

# **CANADIAN PROJECTS LIMITED**

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File: 1052-001-3.1.3.2

# "CONFIDENTIAL AND PRIVILEGED FOR XENECA USE ONLY"

September 20, 2012

Xeneca Power Development Inc. 5160 Yonge Street, Suite 520 Toronto, ON, M2N 6L9

Attn:

Mr. Nava Pokharel, M.Sc., P.Eng

Senior Project Manager

Re:

Wabagishik Rapids Rating Curve Development

### 1. Introduction

Xeneca Power Development (Xeneca) requested that Canadian Projects Limited (CPL) develop rating curves for the four (4) locations where level loggers were installed by Xeneca on the Vermillion River near the Wabagishik Rapids Project (the Project). Flow data was provided by Vale at the Lorne Falls Generating Station, located approximately 12 km upstream of the Project. In addition, the rating curves produced by the Wabagishik HEC-RAS hydraulic model were compared to the flow and water level data and the developed rating curves provided in order to comment on the accuracy of the HEC-RAS model.

# 2. Background

Xeneca provided CPL with 15 minute interval level logger data from four locations along the Vermillion River near the Project. The water level data extends from November 2011 to September 2012. The four locations are listed below in order of most upstream to most downstream:

- Level Logger 1: Near Lorne Falls Tailrace Area
- 2. Level Logger 2: Wabagishik Lake Near Lake Outlet
- 3. Level Logger 3: Downstream of Wabagishik Rapid Tailrace Area
- 4. Level Logger 4: Near Graveyard Rapid Toe

Xeneca provided CPL with average daily discharge data that was obtained from Vale at the Lorne Falls Generating Station. The data extends from November 2011 to August 2012.

# 3. Assumptions

In order to develop rating curves for the four level logger locations it was assumed that the discharge data provided was the same for all four locations. This was considered to be a reasonable assumption since no significant tributaries enter the Vermillion River between the Lorne Falls Generating Station and Level Logger 3.

It was assumed that the time lagging effects and flow attenuation effects were negligible. Accordingly there is an increasing error associated with the assumed flow data when moving further downstream of the Lorne Falls Generating Station. An additional error is introduced from the attenuation effects of Wabagishik Lake, introducing a greater error in the data sets downstream of the Lake.

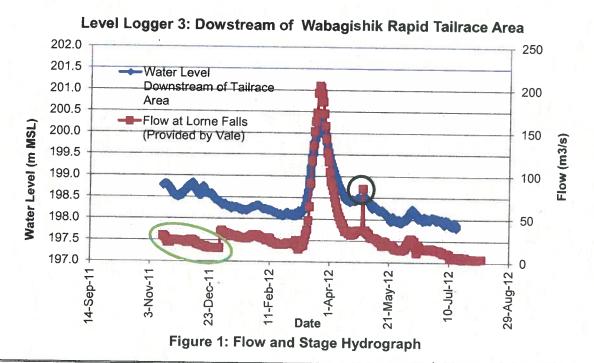
When examining Level Logger 4 it was clear that the backwater effects from the Spanish River affected the gauge and the assumptions listed above were not appropriate therefore it was necessary to examine this station differently from the others. Furthermore the water level data indicated that the water level at this location is largely controlled by the Spanish Generating Station located approximately 8.5 km further downstream.

### 4. Procedure

# 4.1. Visually plot and check data for any erroneous data points in flow or level

The 15 minute interval Level logger data was adjusted by the datum provided by Xeneca to produce 15 minute interval water surface elevation data. Then the daily average flow rate was applied to each water surface elevation, assuming no change in flow rate throughout the day.

The resulting data sets were then plotted to check for any erroneous data points. Figures 1 and 2 below show the data sets for Level Logger 3. In general Level Loggers 1 and 2 follow the same trends.





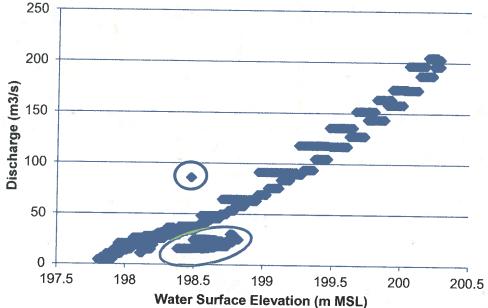


Figure 2: Flow vs Stage

It was concluded that the data from November 2011 to the end of December 2011 (shown in the green circles in the following figures) was erroneous and was removed from the data set. The recorded level data in this time period is higher than the remaining data and outside the general trend. It is likely that there was ice coverage or debris blocking the river channel.

Additional data points were removed on April 29, 2012 (shown in the black circles in the following figures) as it too was erroneous and was removed from the data set.

# 4.2. <u>Develop Rating Curve</u>

Below is the equation for a rating curve. The value of Stage Zero was estimated; Microsoft Excel was used to fit a rating curve to the data. The Stage Zero was adjusted to produce the largest R<sup>2</sup> value and to allow the curve to visually fit the data set.

$$Q = A(EL_{ws} - SZ)^c$$

Where:

Q	=	Discharge (m³/s)
A	=	Discharge Coefficient (m³-C/s
ELws	=	Water Surface Elevation (m MSL)
SZ	=	Stage Zero (m)
$EL_{ws} - SZ$	=	Stage (m)
С	=	Power Coefficient

**Equation 1: Rating Curve Equation** 

## 5. Rating Curves

Sections 5.1 to 5.4 show the developed rating curves along with the value of the coefficients in the equation (on page 3) Figures 3 through 6 show the plotted data, rating curves and the HEC-RAS model rating curves for the nearest cross section. Tables 1 through 5 show the values of the constants for the developed rating curves.

# 5.1. Level Logger 1: Near Lorne Falls Tailrace Area

**Table 1: Rating Curve Equation Constant Values** 

Constant	Value	Units
 Α	20.048	m <sup>3-C</sup> /s
SZ	203.3	m
С	2.2031	None

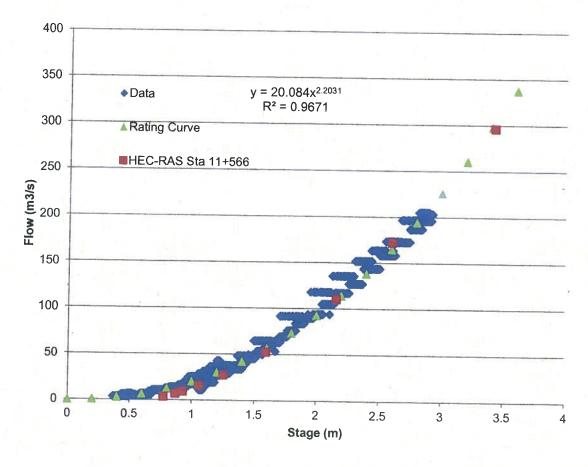


Figure 3: Comparison of Data, Rating Curve and HEC-RAS Rating Curve

# 5.2. <u>Level Logger 2: Wabagishik Lake Near lake Outlet</u>

Table 2: Rating Curve Equation Constant Values

Constant	Value	Units
Α	40.915	m <sup>3-C</sup> /s
SZ	203.55	m
C	1.7605	None

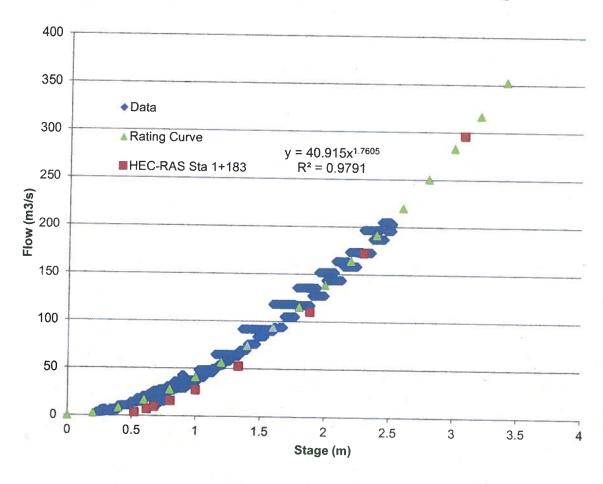


Figure 4: Comparison of Data, Rating Curve and HEC-RAS Rating Curve

# 5.3. Level Logger 3: Downstream of Wabagishik Rapids Tailrace Area

**Table 3: Rating Curve Equation Constant Values** 

Constant	Value	Units
Α	49.656	m <sup>3-C</sup> /s
SZ	197.6	m
C	1.44	None

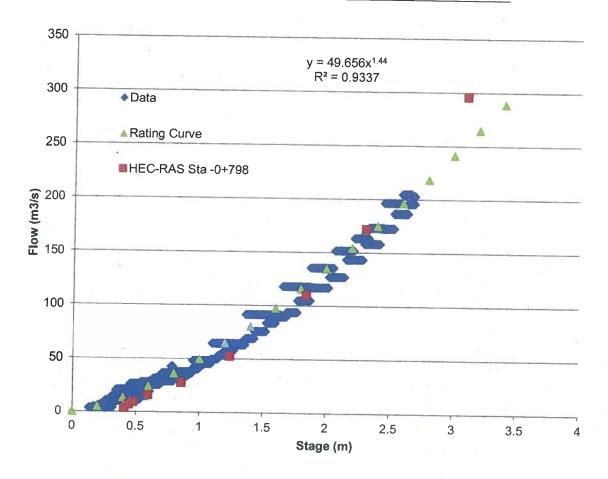


Figure 5: Comparison of Data, Rating Curve and HEC-RAS Rating Curve

# 5.4. Level Logger 4: Near Graveyard Rapid Toe

Figures 6 and 7 show the Flow and Stage data for Level Logger 4. The extreme scatter of the data is due to high variance in daily level logger data. Figure 7 shows that the recorded water surface elevation varies up to 50% of the total range of water surface elevations. This results in a poor trend in the data.

In order to clean up the data, the daily average stage was calculated from the 15 minute interval Level Logger data. Table 4 and Figure 8 show the developed rating curve. The HEC-RAS model did not have a rating curve at this location since the model ended at this location. Instead a constant water surface of 198 m MSL was assumed. As shown in Figures 7, this assumption was reasonable.

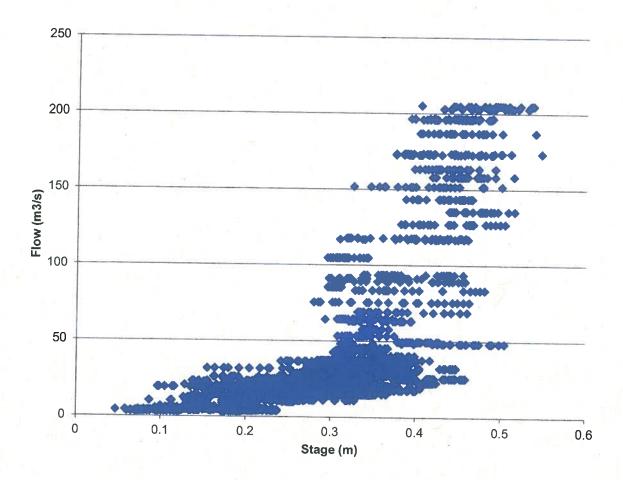


Figure 6: 15 Minute Level Logger Data vs Daily Average Flow Rate

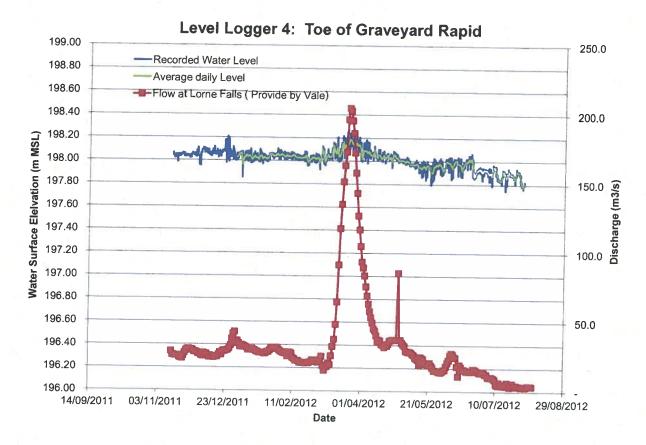


Figure 7: Flow and Stage Hydrographs

**Table 3: Rating Curve Equation Constant Values** 

Constant	Value	Units
Α	496.81	m <sup>0.5637</sup> /s
SZ	197.7	m m
С	2.4363	None

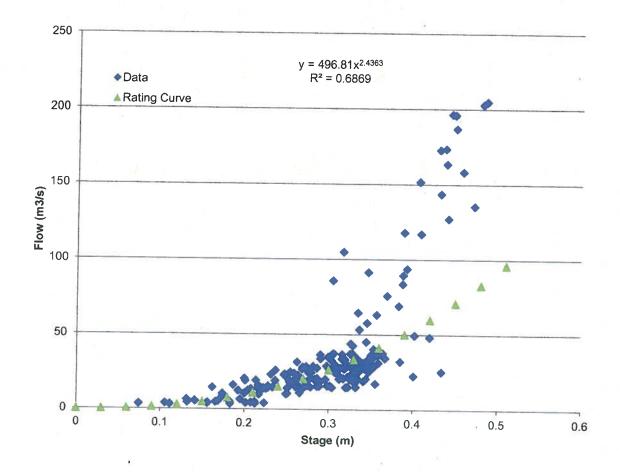


Figure 8: Comparison of Data and Rating Curve

Nava Pokharel Xeneca Power Development 20 September 2012 Page 10

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# 6. Summary

Discharge rating curves to convert water level data collected at the four (4) locations where level loggers were installed by Xeneca on the Vermillion River near the Wabagishik Rapids Project (the Project) were developed using available upstream flow data. The accuracy of the developed rating curves is largely dependent on the accuracy of the flow data obtained from Lorne Falls. Several flow measurements should be taken at each level logger location in order to increase the accuracy of the developed rating curves.

In addition, the rating curves produced by the Wabagishik HEC-RAS hydraulic model<sup>i</sup> were compared to the flow and water level data and the developed rating curves. In general the HEC-RAS rating curves compared well to the developed rating curves, with a maximum error of 20 cm which occurred in the upper range of the Level Logger 3 rating curve where no level measurements were recorded.

The information expressed herein represents Canadian Projects Limited's best professional judgement and is based on Canadian Projects Limited's experience as applied to the information provided at the time of preparation within the scope of the assignment.

We trust that this report meets with your requirements. If you require any clarification, have questions or would like to discuss the information contained within, please contact us.

Sincerely,

CANADIAN PROJECTS LIMITED

David Kushner, E.I.T.

Junior Engineer

That the

Richard Slopek, P.Eng. Project Manager

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Ontario South Hydro HEC-RAS Inundation Mapping and Environmentally Sensitive Area Modelling Petawawa River – Big Eddy. Canadian Projects Limited. March 5, 2012.



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#240, 523 Woodpark Blvd SW Calgary, Alberta T2W 4J3 Phone: (403) 508-1560 Fax: (403) 238-5460

File:

1052-001-3.1.3.4

June 24, 2013

Xeneca Power Development Inc. 5255 Yonge Street, Suite 1200 Toronto, ON, M2N 6P4

Attn: Mr. Nava Pokharel, M.Sc., P.Eng.

Senior Project Manager

Re: Vermilion River Site #6 - Wabagishik Rapids

Additional Peaking Scenarios - Hydraulic Modeling

## 1.0 Introduction

Canadian Projects Limited (CPL) issued the report *Vermilion River Site #6 – Wabagishik Rapids HEC-RAS Unsteady Flow Modelling* to Xeneca Power Development Inc. (Xeneca) on July 10, 2012. Xeneca subsequently requested that CPL provide unsteady HEC-RAS model results for additional operating scenarios for the Wabagishik Rapids Project (the Project).

This summary letter report is provided as an addendum to the July 10, 2012 CPL report and should be read in conjunction with it.

The scope for this work included:

- The modelling of additional Project peaking operations using the unsteady HEC-RAS model developed with the July 10, 2012 CPL report, and
- The presentation of Figures and Tables of the model results

### 2.0 Background

Xeneca provided CPL with three (3) additional August operating curves developed by Ortech Consulting Inc. The operating curves were developed for various values of the limited turbine flow ( $Q_{TL}$ ) ranging from 25.0 to 41.6 m³/s. Figure 1 shows the original August operating curve modeled in the July 10, 2012 report and Figures 2 through 4 show the three (3) additional operating curves.

In the July 10, 2012 report it was shown that the largest fluctuation due to plant operation was during August operations.

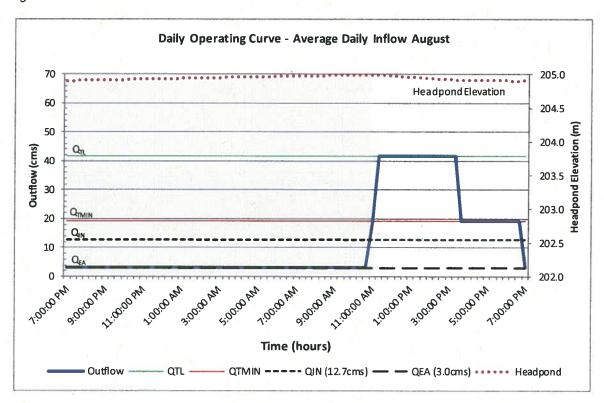


Figure 1: Typical August Daily Peaking Operating Curve –  $Q_{TL}$  = 41.6 m<sup>3</sup>/s

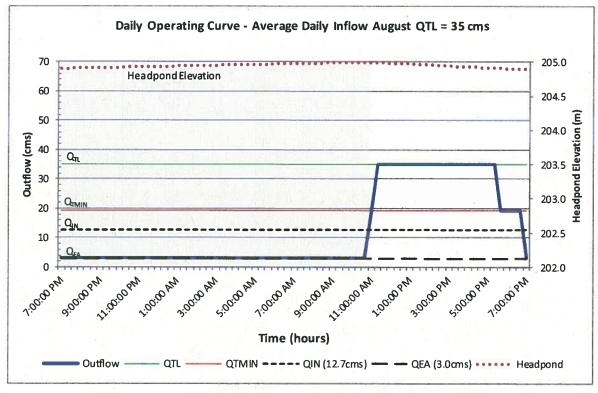


Figure 2: Typical August Daily Peaking Operating Curve –  $Q_{TL}$  = 35.0 m<sup>3</sup>/s

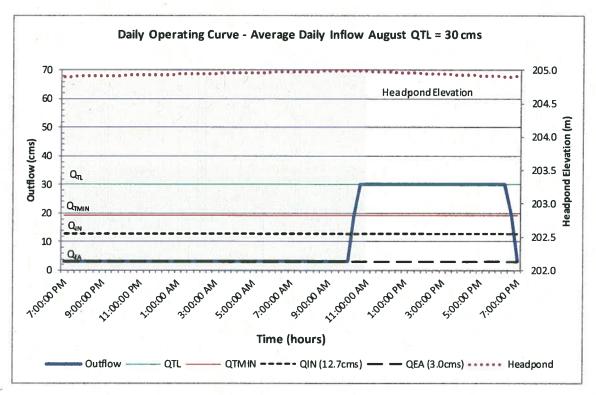


Figure 3: Typical August Daily Peaking Operating Curve - Q<sub>TL</sub> = 30.0 m<sup>3</sup>/s

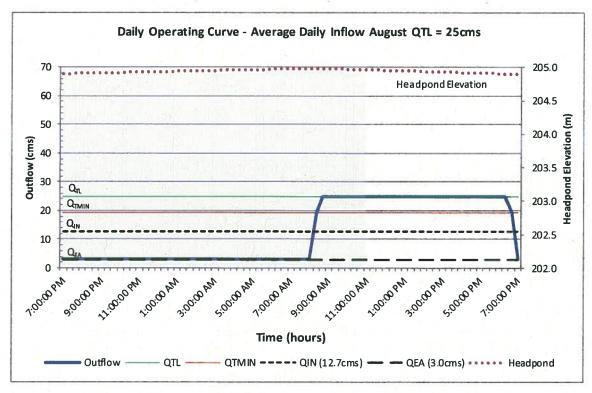


Figure 4: Typical August Daily Peaking Operating Curve –  $Q_{TL}$  = 25.0 m<sup>3</sup>/s

## 3.0 Hydraulic Modeling

Additional Project Peaking operations were modeled using the unsteady HEC-RAS model included with the July 10, 2012 report. The model input hydrographs were the operating curves shown in Section 2.

The resulting water level fluctuation and flow fluctuations are shown in Figure 5 and Tables 1 through 4.

The water depth fluctuations decrease as  $Q_{TL}$  decreases. The maximum depth fluctuation is reduced from 84 to 58 cm by reducing  $Q_{TL}$  from 41.6 to 25 m<sup>3</sup>/s.

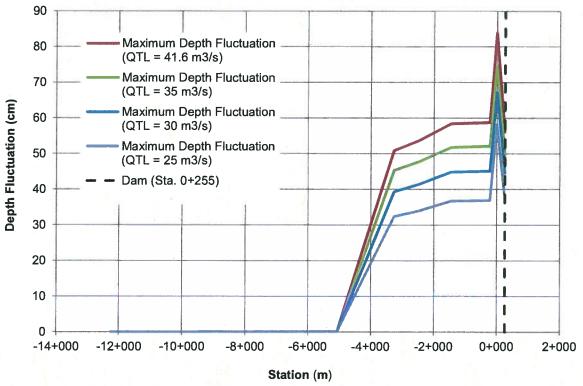


Figure 5: August Additional Operating Scenarios Water Surface Fluctuation

Table 1: Q<sub>TL</sub> = 41.6 m<sup>3</sup>/s August Relative Downstream Hydraulic Peaking Effects

Station (m)	Existing Flow (m³/s)	Max Flow (m³/s)	Min Flow (m³/s)	Max Water Level Increase (cm)	Max Water Level Decrease (cm)	Depth Fluctuation (cm)
0+255	12.7	41.6	3.0	38	-18	56
0+000	12.7	41.6	3.0	52	-32	84
-0+219	12.7	40.9	3.0	44	-15	59
-1+452	12.7	38.2	3.0	44	<sup>''</sup> -15	58
-2+478	12.7	37.4	3.0	40	-14	54
-3+261	12.7	37.0	3.0	38	-13	51
-5+068	43.1	36.8	3.0	0	0	0
-10+369	111.8	57.4	23.3	0	0	0
-12+265	111.8	57.4	23.3	0	0	0

Table 2: Q<sub>TL</sub> = 35.0 m<sup>3</sup>/s August Relative Downstream Hydraulic Peaking Effects

Station (m)	Existing Flow (m³/s)	Max Flow (m³/s)	Min Flow (m³/s)	Max Water Level Increase (cm)	Max Water Level Decrease (cm)	Depth Fluctuation (cm)
0+255	12.7	35.0	3.0	31	-19	50
0+000	12.7	35.0	3.0	43	-32	75
-0+219	12.7	34.7	3.0	37	-15	52
-1+452	12.7	33.7	3.0	37	-15	52
-2+478	12.7	33.4	3.0	34	-14	48
-3+261	12.7	33.2	3.0	32	-13	45
-5+068	43.1	33.1	3.0	0	0	0
-10+369	111.8	53.4	23.3	0	0	0
-12+265	111.8	53.4	23.3	0	0	0

Table 3: Q<sub>TL</sub> = 30.0 m<sup>3</sup>/s August Relative Downstream Hydraulic Peaking Effects

Station (m)	Existing Flow (m³/s)	Max Flow (m³/s)	Min Flow (m³/s)	Max Water Level Increase (cm)	Max Water Level Decrease (cm)	Depth Fluctuation (cm)
0+255	12.7	30.0	3.0	25	-19	45
0+000	12.7	30.0	3.0	35	-32	67
-0+219	12.7	29.9	3.0	30	-15	45
-1+452	12.7	29.5	3.0	30	-15	45
-2+478	12.7	29.3	3.0	28	-14	41
-3+261	12.7	29.3	3.0	27	-13	39
-5+068	43.1	29.3	3.0	0	0	0
-10+369	111.8	49.6	23.3	0	0	0
-12+265	111.8	49.6	23.3	00	0	0

Table 4: Q<sub>TL</sub> = 25.0 m<sup>3</sup>/s August Relative Downstream Hydraulic Peaking Effects

Station (m)	Existing Flow (m³/s)	Max Flow (m³/s)	Min Flow	Max Water Level Increase (cm)	Max Water Level Decrease (cm)	Depth Fluctuation (cm)
0+255	12.7	25.0	3.0	19	-18	38
0+000	12.7	25.0	3.0	26	-32	58
-0+219	12.7	25.0	3.0	22	-15	37
-1+452	12.7	24.8	3.0	22	-15	37
-2+478	12.7	24.8	3.0	20	-14	34
-3+261	12.7	24.8	3.0	19	-13	32
-5+068	43.1	24.8	3.0	0	0	0
-10+369	111.8	45.1	23.3	0	0	0
-12+265	111.8	45.1	23.3	0	0	0

Wabagishik Unsteady Addendum June 24, 2013 Page 7

### 4.0 Conclusion

The results of the Wabagishik Rapids additional peaking scenarios hydraulic modeling are presented within this letter report. This letter report should be read in conjunction with the July 10, 2012 report.

It has been concluded that by reducing the limited turbine flow, fluctuation in water levels downstream of the project can be significantly reduced.

The information expressed in this report represents Canadian Projects Limited's best professional judgement and is based on Canadian Projects Limited's experience as applied to the information provided at the time of preparation within the scope of the assignment.

We trust that this report meets with your requirements. If you require any clarification, have questions or would like to discuss the information contained within, please contact us.

Sincerely,
CANADIAN PROJECTS LIMITED

David Kushner, E.I.T.. Junior Engineer

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Reviewed by,

Jagadish Kayastha, P.Eng. PMP Senior Hydrotechnical Engineer

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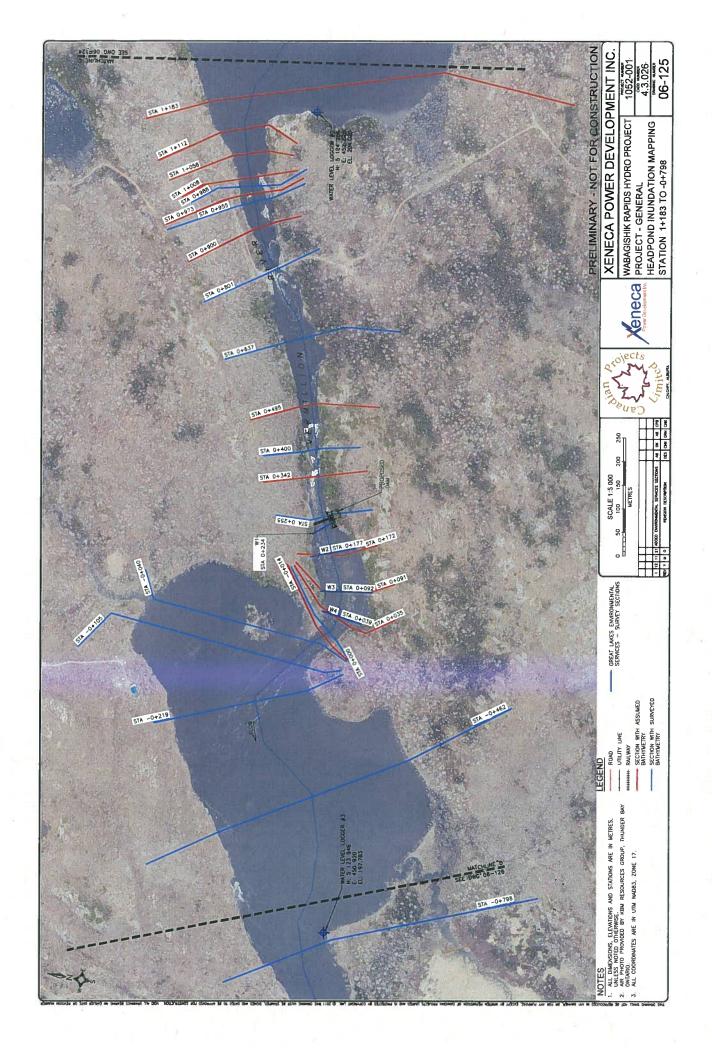
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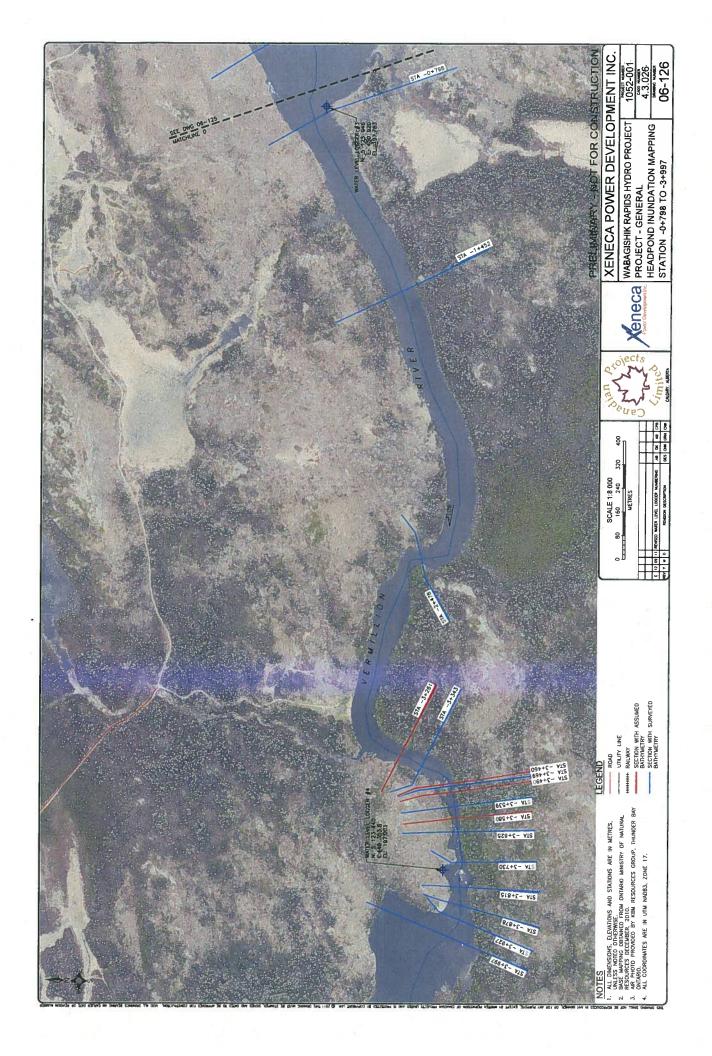
# Wabageshik Rapid

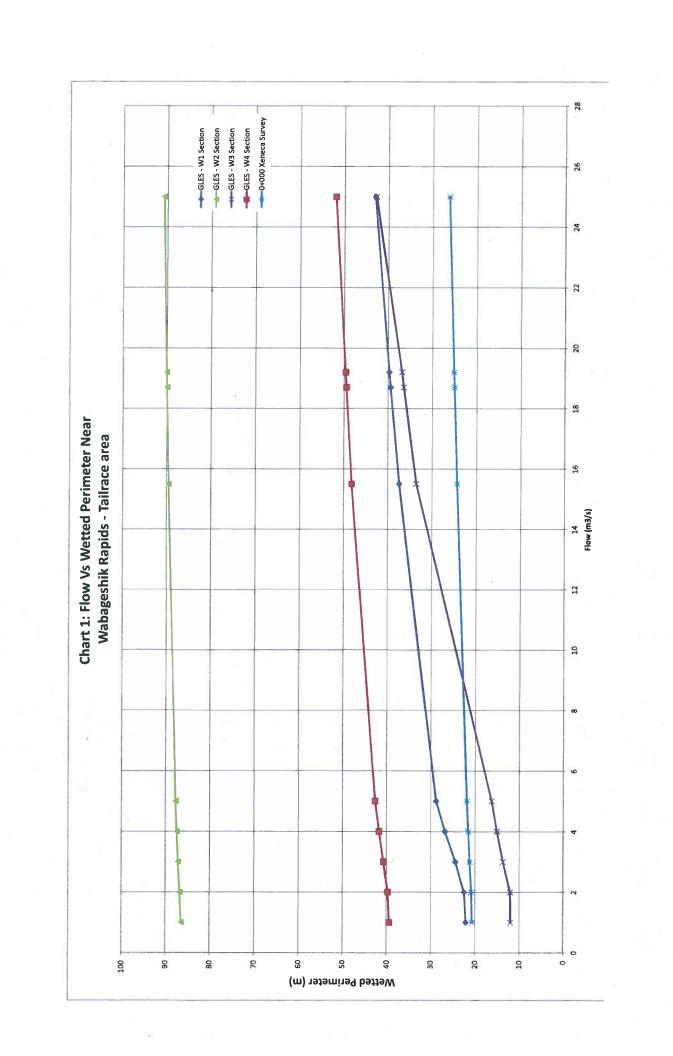
# Additional Hydraulic Analysis - Downstream of Tailrace Area

# November 21, 2012

Xeneca Power Development Inc







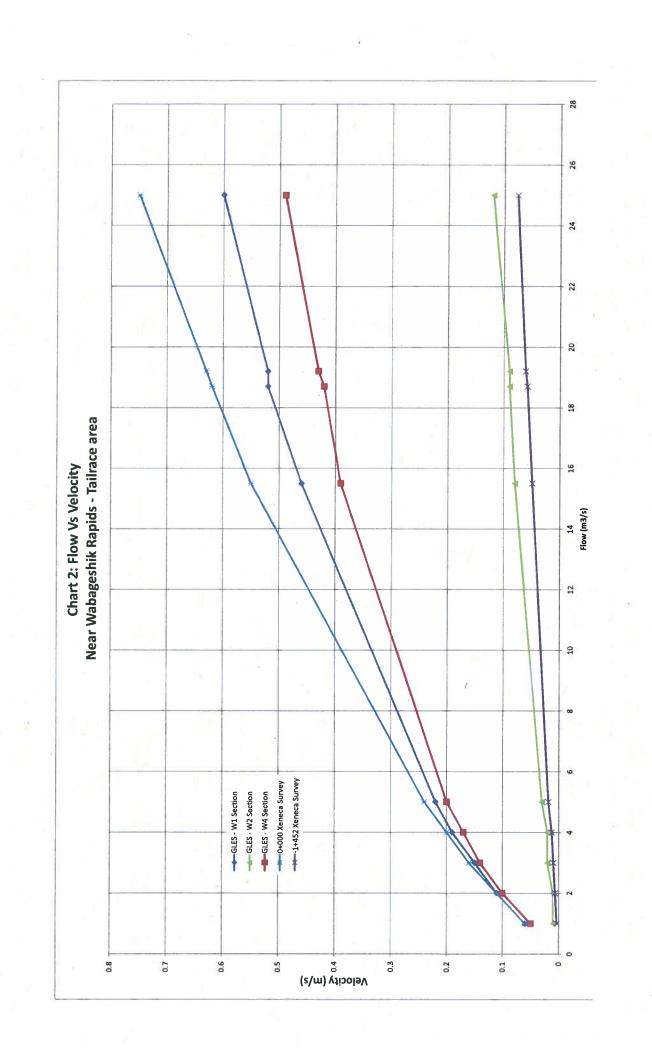
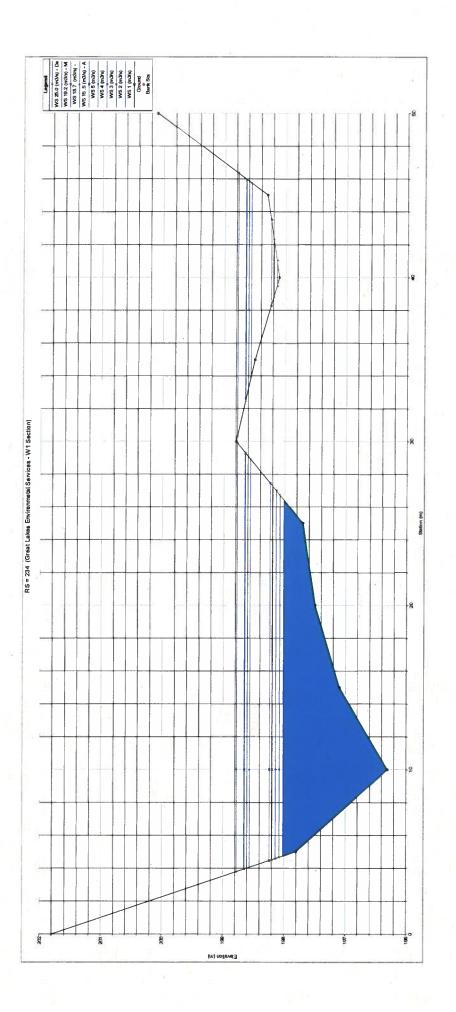
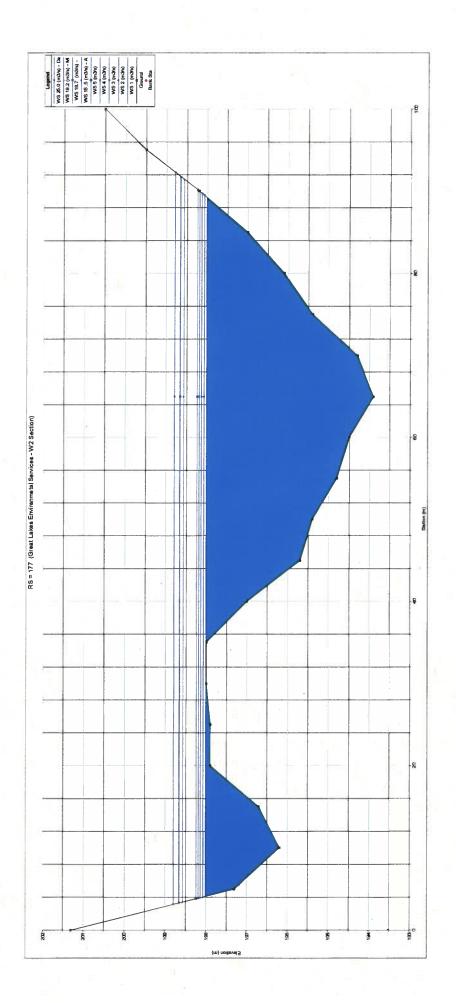
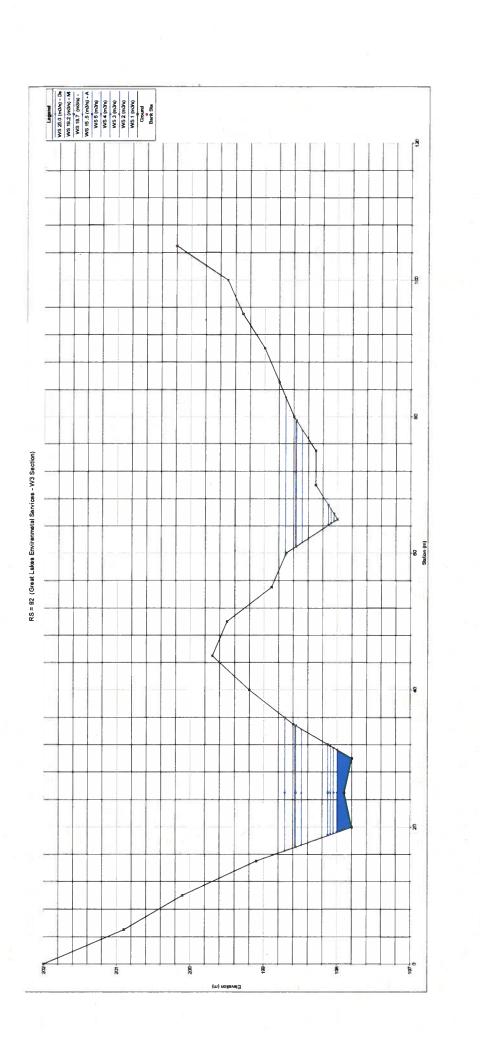


