTEM IS NAD 1983, UTM ZONE 17N.

LEGEND

- WATER BODIES
- SUB-BASINS

SUB BASIN ID	DRAINAGE	AREA (km^2)
SB 01	KINOGAMA RIVER	568
SB 02	IVANHOE RIVER CP 1 (KINOGAMA RIVER)	275
SB 03	IVANHOE LAKE AND RIVER LOCAL	467
SB 04	SHAWMERE RIVER	879
SB 05	IVANHOE RIVER CP 2 (SHAWMERE RIVER)	503
SB 06	OSISHANA CREEK	192
SB 07	IVANHOE RIVER CP 3 (OSISHANA CREEK)	230
SB 08	THREE FALLS DAM SITE LOCAL	128

DRAINAGE AREA SUMMARY:

LOCATION	AREA (km^2)
GAUGE - 04LC002	1310
GAUGE - 04LC003	1612
CHUTES	2723
THREE FALLS	3242

Xeneca Power Development Inc.

0 1 : 500,000 20 Kms

XENECA POWER
IVANHOE RIVER HYDRO DEVELOPMENT
THREE FALLS WATERSHED

FIGURE 1

HATCH

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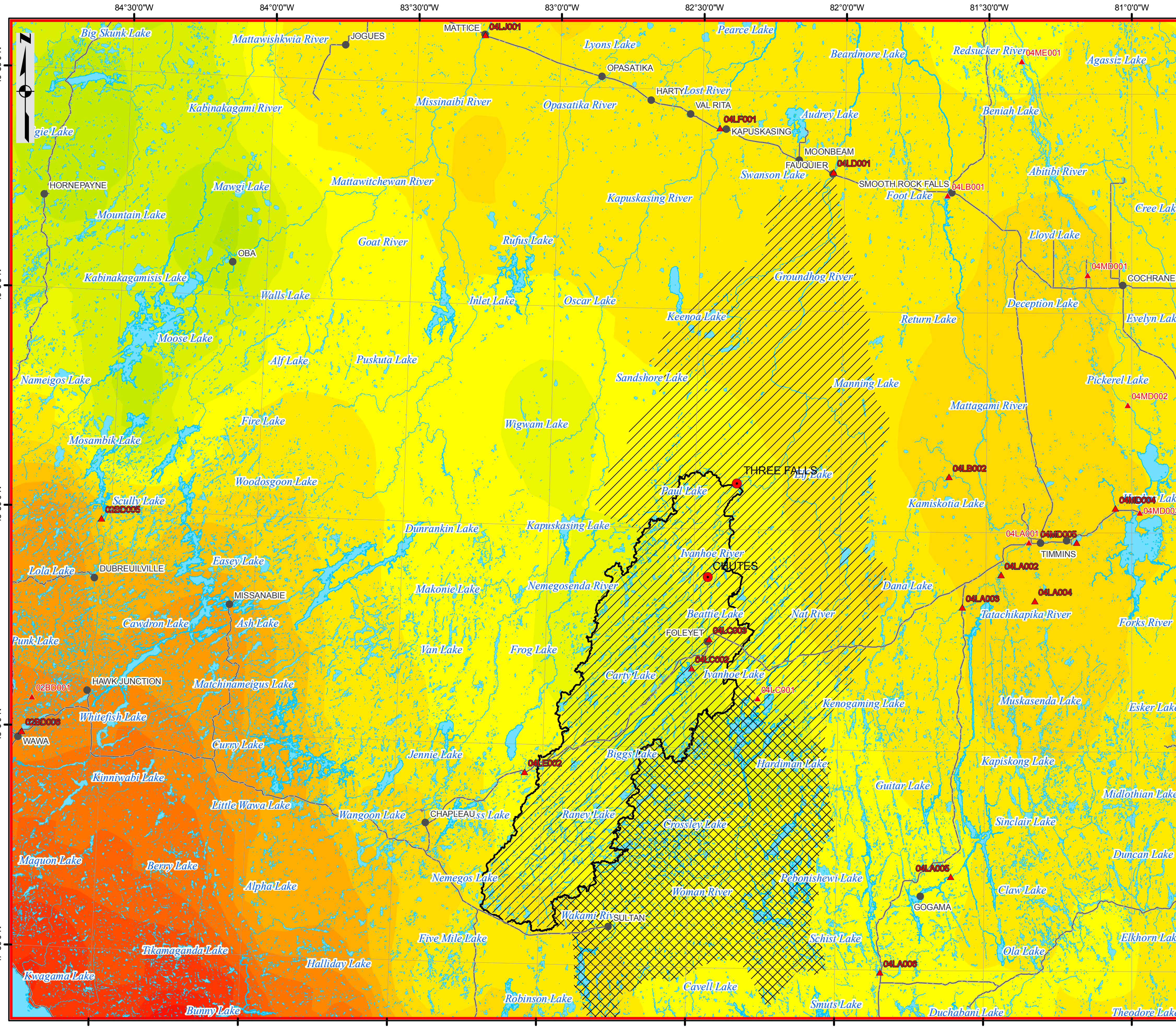
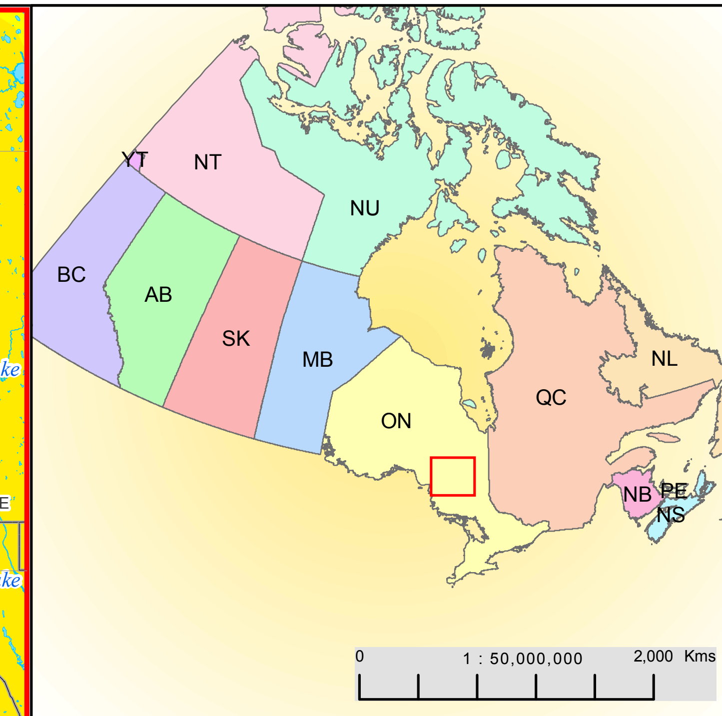




NOTES:

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

LEGEND

- POPULATED PLACES
- GAUGING STATION (ACTIVE)
- GAUGING STATION (DISCONTINUED)
- WATER BODIES
- ROAD NETWORK
- THREE FALLS WATERSHED
- GAUGE 04LD001 WATERSHED
- GAUGE 04LC001 WATERSHED

ANNUAL AVG. PRECIPITATION (MM)

451 - 478	692 - 717	931 - 957
479 - 505	718 - 744	958 - 983
506 - 531	745 - 771	984 - 1,010
532 - 558	772 - 797	1,011 - 1,036
559 - 584	798 - 824	1,037 - 1,063
585 - 611	825 - 850	1,064 - 1,090
612 - 638	851 - 877	1,091 - 1,116
639 - 664	878 - 903	1,117 - 1,143
665 - 691	904 - 930	1,144 - 1,169

Xeneca Power Development Inc.

