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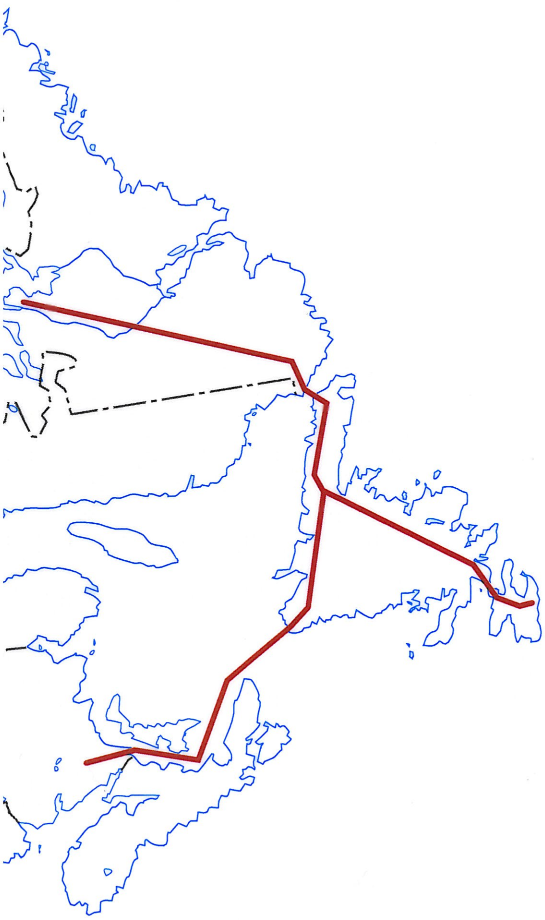

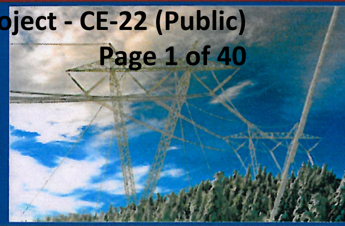

THE Lower Churchill PROJECT

October 2010

MF1330 - Hydraulic Modeling and Studies 2010 Update

Report 1: Hydraulic Modeling of the River

prepared by

HATCH™

nalcor energy

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Executive Summary

Nalcor Energy – Lower Churchill Project (NE-LCP) is undertaking preliminary engineering studies of the development of the hydroelectric potential of the Lower Churchill River at Gull Island and Muskrat Falls. As part of these feasibility studies, Hatch has developed a numerical hydraulic model of the Lower Churchill River. The model was originally developed in 2007 under GI1110 and has been used to analyse the hydraulic regime in several other studies. Since 2007 there have been updates to project layouts and additional bathymetric and hydrometric data have become available. The objective of the current study is to update the hydraulic model based on this new information.

Eighty new cross sections were added to the model based on bathymetric surveys completed in 2006 and 2007. These sections replaced some sections in the original model that were based on much older bathymetric data, and filled in some parts of the river for which bathymetry data were not previously available. Calibration of the model for a range of flows was checked and it was determined that the new bathymetry provided for a successful calibration over the entire modelled reach. In some regions the updated model provided a better representation of measured water levels than the original model, and in some regions there was no difference. There is now a greater level of confidence in the model geometry where sections based on 1970s bathymetric surveys have been replaced with sections based on 2006 and 2007 surveys.

Updated structure details were incorporated into the hydraulic model so that the model could be used to assess the hydraulic regime at every stage of development of the two projects, whether Muskrat Falls or Gull Island is constructed first.

Also as part of this update, the hydraulic model was extended at the downstream end to the coast of Labrador based on nautical charts.

The result of this study is an up-to-date hydraulic model that can be used for the prediction of velocities and water levels throughout the Lower Churchill River. The model will be used for other MF1330 studies including the following.

- Muskrat Falls Probable Maximum Flood (PMF) and Construction Design Flood (CDF) Study – 2010 Update
- Muskrat Falls Dam Break Study – 2010 Update
- Muskrat Falls Ice Study – 2010 Update
- Gull Island CDF Analysis (1:60 year)

1. Introduction

Nalcor Energy – Lower Churchill Project (NE-LCP) is undertaking preliminary engineering studies of the development of the hydroelectric potential of the Lower Churchill River at Gull Island and Muskrat Falls. These sites are located 231 km and 291 km downstream respectively from the Upper Churchill hydroelectric facility that was developed in the early 1970's. The total potential capacity at the two sites is 3,074 megawatts (MW); the Gull Island site being the larger at 2,250 MW and the Muskrat Falls site having a capacity of 824 MW. In addition to the development of these sites, the overall concept includes various potential alternative power transmission arrangements involving combinations of AC and DC lines of various capacities.

In April 2007, Nalcor contracted Hatch Ltd. of St. John's to undertake a program of studies to address aspects of this development. In January 2008 Hatch issued the final report of GI1110 – Hydraulic Modeling of the River to NE-LCP. The scope of work for that study included the development and calibration of a fully geo-referenced HEC-RAS open water hydraulic model that could be used to assess flow conditions in the existing river as well as during and post-construction. This model was used for several other studies completed by Hatch, including the PMF Study, the Ice Study, the Dam Break Study, and various other studies related to the preparation of the Environmental Impact Statement (EIS). Since the development of this hydraulic model, there have been changes to project layouts and additional bathymetric and hydrometric data collected. The objective of this study is to incorporate these additional data and to update the hydraulic model so that it may be used for other hydrotechnical studies and updates.

2. Extension of the Model to Lake Melville

The original GI1110 hydraulic model extended part way through Goose Bay (approximate chainage -9.4 km, i.e. 9.4 km downstream of the river outlet). Typically for dam break modeling it is important that the downstream model boundary extends to a location where the results of a dam breach would not induce a significant increase in water level. These locations are usually large lakes or bodies of water influenced by tidal fluctuations. As part of the Churchill Falls Dam Break Study completed by Hatch in 2010 for Nalcor Energy – Churchill Falls (NE-CF), the model reach was extended downstream through Lake Melville to the Atlantic Ocean at Groswater Bay, in anticipation of the potentially large outflow volumes associated with a hypothetical dam breach in the Upper Churchill system. Nautical charts were acquired from the Canadian Hydrographic Service which provided detailed bathymetric information in this area. This information was manually digitized in ArcGIS, cross sections were cut using Hec-GeoRAS, and the model was extended to Groswater Bay on the coast of Labrador. The model centreline which represents the extents of the model is illustrated in Figure 2.1.

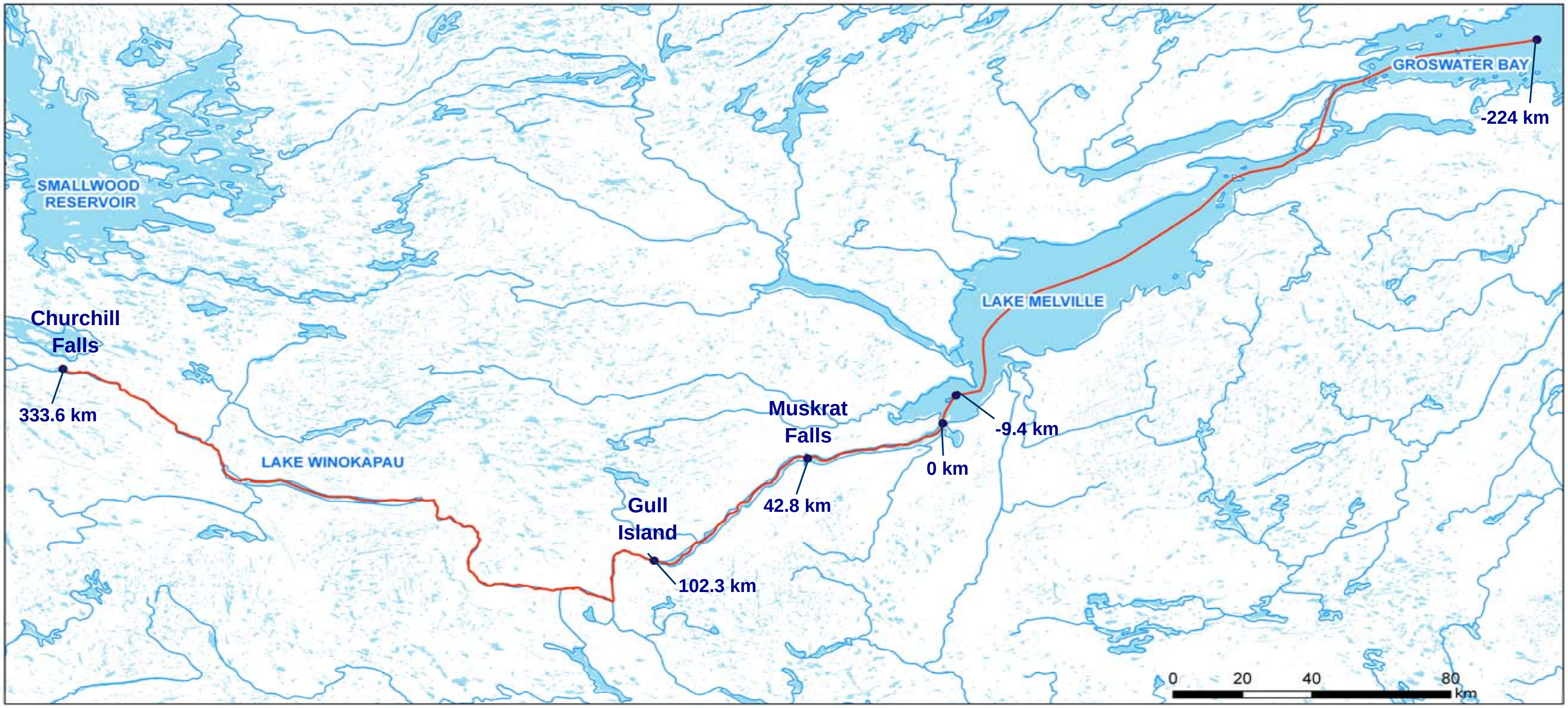

Figure 2.1
Hydraulic Model Extents
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3. New Bathymetric Information

Since the original GI1110 hydraulic model was developed, new bathymetric data have become available for various parts of the Churchill River. A summary of the additional bathymetric data is provided in Table 3.1.

Table 3.1 - Additional Bathymetric Information

Area	Chainage	Source (Date)
Near Lake Winokapau Outlet	219 km to 226 km	AMEC (September 2006)
Upstream of Gull Rapids	105 km to 107 km	AMEC (September 2006)
Gull Island reach	102 km to 103 km	Survey completed by N.E. Parrott Surveys Limited of Goose Bay (Parrott) for SNC Lavalin (September 2007)
Upstream of Muskrat Falls	45 km to 52 km	AMEC (September 2006)
Downstream of Muskrat Falls	39 km to 42 km	AMEC (September 2006)

Figure 3.1 illustrates the bathymetric contours in these areas. The AMEC surveys were completed as part of some habitat quantification work which took place between September 21 and 30, 2006. The Parrott survey of the Gull Island reach took place between September 8 and 15, 2007; this was separate from the Parrott survey commissioned by Hatch in 2007 which extended between Minipi Rapids and the Churchill Falls tailrace.

AMEC used a SONAR/GPS unit to collect bathymetric points from a boat as they conducted habitat surveys through the reach. AMEC converted these points into contours which are shown in Figure 3.1. The contours were provided as depths of water rather than geodetic elevations and the water surface elevation at the time of the survey was not recorded. However, the surface water elevation had been recorded at the time of the LiDAR topographical survey completed just two weeks earlier at a slightly lower flow rate. To estimate the water levels at the time of the AMEC survey, flows throughout the reach for both surveys were estimated and the GI1110 hydraulic model was used to determine the expected difference in water levels corresponding to the difference in flows. This difference was added to the measured water levels obtained during the LiDAR survey to get an estimate of the water levels at the time of the AMEC survey. These water levels were then used to convert the AMEC depth contours to geodetic elevation contours. In total, 71 cross sections were extracted and included in the updated hydraulic model based on the AMEC bathymetric contours. Sixteen (16) of these were in Lake Winokapau, 12 upstream of Gull Rapids, 19 in Gull Lake, 15 upstream of Muskrat Falls, and 9 downstream of Muskrat Falls.