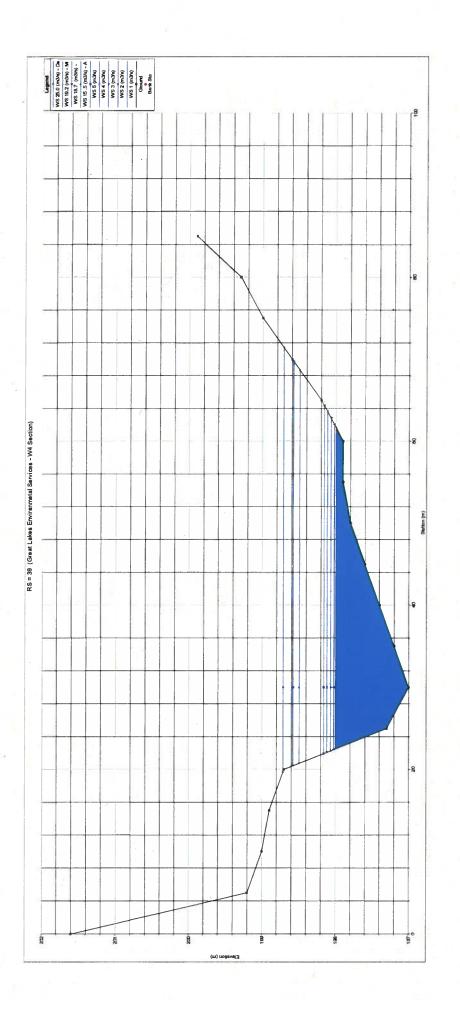
Table 1 - Wabageshik Rapids Tailrace Area Hydraulic Parameters at various flows

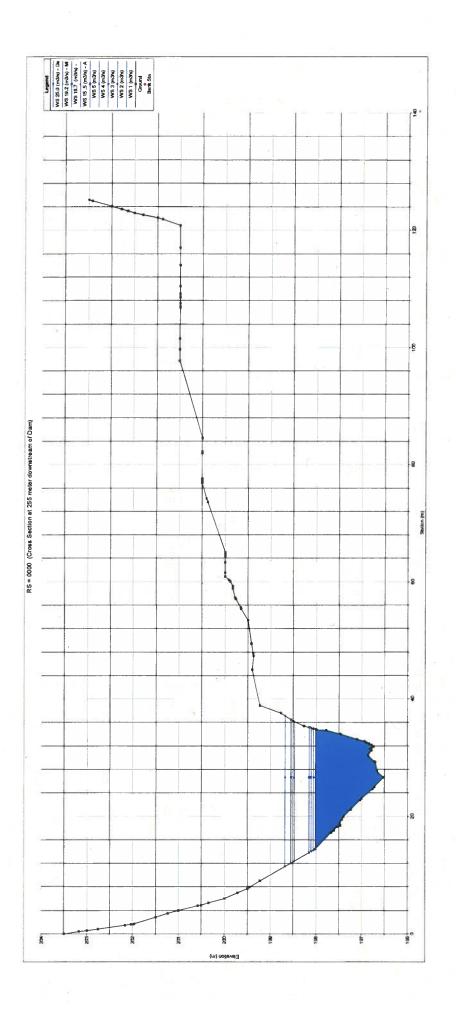
Reach	River Station	Q Total	Flow Description	Min Ch El	W.S. Elev	Vei Chni	Flow Area	Top Width	Hyds Depth	Max Chi Dpth	W.P. Total
	1	(m3/s)		(m)	(m)	(m/s)	(m2)	(m)	(m)	(m)	(m)
Wabageshik Rapids	0+255 ( Xaneca Survey)	. 1	Low Flow	196.78	198.01	0.06	17.3	29.12	0.59	1.24	30.62
Wabageshik Rapids	0+255 (Xeneca Survey)	2	Low Flow	196.78		0.1	19.15	29.54	0.65		31.08
Wabageshik Rapids	0+255 ( Xeneca Survey)		Low Flow	196.78		0.14	21.07	29.88	0.71		31.45
Wabageshik Rapids	0+255 ( Xeneca Survey)		Law Flow	196.78		0.18	22.68	30.09	0.75		31.7
Wabageshik Rapids	0+255 ( Xeneca Survey)	5		196.78		0.21	24.08	30.27	0.8		31.9
Wabageshik Rapids	0+255 ( Xeneca Survey)		Avg. Aug Flow	196.78		0.45	34.21	31.53	1.08		33.38
Wabageshik Rapids	0+255 ( Xeneca Survey)		Avg. Feb Flow	196.78		0.51	36.72	31.84	1.15	1.87	33.74
Wabageshik Rapids	0+255 ( Xeneca Survey)		Min. Turbine Flow	196.78	198.66	0.52	37.1	31.89	1.16	1.88	33.79
Wabageshik Rapids	0+255 ( Xeneca Survey)	25	Limited Turbine Flow	196.78	198.79	0.61	41.22	32.38	1,27	2.01	34.37
Wabageshik Rapids	0+234 (GLES - W1)		Low Flow	196.3	198.01	0.06	17.29	21.7	0.8	1.71	22.11
Wabageshik Rapids	0+234 (GLES - W1)		Low Flow	196.3	198.08	0.11	18.66	22.06	0.85	1.78	22.5
Wabageshik Rapids	0+234 (GLES - W1)		Low Flow	196.3	198.14	0.15	20.12	23.98	0.84	1.84	24.45
Wabageshik Rapids	0+234 (GLES - W1)		Low Flow	196.3	198.19	0.19	21.45	26.27	0.82	1.89	26,77
Wabageshik Rapids	0+234 (GLES - W1)		Low Flow	196.3	198.24	0.22	22.7	28.26	0.8	1.94	28.78
Wabageshik Rapids	0+234 (GLES - W1)		Avg. Aug Flow	196.3	198.56	0.46	33.34	36.67	0.91	2.26	37.4
Wabageshik Rapids	0+234 (GLES - W1)		Avg. Feb Flow	196.3	198.64	0.52	36.3	38.65	0.34	2.34	39.44 39.74
Wabageshik Rapids	0+234 (GLES - W1)		Min, Turbine Flow	196.3	198.65	0.52	36.76	38.95	0.94	2.35	
Wabageshik Rapids	0+234 (GLES - W1)	25	Limited Turbine Flow	196.3	198.78	0,6	41.93	42.17	0.99	2.48	43.05
Wabageshik Rapids	0+177 ( GLES - W2)		Low Flow	193.9	198.01	0.01	148.86	85.12	1.75	4.11	86.4
	0+177 (GLES - W2)			193.9	198.01					4.11	
Wabageshik Rapids Wabageshik Rapids	0+177 (GLES - W2)		Low Flow Low Flow	193.9	198.08	0.01	154.25 159.77	85.46 85.81	1.8	4.18	86.77 87.15
Wabageshik Rapids	0+177 (GLES - W2)		Low Flow	193.9	198.14	0.02	164.36	86.1	1.91	4.24	87.46
Wabageshik Rapids	0+177 (GLES - W2)		Low Flow	193.9	198.24	0.02	168.35	86.34	1.91	4.3	87.46
Wabageshik Rapids	0+177 (GLES - W2)		Avg. Aug Flow	193.9	198.24	0.08	197.02	88.01	2.24	4.54	89.56
Wabageshik Rapids	0+177 (GLES - W2)		Avg. Feb Flow	193.9	198.65	0.09	204.09	88.42	2.24	4.67	90
Wabageshik Rapids	0+177 (GLES - W2)		Min. Turbine Flow	193.9	198.66	0.09	205.15	88.48	2.32	4.76	90.07
Wabageshik Rapids	0+177 (GLES - W2)		Limited Turbine Flow	193.9	198.79	0.12	216.7	89.15	2,43	4.89	90.79
Trabagasiik Kapitas	0.277 ( 0.2.5 - 172)		Limited Fotomie Flow	155.5	130.73		210.7		2.73	4.03	50.73
Wabageshik Rapids	0+92 (GLES - W3)	1	Low Flow	197.8	197.99	0.62	1.62	11.95	0.14	0.19	11.99
Wabageshik Rapids	0+92 (GLES - W3)	2		197.8	198	1.19	1.69	12.01	0.14	0.2	12.05
Wabageshik Rapids	0+92 (GLES - W3)		Low Flow	137.8	198.05	1.3	2.31	13.63	0.17	0.25	13.69
Wabageshik Rapids	0+92 (GLES - W3)		Low Flow	197.8	198.09	1,39	2.89	14.99	0.19	0.29	15.06
Wabageshik Rapids	0+92 (GLE5 - W3)		Low Flow	197.8	198.12	1.46	3,43	16.18	0.21	0.32	16.26
Wabageshik Rapids	0+92 (GLES - W3)		Avg. Aug Flow	197.8	198.48	1.26	12.32	33.33	0.37	0.68	33,52
Wabageshik Rapids	0+92 (GLES - W3)		Avg. Feb Flow	197.8	198.57	1.23	15.26	36.2	0.42	0.77	36.42
Wabageshik Rapids	0+92 (GLES - W3)		Min. Turbine Flow	197.8	198.58	1.22	15.71	36.62	0.43	0.78	36.84
	0+92 (GLES - W3)		Umited Turbine Flow	197.8	198.71	1.19	20.99	42.56	0.49	0.91	42.81
Wabageshik	0+39 (GLES - W4)	1	Low Flow	197	198	0.05	18.62	39.25	0.47	1	39.38
	0+39 (GLE5 - W4)		Low Flow	197	198.02	0.1	19.26	39.58	0.49	1.02	39.71
Wabageshik .	0+39 (GLES - W4)	3	Low Flow	197	198.07	0.14	21.23	40.57	0.52	1.07	40.71
Wabageshik	0+39 (GLES - W4)	4	Low Flow	197	198.12	0.17	23.22	41.56	0.56	1.12	41.7
Wabageshik	0+39 (GLES - W4)	5	Low Flow	197	198.16	0.2	25.06	42.44	0.59	1.16	42.59
Wabageshik	0+39 (GLES - W4)	15.5	Avg. Aug Flow	197	198.5	0.33	40.23	47.98	0.84	1.5	48.2
Wabageshik	0+39 (GLES - W4)	18.7	Avg. Feb Flow	197	198.58	0.42	44.06	49.25	0.89	1.58	49.48
	0+39 (GLES - W4)		Min. Turbine Flow	197	198.59	0.43	44.64	49,44	0,9	1.59	49,66
Wabageshik	0+39 (GLES - W4)	25	Limited Turbine Flow	197	198.71	0.49	51.01	51.76	0.99	1.71	52
	0+00 (Xeneca Survey)		Low Flow	196.51	198	0.06	17.8	20.22	0.88	1.49	20.7
	0+00 (Xeneca Survey)		Low Flow	196.51	198.02	0.11	18.12	20.37	0.89	1.51	20.86
	0+00 (Xeneca Survey)		Low Flow	196.51	198.07	0.16	19.11	20.73	0.92	1.56	21.23
	0+00 (Xeneca Survey)		Low Flow	196.51	198.11	0.2	20.09	21.05	0.95	1.6	21.56
	0+00 (Xeneca Survey)		Low Flow	196.51	198.16	0.24	21	21.33	0.98	1.65	21.86
Wabageshik	0+00 (Xeneca Survey)		Avg. Aug Flow	196,51	198.48	0.55	28.2	23.76	1.19	1.97	24.38
Wabageshik	0+00 (Xeneca Survey)		Avg. Feb Flow	196.51	198.55	0.62	29.99	24.42	1.23	2.04	25.06
Wabageshik	O+OO (Xeneca Survey)		Min. Turbine Flow	196.51	198.56	0.63	30.25	24.53	1.23	2.05	25.16
Wabageshik	0+00 (Xeneca Survey)	25	Limited Turbine Flow	196.51	198.68	0.75	33.2	25.64	1.29	2.17	26.3
11			-		121						
Wabageshik	-1+452 (Xeneca Survey)		Low Flow	194.01	198	0.003	292.34	94.5	3.09	3.99	96.24
Wabageshik	-1+452 (Xeneca Survey)		Low Flow	194.01	198	0,006	292.62	94.51	3.1	3.99	96.25
Wabageshik	-1+452 (Xeneca Survey)		Low Flow	194.01	198.01	0.009	293.08	94.53	3.1	4	96.27
Wabageshik	-1+452 (Xeneca Survey)		Low Flow	194.01	198.02	0.012	293.73	94.55	3.11	4.01	96.29
Wabageshik	-1+452 (Xeneca Survey)		Low Flow	194.01	198.02	0.018	294.55	94.57	3.11	4.01	96.32
Wabageshik	-1+452 (Xeneca Survey)		Avg. Aug Flow	194.01	198.19	0.049	310.55	96.4	3.22	4.18	98.22
Wabageshik	-1+452 (Xeneca Survey)		Avg. Feb Flow	194.01	198.26	0.058	317.28	97.75	3.25	4.25	99.61
Wabageshik	-1+452 (Xeneca Survey)		Min. Turbine Flow	194.01	198.27	0.061	318.41	97.84	3.25	4.26	99.7
Wabageshik	-1+452 ( Xeneca Survey)	25	Limited Turbine Flow	194.01	198.41	0.076	332.09	98.9	3.36	4.4	100.82

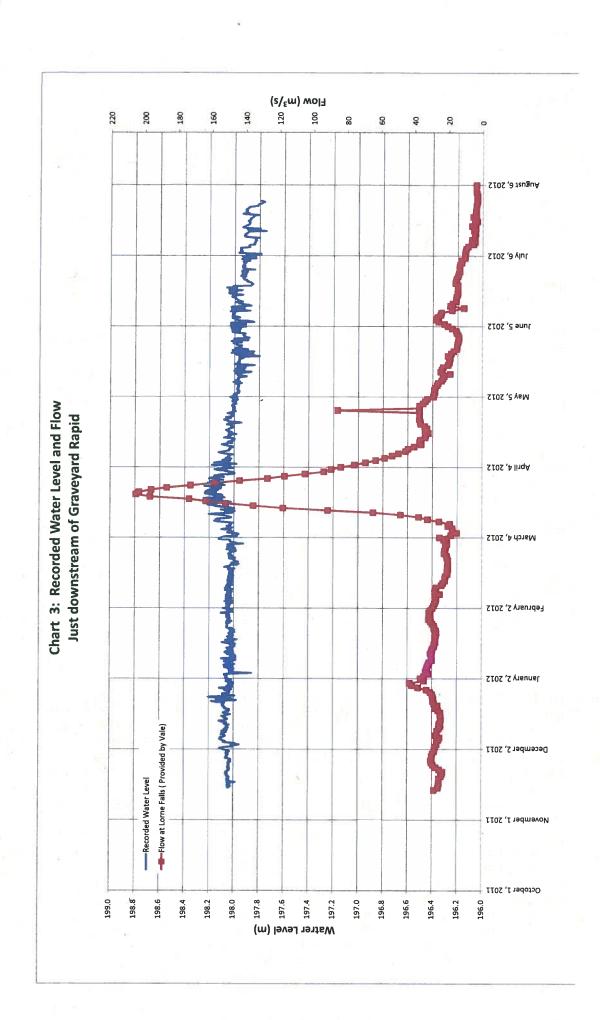


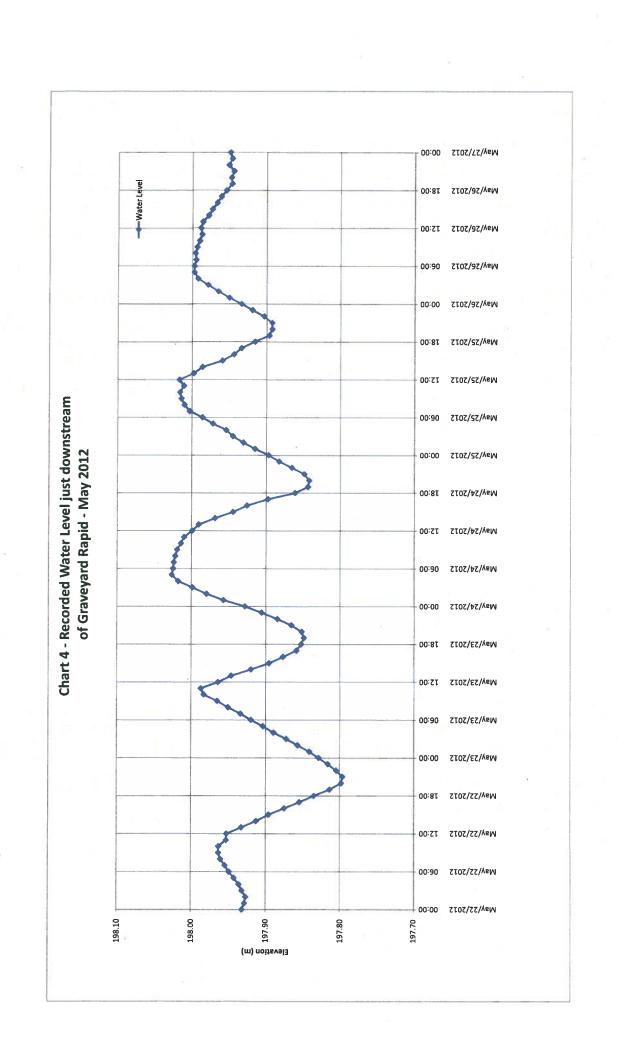












Wabageshik Rapid - Area Just Downstream of Tailrace

Photographs at Various Flow conditions



Photo 1: Looking Downstream (Northwest) in Tailrace Area

Flow: 15 (m<sup>3</sup>/s)

Date: Oct 22, 2010

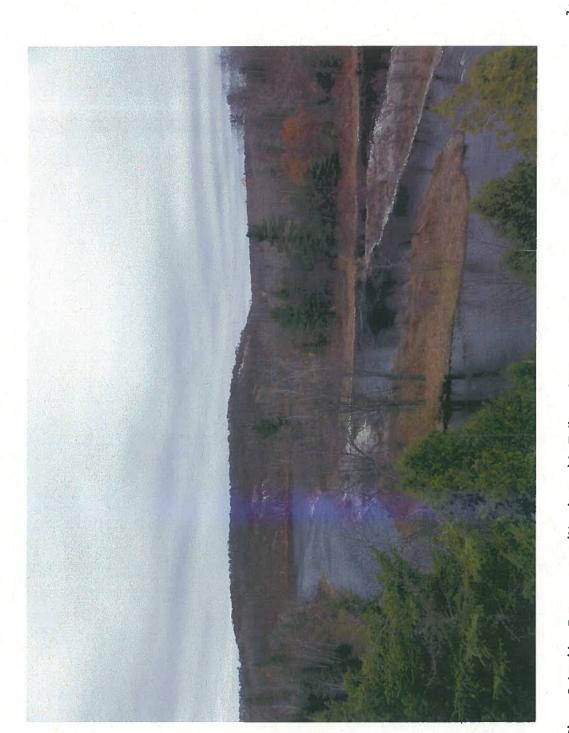


Photo 2: Looking Downstream (Northwest) in Tailrace Area

Date: Oct 22, 2010

Flow: 15 (m<sup>3</sup>/s)

Flow: 15 (m<sup>3</sup>/s)

Photo 3: Looking Upstream (North) in Tailrace Area

Date: Oct 22, 2010

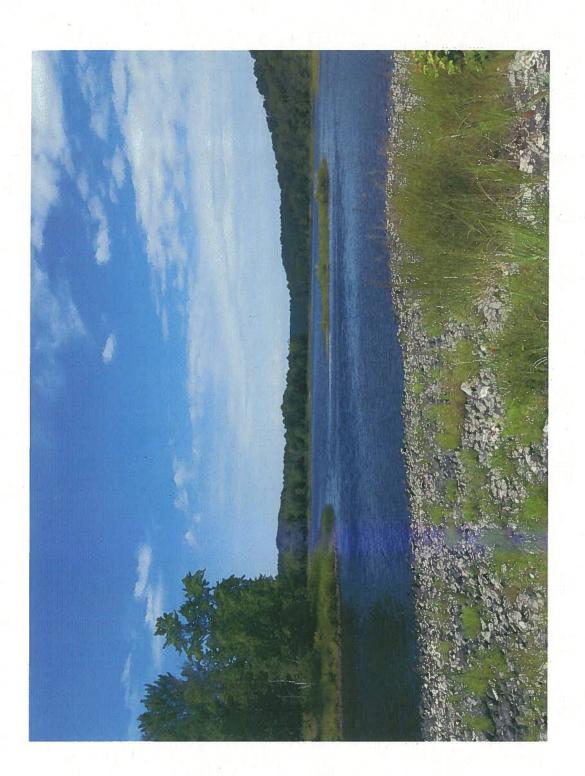


Photo 4: Looking Downstream (Northwest) in Tailrace Area

Date: Oct 22, 2010

Flow: 15 (m<sup>3</sup>/s)

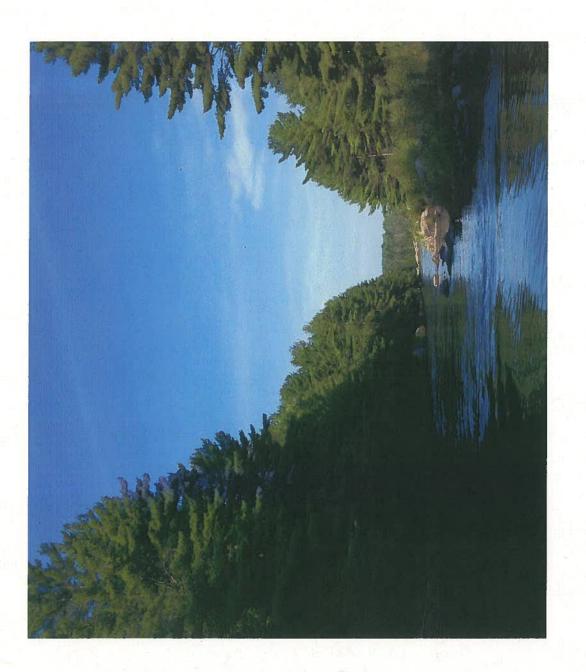
Photo 5: Looking Upstream just before the bay area



Flow: 3.5 (m<sup>3</sup>/s)

Date: July 30, 2012

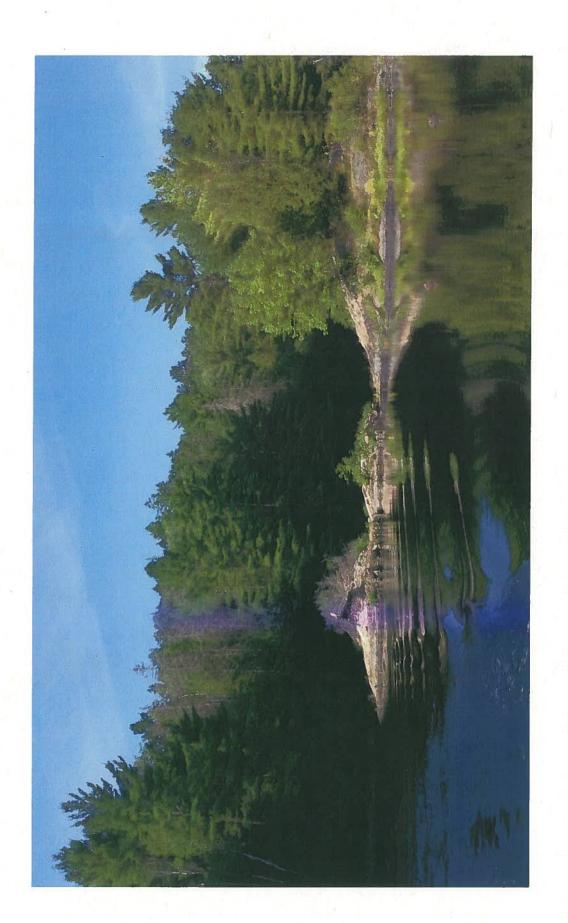
Photo 6: Looking Downstream (Bay Area)



Flow: 3.5 (m<sup>3</sup>/s)

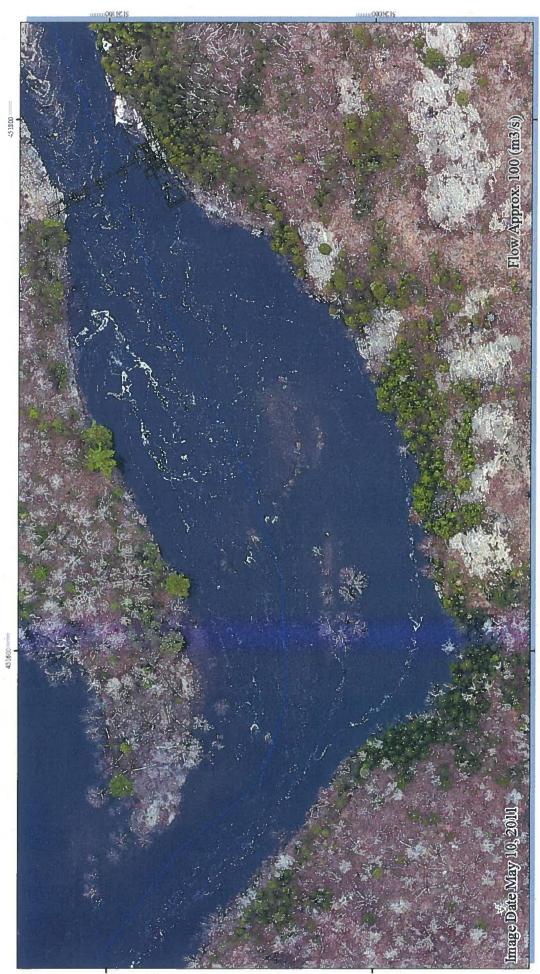
Photo 7: Graveyard Rapids

Date: July 30, 2012



Flow: 3.5 (m<sup>3</sup>/s)

Photo 8: Graveyard Rapids - Upstream End Control Section



21 Nov 2012 - Produced by N Collard





Xeneca Power Development Inc.

Hydrology Review

For

Vermilion River Hydropower Project

H333443 Rev. 0 October 6, 2009



**Project Report** 

October 6, 2009

Xeneca Power Development Inc. Vermilion Hydropower Sites Hydrology Review

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Xeneca

Attention: Mr. Patrick Gillette Xeneca Power Development Inc.

5160 Yonge Street, Suite 520 Toronto, Ontario M2N 6L9 1 hard copy and 1 electronic copy (posted to Xeneca FTP site)

Jim Law/File H333443

Hatch, Oakville

1 hard copy



# Xeneca Power Development Inc. Vermilion Hydropower Sites

# **Hydrology Review**

Prepared by:	M.C.C.C.	October 6, 2009 Date
Approvals		
Hatch		
	( ) / Au	
Approved by:		October 6, 2009
	Jim Law	Date
Xeneca Power		
Approved by:		October 6, 2009
	Patrick Gillette	Date



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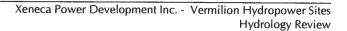






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#### 1. Introduction

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

- McPherson Falls
- Cascade Falls
- At Soo Crossing
- Wabageshik Rapids

Flows in the Vermilion River and its tributaries have been measured at a number of locations, but not at any of the project sites; so long term flow series at each location must be synthesized from flow records on the Vermilion River and on other rivers in the region.

Figure 1 shows the Vermilion River watershed at the four project sites. Figure 2 shows the Vermilion 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 Vermilion River basin is sufficient to determine the runoff at the Wabageshik Rapids site, but a calibrated water balance within the Vermilion River basin has been used to model the variation in runoff between the sites and existing streamflow stations in the region. This is described in Section 2.3.

#### 2.2 Long Term Flow in the Vermilion River

Flows have been measured on the Vermilion River at Lorne Falls [02CF004] from 1954 – 1993 and near Val Caron [02CF011] from 1970 – 1993; and within the Vermilion River basin, on the Whitson River at Chelmsford [02CF007] from 1961 – 2005; on the Onaping River near Levack [02CF010] from 1976 – 1997 and 2003 - 2005; and on Junction Creek below Kelly Lake [02CF012] from 1977 - 2005. Other records also exist on these rivers but for shorter durations. Some of these streamflow station records are classified as "regulated" and some "natural" by WSC.

The Aux Sables River at Massey [02CE002] to the west of the Vermilion River basin was also included in the regional runoff analysis as is has a complete record from 1921 – 2005, a period that encompasses all the other streamflow records in the region.

#### 2.3 Regional Runoff

The runoff at nine regional WSC streamflow gauges was analysed to examine runoff trends in and around the Vermilion River basin. Mean annual runoff estimates were adjusted to the 1921 to 2005 period for which complete flow records are available on the Aux Sables River at Massey [02CE002]. The estimated mean annual runoffs for this period vary from 199 mm for the Onaping River near Levack [02CF010] to 556 mm for Junction Creek below Kelly Lake [02CF012].

A simple water balance model was constructed to explain this variation in runoff. Regional runoff and precipitation, together with estimated evaporation loss have been used to calibrate a water balance model for the region.

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, lake coverage and precipitation, but, in the long term, can be considered as a constant times lake evaporation for a given ground cover and region, i.e.

Annual average evaporation loss = C \* Annual average lake evaporation





By accumulating annual average precipitation and evaporation loss for each river basin the runoff can be calculated. The average runoff at the flow monitoring stations can be computed from the flow records, so the constant C can be computed for each river basin. Table 1 shows the water balance calibration for rivers in the Vermilion River region.

Table 1 Water Balance Calibration for the Vermilion River Region

WSC No.	Years of Record	Drainage Area (km²)	Annual Average Precipitation (mm)	Mean Annual Runoff (mm)	Evaporation Loss Et (mm)	Basin Latitude (°N)	Lake Evaporation Eo (mm)	"C"
02CE002	85	1350	865	425	440	46.5	617	0.71
02CF002	12	4070	840	371	469	46.76	607	0.77
02CF004	40	4190	840	340	500	46.75	608	0.82
02CF005	35	89.1	848	462	386	46.52	616	0.63
02CF007	45	272	844	350	494	46.62	613	0.81
02CF008	29	179	843	332	511	46.64	612	0.84
02CF010	24	1570	832	199	633	46.93	601	1.05
02CF011	15	704	832	393	439	46.92	602	0.73
02CF012	29	207	848	556	292	46.48	618	0.47

The annual lake evaporation adjustment factor increases with the density of lake coverage in the river basin, because open water is always available to evaporate whereas evaporation from the ground surface depends on soil moisture content which depletes through the summer when evaporation potential is highest. There is a large variation in C values in the Vermilion River basin due to the different land use and lake coverage.

Junction Creek, stations 02CF005 and 02CF012, have the lowest C value because the catchment area is Greater Sudbury, which is largely urban and as a result has a greater proportion of direct runoff. The runoff and C value for Junction Creek below Kelly Lake [02CF012] are influenced by mine tailing ponds in Sudbury, which pump water from Whitewater Lake, outside Junction Creek drainage area, and discharge the water to Junction Creek via Coppercliff Creek.

The high C value for the Onaping River near Levack [02CF010] is due to high lake coverage of Onaping Lake in the upper part of the basin. The other streamflow stations have C values between 0.73 and 0.82, typical of basins with moderate lake coverage.

The C values for the main tributary streamflow stations in Table 1 can be applied to the sub-basins in Figure 1 to estimate the runoffs at each project site. The C values for Junction Creek and Onaping River were adjusted for the full sub-basin areas represented.

Table 2 shows the water balance for the Vermilion River to the four project sites.



Table 2 Vermilion Hydropower Sites – Estimated Mean Annual Runoff

Sub-basin	PPT	Latitude	Lake Eo	С	Evap Et	PPT-Et	Агеа	Area*(PPT-Et)	∑Area	∑Area*(ppt-Et)	MAR	LTAF
Out busin	mm	°N	mm	Value	mm	mm	km²	mm.km²	km²	mm.km²	mm	m³/s
SB01 & SB05	830	46.92	602	1.00	602	228	1677	382844	1677	382844	228	12.1
SB02, SB03 & SB04	834	46.85	604	0.73	441	393	1091	428661	2768	811505	393	13.6
SB06, SB07 & SB08 to	840	46.55	615	0.81	498	342	1045	357170	3813	1168676	342	11.3
McPherson Falls	833	46.80	606	0.87	528	305	959	1137047	3727	1137047	305	36.0
Cascade Falls	834	46.79	606	0.87	528	306	20	74940	3747	1145717	306	36.3
At Soo Crossing	835	46.78	607	0.87	528	306	66	251658	3813	1168511	306	37.0
SB09	848	46.45	619	0.60	371	477	321	153049	4134	1321560	477	4.8
SB10 to	845	46.32	623	0.81	505	340	259	88076	4393	1493884	340	2.8
Wabageshik Falls	840	46.70	610	0.82	500	340	0	0	4393	1493884	340	47.3

The highlighted values in Table 2 apply to the sub-basins specified, while the other values are computed and are cumulative at each project location.

When the sub-basin areas and MAR values are combined the resulting MAR and LTAF values for the four project sites are:

McPherson Falls

305 mm and 36.0 m<sup>3</sup>/s

Cascade Falls

306 mm and 36.3 m<sup>3</sup>/s

At Soo Crossing

306 mm and 37.0 m<sup>3</sup>/s

Wabageshik Rapids 340 mm and 47.3 m<sup>3</sup>/s.

#### 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 tributary streamflow stations used above have been compared to examine the impacts of location, drainage area and natural lake regulation. Figure 3 shows the seasonal flow patterns for these streamflow records, with each month expressed as a ratio to the LTAF.

All of the long term river records are regulated to some extent, except the Whitson River [02CF007], which has a higher spring peak. The year round pumping to the Coppercliff mines in Sudbury is evident as return flows to Junction Creek [02CF012], which raise the summer, fall and winter flows. Otherwise all rivers exhibit similar seasonal patterns with maximum flows of 275-425% LTAF occurring in spring and lowest flows of 35-50% LTAF occurring in winter and summer.

This comparison suggests that the longest flow record, the Vermilion River at Lorne Falls [02CF004] might be the best candidate as a representative gauge to simulate long term flows at all the project sites as it incorporates the trends in tributaries that would be experienced at the project sites.



# 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 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. All five rivers show very similar variations in high and low years, providing further confidence in the 02CF004 record.

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

#### 5. Turbinable Flow

The Run-of-River plants proposed for the Vermilion hydropower sites must use river flows as they arrive, without the use of reservoir storage at each site 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 six long term streamflow stations compared above with flows expressed as ratios of the LTAF at each site.

The flow records in Figure 5 show very similar flow duration curves typical of natural river basins and basins with significant natural lake regulation. The Whitson River [02CF007] is the only "natural" flow record and its curve is lowest below the LTAF. Junction Creek [02CF012], which is supplemented by pumping return flows, is highest below the LTAF. The other three curves have similar profiles, although the Vermilion River at Lorne Falls [02CF004] drops at the end due to daily pondage in the headpond of the power plant.

The Vermilion River at the project sites should have flow duration curves very similar to the 02CF004 flow record in Figure 5, except that the three upstream sites would not drop sharply at the lower end.

# 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 Vermilion River at Lorne Falls [02CF004] was selected as the best choice as the representative gauge for all sites. These flows were pro-rated in proportion to the LTAF values in Table 2, with the lowest flows at the three upstream sites adjusted by reference to the minimum flows in the upstream tributaries.



Before the flows were synthesized using the 02CF004 record it was screened for statistical stationarity using DATSCRN, a software package from the International Institute for Land Reclamation and Improvement (ILRI), Wagenigan, The Netherlands, 1991. The period covered by the 02CF004 record, 1954 – 1993, 40 years, is statistically stationary and can be considered representative of the current flow regime.

Table 3 shows the monthly flow summary table for the Vermilion River at Lorne Falls [02CF004].