0 1 : 1,000,000 50 Kms

XENECA POWER
IVANHOE RIVER HYDRO DEVELOPMENT
ANNUAL AVG. PRECIPITATION

FIGURE 2

HATCH

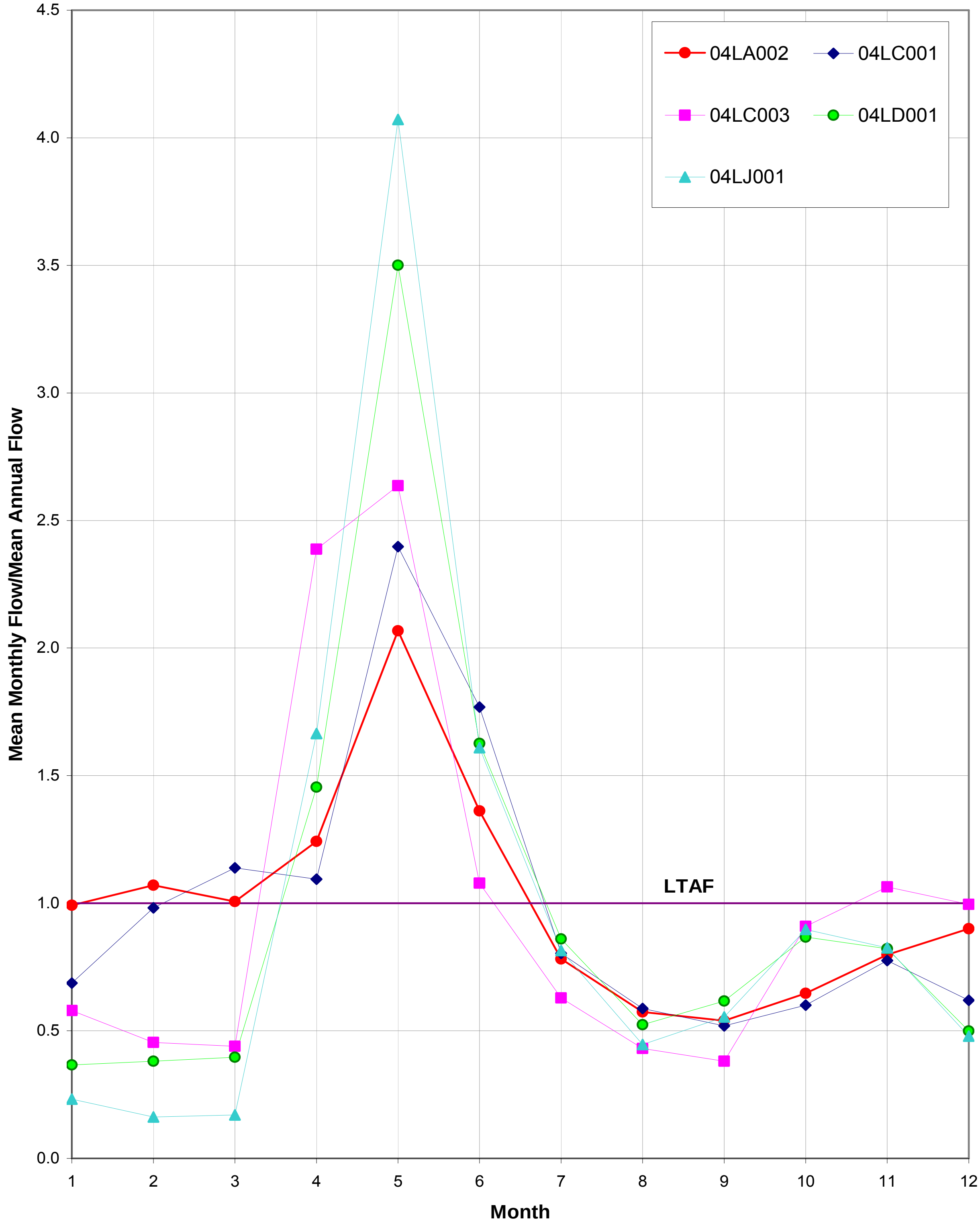


Figure 3
Xeneca Power
Ivanhoe Hydropower Sites
Seasonal Flow Patterns

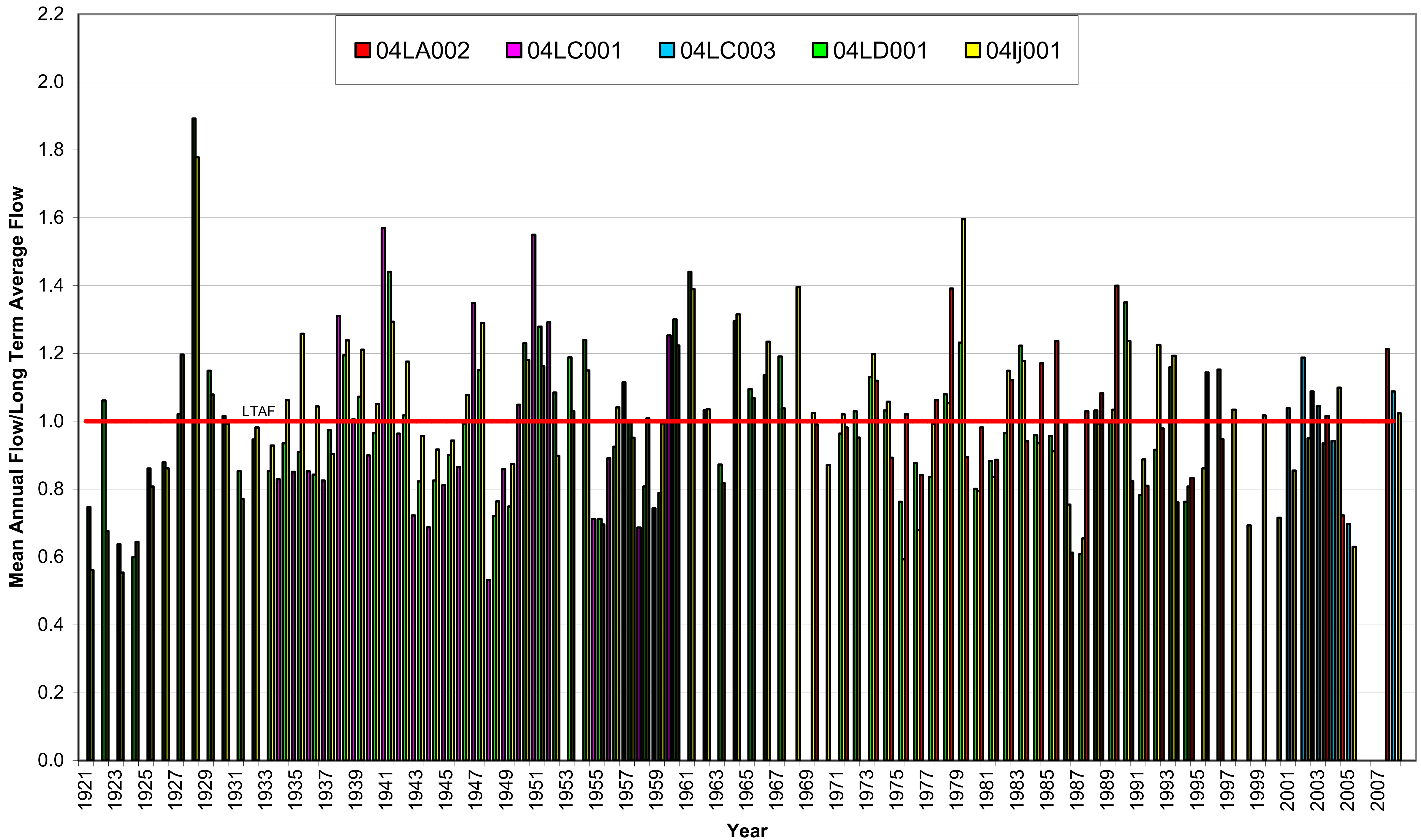


Figure 4
Xeneca Power
Ivanhoe Hydropower Sites
Annual Flow Variability

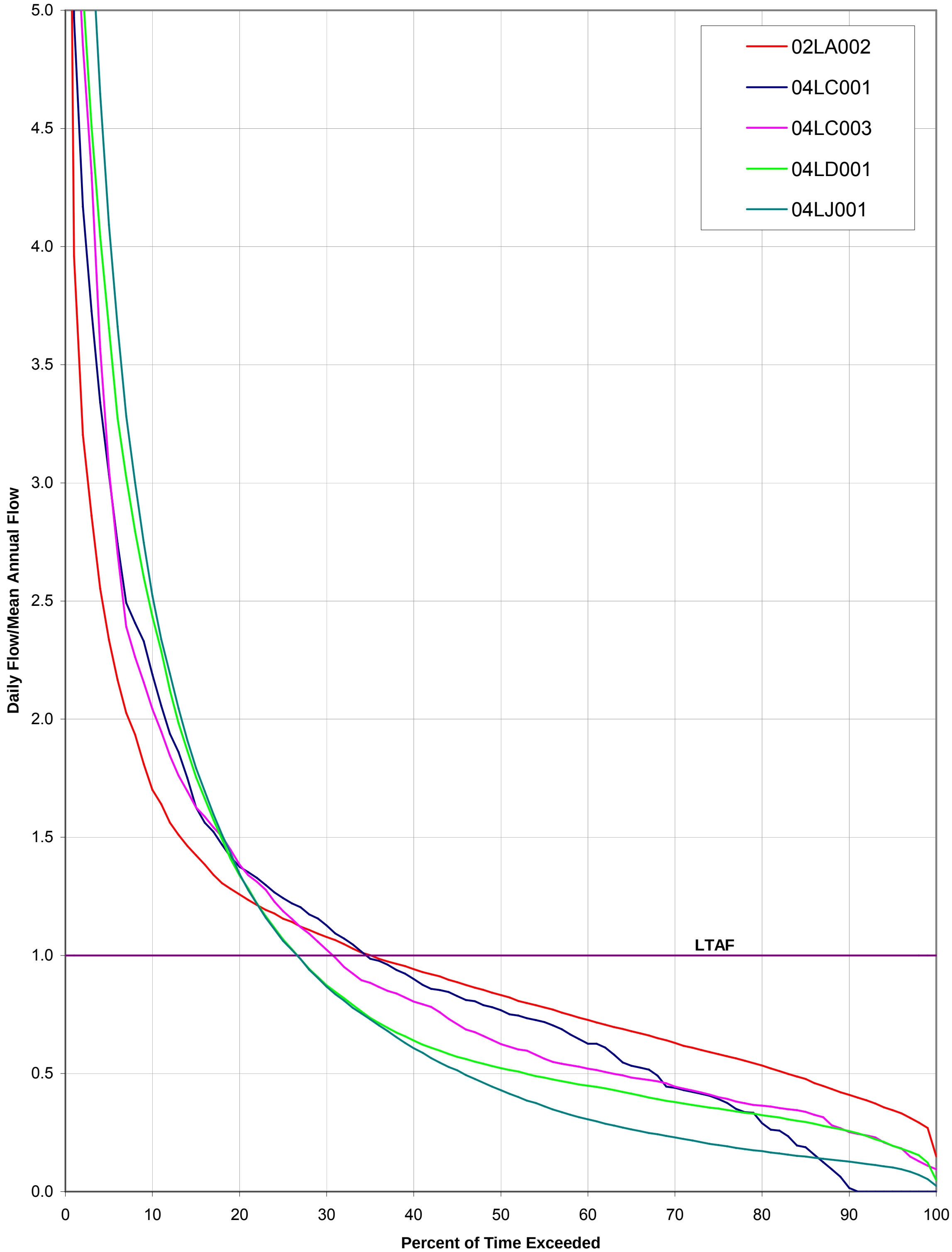


Figure 5
Xeneca Power
Ivanhoe Hydropower Sites
