KEEYASK GENERATION PROJECT STAGE IV STUDIES-PHYSICAL ENVIRONMENT GN-9.1.13- EXISTING AND PROJECT ENVIRONMENT WATER SURFACE PROFILES EFFECTS ASSESSMENT

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KEEYASK GENERATION PROJECT

STAGE IV STUDIES - PHYSICAL ENVIRONMENT

EXISTING AND PROJECT ENVIRONMENT WATER SURFACE PROFILES EFFECTS ASSESSMENT

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INTEROFFICE MEMORANDUM

FROM	J. Malenchak, Ph.D, P.Eng Section Head Sediment and Ice Studies Water Resource Engineering Department Power Planning Division	TO	M.E. St. Laurent, M.Sc., P.Eng. Section Head Nelson River Keeyask Project Hydro Power Planning Department Power Projects Development Division

DATE 2012 09 01

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SUBJECT **KEEYASK GENERATING STATION – PHYSICAL ENVIRONMENT STUDIES EXISTING AND PROJECT ENVIRONMENT WATER SURFACE PROFILES EFFECTS ASSESSMENT MEMORANDUM GN-9.1.13-REV 0**

Please find the attached report "Keeyask Generation Project Stage IV Studies - Physical Environment: Existing and Project Environment Water Surface Profiles Effects Assessment GN-9.1.13". This report documents the differences between existing environment and post-project open-water surface profiles (under steady-state conditions) within the hydraulic zone of influence upstream of the project. Post-project results and effects assessments downstream of the project site will be included where appropriate.

This technical memorandum is to be used in support of the Keeyask Generating Station Environmental Impact Statement. In order to provide appropriate interpretation and guidance, please consult the Water Resource Engineering Department prior to external distribution.

Please contact me at (204) 360-5028 or JMalenchak@hydro.mb.ca if you have any questions or concerns.

Sincerely,

J. Malenchak, Ph.D, P. Eng.

Cc: Efrem Teklemarian, M.Sc., P.Eng.
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1 INTRODUCTION

This report documents the development of the steady-state water surface profiles used in the Keeyask Generating Station (GS) Stage IV Engineering and Physical Environment Environmental Impact Statement (EIS) studies. The steady-state water surface profiles presented are representative of those found during open-water conditions and do not include any effects of ice. The effects assessment of **post-project** water levels at key sites within the study reach under peaking and base-load operations is already covered in Deliverable GN-9.1.12 - "Project Environment - Water Level and Flow Regime at Key Sites Effects Assessment" (Manitoba Hydro, 2012e).

The proposed Keeyask GS project is located on the lower Nelson River approximately 56 km downstream of Split Lake and approximately 4 km upstream of Stephens Lake. Once built, the project will alter various characteristics of the existing water regime within the project's **hydraulic zone of influence**. To illustrate how the **existing environment** will be changed by the Keeyask GS project, **existing environment** and **post-project** water surface profiles have been developed for a range of flow conditions. The methods used to estimate these water surface profiles are provided in the following sections.

All elevations are referenced to the National Geodetic Vertical Datum 1929 adjustment (NGVD 29), unless otherwise stated.

2 DATA AND METHODOLOGY

2.1 PROJECT INFLOWS

The 5^{th}, 50^{th}, and 95^{th} percentile open-water flow quantiles shown in Table 1 below were used to characterize the **existing environment** and **post-project** water regimes under a range of historical flow conditions. The **inflow** files were updated to include data up to and including the 2006 inflows and the flow quantiles were then revised after this study was completed. The development and update of the project **inflows** shown in Table 1 is described in Deliverable GN-9.1.1 - "Existing Environment and Post-Project Flow Files" (Manitoba Hydro, 2012a) and Deliverable GN-9.1.2 - "Sensitivity Analysis of Water Regime Products to Inflows" (Manitoba Hydro, 2012b). All season flow data was used to develop these percentiles. Table 2 below lists the accuracies that the profiles are deemed to represent with respect to the flows. Through the sensitivity analysis described in the memo above, the water surface profiles discussed here are considered to be accurate to ± 2.5% of the quantile flow listed.