Bathymetric contours in the Gull Island reach (based on surveys completed by Parrott in 2007) were provided as geodetic elevation contours, so the procedure noted above was not required for that area. However, the 2007 Parrott contours were compared with the raw sounding data and significant differences between the derived contours and the source data were noted in some areas. Also it was determined that towards the upstream and downstream extents of the contour data, there were very little raw data from which to develop these contours which suggests that the contours may be unrealistic towards the edges of the surveyed area. Based on these problems with the bathymetric contours, some of the original cross sections (based on surveys completed in the 1970s) were considered to be more reliable. In total, nine new cross sections based on the 2007 Parrot survey were added to the model (102.1 km, 102.2 km, 102.3 km, 102.4 km, 102.5 km, 102.6 km, 102.8 km, 103 km, and 103.2 km).

In total, 80 new cross sections were included in the hydraulic model (not including additional sections related to the model extension at the downstream end described in Section 2). All of the new cross sections were compared to cross sections from the original model so that any significant discrepancies could be identified. In general, the new bathymetric sections were very similar to the original cross sections; as such, very little difference in model results was expected.

Figure 3.2 illustrates the location of the 80 new cross sections that were included in the updated hydraulic model. Appendix A includes a list of all of the cross sections in the hydraulic model and the source of bathymetry for each.

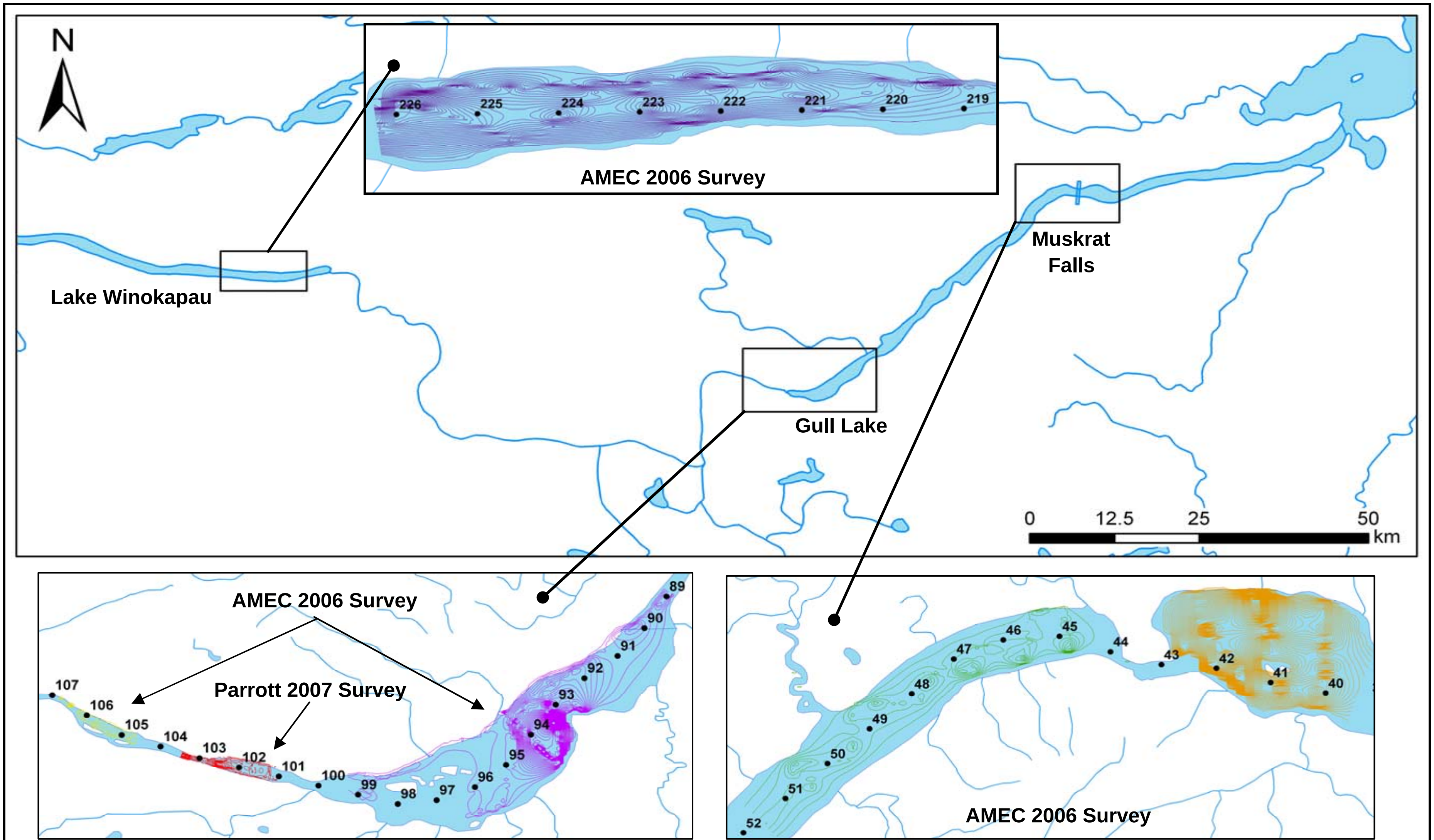

Figure 3.1
Bathymetric Contours
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Nalcor Energy - Lower Churchill Project

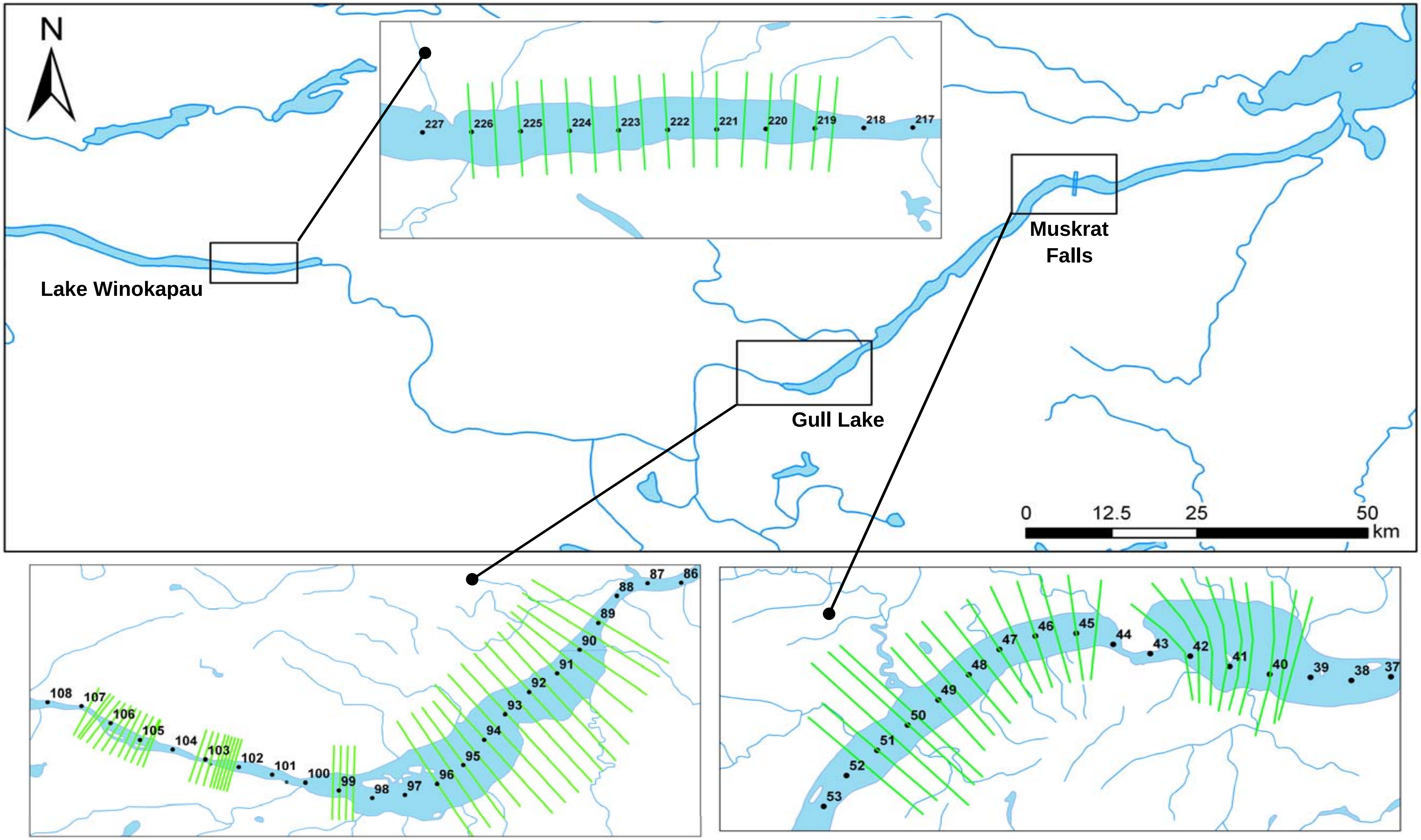

Figure 3.2
New Hydraulic Model Cross Sections
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4. Updated Project Layouts

Since the original GI1110 model was developed there have been some updates to project layouts at both Muskrat Falls (MF) and Gull Island (GI). An objective of the current study was to update the hydraulic model such that it would be capable of simulating hydraulic conditions during each phase of construction, whether the MF or GI project is constructed first. As such, there are eight different configurations (called "geometries" in HEC-RAS) included in the model, as summarized in Table 4.1.

Table 4.1 – Hydraulic Model Geometries

MF constructed prior to GI	GI constructed prior to MF
1. Pre-Project	
2. During construction of MF (no GI)	5. During construction of GI (no MF)
3. Post construction of MF (no GI)	6. Post construction of GI (no MF)
4. During construction of GI (with MF)	7. During construction of MF (with GI)
8. Post-Project (GI and MF)	

Details such as dam and cofferdam crest elevations, spillway sill elevations, gate dimensions and discharge rating curves for GI and MF were obtained from GI1061 and MF1050, respectively and incorporated into the model geometry. Table 4.1 presents some of these details for each structure; Appendix B presents discharge rating curves for each structure in both tabular and graphical format.

Table 4.2 - Structure Details

Structure	Dam Crest Elevation	Discharge Facility	Sill Elevation
Muskrat Falls Cofferdam	26 m	4 Spillway Gates (12.5 m wide x 14.8 m high)	Gates: 5 m
Muskrat Falls Main Dam	45.5 m South 39.5 m North	4 Spillway Gates (12.5 m wide x 14.8 m high) Overflow North Dam (430 m long)	Gates: 5 m Overflow North Dam: 39.5 m
Gull Island Cofferdam	61.4 m	2 Inverted U-shaped Diversion Tunnels (14 m wide x 20.15 m high)	Tunnels: 16 m
Gull Island Main Dam	129 m	8 Spillway Gates (12.9 m wide x 20.1 m high)	Gates: 105.4 m

5. Model Calibration Check

Both steady and unsteady versions of the hydraulic model were updated as part of this work. In a steady state model, flow does not vary with time. In an unsteady model, the variation of flow over time is simulated, for example in the propagation of a natural or dam breach flood. The calibration of both models is discussed below.

5.1 Steady State Model

Calibration of the original GI1110 hydraulic model was completed using a variety of data sources including surveyed water levels and rating curves. The same calibration data were used to check the calibration of the updated model.

Figures 5.1 to 5.5 illustrate the results of the calibration for both the original GI1110 model and the updated MF1330 model. As shown, the results of both models are similar and an acceptable calibration was achieved in both models throughout the reach. There are a few areas in which simulated levels differed from observed levels by more than expected. These areas are summarized in Table 5.1 and a comment is provided regarding the implications of these discrepancies and how the accuracy may be increased if required.