Daily Flow Duration Curves

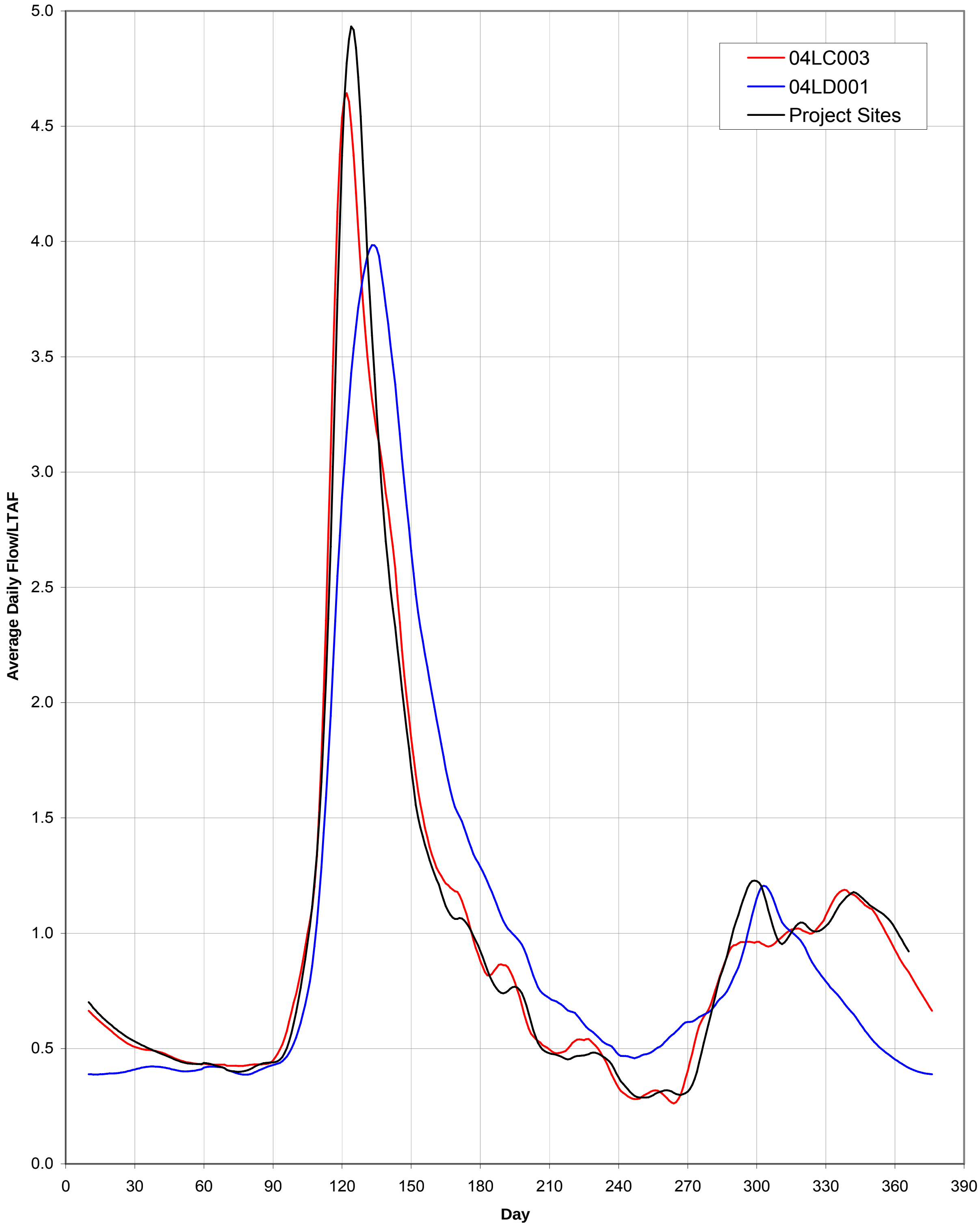


Figure 6
Xeneca Power
Ivanhoe Hydropower Sites
Ten-Day Running Mean Hydrographs

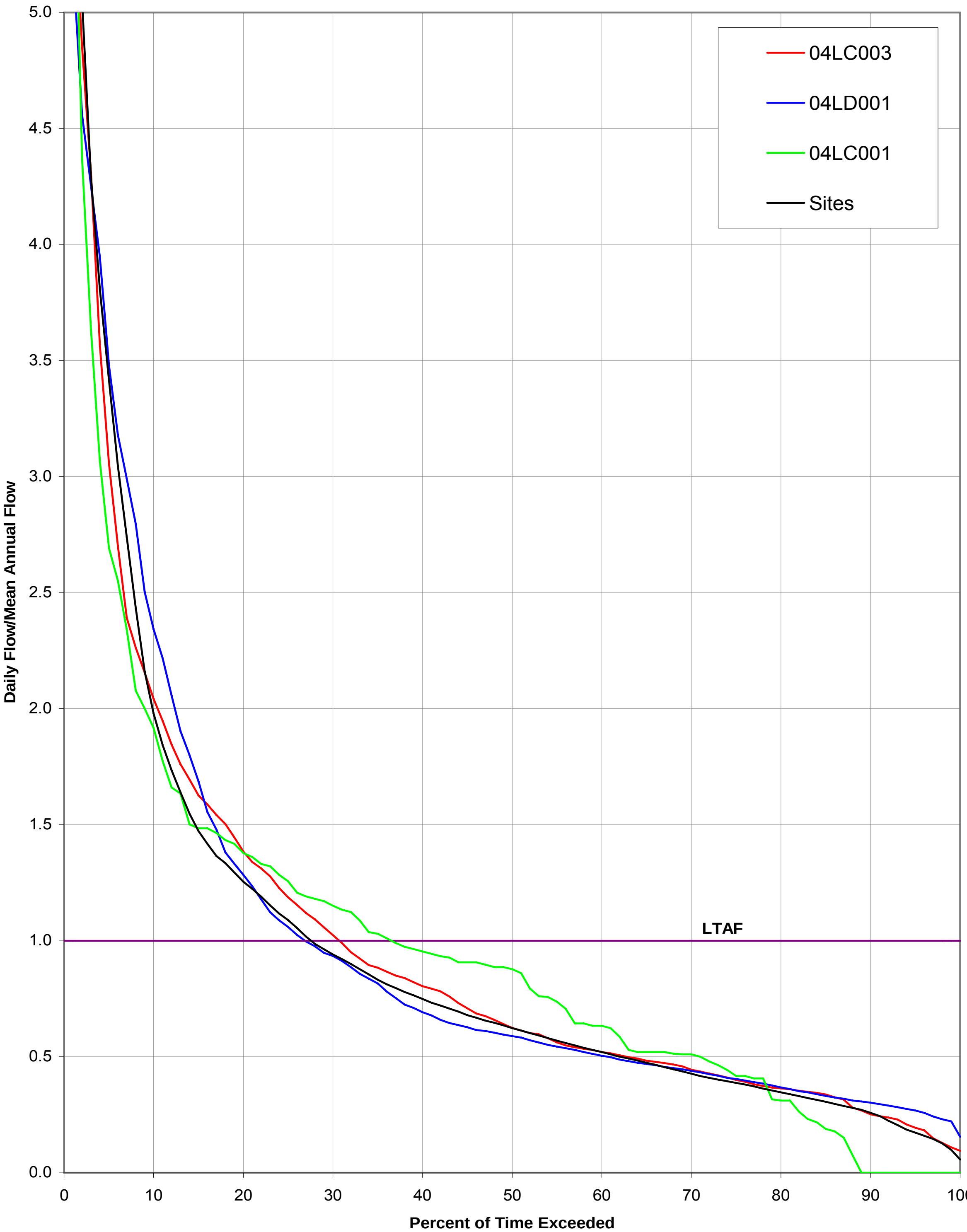


Figure 7
Xeneca Power
Ivanhoe Hydropower Sites
Dimensionless Project Flow Duration Curves

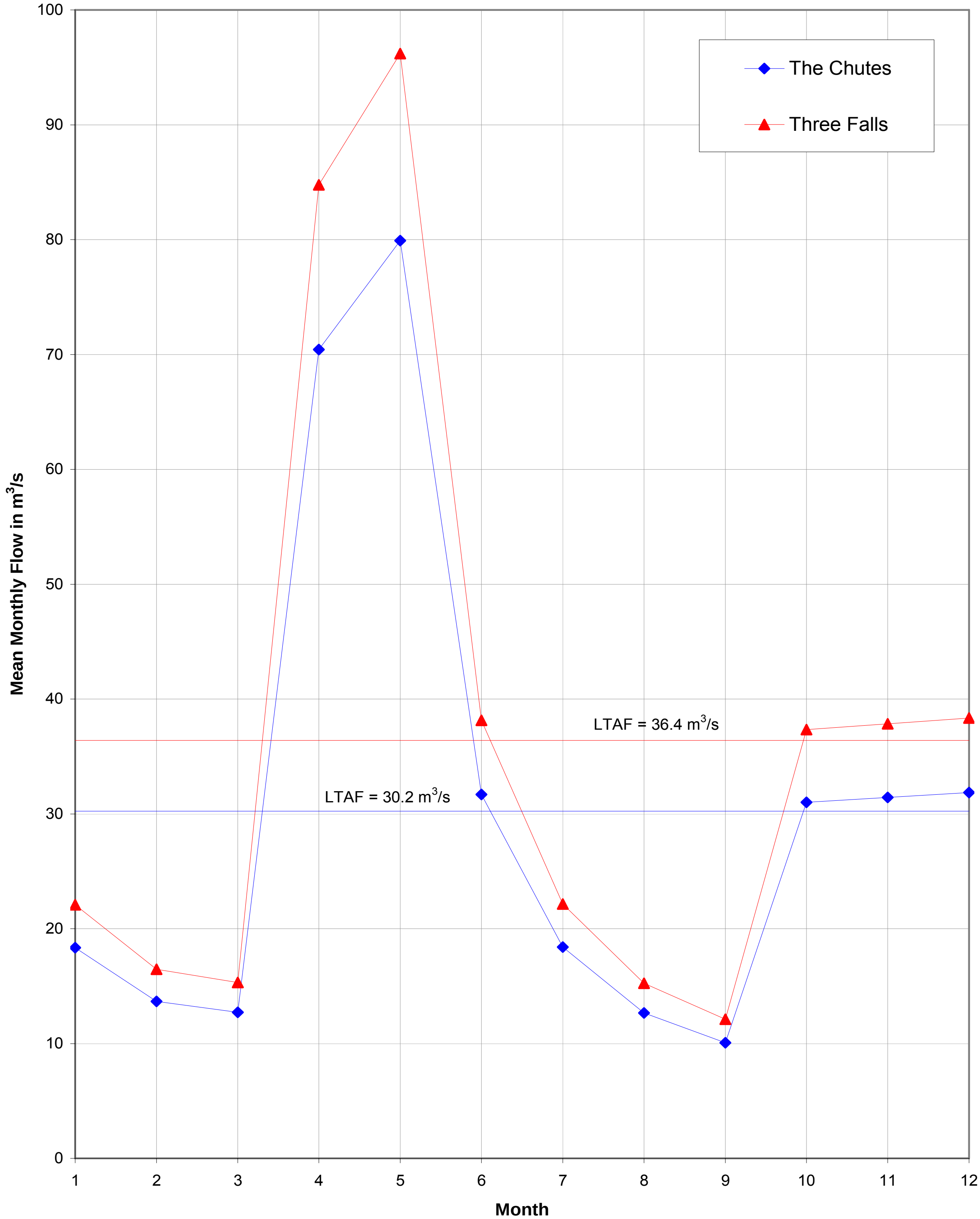


Figure 8
Xeneca Power
Ivanhoe Hydropower Sites
Ivanhoe River Hydropower Sites – Seasonal Flow Pattern