Table 1 - Project Inflows

Quantile	Existing Environment Flows (cms)	Post-Project Environment Flows (cms)
5%	2060	2170
50%	3030	3030
95%	4330	4430

Table 2 - Quantile Flows and Associated Accuracies for Water Level Modeling

Quantile	Existing Environment Flow Range (cms)	Post Project Flow Range (cms)
5%	2060 ± 2.5% = 2009 to 2112	2170 ± 2.5% = 2116 to 2224
50%	3030 ± 2.5% = 2954to 3106	3030 ± 2.5% = 2954 to 3106
95%	4330 ± 2.5% = 4222 to 4438	4430 ± 2.5% = 4319 to 4541

2.2 WATER SURFACE PROFILES

A calibrated one-dimensional steady-state backwater model was developed using the US Army Corps of Engineers' HEC-RAS and HEC-GeoRAS software programs (USACE 1999 & 2002). The HEC-RAS software program simulates the hydraulics of flow within natural rivers and other channels. The US Army Corps of Engineers' HEC-GeoRAS software was used to construct the geometry of the model (USACE, 1999). The HEC-GeoRAS program is an extension developed for use within the Environmental Systems Research Institute (ESRI) ArcGIS (Geographical Information System) software. Two separate model setups were used to simulate the open-water surface profiles for both **existing environment** and **post-project** conditions.

Digital Terrain Models (DTMs) of the study area were used as the source of all geometry to develop the model cross-sections. Details regarding development of the DTMs can be found in Deliverable GN-9.1.5 - "Existing and Project Environment Digital Terrain Models" (Manitoba Hydro, 2012d). Using ArcGIS, a shapefile was developed to include all the cross-sectional cut lines found in the hydraulic model, as shown in Figures 1 and 2 in Appendix B. A shapefile of river centerlines, junctions, and shorelines was also developed. The GeoRAS software was used to cut the cross-sections from the DTMs, which were then imported into HEC-RAS. Reach lengths and bank stations were computed using GeoRAS. A large number of closely spaced cross-sections were used in the hydraulic model so that the dynamic effects of storage within the river reach would be taken into account in other simulations for different purposes.

The hydraulic model was calibrated by adjusting the hydraulic roughness, ineffective flow areas, and localized areas of **bathymetry**, so that estimated water levels matched rating curves based on measured water levels. The rating curves were developed using a series of historical flow and water level measurements. At some locations, cross-sections were fabricated and adjusted where only limited **bathymetry** was available, which usually occurred in high-velocity zones where surveys could not be conducted safely (such as Gull Rapids and Birthday Rapids). The model accuracy is ± 0.1 - 0.3 m, while the majority of the reach is calibrated to ± 0.1 m - 0.15 m. The model is less accurate within Gull Rapids, however, due to complex hydraulic conditions that are present within the rapids and the general lack of measured **bathymetric** data. A detailed description of all rating curves, hydrometric data, vertical control, and model calibration procedures can be found in Gull Generation Project Stage IV Studies Deliverable GN-2.1 - “Updated Open Water Hydraulics” (Manitoba Hydro, 2005).

Once the **existing environment** model was calibrated, it was modified to simulate the hydraulic conditions for the **post-project** environment. The models can be used to effectively simulate open-water hydraulic conditions for a range of flows between 1000 to 6000 cms as this is the range of flow the models were calibrated to as outlined in Deliverable GN-2.1 mentioned in the paragraph above.

The upstream boundary condition for both the **existing environment** and **post-project** models is a constant inflow boundary set as the percentile inflow being considered. A downstream boundary elevation of 140.2 m was used for the **existing environment** model for all three percentile inflows, representing the 50^{th} percentile operating level of the Kettle GS **forebay** (Stephen’s Lake). The location of the downstream boundary for the **existing environment** model is at approximately the inlet of Stephen’s Lake. For the **post-project** hydraulic model, the location of the downstream boundary was moved upstream to the location of the Keeyask GS axis and the reservoir full supply level of 159.0 m was used as the model boundary for all percentile inflows. No initial conditions were required for these steady-state simulations.

