# Columbia River Project Water Use Plan

## Lower Columbia River Fish Management Plan

### Implementation Year 2

### Reference: CLBMON-47

***Lower Columbia River: Whitefish Spawning Ground Topographic Survey: Year 2 Summary Report***

**Study Period: January 2012 to December 2012**

**Golder Associates Ltd.**
**Brad Hildebrand – Project Manager and Author**
**bhildebrand@golder.com**

**July 26, 2013**

**July 26, 2013**

## CLBMON - 47: YEAR 2

# Lower Columbia River Whitefish Spawning Ground Topographic Survey

**Submitted to:**
BC Hydro
6911 Southpoint Drive
11th Floor
Burnaby, BC
V3N 4X8

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REPORT

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Cover Photo: Deploying GPS RTK base station prior to conducting ADCP surveys along selected channel cross sections at the Mountain Whitefish spawning area in the lower Kootenay River, January 13, 2011.

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# Glossary

| | |
|---|---|
| BRD | Brilliant Dam |
| CPR | Canadian Pacific Railway |
| ELM | Egg Loss Model |
| GPS | Global Positioning System |
| GRTS | Generalized Random Tessellation Stratified |
| HEC-RAS | Hydrologic Engineering Centers River Analysis System |
| HLK | Hugh L. Keenleyside Dam |
| LCR | Lower Columbia River |
| LDB | Left Downstream Bank |
| RDB | Right Downstream Bank |
| RTK | Real Time Kinematic |
| SEL | Sproulers' Enterprises |
| TOR | Terms of Reference |
| UTM | Universal Transverse Mercator |
| WFM | Whitefish Flow Management |
| WUP | Water Use Plan |

# Executive Summary

Mountain whitefish (*Prosopium williamsoni*) are the most abundant sportfish in the Keenleyside Reach of the lower Columbia River [defined as the Columbia River from Hugh L. Keenleyside Dam (HLK) to the Canada-US Border and including the lower Kootenay River below Brilliant Dam (BRD)]. This species uses this area for all life history functions. Results of studies conducted by BC Hydro in the early 1990s raised concerns by the environmental regulatory agencies (i.e., BC Ministry of Environment, Lands and Parks; Department of Fisheries and Oceans Canada) about the effects of river regulation on Mountain Whitefish reproductive success in the lower Columbia River. Water level fluctuations associated with dam operations on both the Columbia (HLK) and Kootenay (BRD) rivers can negatively impact whitefish spawning success by exposing incubating embryos when water levels recede. These concerns led to the development and initiation of BC Hydro's Whitefish Flow Management (WFM) program in the winter of 1994/95. A series of intensive studies on Mountain Whitefish life history characteristics were subsequently conducted annually between 1995 and 1999. Additional annual studies were initiated in 2008 as a component of BC Hydro's Water Use Planning program and are scheduled to continue until 2013 (CLBMON 48: Lower Columbia River Whitefish Life History and Egg Mat Monitoring Program). Results from this work will provide updated models as tools for BC Hydro to reduce the uncertainty related to overall reliability of egg loss estimates and will help guide future management of this population.

The present study was developed to provide data to support refinement of the Mountain Whitefish Egg Loss Model currently used to project the proportion of the deposited eggs within defined study areas dewatered during HLK and BRD operations. Refined hydraulic modelling was chosen as the primary tool to assess both habitat use by spawning Mountain Whitefish and to project areas being dewatered during regulated flow changes in the Kootenay and Columbia rivers.

Individual RIVER-2D hydraulic models were setup and calibrated for the two identified key Mountain Whitefish spawning areas. The first RIVER-2D Model corresponds to the Columbia River Reach at the CPR Island spawning area and the other to Kootenay River Reach downstream of the Highway 3A Bridge. The calibrated roughness heights Ks values were 0.25 m and 0.20 m for the Columbia and Kootenay reaches, respectively. The slightly higher Ks value found for the Kootenay River Reach may be due to its slightly steeper bed slope and possible coarser materials than those for the Columbia River Reach.

The developed Columbia Reach RIVER-2D Hydraulic Model adequately represented the river hydraulic situations of the CPR Island spawning area. In order to test the accuracy of the model, a sensitivity analysis was conducted. The results of the sensitivity analysis showed that the simulated water levels were not sensitive to Ks variations during testing. Currently, the Columbia Reach model has only been calibrated under low flow conditions.

In the Kootenay Reach, the hydraulic situation is influenced by the water levels in the Columbia River at its confluence. High water levels in the Columbia River will cause backwater effects in the Kootenay River. During development and testing of the Kootenay RIVER-2D Model, inconsistencies were found that were related to the confluence. To address these inconsistencies, this model was expanded to incorporate the confluence as well. After expansion, sensitivity analysis testing was conducted on the roughness height Ks. As in the Columbia Reach, it was shown that the simulated water levels were not sensitive to Ks variations along the Kootenay River

Reach. Prior to expansion, the Kootenay Reach Model was calibrated under low flow conditions. Calibration of the expanded model under similar conditions is planned for Year 3 of this program.

To facilitate the expansion of the Kootenay spawning area RIVER-2D Model (see Section 4.2), a total of 30 cross sections were surveyed in the confluence area of the Columbia and Kootenay rivers. These cross sections were included in the development of the RIVER-2D Hydraulic Model. The Kootenay River expansion area was divided into three separate sections based on topography; the area upstream of the confluence, the confluence and downstream of the confluence. Topographical features of interest in the expansion area are a boulder garden and multiple benches and ridges in the upstream section and a trend of increasing depth in an upstream to downstream direction.

The RIVER-2D models will be used to predict water velocities and depths within the key spawning areas. This information, in concert with habitat usability information from spawning surveys conducted as part of CLBMON-48, will then be used to update BC Hydro's Mountain Whitefish Egg Loss Model. The Egg Loss Model's will use this information to predict egg deposition patterns and subsequent egg stranding at actual or forecast flow regimes. The ability of the egg loss model to predict egg mortalities as a result of dewatering will not be obtainable as there currently is no field measure to collect egg mortality data. Therefore, the model will demonstrate its ability to predict egg deposition patterns as observed during the CLBMON-48 study. The update of the Egg Loss Model will occur in the third and final year of the CLBMON-47 program.

The progress made to address the study objectives and management questions is summarized in Table I.

**Table EI: CLBMON-47 Year 2: STATUS of OBJECTIVES and MANAGEMENT QUESTIONS**

| Study Objective | Management Question | Current Status |
|---|---|---|
| To design and implement controlled topographical surveys to describe the characteristics of representative whitefish spawning locations in the lower Columbia and Kootenay rivers. | What are the topographic characteristics of the key spawning locations for Mountain Whitefish in the lower Columbia and Kootenay rivers? | At the CPR Island spawning area, topographical features include steep gradient banks along the RDB, a channel between the LDB and CPR Island that remains wetted at higher water elevations, and shallow depths in the downstream portion of the spawning area.<br><br>In the downstream portions of the Kootenay River, topographic features include Kootenay Eddy along the RDB, a large point bar that deflects and constricts the Kootenay River flow creating a deep channel along the LDB adjacent to the eddy, and a ridge between the eddy and the channel. The middle section is dominated by low gradient banks, a relatively wide thalweg with consistent depth, and a large backwater area downstream of two islands along the LDB. Topographical features of interest in the upstream portion include a shallow shoal and a bedrock outcrop along the RDB.<br><br>The upstream section of the Kootenay expansion area is dominated a large boulder garden in the mid-channel and along the LDB. Downstream of the boulder garden, multiple benches and ridges are present. In the mid-channel portion of the confluence section of the expansion area, the river bottom is relatively uniform. Along the LDB, the gradient gradually decreases, while along the RDB, gradients were typically steeper. The downstream section of the expansion area consists of steep gradients along both the LDB and the RDB, while the mid-channel portion of the river bottom is relatively uniform. |
| Assemble, verify, analyze, and input new topographic data of the representative whitefish spawning locations into an existing 1-dimensional steady state hydraulic model (HEC RAS Model). | What is the hydraulic response of the river to discharge fluctuations at these key spawning locations? How do changes in river discharge influence river stage, and how does river stage relate to wetted channel area at these key spawning locations? | Completed for Kootenay river and Upper Reach of the Columbia River. This management question will be addressed in Year 3 after the completion of the RIVER 2D models. |
| Test and calibrate the HEC RAS Model to improve the accuracy of the model. | What is the hydraulic response of the river to discharge fluctuations at these key spawning locations? How do changes in river discharge influence river stage, and how does river stage relate to wetted channel area at these key spawning locations? | Updated HEC RAS Model was calibrated. This management question will be addressed in Year 3 after the completion of the RIVER 2D Model. |
| Refine and redevelop the Egg Loss Model, as appropriate, to enhance the reliability of outputs from the model. | How do daily flow changes contribute to cumulative channel dewatering in key spawning areas over the whitefish reproductive period? | This Study Objective and Management Question will be addressed in Year 3 of this program when the Egg Loss Model is updated. |
| Document changes to the model and compare inter-annual egg loss estimates in relation to the flow stabilization index. | How do daily flow changes contribute to cumulative channel dewatering in key spawning areas over the whitefish reproductive period? | This Study Objective and Management Question will be addressed in Year 3 of this program when the RIVER-2D and Egg Loss models are developed/updated. |
| Assess the impact of the increased number of cross-sections and survey detail from the previous HEC RAS Model, and comment on the accuracy and reliability of the previous model. | What is the hydraulic response of the river to discharge fluctuations at these key spawning locations? How do changes in river discharge influence river stage, and how does river stage relate to wetted channel area at these key spawning locations? | This Study Objective and Management Question will be addressed in Year 3 of this program when the RIVER-2D hydraulic models are completed and calibrated. |
| Make recommendations for further refinement of both the topographic survey and ELM. | N/A | Recommendations presented for Year 3 study program. |

# Acknowledgements

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Margo Dennis, Burnaby

The following employees of **GOLDER ASSOCIATES LTD.** contributed to the collection of data and the preparation of this report.

| | |
|---|---|
| Bradley Hildebrand, B.Sc. | Intermediate Fisheries Biologist, Author |
| Dana Schmidt, Ph.D., R.P.Bio. | Senior Fisheries Scientist/Limnologist, Project Director, Editor |
| Hua Zuang, Ph.D., P.Eng. | Senior River Engineer |
| Wolf Ploeger, Dr. Ing. | River Specialist, Project Modeller/Contributing Author |
| Adriana Camino, Ph.D. | Junior Water Resources Specialist/Contributing Author |
| Dan Ciobotaru, B.Sc. | Project Hydrologist |
| Chris King, Tech. Dipl. | Biological Technician |
| Ron Giles | Warehouse Technician |

The following employees of **SPROULERS' ENTERPRISES LTD.** (SEL) contributed to the collection of data.

| | |
|---|---|
| Bill Sproul, B.Sc., Owner/Manager of SEL | Topography Survey Lead |
| Clint Stubbe, Tech. Dipl. | Certified Topography Survey Technician |

The following employees of **OKANAGAN NATION ALLIANCE** contributed to the collection of data.

| | |
|---|---|
| Natasha Audy, Tech. Dipl. | Certified Technician |

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# 1.0 INTRODUCTION

## 1.1 Background

Mountain Whitefish (*Prosopium williamsoni*) are the most abundant sportfish in the Keenleyside Reach of the lower Columbia River [LCR - defined as the Columbia River from Hugh L. Keenleyside Dam (HLK) to the Canada-US Border and including the lower Kootenay River below Brilliant Dam (BRD)]. This species uses this area for all life history functions (Hildebrand and English 1991; R.L. & L. 1995). Although Mountain Whitefish do not support a recreational fishery in the lower Columbia River, they do represent an important indicator species in this ecosystem. Results of studies conducted by BC Hydro in the early 1990s raised concerns by the environmental regulatory agencies (i.e., BC Ministry of Environment, Lands and Parks; Department of Fisheries and Oceans Canada) about the effects of river regulation on Mountain Whitefish reproductive success in the lower Columbia River. Water level fluctuations associated with dam operations on both the Columbia (HLK) and Kootenay (BRD) rivers can negatively impact whitefish spawning success by exposing incubating embryos when water levels recede. In addition, armoured substrates found in regulated systems like the lower Columbia River have been identified as potentially detrimental to whitefish egg survival by decreasing the egg retention capabilities of incubation habitat. Flow regulation of the lower Columbia River may also affect whitefish spawning behaviour, hatch periodicity, and hatch success through the modification of flows that may provide essential spawning and hatching cues. Finally, flow fluctuations may also affect larval and juvenile Mountain Whitefish, which prefer near shore rearing habitats with relatively low velocities and gradients (R.L. & L. 2001a).

These concerns led to the development and initiation of BC Hydro's Whitefish Flow Management (WFM) program in the winter of 1994/95. A series of intensive studies on Mountain Whitefish life history characteristics were subsequently conducted annually between 1995 and 1999 (R.L. & L. 1997, 1998a, 1998b, 1999, 2000, 2001b). These monitoring programs identified that whitefish eggs are dewatered by flow changes in the lower Columbia River (Golder 2003). A more recent Columbia River Water Use Plan (WUP) study, CLBMON-48 LCR Whitefish Life History and Egg Mat Monitoring Program, was initiated by BC Hydro to expand knowledge on Mountain Whitefish spawning and life history.

In 2003, BC Hydro commissioned Golder to develop the Mountain Whitefish Egg Loss Model (ELM), a tool that estimates the risk of egg loss under alternative WFM flow scenarios (Golder 2003). The Columbia River WUP Consultative Committee expressed concern about the reliability of the ELM for quantifying egg loss resulting from regulated flow changes (BC Hydro 2007). Currently the ELM estimates egg loss in four previously identified spawning areas during flow reductions from HLK and BRD. In each area, egg deposition along one HEC RAS transect is predicted. To update the ELM, current topographical and hydraulic data from multiple transects in the key spawning areas, as well as current egg deposition and developmental rates from CLBMON-48 will be incorporated into the model.