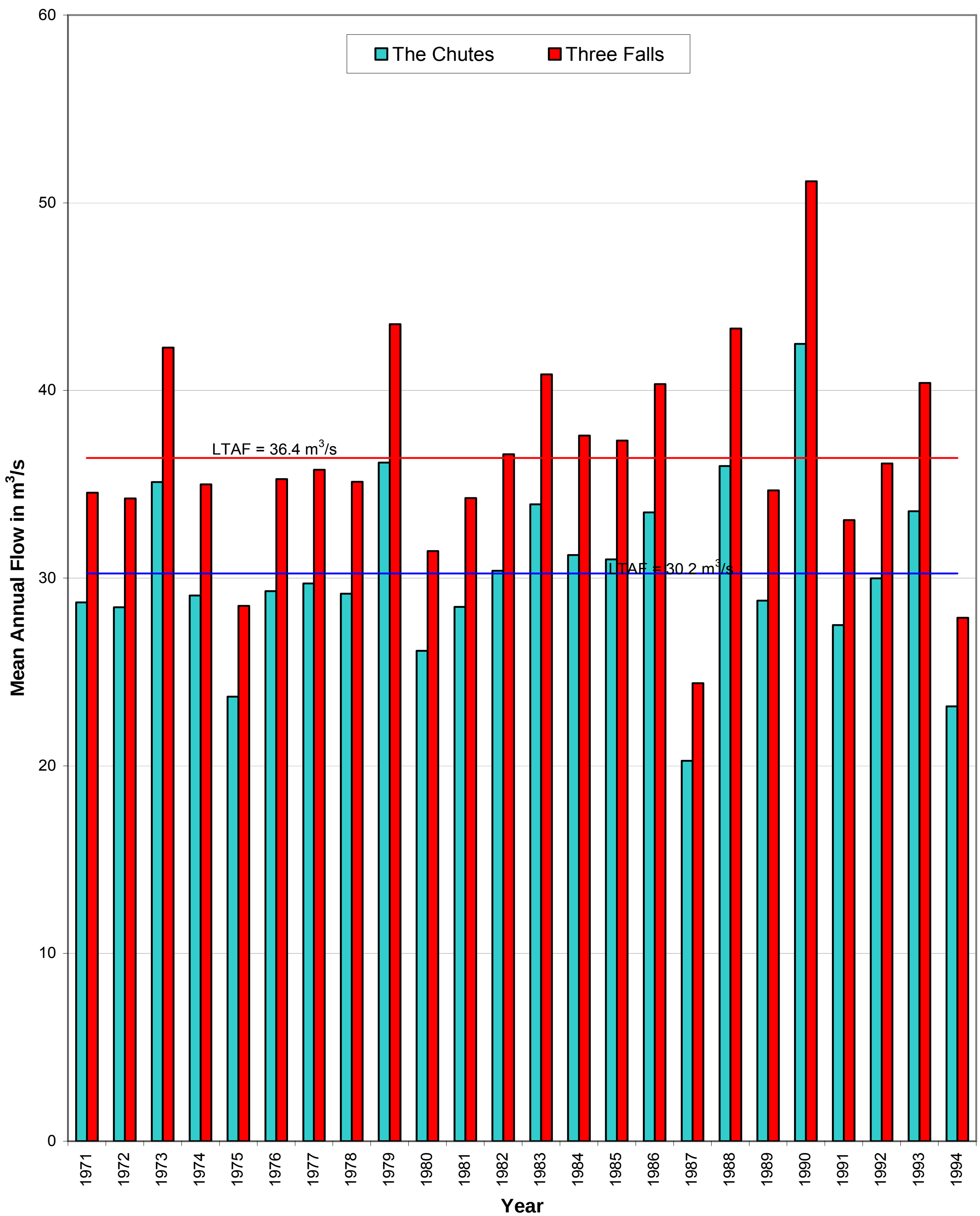
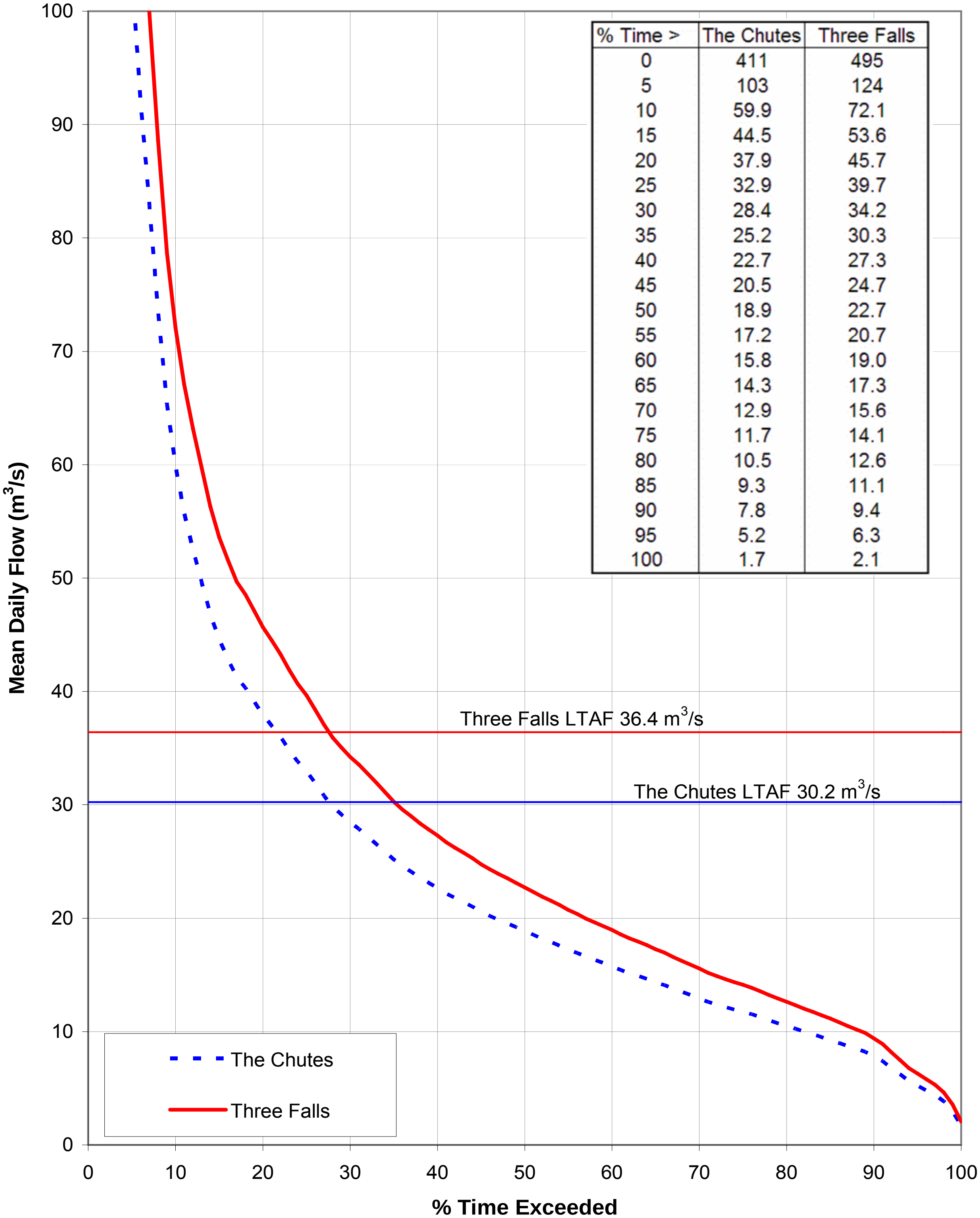


Figure 9
Xeneca Power
Ivanhoe Hydropower Sites
Ivanhoe River at Hydropower Sites – Annual Flow Variability



% Time >	The Chutes	Three Falls
0	411	495
5	103	124
10	59.9	72.1
15	44.5	53.6
20	37.9	45.7
25	32.9	39.7
30	28.4	34.2
35	25.2	30.3
40	22.7	27.3
45	20.5	24.7
50	18.9	22.7
55	17.2	20.7
60	15.8	19.0
65	14.3	17.3
70	12.9	15.6
75	11.7	14.1
80	10.5	12.6
85	9.3	11.1
90	7.8	9.4
95	5.2	6.3
100	1.7	2.1

Figure 10
Xeneca Power
Ivanhoe Hydropower Sites
Ivanhoe River at Hydropower Sites – Daily Flow Duration Curve

HATCH™

APPENDIX A
Flow Metrics

THE CHUTES - IVANHOE RIVER
NATURAL FLOW METRICS DATA SHEET

STATION INFORMATION		
SITE ID	0	
RIVER NAME	IVANHOE RIVER	
SITE NAME	THE CHUTES	
REGION	NORTHEAST	
DISTRICT	CHAPLEAU	
DRAINAGE AREA	2723	km^2
OWNER	XENECA POWER	

Flow metrics are provided for the potential waterpower site based on the Water Survey of Canada (WSC) gauging station, GROUNDHOG RIVER AT FAUQUIER (04LD001). Metrics are based on WSC flows from 1971 to 1994 (24 years).

The flow records for the site have been synthesized by pro-rating adjusted gauge flows at 04LD001 by the ratio of the runoff and drainage areas. Other descriptive metrics have been included in the data sheet to provide a more complete description of the ranges of streamflow on the river system and to facilitate comparisons between river systems.

Annual (1971 - 1994):

I. Streamflow Time Series

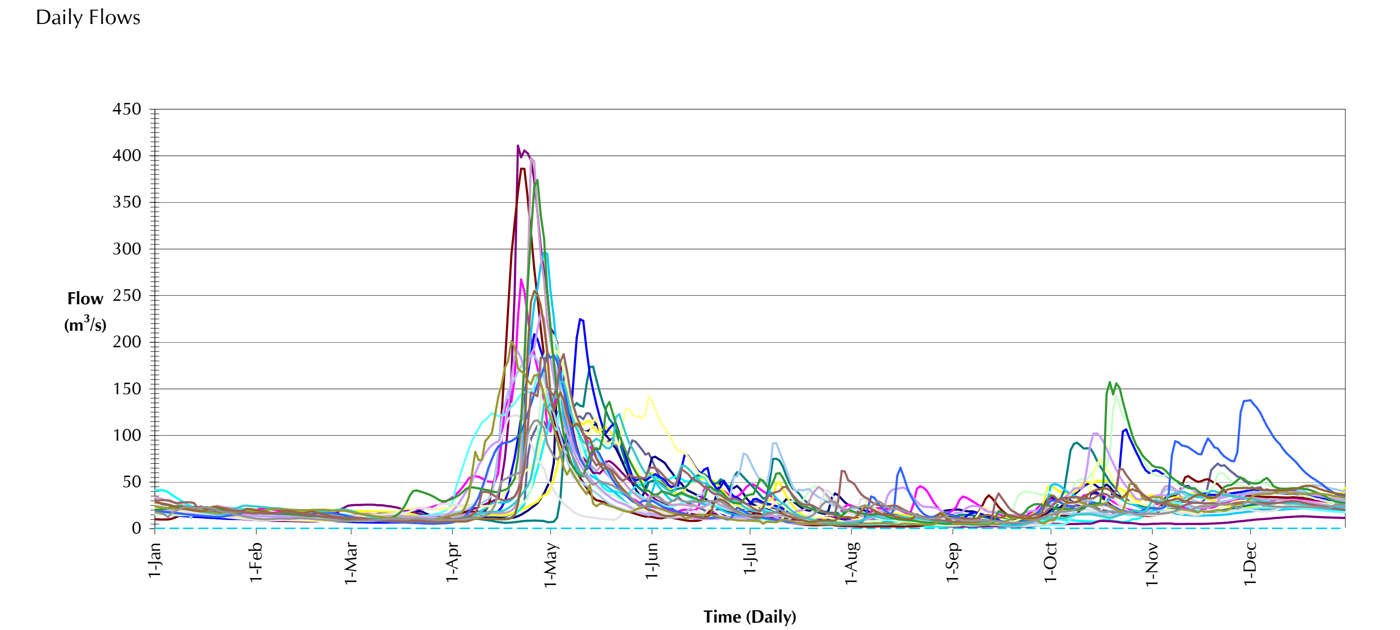


Figure 1 : Annual Daily flow hydrographs from 1971 to 1994.

Table 1 : Annual flow metrics based on 24 years of data.

