Columbia River Project Water Use Plan

Middle Columbia River Juvenile Fish Stranding Assessment (Year 4 of 4)

Reference: CLBMON#53

Columbia River Water Use Plan Monitoring Program:

Middle Columbia River Juvenile Fish Stranding Assessment

Study Period: 2013-2014

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MIDDLE COLUMBIA RIVER JUVENILE FISH STRANDING ASSESSMENT

CLBMON-53 – 2013 REPORT (YEAR 4 OF 4)

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Disclaimer

This report is rendered solely for the use of BC Hydro in connection with the Middle Columbia River Juvenile Fish Stranding Project (CLBMON-53), and no person may rely on it for any other purpose without prior written approval from BC Hydro. Triton accepts no responsibility for loss or damages suffered by any third party as a result of decisions made or actions taken based on this report.

This report is based on facts and opinions contained within the referenced documents. We have attempted to identify and consider relevant facts and documents pertaining to the scope of work, as of the time period during which we conducted this analysis. However, our opinions may change if new information is available or if information we have relied on is altered. We applied accepted professional practices and standards in developing and interpreting data obtained by our field measurement, sampling, and observation. While we used accepted professional practices in interpreting data provided by BC Hydro, we did not verify the accuracy of those data. This report should be considered as a whole and selecting only portions of the report for reliance may create a misleading view of our opinions.

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Executive Summary

This report summarizes the Year 4 results and compares the previous three years' results of a four year study to assess the risk of juvenile fish stranding in the Middle Columbia River associated with operation of the Revelstoke Dam. Specifically, the goals of the study were to characterize the level of stranding that currently occurs at the Greenslide Creek Side channel and other side channel sites downstream of the Trans-Canada Highway Bridge and to determine if stranding risk is likely to increase in extent, magnitude, duration, or frequency with the addition of a fifth generator (Rev 5) at the dam. The study involves two years of pre-Rev 5 data collection as well as two years of post-Rev 5 data collection, with this report representing the second year of post-Rev 5 data collection.

Year 4 of the study involved sampling at three sites: Greenslide Creek Side Channel (September 23 to 25, October 16 to 17, 2013), as well as sampling and water level monitoring at the Begbie Creek gravel bar site (referred to as the Begbie site – October 15 to 17, 2013), and the Highway Bridge gravel bar (referred to as the Highway Bridge site – June 4 to 5, September 23 to 24 and October 16, 2013). Pressure transducers were installed at the sites in order to monitor changes in water level over time and to be able to relate those changes to discharge from the dam. Monitoring of the Greenslide Creek Side Channel in previous years has confirmed that the site does not experience daily fluctuations in water level associated with dam operation post-Rev 5. Instead, the site is inundated in the spring as the Arrow Lakes Reservoir (ALR) elevation increases. It remains wetted through the summer and then dewaters in the winter as the ALR recedes. Therefore any fish mortality at the site associated with dewatering would be the result of ALR operation as opposed to Revelstoke Dam operation.

As observed throughout the study, seasons which experience high ALR elevations are thought to have a mitigative effect on the risk of stranding at each of the three sites. In general, as the ALR elevation increases, varying degrees of backwater effects are experienced at each site and as a result, water levels at the sites fluctuate less in response to changes in dam discharge. ALR influence reduced stranding risk by 66% of the growing season (April to November) at the Greenslide Creek Side Channel, 56% of the growing season at the Begbie site and, 48% of the growing season at the Highway Bridge site. From 2009-2011 and 2013, overall stranding risk is ranked Low at the Greenslide Creek Side Channel, Moderate at the Begbie site and High at the Highway Bridge site. Discharge from the dam in Years 3 and 4 (post-Rev 5) was not found to differ substantially from that of Years 1 and 2 (pre-Rev 5). General findings from Years 1 to 4 of the study include:

Fish strandings – time of day

- Fish strandings typically occur in the early morning (3:00 a.m. to 5:00 a.m.) on nights when the discharge from the dam is ramped down. There is a delay of approximately 20 minutes before the drop in flows is noticeable at the Highway 1 bridge site (located 6 km downstream of the dam) and 3 hours before it is noticeable at the Begbie site (located 12 km downstream of the dam). Water level changes associated with the dam are negligible at the Greenslide Creek side channel located 24 km downstream of the dam.

Fish strandings – time of year

- Stranding potential is highest from fall to spring when the reservoir elevation is lower and a greater proportion of the river is influenced by flow regulations from the dam. The presence of increased numbers of young-of-year and spawning fishes in the system in the fall can increase the likelihood that water level changes will affect fishes at that time of year.

Fish strandings – wetted history

- Fish strandings occur over a wide range of discharge on the falling limb of the hydrograph. Site conditions (e.g., channel morphology and bank slope) and rates of change will affect overall stranding risk. Sites frequently wetted and dewatered may be avoided by fishes due to unpredictable conditions, thereby reducing stranding in those areas.

Fish strandings – substrate type

- Fish strandings resulting from dam operations occur primarily at low-gradient sites where multiple narrow and shallow channels, depressions, and pools form as water levels drop. These narrow and shallow channels and depressions typically have gravel and cobble substrates.

Fish strandings – cover type

- Fish strandings resulting from dam operations occur primarily at low-gradient sites where multiple narrow and shallow channels, depressions, and pools form as water levels drop. These narrow and shallow channels and depressions typically lack cover such as large woody debris.

Objectives	Management Questions	Management Hypotheses	Year 5 (2013) Status
To assess the risk of fish stranding in a discrete portion of the Columbia River potentially influenced by the operation of five units at Revelstoke Dam.	1. Are fish strandings occurring in side channels near Greenslide Creek under the current four units operations in the area of influence of Rev 5? 2. If fish strandings are found to occur in these side channels under the present regime, are they likely to increase in extent, magnitude, duration, or frequency under the five-unit operations? Should stranded fishes be consistently found in the area, the following management questions will arise: 3. What is the relationship between abundance of stranded fishes (stranding risk) and time of day, wetted history, substrate, and cover type in the area of influence of Rev 5? 4. What species and life stages are most likely to be stranded?	H01: Implementation of normal pre-Rev 5 and post-Rev 5 operations do not result in biologically significant fish stranding impacts in the Greenslide Creek area. H02: The number of stranded fishes is independent of time of day, wetted history, or available cover. H03: All fish species (and their life stages) using the habitat near Greenslide Creek are equally likely to be stranded.	1. Fish strandings near Greenslide Creek are independent of dam operations and rather, occur as a result of changes in ALR elevation. 2. Fish strandings do not appear to have increased in extent, duration, or magnitude under the five-unit operations. 3. Stranding occurs primarily at night, in areas of shallow gradient gravel bars, as discharge from the dam decreases. 4. Juvenile fish are more likely to become stranded than adult fish, and coarse fishes, specifically Mountain Whitefish and Redside Shiners, are the species most at risk of stranding.

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1.0 Introduction

The Middle Columbia River is the portion of the Columbia River located downstream of Revelstoke Dam, and it forms the upstream end of the Arrow Lakes Reservoir (ALR). The Middle Columbia River is affected by flows from Revelstoke Dam at the upstream end, and by fluctuating ALR elevations from waters impounded behind the Hugh Keenleyside Dam at its downstream end near Castlegar. As the ALR fills, the floodplain of the Middle Columbia River becomes inundated, typically downstream of the city of Revelstoke. This inundation usually affects approximately 50 km of the Middle Columbia River floodplain (BC Hydro, 2007), and when the reservoir is at full pool, the backwater effects can extend to the Revelstoke Dam. The ALR fills through spring, reaching full pool (maximum elevation) in June or July, remains high throughout the summer, and is drawn down through late fall and during the winter. However, it should be noted that complex flood control treaties and water storage agreements with the United States and downstream facilities drive the operation of the reservoir, and the general operating regime provided here is a very simplistic overview.

The Revelstoke Dam is a peaking facility, with discharge tied to energy demand. This can result in widely fluctuating discharges that typically remain high during the day when power demand is greatest, and are reduced during the night when demand drops. The dam historically housed four turbines, and an additional turbine (known as Rev 5) came online in December 2010. The pre-Rev 5 discharge from the facility ranged from a minimum of 0 m^3/s to a maximum of approximately 1,700 m^3/s (BC Hydro, 2009). The addition of the fifth generating unit increases the projected maximum discharge from the facility to approximately 2,125 m^3/s, with an established minimum base flow of 142 m^3/s (BC Hydro, 2007). The variable discharges from the dam result in daily fluctuating water levels that are greatest near the dam, and attenuate with increasing distance downstream. These daily water level fluctuations can occur quickly and therefore pose a risk of stranding fishes in areas that become rapidly dewatered. The risk is greatest at night, when dewatering typically occurs and juveniles and smaller fishes are particularly susceptible given that they are most likely to use shallow, shoreline habitats.

Following the application for the addition of a fifth generating unit at the Revelstoke Dam facility, a joint environmental assessment and Columbia Water Use Plan (WUP) review were undertaken (BC Hydro, 2007). The Revelstoke Unit 5 Core Committee recommended that the incremental impacts of operation of the new generating unit be assessed. Among the impacts considered was the potential risk of fish stranding due to water level fluctuations. The Committee recommended that an overview study be completed to determine potential juvenile fish stranding in side channel areas downstream of the Trans-Canada Highway Bridge (BC Hydro, 2009). Three sample sites were identified; the Greenslide Creek Side Channel, identified in 2009 as an area that experience rapid channel shifting and therefore poses a risk of fish stranding (BC Hydro, 2009), located 25 km downstream of the Revelstoke Dam, the Begbie Site, identified in 2009, located 12 km downstream of the Revelstoke Dam, and the Highway Bridge Site, identified in 2010, located 6 km downstream of the Revelstoke Dam.

1.1 Management Objectives, Questions, and Hypotheses

The primary objective of this program, as outlined in the Terms of Reference (ToR) (BC Hydro, 2007, 2009), is to assess the risk of fish stranding in a discrete portion of the Columbia River potentially influenced by the operation of five units at Revelstoke Dam. The overall objective of the WUP is to ensure that incremental flows resulting from the operation of five units do not impact the biophysical and abiotic environments in the area of influence of the project. The monitoring program will assess the presence of stranded fishes and collect relevant data on these fishes in the Greenslide side channels area. (BC Hydro, 2009, p. 28)

The monitoring program consists of four years: two years of pre- and two years of post-Rev 5 surveys. Key management questions addressed by the study include the following (BC Hydro, 2009):

1. *Are fish strandings occurring in side channels near Greenslide Creek under the current four units operations in the area of influence of Rev 5?*
2. *If fish strandings are found to occur in these side channels under the present regime, are they likely to increase in extent, magnitude, duration or frequency under the five-unit operations?*

Should stranded fishes be consistently found in the area, the following management questions will arise:

1. *What is the relationship between abundance of stranded fishes (stranding risk) and time of day, wetted history, substrate, and cover type in the area of influence of Rev 5?*
2. *What species and life stages are most likely to be stranded?*

The primary management null hypothesis (BC Hydro, 2009) is as follows:

1. *Implementation of normal pre-Rev 5 and post-Rev 5 operations do not result in biologically significant fish stranding impacts in the Greenslide Creek area.*

Pending rejection of the first null hypothesis, other null hypotheses will be as follows:

2. *The number of stranded fishes is independent of time of day, wetted history, or available cover.*
3. *All fish species (and their life stages) using the habitat near Greenslide Creek are equally likely to be stranded.*

This report describes Year 4 (two years post-Rev 5) results and provides a comparison with previous years' results to assess the risk of juvenile fish stranding as a result of the Revelstoke dam operations. Details on Year 1 (2009), Year 2 (2010), and Year 3 (2011) of the study, which included an initial background information review, site reconnaissance of the study area, and fish sampling, can be found in Sykes and Liebe (2010*a*, 2011*a*, 2012*a*).

2.0 Methodology

2.1 Study Area

The area of study (Figure 2.1-1) is located within a 24 km section of the Middle Columbia River near the town of Revelstoke, BC and contains three sample sites (Greenslide Creek Side Channel, Begbie site and the Highway Bridge site). The Greenslide Creek Side Channel is located on the East bank of the river approximately 24 km downstream of the dam. The Begbie Site is located on the West bank of the river approximately 12 km downstream of the Revelstoke Dam. The Highway Bridge site is located on the West bank of the river, beneath the Highway 5 Bridge and 6 km downstream of the Revelstoke Dam. Table 2.1-1 displays the UTM coordinates for each of the three sample sites.

Table 2.1-1. UTM locations of the Greenslide Creek Side Channel, Begbie site and Highway Bridge site.

Site	UTM
Greenslide Creek Side Channel	11 U 421190 E. 5638576 N.
Begbie site	11 U 415943 E. 5644390 N.
Highway Bridge site	11 U 414465 E. 5650144 N.

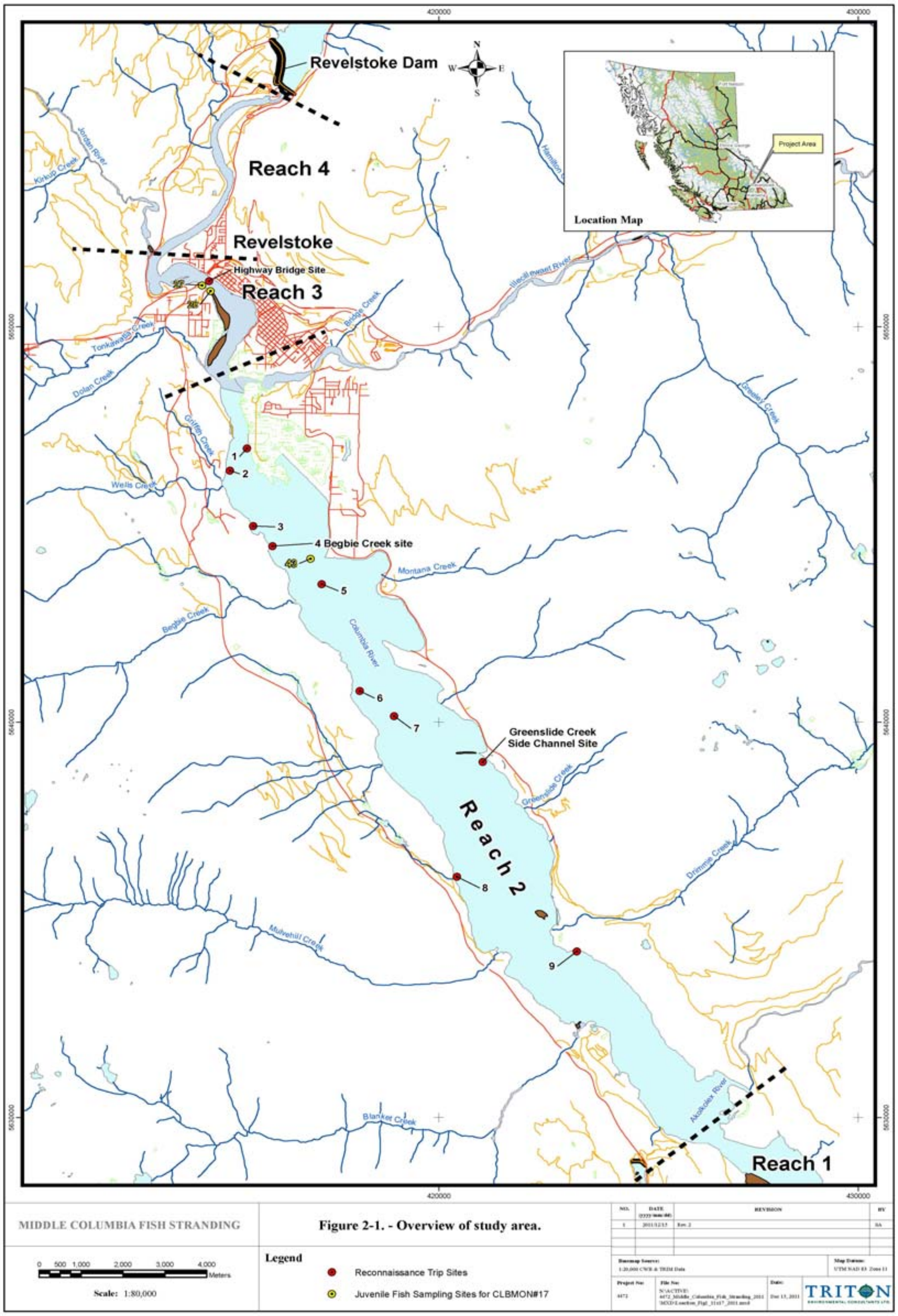

Figure 2.1-1. Overview map of study area for Year 4 of the Middle Columbia River juvenile fish stranding study

2.2 Field Surveys

2.2.1 Reconnaissance Survey

A modified reconnaissance trip was completed during the day on June 4, 2013 to revisit each of the three main sites: Greenslide Creek Side Channel, Begbie Site as originally assessed during the reconnaissance surveys in 2009, and the Highway Bridge Site which was added in 2010 (Figure 2.2-2). During the 2009 assessment, the following questions were addressed:

- Is the site currently wetted or does it show signs of having been recently wetted?
- Are habitat values such that usage by coarse or sport fishes would be expected?
- Are there depressions or pool areas where isolation from the mainstem is likely to occur? Are such areas likely to dewater to the point where fish mortality would be expected?
- Is the profile of the upstream and downstream connection points to the mainstem such that a regular cycle of watering and dewatering would be expected?