3 RESULTS

The **existing environment** and **post-project** steady-state water surface profiles developed for the 5th, 50th and 95th percentile flows are presented in Figures 3 to 5 (Appendix B), respectively. The figures illustrate the extent of the upstream **hydraulic zone of influence** of the Keeyask GS during open-water conditions.

4 EFFECTS ASSESSMENT

Water levels upstream of the Keeyask project will be raised above natural levels, creating a **forebay** that reaches approximately 40 km upstream. Water depths in the river reach downstream of Clark Lake will increase and newly flooded areas, mostly around Gull Lake and Gull Rapids, will be created. The **backwater effect** upstream of the project (during the open-water flow conditions defined in Table 1) extends upstream of Birthday Rapids, but does not reach Clark Lake nor Split Lake. The effects described above are similar throughout the flow range used to characterize the **existing environment** and **post-project** water regimes.

A previous study concluded that Split Lake levels are unaffected by **backwater effects** from the project for flows between 1000 to 6000 cms, as described in Gull Generation Project Stage IV Studies Deliverable GN-2.1 - "Updated Open Water Hydraulics" (Manitoba Hydro, 2004). A detailed summary of estimated changes in depths within the river and newly flooded areas due to impoundment of the Keeyask **forebay** are presented in Deliverable GN-9.1.3 - "Existing and Project Environment Shoreline and Depth Effects Assessment" (Manitoba Hydro, 2012c).

The effects of the project on the water surface profiles downstream of the project site were found to be negligible when compared to the water surface profiles under **existing environment** conditions at the same location. This was expected as the water surface profiles in this area are driven largely by the water level in Stephens Lake which will not be affected by the project.

5 GLOSSARY

backwater effect In hydrologic terms, the effect that a dam or other obstruction has in raising the surface of the water upstream from it.

bathymetry The measurement of the depth of bodies of water.

existing environment Refers to the environment in which a proposed generating station is to be built, under the conditions that exist prior to it actually being built.

forebay A reservoir feeding the intake of a hydroelectric power plant.

inflow Refers to flow discharge to a reservoir/lake/forebay.

post-project Refers to the environment in which a proposed generating station is to be built, under the conditions that exist after it has been built.

6 REFERENCES

Manitoba Hydro (2005). Gull Generation Project Stage IV Studies - Physical Environment: Updated Open Water Hydraulics. GN-2.1, Rev 0.

Manitoba Hydro (2012a). Keeyask Generation Project Stage IV Studies - Physical Environment: Existing and Project Environment Flow Files. GN-9.1.1, Rev 0.

Manitoba Hydro (2012b). Keeyask Generation Project Stage IV Studies - Physical Environment: Sensitivity of Water Regime Products to Inflows. GN-9.1.2, Rev 0.

Manitoba Hydro (2012c). Keeyask Generation Project Stage IV Studies - Physical Environment: Existing and Project Environment Shoreline and Depth Effects Assessment. GN-9.1.3, Rev 0.

Manitoba Hydro (2012d). Keeyask Generation Project Stage IV Studies - Physical Environment: Existing and Project Environment Digital Terrain Models. GN-9.1.5, Rev 0.

Manitoba Hydro (2012e). Keeyask Generation Project Stage IV Studies - Project Environment: Project Environment - Water Level and Flow Regime at Key Sites Effects Assessment. GN-9.1.12, Rev0.

USACE (1999). US Army Corps of Engineers HEC-GeoRAS Users Manual Version 1. CPD-75. USACE Hydrologic Engineering Center (HEC) 609 Second Street Davis, CA 95616-4687 http://www.hec.usace.army.mil/publications/pub_download.html

USACE (2002). US Army Corps of Engineers HEC-RAS River Analysis System Hydraulic Reference Manual Version 3.1. CPD-69. USACE Hydrologic Engineering Center (HEC) 609 Second Street Davis, CA 95616-4687 http://www.hec.usace.army.mil/publications/pub_download.html

