LOWER CHURCHILL PROJECT

MUSKRAT FALLS WATER LEVEL SURVEY AND RATING CURVES UPDATE

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SIGNATURE
12 Apr 2013
DATE
NEWFOUNDLAND & LABRADOR

PROVINCE OF NEWFOUNDLAND AND LABRADOR
PEGA Newfoundland and Labrador
PERMIT HOLDER
This Permit Allows
SNC-LAVALIN INC.
To practice Professional Geoscience in Newfoundland and Labrador.
Permit No. as issued by PEGNL N0458
which is valid for the year 2013

REVISION LIST

Revision					Remarks
N°	By	Chec	Appr.	Date	
00	SW	DD	GS	12-Apr-2013	Issued for use.
PA	SW	DD	GS	21-Mar-2013	Issued for internal review.

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REFERENCES

Ref. No.

1 *Tail Water Rating Curve Analyses*, SNC-Lavalin Inc., June 2012 (SLI No. 505573-3001-4HER-0023_00 – Nalcor No. MFA-SN-CD-2000-CV-RP-0005-01 Rev. B1)

2 *Parrott Survey Report*, N.E. Parrott Surveys Ltd., September 2012

EXECUTIVE SUMMARY

A water level survey was carried out at Muskrat Falls and Water Survey of Canada (WSC) Station 03OE014 – Churchill River 6.15 km Downstream of Muskrat Falls. The measurements were taken on two occasions, August 14, 2012 and on October 19, 2012, during different river discharges. The corresponding river flows during these periods were 1,200 m³/s and 1,640 m³/s, respectively. Based on the measured water levels, the open water rating curves for natural conditions above the falls, between the falls and downstream the falls were updated. The results are presented in Figure 0-1 below:

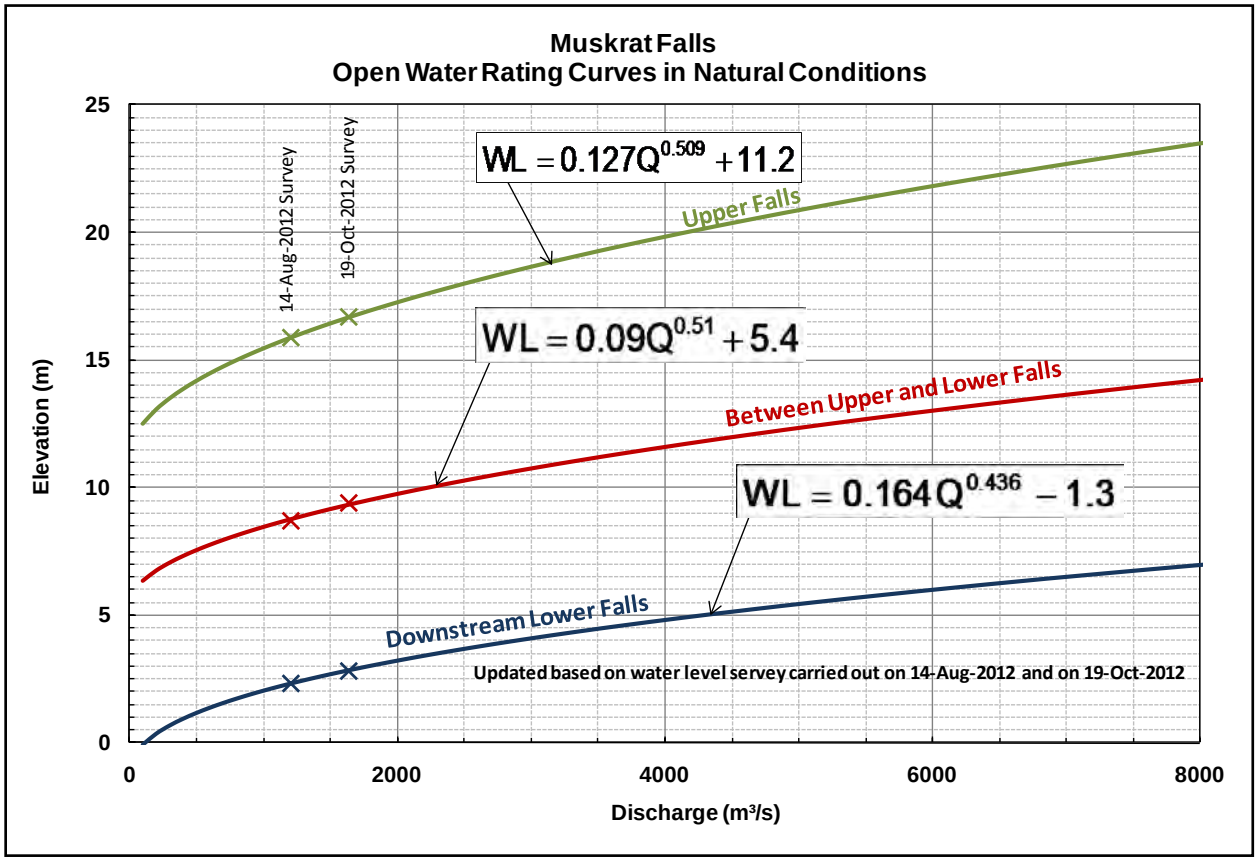


Figure 0-1: Final Muskrat Falls Open Water Rating Curves in Natural Conditions

It is recommended that additional water level surveys be carried out in the future, particularly during high flows in open water conditions. Such conditions may be observed during spring when the river is free of ice and snow melt generates spring inflows greater than 2,000 m^3/s.

1 INTRODUCTION

SNC-Lavalin Inc. (SLI) has signed an agreement with Nalcor Energy-Lower Churchill Project (NE-LCP) to deliver engineering services for the Lower Churchill Project (LCP) in Newfoundland and Labrador, Canada.