The goal of the reconnaissance survey in 2013 was to confirm that the 2009 assessment results were still accurate, and to assess if the risk of stranding at the sites had changed. An additional goal was to determine if there was sign of any new stranding areas following Rev 5 coming online. Each of the sites was accessed by boat, with the crew completing surveys by foot at the sites, as required.

2.2.2 Site Descriptions

Greenslide Creek Side Channel

The Greenslide Creek Side Channel is a broad, U-shaped depression (Figure 2.2-1) on the east side of the river approximately 24 km downstream of the Revelstoke Dam. This site was specifically identified for monitoring in the ToR (BC Hydro, 2007, 2009) and therefore has been included in the field assessments in all four years of study.

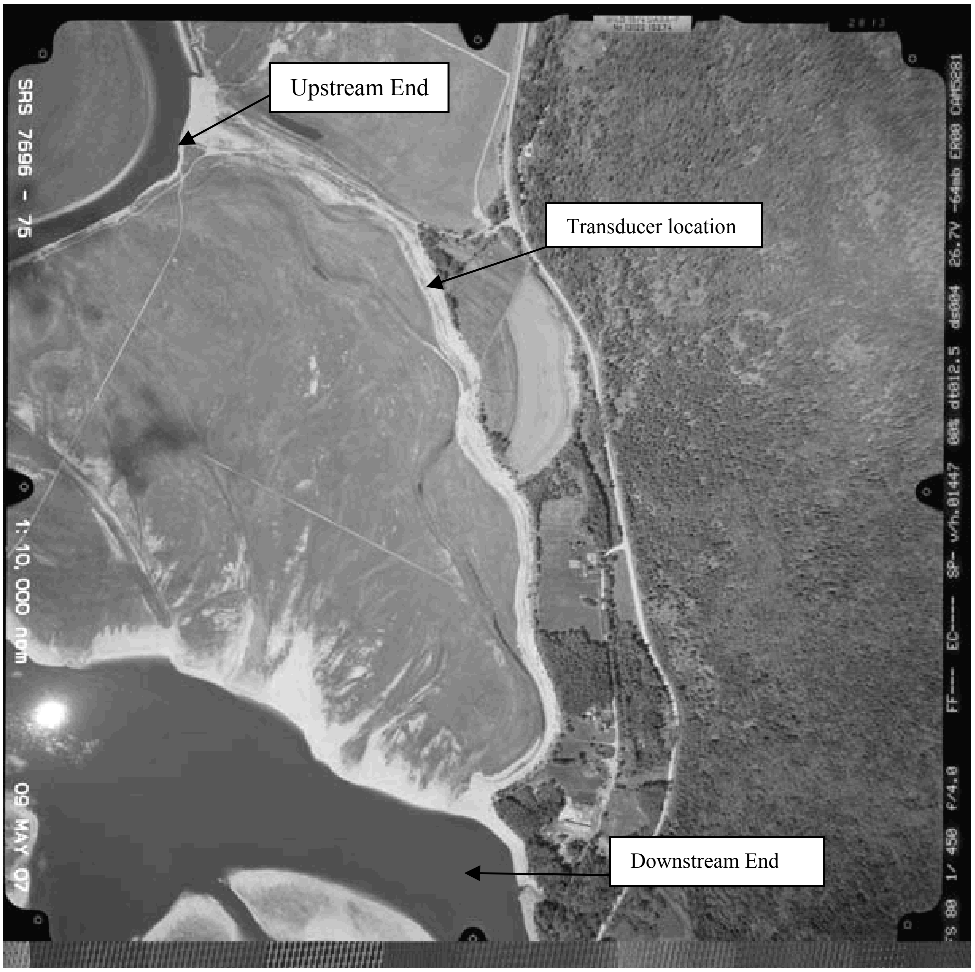

Figure 2.2-1 Overview of the Greenslide Creek Side Channel site showing transducer location

Begbie Site

The Begbie Site (Figure 2.1-1) was identified during the 2009 reconnaissance survey as having the highest potential for stranding among the sites surveyed. The site is located on the west side of the river approximately 12 km downstream of the Revelstoke Dam and consists of a low-gradient gravel and cobble dominated bar with multiple channels and depressions that could result in fish stranding.

Highway Bridge Site

This study site, selected in 2010, is a large gravel bar located downstream of the Highway bridge to approximately 500 m past the single lane bridge, on the west side of the Middle Columbia River (Figure 2.2-2). The site is approximately 6 km downstream of the Revelstoke Dam. The area can be divided into three sections based on habitat characteristics:

- *Area #1* is located between the Highway Bridge and the CP Rail Bridge.
- *Area #2* is located between the CP Rail Bridge and the Single Lane Bridge.
- *Area #3* is located downstream of the Single Lane Bridge.

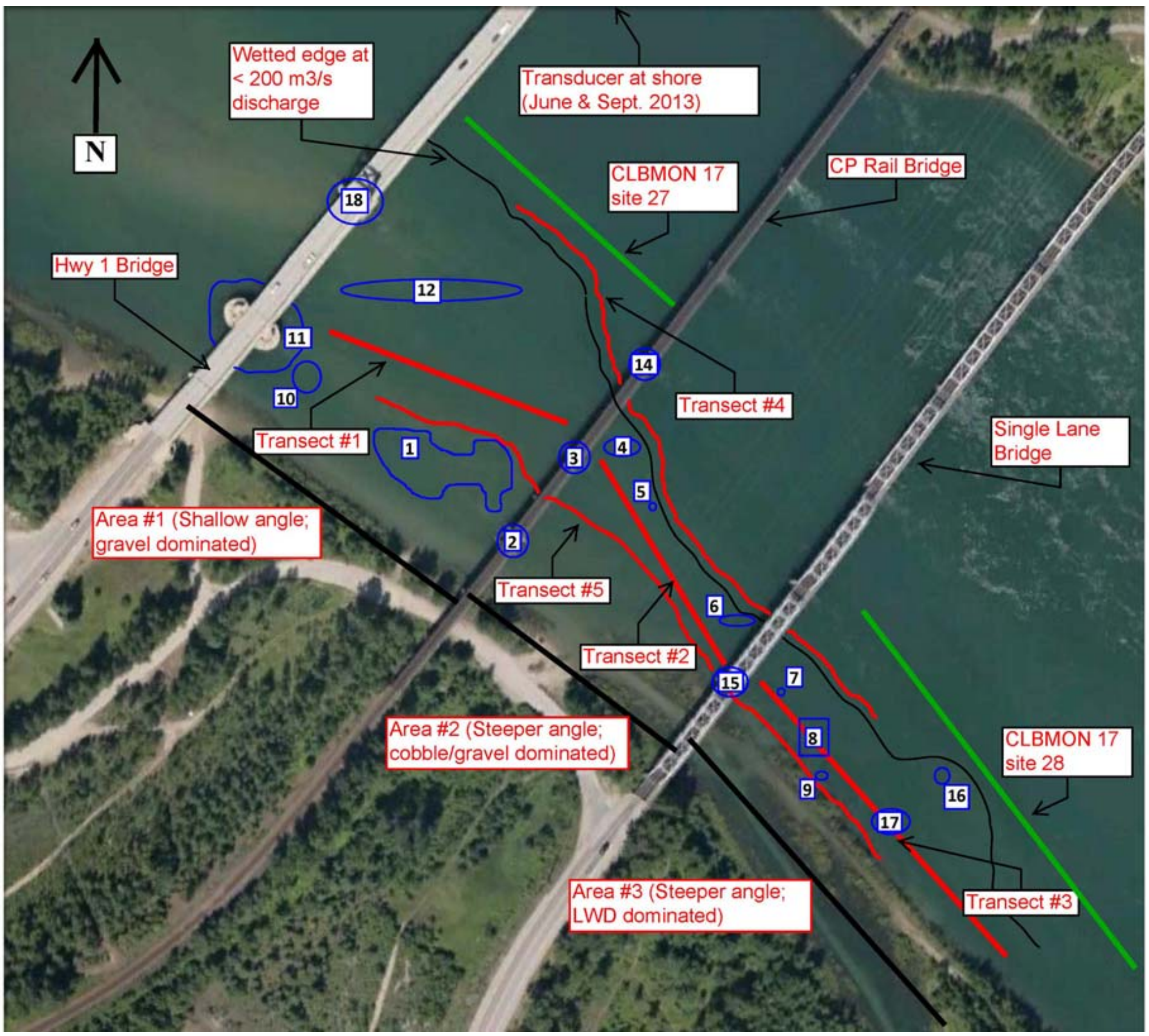

Figure 2.2-2: Overview of the Highway Bridge Site.

Note: Numbers identify transect survey sites completed in 2013. CLBMON-17 sites are associated with a separate juvenile fish index sampling program completed in the spring, summer, and fall of 2008-2013. [1] The Highway Bridge site was identified in the Terms of Reference (BC Hydro, 2009) as the upstream limit of survey for the study.

A chronology of field activities for Year 4 of the study is provided in Table 2.2-1 and a detailed description of the field work conducted at each site is provided in the following sections.

Table 2.2-1 Chronology of field activities associated with the 2013 fish stranding program. Refer to Table 2.1-1 for sampling locations.

Activity	Date
Reconnaissance Survey	June 4, 2013
Begbie Site	
Sampling and transducer (water level logging)	October 15-17, 2013
Highway Bridge Site	
Sampling and transducer (water level logging)	June 4-5, 2013, September 23-25, 2013
Sampling	October 16-18, 2013
Greenslide Creek Side Channel	
Sampling	September 23-25, 2013; October 16-18, 2013

2.2.3 Water Level Loggers

Water level data was collected in all four years of the study using OnSet® HOBO water level loggers with an accuracy of +/- 2 cm over a range of 0–9 m. The loggers function by recording pressure with two loggers being installed at each site. One logger was submerged in an area expected to remain continuously wetted, while the second was installed above the water level to collect baseline barometric pressure data. Loggers were programmed to record data at 10 minute intervals. The depth of the wetted probe at each 10 minute interval was then determined using a software package (HOBOware Pro, ver 3.2.1, Onset Computer Corporation) to analyze the water pressure data and associated barometric pressure datasets. Given that the loggers are stationary, the change in logger depth over time is directly attributable to changes in water level.

Observations of the Greenslide Creek Side Channel were made throughout the spring, summer, and fall to assess water levels and the associated seasonal stranding risk, as the site was specifically identified for sampling in the ToR (BC Hydro, 2007, 2009). However, transducers were not set in the Greenslide Creek Side Channel in 2013 because water level conditions were similar to those observed in 2009 and 2011 in that the side channel was dry in spring, inundated through the summer, and by the fall was fully isolated from the ALR. Transducers were installed at the Begbie Site in October, located along a bedrock outcrop at the downstream end of the site. The Highway Bridge site’s transducers were installed in September and October, located at river left along the rip-rap shore, directly beneath the Highway Bridge. Continuous monitoring of water levels at each site provided an indication of the frequency of dewatering at the sites and allowed for the calculation of dewatering rates.

2.2.4 Discharge Information

As a peaking facility, Revelstoke Dam releases widely fluctuating discharges that typically remain high during the day when there is demand for power and decrease at night when demand is typically lower and the turbines typically shut down. Under the pre-Rev-5 flow regime, flows were reduced to near zero m^3/s at night, while under the post-Rev-5 flow regime, flows rarely declined to levels below the established minimum base flow of 142 m^3/s. The lower the daily minimum discharge, the higher the ramping range (difference between minimum and maximum flows) and the faster the rate of dewatering, the higher the stranding risk (Clarke et al., 2008). Discharge data from the Revelstoke Dam were compared with water level data recorded at each of the sites to determine the degree to which dam discharge influenced water levels at each site. In addition, the dewatering rates were calculated.

2.2.5 Fish Sampling

Year 4 (2013) was the last of two post-Rev 5 sampling events and the last year of the program. Initially, Year 4 sampling was proposed for 2012, but was postponed to 2013 due to abnormally high ALR levels throughout the year. Sampling in 2013 followed the methodology established in Year 1 (2009) to allow for direct before and after comparisons. This included repeating the reconnaissance survey initially completed in 2009 to assess if the stranding risk had changed following implementation of the post-Rev 5 flow regimes. The survey also assessed if new areas of stranding risk had developed due to the increase in the maximum discharge possible with the addition of the fifth generator.

Following the completion of the 2013 reconnaissance survey, fish sampling to quantify stranding risk was completed at each of the three sample sites; the Greenslide Creek Side Channel, the Begbie Site and the Highway Bridge Site. As in 2009, sampling of the Greenslide Creek Side Channel was to be completed in the fall and sampling of the Begbie site was to be completed in both spring and fall. However, due to high ALR elevations early in 2013, the Begbie site could not be sampled in the spring and was, instead, sampled in the fall. As a result, the spring sampling had to be completed at the Highway Bridge site since that was the only portion of the study area[1] that was not completely inundated by the ALR at that time.

Fish sampling was conducted overnight at each of the three sample sites through visual observation, backpack electrofishing, and baited “Gee” type minnow traps. Visual observation was used in areas where river substrates became dewatered as water levels receded and conducted by walking linear transects in groups of 2 to 3 people, using high-powered head lamps and flashlights. Electrofishing was used to sample areas with pooled water depths between 0.05 m and 1.5 m, and baited minnow traps were used in areas with pool depths >1.5 m or in large ponded areas where electrofishing was not appropriate. A Resource Information Standards Committee (RISC) Fish Collection field card was completed at each site which included site location, date, set time, retrieval time, depth, and habitat. Captured fishes were enumerated, identified to species, and their fork lengths were measured (mm) before being released into the mainstem. Though sampling in night-time conditions may introduce some level of uncertainty regarding fish detection, it was necessary as stranding within the Middle Columbia system occurs primarily during the night.

Table 2.2-2 provides a summary of the fish sampling completed at each of the monitoring sites during Years 1 to 4 of CLBMON-53.

Table 2.2-2. Summary of fish sampling by site and season for Years 1 to 4 of CLBMON-53

Site	Year 1 (2009)	Year 2 (2010)	Year 3 (2011)	Year 4 (2013)
Greenslide Creek Side Channel	Fall	Fall	NS	Fall
Begbie Site	Spring/Fall	NS	Spring	Fall
Highway Bridge Site	NS	Spring/Fall	Fall	Spring/Fall

NS: sites not sampled

2.2.5.1 Greenslide Creek Side Channel

In 2013, minnow traps baited with canned cat food were set within the Greenslide Creek Side Channel (Figure 2.2-1) for a total of 252 hours. Four traps were set overnight, at locations specific to previous years, for approximately 19 hours each on September 23, and approximately 21 hours each on September 24 (total of 160 hours). On October 16, 2013, four traps were set overnight for a total of 23 hours each (92 hours total). During both September and October sample events, as in years prior, traps were set at the mid-point of the length of the channel at depths ranging from 0.3 to 0.5 m, were set on the bottom of the channel, and were associated with instream vegetation (grass). All fishes captured were documented as mortalities resulting from ALR operations (Section 4.5) because, though the majority of captured fishes were alive at the time of sampling, all fishes present were expected to expire since the side channel fully dewaters each year with the receding ALR water levels. Fishes captured during the sample events were released into an area of the reservoir that had direct connectivity to the Columbia River mainstem and was not prone to dewatering.

2.2.5.2 Begbie Site

Fish sampling at the Begbie Site was conducted on October 16–17 over an estimated 2,000 m^2, similar to that of 2009. Sampling, as in years prior, was completed through backpack electrofishing, baited minnow traps, and visual observations. A two-person crew accessed the site by boat and remained there throughout the night as flows dropped. As flows dropped and areas became isolated, sampling was conducted to determine the degree to which stranding was occurring and which species and size classes of fish were most impacted. Visual surveys were conducted on the newly exposed gravel bars that had previously been wetted. Electrofishing effort was applied in pools found along the gravel bars and beneath large woody debris (LWD) complexes, while minnow traps were applied to the pools that were too deep to effectively electrofish. Wherever possible, the crew applied the same sample method to the same areas as was conducted in 2009. Fish carcasses on exposed gravel bars were documented as mortalities. Live fishes captured in shallow, isolated pools that were likely to dewater later were also considered to be mortalities. The estimated potential stranding rate (#fish/m^2) was calculated using the observed and potential mortalities recorded at the site. Fishes caught in areas that were unlikely to dewater were not included in the calculation of fish/m^2.