#### 7. Results

The principal output of this hydrology review is four 40-year, daily flow series that can be used in the generation potential analysis of the McPherson Falls, Cascade Falls, At Soo Crossing and Wabageshik Rapids hydropower sites on the Vermilion 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 3-6 Monthly flow summary tables for each site
- Figure 6 Seasonal flow patterns for the four 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 40-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 four sites on the Vermillion River.

As noted previously, the flow series derived for the Vermilion River 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 3 Mean Monthly Flows in the Vermilion River at Lorne Falls [02CF004]

Year	January	February	March	April	May	June	July	August	September	October	November	December	Year
1954	13.6	14.5	62.5	172.6	155.9	77.3	41.6	15.8	14.2	130.4	63.1	38.4	66.9
1955	22.4	16.2	23.8	159.3	46.0	21.9	9.1	7.3	9.3	17.8	46.2	26.1	33.7
1956	16.5	11.8	14.1	112.7	97.8	50.5	25.6	14.6	19.3	32.9	34.8	34.0	38.7
1957	21.8	16.5	37.7	112.0	94.3	35.3	121.8	16.0	13.9	14.6	77.5	58.3	51.8
1958	34.6	17.3	23.5	70.6	44.0	15.4	25.0	10.3	12.2	12.0	37.4	22.4	27.1
1959	15.6	11.3	18.8	164.9	130.9	27.3	18.9	9.7	14.8	43.4	72.3	42.0	47.5
1960	23.0	17.1	17.5	202.1	300.2	56.6	63.0	25.2	16.9	17.9	43.1	31.6	68.0
1961	16.6	12.7	17.6	63.6	67.6	46.5	59.0	30.4	39.4	37.0	44.2	43.7	40.0
1962	24.6	23.9	38.6	110.9	128.0	25.3	10.3	7.3	6.5	7.4	9.7	9.9	33.5
1963	8.6	6.7	17.8	152.1	49.2	29.8	9.8	8.3	8.0	4.9	8.6	15.5	26.5
1964	10.8	11.4	18.5	113.8	87.3	23.9	10.4	7.4	15.0	33.3	26.1	33.0	32.6
1965	22.4	21.8	30.0	134.1	113.8	26.3	13.5	31.6	56.6	74.7	68.0	66.5	55.0
1966	51.1	38.0	63.2	139.2	69.4	33.0	9.7	10.2	9.1	34.9	78.4	119.9	54.7
1967	39.2	27.7	29.3	206.1	158.9	53.0	22.3	24.0	12.2	23.6	73.1	47.3	59.7
1968	27.8	20.9	32.8	123.0	46.1	31.9	29.5	21.1	47.7	45.0	27.5	37.8	40.8
1969	30.6	29.5	30.5	160.7	78.3	37.7	36.5	20.6	10.2	29.7	106.7	36.1	50.4
1970	16.9	14.9	15.6	116.3	114.3	174.4	45.3	18.5	23.5	54.3	50.3	46.6	57.6
1971	25.4	18.6	37.6	185.7	121.2	44.8	12.0	9.5	6.7	11.5	23.5	41.7	44.9
1972	26.7	17.6	15.6	142.2	207.7	32.8	19.8	30.2	31.3	38.2	40.3	23.5	52.2
1973	26.1	20.2	93.1	108.0	109.3	29.3	28.3	35.1	15.0	16.7	28.9	31.7	45.3
1974	17.4	15.5	21.3	144.4	98.5	63.4	22.0	12.1	8.4	20.6	75.3	32.3	44.2
1975	29.6	22.9	21.8	122.8	121.7	29.9	18.9	6.9	4.9	6.6	22.4	45.2	37.8
1976	14.9	10.9	30.6	203.0	114.6	29.0	11.5	5.9	8.3	12.8	13.7	11.3	38.8
1977	8.1	7.7	59.2	176.1	44.3	13.4	10.0	9.7	23.4	66.6	69.3	49.7	44.8
1978	26.6	18.1	15.1	97.7	163.4	24.8	14.0	13.6	29.3	91.5	34.2	27.6	46.6
1979	21.0	15.5	57.7	249.3	221.9	46.7	32.1	21.0	14.0	27.4	71.6	68.2	70.7
1980	40.4	19.4	19.9	190.8	130.5	30.5	16.0	13.2	15.7	42.5	32.5	21.4	47.7
1981	11.7	23.7	42.7	203.8	45.4	28.1	27.7	9.8	20.9	37.0	32.7	23.7	42.1
1982	18.0	13.2	19.7	148.1	117.6	24.8	8.7	6.1	16.8	64.6	68.1	76.8	48.6
1983	48.6	24.6	56.7	147.2	140.9	106.6	18.3	9.7	7.9	40.0	36.3	37.9	56.3
1984	19.6	26.4	27.7	107.7	50.9	63.7	38.6	18.3	21.3	30.7	69.8	56.6	44.1
1985	32.8	21.7	33.9	171.4	123.6	24.5	16.6	11.1	5.3	9.5	34.3	28.9	42.8
1986	16.8	9.3	15.9	130.9	52.9	26.8	13.7	24.9	11.5	29.1	27.7	18.8	31.5
1987	13.4	10.8	24.4	76.9	33.1	29.0	10.0	3.6	2.3	4.9	12.5	26.7	20.6
1988	18.3	18.4	21.0	223.5	95.1	34.7	11.6	14.2	13.3	47.6	118.7	58.3	56.0
1989	31.0	21.9	22.0	129.4	94.3	88.8	26.9	10.5	6.0	3.8	13.4	11.1	38.2
1990	11.7	15.2	57.1	67.4	134.9	55.1	50.8	11.0	6.5	20.0	53.3	69.9	46.3
1991	22.4	16.4	38.0	169.0	55.9	24.8	8.0	5.8	4.3	24.2	55.2	54.8	39.8
1992	28.5	17.9	24.2	103.0	84.9	31.8	23.0	20.8	40.0	49.2	70.7	39.8	44.4
1993	27.8	17.2	13.8	100.4	104.6	80.8	21.5	10.5	10.9	26.9	42.9	36.8	41.2
Mean	23.3	17.9	31.5	142.8	106.2	43.2	25.3	14.8	16.3	33.4	47.9	40.0	45.2



 Table 4
 Mean Monthly Flows in the Vermilion River at McPherson Falls

Year	January	February	March	April	May	June	July	August	September	October	November	Decombo	· Vasa
1954	10.8	11.6	49.8	137.4	124.2	61.6	33.1	12.5	11.3	103.8	50.2	30.6	Year 53.3
1955	17.9	12.9	18.9	126.9	36.6	17.5	7.3	5.8	7.5	14.2	36.8	20.7	26.8
1956	13.2	9.4	11.2	89.8	77.9	40.2	20.4	11.6	15.3	26.2	27.7	27.0	30.8
1957	17.3	13.2	30.0	89.2	75.1	28.1	97.0	12.8	11.0	11.7	61.7	46,4	
1958	27.6	13.8	18.7	56.2	35.1	12.2	19.9	8.2	9.7	9.6	29.7	17.9	41.3 21.5
1959	12.4	9.0	14.9	131.3	104.2	21.7	15.1	7.8	11.8	34.6	57.6	33.5	
1960	18.3	13.6	13.9	160.9	239.0	45.0	50.2	20.1	13.5	14.3	34.3	25.1	37.9
1961	13.2	10.2	14.0	50.6	53.9	37.0	47.0	24.2	31.4	29.5	35.2	34.8	54.1
1962	19.6	19.1	30.8	88.3	101.9	20.1	8.2	5.8	5.2	5.9	7.7	7.9	31.8
1963	6.9	5.3	14.2	121.2	39.2	23.8	7.8	6.6	6.4	4.0	6.9	12.4	26.7
1964	8.6	9.1	14.7	90.7	69.5	19.1	8.3	5.9	11.9	26.5	20.8	26.3	21.1 25.9
1965	17.9	17.4	23.9	106.8	90.6	21.0	10.8	25.2	45.0	59.5	54.2	53.0	
1966	40.7	30.3	50.3	110.9	55.3	26.3	7.8	8.1	7.3	27.8	62.4	95.5	43.8
1967	31.2	22.1	23.3	164.1	126.6	42.2	17.7	19.1	9.7	18.8	58.2	95.5 37.6	43.6
1968	22.1	16.6	26.2	97.9	36.7	25.4	23.5	16.8	38.0	35.8	21.9	30.1	47.5
1969	24.3	23.5	24.3	127.9	62.3	30.0	29.0	16.4	8.1	23.7	84.9	28.8	32.5
1970	13.5	11.9	12.4	92.6	91.1	138.9	36.1	14.7	18.7	43.3	40.1	37.1	40.2
1971	20.2	14.8	29.9	147.9	96.5	35.7	9.6	7.5	5.3	9.2	18.7	33.2	45.8
1972	21.2	14.0	12.4	113.3	165.4	26.1	15.8	24.1	24.9	30.4	32.1	18.7	35.7
1973	20.8	16.1	74.1	86.0	87.0	23.3	22.6	28.0	11.9	13.3	23.0	25.3	41.6 36.1
1974	13.9	12.3	17.0	115.0	78.5	50.5	17.5	9.7	6.7	16.4	60.0	25.7	
1975	23.6	18.2	17.4	97.8	96.9	23.8	15.1	5.5	4.0	5.2	17.8	36.0	35.2 30.1
1976	11.9	8.7	24.4	161.7	91.3	23.1	9.1	4.7	6.6	10.2	10.9	9.0	30.1
1977	6.4	6.1	47.2	140.2	35.3	10.7	7.9	7.7	18.6	53.0	55.2	39.6	35.7
1978	21.2	14.4	12.0	77.8	130.1	19.8	11.2	10.8	23.4	72.9	27.2	21.9	37.1
1979	16.7	12.4	45.9	198.5	176.7	37.2	25.6	16.7	11.2	21.8	57.0	54.3	56.3
1980	32.1	15.5	15.8	151.9	103.9	24.3	12.7	10.5	12.5	33.9	25.9	17.0	38.0
1981	9.3	18.9	34.0	162.3	36.2	22.4	22.0	7.8	16.6	29.5	26.1	18.9	33.5
1982	14.4	10.5	15.7	117.9	93.7	19.8	6.9	4.8	13.3	51.4	54.2	61.1	38.7
1983	38.7	19.6	45.2	117.2	112.2	84.9	14.6	7.7	6.3	31.8	28.9	30.2	44.8
1984	15.6	21.0	22.1	85.8	40.5	50.7	30.7	14.6	17.0	24.4	55.6	45.1	35.2
1985	26.1	17.2	27.0	136.5	98.4	19.5	13.2	8.8	4.3	7.6	27.3	23.0	34.1
1986	13.4	7.4	12.7	104.2	42.1	21.3	10.9	19.8	9.1	23.1	22.1	15.0	25.1
1987	10.6	8.6	19.4	61.2	26.4	23.1	7.9	3.0	2.5	4.0	9.9	21.2	16.5
1988	14.6	14.6	16.7	178.0	75.7	27.6	9.2	11.3	10.6	37.9	94.5	46.4	44.6
1989	24.7	17.5	17.5	103.1	75.1	70.7	21.4	8.4	4.8	3.4	10.6	8.8	30.4
1990	9.3	12.1	45.5	53.7	107.4	43.9	40.5	8.8	5.3	15.9	42.5	55.7	36.9
1991	17.9	13.0	30.3	134.5	44.5	19.7	6.4	4.6	3.6	19.3	44.0	43.6	31.7
1992	22.7	14.3	19.3	82.0	67.6	25.3	18.3	16.6	31.8	39.2	56.3	31.7	35.4
1993	22.2	13.7	11.0	79,9	83.3	64.3	17.1	8.4	8.7	21.4	34.2	29.3	32.8
Mean	18.6	14.2	25.1	113.7	84.6	34.4	20.1	11.8		26.6	38.1	31.9	36.0



 Table 5
 Mean Monthly Flows in the Vermilion River at Cascade Falls

Year	January	February	March	A21	1.4								
1954	10.9	11.7	50.2	April	May	June	July	August	September	October	November	December	Year
1955	18.0	13.0	19.1	138.5	125.1	62.0	33.4	12.6	11.4	104.6	50.6	30.8	53.7
1956	13.3	9.4	11.3	127.8	36.9	17.6	7.4	5.9	7.6	14.3	37.1	20.9	27.0
1957	17.5			90.5	78.5	40.5	20.6	11.7	15.5	26.4	27.9	27.3	31.0
1958	27.8	13.3	30.3	89.8	75.7	28.3	97.7	12.9	11.1	11.7	62.2	46.8	41.6
1959	12.5	13.9	18.9	56.6	35.3	12.3	20.0	8.2	9.8	9.6	30.0	18.0	21.7
1960	1	9.1	15.0	132.3	105.0	21.9	15.2	7.8	11.9	34.8	58.0	33.7	38.2
1961	18.5	13.7	14.0	162.1	240.9	45.4	50.6	20.3	13.6	14.4	34.6	25.3	54.6
1962	13.3	10.2	14.1	51.0	54.3	37.3	47.4	24.4	31.6	29.7	35.5	35.1	32.1
	19.8	19.2	31.0	88.9	102.7	20.3	8.2	5.9	5.2	5.9	7.8	7.9	26.9
1963	6.9	5.4	14.3	122.1	39.5	23.9	7.9	6.7	6.4	4.0	6.9	12.5	21.3
1964	8.6	9.2	14.8	91.3	70.0	19.2	8.3	6.0	12.0	26.7	21.0	26.5	26.1
1965	18.0	17.5	24.1	107.6	91.3	21.1	10.9	25.3	45.4	59.9	54.6	53.4	44.2
1966	41.0	30.5	50.7	111.7	55.7	26.5	7.8	8.2	7.3	28.0	62.9	96.2	43.9
1967	31.4	22.2	23.5	165.4	127.5	42.5	17.9	19.2	9.8	18.9	58.7	37.9	47.9
1968	22.3	16.7	26.4	98.7	37.0	25.6	23.7	16.9	38.3	36.1	22.0	30.3	32.8
1969	24.5	23.7	24.5	128.9	62.8	30.2	29.3	16.6	8.2	23.9	85.6	29.0	40.5
1970	13.6	12.0	12.5	93.3	91.8	140.0	36.4	14.8	18.8	43.6	40.4	37.4	46.2
1971	20.3	14.9	30.2	149.0	97.2	36.0	9.7	7.6	5.4	9.3	18.9	33.5	36.0
1972	21.4	14.1	12.5	114.1	166.7	26.3	15.9	24.2	25.1	30.6	32.3	18.9	41.9
1973	21.0	16.2	74.7	86.7	87.7	23.5	22.7	28.2	12.0	13.4	23.2	25.5	36.4
1974	14.0	12.4	17.1	115.8	79.1	50.8	17.6	9.7	6.7	16.5	60.5	25.9	35.5
1975	23.8	18.4	17.5	98.5	97.6	24.0	15.2	5.6	3.9	5.3	18.0	36.3	30.4
1976	12.0	8.7	24.5	162.9	92.0	23.3	9.2	4.7	6.7	10.3	11.0	9.0	31.1
1977	6.5	6.2	47.5	141.3	35.5	10.7	8.0	7.7	18.8	53.5	55.6	39.9	36.0
1978	21.3	14.5	12.1	78.4	131.1	19.9	11.2	10.9	23.5	73.4	27.4	22.1	37.4
1979	16.8	12.5	46.3	200.1	178.1	37.4	25.8	16.9	11.3	22.0	57.5	54.7	56.7
1980	32.4	15.6	15.9	153.1	104.7	24.5	12.8	10.6	12.6	34.1	26.1	17.2	38.3
1981	9.4	19.0	34.3	163.5	36.5	22.5	22.2	7.8	16.8	29.7	26.3	19.0	33.8
1982	14.5	10.6	15.8	118.8	94.4	19.9	7.0	4.9	13.4	51.8	54.6	61.6	39.0
1983	39.0	19.8	45.5	118.1	113.0	85.5	14.7	7.8	6.3	32.1	29.1	30.4	45.2
1984	15.7	21.2	22.2	86.4	40.8	51.1	31.0	14.7	17.1	24.6	56.0	45.4	35.4
1985	26.3	17.4	27.2	137.5	99.2	19.7	13.3	8.9	4.2	7.6	27.5	23.2	34.3
1986	13.5	7.5	12.8	105.0	42.4	21.5	11.0	20.0	9.2	23.3	22.3	15.1	25.3
1987	10.7	8.6	19.6	61.7	26.6	23.3	8.0	3.0	2.5	4.0	10.0	21.4	16.6
1988	14.7	14.8	16.8	179.4	76.3	27.8	9.3	11.4	10.7	38.2	95.3	46.8	44.9
1989	24.9	17.6	17.7	103.8	75.7	71.3	21.6	8.4	4.8	3.4	10.7	8.9	30.7
1990	9.4	12.2	45.8	54.1	108.2	44.2	40.8	8.8	5.3	16.0	42.8	56.1	37.2
1991	18.0	13.1	30.5	135.6	44.9	19.9	6.4	4.7	3.5	19.5	44.3	44.0	32.0
1992	22.8	14.4	19.4	82.6	68.1	25.5	18.4	16.7	32.1	39.5	56.7	31.9	35.7
1993	22.3	13.8	11.1	80.5	83.9	64.8	17.2	8.5	8.8	21.6	34.4	29.5	33.0
Mean	18.7	14.4	25.3	114.6	85.2	34.7	20.3	11.9	13.1	26.8	38.4	32.1	
									.0.1	20.0	30.4	J∠. I	36.3



Table 6 Mean Monthly Flows in the Vermilion River At Soo Crossing

Year	January	February	March	April	May	June	July	August	September	October	November	December	Year
1954	11.1	11.9	51.2	141.2	127.6	63.3	34.0	12.9	11.6	106.7	51.6	31.4	54.8
1955	18.4	13.3	19.4	130.4	37.6	17.9	7.5	6.0	7.7	14.6	37.8	21.3	27.6
1956	13.5	9.6	11.5	92.3	80.1	41.3	21.0	11.9	15.8	27.0	28.5	27.8	31.7
1957	17.8	13.5	30.9	91.6	77.2	28.9	99.7	13.1	11.3	12.0	63.4	47.7	42.4
1958	28.3	14.2	19.3	57.8	36.0	12.6	20.4	8.4	10.0	9.8	30.6	18.4	22.1
1959	12.7	9.3	15.3	135.0	107.1	22.3	15.5	8.0	12.1	35.5	59.2	34.4	38.9
1960	18.8	14.0	14.3	165.4	245.6	46.3	51.6	20.7	13.8	14.7	35.2	25.8	55.6
1961	13,6	10.4	14.4	52.0	55.4	38.0	48.3	24.8	32.2	30.3	36.2	35.8	32.7
1962	20.2	19.6	31.6	90.7	104.7	20.7	8.4	6.0	5.4	6.0	7.9	8.1	27.5
1963	7.1	5.5	14.6	124.5	40.3	24.4	8.0	6.8	6.6	4.1	7.1	12.7	21.7
1964	8.8	9.3	15.1	93.2	71.4	19.6	8.5	6.1	12.3	27.3	21.4	27.0	26.6
1965	18.4	17.9	24.5	109.8	93.1	21.6	11.1	25.9	46.3	61.1	55.7	54.4	45.0
1966	41.8	31.1	51.7	113.9	56.8	27.0	8.0	8.4	7.5	28.6	64.1	98.1	44.8
1967	32.1	22.7	24.0	168.7	130.1	43.4	18.2	19.6	10.0	19.3	59.8	38.7	48.9
1968	22.7	17.1	26.9	100.6	37.7	26.1	24.2	17.3	39.0	36.8	22.5	30.9	33.4
1969	25.0	24.2	24.9	131.5	64.1	30.8	29.8	16.9	8.3	24.3	87.3	29.6	41.3
1970	13.8	12.2	12.8	95.1	93.6	142.7	37.1	15.1	19.2	44.5	41.2	38.1	47.1
1971	20.7	15.2	30.8	152.0	99.2	36.7	9.9	7.7	5.5	9.5	19.3	34.2	36.7
1972	21.8	14.4	12.8	116.4	170.0	26.8	16.2	24.7	25.6	31.3	33.0	19.3	42.8
1973	21.4	16.5	76.2	88.4	89.4	24.0	23.2	28.8	12.2	13.6	23.6	26.0	37.1
1974	14.3	12.7	17.4	118.1	80.6	51.9	18.0	9.9	6.8	16.9	61.7	26.4	36.2
1975	24.2	18.7	17.9	100.5	99.6	24.5	15.5	5.7	4.0	5.4	18.3	37.0	31.0
1976	12.2	8.9	25.0	166.1	93.8	23.7	9.4	4.8	6.8	10.5	11.2	9.2	31.7
1977	6.6	6.3	48.5	144.1	36.3	11.0	8.2	7.9	19.1	54.5	56.7	40.7	36.7
1978	21.7	14.8	12.3	79.9	133.7	20.3	11.5	11.1	24.0	74.9	28.0	22.6	38.1
1979	17.1	12.7	47.2	204.0	181.6	38.2	26.3	17.2	11.5	22.4	58.6	55.8	57.9
1980	33.0	15.9	16.3	156.2	106.8	25.0	13.1	10.8	12.9	34.8	26.6	17.5	39.0
1981	9.6	19.4	35.0	166.8	37.2	23.0	22.6	8.0	17.1	30.3	26.8	19.4	34.5
1982	14.8	10.8	16.1	121.2	96.3	20.3	7.1	5.0	13.7	52.8	55.7	62.8	39.8
1983	39.8	20.1	46.4	120.4	115.3	87.2	15.0	7.9	6.4	32.7	29.7	31.0	46.1
1984	16.1	21.6	22.7	88.1	41.7	52.1	31.6	15.0	17.5	25.1	57.2	46.3	36.1
1985	26.8	17.7	27.8	140.3	101.1	20.1	13.6	9.0	4.3	7.8	28.0	23.7	35.0
1986	13.7	7.6	13.0	107.1	43.3	21.9	11.2	20.4	9.4	23.8	22.7	15.4	25.8
1987	10.9	8.8	20.0	62.9	27.1	23.7	8.1	3.1	2.6	4.1	10.2	21.8	16.9
1988	15.0	15.1	17.2	182.9	77.8	28.4	9.5	11.6	10.9	39.0	97.2	47.7	45.8
1989	25.4	17.9	18.0	105.9	77.2	72.7	22.0	8.6	4.9	3.5	10.9	9.1	31.3
1990	9.6	12.5	46.8	55.2	110.4	45.1	41.6	9.0	5.4	16.3	43.6	57.2	37.9
1991	18.4	13.4	31.1	138.3	45.8	20.3	6.6	4.8	3.6	19.8	45.2	44.8	32.6
1992	23.3	14.7	19.8	84.3	69.5	26.0	18.8	17.0	32.7	40.2	57.9	32.5	36.4
1993	22.8	14.1	11.3	82.2	85.6	66,1	17.6	8.6	8.9	22.0	35.1	30.1	33.7
Mean	19.1	14.6	25.8	116.9	86.9	35.4	20.7	12.1	13.4	27.3	39.2	32.8	37.0



Table 7 Mean Monthly Flows in the Vermilion River at Wabageshik Rapids

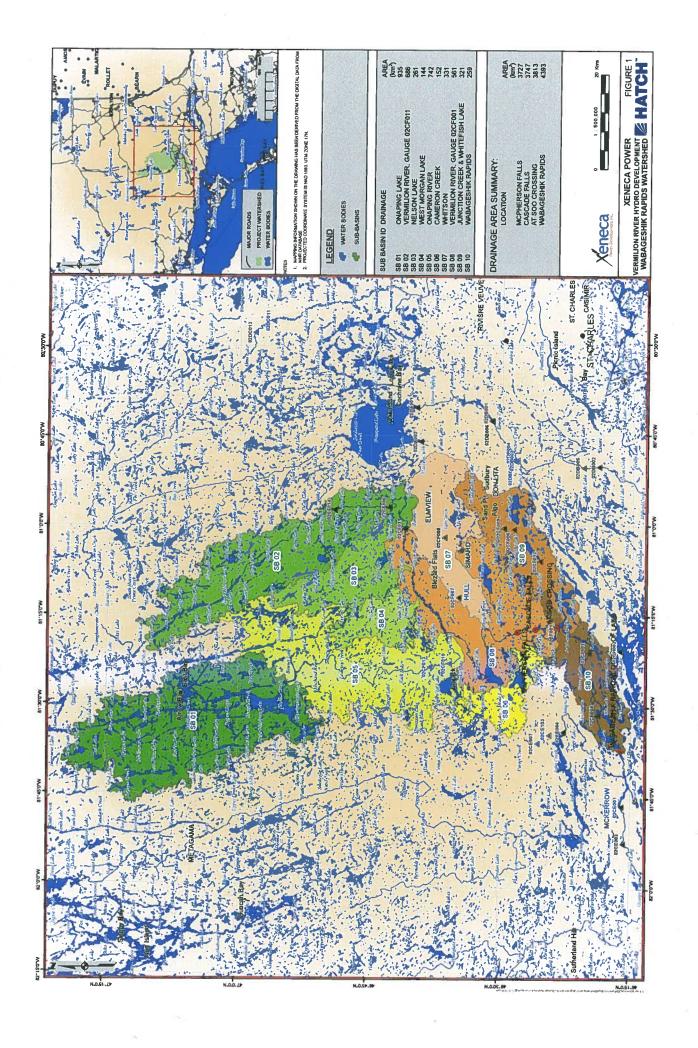
Year	January	February	March	April	May	June	July	August	Contomb	Ontob	Marrian	-	
1954	14.2	15.2	65.4	180.6	163.2	80.9	43.5	16.5	September 14.9	October 136.4		December	Year
1955	23.5	17.0	24.9	166.7	48.1	22.9	9.6	7.6	9.7		66.0	40.2	70.0
1956	17.3	12.3	14.7	118.0	102.4	52.8	26.8	15.3	20.2	18.6 34.5	48.3	27.3	35.2
1957	22.8	17.3	39.5	117.1	98.7	36.9	127.4	16.8	14.5		36.4	35.5	40.5
1958	36.2	18.1	24.6	73.8	46.1	16.1	26.1	10.5	12.8	15.3	81.1	61.0	54.2
1959	16.3	11.9	19.6	172.6	136.9	28.5	19.8	10.7	15.5	12.6	39.1	23.5	28.3
1960	24.1	17.9	18.3	211.4	314.1	59.2	66.0	26.4	17.7	45.4 18.8	75.7	44.0	49.8
1961	17.4	13.3	18.4	66.5	70.8	48.6	61.8	31.8	41.2	38.7	45.1	33.0	71.1
1962	25.8	25.0	40.4	116.0	133.9	26.4	10.7	7.6	6.8		46.3	45.7	41.8
1963	9.0	7.0	18.6	159.2	51.5	31.2	10.2	8.7	8.4	7.7	10.1	10.4	35.1
1964	11.3	12.0	19.3	119.1	91.3	25.0	10.9	7.8	15.7	5.1	9.0	16.2	27.8
1965	23.5	22.8	31.4	140.4	119.1	27.6	14.2	33.1	59.2	34.9	27.3	34.5	34.1
1966	53.5	39.8	66.2	145.7	72.6	34.5	• 10.2	10.7	9.6	78.1	71.2	69.6	57.6
1967	41.0	29.0	30.7	215.6	166.3	55.4	23.3	25.1	12.8	36.6	82.0	125.5	57.3
1968	29.1	21.8	34.4	128.6	48.3	33.3	30.9	22.1	49.9	24.7	76.5	49.5	62.5
1969	32.0	30.9	31.9	168.1	81.9	39.4	38.2	21.6	49.9 10.7	47.1	28.7	39.6	42.7
1970	17.7	15.6	16.3	121.6	119.6	182.5	47.4	19.4	24.5	31.1	111.6	37.8	52.8
1971	26.5	19.5	39.3	194.4	126.8	46.9	12.6	9.9	7.0	56.9	52.7	48.7	60.2
1972	27.9	18.4	16.3	148.8	217.4	34.3	20.7	31.6	7.0 32.7	12.1	24.6	43.7	46.9
1973	27.3	21.1	97.4	113.0	114.4	30.7	29.6	36.8	15.6	40.0	42.1	24.6	54.7
1974	18.2	16.2	22.3	151.0	103.1	66.3	23.0	12.7	8.8	17.5	30.2	33.2	47.4
1975	31.0	23.9	22.8	128.5	127.3	31.3	19.8	7.3	5.1	21.6 6.9	78.8	33.8	46.2
1976	15.6	11.4	32.0	212.4	119.9	30.3	12.0	6.1	8.7		23.4	47.3	39.6
1977	8.5	8.1	62.0	184.3	46.4	14.0	10.4	10.1	24.5	13.4 69.7	14.3	11.8	40.5
1978	27.8	18.9	15.8	102.2	171.0	26.0	14.7	14.3	30.7		72.5	52.0	46.9
1979	21.9	16.3	60.3	260.9	232.2	48.8	33.6	22.0	14.7	95.7 28.7	35.8	28.8	48.7
1980	42.2	20.3	20.8	199.7	136.5	31.9	16.7	13.8	16.5	44.5	74.9	71.4	74.0
1981	12.3	24.8	44.7	213.2	47.5	29.4	28.9	10.2	21.9	38,7	34.0 34.3	22.4	49.9
1982	18.9	13.8	20.6	155.0	123.1	26.0	9.1	6.4	17.5	67.6	71.2	24.8	44.1
1983	50.8	25.8	59.3	154.0	147.4	111.5	19.1	10.1	8.2	41.9	38.0	80.3	50.9
1984	20.5	27.6	29.0	112.7	53.3	66.6	40.4	19.2	22.3	32.1	73.1	39.7	58.9
1985	34.3	22.7	35.5	179.4	129.3	25.7	17.4	11.6	5.6	9.9	35.8	59.2	46.2
1986	17.5	9.7	16.7	136.9	55.3	28.0	14.3	26.1	12.0	30.4	29.0	30.3	44.8
1987	14.0	11.3	25.5	80.4	34.6	30.3	10.4	3.7	2.4	5.2	13.0	19.7	33.0
1988	19.1	19.2	21.9	233.9	99.5	36.3	12.1	14.9	14.0	49.9	124.2	27.9	21.5
1989	32.5	22.9	23.0	135.4	98.7	93.0	28.1	11.0	6.3	3.9	14.0	61.0	58.6
1990	12.2	15.9	59.8	70.5	141.1	57.6	53.2	11.5	6.8	20.9	55,8	11.6	39.9
1991	23.5	17.1	39.8	176.8	58.5	25.9	8.4	6.1	4.5	25.4	. 55,8 57.8	73.1	48.5
1992	29.8	18.7	25.3	107.8	88.9	33.3	24.0	21.8	41.8	51.4	74.0	57.3	41.7
1993	29.1	18.0	14.5	105.0	109.5	84.5	22.5	11.0	11.4	28.1	74.0 44.9	41.6	46.5
Mean	24.4	18.7	33.0	149.4	111.2	45.3	26.5	15.5	17.1	34.9	50.1	38.5 41.9	43.1 47.3

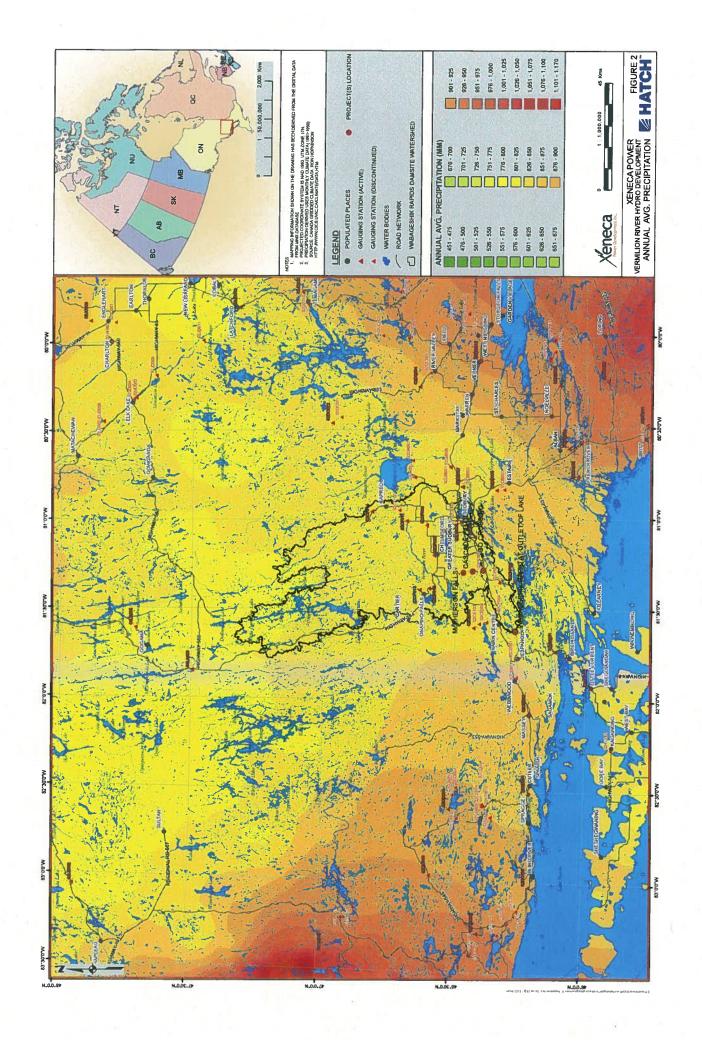
Mark Orton

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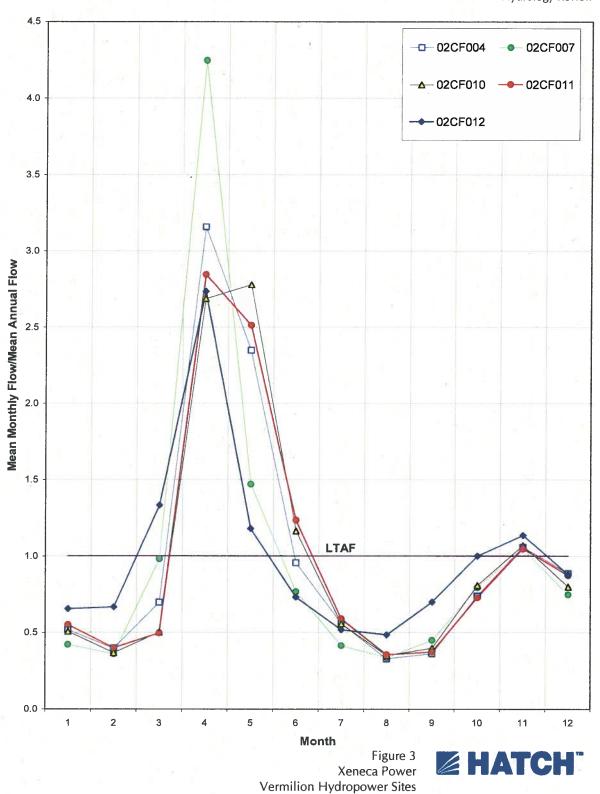


# **FIGURES**









**Seasonal Flow Patterns** 



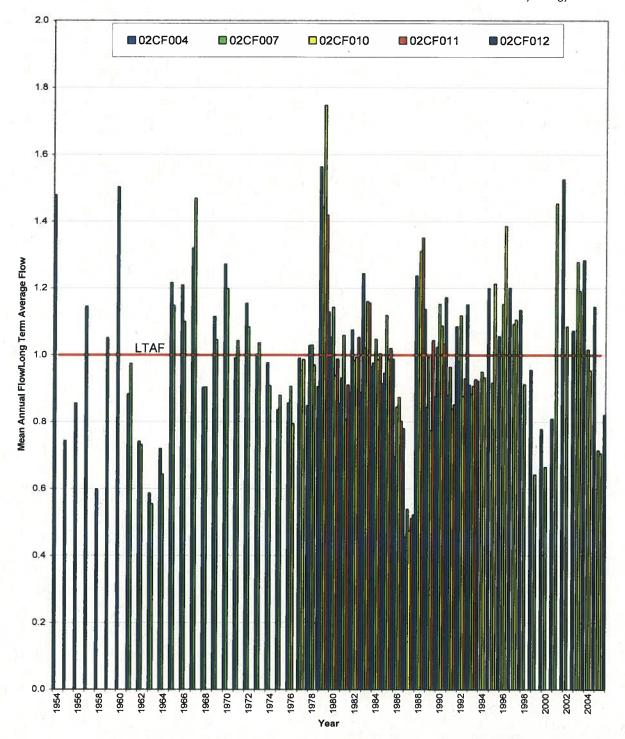


Figure 4 Xeneca Power Vermilion Hydropower Sites Annual Flow Variability





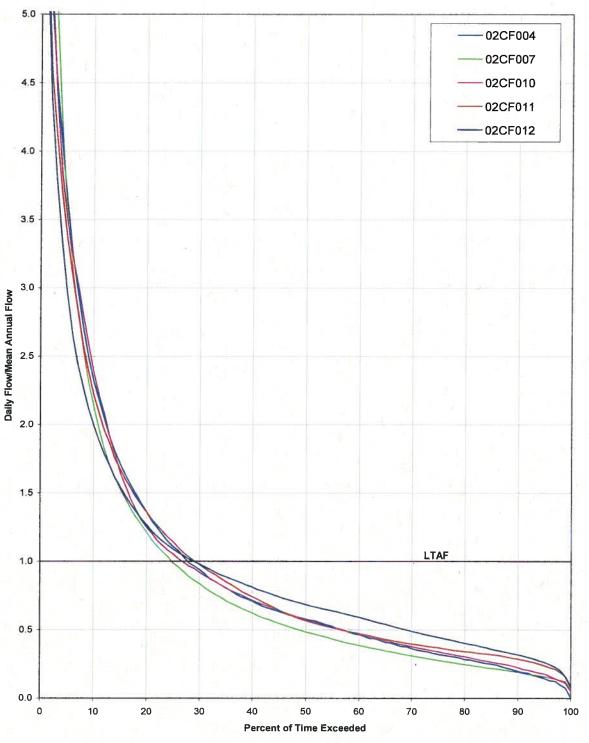
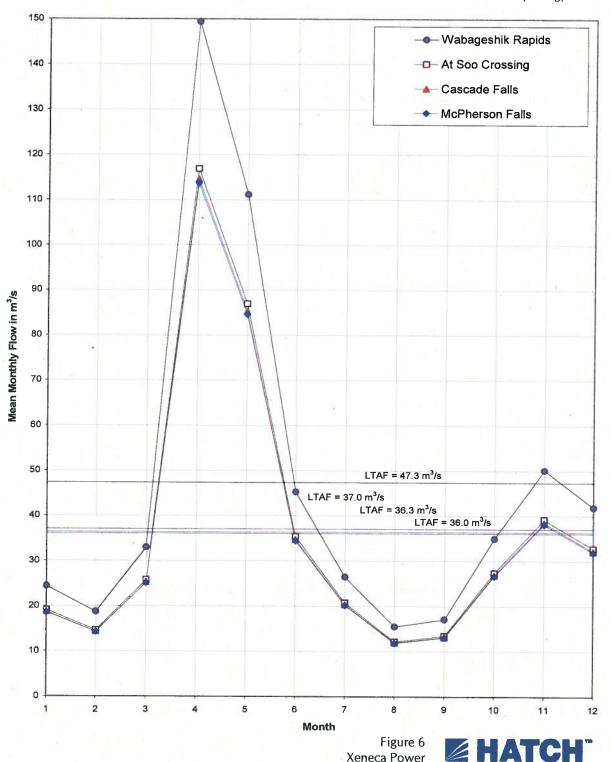