Descriptive Metric		
Mean Annual Flow	30.24	m^3/s
20% Time Exceeded Flow	37.93	m^3/s
Median Flow	18.86	m^3/s
80% Time Exceeded Flow	10.50	m^3/s
Mean Rising Rate of Change of Flow	3.00	$m^3/s/day$
Mean Falling Rate of Change of Flow	-1.80	$m^3/s/day$
Extreme Low Flow Conditions:		
7-day-avg. low flow in 2-yr return period, $7Q_2$	4.86	m^3/s
7-day-avg. low flow in 10-yr return period, $7Q_{10}$	2.14	m^3/s
7-day-avg. low flow in 20-yr return period, $7Q_{20}$	1.56	m^3/s
Target Metric		
Riparian Flows (Q_2 - Q_{20})	206 -391	m^3/s
Bankfull Flows ($Q_{1.5}$ - $Q_{1.7}$)	174 -189	m^3/s

II. Flow Duration

Time Exceeded %	Flow (m^3/s)
0%	410.9
1%	187.1
5%	103.2
10%	59.8
20%	37.9
30%	28.4
40%	22.7
50%	18.9
60%	15.8
70%	12.9
80%	10.5
90%	7.8
95%	5.2
99%	3.0
100%	2.1

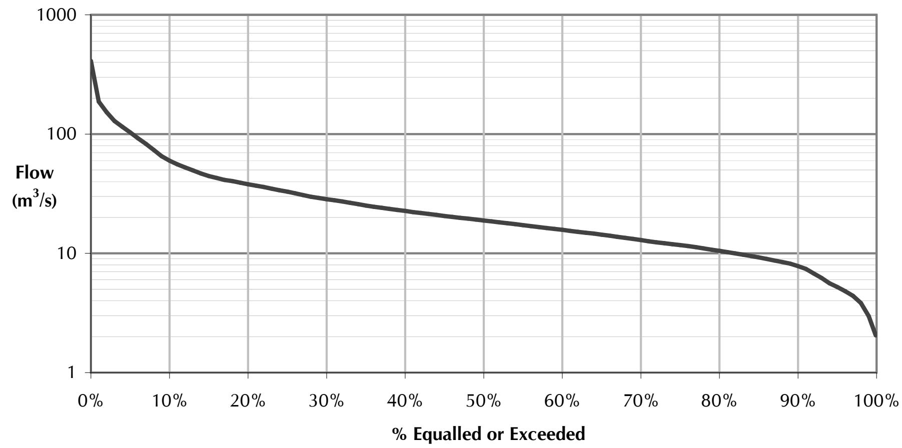


Table 2 & Figure 2 : Flow duration table and curve displaying flow vs. percent time exceeded over 24 years.

III. Flood Frequency Analysis

Return Period (years)	Flow (m^3/s)
1.05	101.7
1.25	146.8
1.5	173.8
1.7	188.9
2	206.4
5	286.6
10	339.7
20	390.6
50	456.6
100	506.0

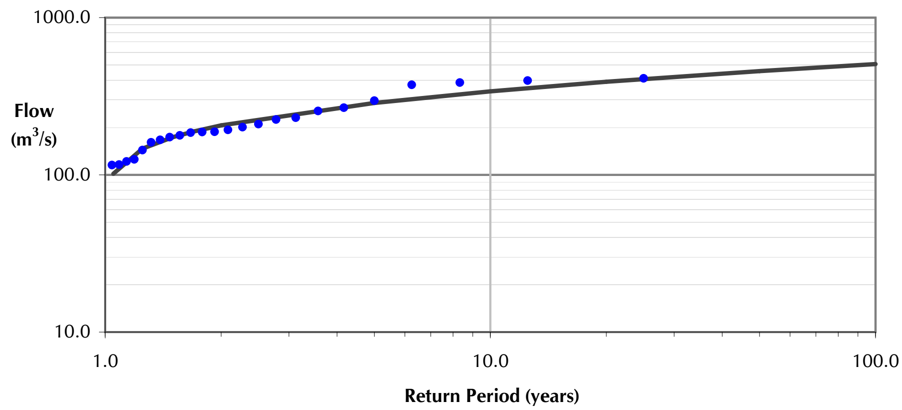


Table 3 & Figure 3 : Flood frequency analysis and curve fitted by the Gumbel probability distribution.

IV. Low Flow Frequency Analysis (Performed using 7-day-average low flow)

Return Period (years)	Flow (m^3/s)
1.005	11.77
1.01	11.08
1.11	8.20
1.25	7.01
2	4.86
5	2.97
10	2.14
20	1.56
50	1.04
100	0.77

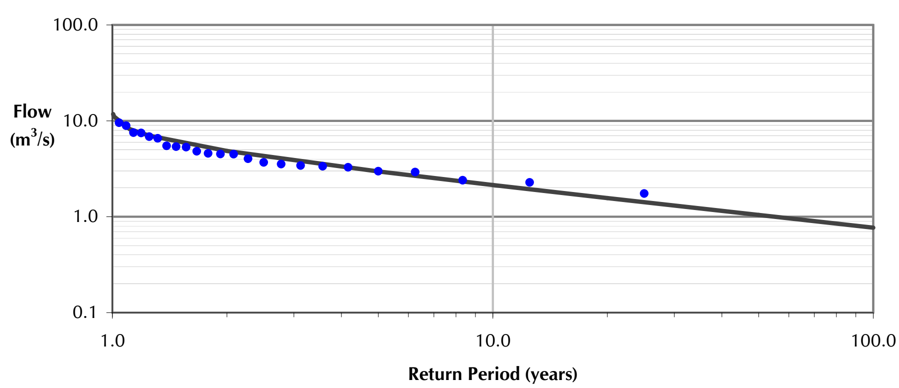


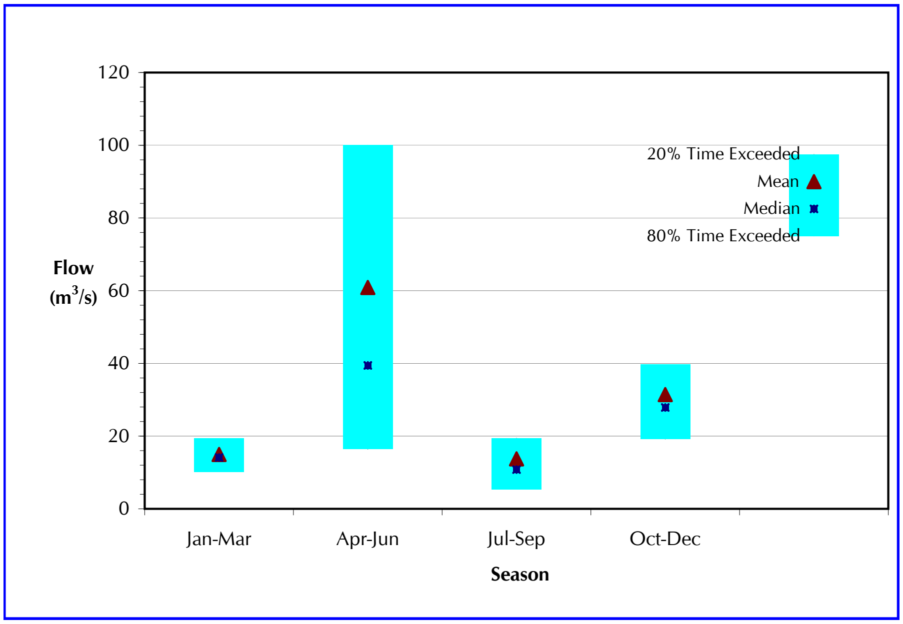
Table 4 & Figure 4 : 7-day-average low flow frequency analysis and curve fitted by the Gumbel probability distribution.

Seasonal :

I. Flow Duration

Table 5 & Figure 5 : Seasonal median flow duration for determining minimum flow targets.

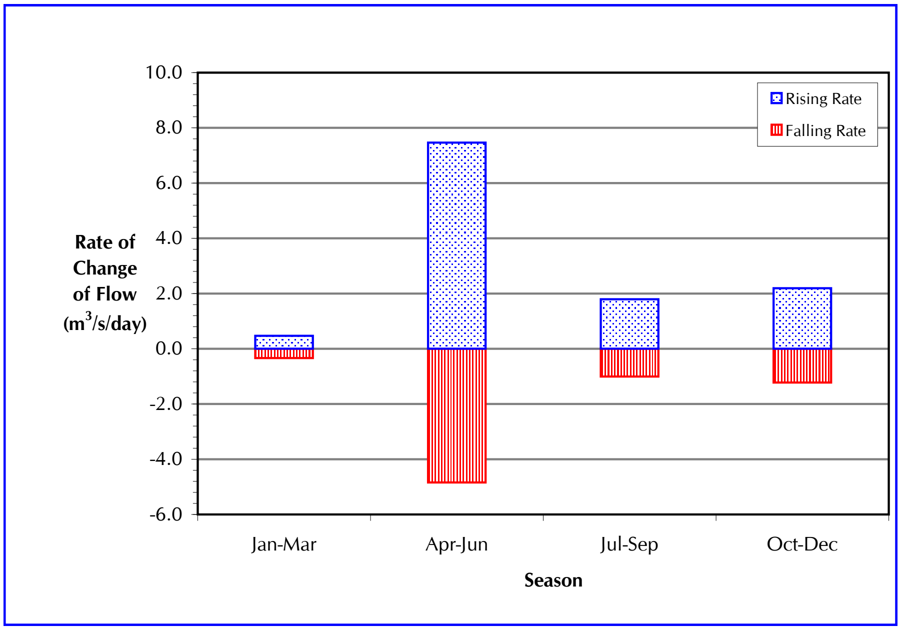
Season	20% Time Exceeded (m^3/s)	Median (m^3/s)	80% Time Exceeded (m^3/s)
Jan-Mar	19.4	14.1	10.2
Apr-Jun	100.1	39.4	16.4
Jul-Sep	19.5	10.8	5.4
Oct-Dec	39.7	27.9	19.2



II. Rate of Change of Flow

Table 6 & Figure 6 : Seasonal rising and falling rates of change of flow for determining ramping rate targets.

Season	Rising Rate ($m^3/s/day$)	Falling Rate ($m^3/s/day$)
Jan-Mar	0.47	-0.34
Apr-Jun	7.46	-4.84
Jul-Sep	1.79	-1.00
Oct-Dec	2.19	-1.22

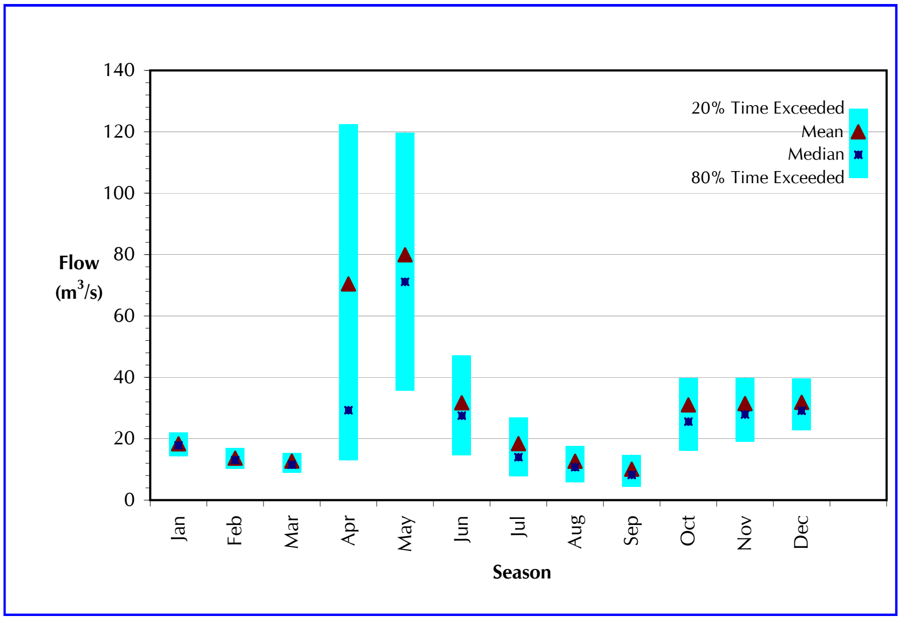


Monthly :

I. Flow Duration

Table 7 & Figure 7 : Monthly median flow duration for determining minimum flow targets.