The low quality and quantity of topographic data was also identified by the WUP Consultative Committee as a key data gap. Updated topographic information within identified Mountain Whitefish spawning areas will allow the ELM to provide more accurate estimates of egg loss. This will be accomplished by providing more precise information on egg deposition in relation to the velocities and depths used by spawning whitefish and to more accurately depict egg deposition areas that are dewatered as a result of operations. To address these uncertainties and data gaps, the Consultative Committee recommended the implantation of a monitoring program to study the topographic characteristics of representative whitefish spawning locations and to update the existing ELM (BC Hydro 2007).

Although in-depth surveys on the topographic and habitat characteristics had not been previously conducted in identified Mountain Whitefish spawning areas, the results of previous study programs on Mountain Whitefish in the lower Columbia River, plus the primary literature reviewed during and subsequent to these studies, form the basis for the present study's site selection, approach and design (R.L. & L. 1997, 1998a, 1998b, 1999, 2000, 2001b; Golder 2009, 2010, 2011). This program represents knowledge gained by the study team from over eight years of study, including three years as part of BC Hydro's LCR WUP study program. Results from this work will provide updated models as tools for BC Hydro to reduce the uncertainty related to overall reliability of egg loss estimates and will help guide future management of this population.

## 1.2 Management Questions, Study Hypotheses and Objectives

As stated in the CLBMON#47 Lower Columbia River Whitefish Spawning Ground Topographic Survey Terms of Reference (BC Hydro 2007), the specific management questions for this study are:

1. *What are the topographic characteristics of the key spawning locations for Mountain Whitefish in the lower Columbia and Kootenay rivers?*
2. *What is the hydraulic response of the river to discharge fluctuations at these key spawning locations? How do changes in river discharge influence river stage, and how does river stage relate to wetted channel area at these key spawning locations?*
3. *How do daily flow changes contribute to cumulative channel dewatering in key spawning areas over the whitefish reproductive period?*

There are no management hypotheses with the above management questions, as this program has been designed to fill data gaps associated with uncertainties about the effects of flow fluctuations on key Mountain Whitefish spawning areas. This monitoring program has also been designed to update or replace and enhance the existing 1D HEC RAS Hydraulic Model and ELM as primary impact analysis tools required for the adaptive management program.

The specific objectives of the Lower Columbia River Whitefish Spawning Ground Topographic Survey Program (the Program) are as follows:

1. *To design and implement controlled topographic surveys to describe the characteristics of representative whitefish spawning locations in the lower Columbia and Kootenay rivers.*
2. *Assemble, verify, analyze and input new topographic data of the representative whitefish spawning locations into an existing 1-dimensional steady state hydraulic model.*
3. *Test and calibrate the model to improve the accuracy of the model.*
4. *Refine and redevelop the Egg Loss Model, as appropriate, to enhance the reliability of outputs from the model.*
5. *Document changes to the model and compare inter-annual egg loss estimates in relation to the flow stabilization index.*
6. *Assess the impact of the increased number of cross-sections and survey detail from the previous model, and comment on the accuracy and reliability of the previous model.*
7. *Make recommendations for further refinement of both the topographic survey and ELM.*

## 1.3 Study Design and Rationale

In Year 1 of this study, project activities were focussed in obtaining topographic data for the key spawning areas and collecting background data required to develop the proposed RIVER-2D models. In the present study year (Year 2), project activities included the development and calibration of the RIVER-2D models. Year 3 will focus on the refinement of the RIVER-2D models and updating the current Mountain Whitefish Egg Loss Model.

### 1.3.1 RIVER-2D Hydraulic Development

The main objective of Year 2 of the CLBMON-47 program was the creation and calibration of the RIVER 2D Hydraulic Models for the Canadian Pacific Railway Island (CPR; Figure 1) and Kootenay River (Figure 2) key Mountain Whitefish spawning areas selected in Year 1 (Golder 2012). RIVER-2D is a two dimensional depth averaged finite element hydrodynamic model that has been specially customized for fish habitat evaluation studies. The RIVER-2D Model which was developed by the University of Alberta was proposed for use in this study (Steffler and Blackburn 2002). To develop the models, the BC Hydro Hydrological Engineering Centers River Analysis System (HEC-RAS) Model, which was updated in Year 1 of this study, was used to establish model boundary conditions within each spawning area. The models were then created using the assembled data during the Year 1 topographic survey and the ADCP measurements (Golder 2012).

The 2D Model can be used for predicting water surface elevations, depths, and velocities at multiple cross sections collected within each of the two key spawning areas that are the major contributors to the spawning population. As requested by the TOR (BC Hydro 2007), the 2D Hydraulic Model will also provide 25 cm vertical resolution at each of the cross sections, and would be sensitive to water levels in both the Kootenay and Columbia rivers.

### 1.3.2 Expansion of the Kootenay River Spawning Area RIVER 2D Hydraulic Model

Inconsistencies related to the confluence of the Columbia and Kootenay rivers were found in the Kootenay River 2D Hydraulic Model during development. To address these inconsistencies, this model was expanded to incorporate the confluence as well. Initially, the Kootenay River Model ended at the confluence (Figure 2), and after expansion it now encompasses the 1 km section of the Columbia River extending 500 m upstream and downstream from the confluence (Figure 2).

### 1.3.3 RIVER 2D Model Calibration

As stated in the overall project proposal, field activities were conducted to calibrate the models after the creation of the River 2D Hydraulic Models. This calibration involved conducting additional Acoustic Doppler Current Profiler (ADCP) surveys to augment those conducted in Year 1. These additional surveys were conducted at the sampling transects (Figure 1) established in Year 1 at lower Columbia River discharges. Lower discharges were selected for the calibration process as these would be the most representative of conditions in the spawning areas during egg deposition and incubation. High flows in the summer of 2012 delayed the Year 2 calibration sampling until fall 2012.

Calibration of the expanded Kootenay River 2D Model will occur in Year 3 of this study.

### 1.3.4 Field Sampling

The Year 2 field sampling program included the following components to calibrate both RIVER 2D Models and expand the Kootenay Model:

- ADCP surveys along the transects in the original models to collect data for calibration;
- Topographical surveys in the expanded area of the Kootenay Model; and,
- ADCP transects in the expanded area of the Kootenay River Model.

The topographical and velocity surveys were limited to the low water period of winter 2012/2013. If warranted and identified by the present analysis, this program may be expanded in Year 3 to include surveys at higher discharge conditions.

#### *1.3.4.1 Cross Section Location Selection in Expanded Kootenay River Model Area*

The selection of the cross sections within the expanded Kootenay River area was consistent with the methodology used in Year 1. The advice of Williams (2010) was followed to ensure that both spatial coverage and randomness are achieved, and used the methods of Generalized Random Tessellation Stratified Design (GRTS) for linear sampling studies (Steven and Olsen 2004). In total, 30 cross sections in each spawning area were selected for sampling. These included 20 main sample transects and 10 over sample transects that may be sampled if some of the main transects could not be sampled due to logistical constraints (Figure 2).

To achieve the level of precision recommended in the TOR (BC Hydro 2007), individual transects were surveyed to obtain sufficient precision to development bathymetric contours with 0.25 m resolution. These data were required to develop vertical strata of whitefish egg deposition depths to a resolution of 0.25 m vertical strata.

#### *1.3.4.2 Topographic Surveys*

To collect the required topographic data to expand the existing Kootenay River Hydraulic Model, boat and land based topographic surveys were conducted at the selected cross sections. As in Year 1, this sampling methodology provided the field crew with the flexibility needed to accurately survey each cross section up to the high water mark of each river bank with sufficient detail to meet the objective of developing bathymetric contours with 0.25 m resolution.

#### *1.3.4.3 ADCP Transects*

To remain consistent with Year 1 methodology, an Acoustic Doppler Current Profiler (ADCP) was used to collect velocity data in the study area. This reduced the challenge of maintaining position in fast flowing water to obtain point velocity data and allowed for a more accurate characterization of the velocity throughout the water column and along the channel transect.

To identify the effects of velocity on egg deposition location, velocity was measured in the CPR Island and Kootenay spawning areas along the same transects sampled in Year 1. To allow for expansion of the Kootenay

RIVER-2D Model, velocity was measured along the same transects sampled during the topographic surveys in the expanded area. The data set collected is sufficient to allow for the development and calibration of the RIVER-2D Hydraulic Models.

### 1.3.5 Mountain Whitefish Egg Loss Model Updating/Development

Currently the Mountain Whitefish Egg Loss Model (ELM) solely predicts the depth at which eggs are deposited. This could potentially constrain the predictive ability of the ELM as flow regulation alters both depth and velocity, and both are usually highly correlated with spawning site selection in salmonids.

As described in Golder's proposal for this program, work on updating the current ELM was not conducted in Years 1 and 2 of this program. The model is scheduled for update in Year 3 after both RIVER 2D Hydraulic Models are completed and calibrated. The updated ELM will include data from the RIVER 2D Models, as well as data collected during Mountain Whitefish spawn monitoring as part of the CLBMON-48: Whitefish Life History and Egg Mat Monitoring program.

# 2.0 METHODS

## 2.1 Study Area

The geographical scope of the CLBMON-47 Year 2 study area was the approximate 2.5 km section of the mainstem Columbia River from the ferry landing in Robson BC to the upstream end of Tin Cup Rapids (Figure 1). The study area also included the 1.8 km section of the lower Kootenay River from the Highway 3A Bridge to the confluence with the Columbia River. The expanded Kootenay RIVER 2D Model encompasses the 1 km section of the Columbia River extending 500 m upstream and downstream from the confluence (Figure 2). The cross sections selected for sampling in each spawning area are also presented in Figures 1 and 2.

## 2.2 Study Period

ADCP surveys to calibrate both RIVER 2D Models were conducted in late November 20, 2012 (Table 1). Velocity surveys in the expanded Kootenay Model area were also conducted in late November, 2012. Topographic surveys in the expanded area were conducted from late November to mid-December, 2012. The chronology of all field sampling activities during CLBMON-47 Year 2 is outlined in Table 1.

**Table 1: Chronology of Sampling Activities for the CLBMON-47 Year 2 (2012) Lower Columbia River Whitefish Spawning Ground Topography Survey Program.**

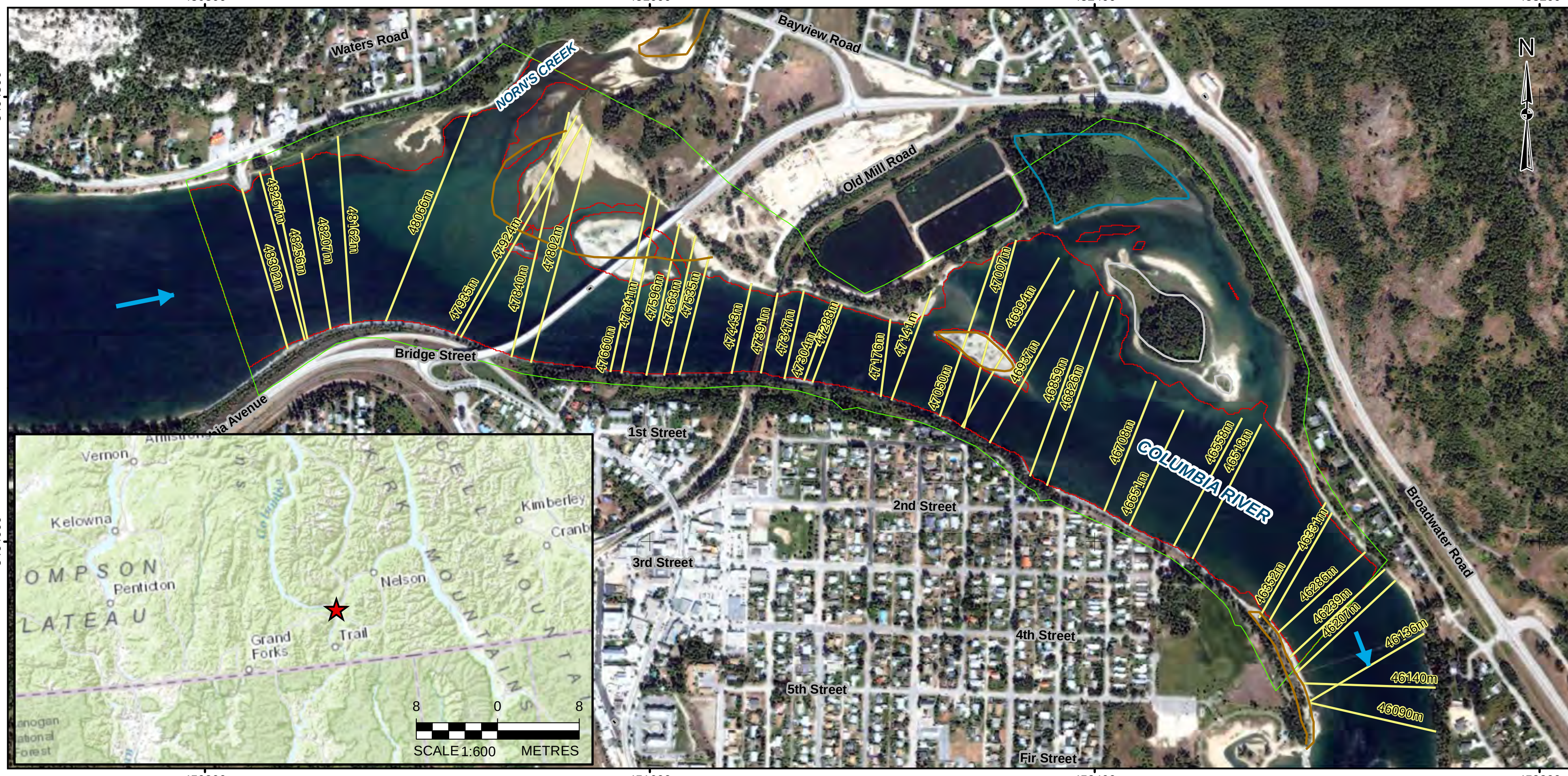
| Date(s) | Sampling Activities |
|---|---|
| November 20, 2012 | ADCP surveys in CPR Island and Kootenay River spawning areas to calibrate existing models |
| November 21, 2012 | ADCP surveys in Kootenay River expanded area |
| November 27 and 28, 2012; and,<br>December 12 and 13; 2012 | Topographic surveys in Kootenay River expanded area |

## 2.3 Physical Parameters

### 2.3.1 Discharge

All discharge data from the Columbia River were provided by BC Hydro Power Records from HLK. Kootenay River discharge during the study period was provided by the operators of BRD (Fortis BC Ltd.) in the form of hourly spill and generation discharges from BRD.