Figure 5 Xeneca Power Vermilion Hydropower Sites **Daily Flow Duration Curves** 







Vermilion Hydropower Sites

Vermilion River Hydropower Sites – Seasonal Flow Pattern





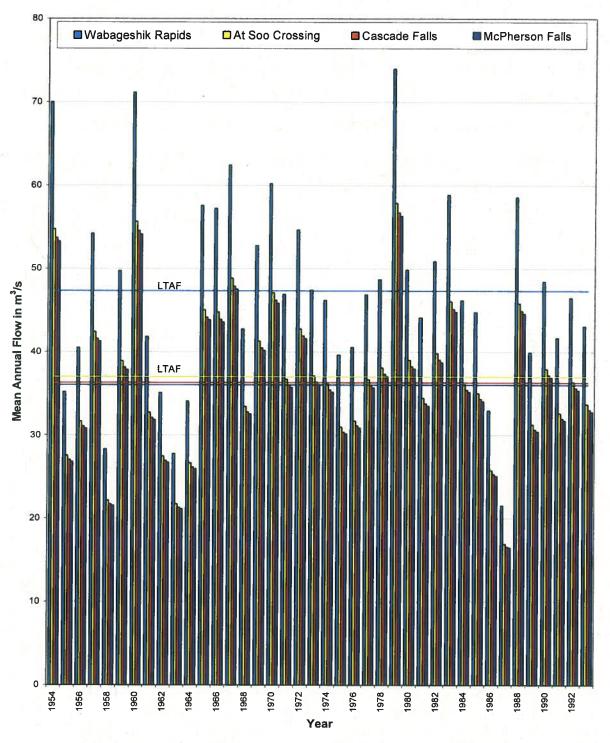


Figure 7 Xeneca Power Vermilion Hydropower Sites Vermilion River Hydropower Sites – Annual Flow Variability

Working Together SAFELY





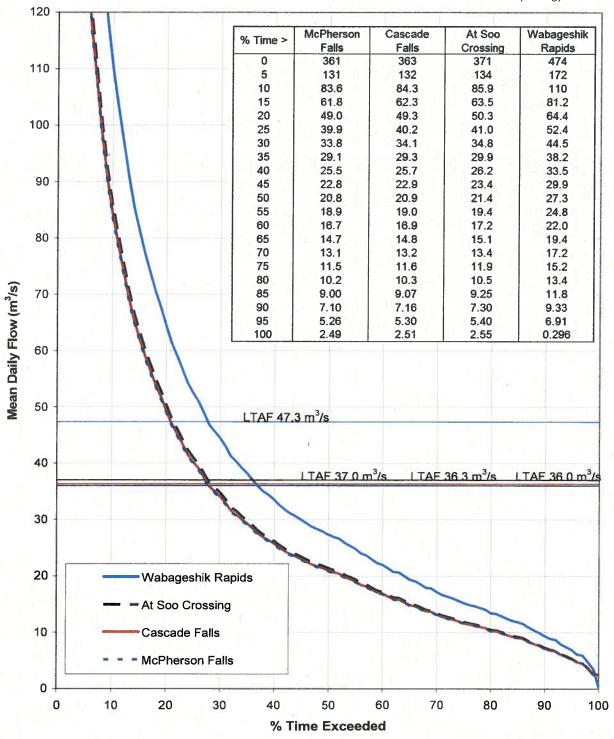


Figure 8 Xeneca Power Vermilion Hydropower Sites

**Vermilion River at Hydropower Sites – Daily Flow Duration Curves** 





# **APPENDIX A Flow Metrics**

# **HATCH**

# MCPHERSON FALLS - VERMILION RIVER NATURAL FLOW METRICS DATA SHEET

STATION INFORMATION

SITE ID 0

RIVER NAME VERMILION RIVER

SITE NAME MCPHERSON FALLS

region northeast District sudbury

DRAINAGE AREA 3727 km² OWNER XENECA POWER How metrics are provided for the potential waterpower site based on the Water Survey of Canada (WSC) gauging station, Vermilion River at Lorne Falls (02CF004) Metrics are based on WSC flows from 1954 to 1993 (40 years).

The flow records for the site have been synthesized by adjusting gauge flows by drainage area and MAR. 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 (1954 - 1993):

#### I. Streamflow Time Series

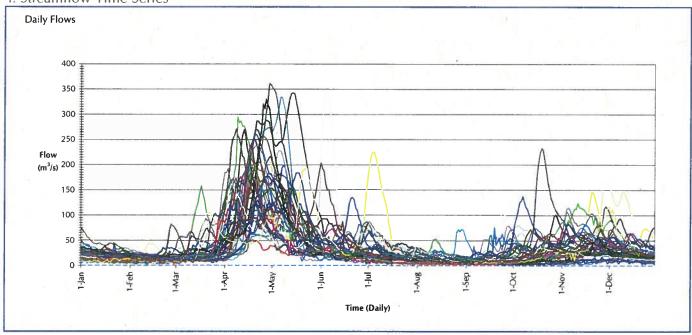


Figure 1: Annual Daily flow hydrographs from 1954 to 1993.

Table 1: Annual flow metrics based on 40 years of data.

Descriptive Metric		
Mean Annual Flow	36.03	m³/s
20% Time Exceeded Flow	48.91	m³/s
Median Flow	20.78	m <sup>3</sup> /s
80% Time Exceeded Flow	10.19	m³/s
Mean Rising Rate of Change of Flow	3.49	m³/s/day
Mean Falling Rate of Change of Flow	-2.87	m³/s/day
Extreme Low Flow Conditions:		
7-day-avg. low flow in 2-yr return period, $7Q_2$	5.98	m³/s
7-day-avg. low flow in 10-yr return period, $7Q_{10}$	2.72	m³/s
7-day-avg. low flow in 20-yr return period, $7Q_{20}$	2.02	m <sup>3</sup> /s
Target Metric		
Riparian Flows ( $Q_2 - Q_{20}$ )	197 -345	m³/s
Bankfull Flows (Q <sub>1.5</sub> - Q <sub>1.7</sub> )	170 -183	m³/s

II. Flow Duration

Time Exceeded %	Flow
Time Exceeded 76	$(\mathbf{m}^3/\mathbf{s})$
0%	360.7
1%	225.4
5%	130.6
10%	83.6
20%	48.9
30%	33.8
40%	25.5
50%	20.8
60%	16. <i>7</i>
70%	13.1
80%	10.2
90%	<i>7</i> .1
95%	5.3
99%	2.6
100%	2.5

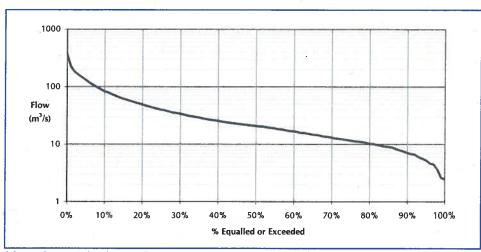


Table 2 & Figure 2: Flow duration table and curve displaying flow vs. percent time exceeded over 40 years.

III. Flood Frequency Analysis

Return Period		Flow	
	(years)	$(\mathbf{m}^3/\mathbf{s})$	
	1.05	112.5	
	1.25	148.7	
	1.5	170.4	
	1.7	182.6	
	2	196.6	
	5	261.1	
	10	303.8	
	20	344.7	
	50	39 <i>7.7</i>	
	100	437.4	

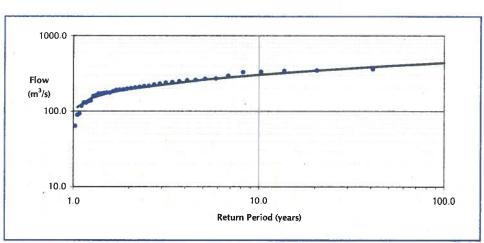


Table 3 & Figure 3: Flood frequency analysis and curve fitted by the Gumbel probability distribution.

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

Return Period		Flow
	(years)	$(\mathbf{m}^3/\mathbf{s})$
E .	1.005	13.98
	1.01	13.19
	1.11	9.88
	1.25	8.50
	2	5.98
	5	3. <i>7</i> 3
	10	2.72
	20	2.02
	50	1.3 <i>7</i>
	100	1.02

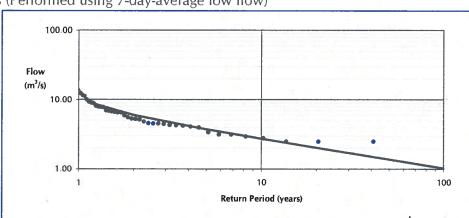


Table 4 & Figure 4: 7-day-average low flow frequency analysis and curve fitted by the Gumbel probability distribution.

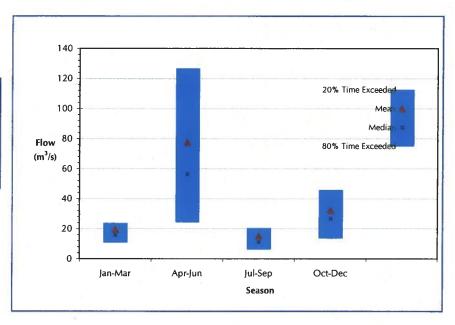


# Seasonal:

#### I. Flow Duration

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

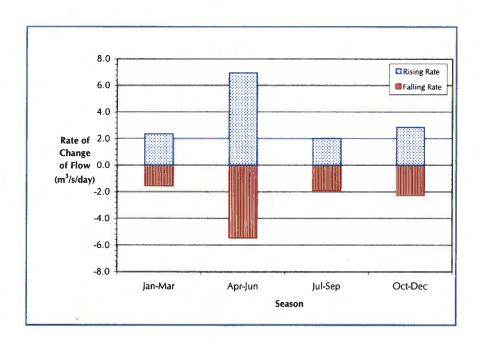
Season	20% Time Exceeded	Median	80% Time Exceeded
	(m <sup>3</sup> /s)	(m <sup>3</sup> /s)	$(m^3/s)$
Jan-Mar	23.7	15.7	10.7
Apr-jun	126.6	56.3	24.4
Jul-Sep	20.4	11.0	6.2
Oct-Dec	45.7	26.6	13.5



# 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	Falling
Season	Rate	Rate
	$(m^3/s/day)$	$(m^3/s/day)$
Jan-Mar	2.34	-1.54
Apr-Jun	6.94	-5.46
Jul-Sep	2.00	-1.90
Oct-Dec	2.86	-2.25



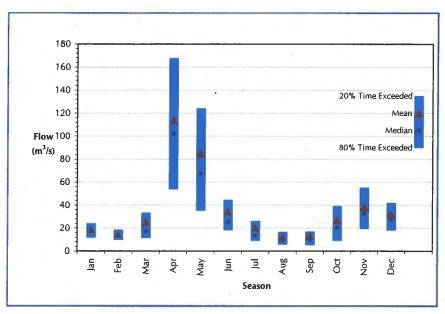


# Monthly:

I. Flow Duration

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

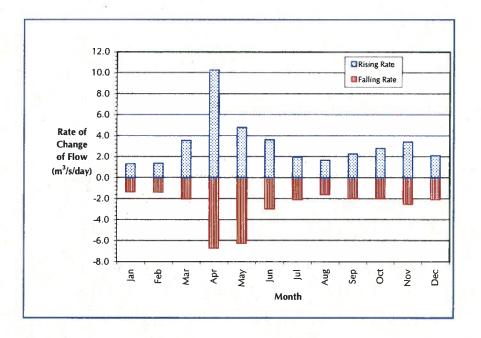
Month	20% Time Exceeded	Median	80% Time Exceeded
	(m <sup>3</sup> /s)	$(m^3/s)$	$(m^3/s)$
Jan	23.9	16.9	11.5
Feb	18.2	13.2	9.5
Mar	33.4	17.4	11.3
Apr	168.0	102.3	53.9
May	124.2	67.4	35.1
Jun	44.5	25.1	18.1
Jul	26.1	13.5	8.8
Aug	16.5	9.7	5.6
Sep	16.9	9.7	5.2
Oct	39.3	20.5	9.0
Nov	55.3	32.8	19.4
Dec	41.9	27.3	17.9



# 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	Falling
WOITH	Rate	Rate
	$(m^3/s/day)$	$(m^3/s/day)$
Jan	1.32	-1.36
Feb	1.38	-1.39
Mar	3.55	-2.03
Apr	10.27	-6.72
- May	4.78	-6.25
Jun	3.62	-2.97
Jul	1.95	-2.10
Aug	1.66	-1.62
Sep	2.26	-1.94
Oct	2.79	-1.97
Nov	3.41	-2.53
Dec	2.12	-2.08



# HATCH

# CASCADE FALLS - VERMILION RIVER NATURAL FLOW METRICS DATA SHEET

STATION INFORMATION

SITE ID 0

RIVER NAME VERMILION RIVER
SITE NAME CASCADE FALLS

REGION NORTHEAST
DISTRICT SUDBURY

DRAINAGE AREA 3747 km²
OWNER XENECA POWER

Metrics are based on WSC flows from 1954 to 1993 (40 years).

The flow records for the site have been synthesized by adjusting gauge flows by drainage area and MAR. Other descriptive metrics have been included in the data

drainage area and MAR. 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 (1954 - 1993):

#### I. Streamflow Time Series

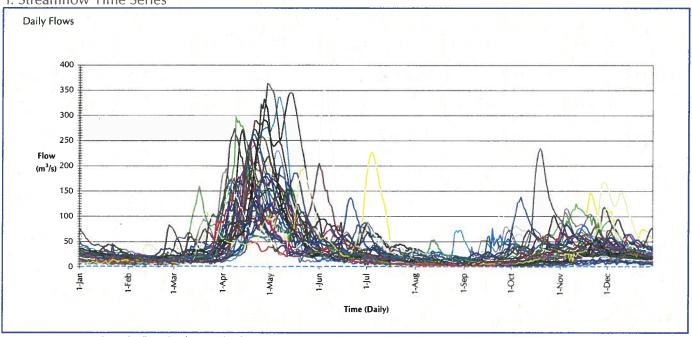


Figure 1: Annual Daily flow hydrographs from 1954 to 1993.

Table 1: Annual flow metrics based on 40 years of data.

Descriptive Metric		
Mean Annual Flow	36.31	m³/s
20% Time Exceeded Flow	49.28	m³/s
Median Flow	20.94	m <sup>3</sup> /s
80% Time Exceeded Flow	10.27	m³/s
Mean Rising Rate of Change of Flow	3.53	m³/s/day
Mean Falling Rate of Change of Flow	-2.90	m³/s/day
Extreme Low Flow Conditions:		
7-day-avg. low flow in 2-yr return period, $7Q_2$	6.01	m³/s
7-day-avg. low flow in 10-yr return period, $7Q_{10}$	2.73	m³/s
7-day-avg. low flow in 20-yr return period, $7Q_{20}$	2.02	m³/s
Target Metric		
Riparian Flows (Q <sub>2</sub> - Q <sub>20</sub> )	198 -347	m³/s
Bankfull Flows (Q <sub>1.5</sub> - Q <sub>1.7</sub> )	172 -184	m³/s

II. Flow Duration

Time Exceeded %		Flow
Time Ext	leeded 76	$(\mathbf{m}^3/\mathbf{s})$
	0%	363.5
V.V.	1%	227.1
	5%	131.6
	10%	84.3
	20%	49.3
10 = 1	30%	34.1
	40%	25. <i>7</i>
	50%	20.9
	60%	16.9
11 17 17	70%	13.2
	80%	10.3
	90%	7.2
7 . =	95%	5.3
	99%	2.5
	100%	2.5

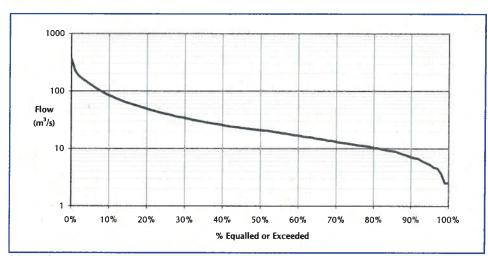


Table 2 & Figure 2: Flow duration table and curve displaying flow vs. percent time exceeded over 40 years.

III. Flood Frequency Analysis

III. Flood Flequency A	Marysis
Return Period	Flow
(years)	$(\mathbf{m}^3/\mathbf{s})$
1.05	113.3
1.25	149.9
1.5	1 <i>7</i> 1. <i>7</i>
1.7	184.0
2	198.1
5	263.1
10	306.1
20	347.4
50	400.8
100	440.8
8	

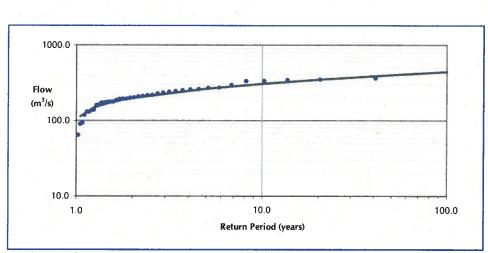


Table 3 & Figure 3: Flood frequency analysis and curve fitted by the Gumbel probability distribution.

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

Return Period	Flow
(years)	$(m^3/s)$
1.005	14.10
1.01	13.30
1.11	9.96
1.25	8.55
2	6.01
5	3.74
10	2.73
20	2.02
50	1.37
100	1.02

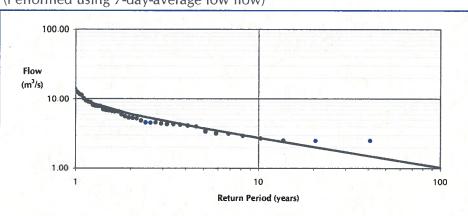


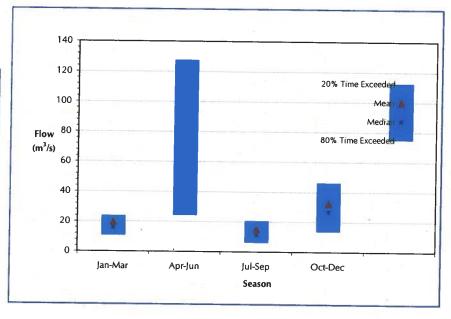
Table 4 & Figure 4: 7-day-average low flow frequency analysis and curve fitted by the Gumbel probability distribution.

#### Seasonal:

I. Flow Duration

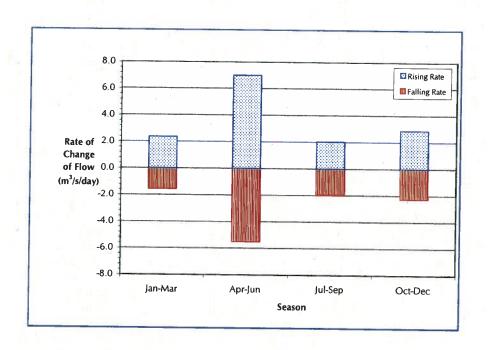
**Table 5 & Figure 5**: Seasonal median flow duration for determining minimum flow targets.

Season	20% Fime Exceeded	Median	80% Time Exceeded
فينطط	(m <sup>3</sup> /s)	(m <sup>3</sup> /s)	(m <sup>3</sup> /s)
Jan-Mar	23.8	15.8	10.8
Apr-Jun	127.6	56.8	24.6
Jui-Sep	20.5	11.1	6.2
Oct-Dec	46.1	26.8	13.6



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

Season	Rising	Falling
SCISON	Rate	Rate
	$(m^3/s/day)$	$(m^3/s/day)$
Jan-Mar	2.36	-1.55
Apr-Jun	6.99	-5.50
Jul-Sep	2.04	-1.93
Oct-Dec	2.88	-2.27



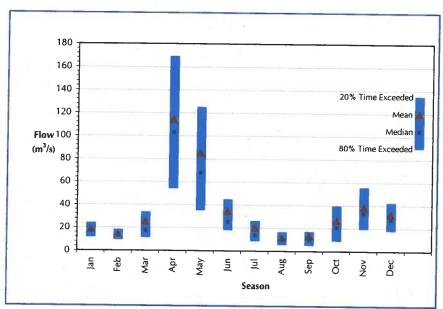


#### Monthly:

I. Flow Duration

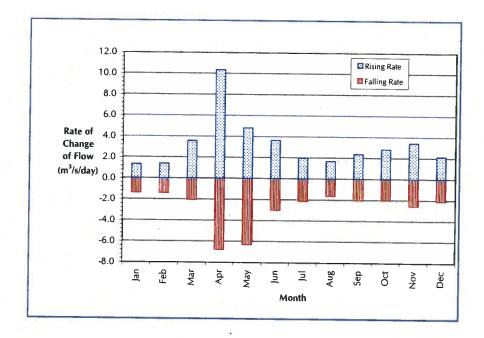
**Table 7 & Figure 7**: Monthly median flow duration for determining minimum flow targets.

Month	20% Time Exceeded	Median	80% Time Exceeded
	(m <sup>3</sup> /s)	$(m^3/s)$	$(m^3/s)$
Jan	24.1	17.0	11.6
Feb	18.4	13.3	9.5
Mar	33.6	17.6	11.4
Apr	169.3	103.1	54.3
May	125.2	68.0	35.4
Jun	44.9	25.3	18.2
Jul	26.3	13.6	8.8
Aug	16.6	9.7	5. <i>7</i>
Sep	1 <i>7</i> .0	9.8	5.2
Oct	39.6	20.7	9.1
Nov	55. <i>7</i>	33.1	19.6
Dec	42.3	2 <b>7</b> .5	18.1



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

Month	Rising	Falling
Wionin	Rate	Rate
	$(m^3/s/day)$	$(m^3/s/day)$
Jan	1.33	<sup>-</sup> -1.3 <i>7</i>
Feb	1.39	-1.40
Mar	3.57	-2.04
Apr	10.35	-6.77
May	4.82	-6.30
Jun	3.64	-2.99
Jul	1.97	-2.12
Aug	1.68	-1.64
Sep	2.37	-2.03
Oct	2.83	-1.99
Nov	3.43	-2.55
Dec	2.13	-2.09



### AT SOO CROSSING - VERMILION RIVER NATURAL FLOW METRICS DATA SHEET

STATION INFORMATION

SITE ID RIVER NAME VERMILION RIVER SITE NAME AT SOO CROSSING

REGION NORTHEAST DISTRICT **SUDBURY** 

OWNER XENECA POWER

DRAINAGE AREA 3813

#### Annual (1954 - 1993):



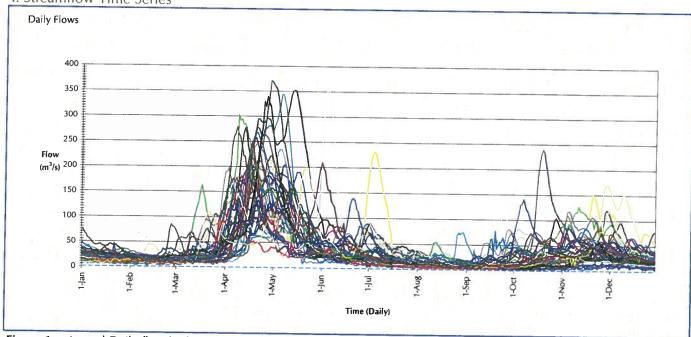


Figure 1: Annual Daily flow hydrographs from 1954 to 1993.

Table 1: Annual flow metrics based on 40 years of data.

Descriptive Metric		
Mean Annual Flow	37.03	m <sup>3</sup> /s
20% Time Exceeded Flow	50.26	m <sup>3</sup> /s
Median Flow	21.36	m <sup>3</sup> /s
80% Time Exceeded Flow	10.48	m <sup>3</sup> /s
Mean Rising Rate of Change of Flow	3.60	m³/s/day
Mean Falling Rate of Change of Flow	-2.95	m <sup>3</sup> /s/day
Extreme Low Flow Conditions:		
7-day-avg. low flow in 2-yr return period, $7Q_2$	6.13	m³/s
7-day-avg. low flow in 10-yr return period, $7Q_{10}$		m³/s
7-day-avg. low flow in 20-yr return period, 7Q <sub>20</sub>	2.06	m³/s
Target Metric		-
Riparian Flows (Q <sub>2</sub> - Q <sub>20</sub> )	202 -354	m³/s
Bankfull Flows (Q <sub>1.5</sub> - Q <sub>1.7</sub> )	175 -188	m³/s

II. Flow Duration

Time Exceeded %	Flow
	$(\mathbf{m}^3/\mathbf{s})$
0%	370.7
1%	231.6
5%	134.2
10%	85.9
20%	50.3
30%	34.8
40%	26.2
50%	21.4
60%	1 <i>7</i> .2
70%	13.4
80%	10.5
90%	7.3
95%	5.4
99%	2.6
100%	2.6

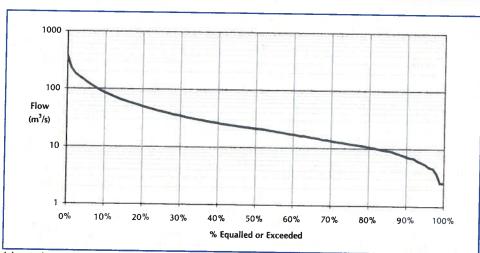


Table 2 & Figure 2: Flow duration table and curve displaying flow vs. percent time exceeded over 40 years.

III. Flood Frequency Analysis

	Return Period	Flow
	(years)	$(m^3/s)$
	1.05	115.6
	1.25	152.8
	1.5	175.2
	1.7	187.6
30	2	202.1
	5	268.3
	10	312.2
	20	354.3
	50	408.8
	100	449.6
		1111

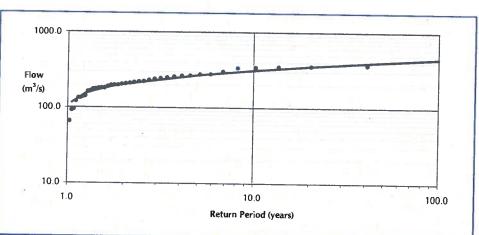


Table 3 & Figure 3: Flood frequency analysis and curve fitted by the Gumbel probability distribution.

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

Refu	rn Period	Flow
	(years)	$(\mathbf{m}^3/\mathbf{s})$
	1.005	14.38
	1.01	13.5 <i>7</i>
	1.11	10.15
	1.25	8.72
	2	6.13
	5	3.81
	10	2. <b>7</b> 8
	20	2.06
	50	1.39
	100	1.04

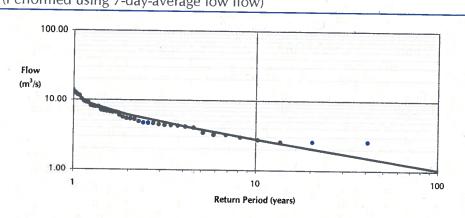


 Table 4 & Figure 4 :
 7-day-average low flow frequency analysis and curve fitted by the Gumbel probability distribution.

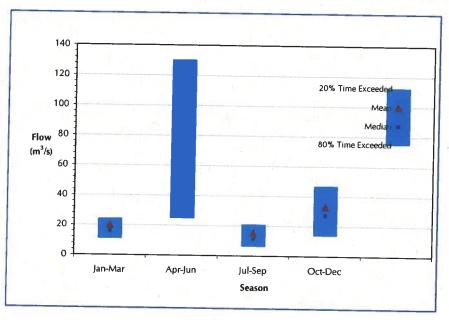


#### Seasonal:

I. Flow Duration

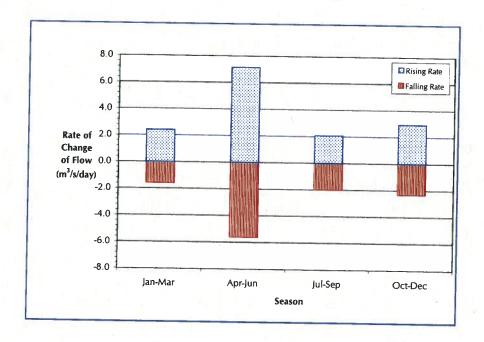
**Table 5 & Figure 5**: Seasonal median flow duration for determining minimum flow targets.

Season	20% Time Exceeded (m³/s)	Median (m³/s)	80% Time Exceeded (m <sup>3</sup> /s)
Jan-Mar	24.3	16.1	11.0
Apr-Jun	130.1	57.9	25.0
Jul-Sep	21.0	11.3	6.3
Oct-Dec	47.0	27.3	13.9



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

***		
Season	Rising	Falling
Deagon	Rate	Rate
	$(m^3/s/day)$	$(m^3/s/day)$
Jan-Mar	2.41	-1.58
Apr-Jun	7.13	-5.61
Jul-Sep	2.08	-1.96
Oct-Dec	2.94	-2.32



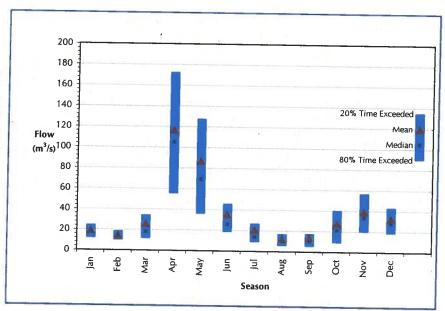


### Monthly:

I. Flow Duration

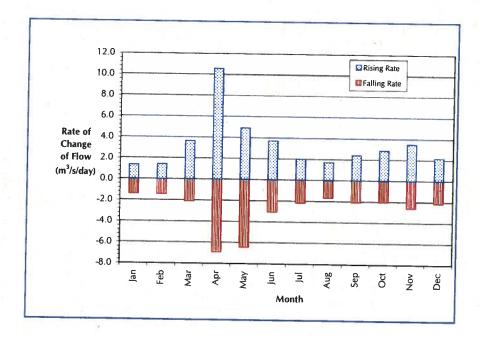
**Table 7 & Figure 7**: Monthly median flow duration for determining minimum flow targets.

Month	20% Time Exceeded	Median	80% Time Exceeded
	(m <sup>3</sup> /s)	$(m^3/s)$	(m <sup>3</sup> /s)
Jan	24.6	17.3	11.8
Feb	18. <i>7</i>	13.6	9. <i>7</i>
Mar	34.3	1 <i>7</i> .9	11.6
Apr	1 <i>7</i> 2. <i>7</i>	105.2	55.4
May	127. <i>7</i>	69.3	36.1
Jun	45.8	25.8	18.6
Jul	26.8	13.9	9.0
Aug	1 <i>7</i> .0	9.9	5.8
Sep	1 <i>7</i> .3	10.0	5.3
Oct	40.3	21.1	9.2
Nov	56.8	33.7	20.0
Dec	43.1	28.1	18.4



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

Month	Rising	Falling
ALCHILI	Rate	Rate
	$(m^3/s/day)$	$(m^3/s/day)$
Jan	1.35	-1.40
Feb	1.42	-1.43
Mar	3.65	-2.08
Apr	10.56	-6.90
May	4.91	-6.43
Jun	3.72	-3.05
Jul	2.01	-2.16
Aug	1.72	-1.67
Sep	2.42	-2.07
Oct	2.88	-2.03
Nov	3.50	-2.60
Dec	2.18	-2.13



# **WABAGESHIK RAPIDS - VERMILION RIVER** NATURAL FLOW METRICS DATA SHEET

STATION INFORMATION

SITE ID RIVER NAME **VERMILION RIVER** 

SITE NAME WABAGESHIK RAPIDS REGION NORTHEAST

DISTRICT SUDBURY DRAINAGE AREA 4393

km<sup>2</sup> OWNER **XENECA POWER** 

## Annual (1954 - 1993):

#### I. Streamflow Time Series

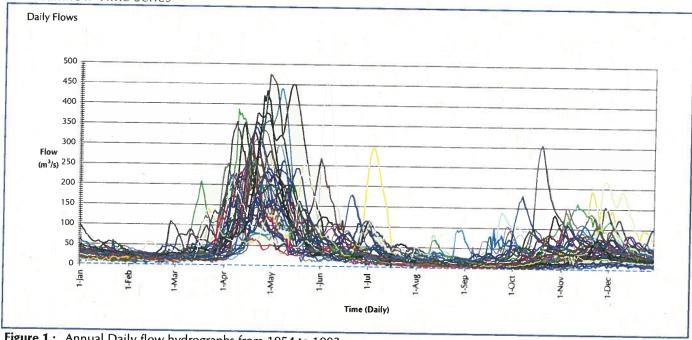


Figure 1: Annual Daily flow hydrographs from 1954 to 1993.

Table 1: Annual flow metrics based on 40 years of data.

Descriptive Metric		W
Mean Annual Flow	47.34	m³/s
20% Time Exceeded Flow		$\frac{m}{s}$ /s
Median Flow	64.27	
80% Time Exceeded Flow	27.31	m <sup>3</sup> /s
Mean Rising Rate of Change of Flow	13.39	m <sup>3</sup> /s
Mean Falling Rate of Change of Flow	4.59	m <sup>3</sup> /s/day
	-3.76	m <sup>3</sup> /s/day
Extreme Low Flow Conditions:		
7-day-avg. low flow in 2-yr return period, $7Q_2$	7.45	m³/s
7-day-avg. low flow in 10-yr return period, 7Q <sub>10</sub>	3.14	m³/s
7-day-avg. low flow in 20-yr return period, $7Q_{20}$	2.26	m <sup>3</sup> /s
Target Metric		
Riparian Flows ( $Q_2 - Q_{20}$ )	258 -453	m³/s
Bankfull Flows (Q <sub>1.5</sub> - Q <sub>1.7</sub> )	224 -240	m³/s

II. Flow Duration

Time Exceeded %		Flow	
		$(\mathbf{m}^3/\mathbf{s})$	
7 7 9	0%	474.0	
	1%	296.1	
	5%	171.6	
10.00	10%	109.9	
	20%	64.3	
	30%	44.5	
	40%	33.5	
	50%	27.3	
	60%	22.0	
The state of	70%	17.2	
157	80%	13.4	
	90%	9.3	
	95%	6.9	
	99%	3.4	
TO LIKE T	100%	1.9	
TILLOGE			

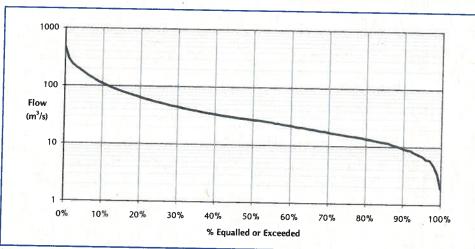


Table 2 & Figure 2: Flow duration table and curve displaying flow vs. percent time exceeded over 40 years.

III. Flood Frequency Analysis

Return Period	Flow
(years)	$(\mathbf{m}^3/\mathbf{s})^{\frac{1}{2}}$
1.05	147.8
1.25	195.4
1.5	223.9
1.7	239.9
2	258.4
5	343.1
10	399.2
. 20	453.0
50	522.6
100	574.8

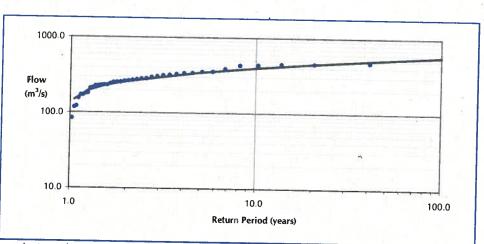


Table 3 & Figure 3: Flood frequency analysis and curve fitted by the Gumbel probability distribution.

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

Return Period	Flow
(years)	$(\mathbf{m}^3/\mathbf{s})$
1.005	18.90
1.01	17.74
1.11	12.92
1.25	10.95
2	7.45
5	4.43
10	3.14
20	2.26
50	1.48
100	1.07

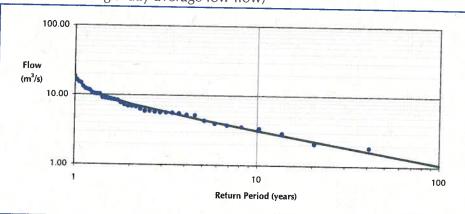


 Table 4 & Figure 4 : 7-day-average low flow frequency analysis and curve fitted by the Gumbel probability distribution.