As part of the LCP, the Muskrat Falls Hydroelectric Development is located on the Churchill River, about 291 km downstream of the Churchill Falls Hydroelectric Development, which was developed in the early 1970's. The installed capacity of the project will be 824 MW (4 units of 206 MW each).

It was recommended in the Tail Water Rating Curve Analyses report (SLI No. 505573-3001-4HER-0023_00 – Nalcor No. MFA-SN-CD-2000-CV-RP-0005-01 Rev. B1) to undertake water level measurements in the downstream pool of Muskrat Falls in order to validate the open water rating curve found and to confirm the geodetic datum at the installed hydrometric stations. In the summer 2012, NE-LCP contracted N.E. Parrott Surveys Ltd. (Parrott) to conduct a water level and bench mark survey on the Lower Churchill River near Muskrat Falls.

The following report presents the results of the survey and the associated revisions to the open water rating curves at Muskrat Falls during natural conditions. During the winter season, the water levels downstream of Muskrat Falls are effected by an ice cover that forms. For rating curves during the winter season please refer to reference 1 in the list of references.

2 OBJECTIVES

The objectives of this report are to:

- Present the results of the water level and bench mark survey by Parrott; and
- Present the rating curves for Muskrat Falls updated based on the results of the survey.

3 SCOPE

The scope of this report is to document the results of the water level and bench mark survey at Muskrat Falls carried out by Parrott in 2012 and the resulting updates to the Muskrat Falls rating curves.

4 WATER LEVEL AND BENCH MARK SURVEY

Two surveys were carried out by Parrott on separate occasions at different river flows. The first survey took place on August 14, 2012 at a river discharge of approximately 1,200 m³/s. The results were as follows:

Table 4-1: Parrott Water Level and Bench Mark Survey Results August 14, 2012

No.	Northing (m)	Easting (m)	Elev. (m)	Description	Local Time
1	5901846.06	648930.058	8.661	WATER LEVEL SC2	AUGUST 14 11:36am
2	5901827.159	648879.287	8.683	WATER LEVEL SC2	AUGUST 14 11:39am
3	5901782.888	648771.786	8.712	WATER LEVEL SC2	AUGUST 14 11:44am
4	5902195.654	647795.363	15.882	WATER LEVEL SC1	AUGUST 14 12:12pm
5	5901681.271	649756.576	2.318	WATER LEVEL SC3	AUGUST 14 1:51pm
6	5901706.579	649720.393	2.319	WATER LEVEL SC3	AUGUST 14 1:54pm
7	5901785.609	649637.177	2.289	WATER LEVEL SC3	AUGUST 14 1:59pm
8	5901220.497	655113.837	2.296	WATER LEVEL SC4	AUGUST 14 2:52pm
9	5901900.172	649285.116	13.552	BM-1	-

The second survey took place on October 19, 2012 at a river discharge of approximately 1,640 m³/s. The results for that survey were as follows:

Table 4-2: Parrott Water Level and Bench Mark Survey Results October 19, 2012

No.	Northing (m)	Easting (m)	Elev. (m)	Description	Local Time
1	5901842.29	648931.643	9.4165	WATER LEVEL SC2	OCTOBER 19 12:47pm
2	5901822.4895	648880.4835	9.365	WATER LEVEL SC2	OCTOBER 19 12:52pm
3	5901782.09	648771.285	9.412	WATER LEVEL SC2	OCTOBER 19 12:56pm
4	5902193.08	647792.8965	16.691	WATER LEVEL SC1	OCTOBER 19 2:04pm
5	5901681.1315	649755.0055	2.8325	WATER LEVEL SC3	OCTOBER 19 2:22pm
6	5901696.925	649720.611	2.796	WATER LEVEL SC3	OCTOBER 19 2:21pm
7	5901784.6095	649635.701	2.7925	WATER LEVEL SC3	OCTOBER 19 1:22pm
8	5901217.1815	655113.1215	2.779	WATER LEVEL SC4	OCTOBER 19 2:38pm

It should be noted that the coordinates shown in Table 4-1 and Table 4-2 were obtained during the surveys and are referenced to control monument 98G9100 (BM-1). Coordinates are 6 degree UTM Zone 20 NAD83. The approximate locations of SC-1, SC-2, SC-3, SC-4 and BM-1 can be seen in Figure 4-1. For a more detailed description of the survey equipment utilized and the water level observation methods, please refer to the Parrott survey report located in Appendix A.