I:\2010\10-1492\10-1492-0142\Mapping\MXD\Hydrology\FIG1_KeyPlan_Columbia.mxd




## LEGEND

**WATER FEATURE**

- ISLAND
- SAND OR GRAVEL BAR
- SWAMP
- COLUMBIA RIVER CROSS SECTION
- FLOW DIRECTION
- SURVEY AREA
- WETTED AREA

400 0 400

SCALE 1:11,000 METRES

DRAFT

## REFERENCE

SERVICE LAYER CREDITS: SOURCES: ESRI, DELORME, NAVTEQ, TOMTOM, INTERMAP, INCREMENT P CORP., GEBCO, USGS, FAO, NPS, NRCAN, GEOBASE, IGN, KADASTER NL, ORDNANCE SURVEY, ESRI JAPAN, METI, ESRI CHINA (HONG KONG), SWISSTOPO, AND THE GIS USER COMMUNITY
SOURCE: ESRI, DIGITALGLOBE, GEOEYE, I-CUBED, USDA, USGS, AEX, GETMAPPING, AEROGRID, IGN, IGP, AND THE GIS USER COMMUNITY. SURVEY WAS COMPLETED IN LOCAL COORDINATE SYSTEM, RECTIFIED BASED ON AIR PHOTO. ROAD LABELS OBTAINED FROM CANVEC © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED. DATUM: NAD83 PROJECTION: UTM ZONE 11

PROJECT

CLBMON-47: LOWER COLUMBIA RIVER WHITEFISH SPAWNING GROUND TOPOGRAPHIC SURVEY

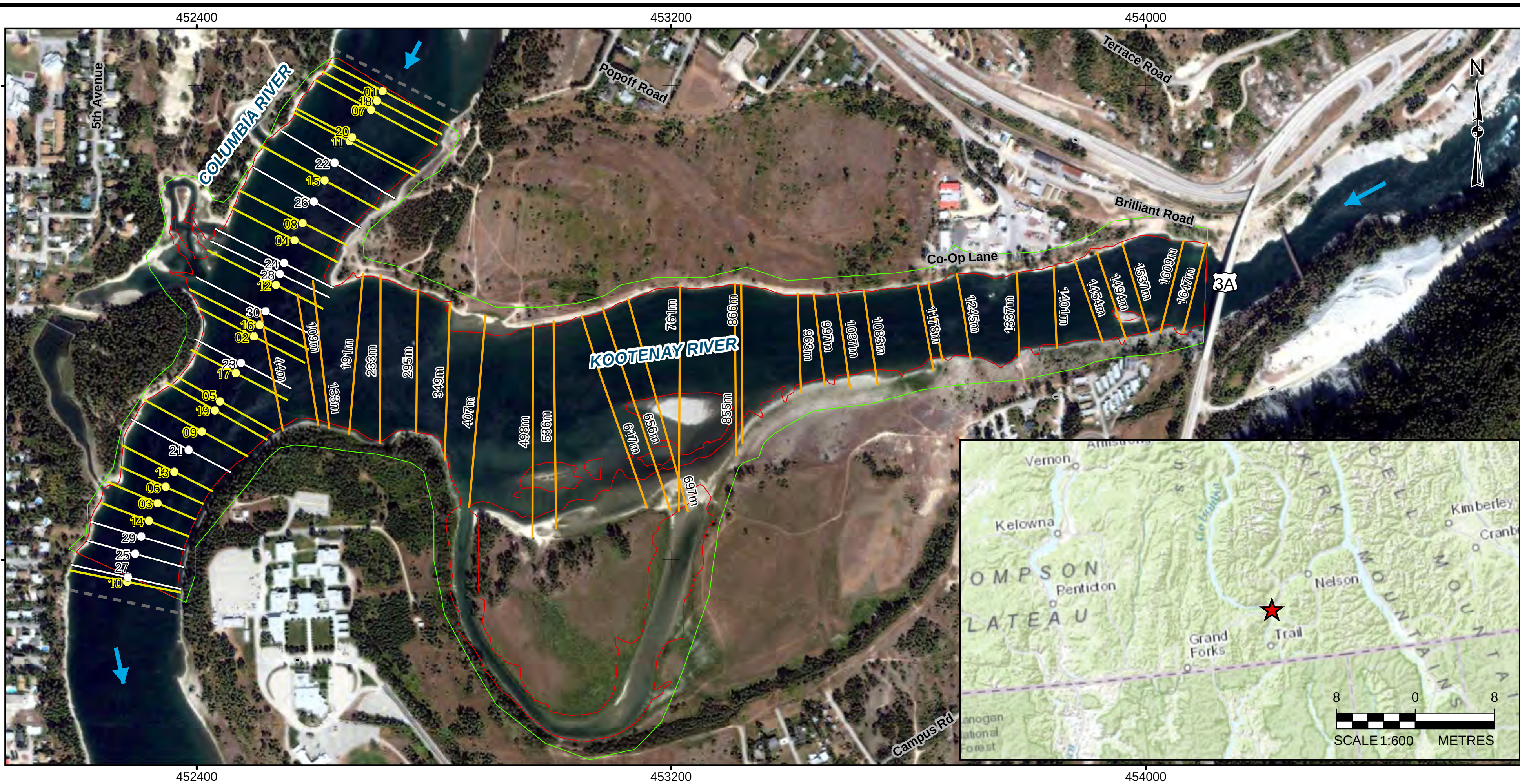
TITLE

**COLUMBIA RIVER MODEL LOCATION**

Golder Associates

| | | | |
|---|---|---|---|
| PROJECT | | 10-1422-0072 | FILE No. |
| DESIGN | WP | 15 Feb. 2012 | SCALE AS SHOWN REV. 0 |
| GIS | KLN | 03 Apr. 2013 | |
| CHECK | | | **FIGURE: 1** |
| REVIEW | | | |

I:\2010\10-1492\10-1492-0142\Mapping\MXD\Hydrology\FIG2_KeyPlan_Kootenay.mxd




400 0 400

SCALE 1:10,000 METRES

## LEGEND

**KOOTENAY RIVER CONFLUENCE**

- MAIN SAMPLE SITE
- OVER SAMPLE SITE
- MAIN SAMPLE TRANSECT (SURVEYED IN NOVEMBER 2012)
- OVER SAMPLE TRANSECT (SURVEYED IN NOVEMBER 2012)
- 1km FOR EXPANDED TRANSECT AREA
- FLOW DIRECTION
- KOOTENAY RIVER CROSS SECTION (SURVEYED IN MAY 2011)
- SURVEY AREA
- WETTED AREA

## REFERENCE

SERVICE LAYER CREDITS: SOURCES: ESRI, DELORME, NAVTEQ, TOMTOM, INTERMAP, INCREMENT P CORP., GEBCO, USGS, FAO, NPS, NRCAN, GEOBASE, IGN, KADASTER NL, ORDNANCE SURVEY, ESRI JAPAN, METI, ESRI CHINA (HONG KONG), SWISSTOPO, AND THE GIS USER COMMUNITY
SOURCE: ESRI, DIGITALGLOBE, GEOEYE, I-CUBED, USDA, USGS, AEX, GETMAPPING, AEROGRID, IGN, IGP, AND THE GIS USER COMMUNITY. SURVEY WAS COMPLETED IN LOCAL COORDINATE SYSTEM, RECTIFIED BASED ON AIR PHOTO.
DATUM: NAD83 PROJECTION: UTM ZONE 11

*DRAFT*

PROJECT
CLBMON-47: LOWER COLUMBIA RIVER WHITEFISH SPAWNING GROUND TOPOGRAPHIC SURVEY

TITLE
**KOOTENAY RIVER MODEL LOCATION**

Golder Associates

| | | | | |
|---|---|---|---|---|
| PROJECT | | 10-1422-0072 | FILE No. | |
| DESIGN | WP | 15 Feb. 2012 | SCALE AS SHOWN | REV. 0 |
| GIS | KLN | 03 Apr. 2013 | | |
| CHECK | | | | |
| REVIEW | | | | |

**FIGURE: 2**

## 2.4 Topographic Surveys

The topographic surveys conducted in the expanded Kootenay River area followed the methodology used in Year 1 of this program (Golder 2012). To obtain accurate 0.25 m contour resolution, a very dense point cloud of sounding data was required. A boat based topography survey was conducted using a jet boat equipped with a TOPCON Real Time Kinematic (RTK) Global Positioning System (GPS) to provide accurate three dimensional (3D) positions, coupled with a Lowrance single beam sounding system. This system allowed for the field crew to log one point a second and get maximum coverage as they drove slowly along each selected cross section. Gaps between each cross section were sampled as well to provide adequate data to produce contour maps of each key spawning area.

The software used to perform the topographic survey was HYPACK Hydrographic Survey and Processing Software from HYPACK, Inc. The software was used for survey planning, navigation, and topographic data collection. The output data included Northing, Easting, and Elevation (UTM, NAD 83) coordinates in ASCI format. Quicksurf running in AutoCAD was used to produce contour maps at the required 0.25 m vertical strata resolution (Appendix A).

As a component of the topography surveys, land-based surveys were conducted in the expanded Kootenay Model area to measure the dewatered portion of each transect up to the high water mark. Gaps between each cross section were also sampled to provide adequate data to produce contour maps of each spawning area. Data were collected with the use of survey equipment and a TOPCON RTK GPS, and a GPS base station.

The output data were in the same format as the Year 1 surveys, and were merged into the topographic dataset. The contour maps produced for the expanded Kootenay River area included the land based data as well.

## 2.5 ADCP Surveys

All velocity data in the present study year were collected during the low flow period prior to the onset of the winter season, which allowed for the calibration of the RIVER-2D Models for low flow conditions.

### 2.5.1 Original Columbia and Kootenay River RIVER-2D Model Calibrations

Velocity measurements conducted in the Columbia and Kootenay River spawning areas to calibrate the RIVER-2D Models followed the methodology utilized in Year 1 (Golder 2012). ADCP surveys were conducted using a jet boat equipped with an ADCP and RTK GPS to provide reliable velocity profile data. Similar to the topographic surveys, the boat operator drove slowly along each selected cross section while the ADCP collected data. The horizontal resolution of the RD Instruments Rio Grande 1200 kHz ADCP velocity profile data was 20-25 m along each cross section (to accuracies of 5% or better of the measured velocities and vertical resolution of 0.5 m or better). The ADCP provided the velocity data and the single beam sounder provided the high degree of resolution necessary to achieve the 0.25 m vertical contour intervals.

### 2.5.2 Expanded Kootenay RIVER-2D Model Development

As in Year 1, sampling within the expanded Kootenay River Model area consisted of ADCP transects that were selected using the methodology of the Generalized Random Tessellation Stratified (GRTS) survey design. Of the twenty main sample transects selected for sampling, nineteen were sampled. Also, ten over-sample transects were selected for sampling in the event that some of the main transects could not be sampled due to logistical constraints (Figure 2). During the ADCP surveys, the field crew was able to sample all over-sample transects. This allowed for the inclusion of these transects into the expanded model as well.

The methodology used for the ADCP surveys will also followed the methodology used during ADCP sampling in Year 1 (see Section 2.5.1). In Year 3, the model calibration of the expanded area will also involve ADCP surveys that follow the methodology used during ADCP surveys completed in Years 1 and 2 (Golder 2012).

## 2.6 RIVER-2D Hydraulic Modeling

In this study, the calibration of water surface elevations was conducted using the RIVER-2D Model. The study reaches of the Columbia and Kootenay rivers were calibrated separately. The Columbia River reach was about 2.5 km long whereas the Kootenay River was about 1.7 km long. The hydrodynamic component of the RIVER-2D Model is based on the two-dimensional, depth-averaged St. Venant equations expressing the conservation of water mass and momentum components in two directions. RIVER-2D is based on the finite element method. The implicit method is used to solve non-linear equations resulting from finite element discretization. The main advantage of the model is that it can easily handle a computation region with irregular boundaries characterized by diversified flow conditions, including subcritical, supercritical, and transcritical flows.

The RIVER-2D modelling tasks in this study involved the following:

- Create a bathymetric model and generate a finite element mesh;
- Setup model boundary conditions;
- Calibrate the model; and,
- Conduct model sensitivity analysis.

## 2.7 Columbia River Modelling

### 2.7.1 Bathymetric Model

The bathymetric survey on May 4, 2011 was used to setup the RIVER-2D Model for the Columbia River reach.

### 2.7.2 Model Boundary Conditions

The range of measured discharges on May 4, 2011 (Table 2) was used as upstream boundary conditions. This range was also used to calibrate the HEC RAS model in this spawning area during Year 1 project activities (Golder 2012), and therefore, was the range used for the RIVER-2D calibration. The model calibration was conducted based on four different discharges within that range for the selected river segments (stations)

(Table 3). The updated HEC-RAS Model was used to establish downstream boundary conditions for discharges where surveyed water levels at the downstream boundary were not available. The HEC-RAS Model was calibrated using the assembled data of the topographic survey and the ADCP measurements (Golder 2012).