2.2.5.3 Highway Bridge Gravel Bar

Fish sampling at the Highway Bridge Site (Figure 2.2-2) was conducted over approximately 6,000 m^2 on June 4 and 5, September 23 to 24, and October 17, 2013. As in years prior, sampling was completed through backpack electrofishing, baited minnow traps, and visual observations. A two-person crew accessed the site by truck as flows began to drop for the night. Sampling was initially conducted during the day when areas were still wetted to determine fish use of the site at higher discharges. As flows dropped and areas became isolated, sampling was conducted to determine the degree to which stranding was occurring and which species and size classes of fish were most impacted. Visual surveys of exposed gravel bars that had previously been wetted were conducted to detect the presence of stranded fishes. Electrofishing was applied to the small pools found along the gravel bars and beneath LWD complexes, while minnow traps were applied to the pools surrounding the Highway Bridge pillars and CN Railway bridge pillars. Wherever possible, the crew sampled the same sites originally sampled in 2010. Fish carcasses on exposed gravel bars were documented as mortalities. Live fishes captured in shallow, isolated pools that were likely to dewater later were also considered to be mortalities. The estimated potential stranding rate (#fish/m^2) was calculated using the observed and potential mortalities found at the site. Fish caught in areas that were unlikely to dewater were not included in the calculation of fish/m^2.

2.3 Data Analyses

Data from the water level loggers were offloaded to a data shuttle via a USB-based optical interface while in the field and were then transferred to a laptop for analysis. HOBOware Pro (Version 2.7.3) was used to download, manage, and analyze data. Compensation for barometric pressure was completed using the Barometric Compensation Assistant available in the HOBOware Pro software package.

Estimated potential stranding rate at the Begbie Site and the Highway Bridge Site was calculated in units of fish/m^2 while stranding rate within the Greenslide Creek Side Channel was calculated as catch per unit effort (CPUE; fish/hour of minnow trapping). Fish/m^2 was chosen for the Begbie and Highway Bridge sites as it best represents the density of mortalities per unit area of exposed gravel bar. Typically, baited minnow trap and electroshocking data are analysed as CPUE; however, because of the small area in which these methods were applied, our ability to confidently capture all individuals present within the sample areas was increased. Fish catches could therefore be considered absolute and expressed in units of density (fish/m^2).

Fish data within the Greenslide Creek Side Channel were calculated in units of CPUE due to the large area of the side channel and the fact that the entire area of the channel could not be effectively sampled. Fish presence within the side channel represents actual strandings rather than stranding risk, as all fish captured will expire as water recedes through the winter (Section 4-5). Consequently, as the side channel could not be fully sampled, CPUE was used as a measure of relative abundance.

2.4 Stranding Risk Analysis

Stranding risk was characterized for each site by considering a combination of three key physical factors; proximity to the dam (km), ramping rates (cm/hr.), and % of the growing season for fish (April to November – 244 days) that experiences ALR influence. A measure of estimated potential stranding rate (fish/m² or fish/hr. of minnow trapping) was collected to assess if fish strandings were in fact occurring at each site.

Proximity to the dam has the greatest implications when determining stranding risk as it determines the degree to which each site experiences changes in water levels resulting from changes in discharge. Sites which are located closer to the dam experience changes in water level more quickly and more severely than sites that are further downstream. Consequently, sites which are closer to the dam typically have a greater risk of stranding.

Ramping rates determine how quickly shoreline substrates dewater and thereby, how much time fish have to escape to refuge. Typically sites which are closer to the dam experience higher ramping rates and thus have a greater risk of stranding.

The percent of the growing season for fish that experiences ALR influence has a large effect on stranding risk of fish. Growing season for fish was classified as from April to November – 244 days, based upon months in which the average water temperatures in the Middle Columbia River are warm enough to support fish growth (≥ 5 degrees Celsius). Since the juvenile stage of most fish species inhabit shoreline habitat through the growing season, while adult life stages generally inhabit deeper water, changes in water levels resulting from changes in discharge can result in juvenile strandings. When the site is influenced by the ALR, the resulting changes in water levels are reduced, thus decreasing stranding risk. Typically, sites which experience shorter periods of ALR influence have a greater risk of stranding.

After considering the combination and importance of these key factors, a qualitative measure of risk (low, moderate or high) was then determined for each site.

2.5 Reporting

Fish species codes used in this report and in the associated database follow those outlined in the *Fish Collection Methods and Standards* (BC Ministry of Environment, Lands and Parks, 1997) and are summarized in Table 2.5-1.

Table 2.5-1. Fish species typically captured in the Middle Columbia River

Common Name	Code	Family	Scientific Name
Bull Trout	BT	Salmonidae	*Salvelinus confluentus*
Brook Trout	EB	Salmonidae	*Salvelinus fontinalis*
Burbot	BB	Gadidae	*Lota lota*
Common Carp	CP	Cyprinidae	*Cyprinus carpio*
Kokanee	KO	Salmonidae	*Oncorhynchus nerka*
Largescale Sucker	CSU	Catostomidae	*Catostomus macrocheilus*
Longnose Sucker	LSU	Catostomidae	*Catostomus catostomus*
Mountain Whitefish	**MW**	**Salmonidae**	***Prosopium williamsoni***
Northern Pikeminnow	NSC	Cyprinidae	*Ptychocheilus oregonensis*
Peamouth Chub	**PCC**	**Cyprinidae**	***Mylocheilus caurinus***
Prickly Sculpin	CAS	Cottidae	*Cottus asper*
Rainbow Trout	RB	Salmonidae	*Oncorhynchus mykiss*
Redside Shiner	**RSC**	**Cyprinidae**	***Richardsonius balteatus***
Slimy Sculpin	CCG	Cottidae	*Cottus cognatus*
Tench	TC	Cyprinidae	*Tinca tinca*
Yellow Perch	YP	Percidae	*Perca flavescens*

Note:

Bolded entries represent species found to be at greater risk of stranding.

3.0 Results

3.1 Reconnaissance Survey

The 2013 reconnaissance survey showed that, in general, the results of the 2009 assessment (Appendix 3) were representative of all three years following, and that conditions at the identified sample sites were still appropriate to assess stranding (see Section 2.2.1 for assessment criteria). No new side channel sites were identified, and there were no observations of new areas being flooded in either of the two years following implementation of the Rev 5 flow regime.

3.1.1 Greenslide Creek Side Channel

The 2013 survey of the Greenslide Creek Side Channel recorded similar conditions to those observed in 2009–2011 in that the channel was dewatered in May, with rooted vegetation present throughout the channel, and showed no signs of scour or recent flow. As the ALR elevation increased in the spring, the channel became wetted from its downstream end and was fully inundated by the end of June. Once wetted, cover was limited to that provided by flooded vegetation, with limited habitat complexity. By September 2, due to the receding ALR, the channel had become fully isolated. Representative photos are provided in Appendix 1 (Photos 1 to 10). Due to the extent of ALR influence and distance from the Revelstoke Dam, stranding risk as a result of the Revelstoke Dam operations is considered to be low.

3.1.2 Begbie Site

Though the timing of the 2013 survey (October) differed from that of 2011 (June), the survey observed that 2013 conditions were similar to those of the previous years' surveys. The two large pools containing LWD increase the habitat complexity of the site compared to other sites assessed during the reconnaissance survey. Representative photos of the site are provided in Appendix 1 (Photos 11 to 16). Stranding risk at the site was considered to be high due to the size of the area that can dewater, the frequency of depressions in which fish can become trapped, and its habitat complexity. Sampling could not occur in June 2013 due to inundation from the ALR.

3.1.3 Highway Bridge Site

The 2013 survey of the Highway Bridge site observed conditions very similar to those in 2010 and 2011 in that the area consists of a shallow, sloping gravel bar with multiple depressions that become isolated with decreasing discharge. Woody debris present at the downstream end of the site, and the bridge pilings (Highway 1, CP Rail, and single lane bridge) all provide cover for fish. The area can be divided into three sections based on habitat characteristics (Figure 2.2-2):

- *Area #1*, located between the Highway bridge and the CP Rail bridge, is characterized by a low-gradient gravel shoreline (<5 per cent) with several depressions that become isolated and dewatered as flows drop. Cover is limited; however, the risk of stranding is considered to be high due to the size of the area that can potentially dewater and the number of depressions in which fishes can become trapped. Representative photos can be found in Appendix 1 (Photos 17 to 22).

- *Area #2*, located between the CP Rail bridge and the single lane bridge, is characterized by a steeper shoreline (5 to 10 per cent) than that of Area #1 and a substrate dominated by cobble and gravel. There are fewer pools than in Area #1 but interstitial spaces in the larger substrate could trap smaller fishes as water levels recede. Stranding risk is considered to be moderate due to steeper slopes and fewer depressions than in Area 1.
- *Area #3* is located downstream of the single lane bridge, and the shoreline is dominated by LWD. The bank angle is comparable to that of Area #2, and substrates are predominantly gravel and fines. The presence of LWD cover results in the risk of stranding being classified as moderate in this area. Representative photos can be found in Appendix 1 (Photos 23 to 25).

3.2 Water Level Monitoring

3.2.1 Greenslide Creek Side Channel

Water level data for 2013 were not collected at the Greenslide Creek Side Channel however, data from 2010 and 2011 (Figure 3.2-1 and Figure 3.2-2) show that water levels remain relatively stable, even with changes in discharge from the dam. Water level data in 2013 could not be collected because the channel was inundated by the ALR during the spring sample event, and had fully isolated from the reservoir by the fall sample events.

The 2010 water levels (depth) within the Greenslide Creek Side Channel remained relatively stable, experiencing only slight variations of approximately 20 cm or less, while the ten-minute mean discharge from the Revelstoke Dam varies greatly, with fluctuations between a high of 1,044.4 m^3/s to a low of 18.6 m^3/s (Figure 3.2-1).

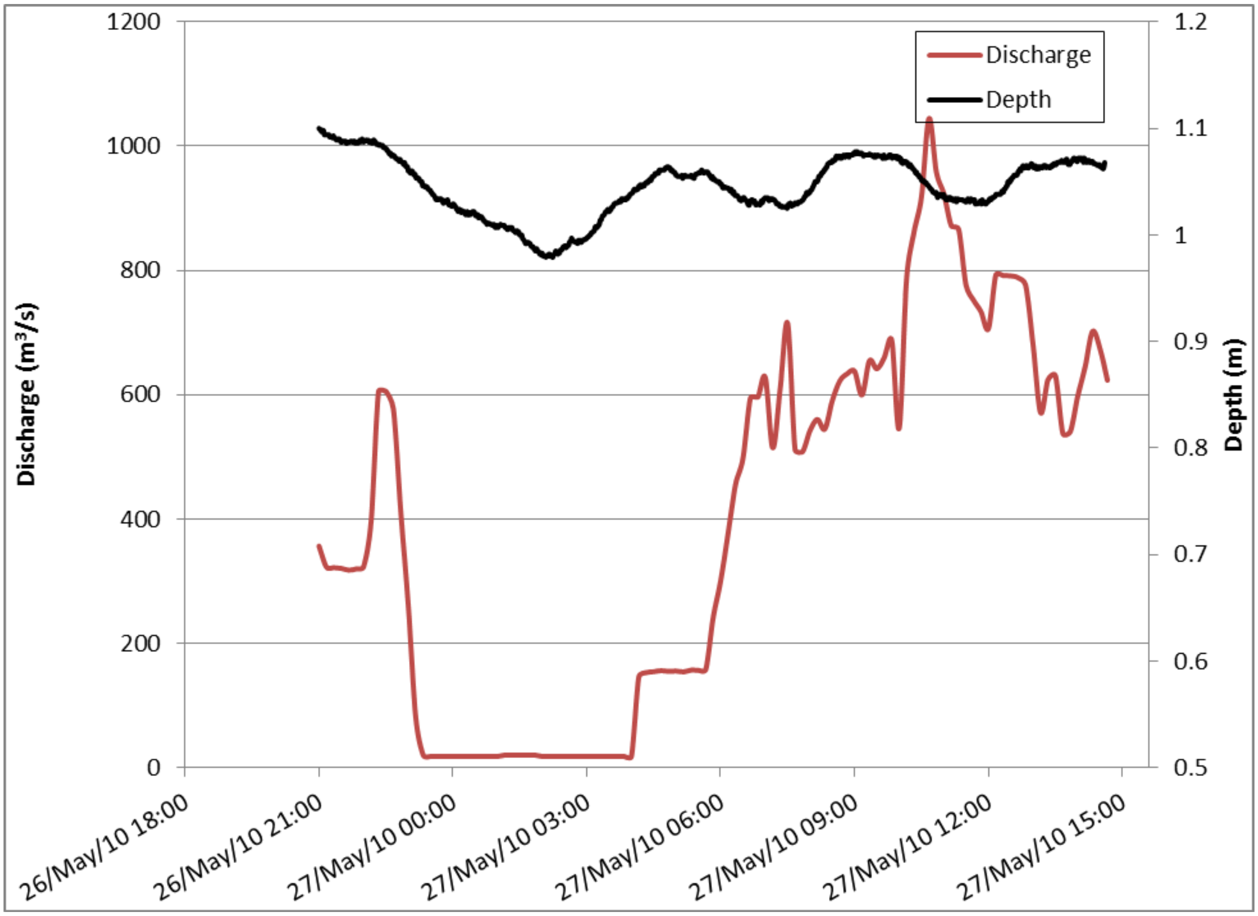

Figure 3.2-1. Ten-minute mean discharge from the Revelstoke Dam and depth at the Greenslide Creek Side Channel for May 26–27, 2010.

The 2011 water levels within the Greenslide Creek Side Channel remained relatively stable, experiencing only slight variations of approximately 10 cm or less, while the ten-minute mean discharge from the Revelstoke Dam varies greatly, with fluctuations between a high of 1,234 m^3/s to a low of 9.3 m^3/s (Figure 3.2-2).

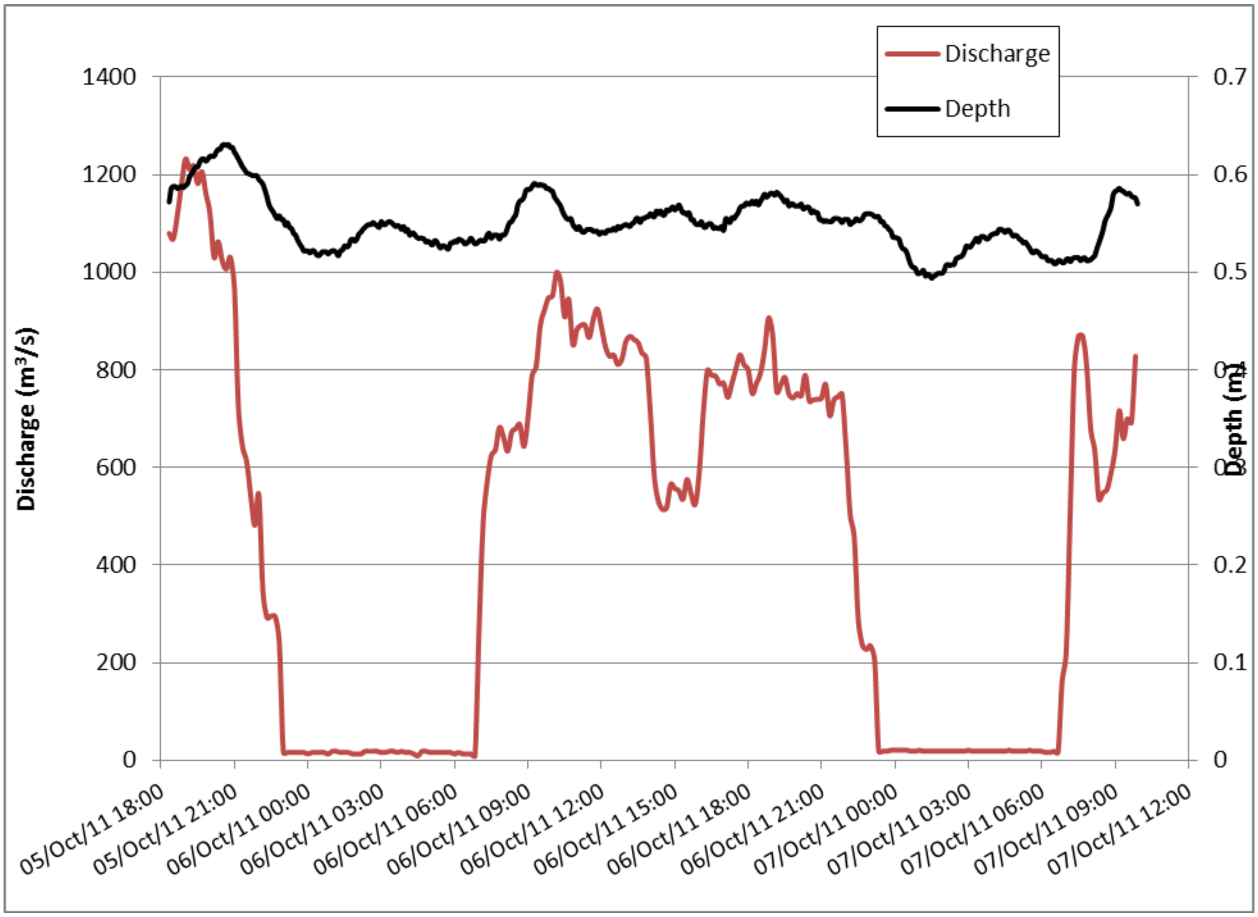

Figure 3.2-2 Ten-minute mean discharge from the Revelstoke Dam and water depth at the Greenslide Creek Side Channel (October 5 to 7, 2011).