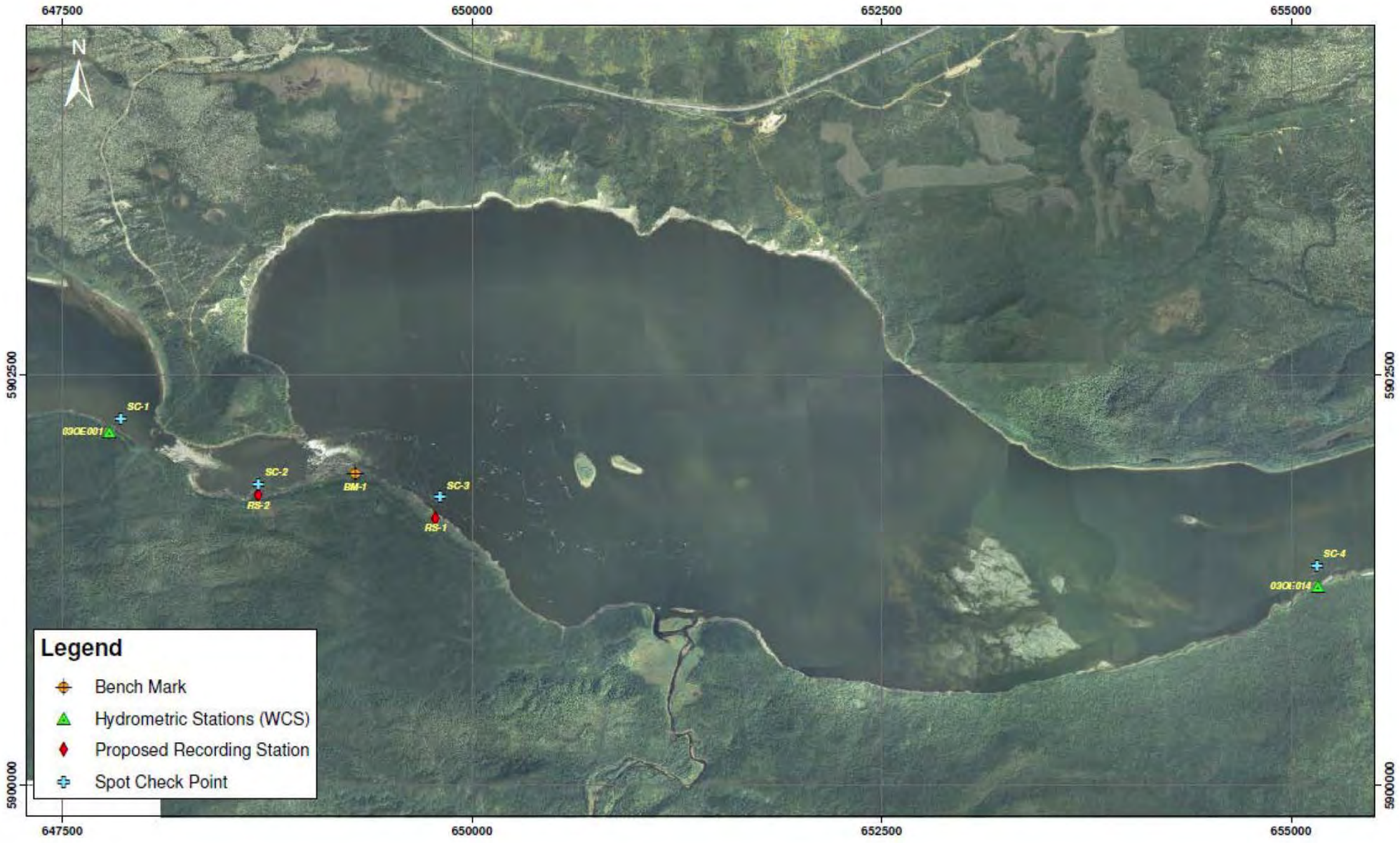


Figure 4-1: Approximate Locations of Bench Marks, Hydrometric Stations and Spot Check Points for the 2012 Parrott Surveys

5 ANALYSIS OF RESULTS

The open water rating curves for Muskrat Falls were established based on historical information of flow and water level recorded at the WSC Hydrometric Stations located in the area as well as information from surveys carried out over the years. Information from Station 03OE001 – Above Upper Muskrat Falls was used to develop the rating curve for above the upper falls. Information from Station 03OE005 – Between Upper and Lower Muskrat Falls was used to develop the rating curve for between the falls. Information from Station 03OE007 – At the Foot of Lower Muskrat Falls along with Station 03OE004 – Below Muskrat Falls and Station 03OE014 – 6.15 km Below Lower Muskrat Falls were all used to develop the rating curve for below lower Muskrat Falls. The locations of the Hydrometric Stations are shown in Figure 5-1. Please note that only Station 03OE001 and Station 03OE014 are currently operational.

The original open water rating curves in natural conditions for Muskrat Falls are shown in Figure 5-2.

Figure 5-1: Location of Environment Canada Hydrometric Stations Near Muskrat Falls