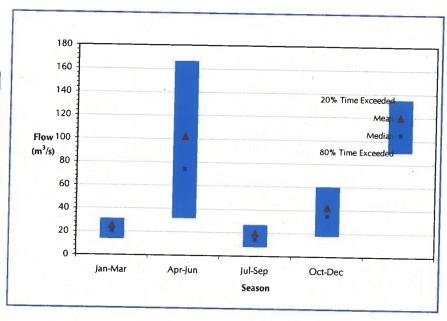


#### Seasonal:

I. Flow Duration

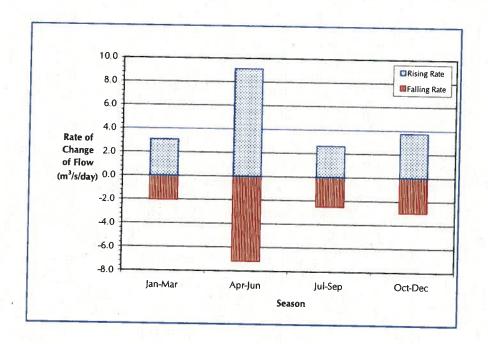
**Table 5 & Figure 5**: Seasonal median flow duration for determining minimum flow targets.

Season	20% Time Exceeded (m³/s)	Median (m³/s)	80% Time Exceeded (m³/s)
Jan-Mar	31.1	20.6	14.0
Apr-Jun	166.4	74.0	32.0
Jul-Sep	26.8	14.4	8.1
Oct-Dec	60.1	34.9	17.8



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

Season	Rising	Falling
Jeason	Rate	Rate
	$(m^3/s/day)$	$(m^3/s/day)$
Jan-Mar	3.08	-2.03
Apr-Jun	9.12	<i>-7</i> .18
Jul-Sep	2.64	-2.50
Oct-Dec	3.75	-2.96



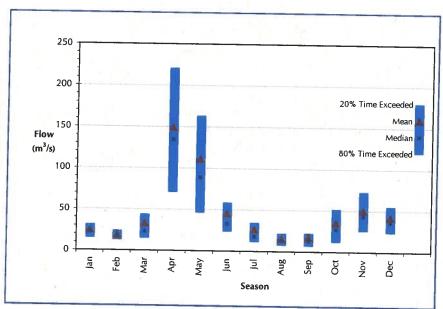


# Monthly:

I. Flow Duration

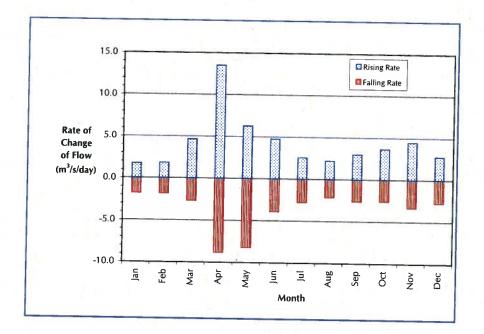
**Table 7 & Figure 7**: Monthly median flow duration for determining minimum flow targets.

ALCOHOL: NO				
Mon	th	20% Time Exceeded	Median	80% Time Exceeded
		(m <sup>3</sup> /s)	(m <sup>3</sup> /s)	$(m^3/s)$
Ja	an	31.4	22.2	15.1
Fe	eb	24.0	17.4	12.4
M	ar	43.9	22.9	14.9
A	or	220.8	134.5	70.8
Má	ay	163.2	88.6	46.1
Ji	ın	58.5	33.0	23.8
J	ul –	34.3	1 <i>7</i> .8	11.5
Αι	g	21.7	12.7	7.4
Se	р	22.2	12.8	6.8
0	ct	51.6	27.0	11.8
No	V	72.6	43.1	25.5
De	C	55.1	35.9	23.5



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

Month	Rising	Falling
, and the	Rate	Rate
	$(m^3/s/day)$	$(m^3/s/day)$
Jan	1.73	-1.79
Feb	1.82	-1.83
Mar	4.66	-2.67
Apr	13.50	-8.82
May	6.28	-8.22
Jun	4.75	-3.90
Jul	2.56	-2.7 <i>7</i>
Aug	2.20	-2.14
Sep	3.00	-2.59
Oct	3.66	-2.58
Nov	4.48	-3.32
Dec	2.78	-2.73





# 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 lake evaporation 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	Altitude	Annual E <sub>Lake</sub>
·	1 TOVINCE	° N	m	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  $R^2 = 0.9655$  and gives the relationship for annual average lake evaporation:

 $E_{Lake} = 2296.6 - 36.123 * Latitude$ 

Where: Elake is annual average lake evaporation in mm

Latitude is in decimal o N.



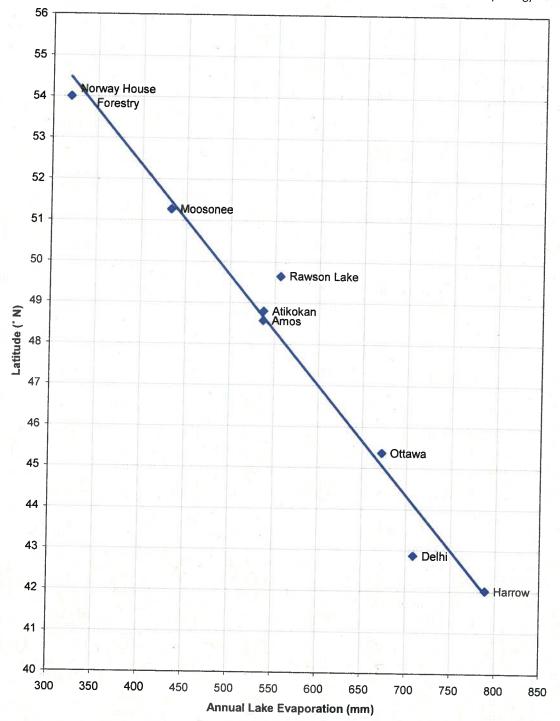


Figure B-1 Xeneca Power Vermilion Hydropower Sites Annual Average Lake Evaporation vs. Latitude





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

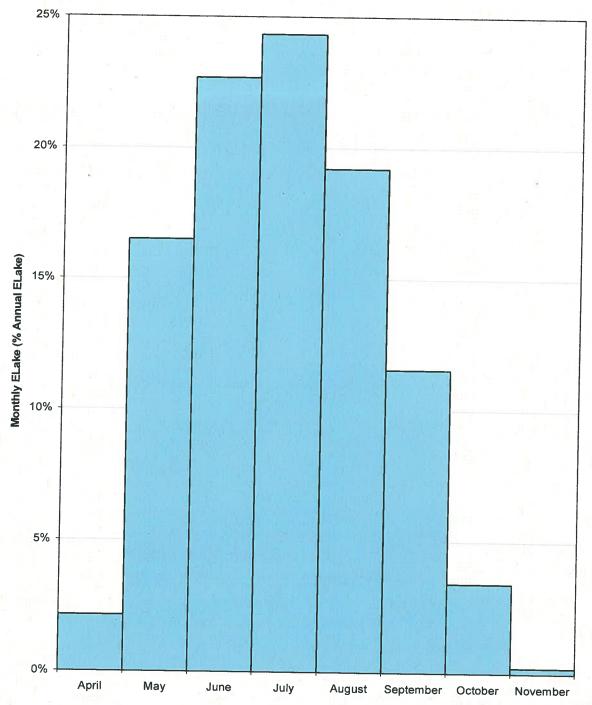


Figure B-2 Xeneca Power Vermilion Hydropower Sites Monthly Lake Evaporation Distribution in Ontario





# APPENDIX C CD-ROM containing Flow Series Datasets



1235 North Service Road West Oakville, Ontario, Canada L6M 2W2 Tel 905 469 3400 • Fax 905 469 3404



#### **CANADIAN PROJECTS LIMITED**

#240, 523 Woodpark Blvd SW Calgary, Alberta T2W 4J3 Phone: (403) 508-1560 Fax: (403) 238-5460

File: 1052-001-3.1.1

April 11, 2011

Mr. Nava Pokharel, M.Sc., P.Eng. Senior Project Manager Xeneca Power Development Inc. 5160 Yonge Street, Suite 520 Toronto, ON, M2N 6L9

Dear Nava:

Re: Ontario South Hydro

Vermilion River at Wabagishik Rapid Hydrologic Analyses

Xeneca Power Development Inc. is proposing to develop the Wabagishik hydropower project on the Vermilion River in Ontario. Xeneca commissioned Canadian Projects Ltd. (CPL) to prepare hydrologic analyses for the project in accordance with Ontario Ministry of the Environment (MOE) requirements as listed in Table 1. The table provides a concordance between the MOE requirements and the various sections, tables and figures in this letter report.

The analyses relied on hydrologic information, including the site catchment area and a set of synthetic daily flow estimates for the project, provided by Hatch<sup>1</sup>. The dataset covered the period 1954 – 1993. There was no additional data available to extend the data series beyond this date.

#### 1. Season Definitions

Xeneca defined four seasons for the hydrologic analyses, as described in the project Operating Plan<sup>2</sup>. The season definitions are illustrated on Figure 1.

#### 2. Flow-Duration Curves of Total Streamflow

MOE requirements c) and e) include analyses of daily mean discharges to obtain flow-duration curves for the full year, and on a monthly and seasonal basis. Flow-duration estimates were obtained by analysis of the synthetic dataset as follows:

<sup>1</sup> Hydrology Review for Vermilion River Hydropower Project. Rev 0. Hatch Ltd. October 6, 2009.

<sup>&</sup>lt;sup>2</sup> Proposed Operating Flows and Levels: Wabagishik Hydro Project. Xeneca Power Development Inc., March 2011.

- Standard (or Period of Record) flow-duration curves for the full year and for each season of the year are shown on Figure 2 and Table 2.
- Standard (or Period of Record) flow-duration curves for each month of the year are shown on Figure 3 and Table 3.

#### 3. Flow-Duration Curves of Baseflow

MOE requirement d) specifies a flow-duration analysis of baseflow data. The series of synthetic daily discharges was analyzed to obtain estimates of daily baseflow using the Streamflow Analysis and Assessment Software (SAAS) developed at Trent University and recommended by MOE. SAAS implements a recursive digital filtering method to estimate baseflow. Following the SAAS methodology, the first and last months of the dataset were removed to eliminate the end effects of the filtering procedure.

- Standard (or Period of Record) baseflow flow-duration curves for the full year and for each season of the year are shown on Figure 4 and Table 4.
- Standard (or Period of Record) baseflow flow-duration curves for each month of the year are shown on Figure 5 and Table 5.

#### 4. Median of Percentiles Analysis

MOE requirement e) specifies a "median of percentiles" analysis in which the period of record is subdivided into years, seasons or months; flow exceedance statistics are computed individually for each period; and then the values for each percentile are analyzed to obtain the median value for that percentile across the years of record.

- Median of Percentiles analysis results for the full year and for each season of the year are shown on Figure 6 and Table 6.
- Median of Percentiles analysis results for each month of the year are shown on Figure 7 and Table 7.

#### 5. Low Flow Analysis

MOE requirements b) and g) specify a low-flow frequency analysis of 7-day average low flow for return periods of 2, 10 and 20 years. The Hatch report provided preliminary drought frequency estimates, but recommended that detailed low flow analyses be undertaken for environmental assessment and design phases of the projects. Therefore CPL conducted low flow analyses. The analyses were based on the series of minimum 7-day average discharges on a water year basis (May 1 – April 30). Four probability distributions were tested using the Hyfran<sup>3</sup> software: Gumbel (used by Hatch), Weibull or Gumbel III (recommended by Environment Canada<sup>4</sup>), Pearson III, and lognormal.

The lognormal distribution provided the best fit to the data. Results are presented in Table 8.

<sup>&</sup>lt;sup>3</sup> Developed by the Institut National de la Recherche Scientifique - Eau Terre et Environnement (INRS-ETE) at the University of Quebec with sponsorship from Hydro-Quebec and the Natural Sciences and Engineering Research Council of Canada.

<sup>&</sup>lt;sup>4</sup> Modelling of Low Flow Frequency Distributions and Parameter Estimation. R. Condie and G.A. Nix. International Water Resources Symposium, Water for Arid Lands, Teheran, Iran, December 8-9, 1975.

#### 6. Flood Frequency Analysis

MOE requirement f) specifies a flood frequency analysis of maximum instantaneous discharges. The Hatch report provided preliminary flood frequency estimates, but recommended that detailed flood analyses should be undertaken for environmental assessment and design phases of the projects. Therefore CPL conducted a new flood frequency analysis which encompassed the 1:2 year to the 1:10,000 year instantaneous flood flows as documented in a separate report<sup>5</sup>.

Maximum instantaneous flood estimates for various return periods are provided in Table 9.

#### 7. **Summary Statistics**

MOE requirement a) specifies descriptive statistics of daily discharges including the maximum. mean, median, minimum and 20% and 80% exceedance values. Summary statistics are presented in Table 10.

#### 8. Conclusion

This hydrological analysis letter report was prepared and provides the information compiled in accordance with MOE requirements. We trust that the information contained in this letter meets with your requirements.

Sincerely,

CANADIAN PROJECTS LIMITED

Reviewed By

Wes Dick, M.Sc.

Senior Hydrologist

Wes Deik

Paul Kemp, P.Eng. **Project Director** 

WD/wd

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<sup>&</sup>lt;sup>5</sup> Ontario South Hydro: Hydrology Review and Flood Frequency Analyses – DRAFT. Letter report to Xeneca, Canadian Projects Limited, February 17, 2011.

Table 1
Concordance between MOE Requirements and Report

MOE Requirement	Res	Results Presented In					
	Section No.	Figure No.	Table No.				
a) Descriptive flow statistics using all available daily flows for all years: mean, median, minimum, maximum, flow exceeded 20% time, flow exceeded 80% time.	7		10				
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).	5		8				
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.	2	2-3	2-3				
d) Flow duration curves and tables using daily baseflow data for the entire period, for all four seasons and for all twelve months.	3	4 – 5	4 – 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 http://trentu.ca/iws/software.php.	2, 4	2 – 3, 6 – 7	2 – 3, 6 – 7				
f) Flood frequency analysis using instantaneous maximum flow of each year for the entire period of records.	6		9				
g) Low flow frequency analysis using 7-day- average-low flow for the entire period of records.	5	<del></del>	8				
h) Altered flow of the bypass reach and the reach below tailrace, if applicable.*	<u></u> 85	 					
i) Compensation flow for the bypass reach and the reach below tailrace, if applicable.*							

<sup>\*</sup> These items are addressed in the Operation Plan.

Figure 1
Hydrologic Season Definitions

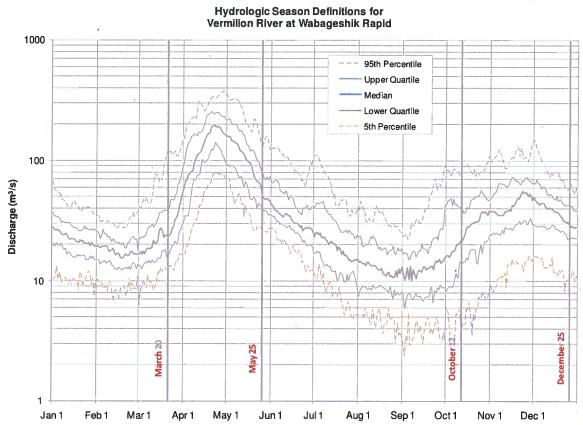


Figure 2

Annual and Seasonal Flow-Duration Curves
Vermilion River at Wabagishik Rapid

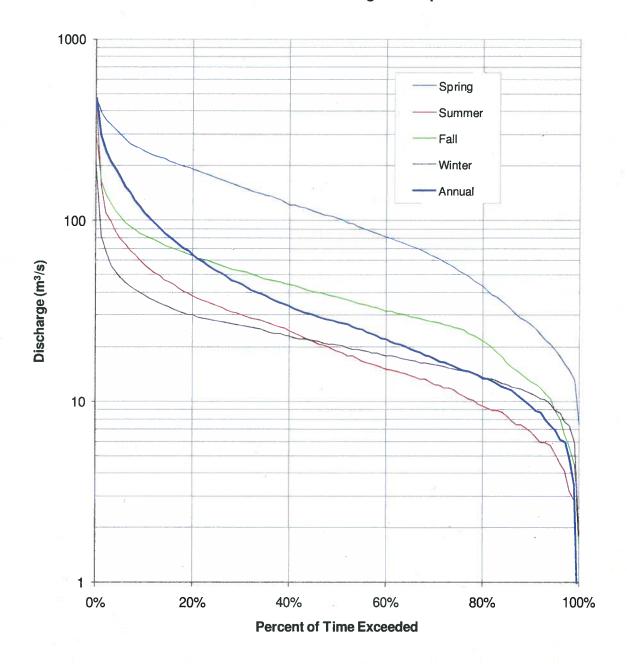


Table 2
Annual and Seasonal Flow-Duration Estimates
Vermilion River at Wabagishik Rapid

	Discharge (m³/s)								
% of	Spring	Summer	Fall	Winter	Annual				
Time	Mar 20	May 25	Oct 12	Dec 25					
Exceeded	May 24	Oct 11	Dec 24	Mar 19					
11	391	156	164	81.5	296				
5	297	79.4	104	48.3	172				
10	240	56.9	83.0	38.5	110				
15	213	45.9	71.7	33.4	81.2				
20	193	38.2	63.4	29.9	64.3				
25	172	33.6	57.7	27.8	52.4				
30	153	30.2	52.4	26.4	44.5				
35	138	27.4	47.5	24.5	38.2				
40	122	24.5	44.2	22.8	33.5				
45	112	21.3	40.6	21.6	29.9				
50	102	18.9	37.7	20.5	27.3				
55	90.7	16.6	34.4	19.1	24.8				
60	80.9	15.1	31.5	17.8	22.0				
65	72.2	13.9	29.4	16.8	19.4				
70	62.9	12.5	27.4	15.9	17.2				
75	52.7	11.1	25.2	14.9	15.2				
80	43.2	9.40	21.6	13.5	13.4				
85	34.0	8.29	16.3	12.5	11.8				
90	26.6	6.81	12.9	11.1	9.3				
95	19.3	5.19	8.89	8.93	6.9				
99	13.2	2.78	4.45	5.92	3.4				

Figure 3

Monthly Flow-Duration Curves

Vermilion River at Wabagishik Rapid

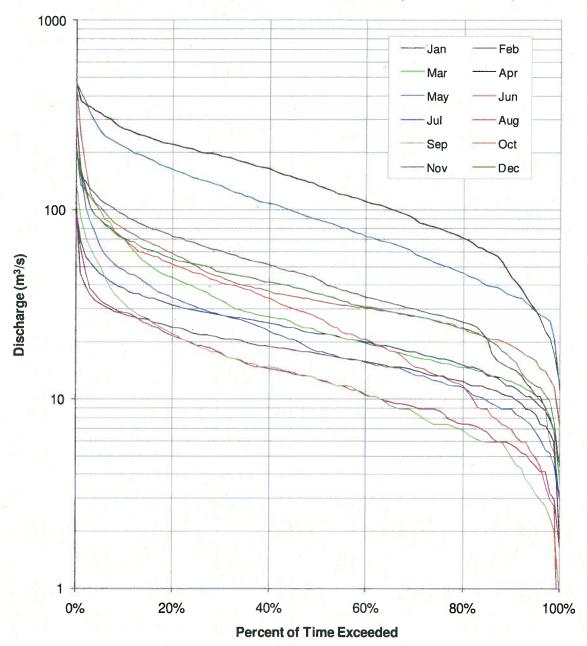


Table 3
Monthly Flow-Duration Estimates
Vermilion River at Wabagishik Rapid

% of Time		Discharge (m³/s)										
Exceeded	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	69.5	46.5	136	377	417	250	157	63.4	92.3	166	151	158
5	46.0	31.9	99.6	326	260	104	64.3	33.3	50.7	89.1	113	88.7
10	38.5	28.0	70.3	268	215	78.8	47.7	28.7	32.0	69.9	93.5	70.6
15	34.3	26.2	51.7	241	185	67.6	40.3	24.9	26.7	58.3	80.6	61.5
20	31.4	24.0	43.9	221	163	58.5	34.3	21.7	22.2	51.6	72.6	55.1
25	29.4	22.2	38.5	206	146	50.3	30.8	19.3	19.3	46.2	66.7	51.6
30	27.7	20.9	33.4	193	134	44.3	27.8	17.6	17.4	41.2	60.7	46.8
35	26.7	20.0	28.9	178	118	39.7	25.8	15.4	15.6	38.2	55.1	44.2
40	25.2	19.0	27.0	165	108	37.1	22.9	14.5	14.9	34.0	51.3	41.3
45	23.8	18.2	25.2	149	98.2	34.9	20.7	13.6	13.8	30.0	47.1	39.1
50	22.2	17.4	22.9	134	88.6	33.0	17.8	12.7	12.8	27.0	43.1	35.9
55	21.1	16.4	21.1	120	80.9	31.4	16.4	11.8	11.8	22.6	37.7	33.2
60	20.0	15.8	19.8	111	72.7	30.2	15.7	10.5	10.5	20.7	34.5	30.8
65	18.9	14.9	17.9	101	66.8	28.9	14.9	9.69	9.27	18.0	32.3	28.9
70	17.8	14.2	16.6	89.1	58.4	27.6	13.4	9.04	8.53	14.9	30.0	27.4
75	16.3	13.3	15.6	79.8	51.9	25.6	12.4	8.68	7.41	13.3	27.7	25.5
80	15.1	12.4	14.9	70.8	46.1	23.8	11.5	7.41	6.81	11.8	25.5	23.5
85	13.3	11.4	13.6	60.1	40.0	20.9	9.74	6.66	5.92	8.89	20.7	20.7
90	11.8	10.3	12.4	43.9	35.3	19.3	8.86	5.72	4.94	6.91	14.4	16.3
95 '	9.69	8.28	10.5	29.4	28.9	16.0	6.67	4.45	3.17	4.86	10.4	11.8
99	6.80	5.92	6.82	16.9	20.5	11.5	4.45	2.96	2.02	2.71	5.19	7.59

Figure 4

Annual and Seasonal Flow-Duration Curves
Vermilion River Baseflow at Wabagishik Rapid

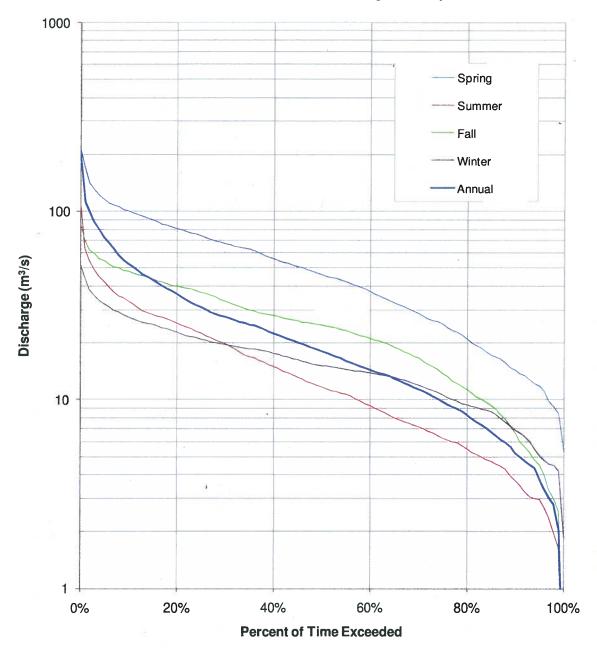


Table 4
Annual and Seasonal Baseflow Flow-Duration Estimates
Vermilion River at Wabagishik Rapid

	Discharge (m³/s)								
% of	Spring	Summer	Fall	Winter	Annual				
Time	Mar 20	May 25	Oct 12	Dec 25					
Exceeded	May 24	Oct 11	Dec 24	Mar 19					
1	171	63.3	70.3	44.6	112				
5	116	42.2	54.3	32.1	72.9				
10	99.6	33.3	47.8	27.4	52.5				
15	89.5	28.3	43.5	25.0	43.2				
20	81.0	25.4	40.0	22.8	36.3				
25	73.6	22.4	37.2	20.9	30.9				
30	67.2	19.8	33.2	19.5	27.4				
35	62.6	16.9	29.9	18.6	25.0				
40	55.8	15.0	27.9	17.6	22.5				
45	50.7	13.2	26.1	16.3	20.1				
50	45.8	11.7	24.9	15.2	18.2				
55	42.0	10.7	23.2	14.5	16.1				
60	37.3	9.25	21.2	13.8	14.4				
65	32.7	8.03	19.0	13.1	13.0				
70	28.6	7.19	16.6	11.9	11.4				
75	25.1	6.27	13.7	10.6	9.76				
80	20.9	5.46	11.3	9.41	8.33				
85	17.3	4.69	9.28	8.59	6.78				
90	14.3	3.71	6.62	6.89	5.25				
95	11.7	2.95	4.51	5.00	3.84				
99	8.45	1.66	2.58	4.17	2.02				

Figure 5

Monthly Flow-Duration Curves
Vermilion River Baseflow at Wabagishik Rapid

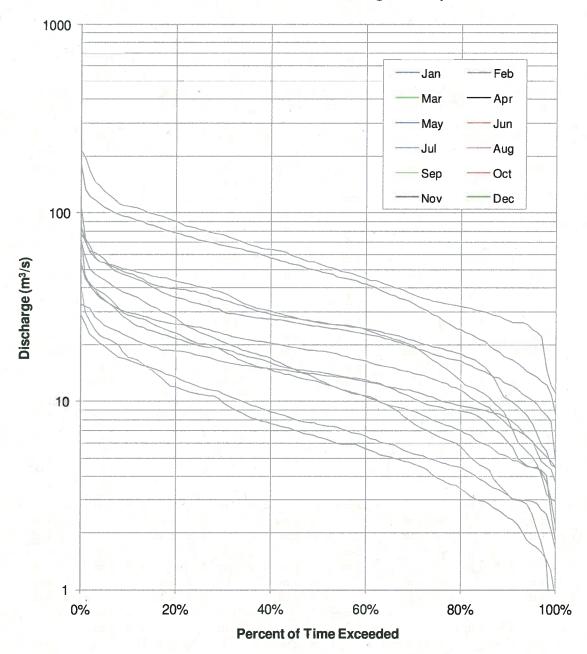


Table 5
Monthly Baseflow Flow-Duration Estimates
Vermilion River at Wabagishik Rapid

% of		Discharge (m³/s)										
Time							30 (	, <u>, , , , , , , , , , , , , , , , , , </u>	T		8	T
Exceeded	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	46.5	32.0	45.4	133	196	73.5	44.9	25.9	30.0	59.0	71.6	70.5
.5	34.3	25.4	34.8	107	130	54.3	37.1	19.7	21.8	44.3	54.5	56.7
10	29.6	22.0	27.1	94.9	108	46.0	28.6	16.6	17.1	37.1	50.1	48.0
15	27.3	19.5	23.8	86.0	98.8	40.7	25.9	15.1	14.7	31.9	46.4	41.9
20	25.7	18.5	21.4	78.2	89.7	35.5	22.9	13.4	11.9	27.7	43.4	39.6
25	24.7	17.5	19.7	71.7	81.9	32.8	20.2	11.9	10.9	23.3	40.4	37.7
30	22.8	16.2	19.0	67.2	76.1	29.9	18.4	11.0	9.80	20.7	37.5	34.6
35	21.3	15.5	17.3	62.8	68.9	28.2	16.0	9.75	8.39	18.4	32.6	31.5
40	20.3	14.9	16.1	57.5	64.1	27.3	14.6	8.82	7.63	16.9	30.1	29.0
45	19.3	14.4	14.9	53.2	59.0	26.2	13.6	8.03	7.08	14.8	27.8	27.7
50	18.5	13.9	14.3	49.4	53.9	25.0	12.7	7.55	6.50	13.0	26.3	26.4
55	17.5	13.4	13.6	45.3	48.9	24.0	11.6	7.12	5.94	11.5	25.2	25.4
60	16.3	12.8	13.0	41.7	44.7	22.6	10.7	6.53	5.60	10.6	24.0	24.3
65	15.2	11.8	11.9	36.9	41.0	21.2	9.50	5.93	5.08	9.36	21.7	22.7
70	14.1	10.3	11.3	32.8	36.8	19.3	8.89	5.25	4.65	7.62	19.7	21.0
75	12.9	9.35	10.2	28.2	33.6	17.5	7.78	4.80	3.92	6.57	16.0	19.3
80	11.4	8.90	9.51	23.9	31.7	16.3	6.95	4.45	3.44	5.71	12.9	17.8
85	9.51	7.85	8.93	20.8	29.8	14.3	5.95	3.75	2.96	4.47	10.9	15.2
90	7.45	6.06	8.14	16.9	26.7	12.4	5.09	3.17	2.42	3.21	7.99	10.2
95	6.10	4.45	6.18	13.9	24.1	10.1	4.47	2.96	1.74	2.54	5.10	7.63
99	4.83	2.55	4.39	10.8	12.1	7.77	3.05	2.10	1.27	0.615	3.00	4.62

Figure 6

Annual and Seasonal Medians of Percentiles
Vermilion River at Wabagishik Rapid

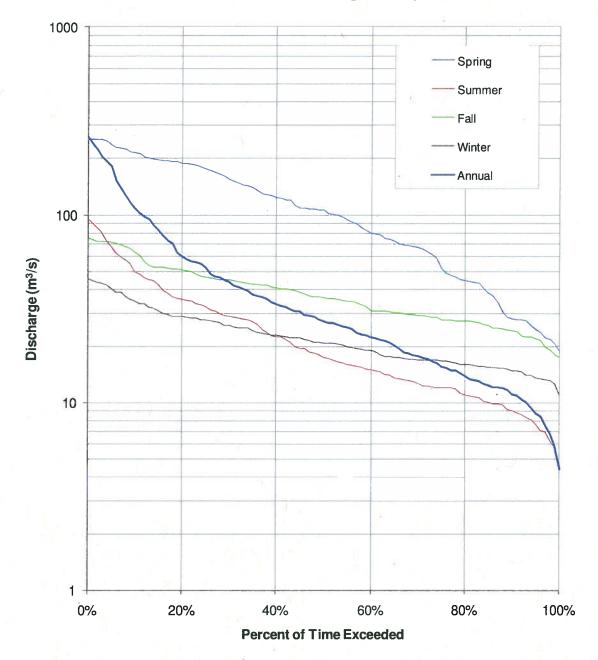


Table 6
Annual and Seasonal Medians of Percentiles
Vermilion River at Wabagishik Rapid

,	Discharge (m³/s)								
	Spring	Summer	Fall	Winter	Annual				
Percent	Mar 20	May 25	Oct 12	Dec 25					
of Time	May 24	Oct 11	Dec 24	Mar 19					
1	254	90.3	73.8	44.7	243				
5	237	68.2	71.9	40.7	181				
10	215	50.1	63.6	34.7	109				
15	197	42.4	52.7	30.7	83.2				
20	188	35.7	51.1	29.0	60.6				
25	176	32.4	46.9	27.7	52.3				
30	154	29.0	45.0	25.8	44.0				
35	140	27.1	43.0	24.4	37.8				
40	124	22.6	41.2	22.9	33.5				
45	109	19.5	38.9	22.2	30.5				
50	106	17.4	36.4	20.8	27.0				
. 55	94.2	16.0	34.8	19.9	25.1				
60	80.3	15.0	31.0	19.0	22.4				
65	72.2	13.6	30.3	17.5	20.2				
70	67.0	12.6	29.3	17.0	17.7				
75	51.5	12.1	27.6	16.7	15.5				
80	44.6	11.0	27.4	16.0	14.0				
85	38.5	10.1	25.8	15.5	12.3				
90	28.1	9.00	24.2	14.9	11.1				
95	24.5	7.69	22.0	13.6	8.85				
99	20.6	5.76	18.0	12.5	5.95				

Figure 7

Monthly Medians of Percentiles
Vermilion River at Wabagishik Rapid

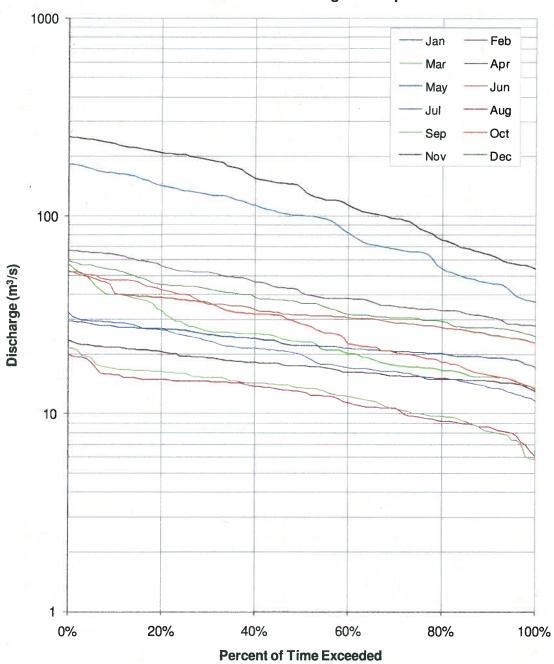


Table 7
Monthly Medians of Percentiles
Vermilion River at Wabagishik Rapid

Percent		Discharge (m <sup>3</sup> /s)										
of Time	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
11	29.2	23.0	54.8	251	182	51.8	30.9	19.6	21.4	51.9	66.7	58.5
5	28.4	22.1	46.8	244	173	48.6	29.3	18.2	19.1	50.1	65.5	56.2
10	27.5	21.7	40.1	231	164	40.4	28.8	15.7	16.9	47.5	63.7	53.4
15	27.1	21.1	38.0	220	156	39.3	27.6	15.1	16.6	46.2	59.6	49.0
20	26.9	20.7	33.1	208	142	38.7	26.5	14.9	16.3	42.2	56.1	45.1
25	26.3	19.5	28.4	204	134	37.5	24.8	14.6	16.0	40.0	52.4	44.2
30	25.2	19.2	26.1	193	128	36.5	23.3	14.5	15.2	35.8	51.7	42.8
35	24.5	18.5	25.7	176	123	35.1	21.8	14.4	14.6	32.9	49.2	40.8
40	24.0	18.1	25.4	156	113	33.7	21.5	13.8	14.3	32.0	46.5	38.7
45	23.0	17.9	24.2	147	104	32.5	20.9	13.3	14.1	31.4	43.4	37.6
50	22.1	17.4	23.1	139	101	31.5	20.0	12.9	13.6	28.4	41.0	36.2
55	22.0	17.0	21.1	120	96.7	31.1	17.8	12.3	13.0	25.7	38.6	34.7
60	21.5	16.2	20.2	114	81.8	30.4	17.0	11.4	12.2	22.5	38.3	31.7
65	21.0	16.0	18.9	104	71.5	30.3	16.8	10.8	11.6	21.8	37.0	31.3
70	20.6	15.5	17.7	97.4	68.3	28.8	16.3	10.7	10.6	20.4	35.0	30.7
75	20.4	15.4	17.2	86.8	65.8	28.1	15.5	9.63	10.0	19.6	34.0	30.3
80	20.1	15.0	16.5	75.9	54.1	27.3	14.9	9.16	9.70	18.2	33.4	29.5
85	19.5	14.8	15.9	68.9	48.8	26.3	14.5	8.89	9.15	16.9	32.3	27.4
90	19.2	14.7	15.4	63.7	45.9	25.2	13.6	8.55	8.19	15.7	31.0	27.3
95	18.8	14.2	14.8	57.8	40.8	24.1	12.7	7.95	7.39	14.9	28.4	26.4
99	17.5	13.3	13.7	55.2	37.2	23.2	11.9	6.43	5.92	13.7	28.0	25.0

Table 8
Seven-Day Low Flow Frequency Estimates
Vermilion River at Wabagishik Rapid

Return Period (years)	Discharge (m³/s)
100	2.03
50	2.34
20	2.89
10	3.50
5	4.40
3.3	5.20
2	6.84

Table 9
Maximum Instantaneous Flood Estimates
Vermilion River at Wabagishik Rapid

Return Period (years)	Maximum Instantaneous Discharge (m³/s)
2	268
5	356
10	402
20	440
50	480
100	507
1000	572
10,000	617

Table 10
Descriptive Flow Statistics
Vermilion River at Wabagishik Rapid

Statistic	Daily Discharge (m³/s)
Maximum	474
20% Exceedance	64.3
Mean	47.3
Median	27.3
80% Exceedance	13.4
Minimum	0.296

Addendum II: Hydrologic Regime Assessment Table

-		_	-			_	_										
Condition (i.e.	high	Flow	V	% exceed						0							
Degree of alteration: proposed condition (i.e. from reference condition)	medium	Flow	between	38th - 13th	% exceed			0						0			
Degree of alteration: pro from reference condition	woj	Flow	Within	20 - 05 % exceed,													
ndition (i.e.	high	Flow	< 13" or > 87th	7º exceed.		Ø	Ø	×			Ø	Ø	Ø	Ø	Ø	⊠	Ø
ition: current cor condition)	medium	Flow		38th - 13th	% exceed.												
Degree of alteration: current condition (i.e. from reference condition)	wol	Flow							Ø	Ø							
Expected condition with new	development			4	(m, sec.)	Intermittent	Intermittent	Intermittent	No Int. Op	No Int. Op	No Int. Op	Intermittent	Intermittent	Intermittent	Infermittent	Intermittent	Intermittent
	<u> </u>	ed.	nent)		874	10.0	8.2	9.5	21.0	27.6	13.4	5.6	3.4	2.6	3.8	10.5	15.6
9. not natu		% exceed.	requirement)	(m³ sec <sup>-1</sup> )	62 <sup>nd</sup>	18.1	14.0	14.0	40.0	43.8	23.3	11.3	6.4	5.5	10.6	23.7	25.4
altered (i.e		seflow	nent)	c. <sub>1</sub> )	38#	22.7	16.6	17.8	59.6	65.3	29.0	16.7	9.7	1.00	17.8	31.2	31.8
if already		% exceed.	requirement)	(m³ sec <sup>-1</sup> )	13th	30.1	22.6	27.4	90.4	101.0	43.6	26.9	15.8	15.2	36.7	49.5	47.6
Current condition if already altered (i.e. not natural)	5	Established baseflow	requirement	÷	( Sec .)	NEŧ	NE	N.	¥	뜅	J.	NE PE	N.	빙	밀	¥	Z.
		ceed.	(m³ sec <sup>-1</sup> )		<sub>\$2</sub> 42												
Reference condition characterisation		% өхсөөд	(m <sub>3</sub> s		<sub>14</sub> 29												
ence conditi		, pee	ac <sup>-1</sup> )		384				F-1	¥			2				
Refer		% ехсеед	(m³ sec <sup>-1</sup> )		13 <sup>th</sup>										-		
Indicators						January	February	March	April	May	June	July	August	September	October	November	December
Characteristic		Baseflow															
Key ecosystem component		Hydrology															

Notes:

1) The assessment of Degree of Alternation from current baseflow conditions utilizes the maximum and minimum houtly operating flow rates being proposed for this development and therefore overestimates the degree of change.