3.2.2 Begbie Site

In general, discharge during the sampling period at the Begbie site remained relatively low, with the minimum discharge (153.3 m^3/s) occurring on October 17 and October 18 while the maximum (389.3 m^3/s) occurred on October 17. Water depths at the site ranged from a maximum of 0.93 m on October 16 to a low of 0.47 m on October 18, a variation of 0.46 m. The maximum dewatering rate during the period was 12.6 cm/h. Due to high ALR levels inundating the Begbie site in June 2013, spring sampling could not occur. Instead, sampling took place on October 16 to 18, 2013. Figure 3.2-3 shows 10-minute mean discharge from the Revelstoke Dam and recorded water levels at the Begbie Site for October 16 to 18, 2013.

By comparison, in June 2011 (Figure 3.2-4), the minimum discharge was 22.8 m^3/s while the maximum was 399.4 m^3/s. Water depths at the site ranged from 1.08 m to 0.81 m, a variation of 0.27 m, and the maximum dewatering rate during the period was 7.9 cm/h (Sykes and Liebe, 2012*a*). During the 2009 surveys at the same site, daily maximum discharges typically exceeded 1,200 m^3/s, while daily minimums were typically close to 0 m^3/s. The maximum dewatering rate recorded at the site was 18 cm/h (Sykes and Liebe, 2010*a*). Comparison of the discharge data and water level data from 2009 and 2013 suggests a lag time of approximately three hours between dam discharge and observed changes in water level 12 km downstream at the Begbie site.

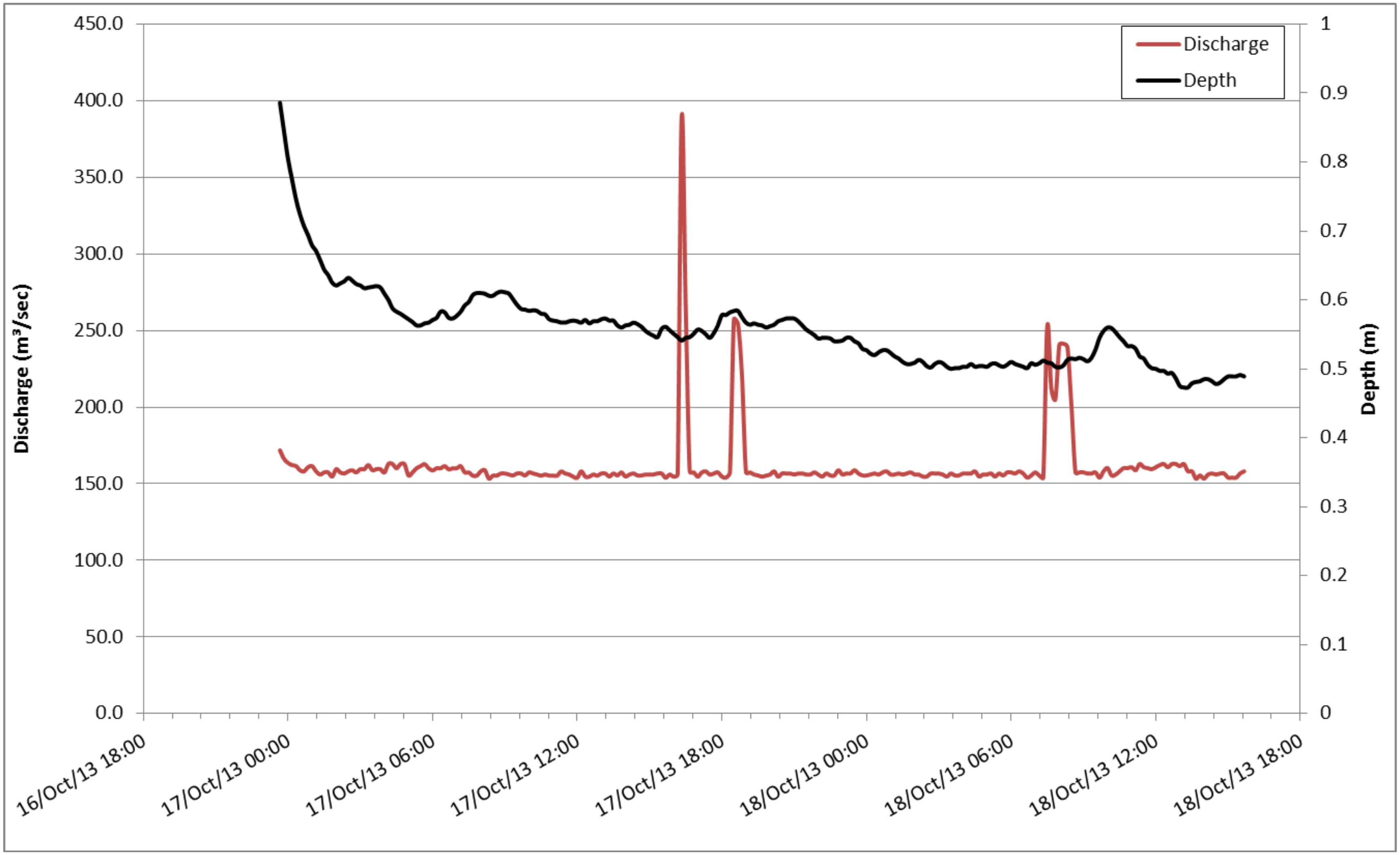

Figure 3.2-3. Ten-minute mean discharge from the Revelstoke Dam and water depth at the Begbie site during field assessments (October 16 to 18, 2013)

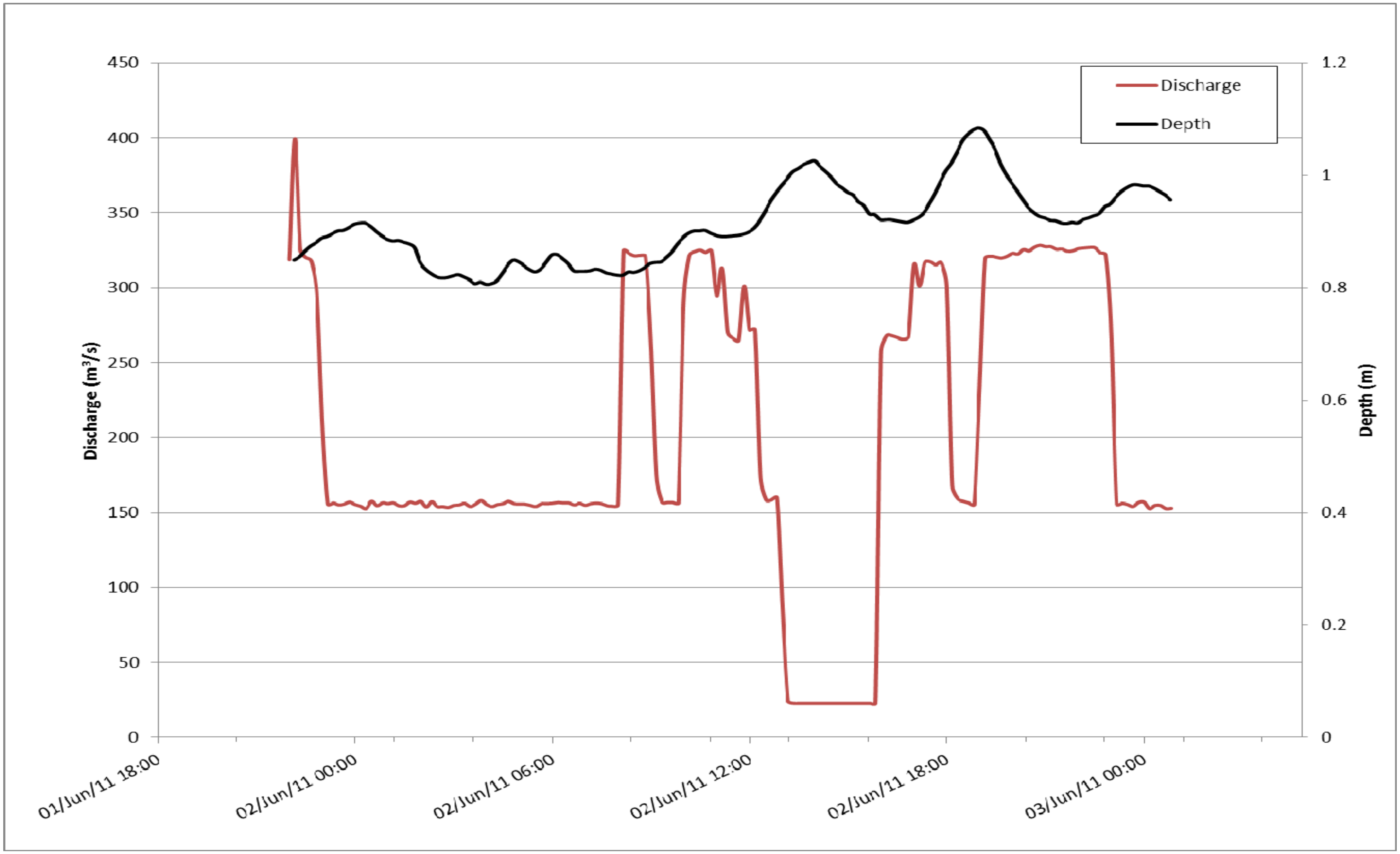

Figure 3.2-4. Ten-minute mean discharge from the Revelstoke Dam and water levels at the Begbie Creek site during field assessments (June 1 to 3, 2011)

3.2.3 Highway Bridge Site

In June 2013, the discharge at the Highway Bridge site ranged from a maximum of 1,252.3 m^3/s on June 6 (3:40 p.m.) to a low of 89.9 m^3/s on June 6 (9:40 a.m.). Water depths at the site ranged from a high of 2.05 m on June 6 at to a low of 0.64 m on June, a variation of 1.41 m. The maximum dewatering rate during the sampling period, 55.4 cm/h, occurred at midnight on June 5, followed immediately by 39.7 cm/h between midnight and 1:00 a.m. Another event of 54.2 cm/h occurred at 8:00 p.m. on June 5. Figure 3.2-5 shows 10-minute mean discharge from the Revelstoke Dam and recorded water levels at the Highway Bridge site for June 4 to 6, 2013.

In September 2013 the discharge at the Highway Bridge site ranged from a maximum of 1,151.9 m^3/s on Sept 24 (7:20 a.m.) to a low of 253.2 m^3/s on Sept 25 between midnight and 1:00 a.m. Water depths ranged from a high of 2.8 m on Sept 24 to a low of 0.57 m on Sept 23, a variation on 2.23. The maximum dewatering rate during the sample period, 47.9 cm/h, occurred at 10:00 a.m. on Sept 24. Figure 3.2-6 shows 10-minute mean discharge from the Revelstoke Dam and recorded water levels at the Highway Bridge site for September 23 to 25, 2013.

Figure 3.2-7 outlines the 10-minute mean discharge from the Revelstoke Dam at the Highway Bridge site from September 19 to October 19, 2013. Water depth is not displayed, as water level loggers were not installed for the entire month-long period. However, the discharge trend in 2013 (Figure 3.2-7) is comparable to that of 2011 when loggers were installed (Figure 3.2-8), with maximum discharge of approximately 1,800 m^3/s and the average minimum discharge of approximately 230 m^3/s. Much like the short-term records in 2013 (Figure 3.2-5 and Figure 3.2-6); water level through the whole month-long period appears to be strongly related to discharge.

By comparison, in October 2011 (Appendix 4, Figure A4-2), the discharge ranged from a maximum of 1,231 m^3/s to a low of 9.3 m^3/s during the sample period (Table 3.2-1). Water depths at the site ranged from a high of 2.5 m to a low of approximately 0.75 m, a variance of 1.95 m. The maximum dewatering rate during the sampling period was 27 cm/h (Sykes and Liebe, 2012*a*). In October 2010 (Appendix 4, Figure A4-3) the discharge ranged from a high of 1,193 m^3/s to a low of 20.8 m^3/s during the sampling period. Water depths ranged from a high of 1.8 m to a low of approximately 0 m when the transducer presumably became dewatered. The maximum dewatering rate was 132.5 cm/h (Sykes and Liebe, 2011*a*). Comparison of the discharge data and water level data from 2010, 2011, and 2013 suggests that water level at the Highway Bridge site is strongly related to discharge rates from the Revelstoke Dam even in years of ALR influence. Comparison of the data also shows a lag time of approximately 20 to 30 minutes between dam discharge and observed changes in water level 6 km downstream at the Highway Bridge site.

Table 3.2-1. Maximum and minimum discharge, maximum and minimum water depth, and maximum dewatering rate at the Highway Bridge site for 2010, 2011, and 2013

Sample Season	Rev 5 status	Max. Discharge (m^3/s)	Min. Discharge (m^3/s)	Max. Depth (m)	Min. Depth (m)	Max. Dewatering Rate (cm/h)
June 2013	Post-Rev 5	1,252.3	89.9	2.05	0.64	55.4
Sept 2013	Post-Rev 5	1,151.9	253.2	2.80	0.57	47.9
Oct 2011	Pre-Rev 5	1,231.0	9.3	2.50	0.75	27.0
Oct 2010	Pre-Rev 5	1,193.0	20.8	1.80	0	132.5

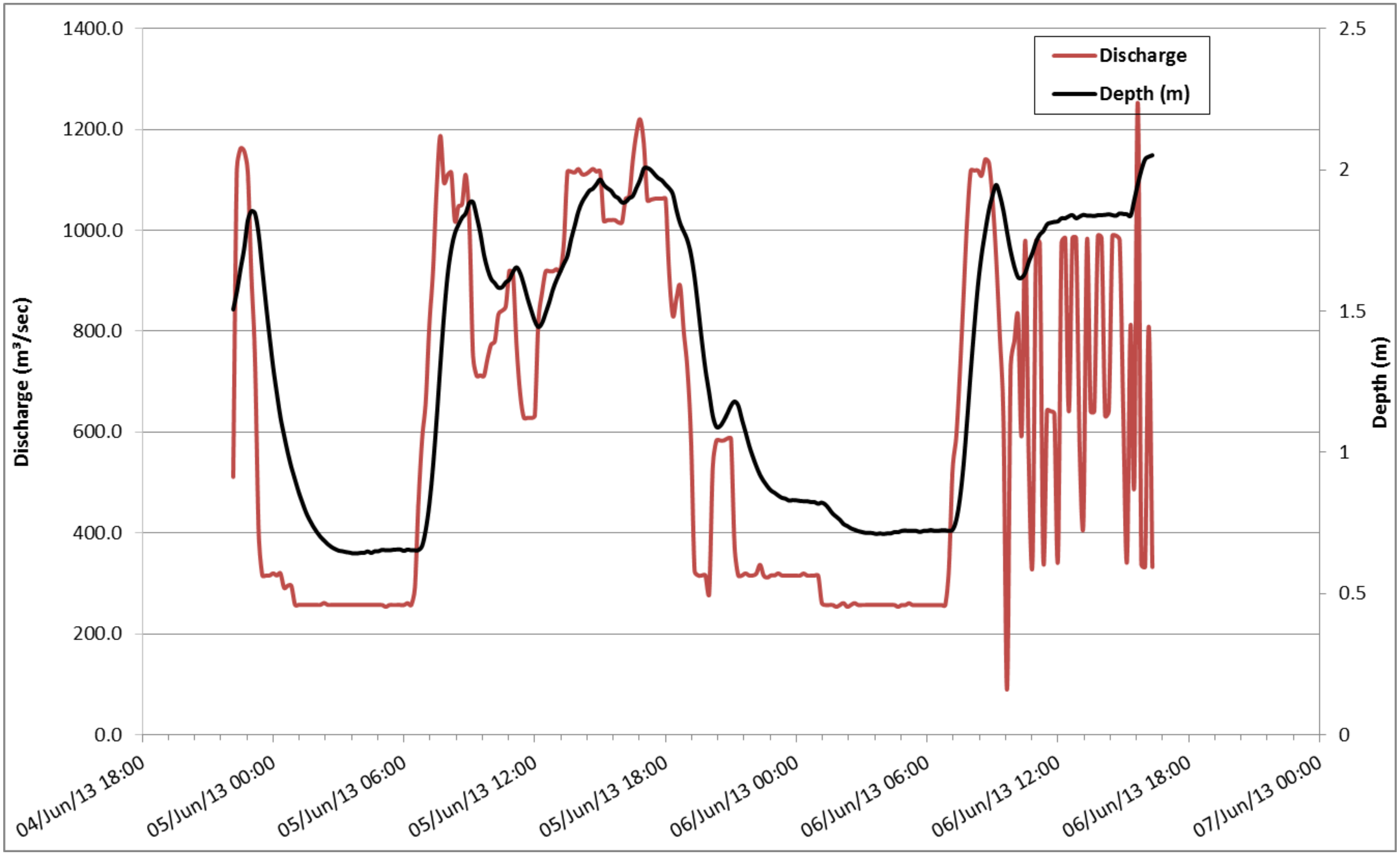

Figure 3.2-5 Ten-minute mean discharge from the Revelstoke Dam and water depth at the Highway Bridge site during field assessments (June 4 to 6, 2013)