Table 5.1 - Summary of Calibration Discrepancies

Location (Chainage)	Calibration Result	Comment
Lake Winokapau Outlet (206 km to 210 km)	Simulated levels are lower than observed by 2 - 5 m for the flow during the 2007 Parrott Survey.	This discrepancy has not been a concern for the studies completed to date. If more accuracy is desired for specific analyses in this area, additional bathymetry should be obtained.
Muskrat Falls hydrometric station (43.8 km)	Simulated levels are lower than observed by approximately 0.5 m for most flows.	This discrepancy has not been a concern for the studies completed to date. The assumed location of the hydrometric station may be slightly inaccurate which could affect the water levels since the profile is steep in this region. If required, an attempt could be made to increase the accuracy by adding additional cross sections.
Blackrock Bridge (24.1 km)	Simulated levels are higher than observed by approximately 0.3 m for average flows.	This discrepancy has not been a concern for the studies completed to date. It is possible that the rating curve was developed for different tidal condition than used for simulations. Accuracy of rating curve should be checked prior to collecting additional bathymetry.

Additional calibration information in the Gull Island reach was obtained by Hatch for GI1500, Detailed Engineering for Gull Island South Side Access. During the 2007 Parrott survey in the Gull Island reach, water levels were measured at both North and South shores for each surveyed transect between chainage 102.9 km and 103.5 km. These measured water levels were compared to simulated water levels for the flow estimated at the time of the survey; water levels were within 10 cm for each cross section in this short reach. LiDAR topographic contours at 30 cm intervals were available between approximate chainages 100.8 km and 103.0 km. Although LiDAR cannot directly measure the elevation of the water surface, the elevation of the land where the LiDAR contours cross the river can be assumed to equal the water surface elevation. A slight adjustment was made to the 1975 survey section at 101.9 km to ensure a good match between measured and simulated water levels in this reach.

Although there are water level gauges upstream and downstream of Grizzle Rapids that have been in operation since September 2008, the data has not yet been released by Environment Canada from its internal quality control process and therefore could not be used to check the calibration of the hydraulic model in this study.

5.2 Unsteady Model

As part of GI1140 (PMF and Construction Design Flood Study), the GI1110 hydraulic model was used for channel routing in place of the SSARR hydrological model. Dynamic hydraulic models are based on the physical characteristics of the river channel and solution of the Saint-Venant equations of unsteady flow and are not subject to the uncertainties of extrapolation applicable to hydrological routing approaches. The calibration of the GI1110 hydraulic model under unsteady flow conditions was tested for 1981 since this was the year in which the hydrograph at Muskrat Falls predicted by the SSARR hydrological model was in closest agreement with recorded flows. Based on this good agreement, the lateral inflow hydrographs (tributary flows) predicted by the hydrological model for 1981 were also assumed to be close to actual. In the current study, the calibration of the updated unsteady hydraulic model was checked using the same year. The outflows from the Churchill Falls powerhouse (03OD005) and lateral inflow hydrographs from the SSARR model were routed through the hydraulic model. Simulated flows at Muskrat Falls were compared with measured flows (at Water Survey of Canada Station 03OE001) and the hydrographs were in close agreement, especially at the peak of the hydrograph, as shown in Figure 5.6.

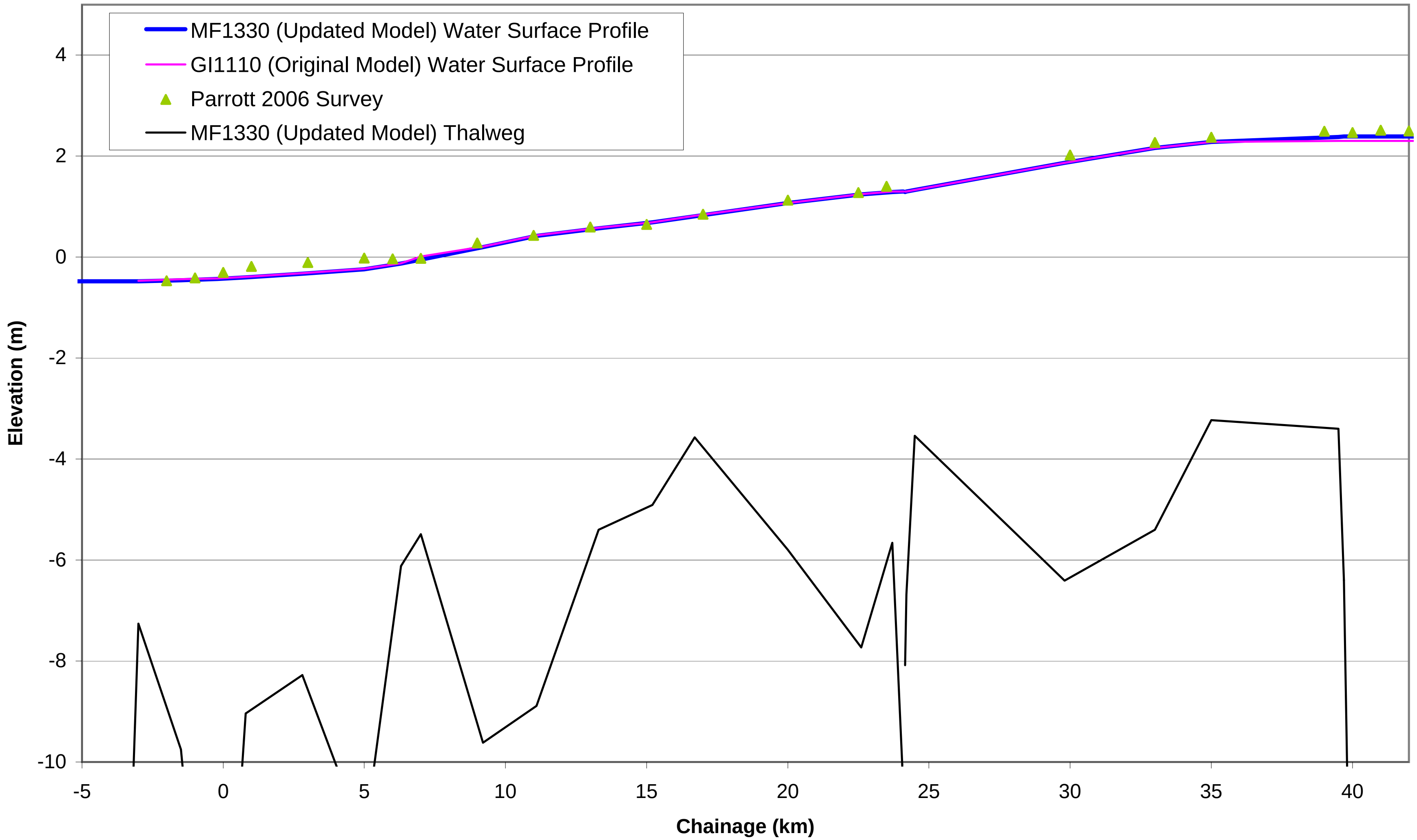

Figure 5.1
Calibration to 2006 Parrott Survey Water Levels
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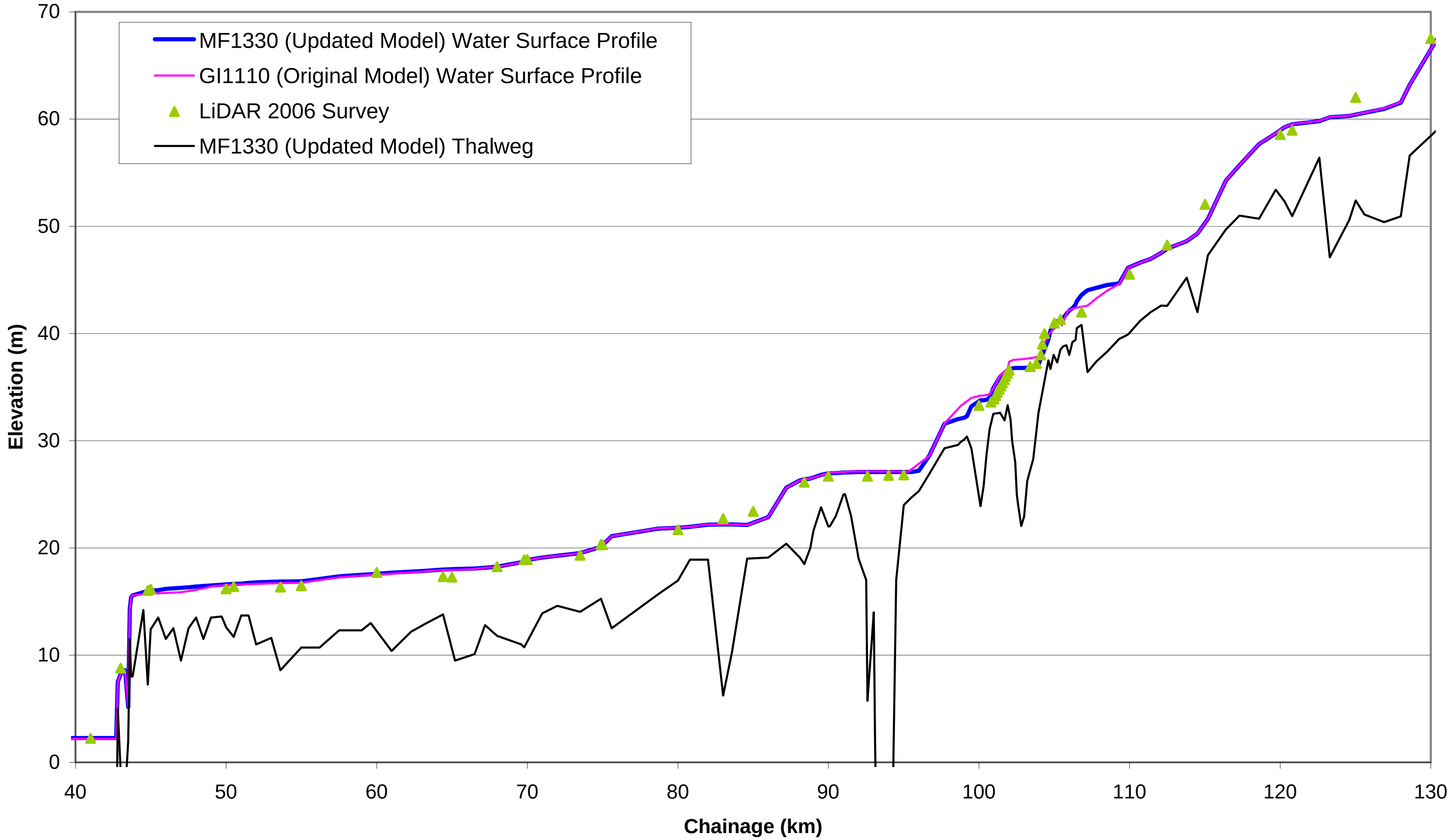