APPENDIX A - ABBREVIATIONS

ABBREVIATIONS

cms ....cubic metres per second

DTM...........................digital terrain model

EIS..............................environmental impact statement

GIS ....Geographical Information System

GS ....generating station

km ....kilometre

m ....metre

NGVD........................National Geodetic Vertical Datum

APPENDIX B - FIGURES

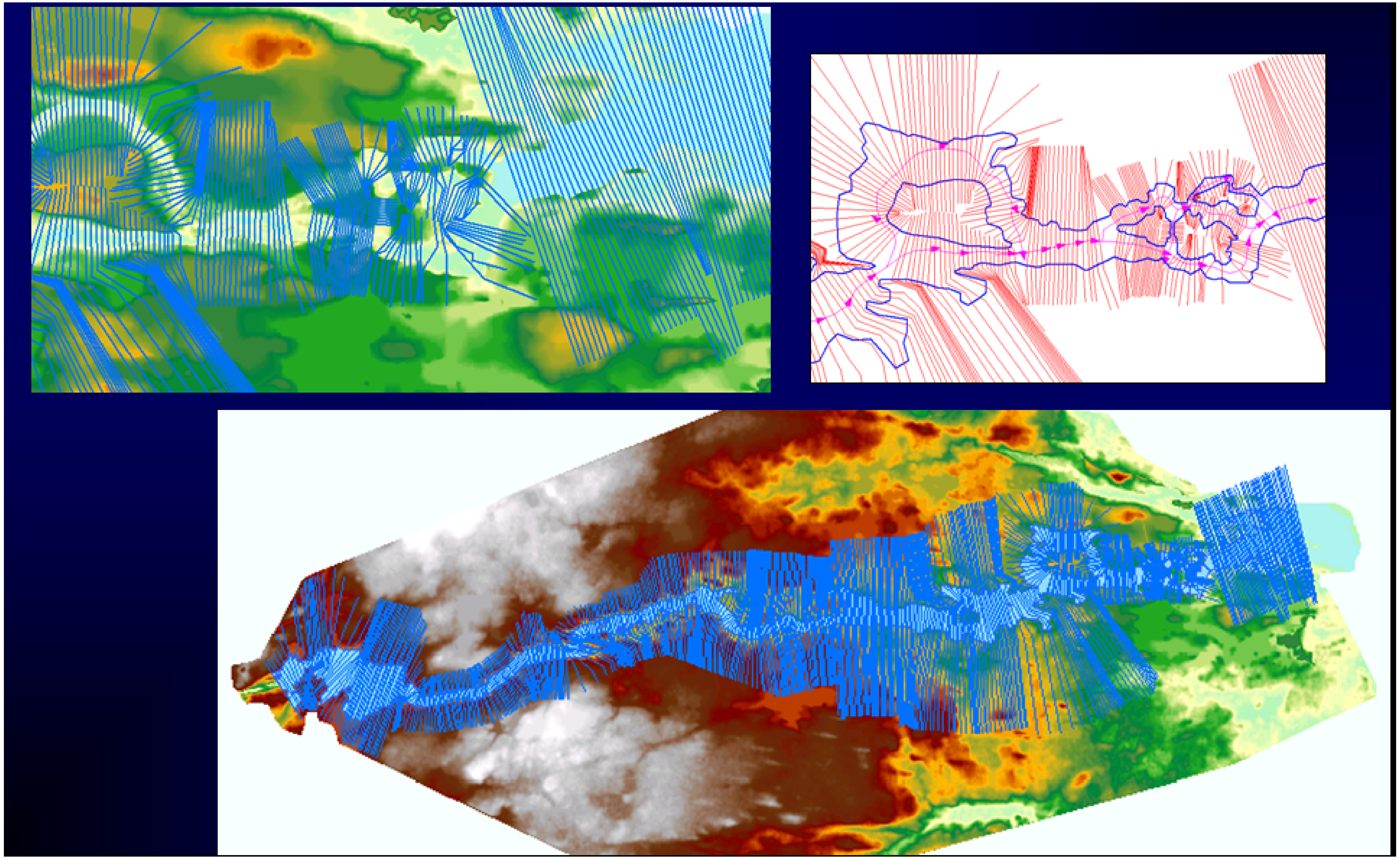

Figure 1 - Cross-Sections Used to Develop the HEC-RAS Existing Environment Model