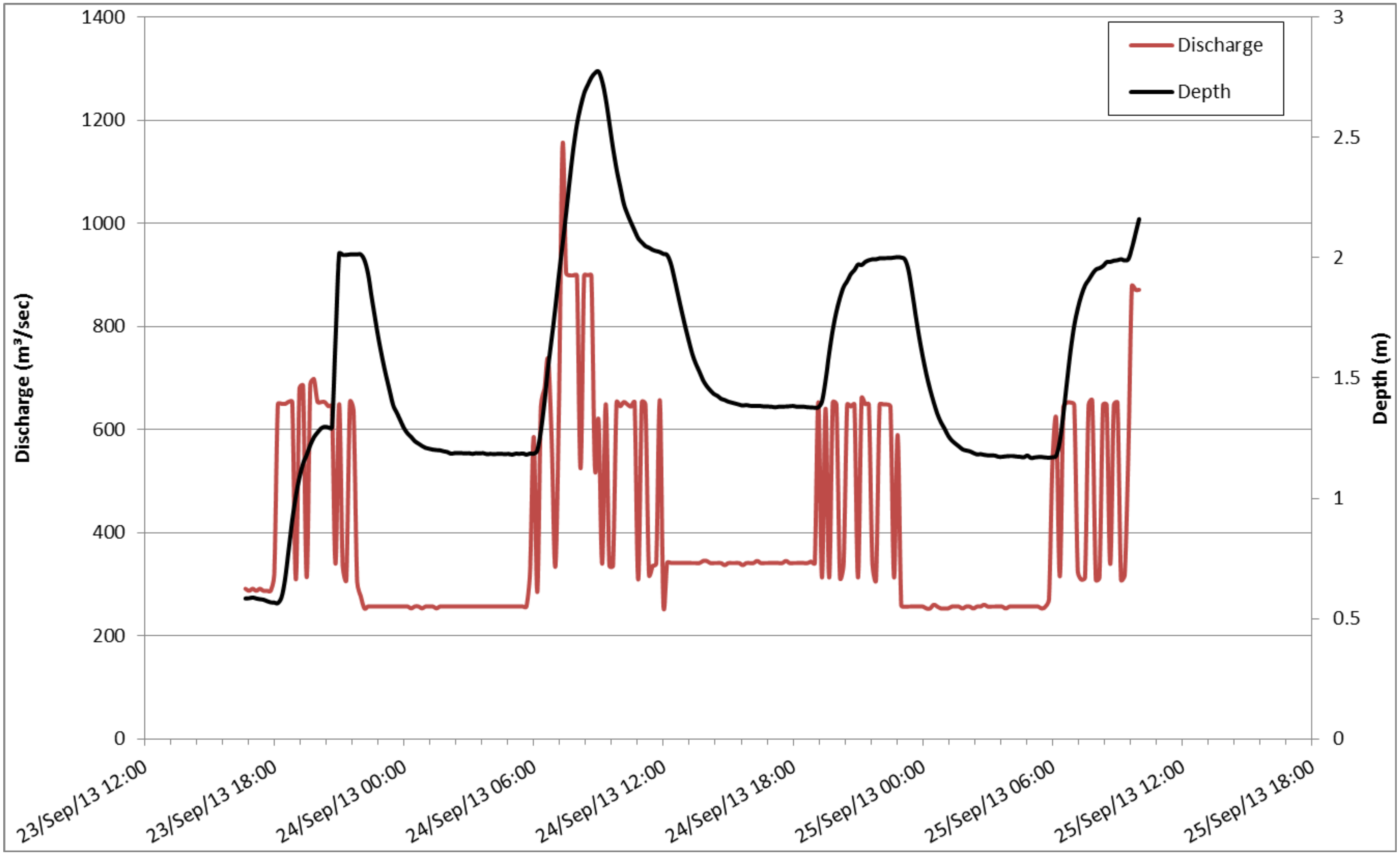

Figure 3.2-6 Ten-minute mean discharge from the Revelstoke Dam and water levels at the Highway Bridge site during field assessments (Sept. 23 to 25, 2013)

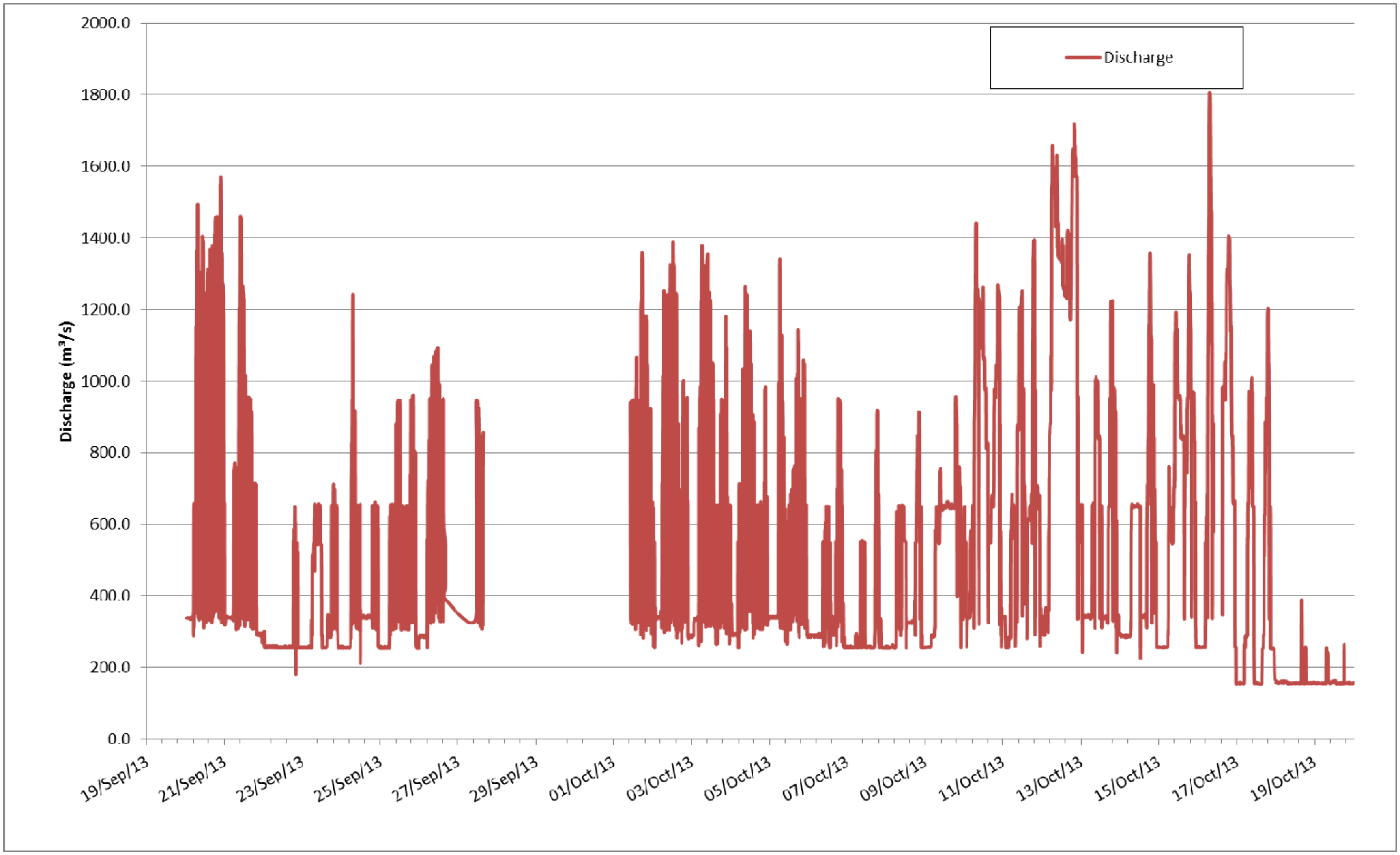

Figure 3.2-7. Ten-minute mean discharge from the Revelstoke Dam at the Highway Bridge site during field assessments (Sept 19 to Oct 19, 2013)

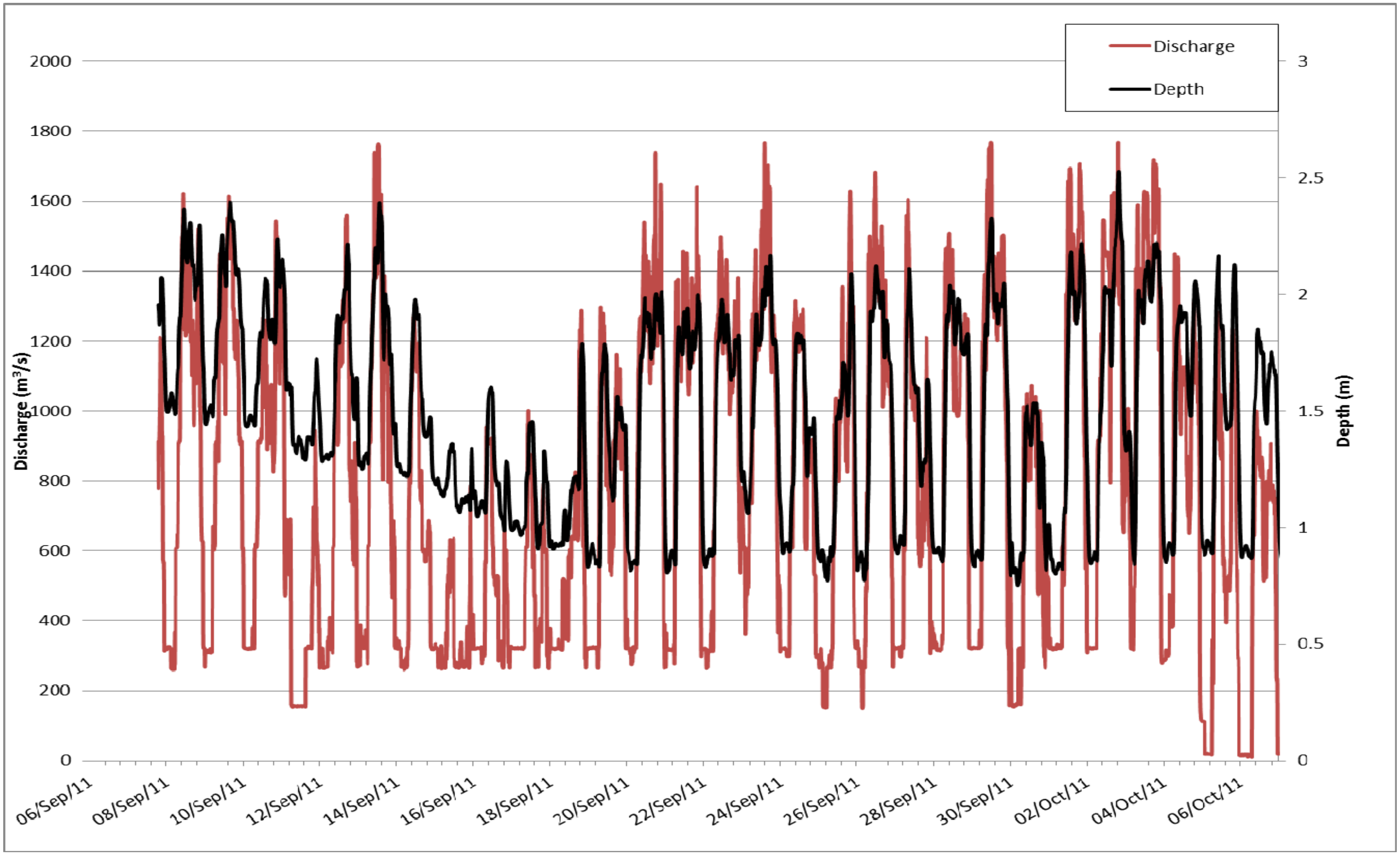

Figure 3.2-8. Ten-minute mean discharge from the Revelstoke Dam and water depth at the Highway Bridge site during field assessments (Sept 6 to Oct 6, 2011

3.3 Influence of the Arrow Lakes Reservoir

The ALR daily mean elevation for 2009-2011 and 2013 was compared with the approximate elevations of the Greenslide Creek Side Channel (433 m; Figure 3.3-1), Begbie Site (434 m; Figure 3.3-2), and the Highway Bridge Site (435 m; Figure 3.3-3)[2] to determine when ALR levels most likely influenced each site in 2013. The risk of fish stranding was considered to be lower during the period of ALR inundation since the changes in water levels were both slower and less extreme. For each of the following figures, data from 2009 to 2011 along with 2013 are presented. It should be noted that in 2009, 2010 and 2013, the ALR elevation data was not available for the entire calendar year. In 2009, the data set runs until December 03, in 2010 until October 31 and in 2013 until December 10.

In 2013 the Greenslide Creek Side Channel (Figure 3.3-1) was influenced by the ALR on January 1 and from May 17 and remained inundated to September 1. In 2011, the site was inundated from January 1 to February 14 and from May 29 to December 31, in 2010 from May 5 to October 31, and in 2009 from January 1-26 and from June 1 until November 7. Therefore, stranding risk at the site was at least partially mitigated by the ALR for a total of 109 days (30 % of the year) in 2013, a total of 262 days (72%) in 2011, at least 180 days (49 %) in 2010, and for a total of 186 days in 2009 (50 %).

Since the ALR elevation data is not available beyond October 31 in 2010, the specific date when ALR levels receded below the elevation of the Greenslide Creek Side Channel cannot be determined. To be conservative, October 31, 2010 is considered the date when ALR levels receded below the sites elevation, thus the Greenslide Creek Side Channel remained inundated for an average of 184 days of the year (50 % of the year).

[2] In 2010 the reported elevation of the Highway Bridge Site was 438 m; however, this was corrected in 2011 based on discussion with Karen Bray, BC Hydro.

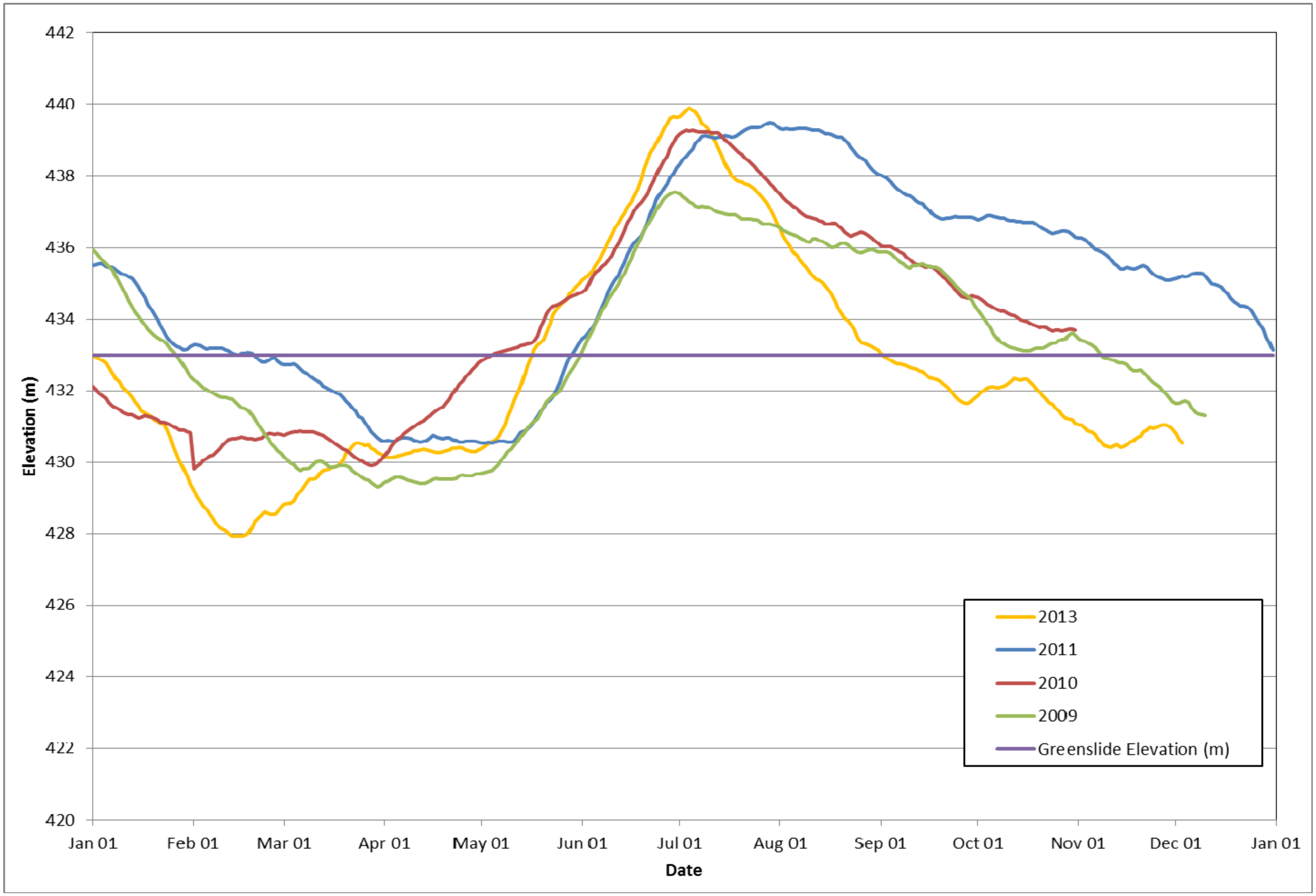

Figure 3.3-1 Arrow Lakes reservoir elevation for 2009-2011 and 2013 compared to the approximate elevation of the Greenslide Creek Side Channel. During periods when reservoir elevation is above that of the site, the stranding risk at the site is reduced.