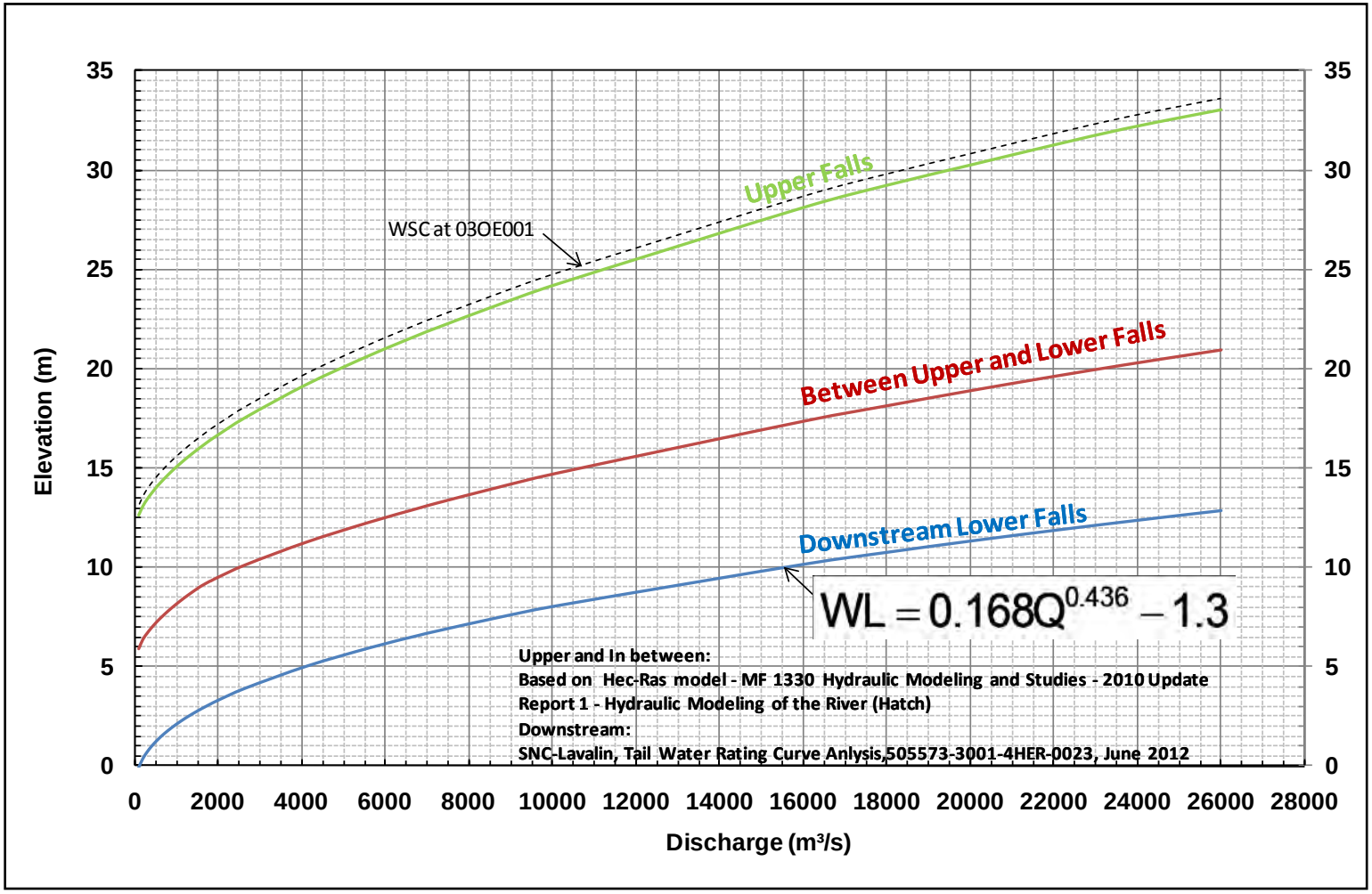


Figure 5-2: Original Muskrat Falls Open Water Rating Curves in Natural Conditions

The results of the Parrott survey were then compared with the three existing open water rating curves at Muskrat Falls. The results for SC-1 correspond to the rating curve for upstream of the upper falls, the results for SC-2 correspond to the rating curve for between the falls and the results of SC-3 correspond to downstream of the lower falls.

For upstream of the upper falls, the plotted points are as shown in Figure 5-3. The x-axis has been modified to focus on discharges between 1,000 m³/s and 2,000 m³/s. It can be seen from the figure that the survey points match well with the Water Survey of Canada rating curve and are above SLI's current rating curve (a difference of 0.6 m). Therefore, the SLI rating curve must be raised.

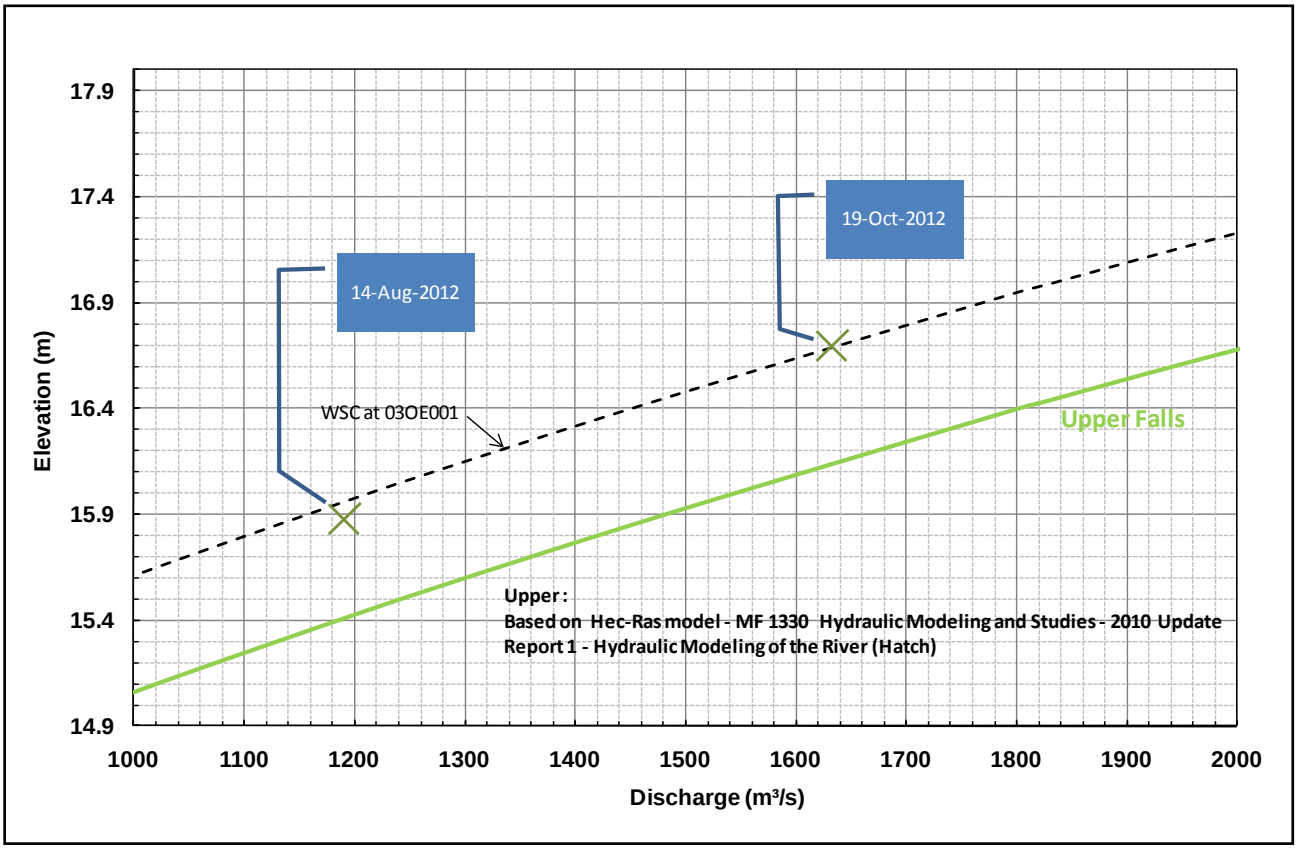


Figure 5-3: Open Water Rating Curve Above Upper Muskrat Falls with Parrott Survey Points Plotted