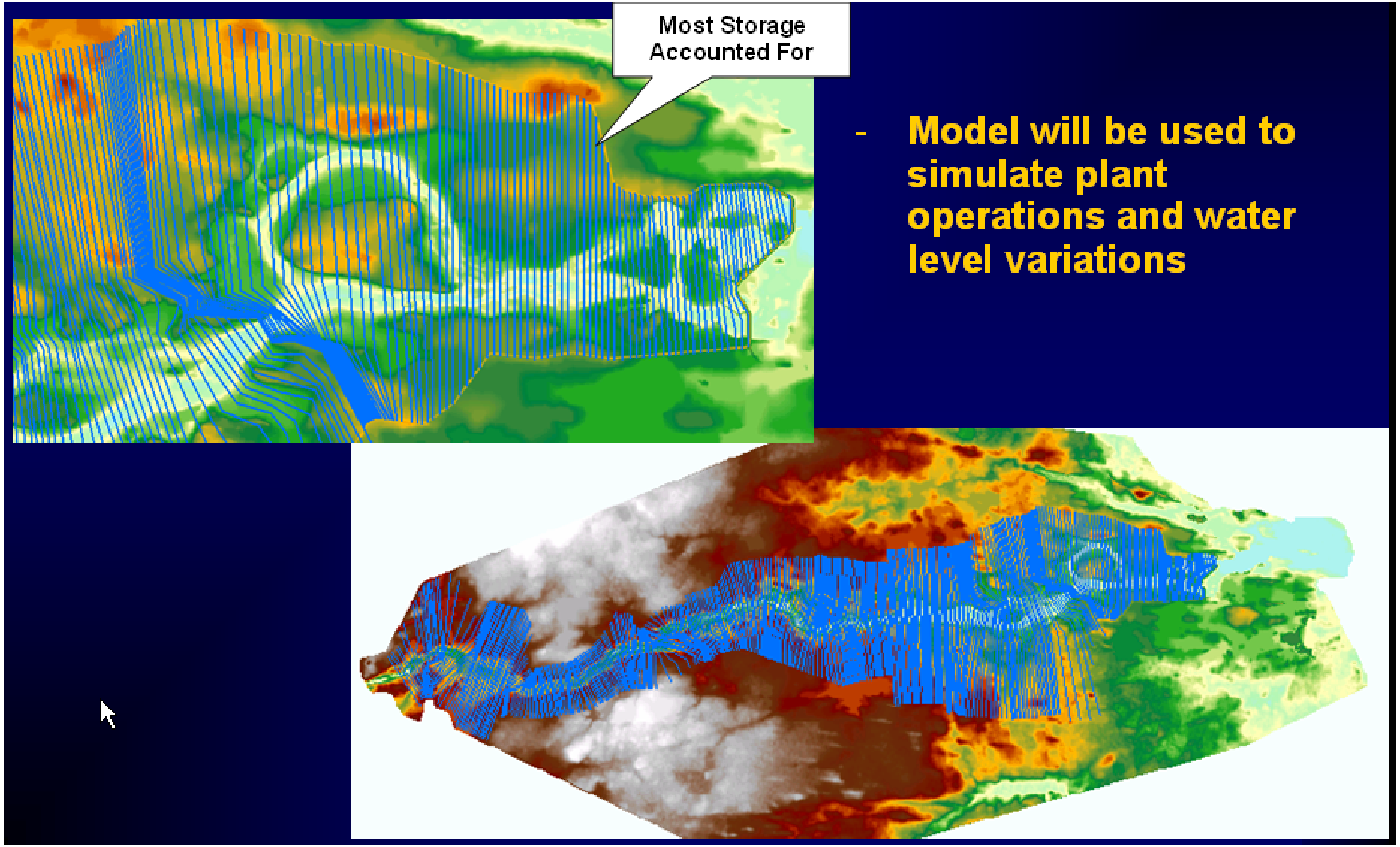

Figure 2 - Cross-Sections Used to Develop the HEC-RAS Post-Project Model

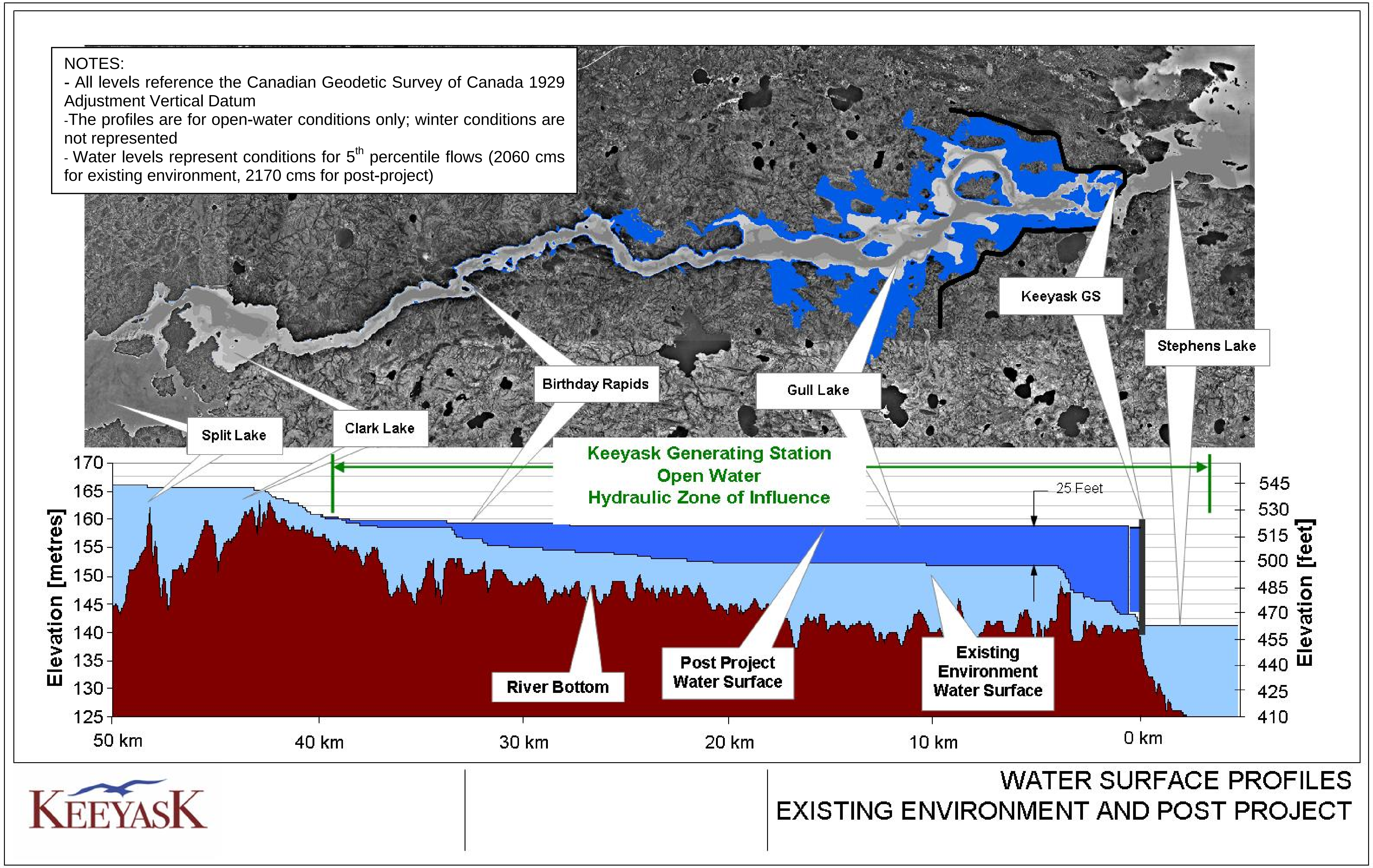

Figure 3 - Existing Environment and Post-Project Water Surface Profiles (5th Percentile, Open-Water Flow)