In 2013 the Begbie site (Figure 3.3-2) began to be influenced by the ALR on approximately May 23 and remained inundated to August 21. In 2011, the site was inundated from January 1-20 and from June 6 to December 25, in 2010 from May 21 to October 13, and in 2009 from June 6 to October 3. Therefore, stranding risk at the site was at least partially mitigated by the ALR for a total of 91 days (25 % of the year) in 2013, 223 days (61 %) in 2011, 146 days (40 %) in 2010, and only 120 days (33 %) in 2009.

The total number of days that stranding risk is mitigated in 2010, however, is a conservative estimate. When comparing the ALR elevation of Oct 31, 2010 to that of Jan 01, 2011, there is a difference of approximately 2 m in elevation. As the 2010 data does not extend beyond Oct 31, the date when ALR elevation rises above the Begbie Site elevation cannot be determined, thus the ALR elevation is assumed to remain below the Begbie Sites elevation for the remainder of the year.

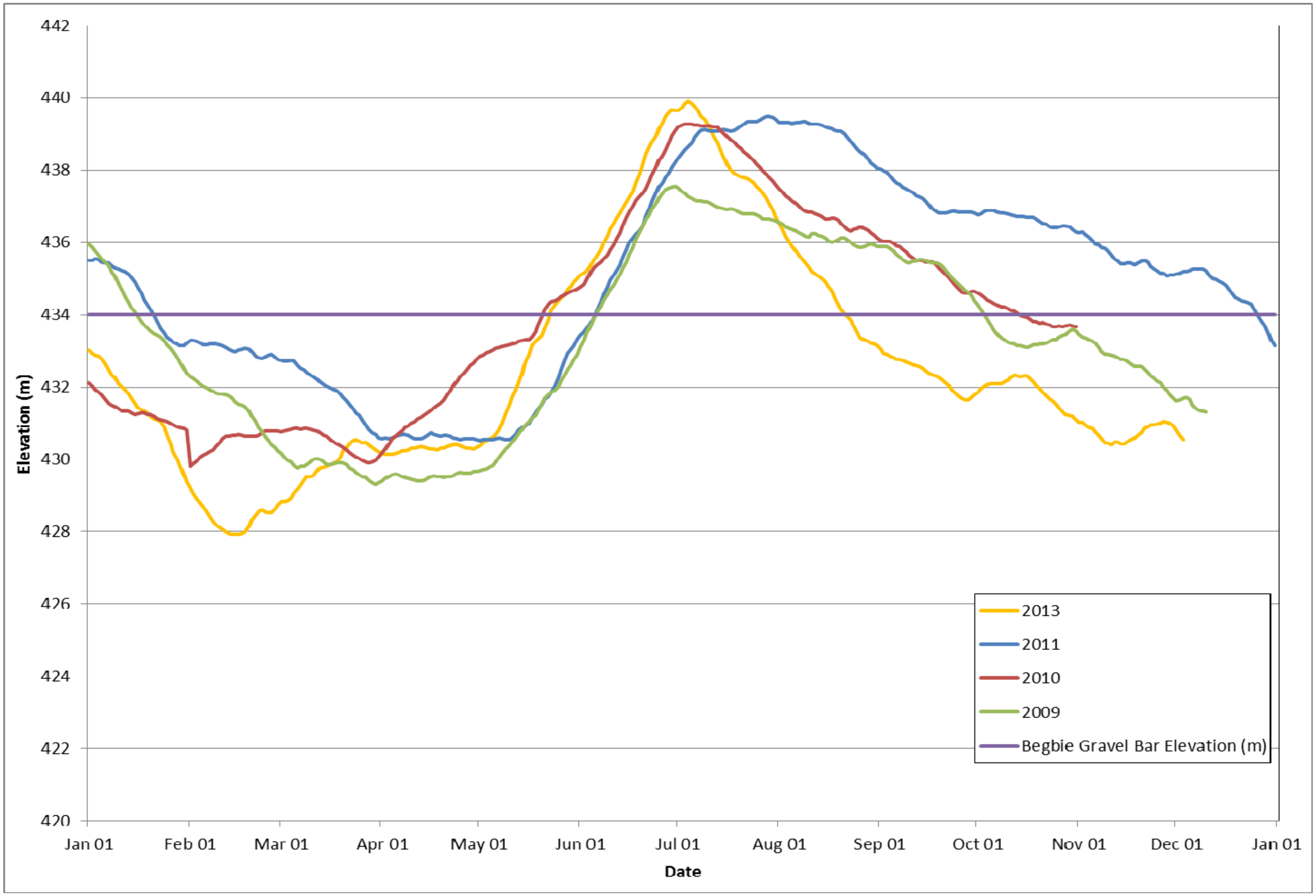

Figure 3.3-2. Arrow Lakes reservoir elevation for 2009-2011 and 2013 compared to the approximate elevation of the Begbie side channel. During periods when reservoir elevation is above that of the site, the stranding risk at the site is reduced.

In 2013, the Highway Bridge site (Figure 3.3-3) began to be influenced by the ALR on approximately June 1 and remained inundated to August 14. In 2011, the site was inundated from January 1-15 and from June 11 to December 11, in 2010 from June 4 to September 22, and in 2009 from January 1-9 and from June 13 to September 23. Therefore, stranding risk at the site was at least partially mitigated by the ALR for a total of 75 days (21 % of the year) in 2013, 98 days (27 %) in 2011, 111 days (30 %) in 2010, and 112 days (31%) in 2009.

The total number of days that stranding risk is mitigated in 2010, however, is a conservative estimate. When comparing the ALR elevation of Oct 31, 2010 to that of Jan 01, 2011, there is a difference of approximately 2 m in elevation. As the 2010 data does not extend beyond Oct 31, the date when ALR elevation rises above the Highway Bridge Site elevation cannot be determined, thus the ALR elevation is assumed to remain below the elevation of the Highway Bridge Site for the remainder of the year.

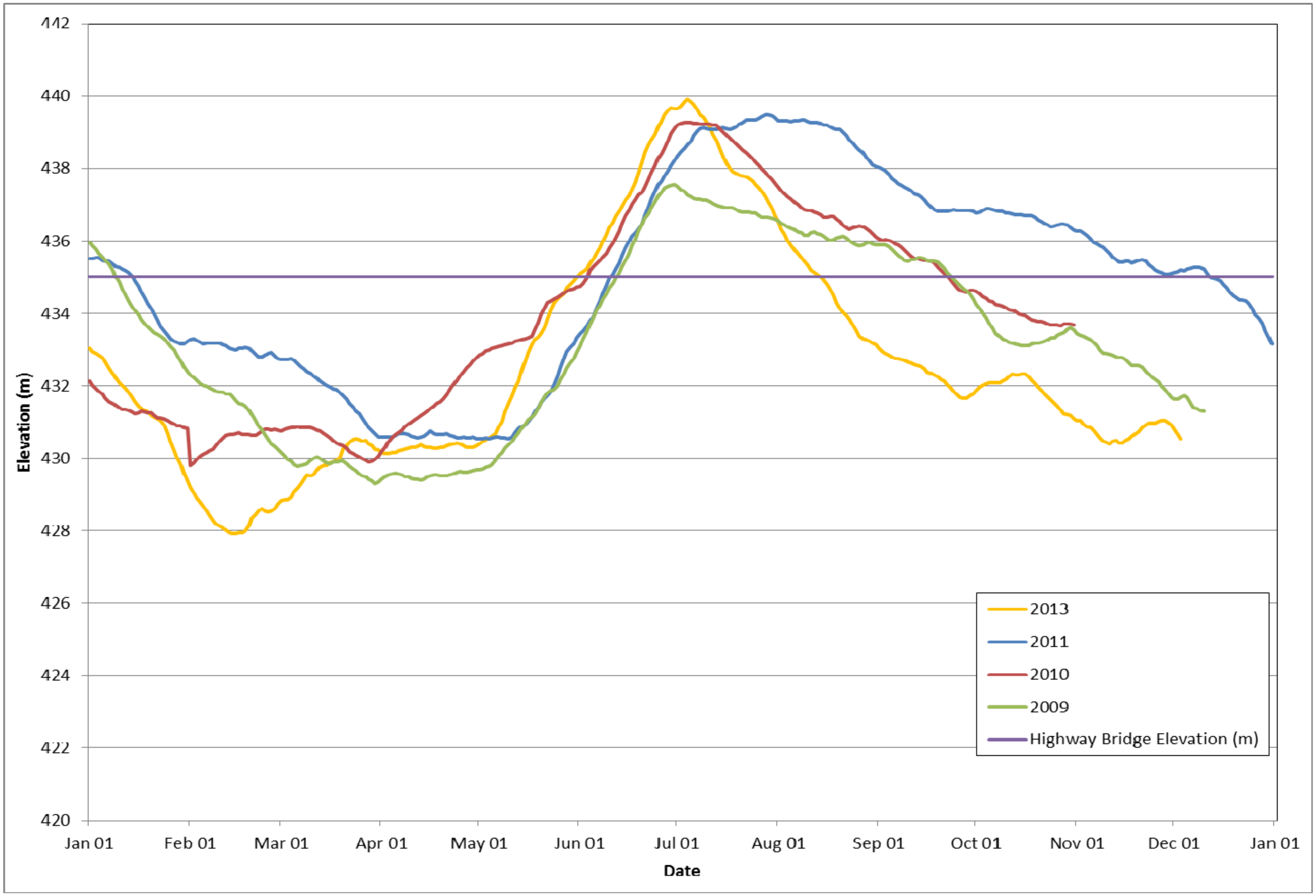

Figure 3.3-3. Arrow Lakes reservoir elevation for 2009-2011 and 2013 compared to the approximate elevation of the Highway Bridge site. During periods when reservoir elevation is above that of the site, the stranding risk at the site is reduced.

3.4 Fish Sampling

3.4.1 Background Fisheries Information

A substantial data set of fisheries information has been collected for the Middle Columbia River. The most recent and applicable data (due to the focus of the study on juvenile fishes) come from the *Middle Columbia River Juvenile Fish Use Study* (CLBMON-17, 2009 to present). Approximately 60 sites along the Middle Columbia River margins are sampled by boat electrofishing at night in spring, summer, and fall as part of that study. Although 16 juvenile fish species are typically captured in the Middle Columbia River, they vary by season and reach. Prickly Sculpin, Redside Shiner, Mountain Whitefish, and Kokanee are the species most commonly captured (Sykes and Liebe, 2009, 2010*b*, 2011*b, 2012b*).

Three CLBMON-17 sample sites overlap with the fish stranding sites, specifically sites 27 and 28, which both overlap with the Highway bridge fish stranding site and site 43 which overlaps with the Begbie fish stranding site. Table 3.4-1 outlines the fish capture at each CLBMON-17 sample for each year corresponding to the fish stranding sites.

Site 27 of CLBMON-17 is located between the Highway Bridge and the CP Rail Bridge (Area #1; Figure 2.2-2). A review of the CLBMON-17 data from 2009-2011 and 2013 (Table 3.4-1) showed that a total of 160 fishes of 7 species were captured, over half of which were juveniles (69%). Mountain Whitefish and Prickly Sculpin dominated the catch at the site; other species encountered were Kokanee, Bull Trout, Burbot, and Redside Shiner.

Site 28 of CLBMON-17 is located downstream of the single lane bridge (Area #3; Figure 2.2-2). A review of the CLBMON-17 data from 2009-2011 and 2013 (Table 3.4-1) showed that a total of 153 fishes of 10 species were captured. Only 33% of the catch comprised juveniles; however, the data are slightly skewed by the presence of adult Kokanee (representing 44% of the catch), which spawn in the area in the fall. Coarse fish species captured included Prickly Sculpin, Redside Shiner, Yellow Perch, and Largescale Sucker, while sport fish encountered were Bull Trout, Mountain Whitefish, Rainbow Trout, Brook Trout, and Burbot.

Site 43 of CLBMON-17 is in the same general area as the Begbie Site. A review of the CLBMON-17 data from 2009-2011 and 2013 (Table 3.4-1) showed that 321 fishes of 9 different species were caught at site 43 in the vicinity of the Begbie Site, the majority of which were juveniles (81%). Peamouth Chub was the most commonly encountered species. Other species frequently encountered included Mountain Whitefish, Prickly Sculpin, and Redside Shiner. Additional sport fish species encountered included Kokanee, Bull Trout, and Rainbow Trout.

Table 3.4-1. Fishes captured by boat electrofishing as part of CLBMON-17 (2008–2011 and 2013) in the vicinity of the 2013 fish stranding sites

Year	BB (J/A)	BT (J/A)	CAS (J/A)	KO (J/A)	MW (J/A)	EB (J/A)	RB (J/A)	RSC (J/A)	YP (J/A)	PCC (J/A)	CSU (J/A)	COTT (J/A)	Total (J/A)
	CLBMON-17 Site # 43 (Begbie)												
2009-S	-	-	-	-	-	-	-	-	-	-	-	3/0	3/0
2009-F	-	-	1/14	1/0	24/0	-	-	2/0	8/0	8/0	-	2/0	46/14
2010-S	-	-	2/6	-	-	-	3/0	2/0	-	-	-	-	7/6
2010-F	-	-	1/10	2/0	50/0	-	-	0/1	-	-	-	4/11	57/22
2011-S	-	-	1/7	-	1/0	-	-	0/5	-	5/0	-	0/3	7/15
2011-F	-	-	0/3	0/7	2/0	-	-	-	-	-	0/1	-	2/11
2013-S	-	-	2/2	-	1/0	-	1/0	1/0	-	1/0	1/0	-	7/2
2013-F		5/0	2/2	1/1	-	-	-	7/2	-	125/0	-	0/3	140/11
	CLBMON-17 Site # 27 (Highway Area #1)												
2009-S	-	-	-	-	-	-	-	-	-	-	-	-	-
2009-F	1/0	2/0	3/20	0/4	53/2	-	-	-	-	-	-	-	59/26
2010-S	-	1/0	0/2	2/1	16/0	-	1/0	-	-	-	-	-	20/3
2010-F	-	1/0	0/13	3/2	9/0	-	-	-	-	-	-	10/45	23/60
2011-S	-	-	-	-	-	-	-	-	-	-	-	-	NFC
2011-F	-	-	1/4	2/0	7/0	-	-	-	-	-	-	-	10/4
2013-S	-	-	-	-	1/0	-	-	-	-	-	-	-	1/0
2013-F	-	1/0	0/1	-	6/0	-	-	1/0	-	-	-	-	8/1
	CLBMON-17 Site # 28 (Highway Area #3)												
2009-S	-	1/2	-	0/1	3/1	1/0	1/1	-	-	-	-	-	6/5
2009-F	1/0	0/1	0/1	2/26	4/0	1/0	1/0	-	1/0	-	-	-	10/28
2010-S	1/0	5/0	1/1	-	2/0	-	1/0	-	-	-	-	-	10/1
2010-F	-	1/0	0/3	0/32	-	0/1	-	0/1	0/1	-	-	2/7	3/45
2011-S	-	3/0	0/2	-	-	-	2/0	-	-	-	-	-	5/2
2011-F	-	-	1/13	10/0	-	-	4/0	-	-	-	-	6/0	21/13
2013-S	-	2/0	0/3	1/0	-	-	-	-	-	-	-	-	3/3
2013-F	-	1/0	-	0/9	-	0/1	-	-	-	-	0/2	-	1/12

Notes:
J = juvenile
A= adult
2009-S = Spring
2009-F = Fall
Refer to Table 2.5-1 for species codes and to Figure 2.2-1 & Figure 2.2-2 for approximate location of sites.
COTT: Visual observation of sculpins; unable to identify to species.

3.4.2 Greenslide Creek Side Channel

In September 2013, sampling resulted in the capture of 44 fishes within the Greenslide Creek Side Channel, resulting in a CPUE of 0.262 fish/hour of minnow trapping (Table 3.4-2). All fishes were coarse fish, (24 Largescale Sucker and 20 Prickly Sculpin) and all were less than 100 mm in length and considered juveniles. On October 16, 2013, one juvenile Prickly Sculpin was captured, resulting in a CPUE of 0.012 fish/hour of minnow trapping. All fishes captured within the Greenslide Creek Side Channel are considered mortalities as the side channel remains isolated from the declining ALR throughout the winter and dewaters completely.