**Table 2: Model Boundary Conditions for the RIVER-2D Calibration.**

| River | Date | Discharge (Upstream Boundary Condition) | Measured Water Level (Downstream Boundary Condition) |
|---|---|---|---|
| Columbia River | May 4, 2011 | 707 $m^3$/s - 834 $m^3$/s | 418.08 m (1) |

(1) Corresponding discharge at time of measurement was 707 $m^3$/s.

**Table 3: Hourly Discharge Data for RIVER-2D Calibration of the Columbia River Reach.**

| River Station (m, upstream of Canada/Us Border) | | Discharge ($m^3$/s) |
|---|---|---|
| From | To | |
| 48,302 | 48,066 | 793 |
| 47,935 | 47,924 | 811 |
| 47,802 | 47,443 | 830 |
| 47,391 | 46,239 | 707 |

## 2.8 Kootenay River

The model calibration of the Kootenay River spawning area was conducted by incorporating a section of the Columbia River and the Kootenay River. Recirculating low velocity flow areas were spotted just upstream of the Kootenay River confluence with the Columbia River, which may be essential for Mountain Whitefish holding and feeding during the spawning season.

### 2.8.1 Bathymetric Model

The model was setup based on the bathymetric data collected on May 3, 2011 at the Kootenay River and Columbia River at the Kootenay River confluence on November 28, 2012.

### 2.8.2 Model Boundary Conditions

The model upstream boundary conditions were discharges at the Columbia and Kootenay rivers. The downstream boundary condition was water surface elevation at the Columbia River confluence with the Columbia River. Mean daily discharges were 708 $m^3$/s and 825 $m^3$/s recorded on May 3, 2011 for the Columbia and Kootenay Rivers, respectively (Table 4). These discharges were used for the model calibration.

However, there were no survey water level data available in the Columbia River immediately downstream of the Kootenay River confluence for the model calibration. An initial adjustment of the model downstream boundary condition was made to relate the simulated water level on the Columbia River to the surveyed water level

(417.62 m) at the most downstream survey cross section on the Kootenay River. Accordingly, the downstream boundary condition for the RIVER-2D Model calibration was estimated to be 417.60 m at the Columbia River.

**Table 4: Model Boundary Conditions for RIVER-2D Model Calibration.**

| River | Date | Discharge (Upstream Boundary Condition) | Measured Water Level (Downstream Boundary Condition) |
|---|---|---|---|
| Kootenay River | May 3, 2011 | 825 $m^3/s$ | 417.60 m |
| Columbia River | May 3, 2011 | 708 $m^3/s$ | 417.62 m (1) |

(1) Adjusted based on the surveyed downstream water level at the Kootenay River.

# 3.0 RESULTS

## 3.1 Discharge

The hydrograph in the study area for Year 2 of this program is provided in Figure 3. High flows in the summer season precluded ADCP and bathymetric surveys, and therefore all field work was delayed until the low water period in the fall season. During Year 2 ADCP surveys in late November 2012, Columbia River discharge below HLK remained stable before increasing substantially prior to the bathymetric surveys (Figure 3). Flows then remained stable during the two days of bathymetric surveys in November (Table 1). Another substantial increase in flows occurred in the Columbia River prior to the second session of bathymetric surveys in December 2012.

Hourly discharge of the Kootenay River below BRD fluctuated repeatedly between November and December 2012. During the first day of ADCP surveys, Kootenay River discharge increased, followed by a decrease on the second day of sampling. The Kootenay River remained relatively stable during both the late November and mid-December bathymetric sample sessions, but exhibited a substantial, temporary increase between the sessions (Figure 3).

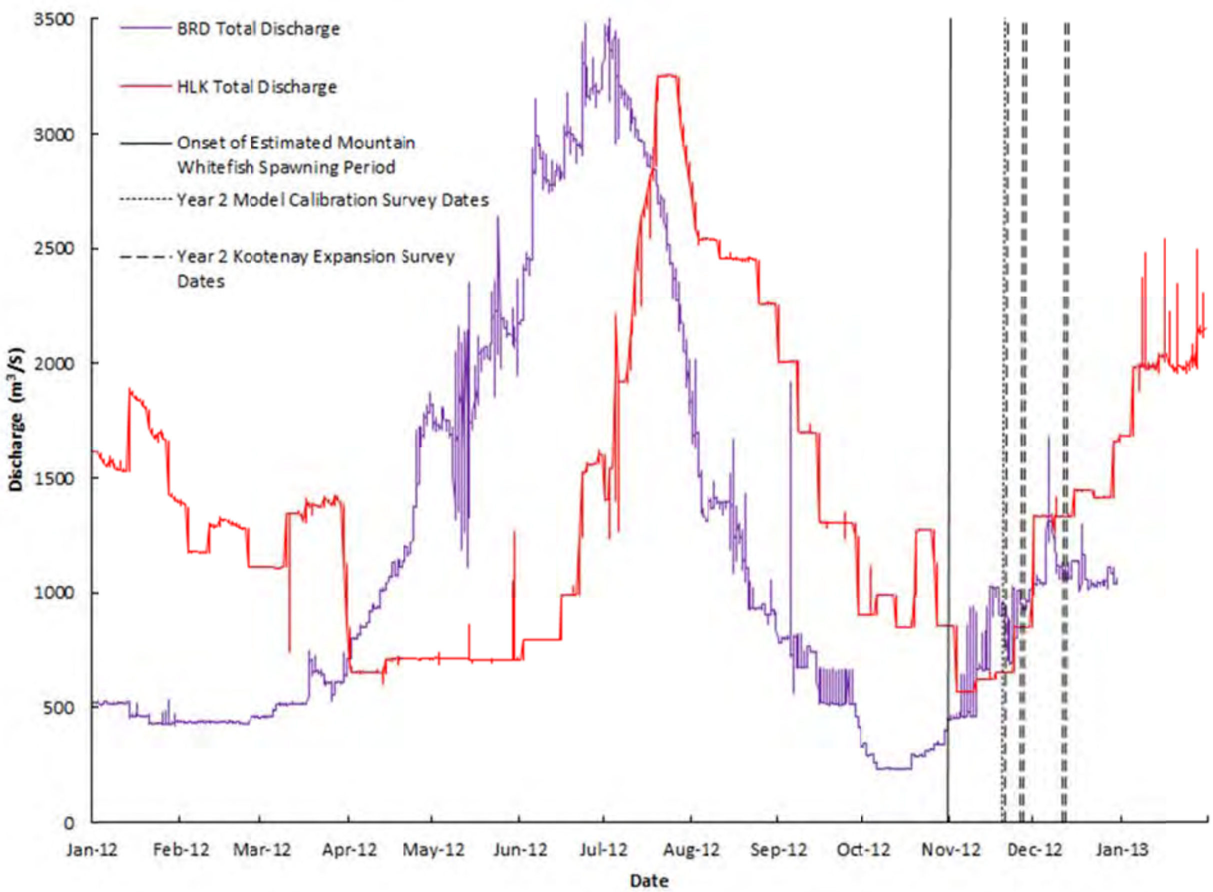



*Figure 3: Hourly discharge of the Columbia River below Hugh L. Keenleyside Dam (HLK), and the Kootenay River below Brilliant Dam (BRD) during the CLBMON-47 Year 2 study period, January 1, 2012 to January 31, 2013. Note: solid black line depicts the estimated onset of the Mountain Whitefish Spawning season, while the dashed lines depict the timing of Year 2 sampling activities.*

### 3.1.1 Bathymetric Survey and Monitoring

The survey data used for the RIVER-2D Model calibration was obtained from the survey programs in April to May 2011 and November to December 2012, which were collected by Sproulers' Enterprises Limited (SEL). A total of 69 and 30 cross sections were surveyed at the Columbia River (see Figure 1) and the Kootenay River (see Figure 2), respectively.

In addition, BC Hydro provided mean daily discharges for the Columbia and Kootenay Rivers during the bathymetric survey (Table 5).

**Table 5: Mean Daily Discharges during the Survey Period (Provided by BC Hydro).**

| Date | Survey Activity | Mean Columbia River Daily Discharge ($m^3/s$) | Mean Kootenay River Daily Discharge ($m^3/s$) |
|---|---|---|---|
| 4/19/2011 | Year 1 - Bathymetric Survey of Kootenay River | 714 | 752 |
| 4/25/2011 | Year 1 - Bathymetric Survey of Kootenay River | 707 | 714 |
| 4/26/2011 | Year 1 - Bathymetric Survey of CPR Island | 709 | 748 |
| 4/28/2011 | Year 1 - Bathymetric Survey of CPR Island | 709 | 758 |
| 4/29/2011 | Year 1 - Bathymetric Survey of Kootenay River | 710 | 756 |
| 5/3/2011 | Year 1 - Bathymetric Survey of Kootenay River | 708 | 825 |
| 5/4/2011 | Year 1 - Bathymetric Survey of CPR Island | 777 | 852 |
| 5/5/2011 | Year 1 - Bathymetric Survey of CPR Island | 849 | 912 |
| 11/27/2012 | Year 2 - Bathymetric Survey of Columbia/Kootenay Confluence | 847 | 933 |
| 11/28/2012 | Year 2 - Bathymetric Survey of Columbia/Kootenay Confluence | 847 | 947 |
| 12/12/2012 | Year 2 - Bathymetric Survey of Columbia/Kootenay Confluence | 1330 | 1094 |
| 12/13/2012 | Year 2 - Bathymetric Survey of Columbia/Kootenay Confluence | 1332 | 1092 |

An initial modeling exercise on the Kootenay River section based on the Year 1 (2011) survey information suggested that zones near the Kootenay River confluence were not be adequately surveyed. Therefore, additional field sampling was performed in Year 2 (2012) to survey the portion of the Columbia River at the Kootenay River confluence.

## 3.2 Topography Surveys

### 3.2.1 Expanded Kootenay River Model Area

Topographic surveys in the Columbia/Kootenay River confluence area to expand the Kootenay RIVER-2D Model occurred from November 27 to December 13, 2012 (Table 1). In total, 30 cross sections were conducted, which were included in the Kootenay RIVER-2D Hydraulic Model expansion (Appendix A, Sheets 9 to 12). As these cross sections were selected at random using GRTS (Section 1.3.3.1), they are not in numerical order when viewed on the figure presented in Appendix A.

The Kootenay RIVER-2D expansion area can be divided into three separate sections based on topography; the area upstream of the confluence, the confluence itself and downstream of the confluence. The upstream section of the expansion area is characterized by the ten cross sections from no. 1 and no. 4 (Appendix A, Sheet 9 and 10). This section is dominated a large boulder garden (cross sections 1, 18, 7, and 20) mid-channel and along the left downstream bank (LDB). Downstream of the boulder garden, multiple benches and ridges are present (cross sections no. 22, 15, 26, 8, and 4).

The confluence section of the expansion area is represented by the 8 cross sections from no. 24 to no. 17 (Appendix A, Sheets 9 to 11). Along LDB in the upstream portion of the confluence section, gradient gradually decreases (cross sections 24, 28, 12, 30, and 16). Farther downstream, the channel constricts and gradients along LDB steepen (cross sections 2, 23, and 17). The river bottom is relatively uniform in the mid-channel portion of the confluence section (cross sections 30, 6, and 2). Along the right downstream banks (RDB) gradients were typically steep (cross sections 24, 28, 12, and 17).

The downstream section of the expansion area is represented by 12 cross sections from no. 5 to no. 10 (Appendix A, Sheets 9, 11 and 12). The section consists of steep gradients along both LDB and RDB. The mid-channel portion of the river bottom is relatively uniform, with one large ridge observed at cross sections 9 and 21. The greatest depths within the expansion area occur in this section.

## 3.3 Columbia River Hydraulic Modelling

### 3.3.1 Columbia RIVER-2D Model Calibration

The Columbia River bed consists mainly of coarse materials (i.e., gravels/cobbles). A roughness height (Ks) of 0.20 m was initially assigned for the RIVER-2D Model. During the model calibration, the modelling results were compared to the measured water levels. It was found that the initially set roughness height of 0.2 m is the best fit for this model reach and no further adjustments were necessary. The surveyed and simulated water surface elevations along the right and left banks for the calibration model run are presented in Figure 4 and Figure 5. Differences between the measured and simulated water levels at the water edge (right and left banks) are shown in Figure 6. The mean water level difference between surveyed and simulated water levels along the right bank was -0.01 m and ranged between -0.08 m and 0.05 m, and the mean water level difference between surveyed and simulated water levels along the left bank was 0.05 m and ranged between -0.06 m and 0.13 m. The simulated water edges, water depths and velocity vectors for the calibration run of the Columbia River Reach are presented in Figure 7.

The effective roughness height, Ks, is a bed resistance parameter. Bed roughness, in the form of a roughness height or Manning's n value, is an input parameter to any river modelling. Compared to traditional one-dimensional models, where most two-dimensional effects are abstracted into the resistance parameter, the two-dimensional resistance term accounts only for the direct bed shear stress (Steffler and Blackburn 2002), Observations of bed material and bed form size are usually sufficient to establish reasonable initial roughness estimates. Calibration to observed water surface elevations gives the final values.