For between the falls, the plotted points are as shown in Figure 5-4. It can be seen from the figure that the survey points are above SLI's current rating curve (a difference of 0.4 m). Therefore, again in this case, the SLI rating curve must be raised.

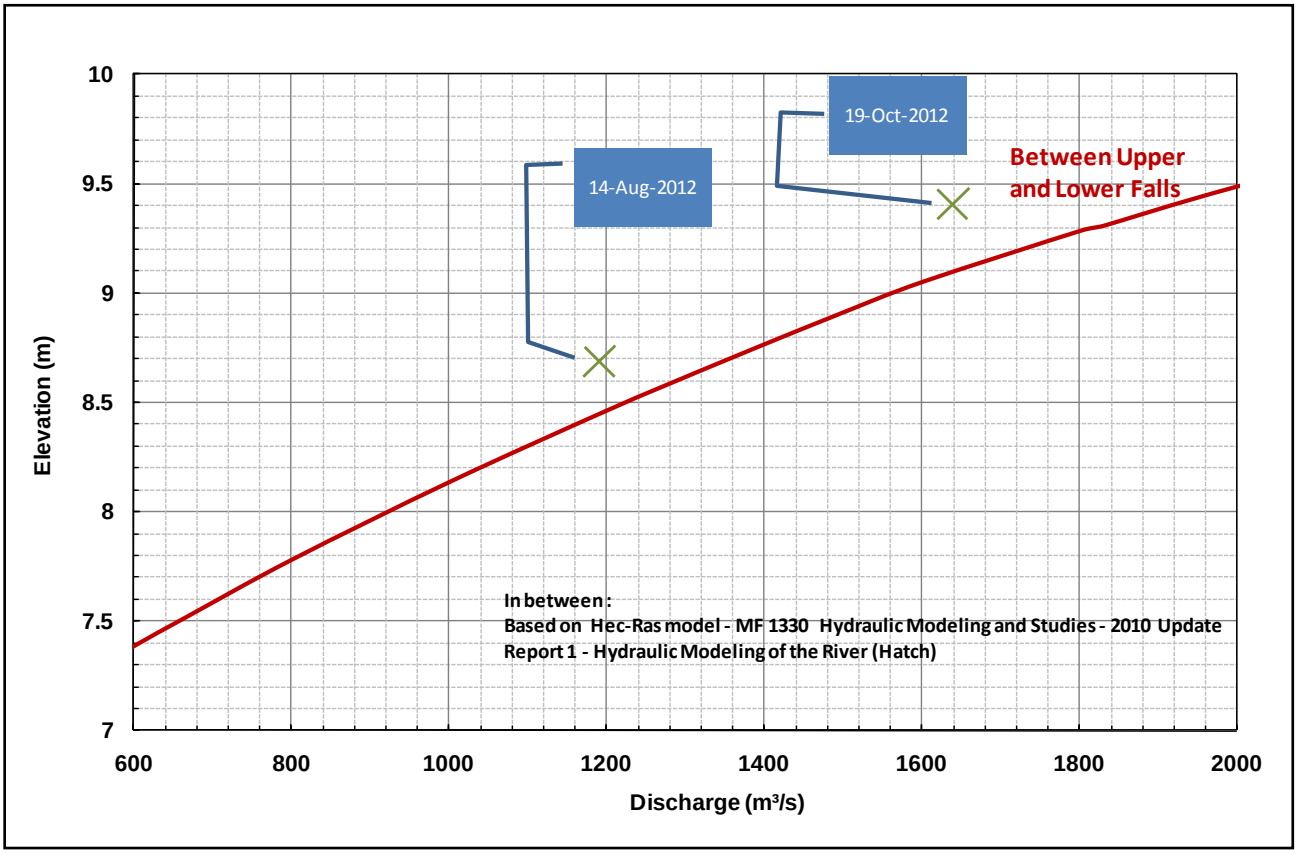


Figure 5-4: Open Water Rating Curve Between Upper and Lower Muskrat Falls with Parrott Survey Points Plotted

Downstream of the lower falls, the plotted points are as shown in Figure 5-5. It can be seen from the figure that the survey points are nearly in line with SLI's current rating curve but are slightly below.