2) The proposed development will not result in an alteration of flowrates on a daily basis.

	_	-	_	_		_		_	_		
	0										
					0						_
□										_	
(m³ sec⁻¹) NA (Closed Coupled)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
N	NA NA	NE	NE	NE	NE	NE	NE	NE	NE	NE	N.
NE	H	N.	NE	ii Z	NE NE	NA.	NE	NE	NE	NE	II.
5.2	3.1	4.7	11.9	12.4	8.0	3.1	2.0	1,4	0.8	3.2	5.1
7.0	4.9	6.9	15.3	19.1	6.6	4.6	2.8	1.9	2.6	5.4	9.1
January	February	March	April	May	June	July	August	September	October	November	December
-				•		1					
	7.0 5.2 NE NE (M³sec¹)	7.0 5.2 NE NE NA	V         7.0         5.2         NE         NE         NA (Closed Coupled)         Coupled)	γ         το         5.2         NE         NE         NA (Closed Coupled)         Π <td>y         TO         5.2         NE         NE         NA (Closed order)         Coupled)         Coupled)</td> <td>γ         7.0         5.2         NE         NE         (m² sec²)         (m²</td> <td>γ         7.0         5.2         NE         NE         NA (closed coordinate)         (m² sec²)         (m² sec²)</td> <td>γ         π         π         (m³ sec¹)         (m³ sec¹)         (m² sec¹)         (m² sec¹)         (m² sec¹)         (m² sec¹)         (m² sec¹)         (m² sec²)         (m² sec²)</td> <td>γ         π         π         (m³ sec¹)         (m² sec²)         (m² sec²)</td> <td>γ         π         π         (m³ sec¹)         π</td> <td>γ         5.2         NE         NE         NA (Gosed) (Go</td>	y         TO         5.2         NE         NE         NA (Closed order)         Coupled)         Coupled)	γ         7.0         5.2         NE         NE         (m² sec²)         (m²	γ         7.0         5.2         NE         NE         NA (closed coordinate)         (m² sec²)         (m² sec²)	γ         π         π         (m³ sec¹)         (m³ sec¹)         (m² sec¹)         (m² sec¹)         (m² sec¹)         (m² sec¹)         (m² sec¹)         (m² sec²)         (m² sec²)	γ         π         π         (m³ sec¹)         (m² sec²)         (m² sec²)	γ         π         π         (m³ sec¹)         π	γ         5.2         NE         NE         NA (Gosed) (Go

Notes:

1) Proposed development is a closed coupled design whereby the tailrace will be located adjacent to the dam/weir structure.

											_	_
Flow magnitude covers < 50% or the wetted or the wetted perimeter for fivers < 15m wide for fivers > 15 m wide												
				_	0	_	_		0			
Flow magnitude covers 2 50% of the wetted wetted for rivers for five many and 2 3 and 2 3 wide for rivers % f							_					
Flow magnitude covers < 50% of the wetted perimeter for my wide and < 70% for fivers > 15 m wide												
Flow magnitude covers ≥ 50% of the wetted of the wetted for the wide and wide and wide and thers > 15 m wide	Ø	Ø	⊠	Ø	⊠	×	Ø	Ø	⋈	Ø	Ø	Ø
Subsistence Prow with Proposed Development	(m sec )	-	-	19	19	19	9	3	8	2	2	2
Estimated/measured median baseflow for bypassed natural channel reaches if no requirement	(m sec )	15.2	15.5	49.5	52.6	26.3	13.7	7.9	6.4	13.4	26.9	28.2
Established baseflow requirement for bypassed natural channel reaches	(m sec )	AN	NA									
0118								10				
1 1 1					ш		6			1	1	
Flow magnitude that covers ≥ 50% of the wetted perimeler for rivers < 15 m wide and ≥ 70% for rivers > 15 m wide (70% of 104 m = 72.8 m)	1 (91% of W.P.)											
	January	February	March	April	May	June	July	August	September	October	November	December
Subsistence flow (Field-based assessment) Station -1+1452 (D.S. of Development) LTAF = 47.3 cms Wetted Perimeter (W.P.) = 104 m		i i			ì						4	
Hydrology		H									÷	
				_		_						_

Notes:
Station - 1+452 represents a relatively straight and flatwater section of the river. Alternate locations such as fast water (rapid sections) are difficult to obtain field data, other sections such as pools may not be representative of the larger river system.

o	pper	1							_	_	_		_	
800	3300	1000			Ш									
ROG	Lower IOR	- Upper IQR							0				0	0
ROC within	- 75° Percentile												_	
ROC	or > Upper		×	×	⊠			×	⊠	×	⊠	⋈	⊠	
Soc	Lower IQR - 25th , 75th	- Upper IQR	0			0	0							
ROC within	Lower ICR - 75 <sup>th</sup> percentile				_	×	×			_			_	
Expected	Proposed Development	(m³ sec-1 hr -1)	> Upper IQR	> Upper IQR	> Upper IQR	S	O	> Upper IQR						
Percentile.	(m³ sac-1 hr -1)	Upper IQR	0.4114	0.4114	0.4050	0.3657	0.4063	0.3748	0.4114	0.4114	0.3531	0.3120	0.3200	0.3386
Perce	(m³ sac	75th	0.1554	0.1705	0.1554	0.1515	0.1828	0.1423	0.1554	0. t417	0.1371	0.1417	0.1039	0.1211
ntile	¹ hr ¹)	25th	0.0515	0.0544	0.0549	0.0457	0.0507	0.0476	0.0549	0.0482	0.0503	0.0457	0.0411	0.0397
Percentile	(m³ sec¹ hr ¹)	LowerIQR	0.0025	0.0025	0.0037	0.0012	0.0012	0.0012	0.0025	0.0025	0.0012	0.0012	0.0012	0.0037
rtile.	¹ hr ⁴)													
Percentile.	(m³ sec¹ hr ¹)													
utile	¹ hr ¹)											,		
Percentile	(m³ sec¹ hr ¹)													
(Positive rates)			January	February	March	April	May	June	July	August	September	October	November	December
Rate of change of flow (ROC)				~						-		-		
Hydrology														

Notes:

2) Rate of change (positive) for current conditions is based upon daily hydrological data. On a daily basis the proposed development will not result in an alteration to these values. On an hourly basis, alternation to flows will occur during most months at a magnitude greater than the current daily Upper IQR. Average monthly fowrates for April and May exceed turbine capacity and under these conditions no flow alterations would occur.

Hydrology	Rate of change of (Negative rates)	(Negative rates)	Percentile	95	Percentile.	Pe	Percentile	Perc	Percentile.	Constant	ROC within	ROC	ROC	ROC within	800	ROG
			(m³ sec¹ hr¹)	hr.¹)	(m³ sec¹ hr¹)	s <sub>E</sub> m)	(m³ sec¹ hr ¹)	(m³ sec	(m³ sec¹ hr ¹)	Condition with Proposed	75th 75th percentile	ا تــــــــــــــــــــــــــــــــــــ	or > Upper	Lower IQR - 75° Dercentile	Lower IQR	or > Upper
										Development		- Upper IQR			- Upper IQR	
			-			Lower IQR	25th	75th	Upper IQR			-				
										(m³ sec 1 hr 1)						
		January				0.0025	0.0503	0.1188	0.2697	< Lower IQR	0		×			
		February				0.0025	0.0457	0.1234	0.2788	< Lower 1QR			×			
		March				0.0025	0.0503	0.1143	0.2697	< Lower IQR			×			
		April				0.0012	0.0503	0.1280	0.2697	S	×					
		Мау				0.0024	0.0503	0.1280	0.2793	S	Ø					
		June				0.0037	0.0503	0.1280	0.2743	< Lower IQR			×			
		July				0.0046	0.0503	0.1188	0.2208	< Lower IQR			×		-	
		August				0.0012	0.0594	0.1188	0.2598	< Lower IQR			×			
.		September		-		0.0046	0.0633	0.1311	0.2743	< Lower IQR			Ø			
		October				0.0037	0.0549	0.1326	0.2743	< Lower IQR	0		×			
		November				0.0012	0.0503	0.1206	0.3017	< Lower IQR			Ø			
		December				0.0012	0.0457	0.1277	0.2743	< Lower IQR			Ø			

Notes:
Rate of change (negtive) for current conditions is based upon daily hydrological data. On a daily basis the proposed development will not result in an alteration to these values. On an hourly basis, alternation to flows will occur during most months at a magnitude greater than the current daily Lower IQR. Average monthly fowrates for April and May exceed turbine capacity and under these conditions no flow alterations would occur.

Hydrology	High flow pulses (< bankfull) 1:1.003 Return Q = 76.3 cms	Frequency		Reference Condition Number of Events on Period of Record	condition wents on Record	Number of Events on Period of Record	ents on scord	Current Condition Number of Events on Period of Record		Expected Condition with Proposed Development	Frequency within 38th - 62th percentile	Frequency between 13 <sup>th</sup> - 38 <sup>th</sup> 62 <sup>th</sup> - 87 <sup>rd</sup> percentiles.	Frequency < 13 <sup>th</sup> or > 87 <sup>th</sup> percentile.	Frequency Within 38th - 62m percentile	Frequency between 13th - 38th 62th - 87th Dercentiles.	Frequency < 13 <sup>th</sup> or > 87 <sup>th</sup> percentile.
					*				*	(frequency)						
		Annual							327	NC	Ø					
		January							31	S	×		0			
		February							35	NC	Ø					
		March							29	NC	Ø					
		April							30	NC	Ø					
		May							30	NC	Ø					
		June		,					34	NC	Ø					
		July							31	NC	×					
		August							22	NC	Ø					
		September							18	NC	Ø					
		October	•						25	NC	Ø	_	0			
		November							16	NC	Ø		٥			
		December							26	NC	Ø					

Notes:
Proposed development will have a maximum turbine capacity of 64 cms. No change in flowrates will occur when inflow exceeds turbine capacity. Hence no change (NC) is predicted during high flow pulses of 64 cms or greater.
Refer to attached SAAS screen shot displaying high flow events and frequency.

River	
Vermillion	
Rapids -	
Wabageshik	

Condition with   Proposed   38 <sup>m</sup>   Proposed   28		Duration	Percentile	Percentile.	Percentile	Percentile.	Expected	-	Duration	Duration	Duration	Duration	
Development			(days)	(days)	(days)	(days)	Condition with Proposed		between 13th - 38th	< 13 <sup>th</sup> or > 87 <sup>th</sup>	within 38th - 62m	between	
							Development (days)		62 <sup>th</sup> - 87 <sup>nd</sup> percentiles.	percentile.	percentile	62th - 87" percentiles.	
		Annual					NC	Ø					
		January					NC	×	0				[
h	1	February			53		NC	×					1
st		March					S	Ø					
st         NC           amber         NC           mber         NC           mber         NC           mber         NC           mber         NC           mber         NC           mber         NC		April					NC	×					1
st         NC           ember         NC           mber         NC           mber         NC           mber         NC           mber         NC           mber         NC		May					NC	×	0				ı
st         NC           amber         NC           mer         NC           mber         NC           mber         NC           mber         NC		June					NC	×					ı
er NC		July					S	Ø					
		August					NC	×					1
		September					NC	×					Į .
ON NC		October					NC	⊠					
OV NO		November					NC	×	_				
		December					S	×	_	_			ĺ

Proposed development will have a maximum turbine capacity of 64 cms. No change in duration of high flow events (> 64 cms) will occur when inflow exceeds turbine capacity. Hence no change (NC) in predicted high flow duration. Refer to attached SAAS screen shot displaying high flow events and frequency. Notes:

Wabageshik Rapids - Vermillion River

Aquatic Ecosystem Assessments for Dams (Draft)

Charmel-forming   Magnitude   Flow magnitude   Row magnitude	Magnitude         Flow magnitude         Current (m³ sec¹)         Expected (m³ sec¹)         2 the 1:1.5 (m³ sec¹)         2 80% of the 1:1.5 (m³ sec¹)         2 the 1:1.5 (m³ sec¹)         1:1.5 (m³ sec²)         1:1.5 (m	Current   Current   Expected   2 the 1:1.5   2 80% of 1   2 the 1:1.5   2 t
Flow magnitude   80% of flow magnitude   Expected   2 the 1:1.5   2 80% of 1 6 80% of 1 flow magnitude   1:1.5   1:1	Flow magnitude   B00% of flow magnitude   Flow magnitud	Current   Current   Expected   2 the 1:1.5   2 80% of   < 80% of the 2 the 1:1.5   Flow magnitude   Row of flow magnitude   Roy of flow magnitude
Flow magnitude   80% of flow magnitude   Expected   E	Flow magnitude   80% of flow magnitude   Flow magnitude	Current   Current   Expected   2 the 11.15   2 80% of 1 centrence   11.15
Flow magnitude   80% of flow magnitude   Row current   Expected   2 the 1.1.5   2 80% of flow magnitude   Row corrected   Current   Expected   2 the 1.1.5   2 80% of flow magnitude   Row corrected   2 the 1.1.5   2 80% of flow magnitude   Row corrected   2 the 1.1.5   2 80% of flow magnitude   2 the 1.1.5	Flow magnitude   B0% of flow magnitude   Current   Expected   2 the 1:1.5   2 80% of flow magnitude   Tecurence   The 1:1.5   Proposed   Tecurence   The 1:1.5   Proposed   Tecurence   The 1:1.5   Tecurence	Current   Current   Expected   2 the 1:1.5   2 80% of flow magnitude   Roberton   Proposed   Prop
Flow magnitude   80% of flow magnitude   Row current   Expected   2 the 1.1.5   2 80% of flow magnitude   Row corrected   Current   Expected   2 the 1.1.5   2 80% of flow magnitude   Row corrected   2 the 1.1.5   2 80% of flow magnitude   Row corrected   2 the 1.1.5   2 80% of flow magnitude   2 the 1.1.5	Flow magnitude   B0% of flow magnitude   Current   Expected   2 the 1:1.5   2 80% of flow magnitude   Tecurence   The 1:1.5   Proposed   Tecurence   The 1:1.5   Proposed   Tecurence   The 1:1.5   Tecurence	Current   Current   Expected   2 the 1:1.5   2 80% of flow magnitude   Roberton   Proposed   Prop
Flow magnitude 80% of flow magnitude Flow magnitude Flow magnitude Current Flow magnitude Current Current Condition with Proposed (m³ sec¹) (m³ sec²) (m³ se	Flow magnitude B0% of flow magnitude Flow magnitude B0% of flow magnitude Flow magnitude Current Flow magnitude Current Current Condition with Proposed (m³ sec¹) (m³ sec¹) (m³ sec¹) (m³ sec¹) Development Current Current Current Condition with Proposed (m³ sec¹) (m³ sec²) (m³ sec²) (m³ sec¹) (m³ sec²) (m³	Current Current Expected Flow magnitude Condition with Proposed (m³ sec¹) (m³ sec¹) Development  210 168 NC
Flow magnitude   80% of flow magnitude   Current   Flow magnitude   80% of flow magnitude   80% of flow magnitude   Rlow magnitude   80% of flow magnitude   Rlow magnitude   80% of flow magnitude   Rlow magni	Flow magnitude   80% of flow magnitude   Current   Current   Current   Row magnitude   Row m	Current Current Flow magnitude (m² sec¹) (m² sec¹) (m² NA NA
Flow magnitude 80% of flow magnitude Current Flow magnitude (m³ sec¹) (m³ sec¹) (m³ sec¹) and sec¹) and ange NA NA NA	Flow magnitude 80% of flow magnitude Current Flow magnitude (m² sec¹) (m² sec¹) (m² sec¹) and sec¹)	Current Flow magnitude (m² sec¹) 210
Flow magnitude 80% of flow magnitude (m³ sec") (m³ sec") (e of flow magnitude (m³ sec") (m³ sec") (m³ sec")	Flow magnitude 60% of flow magnitude (m³ sec") (m³ sec")  nce e of NA NA	
nce e of	noce narge	nde
nce e of	noce narge	80% of flow magnii (m³ sec¹)
1:1.5 recurrence assessment Field-based Field estimate of bankfull discharge	Channel-forming Magnitude flow Preliminary 1:1.5 recurrence assessment interval flow Field-based Field estimate of bankful discharge	Flow magnitude (m² sec.¹)
Channel-forming flow Preliminary assessment Field-based assessment	Ghannel-forming flow Row Preliminary assessment Field-based assessment	Magnitude 1:1.5 recurrence interval flow Field estimate of bankfull discharge
8	KBoj	Channel-forming flow Preliminary assessment Field-based assessment
Hydrolog	Hydro	Hydrology

Notes: Proposed development will have a maximum turbine capacity of 64 cms. No change in the magnitude of the 1:1.5 flood event.

C 13th or >	percentile		
Duration between	62th - 87th	0	
Within Mithin	percentile		
Duration < 13 <sup>th</sup> or >	percentile.		0
Duration between	62th - 87nd percentiles.		0
Duration within 38th - 62nd	percentile	⊠	
Expected Condition with Proposed	Development	NC	
Surrent Duration		11 days (June)	A A
Current			Ą.
			NA A
			₹
	1 1 40		Ą
			ΝΑ
	4		¥
			¥.
Duration		1:1,5 recurrence interval flow	Field estimate of bankfull discharge
		Preliminary assessment	Field-based assessment

Notes: Proposed development will have a maximum turbine capacity of 64 cms. No change in duration of 1:1.5 flow event.

Beyond 1 month of modal month	0	
Within 1 month of modal month	0	
Within modal month		
Beyond 1 month of modal month		
Within 1 month of modal month		
Within modal month	⊠	
Expected Condition with Proposed Development	N-	
Current Modal month ±1 month	May / July	۸۸
Current Modal month	hune	NA
Modal month ±1 month		WA
Modal month		ΑĀ
Timing	1:1.5 recurrence interval flow	Field estimate of bankfull discharge
	Preliminary assessment	Field-based assessment

Notes: Proposed development will have a maximum turbine capacity of 64 cms. No change in duration of  $1:1.5~\mathrm{flow}$  event.

1					7	T				_
	0	0	Duration < 13 <sup>th</sup> or > 87 <sup>th</sup> Dercentile				Beyond 1 month of modal month		0	
0		0	Duration between 13th - 38th 62th - 87th	percentiles	0		Within 1 month of model			
0			Duration within 38th - 62m				Within modal	0		
			Duration < 13 <sup>th</sup> or > 87 <sup>th</sup> percentile.				Beyond 1 month of modal month			
0			Duration between 13th - 38th 62th - 87rd	percentiles.			Within 1 month of modal month	0	0	
Ø	×	×	Duration within 38th - 62rd percentile	Ø	×	×	Within modal month	Ø	Ø	×
NC	S	N O	Expected Condition with Proposed Development	NC	S	NC	Expected Condition with Proposed Development	S	S	NC
		The second	(days)				Modal month ±1 month	August / October	January / March	Multiple
254	415	465	(days)	8.88	5.50	3.75	Modal month	September	February	Multiple
			(days)				Modal month ±1 month			-
			(days)				Modal month			- II NII III
1:2 recurrence interval flow	1:10 recurrence interval flow	1:20 recurrence interval flow	Duration	1:2 recurrence interval flow	1:10 recurrence interval flow	1:20 recurrence interval flow	Timing	1:2 recurrence interval flow	1:10 recurrence interval flow	1:20 recurrence interval flow
П	n <sup>1</sup>									
							131			
	08 NC SS C C C C C C C C C C C C C C C C C	254 NC SS C C C C C C C C C C C C C C C C C	254         NC         SM         O         O         O           415         NC         SM         O         O         O           465         NC         SM         O         O         O	A   A   A   A   A   A   A   A   A   A	A	1	10   10   10   10   10   10   10   10	1	1	The control of the

Notes: Proposed development will have a maximum turbine capacity of 64 cms. No change in high flow events, timing, duration or magnitude.

Notes: Flow Simulation for the Vermillion River at Wabageshik Rapids (Hatch 2009); Period of Record 1954 - 2011

<sup>\*</sup> Not Established

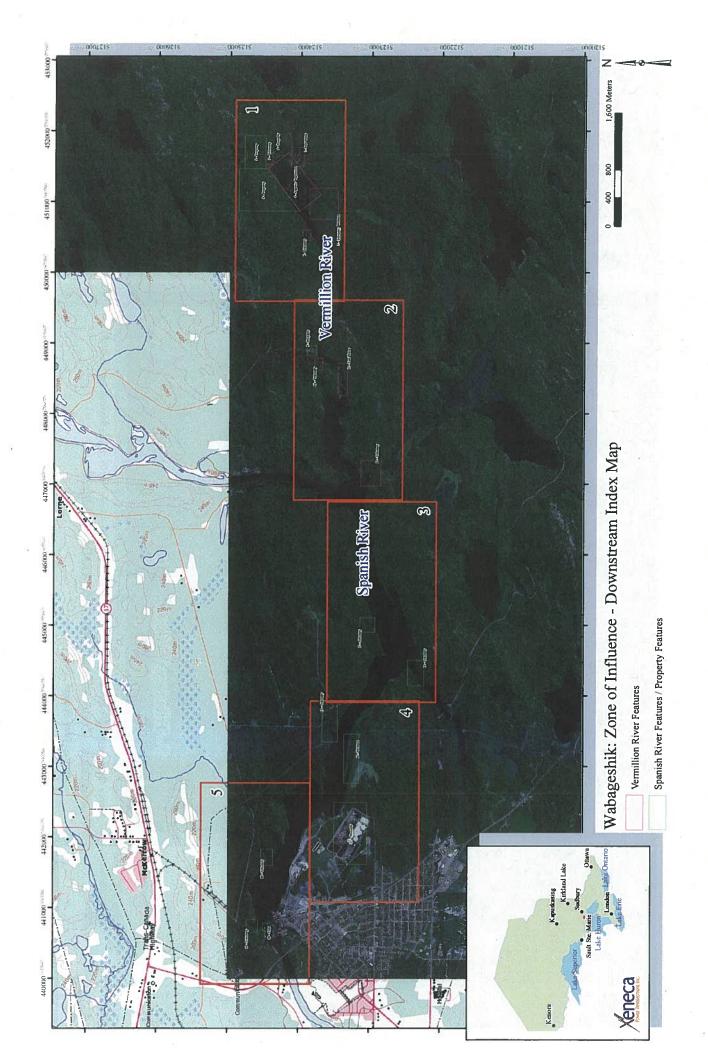
\* Not Applicable – Requires field data

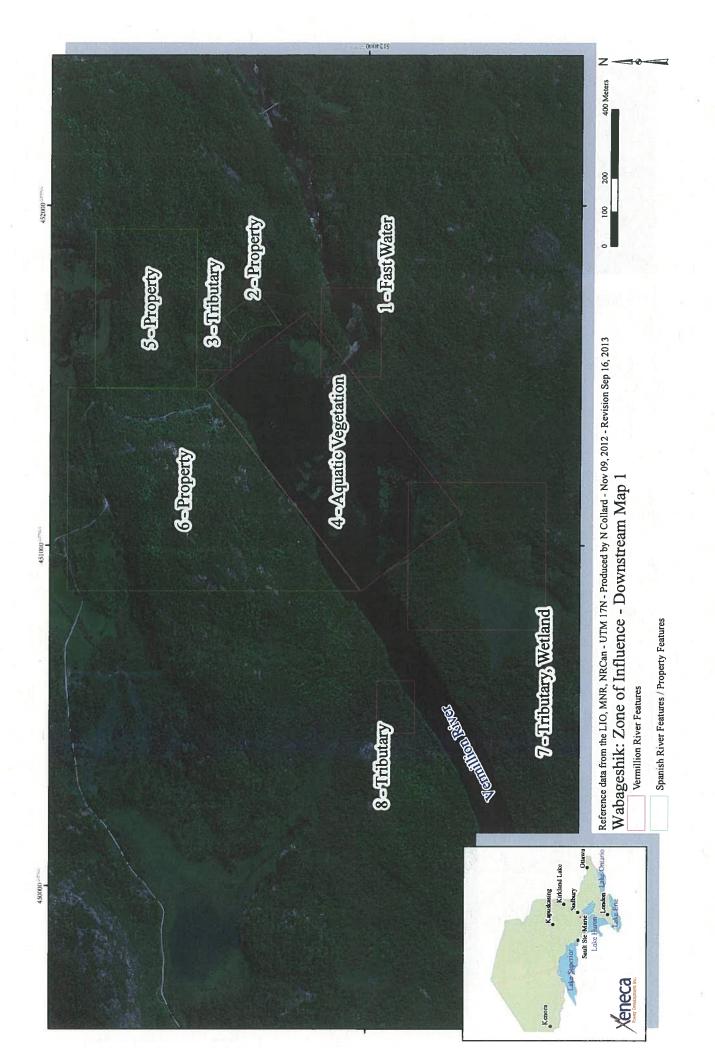
\* No events of this recurrence interval recorded during this month for period examined

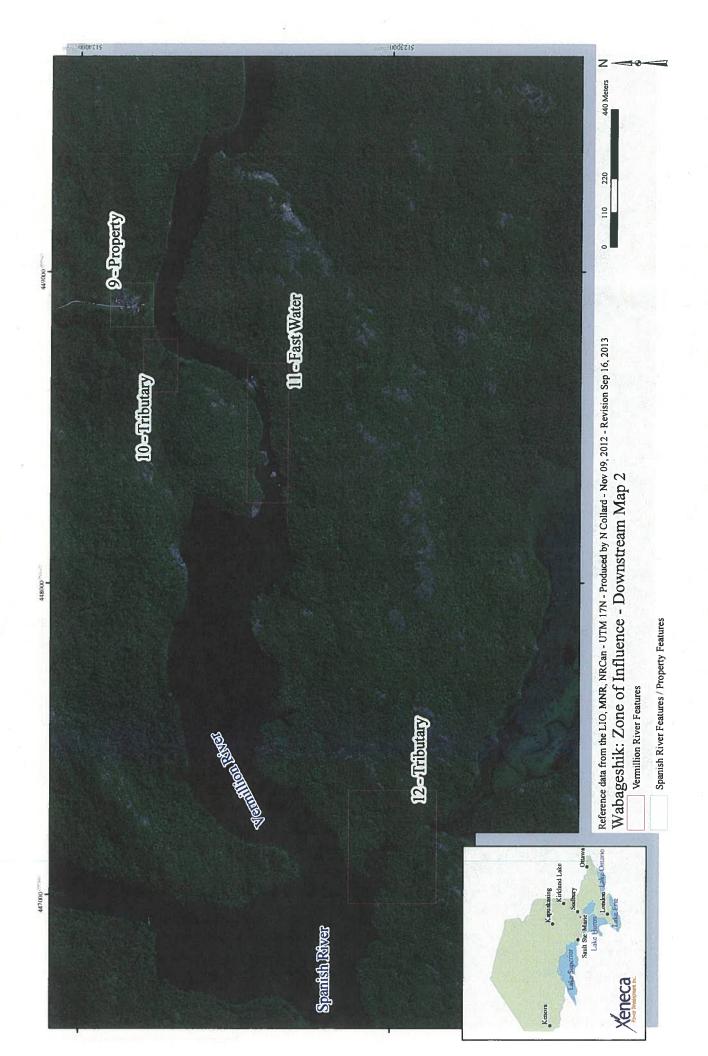
A No events of this recurrence interval recorded during this month for period examined

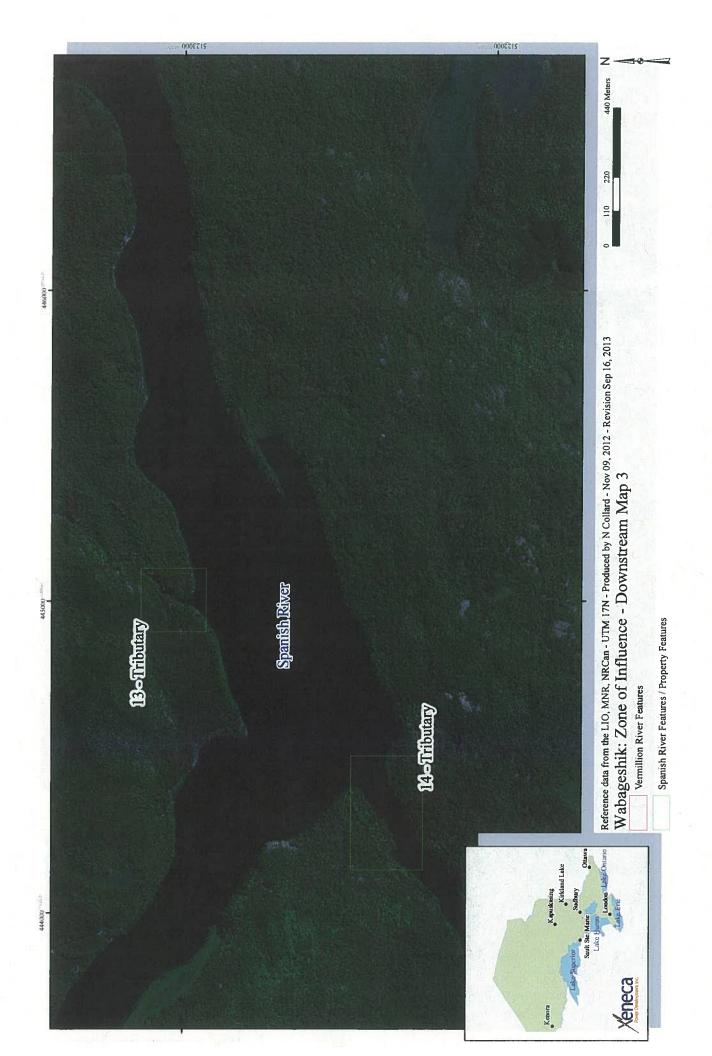
(Bi-modal) Equal rumber of events for these two morths

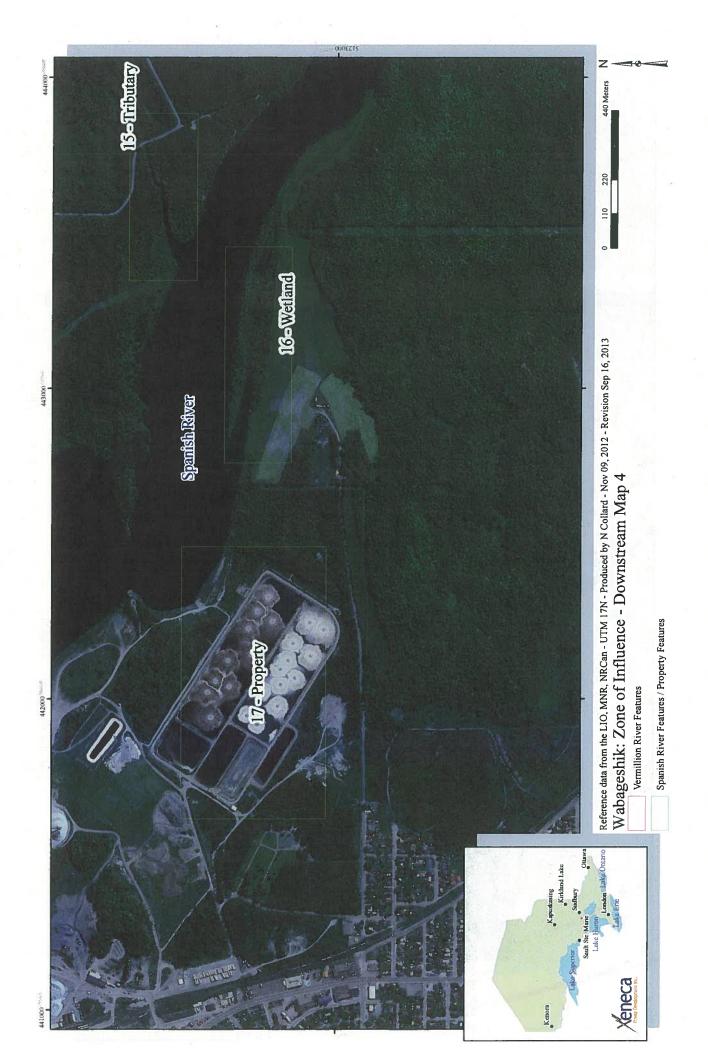
NC – No Change in Daily value. Changes related to development may occur on an hourly basis.

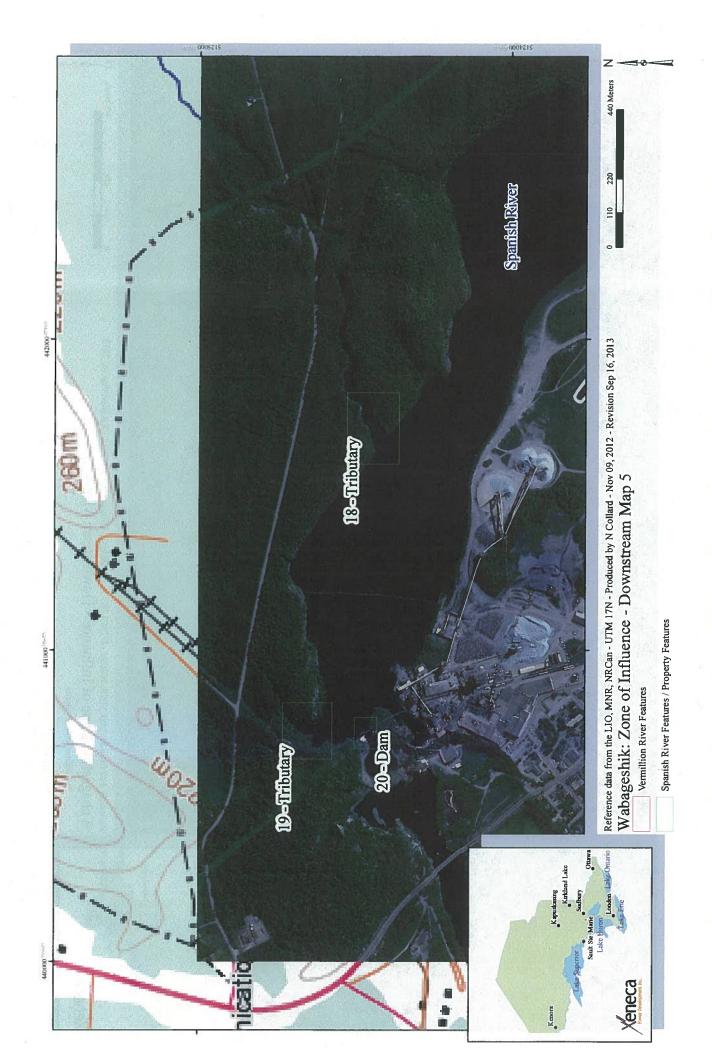














# Report:

Erosion Potential Assessment of Northern Ontario Waterpower Sites for Xeneca Power Development Inc., Wabageshik Rapids

Date:

September 19, 2013





# Report:

Erosion Potential Assessment of Northern Ontario Waterpower Sites for Xeneca Power Development Inc., Wabageshik Rapids

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Report No.:

90881

12 pages, 3 Attachments

#### **Revision History**

Version	Date	Summary Changes/Purpose of Revision
1	June 2011	None
2	September 19, 2013	Update on Wabageshik dam location, removal of reference to other projects.
The Ref.		



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#### **ACKNOWLEDGEMENT**

This Erosion Potential Assessment of Northern Ontario Waterpower Sites – Wabageshik Rapids was prepared under the direction of Xeneca Power Development Inc. (Xeneca Power). Xeneca Power acknowledges the assistance and input from ORTECH Consulting Inc. (ORTECH), R.J. Burnside and AquaLogic Consulting.

# **AUTHENTICATION**

This Erosion Potential Assessment document was prepared under the direction of Xeneca Power.

The main participants in the assessment were:

Name	Position	Responsibilities		
Xeneca Power Development Inc. Nava Pokharel	Senior Project Manager	Project Management and Coordination		
ORTECH Consulting Inc. Scott Manser	Senior Project Manager	Overall development and report summary.		
R.J. Burnside Dan Miller, P.Eng.	Project Manager, Senior Water Resources Engineer	Preparation of HEC RAS related modelling, figures and tables.		
Tim Lozon	Water Resources Engineer	Preparation of HEC RAS related modelling, figures and tables.		
AquaLogic  Bill de Geus., CET, CPESC, EP	Project Manager	Development of erosion potential methodology and detailed report.		