Table 3.4-2. Total catch, number of species, and catch per unit effort (CPUE) at the Greenslide Side Channel in each year of survey

Year	Sample Season	Total catch	Number of Species	CPUE
2013	May	NS	-	-
	September	44	2	0.262
	October	1	1	0.012
2011	May	NS	-	-
	October	NS	-	-
2010	May	NS	-	-
	October	1	1	0.008
2009	May	NS	-	-
	October	119	6	0.567

Note: (NS = not sampled)

Sampling could not be completed in 2011 due to prolonged high ALR elevation; the side channel was inundated before the spring sample trip and remained as such until after the fall sampling trip. In October 2010, 1 juvenile Tench was captured over one night and 129 minnow trap hours, resulting in a CPUE of 0.008, while in 2009 119 fishes of 6 species were captured over two nights and 210 minnow trap hours, resulting in a CPUE of 0.567. Of the total catch in 2009, 118 fishes, representing 99%, were coarse fish (111 Common Carp, 3 Prickly Sculpin, 2 Largescale Sucker, 1 Tench, and 1 Peamouth) while the single sport fish (Rainbow Trout) represented 1% of the total catch.

3.4.3 Begbie Site

Sampling at the Begbie site in October 2013, produced two Redside Shiner mortalities, resulting in an estimated potential stranding rate of 0.001 fish/m^2. Sampling also resulted in capture or observation of 6 fishes of 4 different species that were considered not at risk of perishing: 3 fish, representing half of the total catch, were coarse fish (1 Largescale Sucker, 1 Prickly Sculpin, and 1 Slimy Sculpin), while 3 Kokanee were the only sport fish. All individuals, including mortalities, were less than 100 mm in length, and were considered to be juveniles.

Table 3.4-3 summarizes the potential strandings[3] observed at the Begbie site during years 1 to 4 of CLBMON-53.

Table 3.4-3: Total catch, number of species and potential strandings (fishes/m^2) observed at the Begbie site in each year of survey

Year	Sample Season	Total catch	Number of Species	Estimated potential stranding rate (fish/m^2)
2013	June	NS	-	-
	September	NS	-	-
	October	2	1	0.001
2011	June	6	0	0.004
	October	NS	-	-
2010	June	NS	-	-
	October	NS	-	-
2009	June	0	0	0
	October	41	8	0.0205

Note: (NS = not sampled)

By comparison, sampling in June 2011 produced 1 Redside Shiner mortality along with 5 desiccated coarse fishes, resulting in an estimated potential stranding rate of 0.004 fish/m^2. Sampling also resulted in capture or observation of 61 fishes of six different species that were considered not at risk of perishing; 60 fish, representing 98% of the total catch, were coarse fish (18 Prickly Sculpin, 17 Redside Shiner, 11 Largescale Sucker, 10 Peamouth Chub, and 4 Northern Pikeminnow), and one sport fish (Mountain Whitefish) represented 2% of the total catch. All individuals, including mortalities, were less than 100 mm in length, and most were considered to be juveniles. Due to high ALR levels partially inundating the site, however, only 1,400 m^2 (roughly 70% of the area surveyed in 2009) was sampled. The desiccated fishes were presumably as a result of stranding, and could not be identified to species.

Sampling was not completed in 2010 as prolonged high ALR levels had fully inundated the site. In May 2009, 0 mortalities were observed over an area of 2,000 m^2, resulting in an estimated potential stranding rate of 0 fish/m^2 (Sykes and Liebe, 2010*a*). Sampling also resulted in the capture or observation of 21 fishes of five species that were considered not at risk of perishing; 18 fish, representing 86% of the total catch, were coarse fish (11 Prickly Sculpin, 2 Longnose Sucker, and 5 Redside Shiner) and 3 sport fish (2 Rainbow Trout and 1 Burbot) represented 14% of the total catch. With the exception of the 1 Burbot, all fishes were less than 100 mm in length and most were juveniles.

In October 2009, 41 mortalities of 8 different species (4 Prickly Sculpin, 1 Kokanee, 1 Mountain Whitefish, 8 Redside Shiner, 8 Peamouth Chub, 11 Largescale Sucker, 1 Yellow Perch and 10 fishes that we un-identifiable) were observed over an area of 2,000 m^2, resulting in an estimated potential stranding rate of 0.0205 fish/m^2 (Sykes and Liebe, 2010*a*). Sampling also resulted in the capture or observation of 131 fishes of 9 different species that were considered not at risk of perishing; 118 fish, representing 90% of the total catch, were coarse fish (30 Peamouth Chub, 27 Prickly Sculpin, 22 Redside Shiner, 18 sucker sp., 12 Largescale Suckers, and 9 Carp). A total of

[3]Includes confirmed mortalities as well as fish found in isolated pools likely to dewater completely.

13 sport fish, representing 10% of the total catch, were captured (8 Mountain Whitefish, 3 Kokanee, 2 Bull Trout). All fishes, including mortalities, were less than 100 mm in length and the majority were juveniles.

3.4.4 Highway Bridge Site

Sampling at the Highway Bridge site in 2013 resulted in 0 observed mortalities during the June, September, and October sample events and resulted in estimated potential stranding rates of 0 for all three months. Sampling in June also resulted in the capture or observation of 9 fish of 3 different species that were considered not at risk of perishing, 5 of which were coarse fish (Prickly Sculpin) with the other 4 being sport fish (3 Bull Trout and 1 Kokanee). The September sampling resulted in 1 Prickly Sculpin, while the October sampling resulted in 1 Prickly Sculpin and 1 Kokanee, all of which had direct access to the mainstem or had adequate depth and cover to survive until connectivity was established the next day. Table 3.4-4 summarizes the potential strandings[4] observed at the Highway Bridge site during years 1 to 4 of CLBMON-53.

Table 3.4-4. Total catch, number of species, and potential strandings (fishes/m^2) observed at the Highway Bridge site in each year of survey

Year	Sample Season	Total catch	Number of Species	Estimated potential stranding rate (fish/m^2)
2013	June	0	0	0
	September	0	0	0
	October	0	0	0
2011	May	NS	-	-
	October	0	0	0
2010	May	3	1	0.0005
	October	7	1	0.0012
2009	May	NS	-	-
	September	NS	-	-

Note: NS = not sampled

By comparison, October 2011 sampling resulted in zero mortalities and, though no fish were observed at any of the survey sites, numerous adult Kokanee showing spawning colours and two Kokanee carcasses, presumably post-spawn mortalities, were observed from both the Highway bridge and the single lane bridge. Spawning was not observed in any of the dewatered areas during October sampling. Due to high ALR levels, however, only 1,200 m^2 was sampled, approximately 20% of the area sampled in 2010.

Sampling in May 2010 produced 3 Mountain Whitefish mortalities over an area of 6,000 m^2, which resulted in an estimated potential stranding rate of 0.0005 fish/m^2 (Sykes and Liebe, 2011*a*). Sampling also resulted in the capture or observation of 22 fishes of 2 species that were considered not at risk of perishing; 16 Sculpins and 6 Mountain Whitefish, all of which were less than 100 mm and considered juveniles. During the May survey, fish use was low, with the existing fish primarily using habitat that remained connected to permanently wetted channels.

[4]Includes confirmed mortalities as well as fish found in isolated pools likely to dewater completely.

Sampling in October 2010 produced 7 mortalities over an area of 6,000 m^2, resulting in an estimated potential stranding rate of 0.0012 fish/m^2 (Sykes and Liebe, 2011*a*). Sampling also resulted in the capture or observation of 94 fishes of 4 species that were considered not at risk of perishing, though 53 were adult Kokanee displaying spawning colours and behaviour (pairing, redd building). One redd that had been excavated became dewatered as the discharge dropped. The remaining fish included 26 Sculpin, 14 Redside Shiner, and 1 Mountain Whitefish, all of which were less than 100 mm in length and considered juveniles.

3.5 Stranding Risk

3.5.1 Greenslide Creek Side Channel

Stranding risk within the Greenslide Creek Side Channel is ranked as low (Table 3.5-1), based upon its proximity to the dam, ramping rate, and % of growing season with ALR influence. As the site is located 24 km downstream of the dam, no measurable variations in water level as a result of dam operations were observed (Section 3.2.1) which, in turn, results in no measurable ramping rates. The site experiences ALR influence for approximately 61% of the growing season for fish, the longest period of all three sample sites. The estimated potential stranding rate at the site is 0.212 fish/hour of minnow trapping. Strandings at the Greenslide Creek Side Channel, however, result from ALR operations and not from the Revelstoke Dam operations, further details of which are provided in Section 4.5.

Table 3.5-1. Four year average of stranding risk at the Greenslide Creek Side Channel, Begbie site and Highway Bridge site.

Site	Proximity to Dam (km)	Ramping (cm/hr.)	% of Growing Season with ALR influence	Stranding Risk	Estimated potential stranding rate (fish/m^2)
Greenslide	24	0	61%	Low	0.212*
Begbie	15	20	51%	Mod	0.006
Highway	7	132	44%	High	0.0003

Note:

* Greenslide Creek Side Channel measured as 0.212 fish/hour of minnow trapping (Section 2.3).

3.5.2 Begbie Site

Stranding risk at the Begbie site is ranked as moderate (Table 3.5-1) based on the three key physical factors. The site is 15 km downstream of the dam, and showed moderate changes in water levels with change in discharge from the dam (Section 3.2.2), thus resulting in a maximum recorded ramping rate of 20 cm/hour. The site experienced ALR influence for approximately 51% of the growing season for fish. The estimated potential stranding rate as a result of Revelstoke Dam operations is 0.006 fish/m^2.

3.5.3 Highway Bridge Site

Stranding risk at the Highway Bridge site is ranked as high (Table 3.5-1) based on the three key factors. The site is 7 km from the Revelstoke Dam, the closest of the three sites. Consequently the site experiences the greatest variations in water levels due to changes in discharge from the dam (Section 3.2.3), and thus resulting in a maximum observed ramping rate of 132 cm/hour. The site experienced ALR influence for approximately 44% of the year, the shortest of the three sites. However, the estimated potential stranding rate as a result of the Revelstoke Dam operations is 0.0003 fish/m^2, which was lower than that observed at the other sites.

4.0 Discussion

The results of Year 4 of the juvenile stranding assessment supported the findings of Years 1, 2, and 3 in that fish stranding mortalities are occurring in the Middle Columbia River as a result of flow fluctuations due to operations of the Revelstoke Dam. Stranding risk due to Revelstoke Dam operations is considered low at the Greenslide Creek Side Channel, moderate at the Begbie site, and high at the Highway Bridge site. It was also observed over the four years that annual variations in the ALR elevation can have an effect within the study area and, in such instances, stranding risk is greatly reduced, i.e. when high ALR levels prevent the dewatering of shoreline habitat normally resulting from decreases in discharge. This is because the ALR helps mitigate the primary factors that determine the risk of stranding. Becker et al. (1981, as cited in Cushman, 1985) found that, in general, the possibility of stranding increases when:

1. flows decrease at night when fish tend to move into shallow areas to feed and escape is made more difficult
2. flows decrease after a period of high discharge, which allows access to more low-gradient flooded areas
3. flows decrease rapidly, reducing the possibility of escape
4. flows decrease to a very low level, which results in more depressions becoming isolated and increases the chance of complete dewatering

The influence of the ALR also had direct effects on the ability of the crew to maintain consistent sample periods throughout the study. Due to the difficulty of accurately forecasting the timing and magnitude of the ALR which are highly variable, high ALR levels prevented or influenced a number of the sample events at specific sites (Table 2.2-2). At the Greenslide site, prolonged high ALR levels prevented sampling from occurring in the fall of 2011. At the Begbie site, high ALR levels prevented both seasons of sampling from occurring in 2010 and prevented the spring sample event in 2013. At the Highway Bridge site in October 2011, high ALR levels had already inundated approximately 80% of the proposed sample area.

The following sections summarize the findings over the course of the study and discuss additional details on the factors that contribute to stranding risk in the system.

4.1 Habitat Topography

Habitat characteristics such as presence of shallow channels and depressions commonly found in low gradient areas are a key factor in determining if stranding will be an issue at a particular site (Becker et al., 1981; Bradford et al., 1995). The reconnaissance survey completed in 2009 and repeated each year identified several side channels with stranding potential. However, when assessed in the field, most of those sites (Appendix 3, Table A3-1) were considered to have a relatively low risk of fish stranding due to the presence of deep channels or pools that remained connected or that would be able to support fish for long periods of time if isolated. Sampling efforts were, instead, concentrated on the three areas with higher stranding potential; the Greenslide Creek Side Channel, the Begbie site, and the Highway Bridge site.

The Greenslide Creek Side Channel, identified for sampling in the ToR (BC Hydro, 2007, 2009) is a wide, low-gradient side channel with fines and organic substrates that has a high potential to experience seasonal stranding events. Sampling results from 2009, 2010, and 2013 confirmed that the channel is seasonal, becoming wetted for a portion of the year and then dewatering for the remainder. As water levels recede in the fall, the side channel isolates from the mainstem flow and remains as such until rising water levels inundate the channel the following spring. Consequently, the isolation events experienced at the Greenslide Creek Side Channel, as will be discussed in subsequent sections, are not a result of Revelstoke Dam operations but, rather, as a result of the ALR.

Both the Begbie site and the Highway Bridge site consisted of a large area of low-gradient gravel and cobble bar that has the potential to be wetted and dewatered daily for much of the year. Fish sampling results at the Begbie site (2009, 2011, and 2013) and the Highway Bridge site (2010, 2011, and 2013) confirmed that mortalities are occurring. The presence of multiple depressions and pools where fish could get trapped was also a major contributing factor when assessing stranding risk and selection of these sites. As flows dropped and the low-gradient areas dewatered, fish were funnelled into these depressions by the receding waters or were confined in the interstitial spaces of the substrates. Once isolated, these depressions provided no possibility of escape to the main river, and if shallow enough, they would eventually dry up, resulting in mortality. Only the deepest and best defined pools would provide refuge for fish caught in these areas. It should be noted that elevated water temperature, which can increase the risk of mortality in isolated pools, is not thought to be an issue in the Middle Columbia River since isolations typically occur overnight; therefore, the pools receive limited thermal inputs before becoming reconnected.

4.2 Rate of Change

The rate at which water levels change in a system has been identified as a major factor in determining the magnitude of stranding (Becker et al., 1981; Bradford et al., 1995; Irvine et al., 2009). In managed systems such as the Middle Columbia, changes in discharge (termed "ramping rates") are controlled solely by dam operators and are independent of factors such as, but not limited to, substrate type and topography. For the purpose of this study, as the rates of change in water levels observed at the sample sites are not independent of such variables, we use the term dewatering rate. Calculations of dewatering rates at the Begbie site in October showed a maximum of 12.6 cm/h, whereas the Highway Bridge site showed a maximum of 55.4 cm/h in June and 47.9 cm/h in September (Table 4.2-1).

Table 4.2-1 Maximum ramping rates and dates of occurrence for 2009-2011 and 2013 at the Greenslide Creek Side Channel, the Begbie site and the Highway Bridge site.

Year	Greenslide Creek Side Channel (cm/hr.)	Begbie site (cm/hr.)	Highway Bridge site (cm/hr.)
2013	NS	12.6 (October)	55.4 (June)
2011	-	7.9 (June)	27 (October)
2010	-	NS	132.5 (October)
2009	-	18 (June)	NS

Note:

NS = Not Sampled

Additionally, as in Years 1 and 2, the dewatering rates observed at the sites in 2011 and 2013 exceeded those developed by Fisheries and Oceans Canada for British Columbia (KPC, 2005; Table 4.2-2).

Table 4.2-2. Summary of British Columbia ramping rate standards as defined by Fisheries and Oceans Canada

Time of Year	*Life Stage History*	*Day Ramping Rate*	*Night Ramping Rate*
April 1–July 31	Fry emergence	0–2.5 cm/h	2.5–5 cm/h
August 1–October 31	Rearing until temperature < 5°C	0–2.5 cm/h	5–10 cm/h
November 1–March 31	Overwintering	0 cm/h	0–5 cm/h

Source: KPC (2005)

By comparison, in June 2011 the Begbie site showed a maximum dewatering rate of 7.9 cm/h, while the Highway Bridge site in October showed a maximum of 27.0 cm/h. Though the 2011 rates at both sites were higher than the provincial ramping rates guidelines (Table 4.2-2), they were lower than those of any other year of the study (Begbie: 18 cm/h May 2009; Highway Bridge site: 132.5 cm/h October 2010). At the Begbie site, this can be attributed to a combination of ALR influence and discharge from the dam remaining low through the day. At the Highway Bridge site, ALR appears to have mitigated some of the effect of the dam on the site.