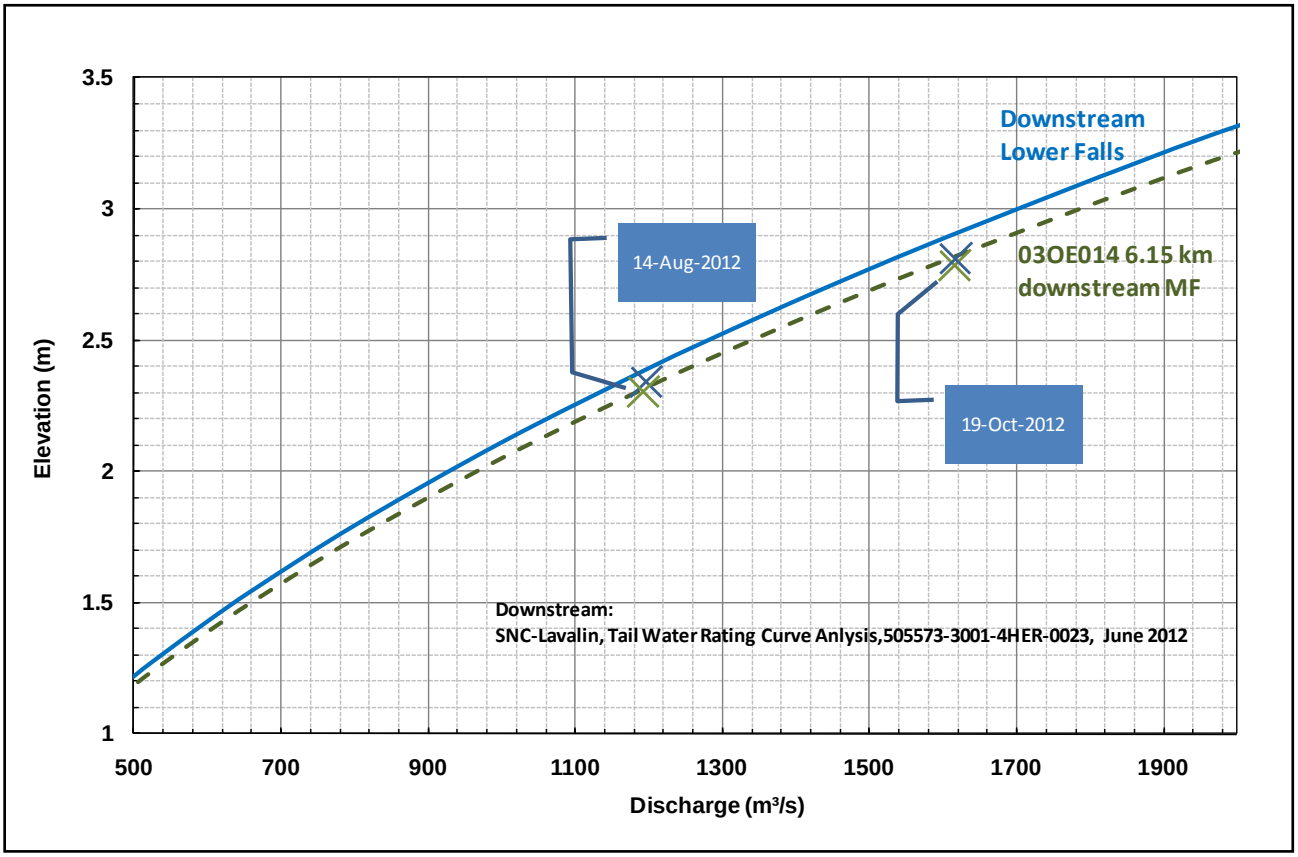


Figure 5-5: Open Water Rating Curve Downstream Lower Muskrat Falls with Parrott Survey Points Plotted

The analysis resulted in a slight raise in the rating curves upstream of the upper falls and between the falls. A slight decrease in the rating curve was noted for downstream of the lower falls. The resulting updated rating curves with their associated equations are shown below in Figure 5-6.