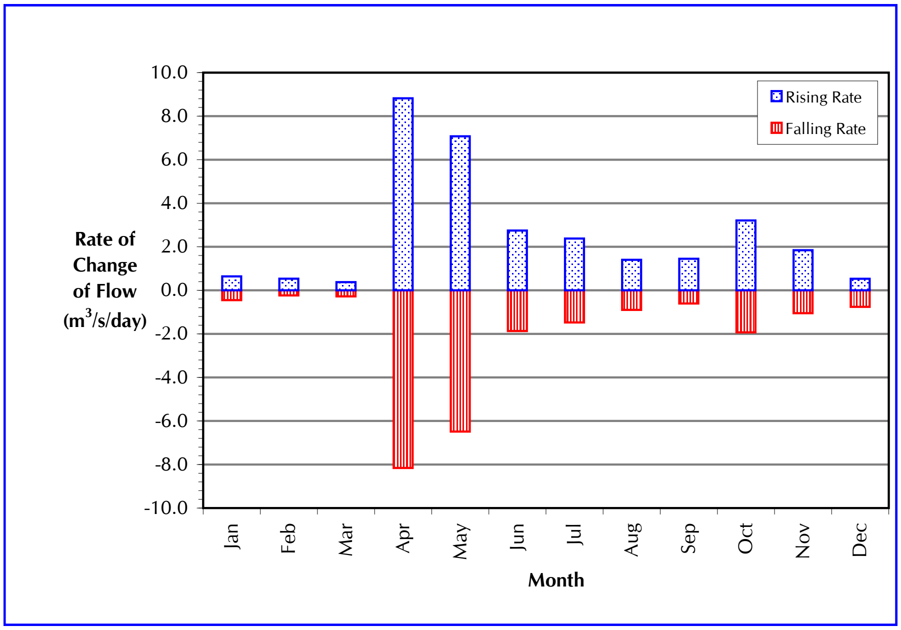
Month	20% Time Exceeded (m^3/s)	Median (m^3/s)	80% Time Exceeded (m^3/s)
Jan	21.9	17.8	14.3
Feb	17.0	13.1	10.2
Mar	15.4	11.6	9.0
Apr	122.4	29.3	12.9
May	119.8	71.1	35.6
Jun	47.2	27.5	14.7
Jul	26.9	14.0	7.7
Aug	17.6	10.8	5.8
Sep	14.8	8.2	4.4
Oct	39.7	25.6	16.1
Nov	39.9	27.9	19.0
Dec	39.5	29.1	22.7



II. Rate of Change of Flow

Table 8 & Figure 8 : Monthly rising and falling rates of change of flow for determining ramping rate targets.

Month	Rising Rate ($m^3/s/day$)	Falling Rate ($m^3/s/day$)
Jan	0.64	-0.45
Feb	0.53	-0.23
Mar	0.38	-0.28
Apr	8.82	-8.16
May	7.07	-6.49
Jun	2.75	-1.87
Jul	2.38	-1.48
Aug	1.40	-0.90
Sep	1.45	-0.60
Oct	3.21	-1.93
Nov	1.84	-1.05
Dec	0.53	-0.76



THREE FALLS - IVANHOE RIVER
NATURAL FLOW METRICS DATA SHEET

STATION INFORMATION		
SITE ID	0	
RIVER NAME	IVANHOE RIVER	
SITE NAME	THREE FALLS	
REGION	NORTHEAST	
DISTRICT	CHAPLEAU	
DRAINAGE AREA	3242	km^2
OWNER	XENECA POWER	

Flow metrics are provided for the potential waterpower site based on the Water Survey of Canada (WSC) gauging station, GROUNDHOG RIVER AT FAUQUIER (04LD001). Metrics are based on WSC flows from 1971 to 1994 (24 years).

The flow records for the site have been synthesized by pro-rating adjusted gauge flows at 04LD001 by the ratio of the runoff and drainage areas. Other descriptive metrics have been included in the data sheet to provide a more complete description of the ranges of streamflow on the river system and to facilitate comparisons between river systems.

Annual (1971 - 1994):

I. Streamflow Time Series

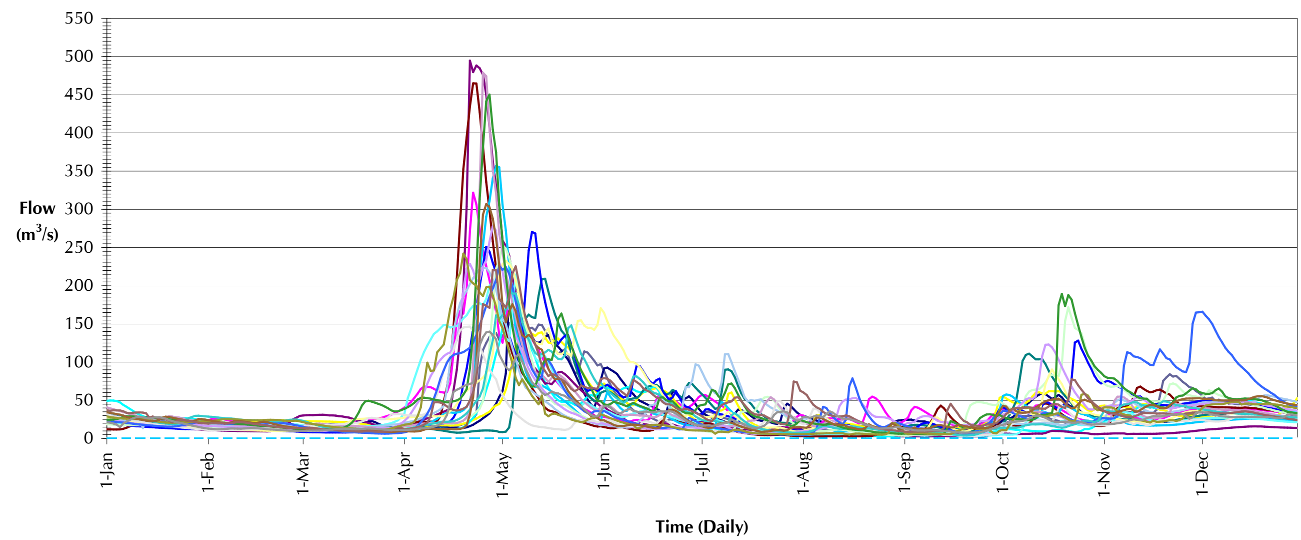


Figure 1 : Annual Daily flow hydrographs from 1971 to 1994.

Table 1 : Annual flow metrics based on 24 years of data.

Descriptive Metric		
Mean Annual Flow	36.41	m^3/s
20% Time Exceeded Flow	45.66	m^3/s
Median Flow	22.70	m^3/s
80% Time Exceeded Flow	12.63	m^3/s
Mean Rising Rate of Change of Flow	3.61	$m^3/s/day$
Mean Falling Rate of Change of Flow	-2.16	$m^3/s/day$
Extreme Low Flow Conditions:		
7-day-avg. low flow in 2-yr return period, $7Q_2$	5.85	m^3/s
7-day-avg. low flow in 10-yr return period, $7Q_{10}$	2.58	m^3/s
7-day-avg. low flow in 20-yr return period, $7Q_{20}$	1.88	m^3/s
Target Metric		
Riparian Flows (Q_2 - Q_{20})	248 -470	m^3/s
Bankfull Flows ($Q_{1.5}$ - $Q_{1.7}$)	209 -227	m^3/s

II. Flow Duration

Time Exceeded %	Flow (m^3/s)
0%	494.6
1%	225.2
5%	124.3
10%	72.0
20%	45.7
30%	34.2
40%	27.3
50%	22.7
60%	19.0
70%	15.6
80%	12.6
90%	9.4
95%	6.3
99%	3.6
100%	2.5

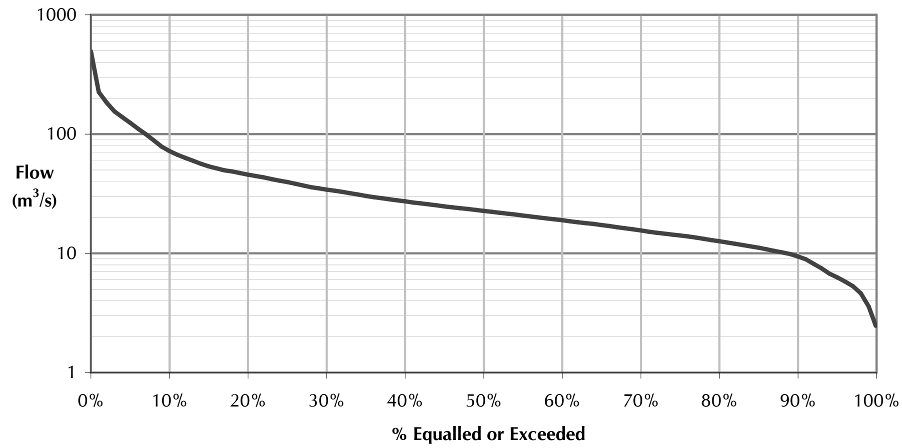


Table 2 & Figure 2 : Flow duration table and curve displaying flow vs. percent time exceeded over 24 years.

III. Flood Frequency Analysis

Return Period (years)	Flow (m^3/s)
1.05	122.4
1.25	176.7
1.5	209.2
1.7	227.4
2	248.4
5	345.0
10	408.9
20	470.2
50	549.6
100	609.1

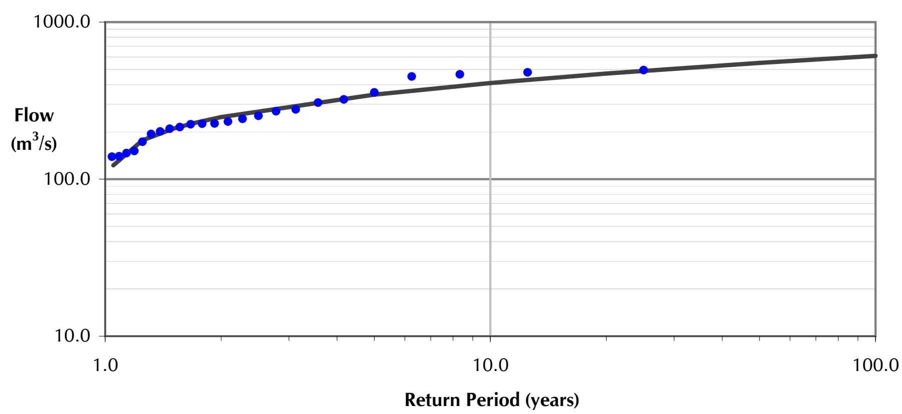


Table 3 & Figure 3 : Flood frequency analysis and curve fitted by the Gumbel probability distribution.