Figure 5.2
Calibration to 2006 LiDAR Survey Water Levels
MF1330 - Hydraulic Modeling of the River - 2010 Update
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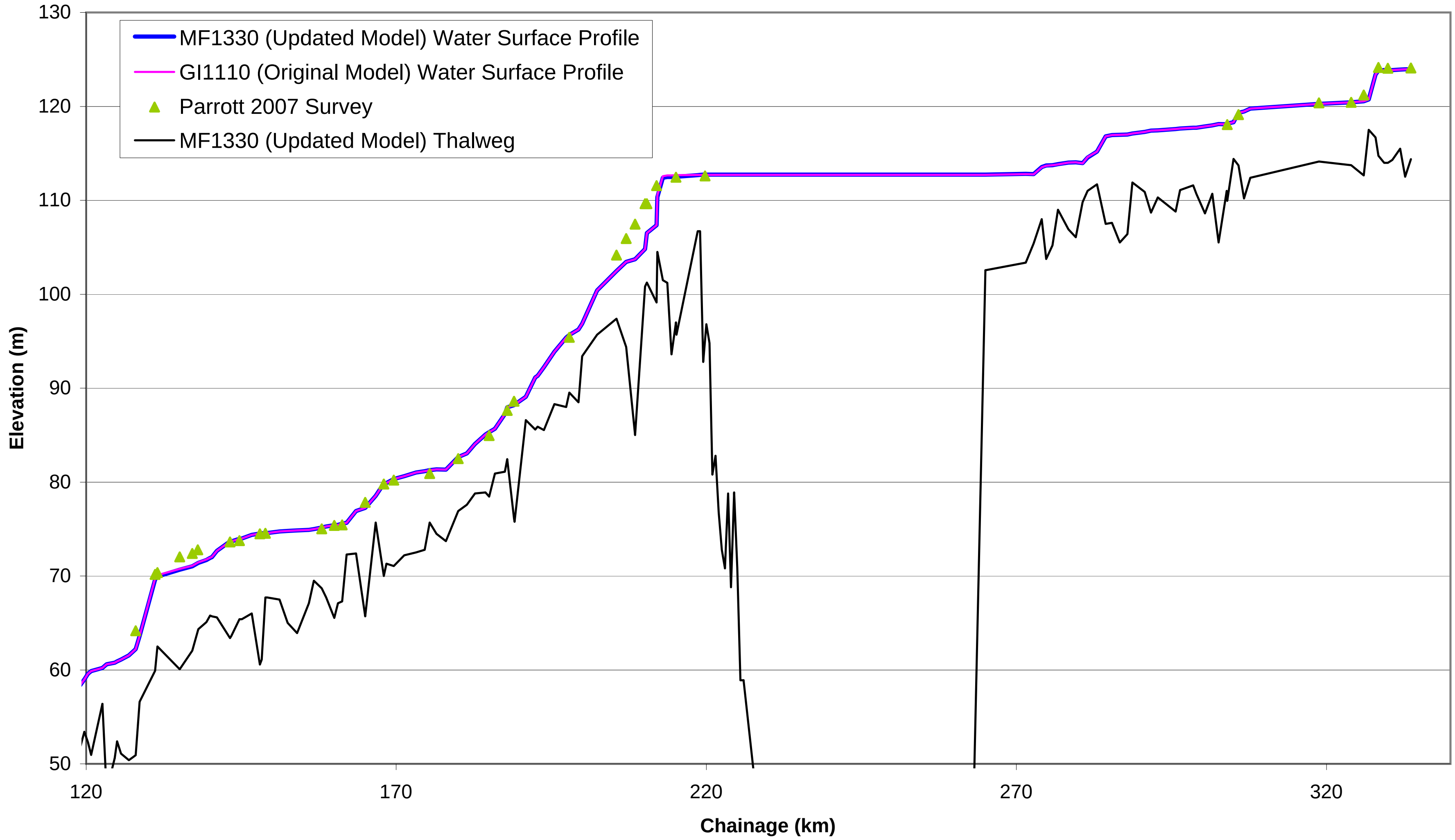

Figure 5.3
Calibration to 2007 Parrott Survey Water Levels
MF1330 - Hydraulic Modeling of the River - 2010 Update
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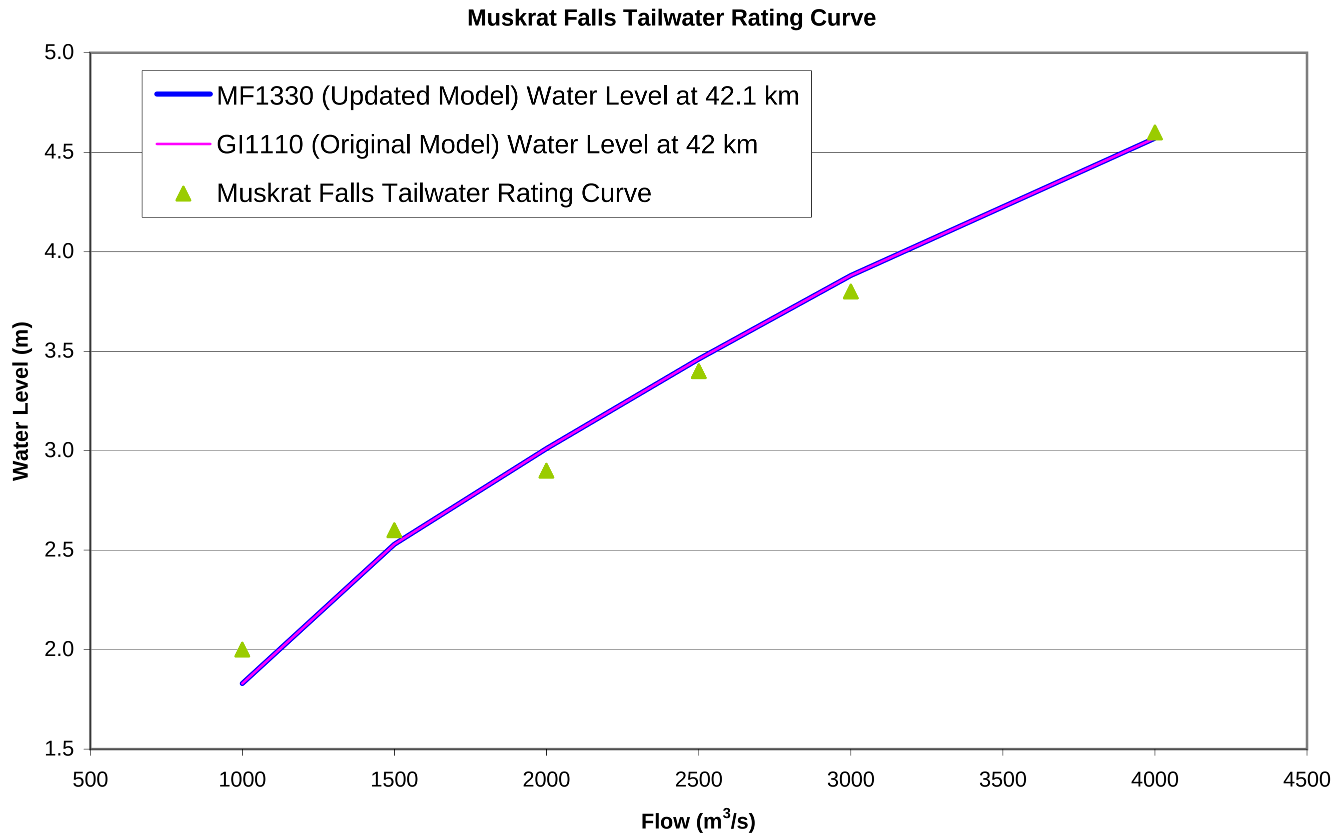

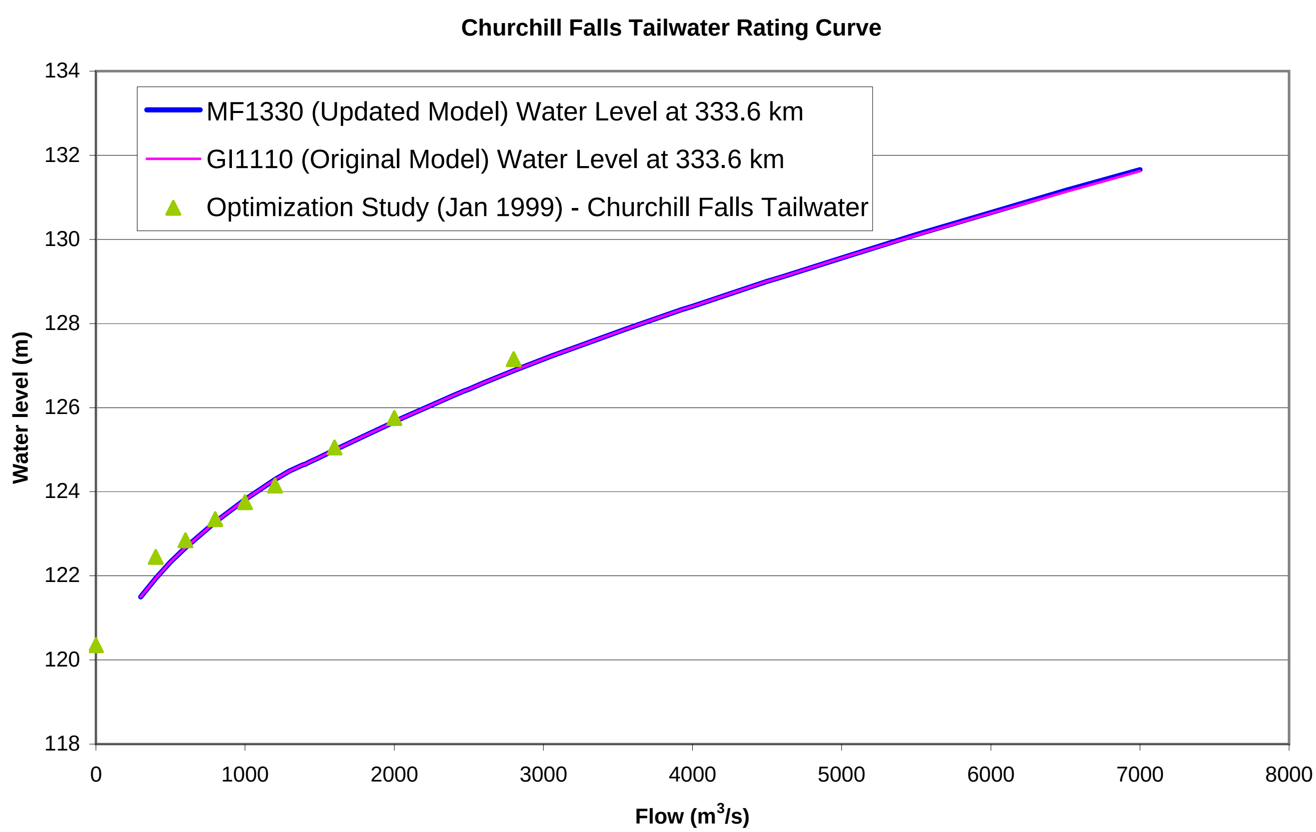

Figure 5.4
Calibration to Rating Curves (1 of 2)
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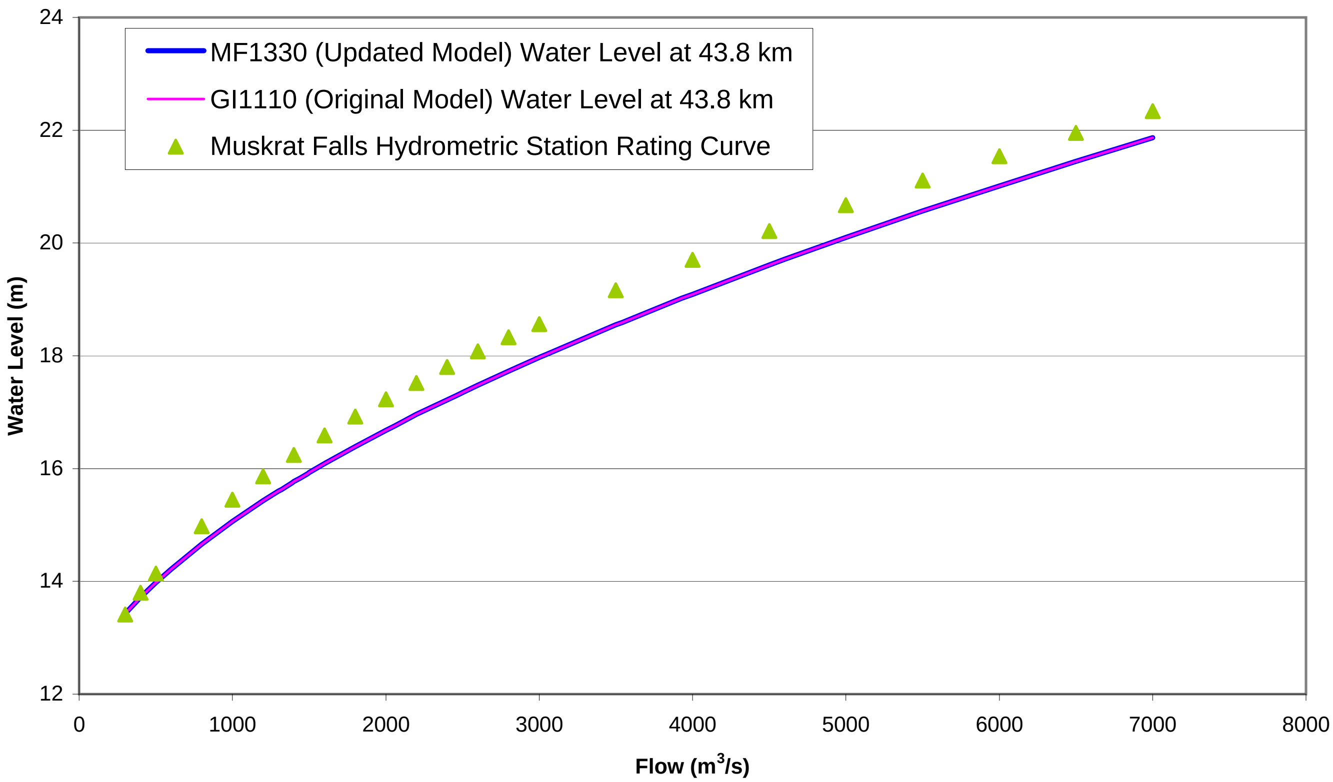
Muskrat Falls Hydrometric Station Rating Curve