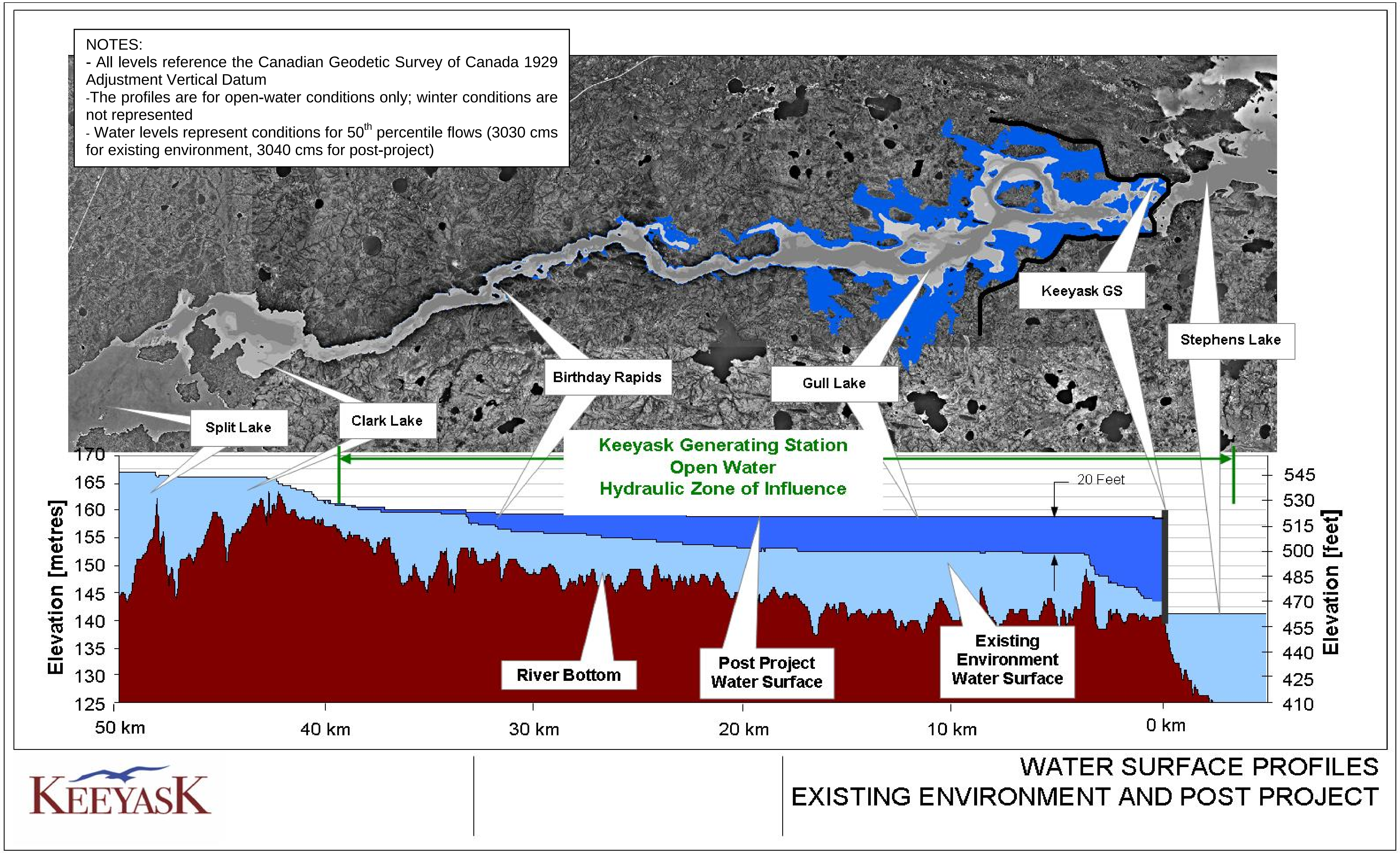

Figure 4 - Existing Environment and Post-Project Water Surface Profiles (50th Percentile, Open-Water Flow)