IV. Low Flow Frequency Analysis (Performed using 7-day-average low flow)

Return Period (years)	Flow (m^3/s)
1.005	14.17
1.01	13.34
1.11	9.87
1.25	8.43
2	5.85
5	3.57
10	2.58
20	1.88
50	1.26
100	0.93

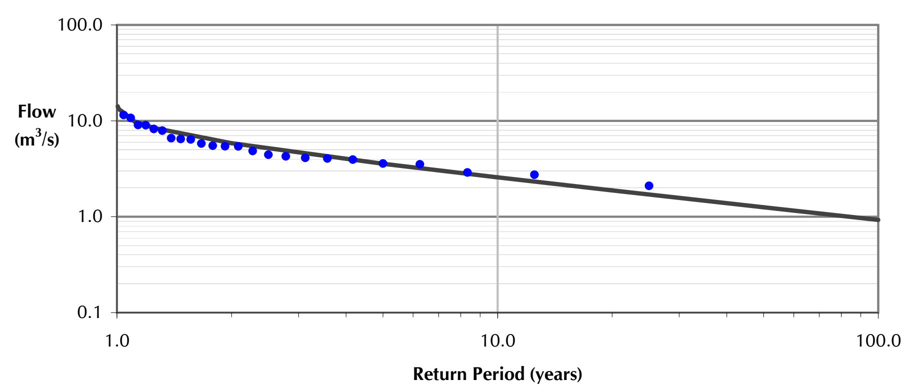


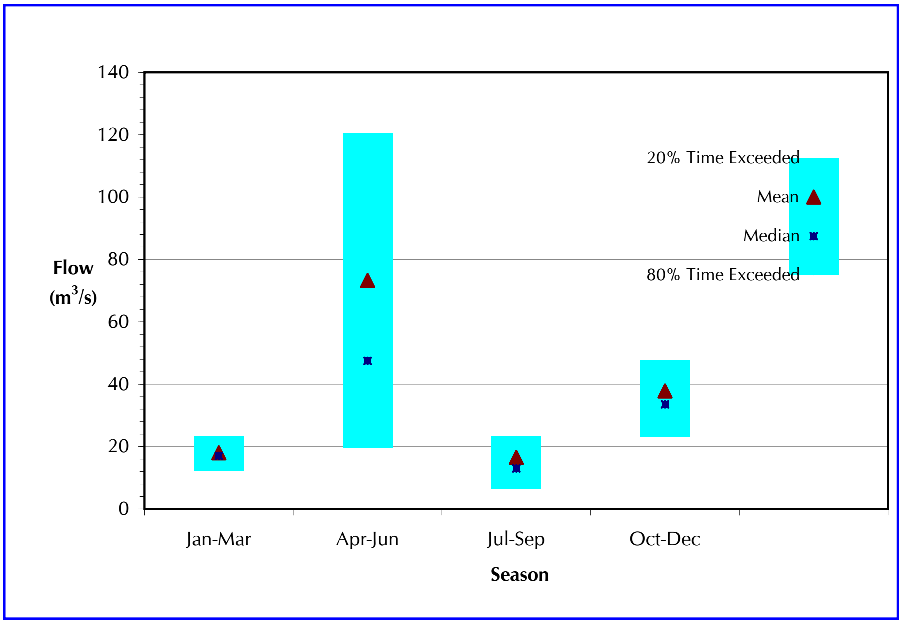
Table 4 & Figure 4 : 7-day-average low flow frequency analysis and curve fitted by the Gumbel probability distribution.

Seasonal :

I. Flow Duration

Table 5 & Figure 5 : Seasonal median flow duration for determining minimum flow targets.

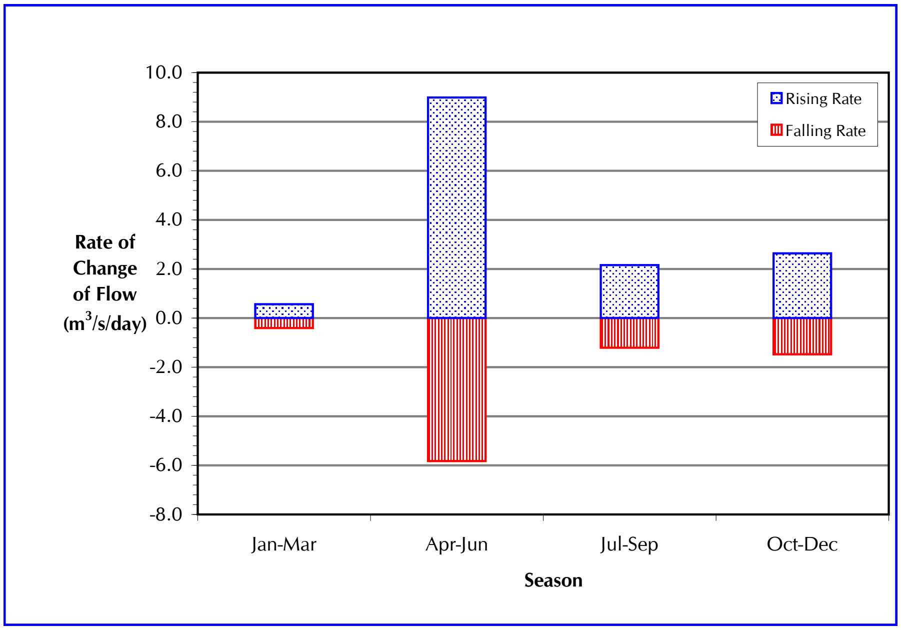
Season	20% Time Exceeded (m^3/s)	Median (m^3/s)	80% Time Exceeded (m^3/s)
Jan-Mar	23.4	17.0	12.2
Apr-Jun	120.5	47.5	19.7
Jul-Sep	23.4	13.0	6.5
Oct-Dec	47.7	33.6	23.1



II. Rate of Change of Flow

Table 6 & Figure 6 : Seasonal rising and falling rates of change of flow for determining ramping rate targets.

Season	Rising Rate ($m^3/s/day$)	Falling Rate ($m^3/s/day$)
Jan-Mar	0.56	-0.41
Apr-Jun	8.98	-5.83
Jul-Sep	2.16	-1.21
Oct-Dec	2.64	-1.47

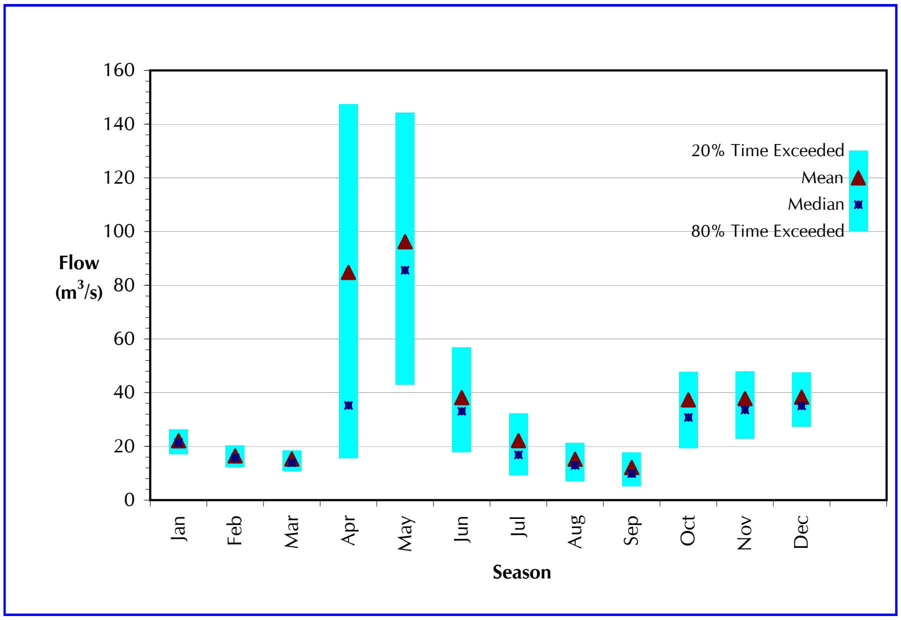


Monthly :

I. Flow Duration

Table 7 & Figure 7 : Monthly median flow duration for determining minimum flow targets.

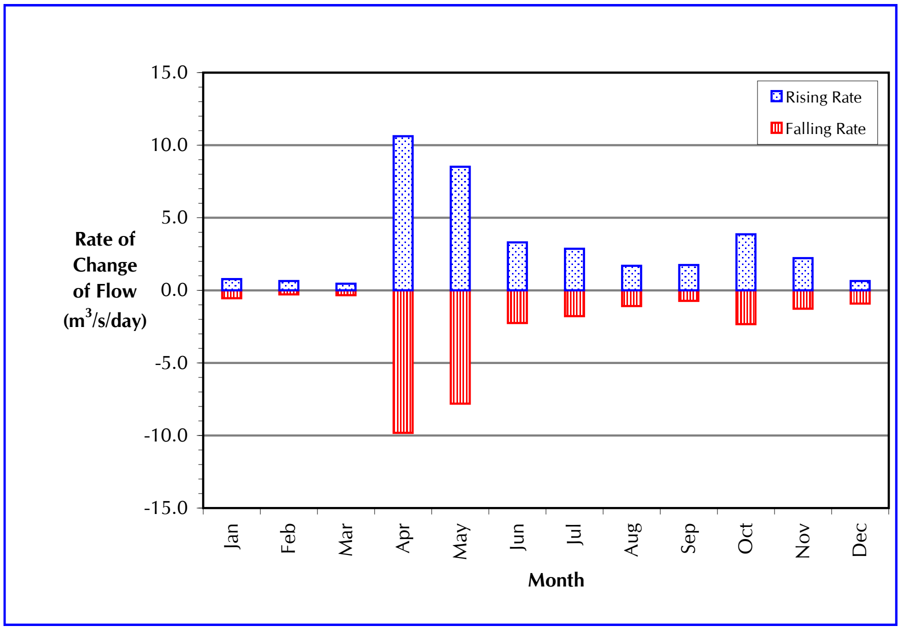
Month	20% Time Exceeded (m^3/s)	Median (m^3/s)	80% Time Exceeded (m^3/s)
Jan	26.4	21.5	17.2
Feb	20.4	15.7	12.2
Mar	18.5	13.9	10.8
Apr	147.3	35.3	15.6
May	144.2	85.6	42.9
Jun	56.8	33.1	17.7
Jul	32.3	16.9	9.3
Aug	21.2	12.9	6.9
Sep	17.8	9.9	5.3
Oct	47.8	30.8	19.4
Nov	48.0	33.6	22.9
Dec	47.6	35.1	27.3



II. Rate of Change of Flow

Table 8 & Figure 8 : Monthly rising and falling rates of change of flow for determining ramping rate targets.