Blackrock Bridge Rating Curve

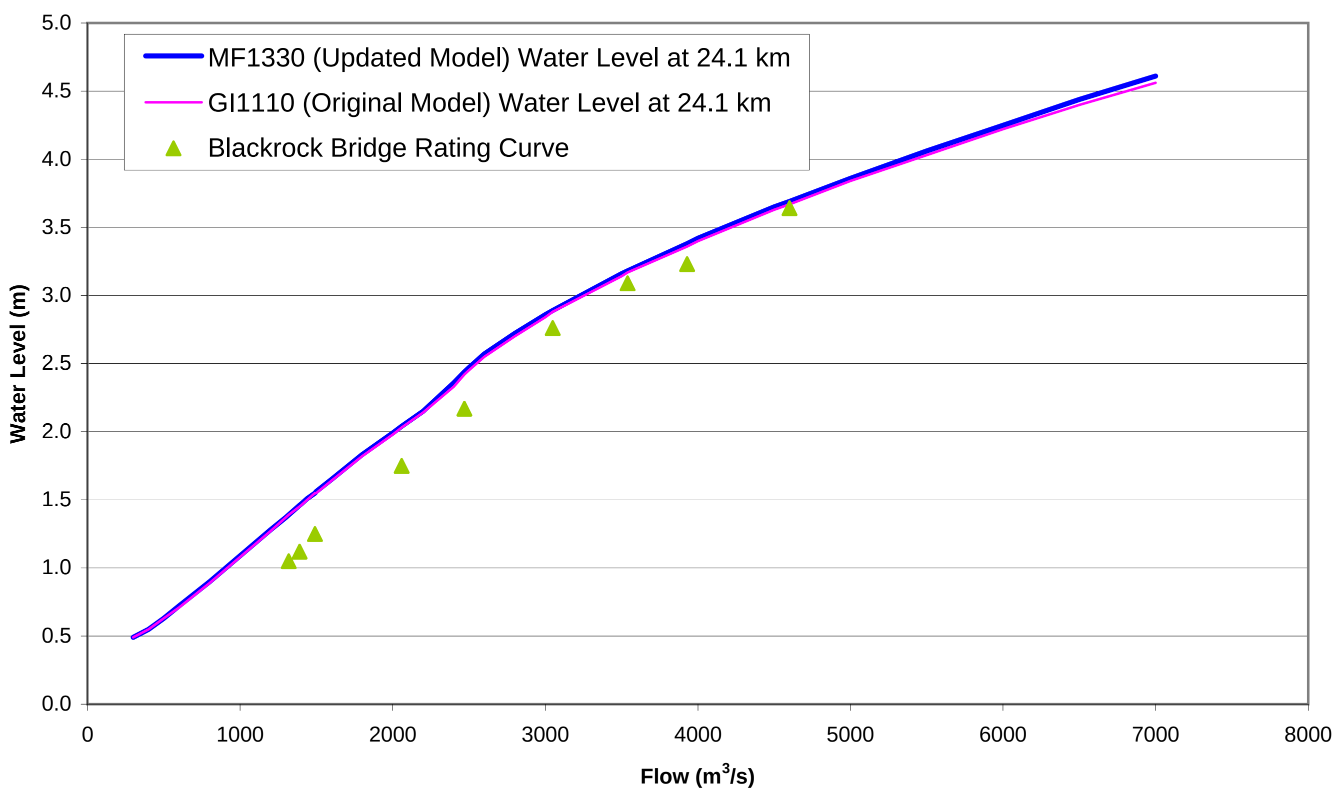


Figure 5.5
Calibration to Rating Curves (2 of 2)
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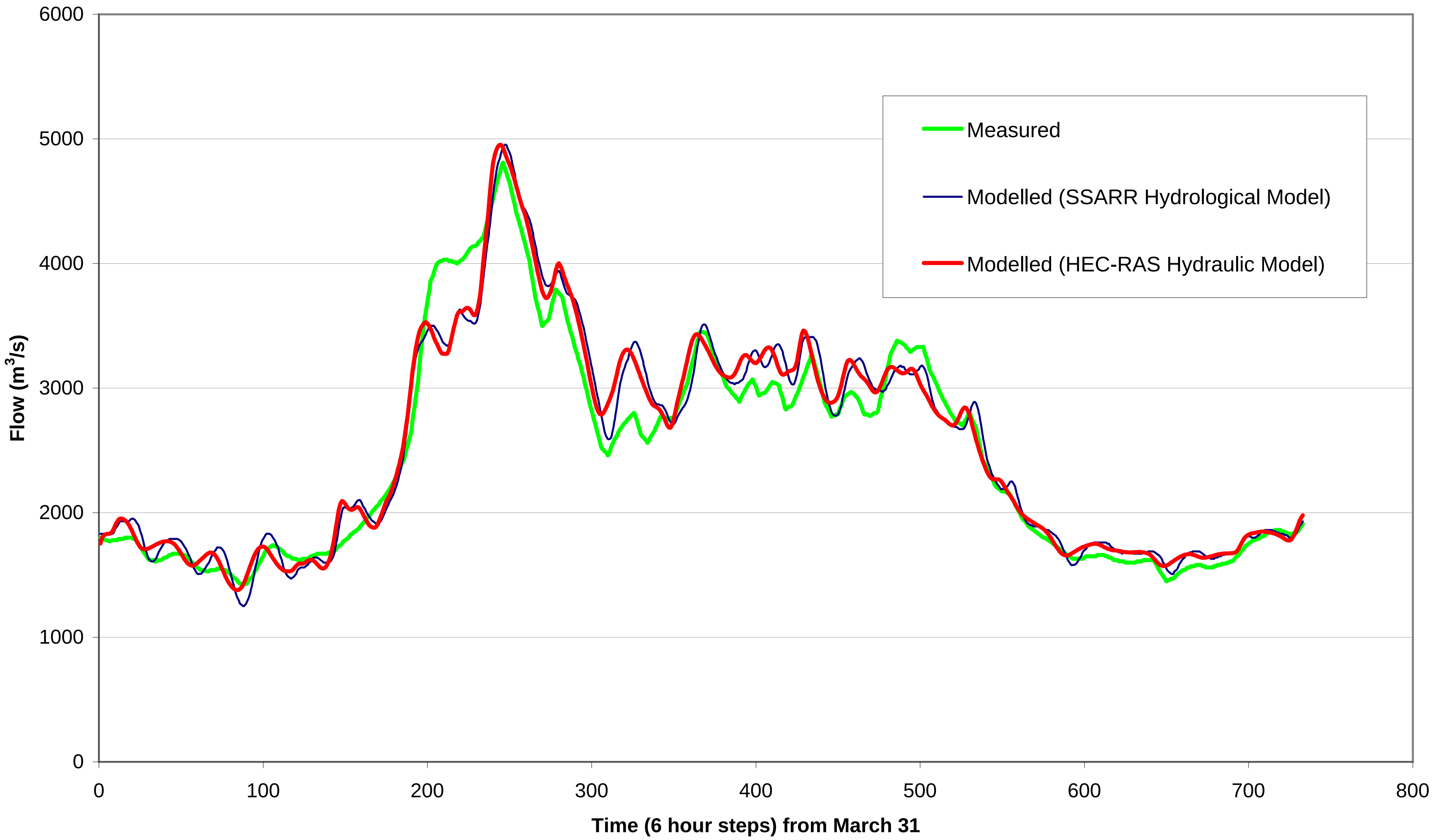

Figure 5.6
Unsteady Model Calibration (1981) - Flows at Muskrat Falls Hydrometric Gauge
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6. Consistency Between Steady and Unsteady Hydraulic Models

Due to the extremely transient nature of unsteady flow simulations, the original GI1110 hydraulic model required modification to remove numerical instabilities for the PMF and Dam Break studies (GI1140 and GI1190, respectively). None of these modifications significantly changed the conveyance characteristics of the model, but added a great deal to its robustness in dealing with rapid change in discharge. The result was a very robust model that while adequately representing the hydraulic characteristics of the study area also allows for a wide range of simulations and discharge variations of several orders of magnitude. Modifications for the purpose of model stability in unsteady flow mode included simplifications of cross sectional geometry, addition of interpolated sections, and introduction of a "pilot" channel to smooth the channel bottom profile. Pilot channels are added to provide additional flow depth to the cross section without significantly affecting the total conveyance of the section. They typically take the shape of a small notch in the bottom of the cross section. Pilot channels are often required for the simulation of low flows as the model can become unstable if depths are too low. Also pilot channels can help to smooth out irregularities in the channel bottom which also helps the stability of the model. The original model without these modifications (the steady model) is favoured for estimating water levels in the reach under non-flood conditions; the unsteady model is used for the simulation of floods. After the two models were updated, a consistency check was performed to ensure that both models included the most up-to-date information, and that the only differences were for the purpose of model stability.

The user-defined cross sections in the two models are the same with one exception: the unsteady model does not include the user-defined section at chainage 200 km (downstream of Lake Winokapau), the bathymetry of which was obtained in a 1979 survey. This section presented an abrupt change in cross-sectional area compared to the adjacent sections, which tends to cause numerical instability in time-varying flow computations. It was found necessary to omit the section so as to simplify the model geometry and achieve computational stability. The effect of this simplification is only apparent for a short distance upstream and is not expected to influence the conveyance capacity of the reach during flood events.

The thalweg (channel bottom) profile of the two models is different as a result of the pilot channels that were introduced in the unsteady model for computational stability. These pilot channels add negligible conveyance area to the sections and therefore should not affect computed water levels. The minimum channel elevation of the pilot channels were calculated such that the average slope of the reach was maintained.

Simulated water levels from the two models for a flow approximately equal to the maximum annual flow were compared. Figure 6.1 compares the two water surface profiles. The water levels were within 0.5 m at 95 percent of the cross sections upstream of Goose Bay; the maximum difference between the two models was approximately one meter.