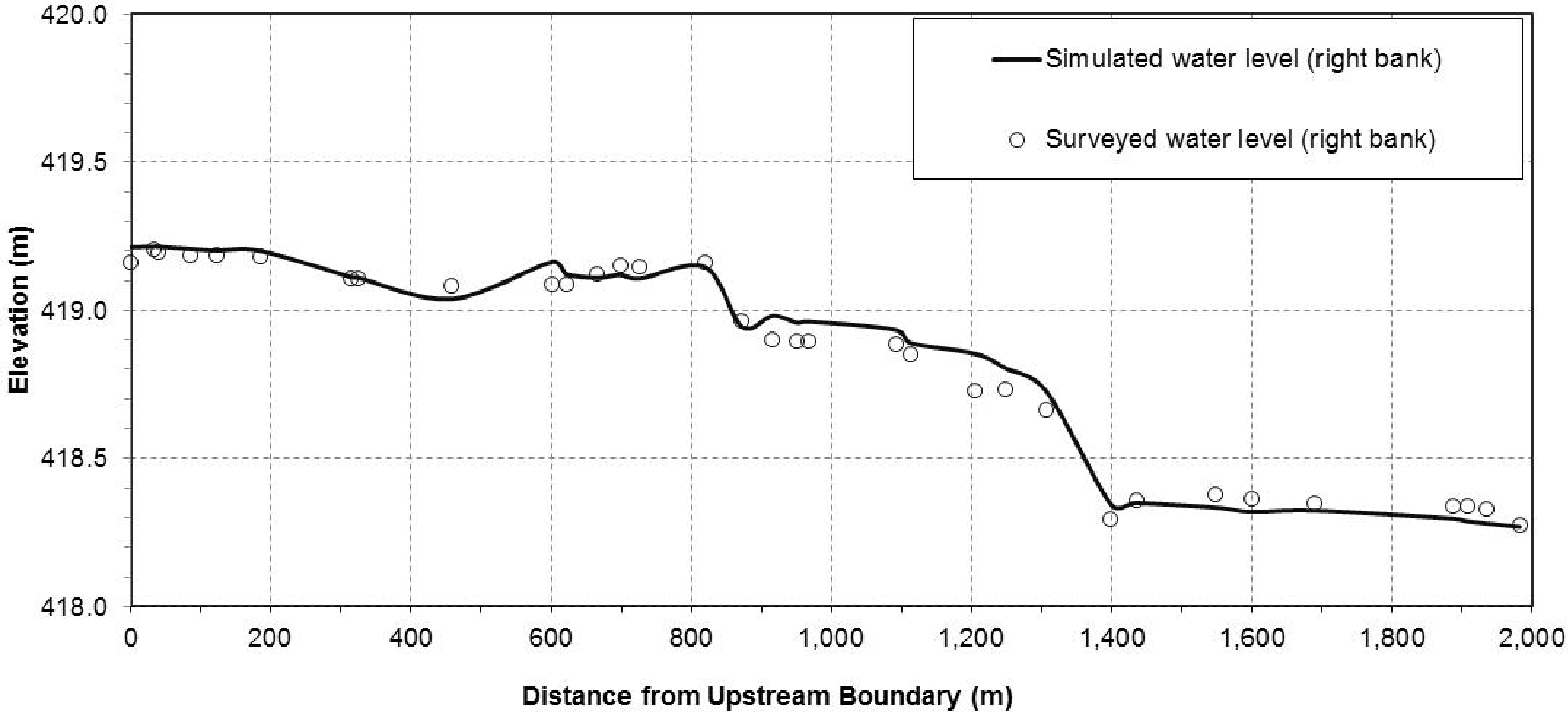



*Figure 4: Comparison of Simulated and Surveyed Water Levels along the Right Bank of the Columbia River Study Reach.*

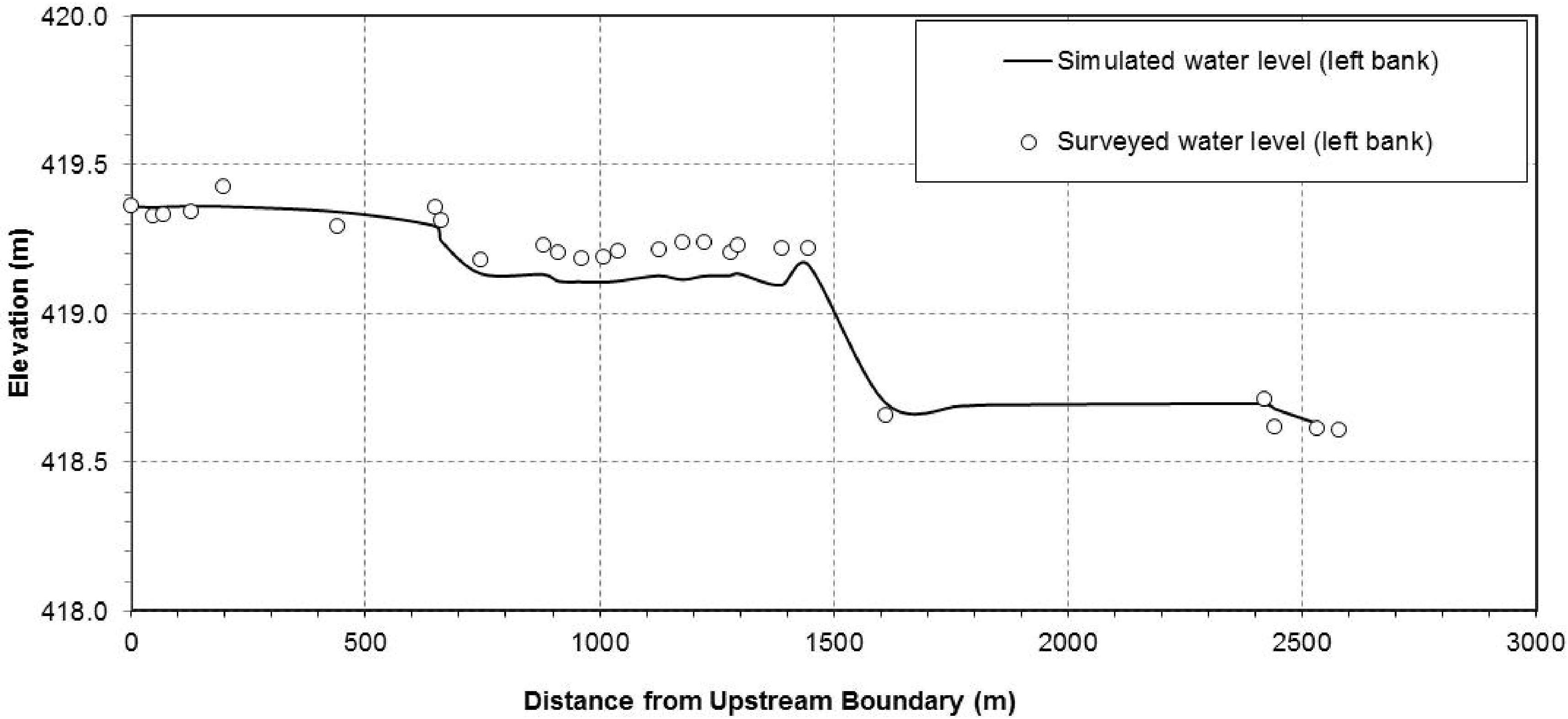



*Figure 5: Comparison of Simulated and Surveyed Water Levels along Left Bank of the Columbia River Reach.*

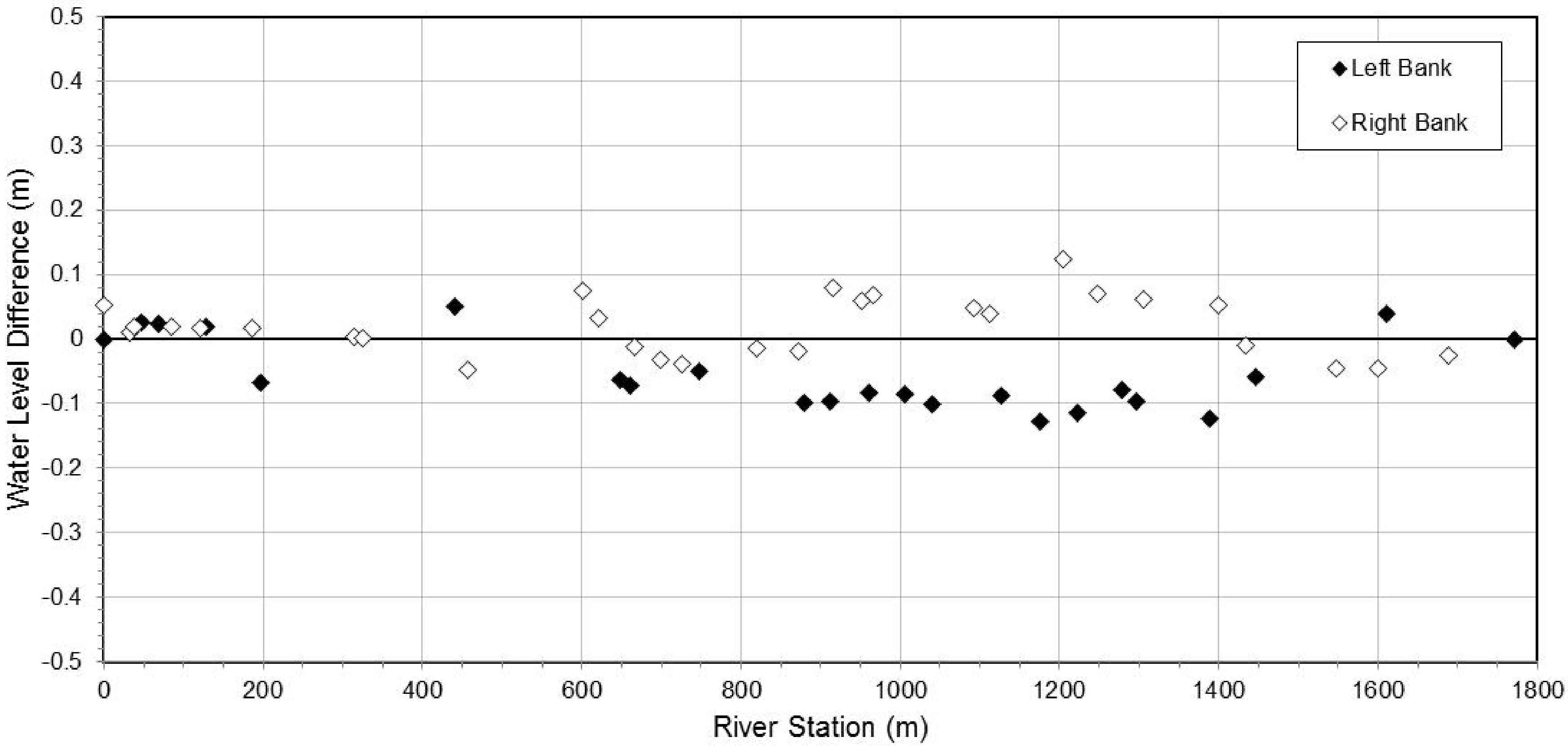
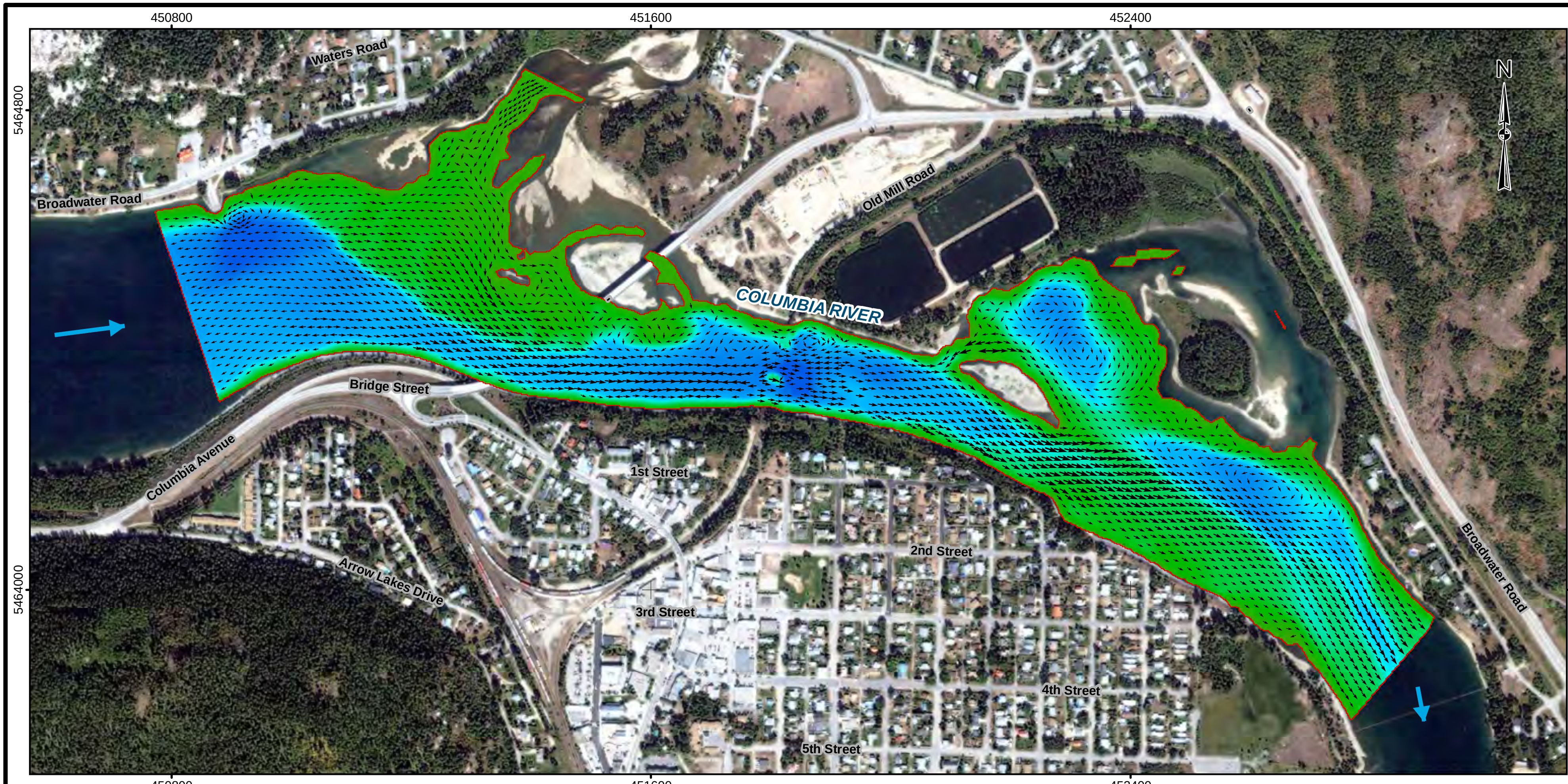