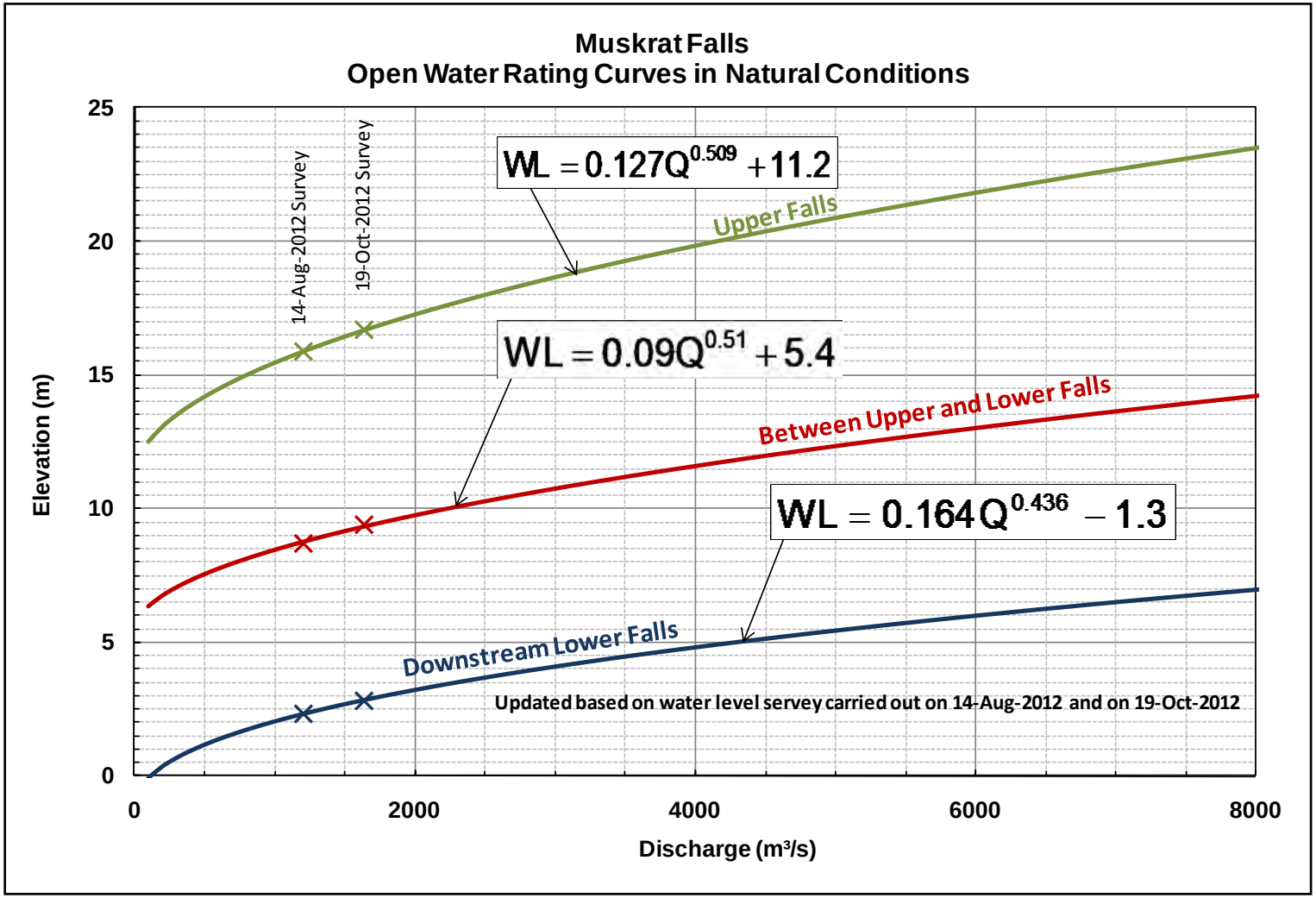


Figure 5-6: Updated Muskrat Falls Rating Curves Based on 2012 Parrott Survey

6 RECOMMENDATIONS

It is recommended that the following updated rating curves adjusted to geodetic datum be used for the natural open water conditions at Muskrat Falls. It is also recommended that additional surveys be carried out in the future, particularly during the 2013 Spring Flood, to ensure the accuracy of the curves.

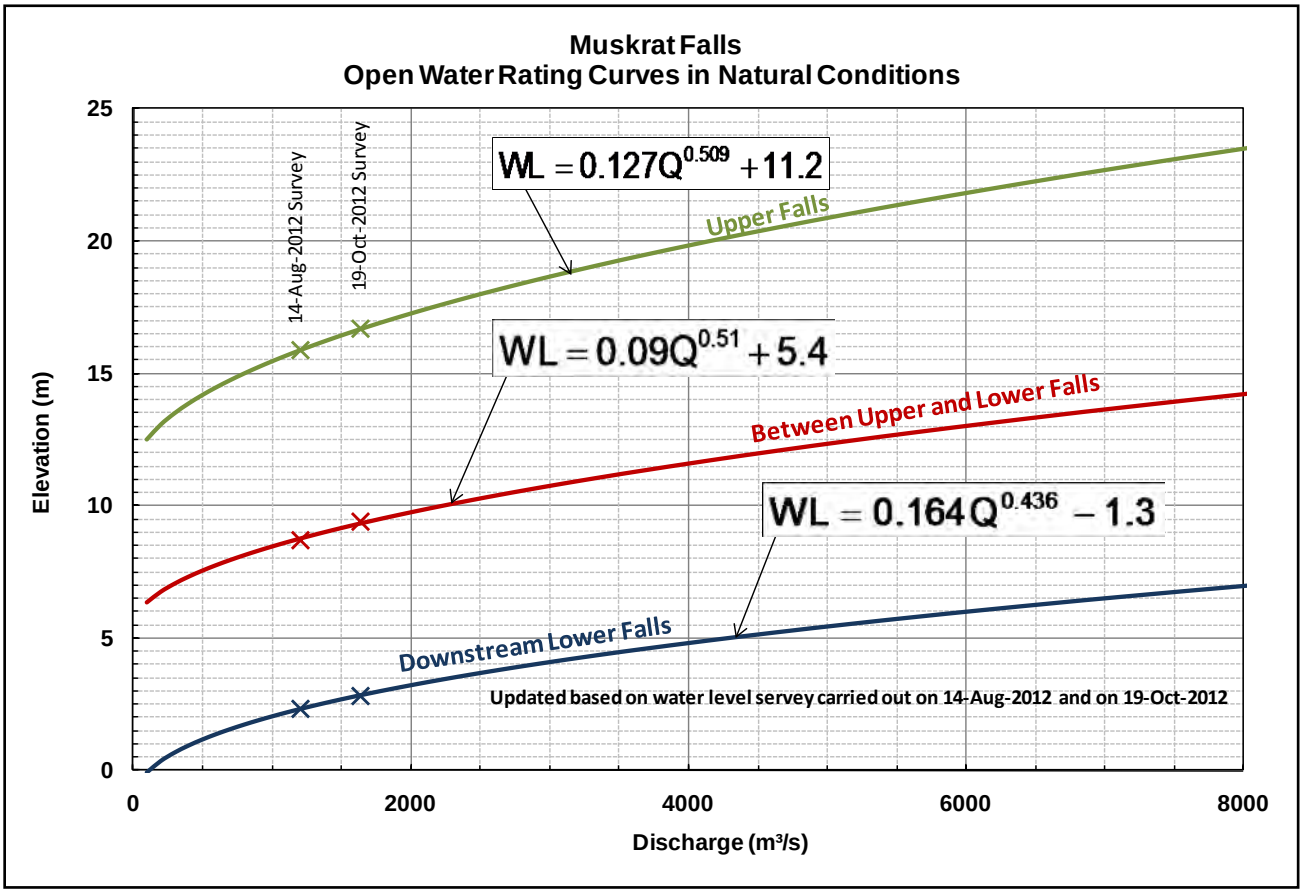


Figure 6-1: Final Muskrat Falls Open Water Rating Curves in Natural Conditions

APPENDIX A

PARROTT SURVEY REPORT

N.E. PARROTT SURVEYS LTD.
Canada Lands Surveyors / Newfoundland & Labrador Land Surveyors
340 Hamilton River Road / P.O. Box 1010, Station "C"
Happy Valley – Goose Bay, NL
A0P 1C0