#### 1. BACKGROUND

Xeneca Power Development Inc. (Xeneca) is proposing to develop a renewable energy project along the Vermillion River at Wabageshik Rapids under a contract from the Ontario Feed in Tariff (FIT) program, regulated by the Ontario Power Authority (OPA). As part of the requirements of the FIT contract Xeneca is working towards the completion of the required Class Environmental Assessments (Class EA) for this project. Xeneca contracted ORTECH Consulting Inc. (ORTECH) to conduct a desktop screening level assessment of the erosion potential for this project in support of the overall Class EA process.

A screening level assessment tool was developed to compare conditions under different water depth scenarios, channel bank angle, channel velocity range and substrate type using available GIS, and topographic data.

#### 2. PROJECT DESCRIPTION

The waterpower project is primarily a run-of-river (ROR) type project with varying storage capacity to allow for some degree of daily peaking operation. This project is therefore referred to as "modified run-of-river" generating facility having dominant properties of ROR projects with short term or limited peaking capability.

With "modified run-of-river" operations, the facility would operate at the same rate as the natural flow in the river (i.e. "run-of-river") with no variation in upstream water levels due to operation and no man-made variation in downstream flows from those experienced naturally. At other times, the facility would "modify" the natural flow in the river by storing some of the natural river flow during night time hours to be used during daytime hours when the need for electricity in the Province is greater.

Run-of-river operation would occur during two (2) types of natural flow conditions:

1) When natural river flows are greater than the maximum turbine capacity (Q<sub>Tmax</sub>): Since the natural flow exceeds the amount of water that can be processed through the turbine, any excess water is bypassed through the spillway structure. The combined flow of the water used in the turbine to generate electricity and the water bypassed over the spillway equals the natural flow. This situation occurs primarily during spring thaw run-off conditions and during major storm events in the spring, summer and fall.



2) When natural flows are so low that any available water must be released to protect the downstream environment: The flow in this situation is typically too low to generate electricity. This situation occurs primarily in late summer and late winter when natural flows are typically very low. This situation may also occur during certain years when spring run-off flow is unusually low and the amount of water available is needed downstream.

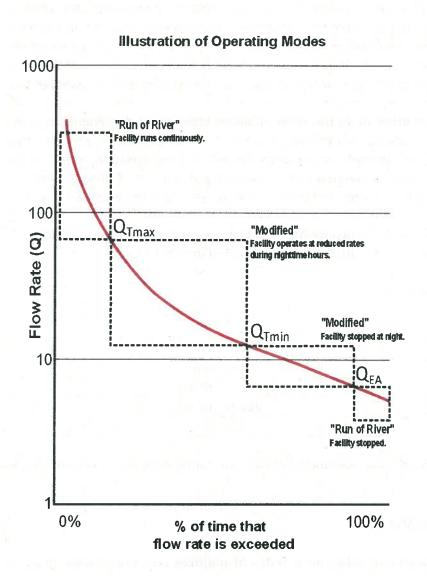
Modified run-of-river operation would occur during moderate and low flows when the natural flow in the river is below the maximum turbine flow capacity ( $Q_{Tmax}$ ) but above the minimum flow required to protect the environment ( $Q_{EA}$ ). During these flow conditions, some of the natural river flow during nighttime and/or weekend hours can be stored and used to produce electricity during daytime hours. There are two modes of modified operation as follows:

- 1) Facility runs at reduced rate at night: When natural river flows are moderate (i.e. between the minimum ( $Q_{Tmin}$ ) and the maximum ( $Q_{Tmax}$ ) rate of turbine capacity), the facility runs continuously, but some of the water is saved during nighttime hours. This operation results in downstream flows that are smaller than natural river flows during nighttime hours and larger than natural river flows during daytime hours when electricity use is higher. However, the minimum flow in this mode of operation is not less than the minimum turbine capacity ( $Q_{Tmin}$ ).
- 2) Facility is stopped at night: When natural river flows are low (i.e. below the minimum turbine capacity  $(Q_{Tmin})$ ), the facility will need to stop operation during some nighttime hours and save water until operation is again possible. The lower the natural river flow, the longer the period of stoppage will be. When the facility operates, it operates at a rate less than maximum turbine capacity  $(Q_{Tmax})$ . To ensure that the downstream river reach receives enough water flow to protect the environment  $(Q_{EA})$ , the appropriate amount of water is released through a bypass while the turbine operation is stopped.

Figure 1 below illustrates the mode of operation that occurs depending on the amount of natural flow in the river.



Figure 1: Mode of Operation



Note: Figure is for illustrative purposes only



An important factor in modified run-of-river operation is the availability of storage upstream of the facility. As described in the project description section of the environmental assessment, the amount of storage created as part of the project is very limited. To achieve the objective of building a project with limited environmental impact, the conceptual design of the facility limits the height of structure, the depth and the area of inundation upstream. Consequently, the amount of storage available for operation is inherently limited in relation the natural flow in the river, thereby limiting the storage to a few hours during moderate and low flows. The ability to use this storage is further constrained by environmental constraints outlined in other parts the environmental assessment document. It is the limited storage that differentiates modified run-of-river projects from hydroelectric projects that create large storage reservoirs with the ability to store water for weeks or seasons to "peak" when seasonal periods of hot or cold spells raise the need for extra electricity production. Typically, modified run-of-river projects have significantly less environmental impact than peaking hydroelectric projects.

For the purpose of this project the range of headpond elevations is represented by the upstream operating parameters provided within the operating plan and provided in Table 1 below.

**Table 1: Upstream Operating Parameters** 

Inundation Area at LTAF	4.4	ha
Inundation Area - Post-project	4.8	ha
Upstream Extent	0.8	km
Normal Operating Target	Nat. Lake Level	m MSL
Minimum Operating Target	204.0	m MSL
Maximum Daily Fluctuation	0.1	m

Note: Values are for normal flow conditions, parameters may vary during droughts or floods due to factors of nature

#### 3. SCREENING LEVEL METHODOLOGY

The erosion potential screening assessment relies on a series of matrices covering a wide range of channel conditions and substrate combinations that represent the range of combinations at the waterpower site. Substrate combinations are summarized in Table 2 with bolded values representing the dominant substrate type.



**Table 2: Substrate Combinations** 

Yi-d 70 -	% Substrate Composition					
Scenario #	Bedrock / Boulder / Cobble	Gravel	Sand	Silt clay		
1	100	III III III		HL DO		
2		100		- 1.1.1.1.		
3			100			
4				100		
5	75	8.3	8.3	8.3		
6	8.3	75	8.3	8.3		
7	8.3	8.3	75	8.3		
8	8.3	8.3	8.3	75		
9	50	16.6	16.6	16.6		
10	16.6	50	16.6	16.6		
11	16.6	16.6	50	16.6		
12	16.6	16.6	16.6	50		
13	25	25	25	25		
14	50	50				
15		50	50	1 = 11		
16		27 7 11 11 11	50	50		

Each substrate combination was modeled using hydraulic geometry and vegetative protection relationships indexed to rating scores, normalized on a 0 to 10 scale, as established in the bank erosion hazard index (BEHI) method. The overall rating represents conditions ranging from very low (0-1.9) to extreme (> 9.0) erosion potential based on how the noted physical and mechanical variables work together to provide natural erosion resistance and dynamic channel stability (AquaLogic, 2011).

The ranges of parameters considered in the assessment are provided in Table 3.

**Table 3: Erosion Potential Data Inputs** 

Parameter	Value			
Bank Height	equal to flow depth			
Flow Depth	0.5 m - 6 m			
Rooting Depth	2 m			
Rooting Density	50%			
Bank Angle	15 - 55 degrees			
Vegetative Bank Face Protection	50%			



A detailed analysis of a 40 km section of the Kapuskasing River was conducted and the range of conditions observed along this project was used to represent typical average site conditions for Wabageshik Rapids. Rooting depth was assumed as an average of 2m, and rooting density and bank face protection as 50%, reflecting the range of scrub to treed conditions in shallow to medium depth soils for Boreal Forest on the Canadian Shield.

Bank angles representing conditions steeper than typical stable slope equilibrium and higher than 2m, under the noted average vegetative cover conditions, were excluded from analysis because they are considered erosion prone and unstable under all flow scenarios.

### 4. APPLYING THE SCREENING METHDOLOGY

Erosion potential scenarios were assessed for each substrate type combination shown in Table 2 with incremental flow depth and bank angles applicable over a range of channel velocities. The resultant index scores are provided in Attachment 1. For each substrate combination velocities below the matrix value would represent "very low" erosion potential whereas velocities above the upper range of values provided would be deemed to trigger sustained erosion potential (AquaLogic, 2011).

Additionally, site areas that are relatively void of significant vegetation should be identified and referenced to the Hjulstrom Curve relationship for velocity as provided in Attachment 2. The Hjulstrom curve relationship is used by hydrologists to determine whether a river system will erode, transport or deposit particles of a given size at a specified channel velocity. This methodology agrees with the MNR guideline approach of identifying the point of incipient erosion as the threshold of channel stability (OMNR, 2002) for channel banks generally less than 2 m high.

The following steps were used in developing the erosion potential assessment for the project site:

- 1) A slope analysis map was produced for each project site based upon topographic information in the form of 0.5 m LIDAR contour data;
- 2) Slopes were categorized in ten degree intervals corresponding to the erosion sensitivity scoring system (15 to 55) degrees;
- 3) Surificial geology mapping was overlaid onto the slope analysis map;
- 4) Surficial geology for each project site was placed into one of the sixteen categories used in the erosion sensitivity scoring index as provided in Attachment 1, and
- 5) Areas deemed as having the potential for "moderate" erosion potential or areas requiring additional analysis were identified by blue circles.

Based upon the above approach the project site is considered to have a "low" erosion potential. Erosion potential mapping for the project site is provided in Attachment 3.



#### 5. **CONCLUSIONS**

Erosion potential scenarios were assessed for each substrate type combination shown in Table 2 with incremental flow depth and bank angles. The resultant index scores are provided in Attachment 1. Modelling results indicate that:

- Good channel stability is generally found under all conditions for bedrock/boulder/cobble scenarios, as typical of most watercourses;
- Good stability conditions in aggregate and soil substrates is generally due to the positive influence
  of vegetative cover supplying additional reinforcement;
- Silt clay conditions are considered to have lower sensitivity to erosion than sand and gravel conditions which is an inherent result of cohesive properties;
- Any shift in velocity to above the identified stability range from one flow scenario to another would require a more detailed analysis;
- For flow depths of 1 m or less, which are proposed under the site operating plans, 100% sand and 75% sand + 25% "mixed" substrates have a potential for "moderate" erosion impacts under specific bank angle and flow velocity conditions; and
- All other substrate combinations, within the prescribed velocity ranges, for flow depths of 1 m or less are predicted to have either "low" or "very low" erosion potentials when bank angles are 45 degrees or less.

Comparative flow depth scenarios (existing and proposed) are possible using the screening methodology. This is typical of dynamic integrated stability under existing conditions representing decades and/or centuries of long term natural cycles and processes acting on a watercourse. Any identified shift from "very low" to "low" or from "low" to "moderate", under a manmade change in flow depth could be generally reflective of an equivalent natural peak flow event that the system is already adjusted to (AquaLogic, 2011).

The methodology presented in this report is a desk top screening level review tool so the assessment is by no means an exhaustive review of all physical, temporal and unknown factors.



#### **REFERENCES**

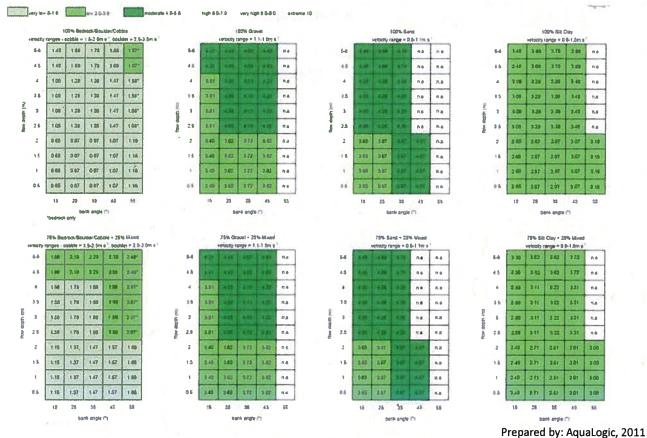
- 1. deGeus, B., 2011 Erosion Sensitivity Analysis Kapuskasing River Hydroelectric Candidate Sties Xeneca Power Development. AquaLogic Consulting
- 2. Ontario Ministry of Natural Resources. 2002. Natural Hazards Technical Guides; River and Steam Systems Erosion Hazard Limit Technical Guide.



# **ATTACHMENT 1**

Erosion Sensitivity Scores (2 pages)

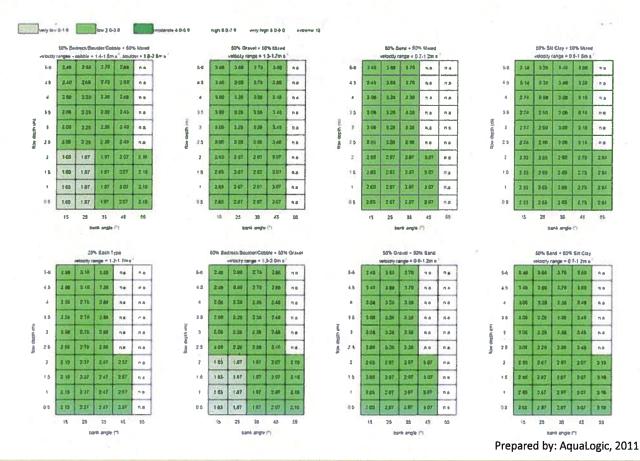




Trepared by: Aquatogic, 2011

Erosion Potential Assessment of Northern Ontario Waterpower Sites for Xeneca Power Development Inc., Wabageshik Rapids, Report #90881 (Revision 1) | Attachment 1





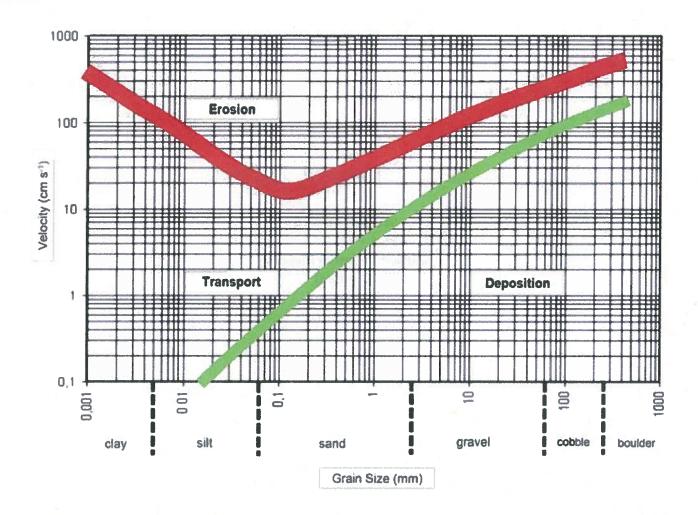
Erosion Potential Assessment of Northern Ontario Waterpower Sites for Xeneca Power Development Inc., Wabageshik Rapids, Report #90881 (Revision 1) | Attachment 1



# **ATTACHMENT 2**

Erosion Sensitivity – Hjulstrom Curve (1 page)







### **ATTACHMENT 3**

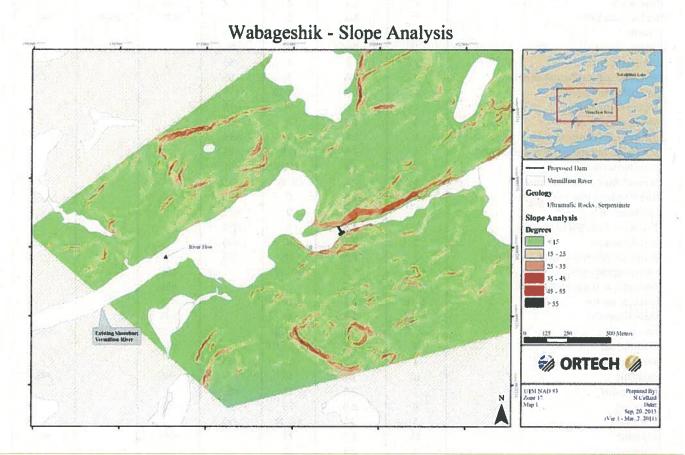
Erosion Potential Mapping (3 pages)



**Table A3: Project Site Surficial Geology and Erosion Potential** 

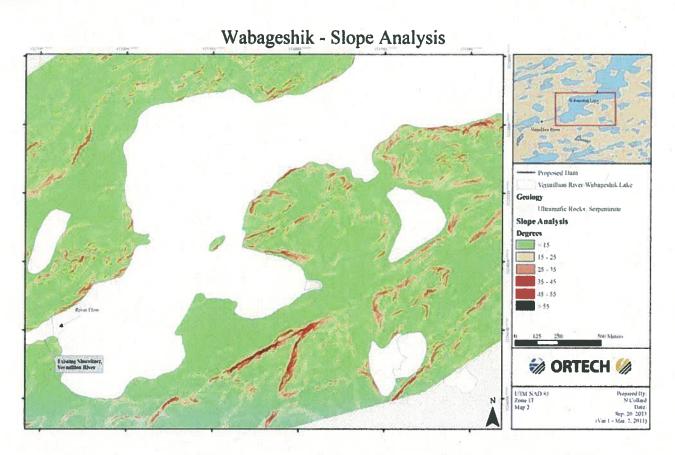
				Erosion Sensitivity at Flow Depth of 1m			
Geological Formation	Substrate Category	Upper Velocity Range (m/s)	Project Site#	Very Low	Low	<b>Mod</b> era <b>te</b>	Additional Analysis Required
Fluvial Gravel	2, 6	1.5	1, 2		<45		>45
Sand	3	1.1	1, 2		<25	25 - 45	>45
Bedrock	1	2.5	2, 13	<55			Transmitted to
Bog Deposits	7	1.1	2		<25	25-45	>45
Glacial Gravel	2, 6	1.5	2	= 2	<45		>45
Glacial Till	7	1.1	2		<25	ľ	
Ice Contract Drift	7	1.1	2		<25	25-45	>45
Granite	1 1	2.5	3	<55		1	
Gneiss	1	2.5	5	<55			
Ultramafic Rock	1	2.5	6	<55			
Volcanic, Sedimentary Material	1	2.5	7	<55			
Batholithic Intrusives	1	2.5	7, 8, 10	<55			
McKim Formation	1	2.5	7	<55			
Mississaji Quarizite	1	2.5	7	<55			
Ramsay Lake Conglomerate	1	2.5	7	<55			2
Schistified Volcanics, Clastic Sediments	1	2.5	7,8	<55			
Basic Intrusives	1	2.5	8, 10	<55			
Noritic "Basic Edge" Differentiate	1	2.5	8,9	<55			10
Nickel Bearing Irruptive	1	2.5	9	<55			
Onaping Tuff	1	2.5	9	<55			
Transition Zone (Tuff / Irruptive)	1	2.5	9	<55		Y <sub>0</sub>	
Schist Complex	1	2.5	10	<55		N 12	W III
Transition Material (Schist / Intrusives)	1	2.5	10	<55			
Glasiolacustrine Deposits	4, 16	1.5	12, 14		<55		
Glaciofluvial Outwash Deposits	4, 16	1.2	13	التخييب	<55	44	
Glaciofluvial Ice	4, 16	1.2	14		<55	en <sub>y</sub>	
Fluvial Deposits	4, 16	1.2	14	The Aspect	<55	giff a	
Beach	3,7	1.1	15, 18	TALL HIE	<25	25-45	>45
Cloustan Silt	4	1.5	15, 17, 18		<55		
Wadsworth Rock Upland	1	2.5	15	<55			
Drumlins	13	1.7	16		<45		>45
Hanging Cliff	1	2.5	16	<55			
Lisgar Silt	× 4	1.5	16		<55		
The Flutes	1	2.5	17, 18	<55			
Ablation	13	1.7	18		<45		>45
Allenby Lake Clay	4	1.5	18		<55		



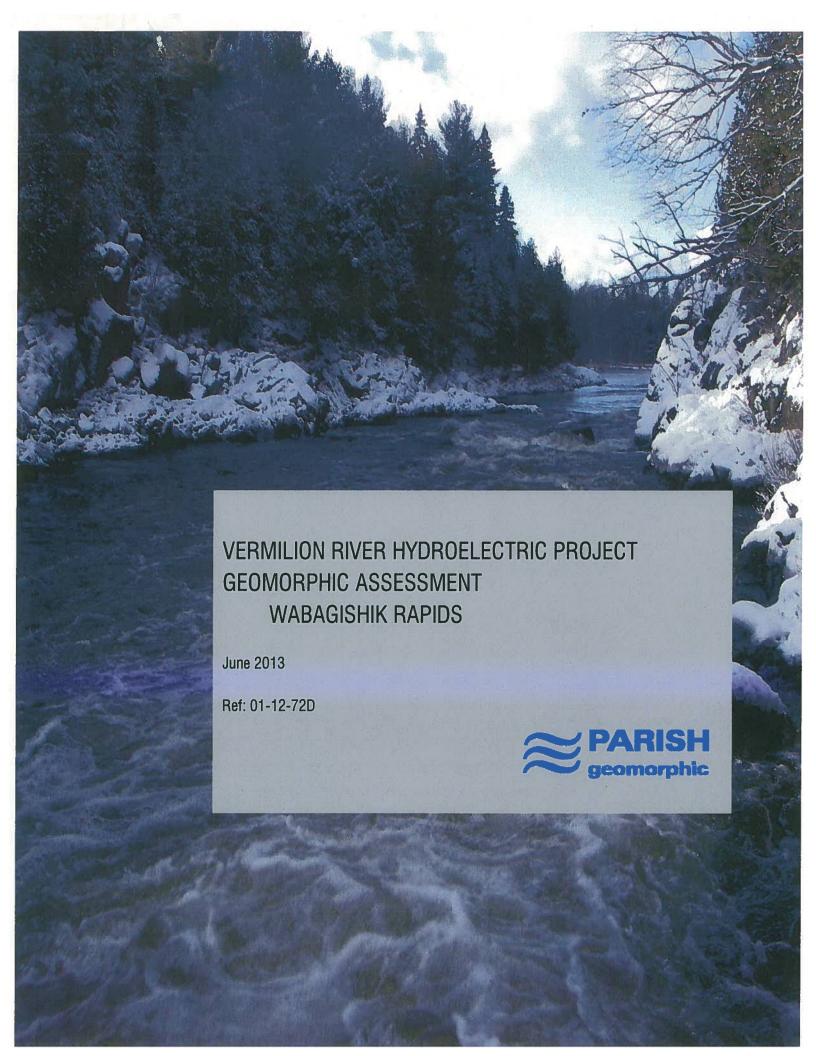


Erosion Potential Assessment of Northern Ontario Waterpower Sites for Xeneca Power Development Inc., Wabageshik Rapids, Report #90881 (Revision 1) | Attachment 3





Erosion Potential Assessment of Northern Ontario Waterpower Sites for Xeneca Power Development Inc., Wabageshik Rapids, Report #90881 (Revision 1) | Attachment 3







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# **Executive Summary**

Xeneca Power Developments, Inc. (Xeneca) proposes to develop a hydroelectric plant on the Vermilion River in Northern Ontario. As part of the Ontario Ministry of Natural Resources (MNR) and Fisheries and Oceans Canada permitting processes, Xeneca completed an extensive amount of work for an initial Environmental Assessment (EA), with the primary aim of addressing concerns over impacts to fish habitat within the system. Further review by the agencies indicated that fluvial geomorphic studies need to be included in the assessment, and therefore, Parish Geomorphic Ltd. (PGL) was retained to provide insight on channel processes along the river. Specifically, PGL's work focuses on determining and quantifying bank and bed erosion potential and general sediment transport associated with the dam site.

The surface geology along the Vermilion River through the development corridor is primarily an area of bedrock, while a mantle of ground moraine till with a thickness of generally less than 1 m commonly overlies the bedrock at some locations. This till is sandy to silty in texture and commonly contains cobbles, stones, and boulders. Organic deposits have accumulated in many poorly drained depressions in bedrock, ground moraine, and lacustrine terrain.

Tasks for this project included conducting a reach-based synoptic survey (Rapid Geomorphic Assessment) and collecting detailed cross section and sediment data to extend existing topographic data (e.g., Xeneca LiDAR and bathymetry) and assess potential sediment transport and bank erosion issues for the hydroelectric corridor. Sediment size distributions were characterized for existing Xeneca hydraulic modeling (HEC-RAS) cross-sections, PGL cross-sections, and exposed bars along the reach using a combination of Wolman (1954) pebble counts, Ponar sediment samples, and visual observations. The sediment data was combined with output from Xeneca's 1-D HEC-RAS hydraulic model to evaluate sediment entrainment potential along the study reaches.

Overall, the channel bed includes a large range of sediment sizes, with distributions being reach-dependent. The bed along study reaches that contained rapids consist of coarser material, primarily bedrock, boulders, and large cobbles. The finer material present in the system tends to accumulate in the backwater areas upstream and downstream of rapids, and in local areas of flow separation (i.e., eddies, mid-channel bars). A number of sand/gravel islands are located in a pool area immediately downstream of the rapids. Along the study area, the river appears to be quite stable. Very few signs of channel instability were observed during the field reconnaissance, and the RGA values suggest the channel is in "regime". The few eroding banks or lateral bars observed along the reach were localized issues, and not always directly related to channel dynamics.



Along the study reach of the river, the juxtaposition of on-line lakes/ backwater zones, and the steep rapids form a system of alternating transport-limited, and sediment limited reaches, where sand and gravel tends to be difficult to entrain in the backwater sections so that the rapids receive very little material and are left armored with bedrock, boulders and large cobbles that are difficult to move. The sand that does arrive at the rapids is either left in the lee of larger clasts or "piped" downstream to replace what little might be moving there.

During the data collection process, bank conditions were noted for most of the study reaches, including general vegetation cover, sediment composition, notable erosion scars, and other indicators of bank instability. Except for very localized issues, most of the banks in the study reach appeared to be stable. In the on-line lake areas, it is unlikely that hydraulic bank erosion activity is occurring.

The analysis results indicate that the development of the proposed hydroelectric dam at Wabagishik Rapids will likely only result in minor changes to the sediment dynamics within the river system. The backwater for the project will extend upstream from the dam to Lake Wabagishik, so at times there will be less energy to move sediment immediately upstream of the dam. In certain scenarios, this may result in deposition of material immediately upstream of the dam, however as the reach is currently sediment limited, this deposition is likely not have a major impact. Immediately downstream of the dam, the rapid section appears to be well armored and should be able to withstand the moderate flows supplied by the dam during operations and the bedrock and boulder-lined channel should maintain the overall existing geomorphology. The cobble island and bar formations immediately downstream of the rapids, and the sand/gravel/cobble island formations in the on-line lake further downstream of the rapids will not see a dramatic change in sediment supplied to, or eroded from the locations, however they may continue to adjust as was observed in the field outing.

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# 1. Introduction

Xeneca Power Developments, Inc. (Xeneca) proposes to develop a hydroelectric plant on the Vermilion River in Northern Ontario. As part of the Ontario Ministry of Natural Resources (MNR), Ontario Ministry of the Environment, and Fisheries and Oceans Canada permitting processes, Xeneca completed an extensive amount of work for an initial Environmental Assessment (EA), with the primary aim of addressing concerns over impacts to fish habitat within the system. Further review by the agencies indicated that fluvial geomorphic studies need to be included in the assessment, and therefore, Parish Geomorphic Limited (PGL) was retained to provide insight on channel processes along the river.

Specifically, PGL's work focuses on determining and quantifying bed and bank erosion potential and general sediment transport associated with the site. The idea was to create a basic sediment budget for each of the rivers, using a combination of previously conducted stream surveys, hydraulic modeling, and newly collected bed and bank sediment data, so that the proposed hydro plant's impact on river processes can be assessed. Additional work was done to help fill in gaps for the earlier EA study. The major aims of the study are defined below:

- Review previous documents, historical aerial photographs, and mapping (including previously collected bathymetry and LiDAR data). The review will focus on environmental setting and channel stability.
- Describe existing channel conditions in the vicinity of the proposed dam sites, including existing
  areas of channel or bank instability, or areas where potential issues may arise (i.e., major changes
  in bed material, bars, bank failures, etc).
- Collect sediment-size distribution data at established cross-sections (e.g., HEC-RAS stations) for channel characterization and entrainment/transport modeling.
- Add data to stage-discharge relationship curves, by collecting flow velocity data at stations where
  pressure transducers are currently monitoring flow stage (i.e., water surface elevation).
- Integrate the above information, as well as work previously completed for the EA, to assess possible impacts to the channel associated with the development project.



# 2. Background Information

# 2.1 Site Location

The proposed development on the Vermilion River, near Espanola, Ontario, is known as the Wabagishik Rapids Hydroelectric Project. The study area for the current investigation is between the Lorne Falls Generating Station approximately 12km upstream of the proposed development site and a set of rapids approximately 4km downstream of the site. **Figure 1** shows the location of the development.

### 2.2 **Proposed Conditions**

The Vermillion River dam site is located at bedrock/boulder rapids (Wabagishik Rapids), immediately downstream of the Lake Wabagishik outlet. A modified run-of-river generating facility has been proposed which involves modifying river flow at some times, while at other times allowing the facility to operate at the same rate as the natural flow in the river. The facility would modify the natural flow in the river by storing some of the natural river flow during low power-usage times and then release flows during hours when the need for electricity in the province is greater (modified peaking). A more detailed description of the development and its operation is provided in the proposed operating plan (Ortech Environmental, 2012).

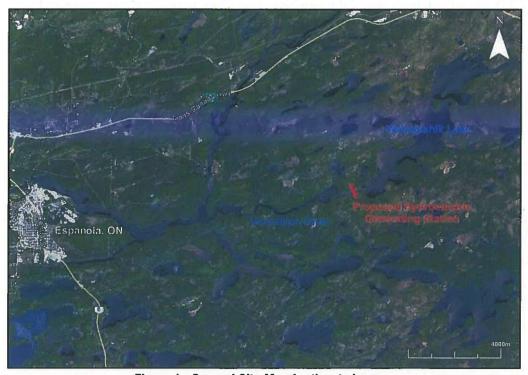


Figure 1. General Site Map for the study area.



### 2.3 Physiography

An engineering terrain map (Gartner, 1978; Figure 2) shows the generalized geology of the valley through the focus reach of the Vermilion River. Rock knobs are the dominant bedrock landform in the map-area. Relief on this landform is moderate and the topography is rugged. A mantle of ground moraine till commonly overlies the bedrock, with till thickness generally being less than 1 m on the crests of bedrock highs, but the thickness may increase to several metres on the flanks or between the highs. This till is sandy to silty in texture and commonly contains cobbles, stones, and boulders. Organic deposits have accumulated in many poorly drained depressions in bedrock, ground moraine, and lacustrine terrain. At the upstream end of the study area near Lorne Falls are glaciolactustrine lake plain deposits. In these areas, waters from a glacial lake washed the till from many of the bedrock highs and redeposited the materials as sand to sandy silt lacustrine plain sediments between the highs. Downstream of the rapids, on the southern shore of the bay-type feature there is organic terrain found. These are thick organic deposits that have accumulated in the depressions between bedrock knobs and in swales in ground moraine (Gartner, 1980).

#### 2.3.1 Previous Work

In order to provide a broader context for the fluvial geomorphology assessment, a background review of available resources was undertaken. The majority of existing documentation pertaining to the Vermilion River comes from the previous Environment Assessment work conducted by Xeneca (2011-2012). Additionally, a one-dimensional hydraulic model (HEC-RAS) and additional spatial data were also supplied by Xeneca to help complete the current study. A description of the data follows in the subsequent sections.

### 2.3.2 Bathymetric Data

Bathymetric survey data for the Vermilion River was obtained on October 28, 2010 and November 14, 2011 by BPR Engineering. River channel elevations were measured with a combination of total station/GPS surveys and sonar measurements while wading or boating. The data were collected at multiple cross sections along the channel, with tighter spacing at proposed dam sites, and additional data were collected between these cross sections.

#### 2.3.3 LiDAR Contour Information

A Light Detection and Ranging (LiDAR) survey was flown on November 15, 16, and 17<sup>th</sup> 2009 for the area 13.1km upstream and 1.4 km downstream of the proposed structure. This survey, performed by Terrapoint, was used to develop the elevations above the river level.



### 2.3.4 Existing Hydraulic Model

Xeneca's original HEC-RAS model started about 12km upstream of the proposed dam site and extended approximately 4km downstream of the site. The river reaches in the vicinity of the proposed hydropower development site were represented by a number of cross-sections; each section was based on a combination of a LiDAR (topography) survey for the overbanks and a bathymetry survey for the underwater geometry.

#### 2.4 Reach Delineation

Because channel materials, sediment inputs, valley types, and flow vary along a creek or stream, channels are often separated into segments, termed "reaches". Reaches comprise stream segments of similar form and function, ranging from several hundred to several thousand meters in length. For this assessment, reach breaks were primarily defined by the shear stress outputs (**Figure 2**) from the HEC-RAS model run at the 2-yr return interval peak flow (i.e., approximating bankfull). Proposed dam locations and general geomorphological changes also factored into the reach delineations. General channel parameters for each reach, taken from Geographic Information System (GIS) measurements and the HEC-RAS model, are listed in **Table 1**.

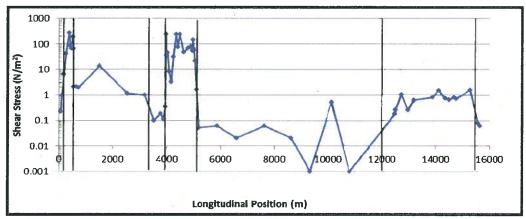


Figure 2. Reach delineation based on shifts in shear stress.



Table 1. General Geomorphic Characteristics of the Vermilion River Study Reaches

Reach	General Geomorphology	Stream Length (m)		
W1	Run	3500		
W2	Wabagishik Lake/ Backwater	6891		
W3	Wabagishik Rapids (Boulders)	1112		
W4	Lake/ Pool	798		
W5	Run	2599		
W6	Rapids (Boulders)	418		
W7	Lake/Pool	182		

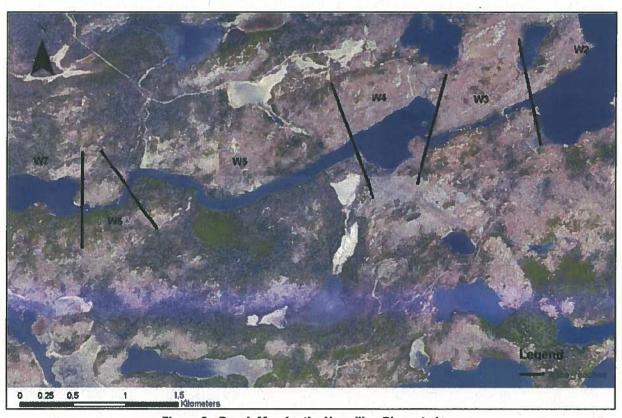


Figure 3. Reach Map for the Vermilion River study area



# 3. Field Assessment

In order to assess existing geomorphic conditions and document any evidence of channel instability, field reconnaissance surveys were conducted along the study section of the Vermilion River, from approximately 1km upstream of the proposed dam site to 4km downstream of the site. During the fieldwork, which was conducted in November, 2012, the focus reaches were canoed or walked and channel conditions and dominant processes were documented. Sediment and bank conditions were measured in detail at sites along the channel. The detailed sites were chosen to coincide with previously surveyed cross-sections used in the HEC-RAS model (i.e., bathymetry data), but also included additional cross sections and sediment measurements at bar features.

# 3.1 Rapid Assessment Methodology

### 3.1.1 Rapid Geomorphic Assessment

The Rapid Geomorphic Assessment (RGA) was designed by the Ontario Ministry of Environment (2003) to assess urban stream channels. It is a qualitative technique based on the presence/absence of key channel indicators of channel instability such as exposed tree roots, bank failure, excessive deposition, etc. The various indicators are grouped into four categories indicating a specific geomorphic process: 1) Aggradation, 2) Degradation, 3) Channel Widening, and 3) Planimetric Form Adjustment. Over the course of the survey, the existing geomorphic conditions of each reach are noted and the presence or absence of specific geomorphic indicators is documented. Upon completion of the field inspection, the indicators are tallied within each category and the subsequent results are used to calculate an overall reach stability index. This index corresponds to one of three stability classes representing the relative degree of channel adjustment and (or) sensitivity to altered sediment and flow regimes (**Table 2**).

Table 2: RGA Classification (Ontario Ministry of Environment, 2003)

Factor Value	Classification	Interpretation
≤0.20	In Regime or Stable (Least Sensitive)	The channel morphology is within a range of variance for streams of similar hydrographic characteristics – evidence of instability is isolated or associated with normal river meander propagation processes
0.21-0.40	Transitional or Stressed (Moderately Sensitive)	Channel morphology is within the range of variance for streams of similar hydrographic characteristics but the evidence of instability is frequent
≥0.41	In Adjustment (Most Sensitive)	Channel morphology is not within the range of variance and evidence of instability is wide spread



#### 3.2 Reach Characterization

#### 3.2.1 Reach descriptions

The delineated reaches cover approximately 16km of the Vermilion River (**Figure 3**). Reaches 3 to 6 were visited and documented as part of the November 2012 PGL field surveys. These reaches are described in **Table 1** and below, and **Appendix A** exhibits photographs taken during the field event.