*Figure 6: Differences between the Surveyed and Simulated Water Levels along Right and Left Banks of the Columbia River Reach. Note: the solid line represents the surveyed water levels, and the data points represent simulated water levels at certain points along each riverbank.*

I:\2010\10-1492\10-1492-0142\Mapping\MXD\Hydrology\FIG7_2DModel_depth_velocity_map_Columbia.mxd




## LEGEND

| FLOW VELOCITY (m/s) | WATER DEPTH (m) |
|---|---|
| < 0.5 | 0.0 - 2.0 |
| 0.5 - 1.0 | 2.1 - 4.0 |
| 1.0 - 1.5 | 4.1 - 6.0 |
| 1.5 - 2.0 | 6.1 - 8.0 |
| 2.0 - 2.5 | 8.1 - 10.0 |
| 2.5 - 3.0 | 10.1 - 12.0 |
| FLOW DIRECTION | 12.1 - 14.0 |
| WETTED AREA | 14.1 - 16.0 |

400 0 400

SCALE 1:10,000 METRES

DRAFT

## REFERENCE

SERVICE LAYER CREDITS: SOURCE: ESRI, DIGITALGLOBE, GEOEYE, I-CUBED, USDA, USGS, AEX, GETMAPPING, AEROGRID, IGN, IGP, AND THE GIS USER COMMUNITY. SURVEY WAS COMPLETED IN LOCAL COORDINATE SYSTEM, RECTIFIED BASED ON AIR PHOTO. ROAD LABELS OBTAINED FROM CANVEC © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.
DATUM: NAD83 PROJECTION: UTM ZONE 11

PROJECT

CLBMON-47: LOWER COLUMBIA RIVER WHITEFISH SPAWNING GROUND TOPOGRAPHIC SURVEY

TITLE

**SIMULATED WATER DEPTHS, FLOW VELOCITIES AND WETTED AREA FOR COLUMBIA RIVER (Q = 793 $m^3/s$)**

Golder Associates

| | | | | |
|---|---|---|---|---|
| PROJECT | | 10-1422-0072 | FILE No. | |
| DESIGN | WP | 15 Feb. 2012 | SCALE AS SHOWN | REV. 0 |
| GIS | KLN | 03 Apr. 2013 | | |
| CHECK | | | FIGURE: 7 | |
| REVIEW | | | | |

### 3.3.2 Columbia RIVER-2D Model Sensitivity Analysis

A sensitivity analysis was conducted on the roughness height Ks. The Ks values were increased and decreased by 25% from the calibrated values: the simulated water levels were not sensitive to Ks variations (Figure 8). It was -0.0004 m due to a decrease of 25% on the Ks value and was +0.02 m due to an increase of on 25% of the Ks for both the right and left banks.

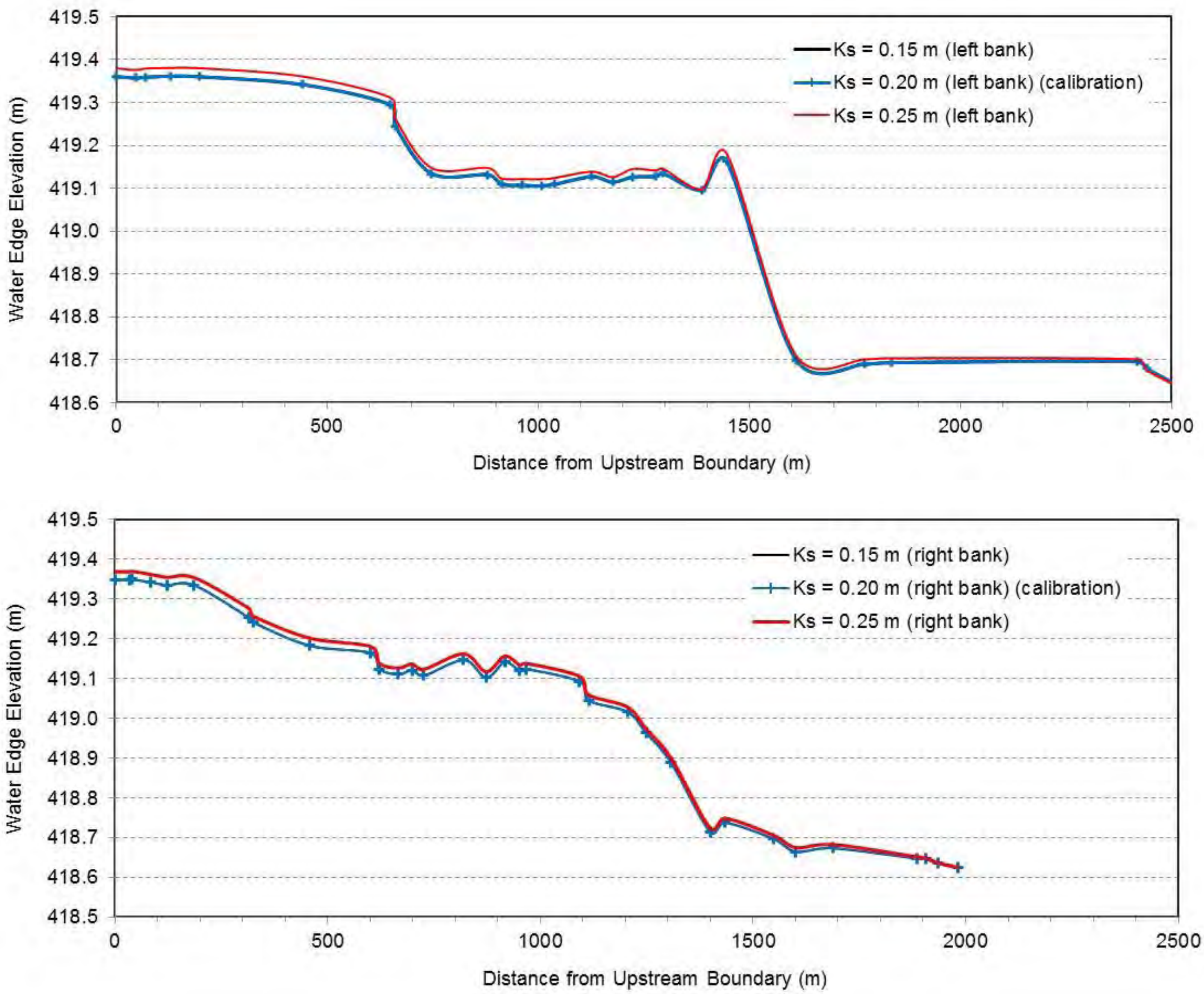



*Figure 8: Model Sensitivity Analysis Results along the Columbia River Reach.*

## 3.4 Kootenay River Hydraulic Modeling

### 3.4.1 Kootenay RIVER-2D Model Calibration

The river bed materials along the Kootenay River consist of coarse materials (i.e., mainly gravels and cobbles). A roughness height (Ks) of 0.25 m was assigned for the RIVER-2D Model. During the model calibration, the simulated water levels were compared to the measured water levels. The surveyed and simulated water levels along the left and right banks of the Kootenay River for the model calibration are presented in Figure 9 and Figure 10. Figure 11 compares the differences between simulated and surveyed water levels along the 1.7 km study reach of the Kootenay River. The average difference between the surveyed and simulated water levels was -0.006 m and ranged from -0.15 m to 0.20 m along the right bank, and the average difference between the surveyed and simulated water levels was 0.013 m and ranged from -0.23 m to 0.35 m along the left bank of the Kootenay River.

The deviations observed in Figure 10 and Figure 11 suggest that there is no strong systematic bias in the results. However, Figure 11 shows some skew at the downstream end and a weak tendency on the simulated water levels to underestimate towards the downstream end and to slightly overestimate towards the upstream boundary. Possible sources of error may include field survey such as operator blunders, equipment problems and variation of discharges during the survey. The downstream boundary condition adjustment could be another source of error.

The simulated water levels, flow depths and velocity vectors for the Kootenay River Model calibration are presented in Figure 12.

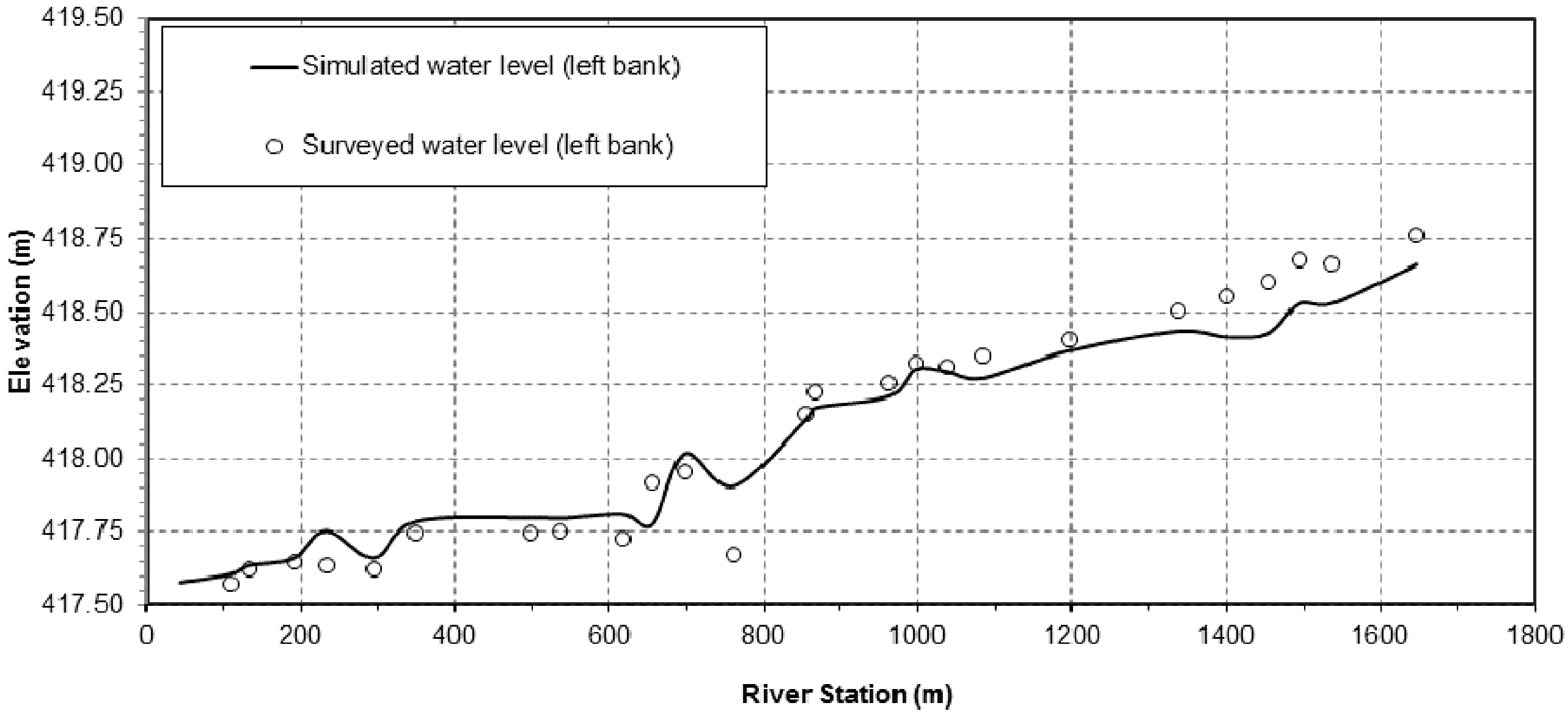



*Figure 9: Comparison of Simulated and Surveyed Water Levels along the Left Bank of the Kootenay River Reach.*