Phone: (709) 896-5019 **Fax:** (709) 896-9439 **E-mail:** nepsl@nf.sympatico.ca
Website: neparrottsurveysltd.com

September 28, 2012

Water Level and Bench Mark Survey **Job No. 12-330**

Survey Equipment Utilized

Topcon II RTK system

Consisting of one base station and a roving unit on a pole and bi-pod utilizing the GNSS network. System was set to 9 epochs for redundancy and weighted averaging conducted with 3 fixes. Two additional receivers were utilized to static main control points and verify authorization of 98G series monuments.

Water Level Observations

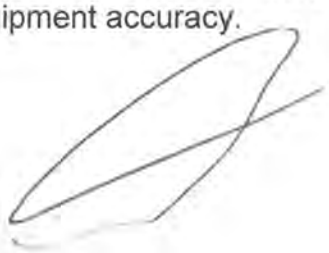
Area in between the lower and upper falls at Muskrat is turbulent water and variations are notable by a shift upstream or downstream. Wind action and waves are also factors in measurement and accuracy thereof.

An area was selected where wind and wave action was minimal and water height observed on a bare rock face. Once confirmed a measurement was taken directly on that mark with a weighted average of 3 shots. For future recording it is recommended to re-stake to the coordinate attached to the water level and record water height at that coordinate.

The lower site was observed by driving a peg in the water and observing water height directly with the GPS on the water mark on the peg. Current and wind action was not as influential as in the rapids area.

Water Level Accuracies

Water levels should be +2.5cm accounting for water conditions and relative equipment accuracy.



Neil Parrott, C.L.S., N.L.S.
N.E. Parrott Surveys Ltd.

Nalcor Energy Bench Mark Check

Nalcor Energy Bench Mark Check								
No.	Northing (m)	Easting (m)	Elev. (m)	Description	Local Time		Recorded	Corrected
1	5901846.060	648930.058	8.661	WATER LEVEL SC2	11:36am	SC2		
2	5901827.159	648879.287	8.683	WATER LEVEL SC2	11:39am	SC2		
3	5901782.888	648771.786	8.712	WATER LEVEL SC2	11:44am	SC2		
4	5902195.654	647795.363	15.882	WATER LEVEL SC1	12:12pm	SC1	15.802	15.83
5	5902184.188	647787.504	21.688	E001	12:35pm	03OE001		
6	5901681.271	649756.576	2.318	WATER LEVEL SC3	1:51pm	SC3		
7	5901706.579	649720.393	2.319	WATER LEVEL SC3	1:54pm	SC3		
8	5901785.609	649637.177	2.289	WATER LEVEL SC3	1:59pm	SC3		
9	5901210.385	655118.065	4.188	E014	2:48pm	03OE014		
10	5901220.497	655113.837	2.296	WATER LEVEL SC4	2:52pm	SC4	2.353	
11	5901900.172	649285.116	13.552	98G9100		BM1		
Coordinates were obtained on August 14, 2012 and Referenced to Control Monument 98G9100. Coordinates are 6 degree UTM Zone 20 NAD83.								

Coordinates were obtained on August 14, 2012 and Referenced to Control Monument 98G9100. Coordinates are 6 degree UTM Zone 20 NAD83.

Nalcor Energy Bench Mark Check

No.	Northing (m)	Easting (m)	Elev. (m)	Description	Local Time	Recorded			
1	5901846.060	648930.058	8.661	WATER LEVEL SC2	AUGUST 14 11:36am				
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3	5901782.888	648771.786	8.712	WATER LEVEL SC2	AUGUST 14 11:44am				
4	5902195.654	647795.363	15.882	WATER LEVEL SC	AUGUST 14 12:12pm				
6	5901681.271	649756.576	2.318	WATER LEVEL SC3	AUGUST 14 1:51pm				
7	5901706.579	649720.393	2.319	WATER LEVEL SC3	AUGUST 14 1:54pm				
8	5901785.609	649637.177	2.289	WATER LEVEL SC3	AUGUST 14 1:59pm				
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11	5901900.172	649285.116	13.552	98G9100					
No.	Northing (m)	Easting (m)	Elev. (m)	Description	Local Time				
1	5901842.290	648931.643	9.417	WATER LEVEL SC2	OCTOBER 19 12:47pm				
2	5901822.490	648880.484	9.365	WATER LEVEL SC2	OCTOBER 19 12:52pm				
3	5901782.090	648771.285	9.412	WATER LEVEL SC2	OCTOBER 19 12:56pm				
4	5902193.080	647792.897	16.691	WATER LEVEL SC	OCTOBER 19 2:04pm				
6	5901681.132	649755.006	2.833	WATER LEVEL SC3	OCTOBER 19 2:22pm				
7	5901696.925	649720.611	2.796	WATER LEVEL SC3	OCTOBER 19 2:21pm				
8	5901784.610	649635.701	2.793	WATER LEVEL SC3	OCTOBER 19 1:22pm				
10	5901217.182	655113.122	2.779	WATER LEVEL SC4	OCTOBER 19 2:38pm	2.812			
Coordinates were obtained on October 19, 2012 and Referenced to Control Monument 98G9100. Coordinates are 6 degree UTM Zone 20 NAD83.									

Coordinates were obtained using RTK Surveying Technique and Referenced to Control Monument 98G9100. Coordinates are 6 degree UTM Zone 20 NAD83.