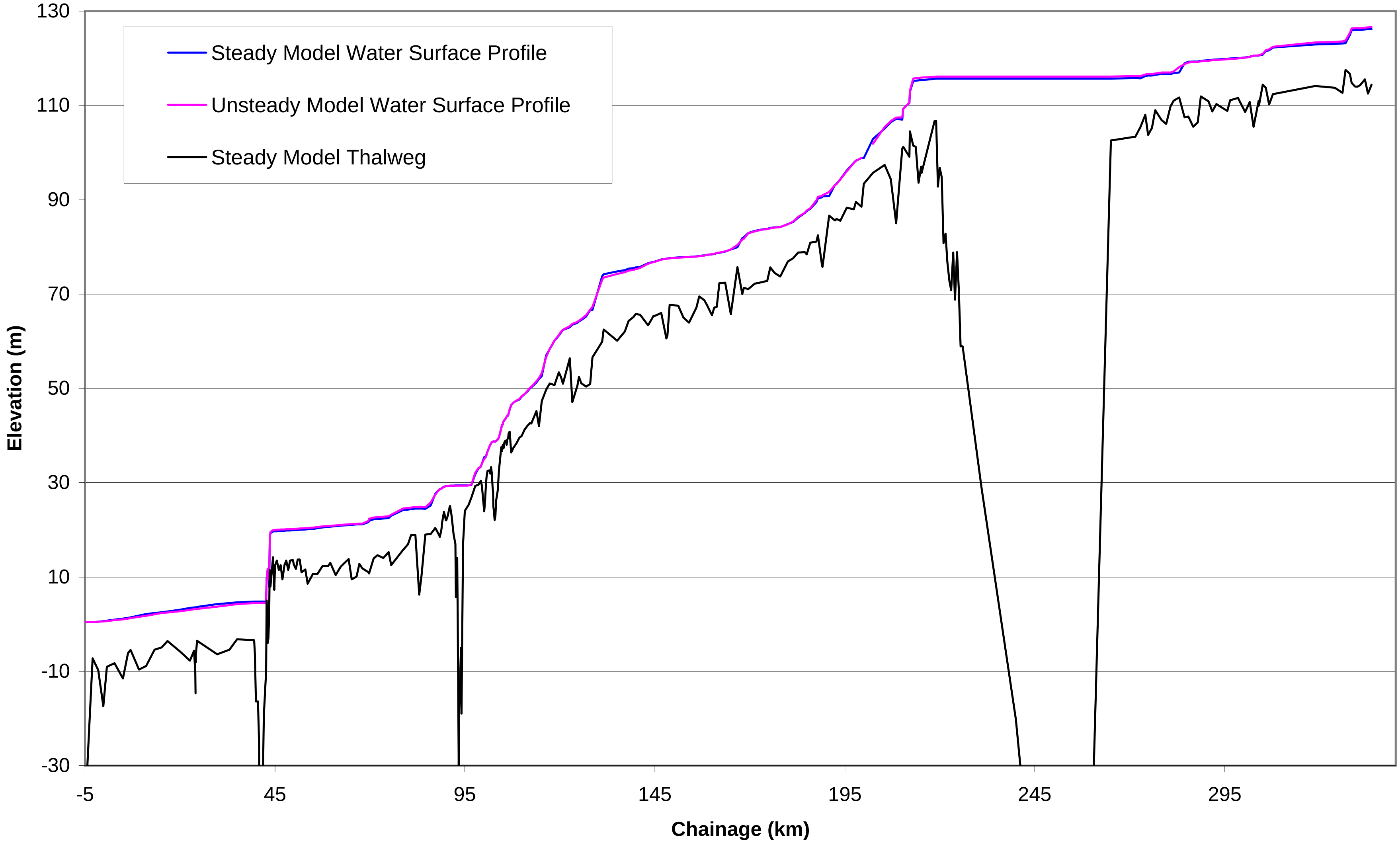

Figure 6.1
Steady and Unsteady Model Simulated Water Level Profiles
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7. Conclusions

The hydraulic model originally developed under GI1110 has been updated to include additional information such as updated project layouts and newly available bathymetric and hydrometric data. In total, eighty new cross sections were added to the model. These sections replaced some sections in the original model that were based on much older bathymetric data, and filled in some parts of the river for which bathymetry data were not previously available. A successful calibration was achieved for the updated model over the entire modelled reach.

Updated structure details were incorporated into the hydraulic model so that the model could be used to assess the hydraulic regime at every stage of development of the two projects, whether Muskrat Falls or Gull Island is constructed first.

The hydraulic model was extended at the downstream end to the coast of Labrador based on nautical charts.

The result of this study is an up-to-date, geo-referenced and calibrated hydraulic model that can be used for the prediction of velocities and water levels throughout the Lower Churchill River. The model may be used for the following studies which are also being completed under MF1330.

- Muskrat Falls PMF and CDF Study – 2010 Update
- Muskrat Falls Dam Break Study – 2010 Update
- Muskrat Falls Ice Study – 2010 Update
- Gull Island CDF Analysis (1:60 year)

Appendix A

Source of Bathymetry for Model Cross Sections

Appendix A - Source of Bathymetry for Model Cross Sections

(Note: shaded rows indicate sections included in MF1330 model update)

Chainage (km)	Source/ Notes
333.6	2007 Parrott 334
332.7	1975 Section 100
331.9	1975 Section 101
330.6	1975 Section 102
329.9	2007 Parrott 330
329.3	1975 Section 103
328.4	2007 Parrott 328
327.9	1975 Section 104 adj. up 1 m
326.8	1975 Section 105
326.0	2007 Parrott 326
324.0	2007 Parrott 324
318.8	2007 Parrott 319
307.7	1975 Section 15
306.7	1975 Section 16
305.8	2007 Parrott 306
305.0	1975 Section 17
304.0	2007 Parrott 304
303.9	1975 Section 18
302.6	1975 Section 19
301.6	1975 Section 20
300.4	1975 Section 21
299.0	1975 Section 22
298.5	1975 Section 23
296.4	1975 Section 24
295.7	1975 Section 25
292.8	1975 Section 27
291.7	1975 Section 28
290.7	1975 Section 29
288.7	1975 Section 30
287.9	1975 Section 31
286.7	1975 Section 32
285.4	2006 AMEC 285
284.4	1975 Section 34
283.0	1975 Section 35
281.5	Derived section
280.7	1975 Section 36 adj. down 1 m
279.6	2006 AMEC 280
278.4	1975 Section 38 adj. down 2 m
276.7	1975 Section 39
275.8	1975 Section 40
274.8	2006 AMEC 275
274.1	1975 Section 41
272.8	1975 Section 42
271.5	2006 AMEC 271
265.0	2006 AMEC 265
260.0	2006 AMEC 260
250.0	2006 AMEC 250
240.0	2006 AMEC 240

Appendix A - Source of Bathymetry for Model Cross Sections
(Note: shaded rows indicate sections included in MF1330 model update)

Chainage (km)	Source/ Notes
231.0	2006 AMEC 230
226.0	AMEC 2006 - 226 km
225.5	AMEC 2006 - 225.5 km
225.0	AMEC 2006 - 225 km
224.5	AMEC 2006 - 224.5 km
224.0	AMEC 2006 - 224 km
223.5	AMEC 2006 - 223.5 km
223.0	AMEC 2006 - 223 km
222.5	AMEC 2006 - 222.5 km
222.0	AMEC 2006 - 222 km
221.5	AMEC 2006 - 221.5 km
221.0	AMEC 2006 - 221 km
220.5	AMEC 2006 - 220.5 km
220.0	AMEC 2006 - 220 km
219.5	AMEC 2006 - 219.5 km
219.0	AMEC 2006 - 219 km
218.6	AMEC 2006 - 218.6 km
215.2	1979 Section H 74 adj. up 7 m
215.1	2007 Parrott 215
214.4	1979 Section H 77 adj. up 7 m
213.7	1979 Section H 76 adj. up 7 m
213.0	1979 Section 77 H adj. up 7 m
212.1	1979 Section 78 H adj. up 7.5 m
212.0	2007 Parrott 212
210.4	2007 Parrott 210.5
210.1	2007 Parrott 210
208.5	2007 Parrott 209 (assumptions req'd)
207.1	2007 Parrott 207
205.5	2007 Parrott 205
202.4	2006 AMEC 202
200.0	1979 Section 2 H adj. up 2 m
199.4	1979 Section 3 H adj. up 2.5 m
197.9	2007 Parrott 198
197.4	1979 Section 4 H adj. up 3 m
195.5	1979 Section 5 H adj. up 3 m
193.8	2006 AMEC 194
192.8	2006 AMEC 193
192.4	1979 Section 7 H adj. up 1.5 m
190.9	1979 Section 8 H adj. up 4 m
189.1	2007 Parrott 189
189.0	1979 Section 9 H adj. up 2 m
187.9	2007 Parrott 188
187.5	1979 Section 10 H adj. up 2.5 m
185.9	1979 Section 11 H adj. up 2 m
185.0	2007 Parrott 185
184.4	1979 Section 12 H adj. up 2.1 m
182.7	1979 Section 13 H adj. up 2 m
181.4	1979 Section 14 H adj. up 2 m

Appendix A - Source of Bathymetry for Model Cross Sections

(Note: shaded rows indicate sections included in MF1330 model update)

Chainage (km)	Source/ Notes
180.0	2007 Parrott 180
178.0	1979 Section 16 H adj. up 3 m
176.5	2006 AMEC 177
175.4	2007 Parrott 175
174.6	1979 Section 18 H adj. up 3 m
173.2	1979 Section 19 H adj. up 3 m
171.3	1979 Section 20 H adj. up 3 m
169.6	2007 PARROTT 170
168.4	1979 Section 22 H (Interpolated elevation) adj. up 3 m
168.0	2007 PARROTT 168
166.7	1979 Section 23 H adj. up 3.5 m
165.0	2007 PARROTT 165
163.5	1979 Section 25 H (Interpolated elevation) adj. up 0.5 m
162.0	1979 Section 26 H (Interpolated elevation) adj. up 2 m
161.3	2007 PARROTT 162
160.6	1979 Section 27 H (Interpolated elevation) adj. up 2 m
160.0	2007 PARROTT 160
158.7	1979 Section 28 H (Interpolated elevation) adj. up 1.5 m
158.0	2007 PARROTT 158
156.7	1979 Section 29 H (Interpolated elevation) adj. up 4 m
155.9	1979 Section 30 H (Interpolated elevation) adj. up 4 m
154.0	2006 AMEC 154
152.5	1979 Section 32 H (Interpolated elevation) adj. up 5.4 m
151.2	1979 Section 33 H (Interpolated elevation) adj. up 6 m
149.2	1979 Section 34 H (Interpolated elevation) adj. up 6.6 m
148.9	2007 PARROTT 149
148.3	1979 Section 35 H (Interpolated elevation) adj. up 6 m
148.0	2007 PARROTT 148
146.7	1979 Section 36 H (Interpolated elevation) adj. up 7 m
145.1	1979 Section 37 H (Interpolated elevation) adj. up 8 m
144.7	2007 PARROTT 145
143.4	1979 Section 38 H adj. up 10 m
143.2	2007 PARROTT 143
141.1	1979 Section 39 H adj. up 9.5 m
140.3	1979 Section 40 H adj. up 9 m
140.0	AMEC 140
139.4	1979 Section 41 H adj. up 9 m
138.1	2007 PARROTT 138
137.1	2007 PARROTT 137
135.1	2007 PARROTT 135
131.5	2007 PARROTT 131.5 km (Above Minipi Rapids)
131.1	2007 PARROTT 131.1 (Above Minipi Rapids)
128.6	1975 Section 28
128.0	2007 PARROTT 128
126.9	1975 Section 27
125.6	1975 Section 26
125.0	AMEC 125
124.6	1975 Section 25

Appendix A - Source of Bathymetry for Model Cross Sections

(Note: shaded rows indicate sections included in MF1330 model update)