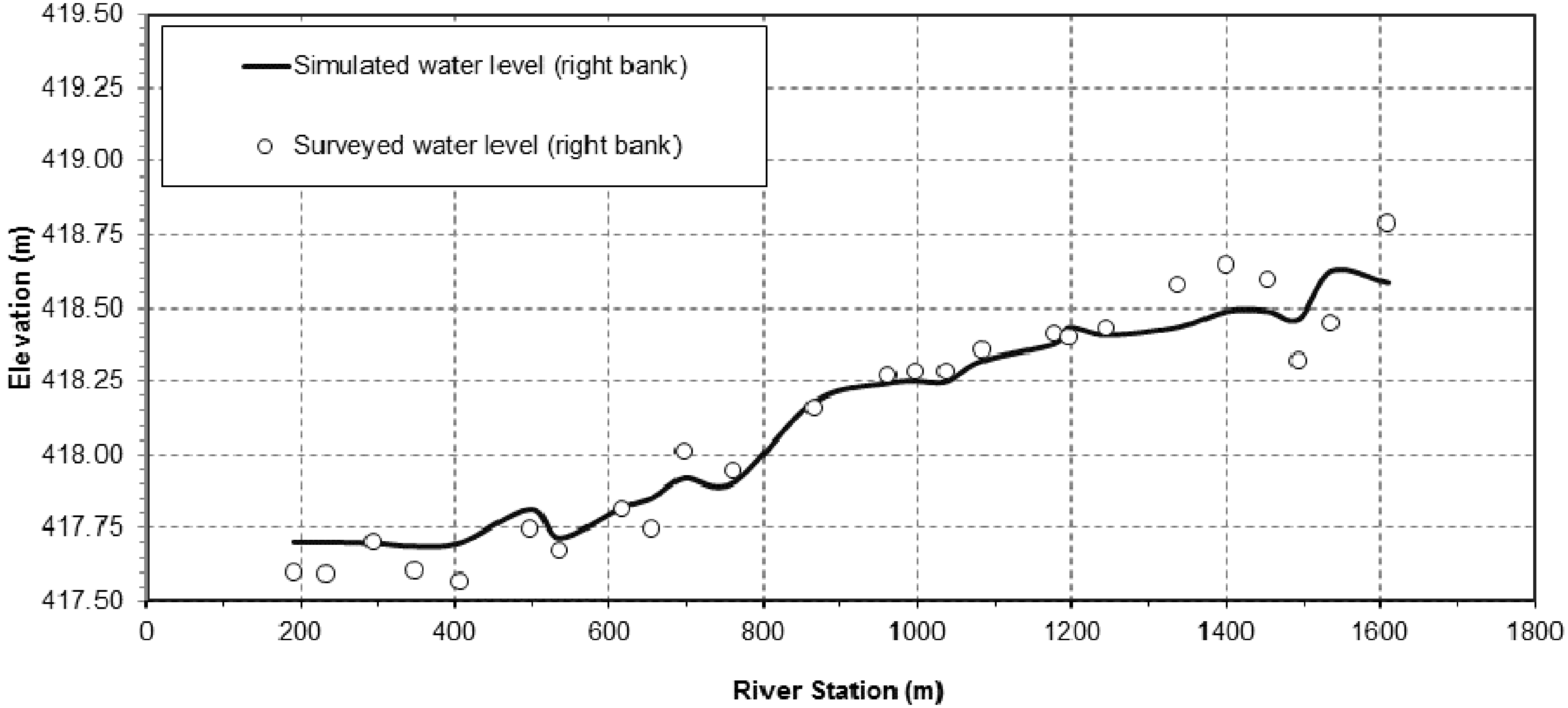



*Figure 10: Comparison of Simulated and Surveyed Water Levels along the Right Bank of the Kootenay River Reach.*

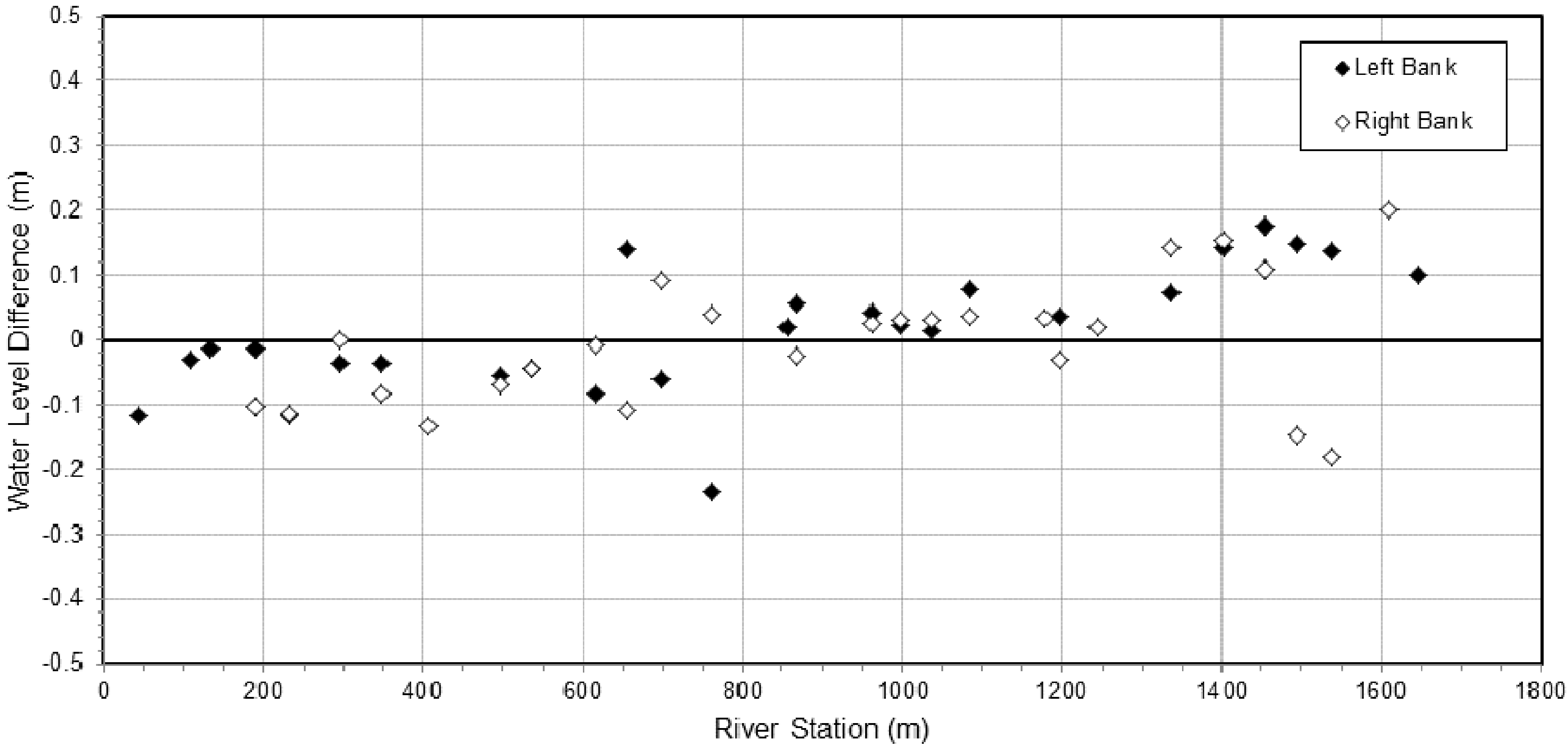
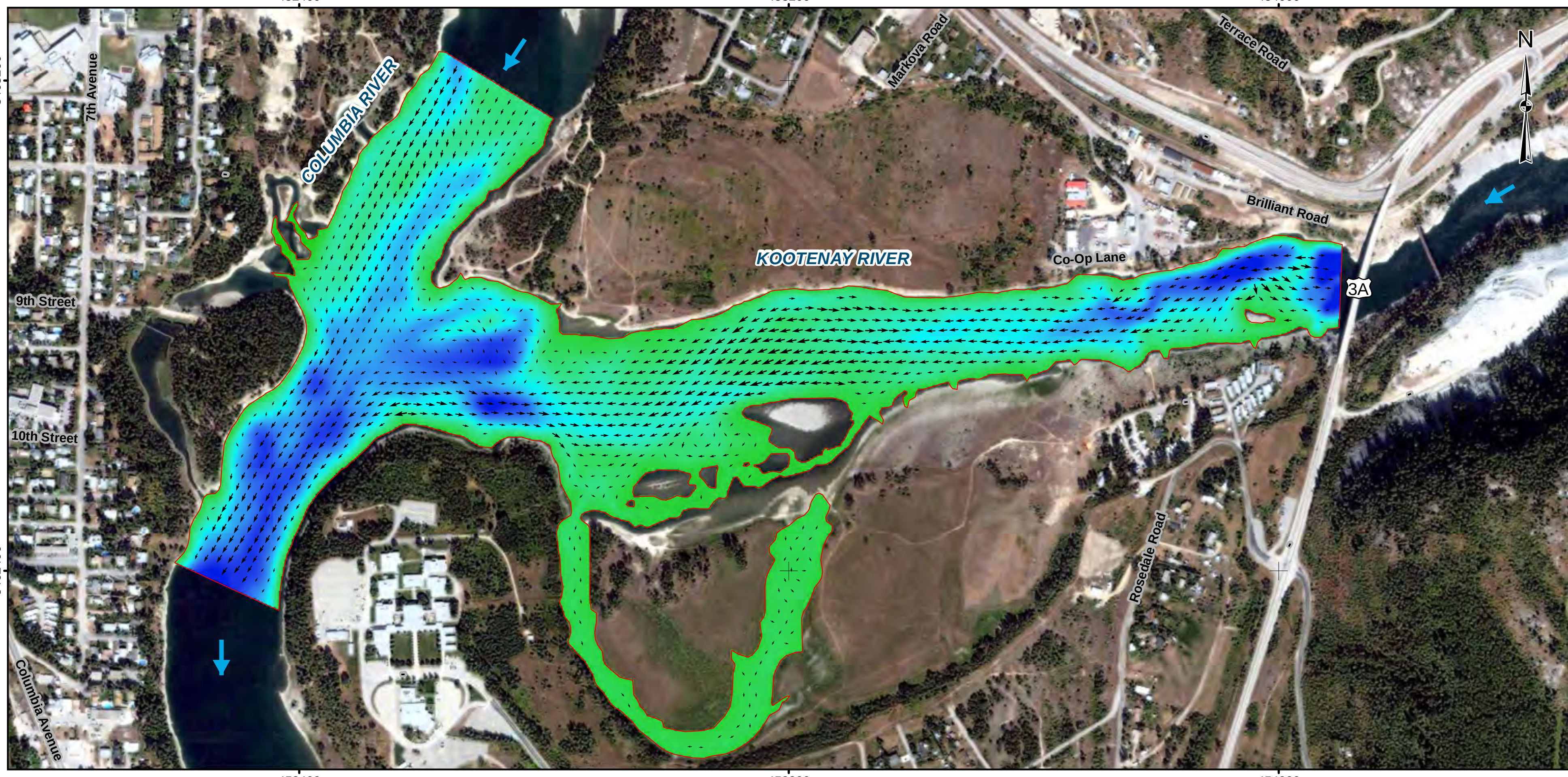



*Figure 11: Differences between the Surveyed and Simulated Water Levels along the Left and Right Banks of the Kootenay River Reach. Note: the solid line represents the surveyed water levels, and the data points represent simulated water levels at certain points along each riverbank.*

I:\2010\10-1492\10-1492-0142\Mapping\MXD\Hydrology\FIG12_2DModel_depth_velocity_map_Kootenay.mxd




## LEGEND

**FLOW VELOCITY (m/s)**

- < 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- FLOW DIRECTION
- WETTED AREA

**WATER DEPTH (m)**

- 0.0 - 2.0
- 2.1 - 4.0
- 4.1 - 6.0
- 6.1 - 8.0
- 8.1 - 10.0
- 10.1 - 12.0
- 12.1 - 14.0
- 14.1 - 16.0

400 0 400

SCALE 1:10,000 METRES

DRAFT

## REFERENCE

SERVICE LAYER CREDITS: SOURCE: ESRI, DIGITALGLOBE, GEOEYE, I-CUBED, USDA, USGS, AEX, GETMAPPING, AEROGRID, IGN, IGP, AND THE GIS USER COMMUNITY. SURVEY WAS COMPLETED IN LOCAL COORDINATE SYSTEM, RECTIFIED BASED ON AIR PHOTO. ROAD LABELS OBTAINED FROM CANVEC © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.
DATUM: NAD83 PROJECTION: UTM ZONE 11

PROJECT

CLBMON-47: LOWER COLUMBIA RIVER WHITEFISH SPAWNING GROUND TOPOGRAPHIC SURVEY

TITLE

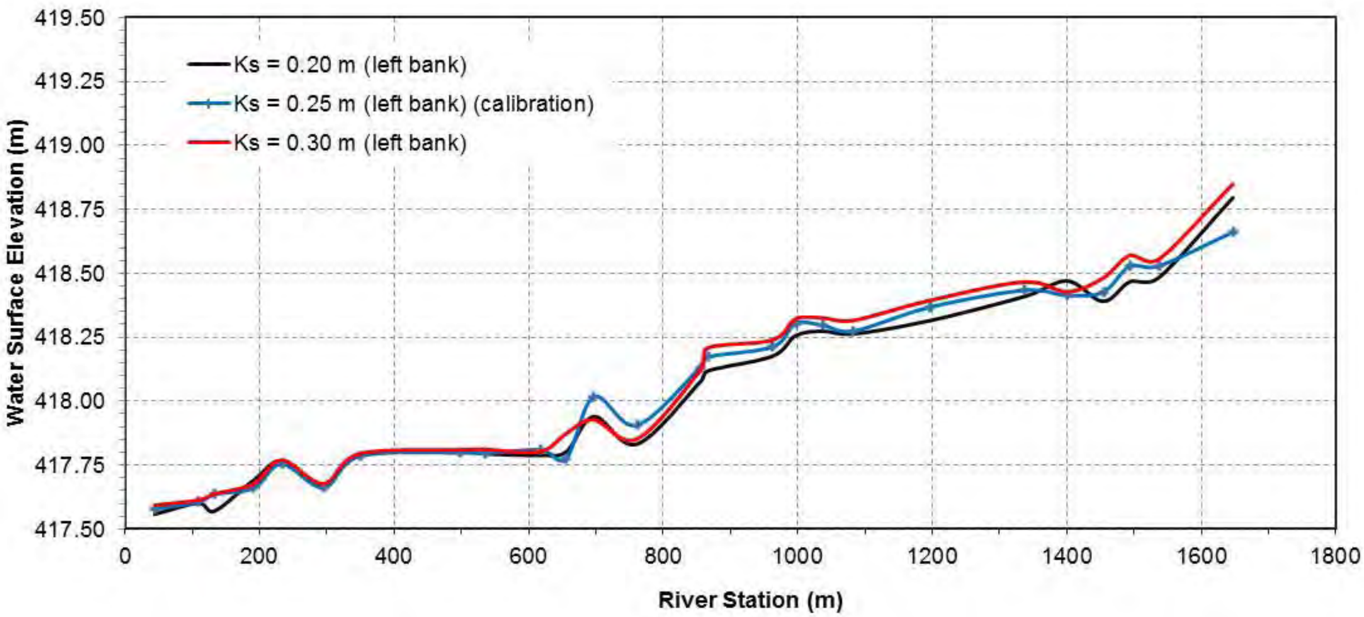
**SIMULATED WATER DEPTHS, FLOW VELOCITIES AND WETTED AREA FOR KOOTENAY (Q = 825 $m^3/s$) AND COLUMBIA (Q = 708 $m^3/s$) RIVERS**

Golder Associates

| | | | | |
|---|---|---|---|---|
| PROJECT | | 10-1422-0072 | FILE No. | |
| DESIGN | WP | 15 Feb. 2012 | SCALE AS SHOWN | REV. 0 |
| GIS | KLN | 03 Apr. 2013 | **FIGURE: 12** | |
| CHECK | | | | |
| REVIEW | | | | |

### 3.4.2 Kootenay RIVER-2D Sensitivity Analysis

A sensitivity analysis of simulated water levels was conducted by varying roughness heights Ks. The Ks values were increased and decreased by 20% from the calibrated values (Figure 13). The simulated water levels were not sensitive to the Ks variations. The simulated water levels changed ±0.02 m, on average, when Ks varied ±20%.