Month	Rising Rate ($m^3/s/day$)	Falling Rate ($m^3/s/day$)
Jan	0.77	-0.54
Feb	0.64	-0.28
Mar	0.45	-0.33
Apr	10.62	-9.82
May	8.51	-7.81
Jun	3.31	-2.25
Jul	2.86	-1.78
Aug	1.69	-1.08
Sep	1.74	-0.73
Oct	3.86	-2.33
Nov	2.22	-1.26
Dec	0.64	-0.91



APPENDIX B

Lake Evaporation vs. Latitude in Ontario

Lake Evaporation vs. Latitude in Ontario

Lake evaporation in Ontario generally occurs between April and November each year when lakes are free of ice. Lake evaporation varies with extra terrestrial radiation, temperature, vapour pressure, humidity and wind speed. Although it varies from year it is more stable than evapotranspiration or general evaporation loss in a river basin because it does not depend on the surficial geology or land use in the basin, which can affect the precipitation reaching the ground and the soil moisture available for transpiration.

Lake Evaporation datasets in Ontario are limited and not always complete, but Environment Canada publishes average lake evaporation data for some climate stations in the online Canadian Climate Normals or Averages 1971-2000 series.

The table below shows Annual Average Lake Evaporation data for six climate stations in Ontario and one each from Manitoba and Quebec.

Station	Province	Latitude ° N	Altitude m	Annual E_{Lake} mm
Amos	QUE	48.57	310	538
Atikokan	ONT	48.80	442	538
Delhi	ONT	42.87	232	709
Harrow	ONT	42.02	191	789
Moosonee	ONT	51.27	8	433
Ottawa	ONT	45.37	79	672
Rawson Lake	ONT	49.65	358	556
Norway House Forestry	MAN	54.00	217	320

The *Evaporation Atlas for the Contiguous 48 United States, NOAA Technical Report NWS 33, Washington D.C. June, 1982* shows that annual free water surface evaporation from shallow lakes (1956-70) varies approximately linearly with latitude in the states contiguous with the Province of Ontario.

To investigate whether this trend persists in Ontario the annual average lake evaporation data above were plotted against climate station latitude in Figure B-1. A linear regression equation fitted to this data set has a correlation coefficient R2 = 0.9655 and gives the relationship for annual average lake evaporation:

$E_{Lake} = 2296.6 – 36.123 * \text{Latitude}$

Where: E_{Lake} is annual average lake evaporation in mm

Latitude is in decimal ° N.

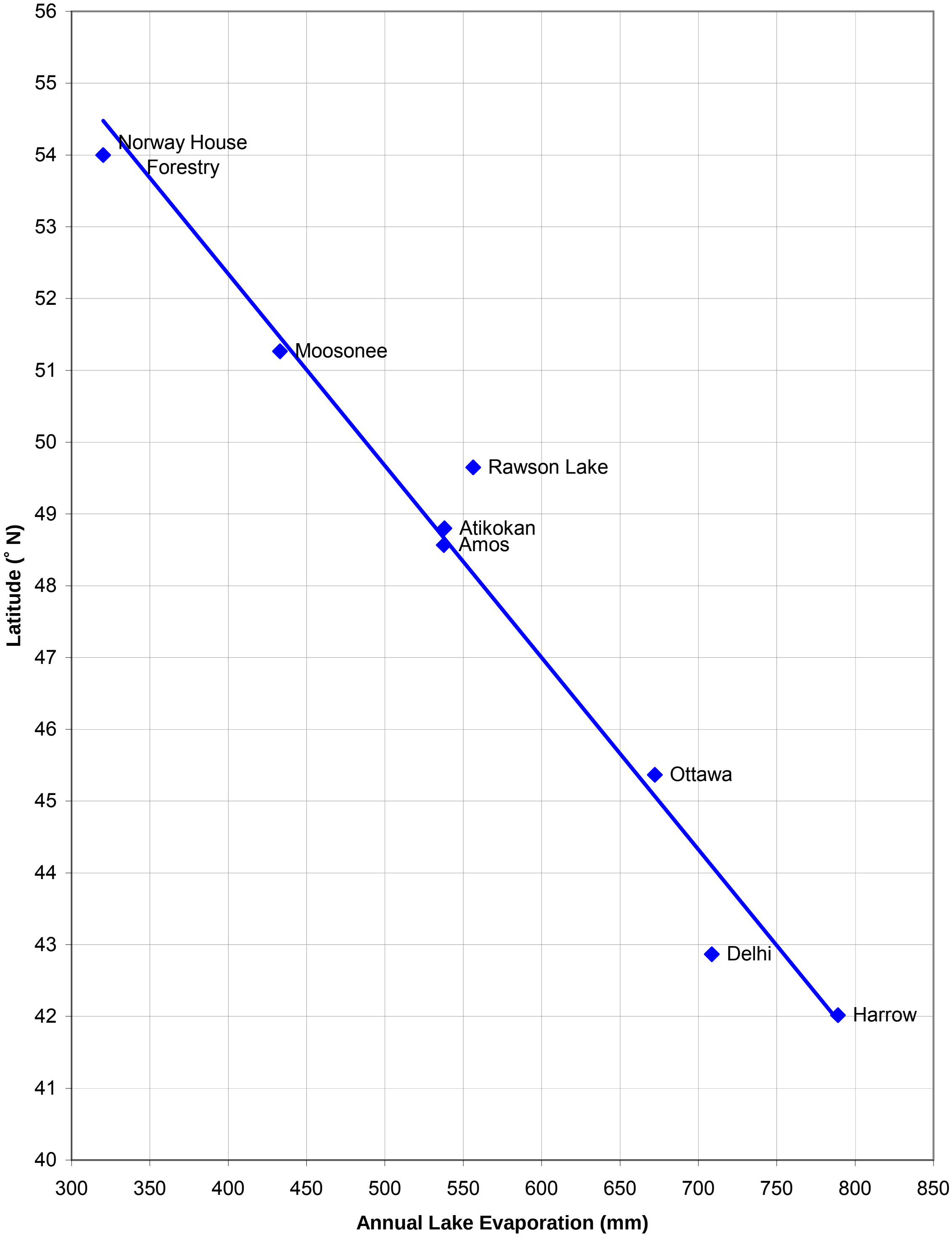


Figure B-1
Xeneca Power
Ivanhoe Hydropower Sites
Annual Average Lake Evaporation vs. Latitude

A typical monthly lake evaporation distribution for the Ivanhoe project sites is shown in Figure B-2.

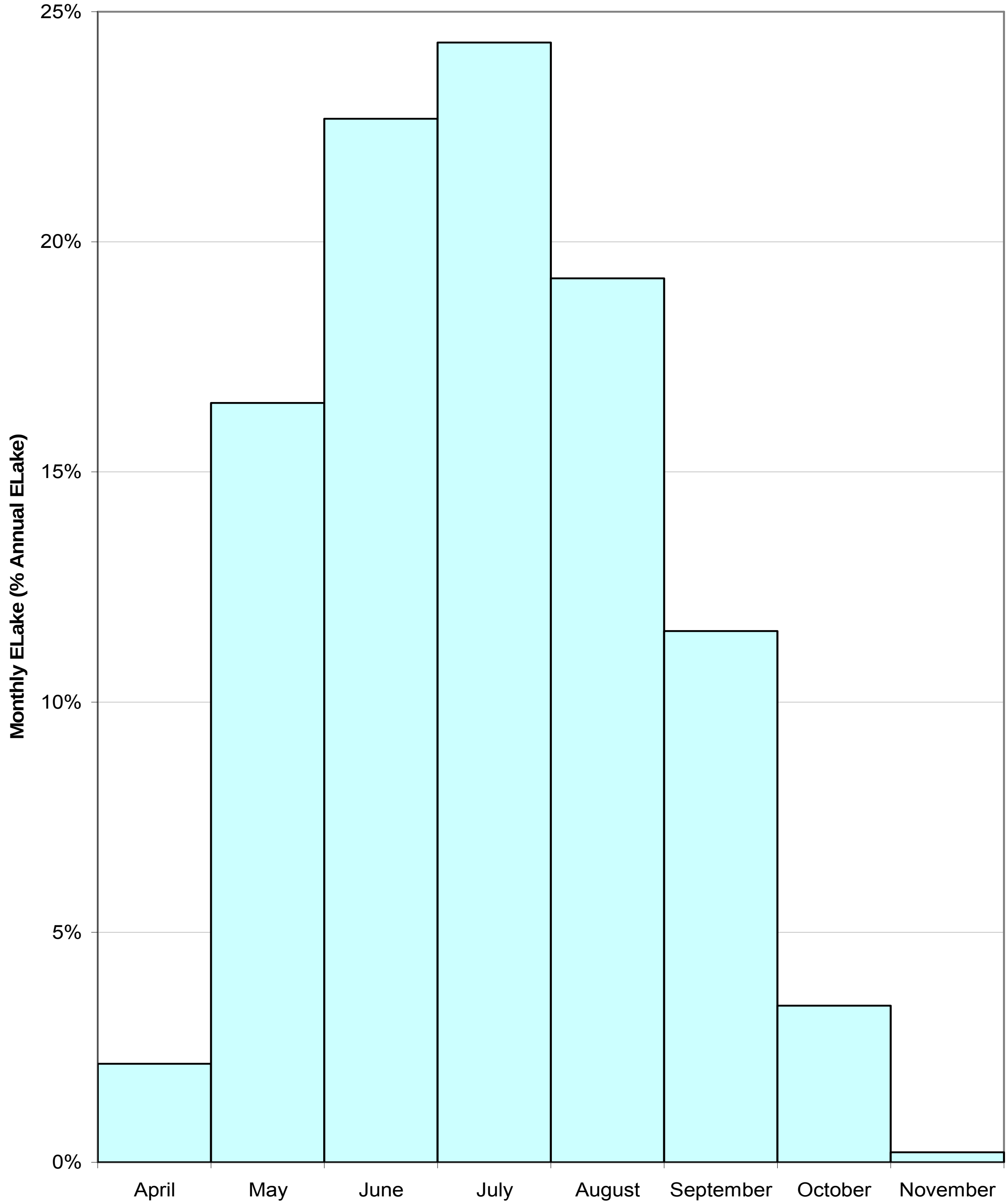


Figure B-2
Xeneca Power
Ivanhoe Hydropower Sites
Monthly Lake Evaporation Distribution at Ivanhoe Hydropower Sites

APPENDIX C

CD-ROM containing Flow Series Datasets

HATCH™

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Oakville, Ontario, Canada L6M 2W2
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