#### Reach W3

The upstream limit of Reach W3 coincides with the transition where the on-line Wabagishik Lake outlets to the Vermillion River. This reach comprises the Wabagishik Rapids associated with the dam site and is primarily bedrock-controlled, especially towards the upstream end. The entire reach is confined by bedrock outcroppings and extends approximately 1100m prior to outletting to a secondary on-line lake, which defines the downstream reach limit. Channel bed sediment was comprised of coarse material throughout this reach and ranged from exposed bedrock, which was predominantly towards the upstream end, to large cobbles which were observed towards the downstream end. Minor evidence of channel-widening and degradation was observed; however the reach was deemed to be in a regime state. Cobble bar features are located at the downstream end of the reach, and appeared to be adjusting to flow during the field investigation.

#### Reach W4

Reach W4 is defined by a secondary on-line lake. Similar to Wabagishik Lake, this section of the Vermillion River serves as a sediment sink. Towards the upstream end, the reach is bounded by steep valley walls that generally consisted of sands, cobbles and boulders, while the banks along the bay-like area were predominantly comprised of sand and some coarser material. A number of depositional features were observed at the time of the survey, most notably some vegetated island features throughout the center of the Lake. These bar islands consisted of fine to coarse materials ranging from silts and sands to cobbles with some organics and were occupied by short to tall grasses and sparse woody shrubs (**Figure 4**). The channel thalweg favored the south-central portion of the lake; however, considerable depths were encountered throughout the entire feature. The reach did not display any significant erosion indicators and aggradation was observed as the primary geomorphic process.







Figure 4. Island formation in the lake downstream of Wabagishik Rapids.

#### Reach W5

Reach W5 extends approximately 2600m and is settled within a semi-confined valley setting. The entire reach is fairly straight, displayed consistent channel dimensions, and slower, backwatered flow. The channel is lined by coniferous and deciduous trees up to the edge of banks consistently throughout the reach. Banks were primarily comprised of fine to coarse sands, but also transitioned to localized bedrock outcrops. Samples of the channel bed revealed either fine silts and sands or coarse gravel. The reach did not show any major signs of instability, with the exception of some widening indicators. Channel widening was generally localized and was observed through fallen/leaning trees, occurrence of large organic debris, and exposed tree roots.

#### Reach W6

Reach W6 is signified by a second set of rapids. This section is fairly short, extending approximately 420m to a third on-line lake feature, which comprises reach W7. Reach W6 displays a marked decrease in channel width, affiliated with an increase in confinement and bedrock control. These conditions correspond to a notable change in channel hydraulics, transitioning from slower backwater in reach W5 to more turbulent flow with higher velocities. The banks through this section are dominated by boulders and bedrock outcroppings, the latter of which obstruct and divide flow near mid-reach (**Figure 5**). Channel depths increased significantly towards the downstream end of the reach, where the channel widens. Due to the bedrock channel boundary, this reach was essentially stable and in regime, with some minor evidence of channel-widening.



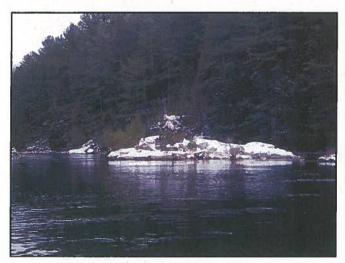




Figure 5. Bedrock outcrops in reach W6.

### 3.2.2 Rapid Assessment Results

**Table 3** provides results from the RGA surveys conducted along the Vermilion River study reach. They basically confirm the general site descriptions which suggested the channel throughout the study area is in regime (stable). The primary adjustment processes for W3, W5, and W6 were identified through the scoring as degradation and widening. For W3 and W6, which were both rapid sections, the presence of exposed bedrock would increase the degradation score, however these stable channel materials does not necessarily indicate an adjusting system. There were bedrock outcrops present at some locations along the channel in reach W5, however the relatively high widening score was a result of fallen/leaning trees, occurrence of large organic debris, and exposed tree roots.

**Table 3: RGA Results for the Vermilion River Study Reaches** 

	Factors							
Reach	Aggradation	Degradation	Widening	Planimetric	Stability Index	Condition		
W3	0.11	0.29	0.25	0.00	0.16	In Regime		
W4	0.33	0.00	0.00	0.14	0.12	In Regime		
W5	0.00	0.29	0.38	0.00	0.17	In Regime		
W6	0.11	0.14	0.25	0.00	0.13	In Regime		



#### 3.3 **Sediment Characteristics**

#### 3.3.1 Bed Material

Channel bed materials were characterized using a modified Wolman pebble count (Wolman, 1954) at Xeneca cross sections, channel bars, and areas of the bed exposed at low flow. In locations where flow depths were too deep or fast for safely wading the channel, sediment samples were collected with a Ponar sediment trap and/or estimated visually through the water and via general probing. Due to time constraints and access issues, sediment data for reaches W1, W2 (Wabagishik Lake), and W7 was not collected. **Figure 6** exhibits sampling locations, cross-sections, and reach breaks. Overall, the channel bed includes a large range of sediment sizes, with distributions being reach-dependent. The bed along study reaches that contained rapids consist of coarser material, primarily bedrock, boulders, and large cobbles. The finer material present in the system tends to accumulate in the backwater areas upstream and downstream of rapids, and in local areas of flow separation (i.e., eddies, mid-channel bars).

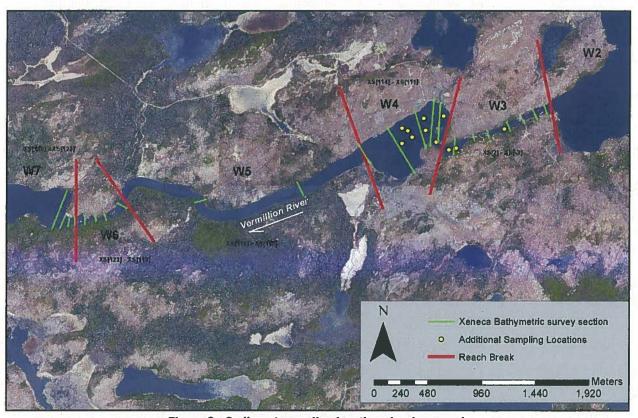


Figure 6: Sediment sampling locations by river reach



#### Pebble Count Data

Sediment distributions from pebble count data were obtained for cross sections in reaches W3 and W5. These distributions were obtained from physical counts of the channel bed in locations that it was accessible and does not include the pebble counts performed for bars/ islands located in the channel or in on-line lakes. For the study area, the pebble counts indicate an overall  $d_{16}$  of 45mm, a  $d_{50}$  of 76mm, and a  $d_{84}$  of 147mm (**Figure 7**).

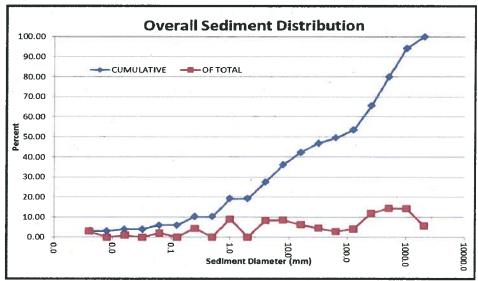


Figure 7: Overall combined sediment distribution for reaches W3 and W5

The differing nature of the reaches should be taken into account, however. For example, upon investigation of **Figure 8**, it is apparent that the distribution from W3 ( $d_{16}$ =90mm,  $d_{50}$ = 150mm,  $d_{84}$ = 284mm) is much greater than that obtained from cross sections in W5, a run reach ( $d_{16}$ =0.2mm,  $d_{50}$ = 2mm,  $d_{84}$ = 10mm). This is to be expected, as the channel at the high energy rapids section consists of much coarser material.



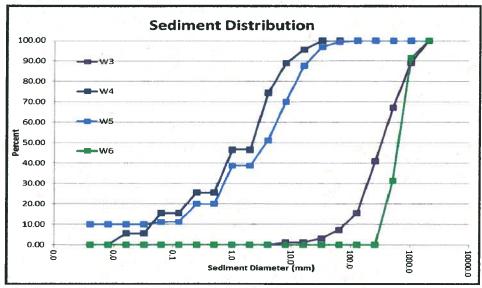


Figure 8: Sediment distributions for reaches W3 and W5

### Sediment characterization from pebble count data and observations

The distributions presented above that were obtained from pebble counts in R3 and R5 do not necessarily represent the overall sediment distribution for the study area as physical sampling was restricted in some areas due to accessibility and safety concerns. In some cases, pebble counts were performed only along the margin of the river, as the centre of the channel was not wadeable. In the circumstance that a Wolman pebble count wasn't performed, or a sample wasn't obtained using Ponar to perform a pebble count, other investigation methods were employed to characterize the sediment. This includes probing the channel bed in various locations, observing the substrate through the water from the surface, and evaluating photos in order to approximate the substrate sizes.

For W3, the pebble counts would likely underestimate the overall sediment distribution, as the river could only be traversed at specific sections, and those areas where the current was too fast were not accessed. Wolman pebble counts were performed at Xeneca cross sections [-3] and [-1], however it was noted that XS[-2], [0], [1], and [2] were primarily bedrock channel with some large boulders. As these cross sections did not have counts performed, the amount of bedrock and large boulders would not have been accounted for in the resultant distribution.

For W4, the depth and width of the on-line lake restricted the ability to perform counts, and at times it was difficult to obtain a sufficient sample size for a count using the Ponar equipment. Probing and visual observations revealed that the substrate in this reach primarily consisted of silt, sands, and some gravel. In the "bay area" along the right bank just downstream of Reach W3, a significant amount of organics and



wood detritus were found. The bars/islands in this reach that consisted of sediment ranging from sands to cobbles and small boulders will be discussed further in the following section.

In W5, a long backwatered reach, sediment samples were collected using Ponar across the channel at cross sections 115, 116, 117, and 118, and pebble counts were performed using the collected material. Bed materials were found to consist primarily of silt and sands, with some clay and gravel present. The distribution created from the pebble count data collected in this reach fairly accurately represents the bed materials present during the field outing.

Reach W6 is a second set of rapids along the study reach and contains coarser material and bedrock. Ponar sampling in this reach did not result in any material being collected as it was too large for the sampling apparatus. At the downstream end of the reach, where the river widens again, bedrock and boulders make up the substrate at XS[123]. A cross section in W7 was also investigated and Ponar samples across the section did not collect any material, it was visually observed that there was likely boulders and small cobbles in the vicinity. It is not believed that this would be representative of the entire W7 reach, because this coarser material is found directly downstream of the rapids.

#### Overall Bed Particle Size Distributions

In order to perform an erosion analysis for the study area, a more complete characterization of sediment size distributions for all of the reaches throughout the length of the channel is required. In order to characterize the sediment size distributions for each of the reaches, the available pebble count data was complemented by estimations through visual observations and via general probing that was performed between reaches W3 to W7. Due to time constraints and access issues, reaches W1 and W2 were not visited as part of the field program. Based on modeling observations, it was felt that the sediment conditions for the upstream reach W1 would be similar to the data collected for a run section (W5), and that the conditions in W2 would be similar to the smaller material collected in pool sections, although due to the size of the lake, there is likely some finer material present.

**Figure 9** provides a conceptual representation of the sediment gradation for the study area, indicating the overall  $d_{16}$ ,  $d_{50}$ , and  $d_{84}$  for each of the reaches. It can be observed that the much higher values for reaches W3 and W6 are indicative of the channel being primarily bedrock with boulders in those sections. Wabageshik Lake exhibits the lowest sediment size values as fine material is present.



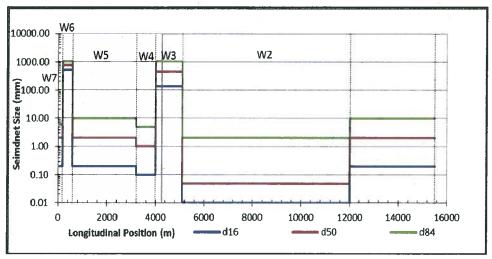


Figure 9: Determined  $d_{16}$ ,  $d_{50}$ ,  $d_{84}$  values for reaches W1 - W7

### Bar/ Island Pebble Particle Size Distributions

A number of Wolman pebble counts were also performed at bar or island features in reaches W3 and W4. Immediately upstream of the dam site (Xeneca XS-1), and also at the downstream end of reach W3 (between Xeneca cross sections 1 and 2), there are a number of island/ bar formations that consisted primarily of cobbles, with the counts resulting in a  $d_{50}$  of 150 mm (**Figures 10 and 11**).

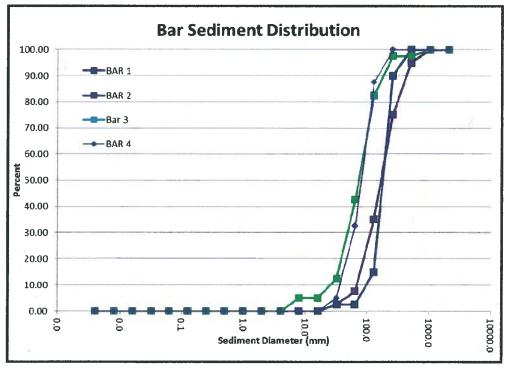


Figure 10: Bar sediment size distributions Reach W3





Figure 11: Looking downstream from Xeneca XS-2 cobble – cobble bar along right bank

In the pool area downstream of the rapids (Reach W4), pebble counts indicate the presence of islands consisting primarily of gravel with an overall  $d_{50}$  of 30 mm (**Figure 12**). It should be noted, however, that due to the presence of snow, pebble counts may have been concentrated along the perimeter of the islands where there is larger material. Field observations indicate that many of the islands in the pool area consist of sands (medium to coarse) with gravel (**Figure 13**).



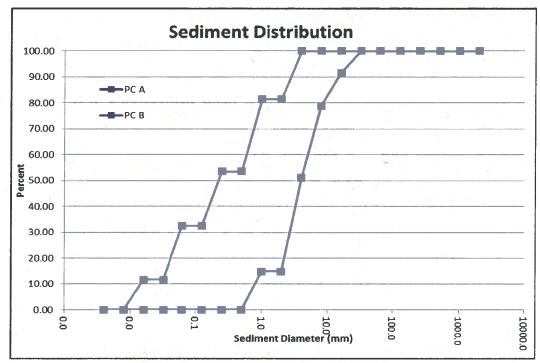


Figure 12: Bar sediment size distributions Reach W3



Figure 13: Sand-sized sediment in pool (Reach W4) downstream of Wabagishik Rapids



# 4. Analysis

The primary goal of the Wabagishik Rapids Geomorphic Assessment is to provide an idea of how channel form and function operate under existing conditions and how they may change once the dams are operational. The existing conditions have largely been documented in the previous sections, and these data were used to address sediment transport issues along the study sections, including estimating entrainment thresholds.

# 4.1 Channel Hydraulics

In order to begin an analysis concerning the bed erosion potential for the study area, an understanding of the flow characteristics in the channel is required. **Table 3** provides output from the Xeneca HEC-RAS model (CPL, 2012) at the estimated 2-yr return interval flow of 200cms. This flow will be used to approximate bankfull flow in the absence of detailed field surveys. As might be expected, the rapid reaches (W3 and W6) have orders-of-magnitude higher shear stress values than the backwater reaches, and significantly higher velocities.

	Flow Area	Top Width	Hydr Depth	Hydr Radius	E.G. Slope	Vel Chnl	Shear Chnl	Q Total
	(m <sup>2</sup> )	(m)	(m)	(m)	(m/m)	(m/s)	(N/m²)	$(m^3/s)$
W1	910	198	4.7	4.6	0.00002	0.28	0.7	200
W2	3975	797	5.0	5.0	0.00000	0.09	0.1	200
W3	111	61	1.8	1.7	0.00604	2.27	85.7	200
W4	1415	380	3.7	3.7	0.00001	0.15	0.2	200
W5	390	105	4.3	4.1	0.00012	0.61	3.7	200
W6	103	49	2.1	1.9	0.00727	2.37	104.6	200
W7	1304	190	7.0	6.6	0.00001	0.22	0.4	200

Table 3: Reach averaged volumes from the HEC-RAS model run at the 2-yr flow (~bankfull).

#### 4.2 Bed Erosion

In essence, an erosion threshold analysis determines the hydraulics, such as discharge, channel depth, or average channel velocity, at which the channel produces enough shear stress to initiate the mobilization of sediment of a given size  $(D_{crit})$ . The analysis also helps evaluate a reach's erosion sensitivity by comparing the boundary shear stress associated with modeled flows to the critical shear stress required to entrain sediment. The HEC-RAS model output and reach averaged sediment data can be used to compare shear stress along the channel and the stress required to move sediment of a certain size. In **Figures 14-17**, the dimensionless shear stress  $(\tau^* = \tau/((\rho_s - \rho_w)gD))$  of the channel for a given sediment size (red/blue lines) is compared to the critical dimensionless shear stress (Shield's Number set to 0.045) altered by the Parker hiding function,  $(\tau^*_{crit} = 0.045(D_i/D_{50})^{-0.85})$ ; black line). The hiding function accounts for the effect of larger



clasts on the entrainment of smaller clasts (e.g., sand can "hide" in the lee of larger cobbles and boulders). Where the colored lines are higher than the black line, clasts of the given size will likely be moved by the flow; where the colored lines are less than the black line the sediment will likely not move.

The results indicate that for both existing and project conditions, medium sand (0.5 mm) may be entrained along Reach W1, W2, and W5 under exiting bankfull conditions (~200 cms). Under more moderate flows (47cms), moving sand is difficult and only occurs along Reach W5 for both existing and project conditions (Figures 14A and 14B).

At 200cms, the entrainment relationships predict gravel (8 mm and 24mm) entrainment in W1, W2, and W5 (**Figures 15A, 15B, 16A, 16B**). At 47cms, very little gravel entrainment occurs along the study area under either existing or project conditions, aside from along reach W5. As gravel sized particles were prevalent in the pool downstream of the rapids (Reach W4), it follows that gravel would not be entrained in this area.

**Figure 17A** illustrates the potential entrainment of very fine sand (0.0625 mm). It indicates that under bankfull flows it can be entrained in all of the reaches upstream of the rapids, under both existing and operating conditions. At the rapids however, there is increased capacity to transport the fines under existing conditions compared to proposed operating conditions, however the difference appears to be minor. There is considerable entrainment potential in reach W5 for fine sand. Under long-term average flow (**Figure 17B**), for both existing and proposed conditions, the fine sand will be entrained only in reach W5.



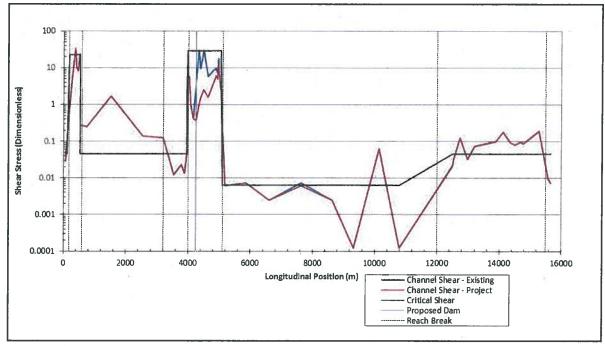


Figure 14A. Comparison of channel shear stress and critical shear stress for 0.5mm sand at 200cms.

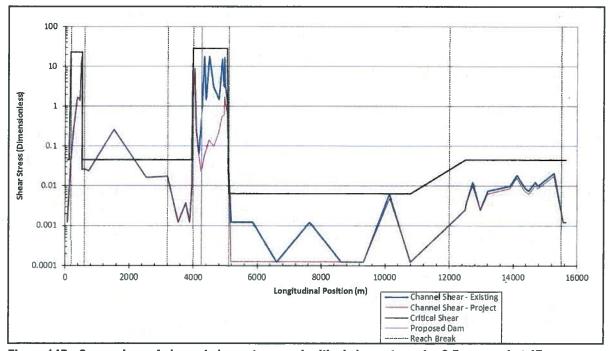


Figure 14B. Comparison of channel shear stress and critical shear stress for 0.5mm sand at 47cms.



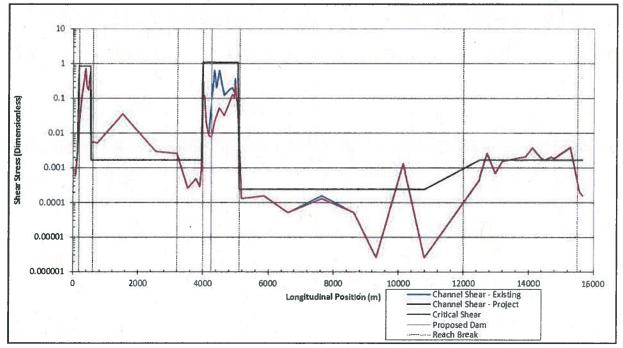


Figure 15A. Comparison of channel shear stress and critical shear stress for 24mm gravel at 200cms.

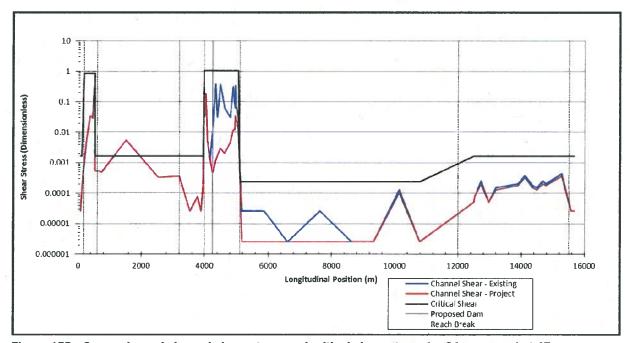


Figure 15B. Comparison of channel shear stress and critical shear stress for 24mm gravel at 47cms.



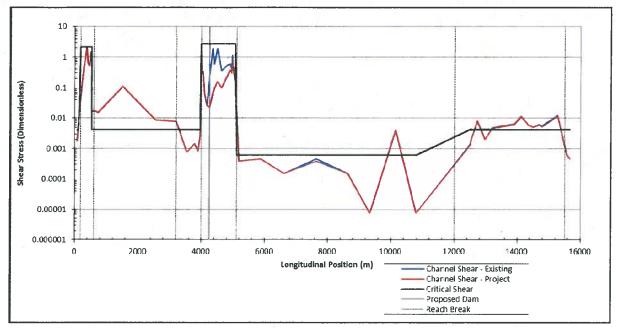


Figure 16A. Comparison of channel shear stress and critical shear stress for 8mm gravel at 200cms.

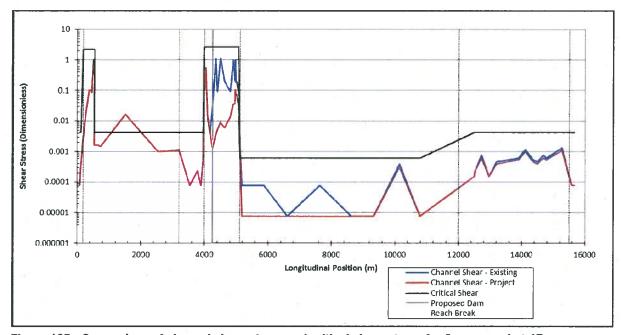


Figure 16B. Comparison of channel shear stress and critical shear stress for 8mm gravel at 47cms.



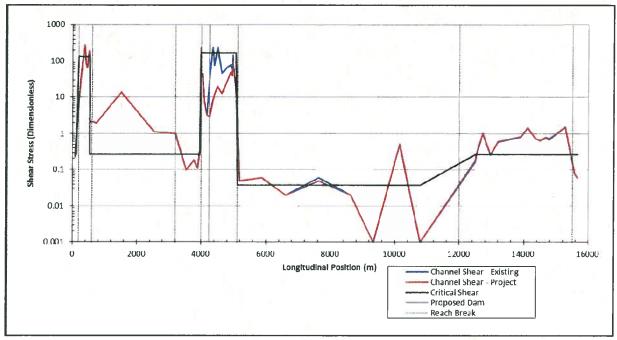


Figure 17A. Comparison of channel shear stress and critical shear stress for 0.0625mm sand at 200cms.

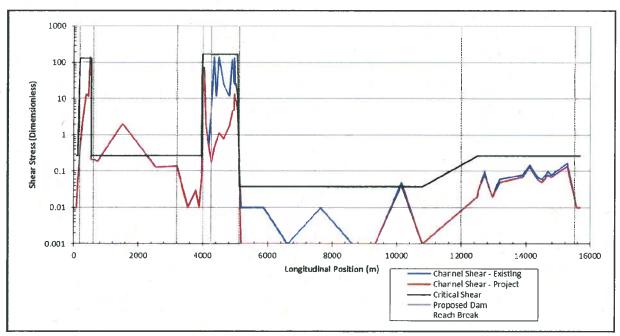


Figure 17B. Comparison of channel shear stress and critical shear stress for 0.0625mm sand at 47cms.



#### 4.3 Bank Erosion

During the data collection process, bank conditions were noted for most of the study reaches, including general vegetation cover, sediment conditions, notable erosion scars, and other indicators of bank instability. Except for very localized issues, most of the banks in the study reach appeared to be very stable with mature vegetation (trees and shrubs) lining both sides of the channel. At rapids sections and along sections of the channel further downstream, the banks were bedrock and/or boulders, and are more resistant to hydraulic and geotechnical erosion. One area that was noted for minor erosion is along the right bank in Reach W5, where some bank slumping and fracture lines were observed, as well as leaning and falling trees (**Figure 18**). There are a number of bedrock outcrops along the channel, and they are not restricted to rapids sections. Outcrops are particularly prevalent in locations where the channel narrows, such as towards the downstream end of reach W5.



Figure 18: Fallen/leaning trees at XS116

The fluctuation of daily water levels upstream of the proposed dam can increase the amount of shoreline erosion that would occur without modified operation. While a small amount of shoreline erosion occurs naturally in the river, accelerated and persistent shoreline erosion is undesirable. For the Wabagishik Rapids development, fluctuation of water levels in the backwatered section of the river upstream of the dam will likely not have an impact on bank stability due to the presence of stable bedrock that lines the channel in this area.



# 5. Conclusions

The proposed Wabagishik Rapids hydroelectric development is situated immediately downstream of Lake Wabigishik, near Vermilion, Ontario. It is the first set of rapids along the Vermilion River downstream of the Lorne Falls Generating Station. A study of the Vermilion River upstream and downstream of the rapids indicates that the river appears to be quite stable along the corridor. Very few signs of channel instability were observed during the field reconnaissance, and the RGA values calculated for the visited reaches suggest that the channel is in "regime" and stable.

The stretch of river studied during the investigation consists of on-line lakes connected by sections of rapids and backwatered channels. This has produced a system that alternates between transport-limited and sediment-limited reaches. Sand and gravel tends to be difficult to entrain in the backwater sections, which results in very little material being supplied to the rapids. These rapid sections are therefore left armored with bedrock, boulders, and large cobbles that are difficult to move. The sand that does arrive at the rapids is either left in the lee of larger clasts or "piped" downstream to replace what little might be moving there.

During the data collection process, bank conditions were noted for most of the study reaches, including general vegetation cover, sediment composition, notable erosion scars, and other indicators of bank instability. Except for very localized issues, most of the banks in the study reach appeared to be stable. In the on-line lake areas, it is unlikely that hydraulic bank erosion activity is occurring.

Construction of the hydroelectric development at Wabagishik Rapids appears to result in minor changes in the existing sediment erosion and transport dynamics of the system. The backwater range of the project will extend upstream from the dam to Lake Wabagishik, so at times there will be less energy to move sediment immediately upstream of the dam. In certain scenarios, this may result in deposition of material immediately upstream of the dam, however as the reach is currently sediment limited, this deposition is likely not have a major impact.

Immediately downstream of the dams, the rapids sections appears to be well armored and should be able to withstand the moderate flows supplied by the dam during operations and the bedrock and boulder-lined channel should maintain the overall existing geomorphology. The cobble island and bar formations immediately downstream of the rapids, and the sand/gravel/cobble island formations in the on-line lake downstream of the rapids will not see a dramatic change in sediment supplied to, or eroded from the locations, however they may continue to adjust as was observed in the field outing.



The fluctuation of daily water levels (+/- 5cm) upstream can increase the amount of shoreline erosion that would occur without modified operation. While a small amount of shoreline erosion occurs naturally in the river, accelerated and persistent shoreline erosion is undesirable. For the Wabagishik Rapids development, fluctuation of daily water levels in the backwatered area upstream of the dam will likely not have an impact on bank stability due to the presence of bedrock lined channel in the backwatered zone.

Although it appears that the current channel is stable and that the development of a generating station at the Wabagishik Rapids is unlikely to greatly alter the sediment dynamics in the system, it is important to continually evaluate potential risks. A monitoring program, which includes the establishment of control and monitoring sections, should be developed. The monitoring program is designed to validate channel dynamics, provide long-term insight into channel processes, and allow for the evaluation of channel performance and to quantify channel migration.



# References

Chow, VT. 1959. Open Channel Hydraulics. McGraw Hill, Boston, MA. 680pp.

Canadian Projects Limited. 2012. Ontario South Hydro HEC-RAS Inundation Mapping Vermilion River – Wabageshik Rapids. Submitted to Xeneca Power Development.

Galli, J., 1996. *Rapid stream assessment technique, field methods*. Metropolitan Washington Council of Governments. 36pp.

Gartner, J.F. 1980. Espanola Area (NTS 411/SW), Districts of Manitoulin and Sudbury; Ontario Geological Survey, Northern Ontario Engineering Geology Terrain Study 99, 14p. Accompanied by Map 5002, scale 1:100 000.

Gartner, J.F. 1978. Northern Ontario Engineering Geology Terrain Study, Data Base Map, Espanola. Ontario Geological Survey, Map 5002. Scale 1:100 000.

Hatch, 2009. Vermilion Hydropower Sites Hydrology Review. Project Report for Xeneca Power Development Inc.

Ministry of the Environment. 2003. Stormwater Management Planning and Design Manual, Ontario Ministry of Environment, March 2003.

Ortech Environmental. 2012. Proposed Operating Plan and Water Management Plan Amendment – Wabageshik Rapids Small Waterpower Project (Draft). Submitted to: Xeneca Power Development Inc.

Wolman, M.G. 1954. A method of sampling coarse bed material. Transactions of the American Geophysical Union, 35(6): 951-956.

# **Appendix A: Photo Summary**



**Photo 1:** Reach 2 – Looking upstream towards Lake Wabageshik from XS[-3]

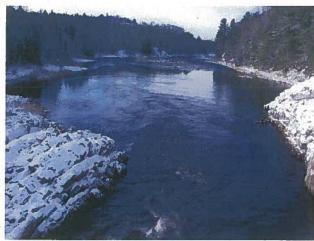


Photo 2: Reach 3 – Looking downstream from snowmobile bridge, XS[-2]



Photo 3: Reach 3 – Looking downstream from cobble/boulder bar at XS[-1]

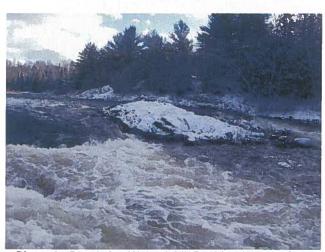
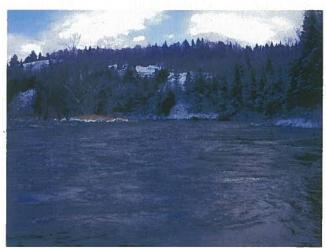


Photo 4: Reach 3 - Wabagishik Rapids, Xeneca XS[0]



**Photo 5:** Reach 4 – In pool area below rapids, looking along right bank – note island on left



Photo 6: Reach 4 - Looking downstream from an island



Photo 7: Reach 4 - Right bank in pool area



Photo 8: Reach 5 – Looking downstream from XS115



Photo 9: Reach 5- Bank conditions XS116



Photo 10: Reach 5 – Looking downstream at channel narrowing/ bedrock outcrops, XS 117



Photo 11: Reach 5 – General bank conditions – note bedrock outcrops



Photo 12: Reach 5/6 - XS118



Photo 13: Reach 6 – Looking upstream at XS119



Photo 14: Reach 6 - XS120



Photo 15: Reach 6 - Looking upstream at XS121



Photo 16: Reach 6 - Looking upstream XS123



Photo 17: Reach 5 - bank conditions XS123



Photo 18: Reach 7 – Looking downstream from XS123



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# <u>Initial Environmental Sound Study</u> <u>Wabagishik Hydro-Power Plant, Espanola, Ontario</u>

As requested, HGC Engineering has conducted an initial acoustical analysis of the proposed Wabagishik Hydropower Development, near Espanola, Ontario. As the project is at the Environmental Assessment stage, and detailed design has not yet been completed, the analysis used predicted sound emission levels and acoustical modeling to assess the potential impact of a single electrical transformer associated with the proposed site, with respect to the guidelines of the Ontario Ministry of Environment ("MOE").

In Ontario, the guidelines of the MOE form the basis of an environmental noise assessment, specifically publications NPC-205, Sound Level Limits for Stationary Sources in Class 1 and Class 2 Areas (Urban), and NPC-232, Sound Level Limits for Stationary Sources in Class 3 Areas (Rural). The area surrounding the proposed facility is likely best categorized as a Class 3 environment, due to its remote location and the absence of human development or roadways. For equipment that could operate during both daytime and nighttime hours in a Class 3 environment, the "exclusionary minimum" limit is 40 dBA at any sound sensitive points of reception in the vicinity. Additionally, some types of sound have a special quality which may tend to increase their audibility and potential for disturbance or annoyance. For tonal sound, such as that typically emitted by electrical transformers, the MOE guidelines stipulate that a penalty of 5 dBA is to be added to the measured source level. In the subsequent analysis, a tonal penalty has been applied to the sound of the transformer.

Xeneca has identified three sound sensitive points of reception (private cottages) within 1000 metres of the facility, as part of their preliminary feasibility work. Therefore, the predicted sound emissions have been assessed at these locations, and are labelled as POR1 through POR3.

The only source anticipated to emit sound to the outdoors at the facility will be a small, oil filled transformer with a capacity of approximately 3.27 Megawatts (3.92 MVA), with integral cooling fans. The location of the transformer will be within 30 metres of the proposed powerhouse, and has been assumed to be as depicted in Figure 1. The sound power emission level of the transformer, which was calculated to be 88 dBA [Ref. 1] including the 5 dBA tonal penalty, was input into a predictive computer model (Cadna-A version 4.3.143). The model is based on the methods from ISO Standard 9613-2.2 "Acoustics - Attenuation of Sound During Propagation Outdoors", which accounts for the reduction in sound level with distance due to geometrical spreading, air absorption, ground attenuation and acoustical shielding by intervening structures (or by topography and foliage where applicable). Ground attenuation was assumed to be spectral for all sources, with a ground factor (G) of 1.0 assumed globally, representing soft ground. For bodies of water, the ground factor was assumed to be 0, representative of a reflective surface. Foliage was conservatively not accounted for in the acoustical model, as some may be removed during the construction of the hydropower facility, the extent of which is not known.







Table 1, below, summarizes the total predicted sound levels at the points of reception, given the modeling assumptions outlined above, along with the applicable sound level limits.

Table 1: Predicted Equivalent Hourly Sound Levels, LEQ [dBA]

Point of Reception	MOE Sound Level Limit	$L_{EQ}$
POR1 (230m From Transformer)	40 dBA	28 dBA
POR2 (490m From Transformer)	40 dBA	21 dBA
POR3 (600m From Transformer)	40 dBA	21 dBA

The prediction results presented in Table 1 indicate that the sound levels from the proposed Wabagishik Hydropower Development will be well within the applicable MOE sound level limits at the nearest sound sensitive points of reception, without the need for physical noise control measures. Figure 1 shows the predicted energy-equivalent ( $L_{\rm EQ}$ ) sound level contours resulting from the sound emissions of the proposed facility.

Given that the specific make and model of the transformer has not yet been selected, its sound power emission level was a prediction based on its MVA rating. In order to ensure that the selected transformer is not louder than assumed in this analysis, it should be selected during the project design to have an IEC/IEEE/NEMA/CSA sound pressure level rating of 62 dBA.

#### REFERENCES

[1] Malcom J. Crocker (Editor), *Encyclopedia of Acoustics*. John Wiley & Sons, Inc. New York, 1997. p. 1050 & 1052.





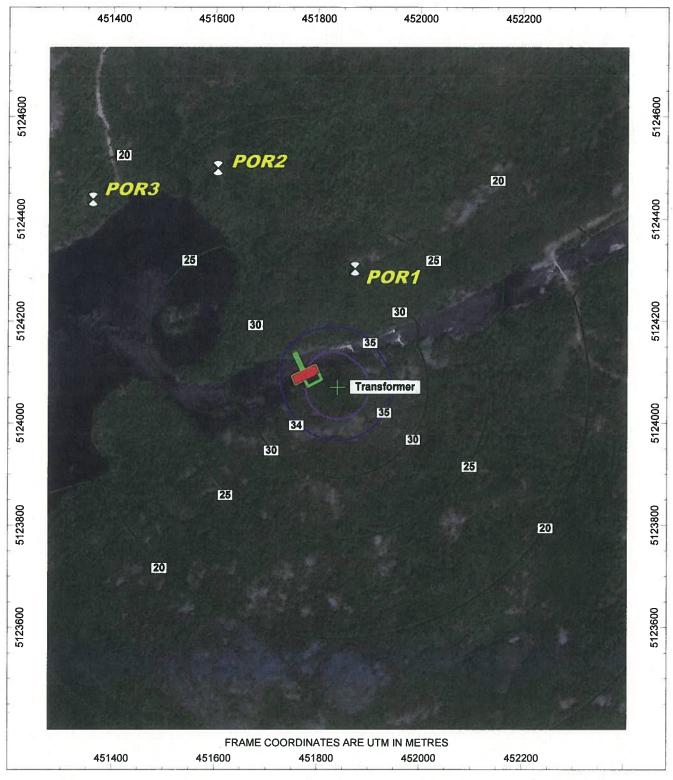


Figure 1: Predicted Sound Level Contours, Leq [dBA] Wabagishik Hydropower Development Prediction Height = 4.5 Metres Above Grade