Chainage (km)	Source/ Notes
123.3	1975 Section 24
122.6	1975 Section 23
120.8	AMEC 121
120.3	1975 Section 22
119.7	1975 Section 21
118.6	1975 Section 20
117.3	1975 Section 19
116.4	1975 Section 18
115.2	1975 Section 17
114.5	1975 Section 16
113.8	1975 Section 15
112.5	AMEC 113
112.1	1975 Section 12
111.4	1975 Section 11
110.7	1975 Section 10
109.9	1975 Section 9
109.3	1975 Section 8
108.5	1975 Section 7
107.8	1975 Section 6
107.2	1975 Section 5
106.8	AMEC 2006 - 106.8 km
106.5	AMEC 2006 - 106.5 km
106.4	AMEC 2006 - 106.4 km
106.2	AMEC 2006 - 106.2 km
106.0	AMEC 2006 - 106.0 km
105.8	AMEC 2006 - 105.8 km
105.6	AMEC 2006 - 105.6 km
105.4	AMEC 2006 - 105.4 km
105.2	AMEC 2006 - 105.2 km
105.0	AMEC 2006 - 104.95 km
104.8	AMEC 2006 - 104.75 km
104.6	AMEC 2006 - 104.6 km
104.0	1975 Sta 54+00 upstream of proposed dam site
103.6	1975 Sta 46+00 upstream of proposed dam site
103.2	Parrott 2007 - 103.2 km
103.0	Parrott 2007 - 103.0 km
102.8	Parrott 2007 - 102.8 km
102.6	Parrott 2007 - 102.6 km
102.5	Parrott 2007 - 102.5 km
102.4	Parrott 2007 - 102.4 km
102.3	Parrott 2007 - 102.3 km
102.2	Parrott 2007 - 102.2 km
102.1	Parrott 2007 - 102.1 km
101.9	1975 Sta 6+00 downstream of dam site (adj. down 1m)
101.7	1975 Sta 14+00 downstream of proposed dam site
101.4	1975 Sta 22+00 downstream of proposed dam site
101.0	1975 Sta 34+00 downstream of proposed dam site
100.7	1975 Sta 42+00 downstream of proposed dam site

Appendix A - Source of Bathymetry for Model Cross Sections
(Note: shaded rows indicate sections included in MF1330 model update)

Chainage (km)	Source/ Notes
100.5	1975 Sta 50+00 downstream of proposed dam site
100.3	1975 Sta 58+00 downstream of proposed dam site
100.1	1975 Sta 62+00 downstream of proposed dam site
99.5	1975 Section 2-1
99.2	AMEC 2006 - 99.2 km
99.0	AMEC 2006 - 99.0 km
98.8	AMEC 2006 - 98.8 km
98.6	AMEC 2006 - 98.6 km
97.7	1975 Section 5-5A & 6-5A
96.7	1975 Section 10-9
96.0	AMEC 2006 - 96.0 km
95.5	AMEC 2006 - 95.5 km
95.0	AMEC 2006 - 95.0 km
94.5	AMEC 2006 - 94.5 km
94.1	Based on 2006 AMEC Gull Lake Bathymetry
94.0	AMEC 2006 - 94.0 km
93.5	AMEC 2006 - 93.5 km
93.4	Based on 2006 AMEC Gull Lake Bathymetry
93.1	Based on 2006 AMEC Gull Lake Bathymetry
93.0	AMEC 2006 - 93.0 km
92.6	AMEC 93
92.5	AMEC 2006 - 92.5 km
92.0	AMEC 2006 - 92.0 km
91.5	AMEC 2006 - 91.5 km
91.1	Based on 2006 AMEC Gull Lake Bathymetry
91.0	AMEC 2006 - 91.0 km
90.5	AMEC 2006 - 90.5 km
90.1	Based on 2006 AMEC Gull Lake Bathymetry
90.0	AMEC 2006 - 90.0 km
89.5	AMEC 2006 - 89.5 km
89.0	AMEC 2006 - 89.0 km
88.8	Based on 2006 AMEC Gull Lake Bathymetry
88.4	AMEC 89
88.1	1975 Section 8
87.2	1975 Section 9
86.0	1975 Section 10
84.6	Derived section to represent inlet to Sandy Island Lake
83.6	1975 Section 12
83.0	AMEC 83
82.0	1975 Section 13
80.8	1975 Section 14
80.0	AMEC 80
78.7	1975 Section 16
75.6	1975 Section 18
74.9	AMEC 75
73.5	AMEC 73
72.0	1975 Section 21
71.0	1975 Section 22

Appendix A - Source of Bathymetry for Model Cross Sections

(Note: shaded rows indicate sections included in MF1330 model update)

Chainage (km)	Source/ Notes
69.8	2006 AMEC 70
69.6	1975 Section 23
68.0	2006 AMEC 68
67.2	1975 Section 25
66.5	1975 Section 26
65.2	1975 Section 27
64.4	2006 AMEC 64
63.2	1975 Section 28
62.3	1975 Section 29
61.0	1975 Section 30
59.6	1975 Section 31
59.0	1975 Section 32
57.5	1975 Section 33
56.2	1975 Section 34
55.0	1975 Section 35
53.6	AMEC 54
53.0	1975 Section 37
52.0	1975 Section 38
51.5	AMEC 2006 - 51.5 km
51.0	AMEC 2006 - 51.0 km
50.5	AMEC 2006 - 50.5 km
50.0	AMEC 2006 - 50.0 km
49.7	AMEC 2006 - 49.7 km
49.0	AMEC 2006 - 49.0 km
48.5	AMEC 2006 - 48.5 km
48.0	AMEC 2006 - 48.0 km
47.5	AMEC 2006 - 47.5 km
47.0	AMEC 2006 - 47.0 km
46.5	AMEC 2006 - 46.5 km
46.0	AMEC 2006 - 46.0 km
45.5	AMEC 2006 - 45.5 km
45.0	AMEC 2006 - 45.0 km
44.8	AMEC 45
44.5	AMEC 2006 - 44.5 km
43.8	Based on Geoscott Exploration Consultants Contours (1998)
43.7	Based on Geoscott Exploration Consultants Contours (1998)
43.6	Based on Geoscott Exploration Consultants Contours (1998)
43.5	Based on Geoscott Exploration Consultants Contours (1998)
43.3	Based on Geoscott Exploration Consultants Contours (1998)
43.1	Based on Geoscott Exploration Consultants Contours (1998)
42.8	Based on Geoscott Explorations Consultants Contours (1998)
42.7	Based on Geoscott Exploration Consultants Contours (1998)
42.1	AMEC 2006 - 42.1 km
41.8	AMEC 2006 - 41.8 km
41.4	AMEC 2006 - 41.4 km
41.1	AMEC 2006 - 41.1 km
40.8	AMEC 2006 - 40.8 km
40.5	AMEC 2006 - 40.5 km

Appendix A - Source of Bathymetry for Model Cross Sections

(Note: shaded rows indicate sections included in MF1330 model update)

Chainage (km)	Source/ Notes
40.0	AMEC 2006 - 40.0 km
39.7	AMEC 2006 - 39.7 km
39.5	AMEC 2006 - 39.5 km
35.0	2006 PARROTT 35
33.0	2006 PARROTT 33
29.8	2006 PARROTT 30
24.5	2006 PARROTT
24.2	Based on 2006 PARROTT survey points - upstream of causeway
24.2	Based on 2006 PARROTT survey points - directly upstream of causeway
24.1	Blackrock Bridge
24.1	Based on 2006 PARROTT survey points - directly downstream of causeway
24.1	Based on 2006 PARROTT survey points - downstream of causeway
23.7	2006 PARROTT
22.6	2006 PARROTT
20.0	2006 PARROTT 20
16.7	2006 PARROTT 17
15.2	2006 PARROTT 15
13.3	2006 PARROTT 13
11.1	2006 PARROTT 11
9.2	2006 PARROTT 9
7.0	2006 PARROTT 7
6.3	2006 PARROTT 6
5.0	2006 PARROTT 5
2.8	2006 PARROTT 3
0.8	2006 PARROTT 1
-0.2	2006 PARROTT 0
-1.5	2006 PARROTT -1
-3.0	2006 PARROTT -2
-4.8	Nautical Charts
-9.4	Nautical Charts
-11.6	Nautical Charts
-16.1	Nautical Charts
-21.4	Nautical Charts
-27.3	Nautical Charts
-31.8	Nautical Charts
-37.4	Nautical Charts
-42.5	Nautical Charts
-47.9	Nautical Charts
-53.6	Nautical Charts
-59.7	Nautical Charts
-65.3	Nautical Charts
-71.0	Nautical Charts
-76.1	Nautical Charts
-81.0	Nautical Charts
-86.1	Nautical Charts
-91.0	Nautical Charts
-95.9	Nautical Charts
-101.0	Nautical Charts

Appendix A - Source of Bathymetry for Model Cross Sections

(Note: shaded rows indicate sections included in MF1330 model update)

Chainage (km)	Source/ Notes
-105.9	Nautical Charts
-111.1	Nautical Charts
-115.6	Nautical Charts
-119.8	Nautical Charts
-124.7	Nautical Charts
-128.5	Nautical Charts
-130.6	Nautical Charts
-133.1	Nautical Charts
-135.6	Nautical Charts
-138.3	Nautical Charts
-140.5	Nautical Charts
-142.8	Nautical Charts
-145.1	Nautical Charts
-147.1	Nautical Charts
-149.4	Nautical Charts
-151.4	Nautical Charts
-153.8	Nautical Charts
-155.2	Nautical Charts
-158.0	Nautical Charts
-160.6	Nautical Charts
-163.0	Nautical Charts
-165.1	Nautical Charts
-167.9	Nautical Charts
-170.3	Nautical Charts
-173.4	Nautical Charts
-175.5	Nautical Charts
-178.1	Nautical Charts
-180.8	Nautical Charts
-185.9	Nautical Charts
-191.6	Nautical Charts
-197.2	Nautical Charts
-202.8	Nautical Charts
-207.8	Nautical Charts
-213.1	Nautical Charts
-218.0	Nautical Charts
-223.0	Nautical Charts
-224.0	Nautical Charts

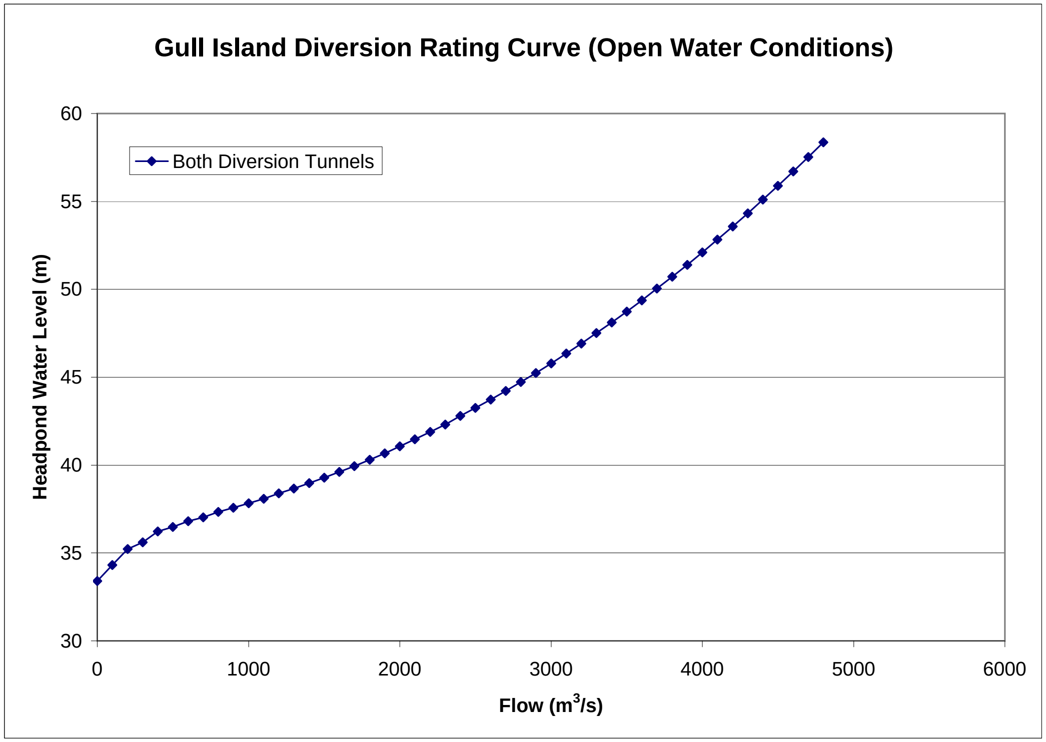
Appendix B

Structure Discharge Rating Curves

Appendix B - Muskrat Falls and Gull Island Discharge Rating Curves

Gull Island Diversion Rating Curve (Open Water Conditions)
Source: GI1061 Figure 4-1