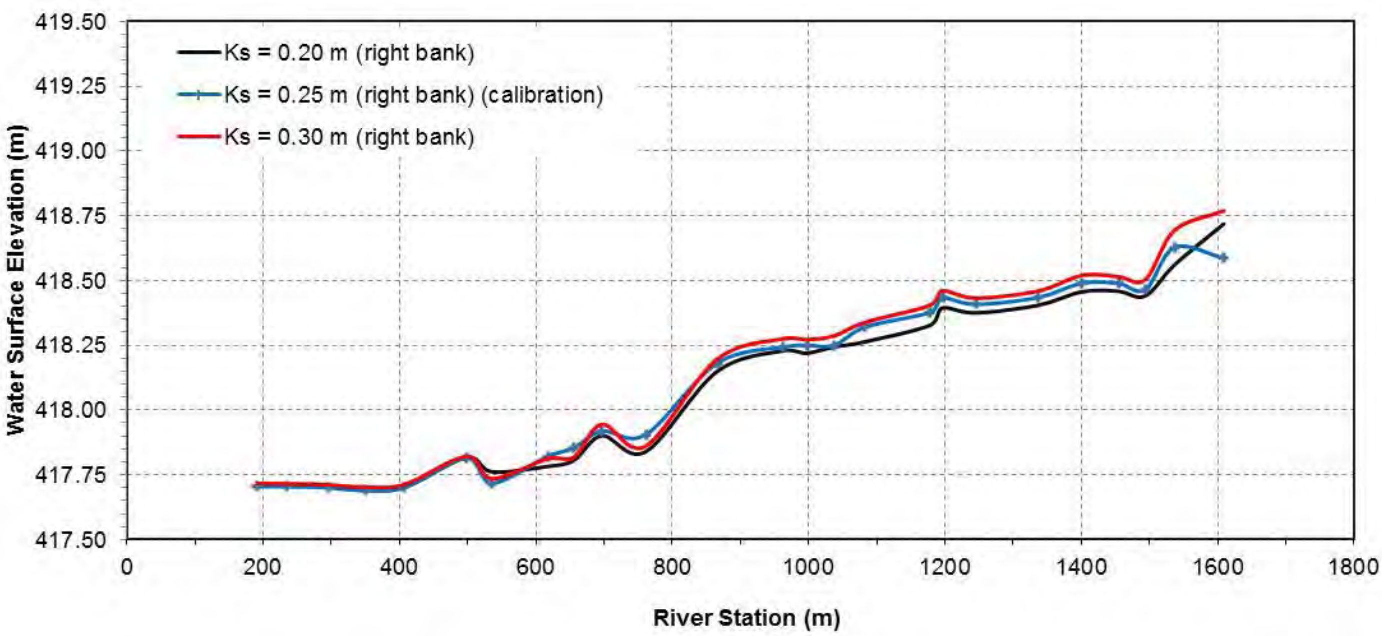




*Figure 13: Model Sensitivity Analysis Results along the Kootenay River Reach.*

# 4.0 DISCUSSION

## 4.1 CLBMON-47 Management Questions

**Management Question 1** *(What are the topographic characteristics of the key spawning locations for Mountain Whitefish in the lower Columbia and Kootenay rivers?)* was addressed. Topographic surveys documented the topographical characteristics of the two key Mountain Whitefish spawning locations at CPR Island and the lower Kootenay River in Year 1 of this study program (Golder 2012). In Year 1, a total of 40 cross sections were conducted in the Columbia River at the CPR Island area, and 30 cross sections were surveyed in the Kootenay River, all of which were included in the RIVER-2D hydraulic model when it was developed in Year 2.

In the CPR Island key spawning area, the upstream hydraulic control selected for the RIVER-2D hydraulic model was originally established at the downstream end of Norn's Creek Fan. The downstream hydraulic control was set at the upstream end of Tin Cup Rapids. The area between these two controls was the original study area for CPR Island. At the request of BC Hydro, the area sampled during the topographic and ADCP surveys was expanded upstream to encompass all of Norn's Creek Fan. Eleven of the 40 cross sections characterize the spawning area near CPR Island. Other topographical features include steep gradient banks along the RDB (Appendix A, Sheets 4, 6 and 7), a channel between the LDB and CPR Island that remains wetted at higher water elevations (Figure 1, transect 47 141 m), and shallow depths in the downstream portion of the spawning area (Figure 1, transects 46 826 m to 46 518 m). At this spawning area, the highest rates of egg deposition have been documented along the mainstem bank of CPR Island, which is dominated by relatively gentle gradients (Figure 1, transects 47 007 m to 46 937 m). Consistent lower use of the thalweg and right downstream bank has also been documented, with sporadic increases in egg deposition (Golder 2011).

The Kootenay River key spawning area was divided into three separate sections based on documented egg depositional rates and topography (Golder 2011). The downstream section of the Kootenay River spawning area is dominated by Kootenay Eddy along RDB (Figure 1, transects 191 m to 295 m), a large point bar (Figure 1, transects 349 m and 470 m) that deflects and constricts the Kootenay River flow creating a deep channel along LDB adjacent to the eddy (Figure 1, transects 295 m to 109 m), and a ridge between the eddy and the channel (Figure 1, transects 295 m to 109 m). This section also exhibits the greatest depth within the Kootenay spawning area. This portion of the spawning area is not considered favourable for whitefish spawning, and the majority of eggs collected in this area are believed to have drifted from upstream (Golder 2011).

The highest rates of Mountain Whitefish egg deposition during the 2009-2010 and 2010-2011 spawning seasons were documented in the middle section of the Kootenay spawning area (Golder 2011). This section is dominated by low gradient banks, a relatively wide thalweg with consistent depth, and a large backwater area downstream of two islands along the LDB (Figure 1, transects 349 m to 866 m).

The upstream section of the Kootenay spawning area (Figure 1, transects 963 m to 1647 m) is the longest and narrowest of the three sections. The upstream portion of this section exhibits greater thalweg depths and steep shorelines (Figure 1, transects 1337 m to 1647 m). Topographical features of interest in this portion include a shallow shoal (Figure 1, transect 1647 m) and a bedrock outcrop along RDB (Figure 1, between transects 1245 m and 1337 m), as well as an island along LDB (Figure 1, transects 1494 m and 1537 m). Upstream of the transition between the upstream and middle sections of the Kootenay spawning area (Figure 1, transects 963 m to 1178 m), shoreline gradients and thalweg depth decrease. During CLBMON-48 egg mat sampling, egg depositional rates in the upper section of the Kootenay River were lower than in the middle section (Golder 2010 and 2011).

To facilitate the expansion of the Kootenay spawning area RIVER-2D Model (see Section 4.2), a total of 30 additional cross sections were conducted in the confluence area of the Columbia and Kootenay rivers. These cross sections were included in the RIVER-2D Hydraulic Model when it is developed. The Kootenay River expansion area was divided into three separate sections based on documented topography; the area upstream of the confluence, the confluence itself and downstream of the confluence.

The upstream section of the expansion area is dominated a large boulder garden in the mid-channel and along LDB. Downstream of the boulder garden, multiple benches and ridges are present. In the mid-channel portion of the confluence section of the expansion area, the river bottom is relatively uniform. Along LDB, gradient gradually decreases, while along RDB gradients were typically steeper. The downstream section of the expansion area consists of steep gradients along both LDB and RDB, while the mid-channel portion of the river bottom is relatively uniform. Over the entire expansion area, depth increased in an upstream to downstream direction (Figure 7).

**Management Questions 2** *(What is the hydraulic response of the river to discharge fluctuations at these key spawning locations? How do changes in river discharge influence river stage, and how does river stage relate to wetted channel area at these key spawning locations?)* **and 3** (*How do daily flow changes contribute to cumulative channel dewatering in key spawning areas over the whitefish reproductive period?)* were not addressed in Year 2. The RIVER-2D models for the key spawning areas have been created, but need to undergo further calibration and refinement before they can be utilized to predict hydraulic conditions. Therefore, these management questions will be addressed in Year 3 of this study program, after the development/calibration/update of the RIVER-2D hydraulic and the Mountain Whitefish Egg Loss Models is completed.

## 4.2 RIVER-2D Hydraulic/HEC RAS Model Development and Calibration

Individual RIVER-2D Hydraulic Models were setup and calibrated for the two key Mountain Whitefish spawning areas. The first RIVER-2D Model corresponds to the Columbia River reach at the CPR Island spawning area and the other to Kootenay River reach downstream of the Highway 3A Bridge. The calibrated roughness heights Ks values were 0.25 m and 0.20 m for the Columbia and Kootenay reaches, respectively. The slightly higher Ks value found for the Kootenay River reach may be due to its slightly steeper bed slope and possible coarser materials than those for the Columbia River reach.

The developed Columbia reach RIVER-2D Hydraulic Model adequately represents the river hydraulic situations of the CPR Island spawning area. The results of the sensitivity analysis for this reach showed that the simulated water levels are not sensitive to Ks variations during testing. Currently, the Columbia Reach model has been calibrated under low flow conditions.

In the Kootenay reach, the hydraulic situation is influenced by the water levels in the Columbia River at its confluence. High water levels in the Columbia River will cause backwater effects in the Kootenay River. During development and testing of the Kootenay RIVER-2D Model, inconsistencies related to the confluence were found. To address these inconsistencies, this model was expanded to incorporate the confluence as well.

Initially, the Kootenay River Model ended at the confluence (Figure 2), and after expansion it now encompasses the 1 km section of the Columbia River extending 500 m upstream and downstream from the confluence as well (Figure 2). Although this expanded area is not classified as a key spawning area for Mountain Whitefish, it has been identified as a potential holding and feeding area for spawners prior to spawning in the Kootenay River (Golder 2009).

After expansion, sensitivity analysis testing was conducted on the roughness height Ks. As in the Columbia reach, it was shown that the simulated water levels were not sensitive to Ks variations along the Kootenay River reach. Prior to expansion, the Kootenay Reach Model was calibrated under low flow conditions. Calibration of the expanded model under similar conditions is planned for Year 3 of this program.

In Year 1 the BC Hydro HEC RAS Model in the key spawning areas was updated (Golder 2012). As stated in the BC Hydro TOR (BC Hydro 2007), an anticipated step to updating the HEC RAS Model was to *Configure the model to provide flow dependant estimates of wetted channel area by vertical strata within the river channel at each of the representative spawning locations chosen for use in the egg loss model (25 cm strata recommended)*. Although the vertical strata condition was met during sampling in Year 1, the wetted channel area estimates by flow will be better calculated using the completed RIVER-2D Models. In the meantime, the CPR Island contour maps can be used to calculate the dewatered area at this spawning area while the 2D Hydraulic Model is completed. This can be conducted using the water elevations recorded at the Norn's' Creek Fan Data Collection Platform.

# 5.0 RECOMMENDATIONS

The recommendations for Year 3 of the CLBMON-47 Lower Columbia River Whitefish Spawning Ground Topography Survey Program are as follows:

- Validate the calibrated RIVER-2D Models under high flow conditions so that the models developed in this study can be used for both high and low flow predictions.
- Validate the updated HEC RAS Model if additional water level data for high flow conditions become available. Low flow data is available from the surveys conducted in the present study Year. From experience with the hydraulic modelling of similar rivers, the roughness values for high and low flows may differ.
- Once the RIVER 2D Model is completed and calibrated, explore the feasibility of conducting model runs at discharges recorded during previous peak spawning periods. This will provide accurate estimates of the main habitat characteristics (depth and velocity) and will allow for the creation of habitat suitability curves for spawning whitefish.
- Once completed, examine the substrate data collected by BC Hydro within the key spawning areas to create a spawning suitability curve for this habitat characteristic.

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## 7.0 CLOSURE

We trust that this report meets your current requirements. If you have any further questions, please do not hesitate to contact the undersigned.

**GOLDER ASSOCIATES LTD.**

*ORIGINAL SIGNED*

Brad Hildebrand, B.Sc.
Project Manager, Fisheries Biologist

*ORIGINAL SIGNED*

Dana Schmidt, Ph.D., R.P.Bio.
Associate, Project Director, Senior Scientist

BH/DS/cmc



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# APPENDIX A

## Key Spawning Area and RIVER 2D Model Area Contour Maps

Attached as digital files.

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| Africa | + 27 11 254 4800 |
| Asia | + 86 21 6258 5522 |
| Australasia | + 61 3 8862 3500 |
| Europe | + 356 21 42 30 20 |
| North America | + 1 800 275 3281 |
| South America | + 55 21 3095 9500 |

solutions@golder.com
www.golder.com

**Golder Associates Ltd.**
**201 Columbia Avenue**
**Castlegar, British Columbia, V1N 1A8**
**Canada**
**T: +1 (250) 365 0344**