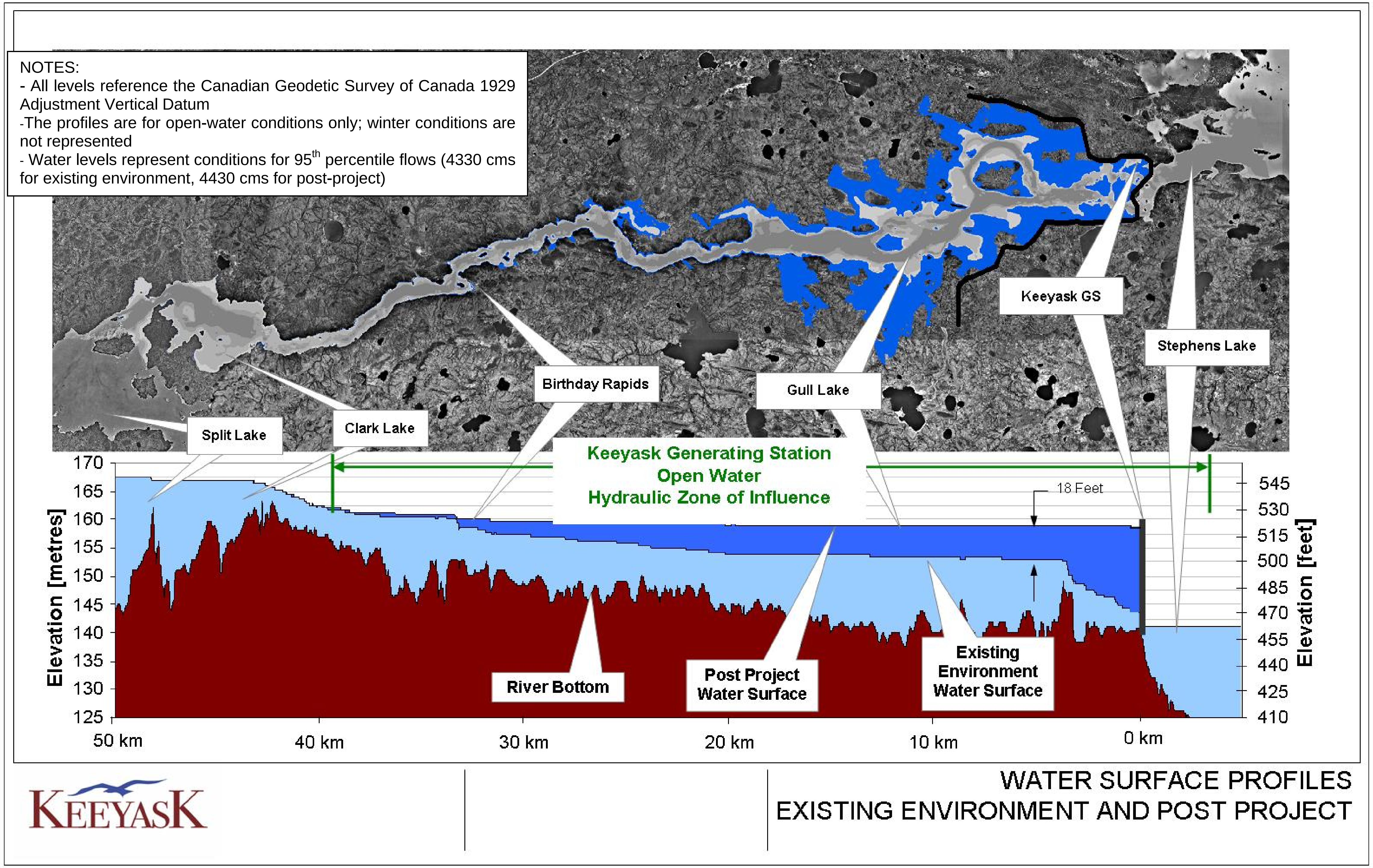

Figure 5 - Existing Environment and Post-Project Water Surface Profiles (95th Percentile, Open-Water Flow)