	Flow (m³/s)	
Headpond Water Level (m)	One Diversion Tunnel	Both Diversion Tunnels
33.4	0	0
34.3	50	100
35.2	100	200
35.6	150	300
36.2	200	400
36.5	250	500
36.8	300	600
37.0	350	700
37.3	400	800
37.6	450	900
37.8	500	1000
38.1	550	1100
38.4	600	1200
38.7	650	1300
39.0	700	1400
39.3	750	1500
39.6	800	1600
39.9	850	1700
40.3	900	1800
40.7	950	1900
41.1	1000	2000
41.5	1050	2100
41.9	1100	2200
42.3	1150	2300
42.8	1200	2400
43.2	1250	2500
43.7	1300	2600
44.2	1350	2700
44.7	1400	2800
45.2	1450	2900
45.8	1500	3000
46.3	1550	3100
46.9	1600	3200
47.5	1650	3300
48.1	1700	3400
48.7	1750	3500
49.4	1800	3600
50.0	1850	3700
50.7	1900	3800
51.4	1950	3900
52.1	2000	4000
52.8	2050	4100
53.6	2100	4200
54.3	2150	4300
55.1	2200	4400
55.9	2250	4500
56.7	2300	4600
57.5	2350	4700
58.4	2400	4800

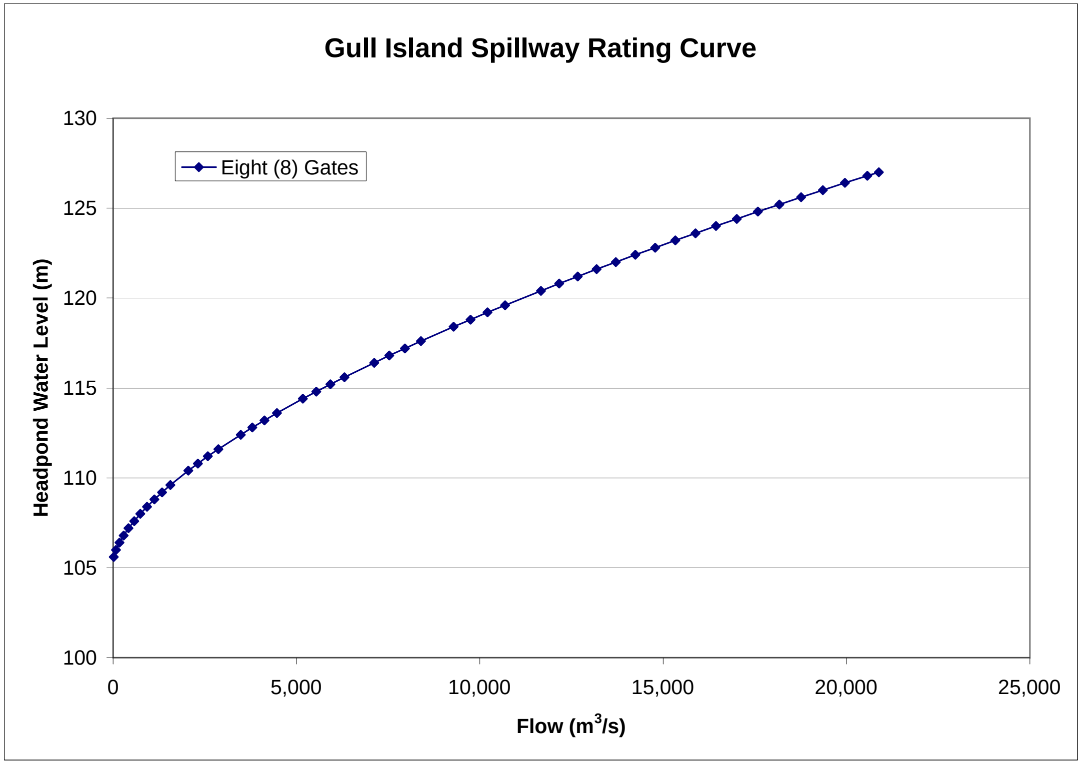


Appendix B - Muskrat Falls and Gull Island Discharge Rating Curves

Gull Island Spillway Rating Curve

Source: GI1061 Figure 5-1

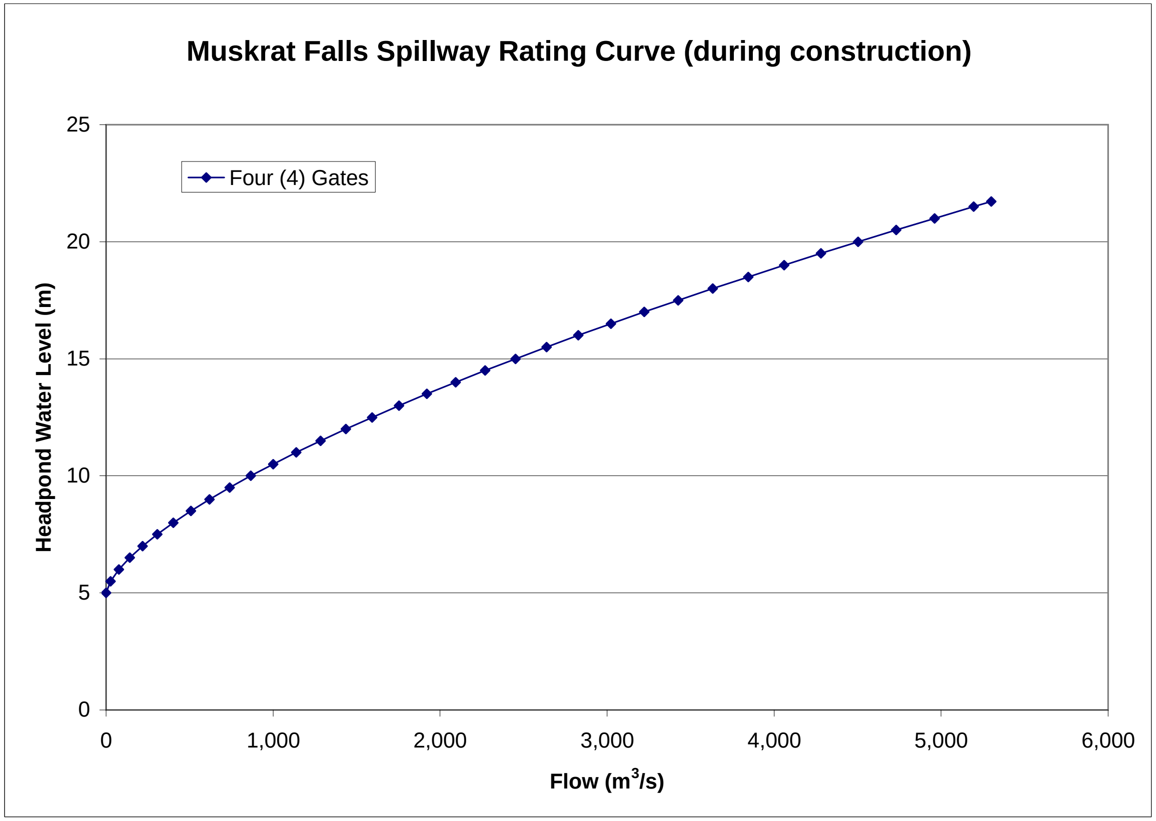
Headpond Water Level (m)	Flow (m^3/s)	
	One Gate	Eight (8) Gates
105.6	1.9	15.1
106.0	9.9	79.3
106.4	21.5	172.0
106.8	35.9	287.1
107.2	52.7	421.7
107.6	71.7	573.8
108.0	92.8	742.2
108.4	115.7	925.8
108.8	140.5	1,123.9
109.2	167.0	1,335.9
109.6	195.1	1,561.1
110.4	256.2	2,049.8
110.8	289.0	2,312.4
111.2	323.3	2,586.8
111.6	359.1	2,872.6
112.4	434.7	3,477.7
112.8	474.5	3,796.4
113.2	515.7	4,125.6
113.6	558.1	4,465.2
114.4	646.8	5,174.5
114.8	693.0	5,543.9
115.2	740.4	5,922.9
115.6	788.9	6,311.4
116.4	889.5	7,116.1
116.8	941.5	7,532.1
117.2	994.6	7,957.1
117.6	1,048.9	8,390.8
118.4	1,160.5	9,284.2
118.8	1,218.0	9,743.6
119.2	1,276.4	10,211.4
119.6	1,335.9	10,687.4
120.4	1,458.0	11,663.8
120.8	1,520.5	12,164.0
121.2	1,584.0	12,672.1
121.6	1,648.5	13,187.9
122.0	1,713.9	13,711.5
122.4	1,780.3	14,242.7
122.8	1,847.7	14,781.4
123.2	1,916.0	15,327.6
123.6	1,985.2	15,881.3
124.0	2,055.3	16,442.2
124.4	2,126.3	17,010.5
124.8	2,198.2	17,585.9
125.2	2,271.1	18,168.5
125.6	2,344.8	18,758.2
126.0	2,419.4	19,355.0
126.4	2,494.8	19,958.7
126.8	2,571.2	20,569.3
127.0	2,609.7	20,877.2



Appendix B - Muskrat Falls and Gull Island Discharge Rating Curves

Muskrat Falls Spillway Rating Curve (during construction)
Source: MF1050 Figure A-6

Headpond Water Level (m)	Flow (m^3/s)	
	One Gate	Four (4) Gates
5.0	0.0	0.0
5.5	6.9	27.4
6.0	19.4	77.5
6.5	35.6	142.4
7.0	54.8	219.2
7.5	76.6	306.4
8.0	100.7	402.8
8.5	126.9	507.6
9.0	155.0	620.1
9.5	185.0	740.0
10.0	216.7	866.6
10.5	250.0	999.8
11.0	284.8	1,139.2
11.5	321.1	1,284.6
12.0	358.9	1,435.6
12.5	398.0	1,592.1
13.0	438.5	1,754.0
13.5	480.2	1,920.9
14.0	523.2	2,092.9
14.5	567.4	2,269.7
15.0	612.8	2,451.2
15.5	659.3	2,637.4
16.0	707.0	2,828.0
16.5	755.7	3,023.0
17.0	805.6	3,222.3
17.5	856.4	3,425.7
18.0	908.3	3,633.3
18.5	961.2	3,844.9
19.0	1,015.1	4,060.5
19.5	1,070.0	4,280.0
20.0	1,125.8	4,503.2
20.5	1,182.6	4,730.3
21.0	1,240.2	4,961.0
21.5	1,298.8	5,195.3
21.7	1,324.9	5,299.6



Appendix B - Muskrat Falls and Gull Island Discharge Rating Curves

Muskrat Falls Spillway Rating Curve (during operation)
Source: MF1050 Figure A-7

Headpond Water Level (m)	Flow (m^3/s)			
	One Gate	Four (4) Gates	North Dam Overflow	Total
30.0	2,663	10,653		10,653
30.5	2,690	10,759		10,759
31.0	2,716	10,864		10,864
31.5	2,742	10,968		10,968
32.0	2,768	11,071		11,071
32.5	2,793	11,173		11,173
33.0	2,818	11,274		11,274
33.5	2,844	11,374		11,374
34.0	2,868	11,473		11,473
34.5	2,893	11,572		11,572
35.0	2,917	11,670		11,670
35.5	2,942	11,766		11,766
36.0	2,966	11,862		11,862
36.5	2,989	11,958		11,958
37.0	3,013	12,052		12,052
37.5	3,037	12,146		12,146
38.0	3,060	12,239		12,239
38.5	3,083	12,332		12,332
39.0	3,106	12,423		12,423
39.5	3,129	12,514	0	12,514
40.0	3,151	12,605	263	12,868
40.5	3,174	12,694	798	13,493
41.0	3,196	12,783	1527	14,311
41.5	3,218	12,872	2420	15,292
42.0	3,240	12,960	3458	16,418
42.5	3,262	13,047	4630	17,677
43.0	3,283	13,134	5924	19,058
43.5	3,305	13,220	7336	20,555
44.0	3,326	13,305	8857	22,162