Results from 2009-2011 and 2013 show that, in some years, high dewatering rates appear to correspond with a relatively high estimated potential stranding risk. The Highway Bridge site in October 2010 shows that the highest recorded dewatering rate of 132.5 cm/h coincides with the highest estimated potential stranding rate (0.0012 fish/m^2) for that site. Results from the 2013 spring and fall sample events, however, were confounding: though both events experienced relatively high dewatering rates (55.4 cm/h in June and 47.9 cm/h in September) and no ALR influence was observed, zero mortalities were recorded in either sample period. Additionally, at the Begbie site, in June 2011 a relatively low dewatering rate of 7.9 cm/h coincided with an estimated potential stranding rate of 0.004 fish/m^2 while in 2013, a higher dewatering rate of 12.6 cm/h coincided with a potential stranding rate of only 0.001 fish/m^2.

The ability to collect consistent data from the sites on a yearly basis, however, was greatly confounded by annual variations in ALR influence at each site. Consequently, the results were somewhat inconclusive in determining the degree to which rate of change affects the magnitude and potential of stranding within the Middle Columbia system. The results did, however, show that strandings are occurring at both high and low dewatering rates. Despite the confounding factors observed throughout the study period, as other studies have shown (Becker et al., 1981; Bradford et al., 1995; Irvine et al., 2009), it seems reasonable to speculate that high dewatering rates will result in a higher potential stranding risk than would low dewatering rates.

4.3 Time of Year

Data collected in Years 1 to 4 suggest that the risk of fish stranding in the Middle Columbia River varies according to the time of year. The results suggest that stranding risk increased in the fall as compared to the spring due to the presence of 0+ juveniles in the system at that time of year. Additionally, in Years 2 and 4, potential impact on Kokanee spawning was observed as a result of water level changes in the fall. However, the results (

Table 4.3-1) also suggest that, over the study duration (2009-2011 and 2013), the ALR has resulted in an average reduced stranding risk for approximately 61% of the growing season of fish (April to November – 244 days) at the Greenslide Creek Side Channel, 51% of the growing season at the Begbie site, and 44% of the growing season at the Highway Bridge site.

Table 4.3-1 Duration of ALR influence, in days and in percentage of growing season, for the Greenslide Creek Side Channel, Begbie site and Highway Bridge site for 2009-2011 and 2013

Greenslide Creek Side Channel	2009	2010	2011	2013	Average
ALR influence (days of growing season*)	153	180	156	108	149
Percent of growing season mitigated	62%	73%	64%	44%	61%
Begbie Creek Site					
ALR influence (days of growing season*)	120	146	148	91	126
Percent of growing season mitigated	49%	59%	60%	37%	51%
Highway Bridge Site					
ALR influence (days of growing season*)	103	111	143	75	108
Percent of growing season mitigated	42%	45%	58%	30%	44%

* April to November - 244 days

Stranding is primarily an issue during periods when the ALR elevation is low enough to result in riverine conditions downstream of the dam, typically in winter. Timing of ALR influence at each site varies from year to year (Figure 3.3-1, Figure 3.3-2, and Figure 3.3-3) due to complex flood control treaties and water storage agreements with the United States and downstream facilities, however, a basic trend is observed. ALR elevation and, thus, influence at each site is lowest in the winter (January to April), increases through the spring (April to July), remains high through the summer (July to September), and then gradually decreases over the fall and winter (September to January). Location of the sites within the Middle Columbia system governs the degree and extent of the ALR influence. In general, the closer the site is to the dam, the shorter the period of ALR influence and the longer the period of increased stranding risk. However, data from all four years of the study show that there was substantial annual variability in the ALR operations, which affected the amount of time sites experienced reduced stranding risk, even at the upstream extent of the sample area (Highway Bridge site).

From Years 1 to 4, the earliest inundation of each site occurred in 2010 (Greenslide Creek Side Channel: May 5; Begbie site: May 21; Highway Bridge site: June 4) while the latest inundation of each of the sites occurred in 2013 (Greenslide Creek Side Channel: May 31; Begbie site: June 5; Highway Bridge site: June 11). The earliest date when ALR levels receded at each site occurred in 2013 (Greenslide Creek Side Channel: Aug 30; Begbie site: Aug 20; Highway Bridge site: Aug 15) and the latest that the ALR influence receded was in 2011 where ALR influence remained beyond December 7.

The longest period of ALR influence (

Table 4.3-1) was 180 days at the Greenslide Creek Side Channel in 2010; 148 days at the Begbie site in 2011; and 143 days at the Highway Bridge site in 2011. This translated into reduced stranding risk for 73% of the growing season for fish (April to November – 244 days) at the Greenslide Creek Side Channel, 60% of the growing season at the Begbie Creek site, and 58% of the growing season at the Highway Bridge site. The shortest period of ALR influence was experienced in 2013 (Greenslide Creek Side Channel: 108 days; Begbie site: 91 days; and Highway Bridge site: 76 days). This translated into a reduced standing risk for approximately 45% (Greenslide Creek Side Channel), 38% (Begbie Site), and 31% (Highway Bridge site) of the growing season for fish.
Therefore, while increased effects of stranding on fish in the Middle Columbia River are observed in the fall, this is mitigated by high ALR elevation.

4.4 Species and Life Stages Impacted

Within the Greenslide Creek Side Channel the total fish catch (24 Largescale Sucker and 20 Prickly Sculpin) represents mortalities as a result of ALR operations only, and not as a result of Revelstoke Dam operations. Further investigation into the relationship between ALR levels and fish stranding was out of the scope of this study. Catches over the four years consisted almost entirely of coarse fishes, with one single sport fish (Rainbow Trout) captured. Because minnow traps were the only sample method used at the site, the catches were limited to juvenile fishes, with the occasional adult sculpin, and thus, presence of adult sport fish (Mountain Whitefish, Bull Trout, Rainbow Trout etc.) is unclear. However, it is reasonable to assume that, with the absence of important habitat features found in abundance at the Begbie Creek and Highway Bridge sites, such as gravel substrates, cover (LWD, overhanging vegetation), and consistent flows, presence of adult sport fish within Greenslide Creek Side channel is low.

The fish catch at the Begbie site during the juvenile index sampling (CLBMON-17 site 43) 2008-2011 and 2013 consisted primarily of Prickly Sculpin and Mountain Whitefish. Other species frequently encountered included Peamouth Chub and Redside Shiner (Table 4.4-1). This is comparable to the species composition observed at the Begbie site during the juvenile fish stranding sampling in 2009, 2011, and 2013. Redside Shiner and Peamouth Chub were the species with the most recorded mortalities in 2011 and 2013, and thus are the species most at risk of stranding at the Begbie site. The remaining five mortalities in 2011 and 10 mortalities in 2009 could not be identified beyond being a coarse fish species.

Table 4.4-1 Comparison of fish presence (CLBMON-17) and documented fish mortalities (CLBMON-53) at the Begbie site.

Study	Year	CAS J/A	KO (J/A)	MW (J/A)	RSC (J/A)	PCC (J/A)	SU (J/A)	Unknown sp.
Begbie site (CLBMON-17 Site # 43)								
CLBMON-17	2013	4/4	1/1	1/0	8/2	126/0	1/0	
CLBMON-17	2011	1/10	0/7	3/0	0/5	5/0	0/1	
CLBMON-17	2010	3/16	2/0	50/0	2/1	-	-	
CLBMON-17	2009	1/14	1/0	24/0	2/0	8/0	-	
CLBMON-17 Total		**9/44**	**4/8**	**78/0**	**12/8**	**139/0**	**1/1**	
CLBMON-53	2013	-	-	-	2/0	-	-	
CLBMON-53	2011	-	-	-	1/0	-	-	5
CLBMON-53	2010	-	-	-	-	-	-	-
CLBMON-53	2009	3/1	1/0	1/0	5/0	8/0	11/0	10
CLBMON-53 Total		3/1	1/0	1/0	**8/0**	**8/0**	11/0	15

Note:

J = Juveniles

A = Adults

Red numbers represent mortalities documented during the CLBMON-53 study.

The fish catch at the Highway Bridge site during the juvenile index sampling (CLBMON-17 site 27 and 28) in 2008-2011 and 2013 consisted primarily of Mountain Whitefish, Prickly Sculpin, Kokanee and, Bull Trout (Table 4.4-2). This is comparable to the species composition observed at the Highway Bridge site during the juvenile fish stranding sampling in the fall of 2010, 2011, and 2013. Mountain Whitefish and Redside Shiner are the two species with observed mortalities and, therefore, are the species most at risk of stranding at that the Highway Bridge site in years when ALR influence is absent.

Table 4.4-2 Comparison of fish presence (CLBMON-17) and documented fish mortalities (CLBMON-53) at the Highway Bridge site.

Study	Year	CAS J/A	KO (J/A)	MW (J/A)	RSC (J/A)	BT (J/A)	RB (J/A)
Highway Bridge site (CLBMON-17 Site # 27 and 28)							
CLBMON-17	2013	0/4	1/9	7/0	1/0	4/0	-
CLBMON-17	2011	2/19	12/0	7/0	-	3/0	6/0
CLBMON-17	2010	1/19	5/35	27/0	0/1	8/0	2/0
CLBMON-17	2009	3/21	2/31	60/3	-	3/3	2/1
CLBMON-17 Total		6/63	20/75	101/3	1/1	18/3	10/1
CLBMON-53	2013	-	-	-	-	-	-
CLBMON-53	2011	-	-	-	-	-	-
CLBMON-53	2010	-	-	3/0	7/0	-	-
CLBMON-53	2009	-	-	-	-	-	-
CLBMON-53 Total		-	-	**3/0**	**7/0**	**-**	-

Note:
J = Juvenile
A = Adult
Red numbers represent mortalities documented during CLBMON-53 study

In general, species composition at both the Highway Bridge and Begbie sites did not differ substantially between survey years, though minor differences were observed. At the Highway Bridge site in fall 2010, 14 live Redside Shiners and 7 mortalities (30 per cent of total) were recorded; yet, no other juvenile stranding sample event captured Redside Shiner at the site. This is also reflected in the juvenile index sampling (CLBMON-17) as only 2 Redside Shiner have been captured in the vicinity of the Highway Bridge site (CLBMON-17 sites 27 and 28) since 2008 (Table 3.4-1). The cause of this is likely natural variations in fish distribution and it is assumed that the risk of stranding for Redside Shiner at the Highway Bridge site is unchanged from 2008. At the Begbie site in September 2013, the juvenile index sampling (CLBMON-17) observed far greater presence of Peamouth Chub (n=125) than 2009 and 2011 combined (n=13). However, the October 2013 juvenile fish stranding survey failed to identify any Peamouth Chub (live or mortalities). This suggests that while they are present in the vicinity of the Begbie site, they are not at risk of stranding likely because they do not utilize the habitats where risk of stranding is greatest.

Most fishes captured during the juvenile index sampling (CLBMON-17 sites 27 and 28) at the Highway Bridge site and all fishes captured at the Begbie site were less than 100 mm and most were considered to be juveniles. This was consistent with the Year 1 and 2 results for those sites and supports the hypothesis that larger juvenile and adult fishes are less susceptible to stranding because they prefer deeper water. As noted by Cushman (1985), mature fishes are less susceptible to stranding because of their habitat preference for main channel habitats. For sport fish species such as Mountain Whitefish, age 1+ and older individuals in particular tend to prefer moderate water velocities and riffle-pool morphology with moderate currents (McPhail, 2007). They are considered to be less susceptible to stranding because of their avoidance of decreasing velocities, as would occur due to dewatering. Alternatively, small juveniles and young-of-year Mountain Whitefish tend to show a preference for shallow, slow moving water over gravel, sand, or silt substrates (McPhail, 2007), and therefore are more likely to be encountered in habitats that have an increased risk of stranding.

Spawning Kokanee were observed during both the 2010 and 2011 fall sampling at the Highway Bridge site. In 2010 the dewatering of redds along the shoreline was observed, which suggests that water level fluctuations may have an impact on spawning Kokanee (Sykes and Liebe, 2011*a*). However, fall 2010 marked a year of high Kokanee spawning, thus the number of redds that dewatered at the Highway Bridge site was likely a result of higher overall presence of Kokanee. Following years observed far fewer numbers of Kokanee (CLBMON-17 sampling observed 37 Kokanee in 2011, 12 in 2011, and 9 in 2013) and in 2011, no redds were observed to be impacted. Consequently, impacts to Kokanee spawning at the Highway Bridge site are mitigated in years of high ALR influence and in years of low Kokanee spawning. However, the overall effect on Kokanee spawning as a result of dam operations is likely minor unless low water restricts access to tributary spawning areas. Further investigation into this, however, was beyond the scope of this study.

4.5 Dam Operations vs. Reservoir Operations

Data collected from the Greenslide Creek Side Channel for years 1-4 confirmed that Revelstoke Dam operations do not result in a high risk of fish stranding at this location. The side channel does dewater during winter and spring as a result of the ALR elevation receding, which likely results in mortalities. However, when the channel is wetted, the combination of ALR influence and distance from the dam results in only minimal daily fluctuations in flow levels and in little to no risk of fish stranding.

Sampling in 2009, 2010, and 2013 showed that once wetted, the Greenslide Creek channel provides fish habitat for coarse fish species such as carps, suckers, chub, and sculpins, but does not provide good habitat for sport fish species such as Mountain Whitefish, Bull Trout and Rainbow Trout (Appendix 1, Photos 3 and 4). Although these fishes are not at risk of stranding from daily flow fluctuations, any fish that remain in the channel once it has become isolated (Appendix 1, Photos 5, 6, 7, and 8) due to the ALR receding in the fall will likely die over the winter. Therefore, fish mortality due to isolation in the Greenslide Creek Side Channel is a result of reservoir operations and not of dam operations. The Greenslide side channel is considered to be representative of many other flooded areas that become dewatered over the winter

(Appendix 3, Table A3.1). Isolation resulting from reservoir operations likely impacts a much larger area than daily flow fluctuations from the dam. Impacts should be most severe on coarse fishes due to their preference for low-velocity habitats that can become isolated with reduced water levels.

At the Begbie site in October 2013, minimal changes in the water levels were observed as a result of changes in discharge from the dam (Figure 3.2-3): approximately 4 cm over two hours as a result of a spike in discharge to 390 m^3/s (a change of 250 m^3/s) which lasted 30 minutes. This event was one of two short duration increases in flow observed at the Begbie site in 2013. For the majority of the sample period, discharge remained low, at approximately 150 m^3/s, and water levels gradually receded from approximately 0.6 m to approximately 0.4 m. The low discharge from the dam was, however, a planned reduction in response to operational maintenance performed at the Mica Dam facility. The receding trend in water levels at the Begbie site in October is consistent with the decreasing ALR levels in the fall and winter months.

By comparison, in June 2011, changes in water levels at the Begbie site were more pronounced than in 2013 (Figure 3.2-4) despite the fact that discharge rates remained low through the day and that the site was influenced by the ALR. This is likely explained by the longer durations of high discharge in 2011. Fluctuations in water levels of 10 to 20 cm were observed in 2011 as a result of spikes in discharge from 165 m^3/s to approximately 325 m^3/s (a change of 160 m^3/s), lasting approximately 5 hours. Over the course of sampling, water levels gradually rose from 0.8 m to 1.0 m. The increasing trend in water levels at the Begbie site in June is consistent with the increasing ALR levels in the spring.

Consequently, results from 2011 and 2013 suggest that the risk of stranding at the Begbie site increases with large daily fluctuations in discharge from the Revelstoke Dam. However, in order for changes in discharge from the dam to have a noticeable effect at the Begbie site, they must be longer in duration than those required to have an effect on water levels further upstream (Highway Bridge Site). Determining a threshold in discharge duration required to exhibit a change in water levels, however, was beyond the scope of this study. The 2011 and 2013 water level data shows that it takes approximately 3 hours for changes in discharge from the dam to be observed at the Begbie site. Therefore, changes in discharge that are much shorter in duration, as observed in 2013, will likely have less noticeable effects on water level at the Begbie site. A likely explanation for this is related to the difference in width of the river between the Begbie site and the Highway Bridge site. At the Highway Bridge site, the river is approximately 300 m wide while at the Begbie Site the river is approximately 1.6 km wide. Changes in discharge and thus water levels are likely to be more evident in areas of confinement, such as the Highway Bridge site and less evident where channel widths are much greater, such as the Begbie site. Additionally, there are four tributaries that enter the Columbia River mainstem between the Highway Bridge site and the Begbie site (Tonkawatla Creek, Illecillewaet River, Griffin Creek and Wells Creek). The total added volume of water to the Columbia River from these tributaries was not calculated however, it is reasonable to assume that their cumulative input of water would have a diluting effect on the degree to which changes in discharge from the dam are evident at the Begbie site.

At the Highway Bridge site, because of its close proximity to the dam and narrower channel, changes in water level associated with changes in discharge are much more immediate (within 20 minutes) than they are at the Begbie site (within 3 hours). Additionally, changes in water levels were observed at the Highway Bridge site even after relatively short durations of higher discharge. Water levels from all years at the Highway Bridge site display prompt and equivalent responses to change in discharge; June, and September 2013 (Figure 3.2-5 and Figure 3.2-6 respectively), September and October 2011 (Figure 3.2-8 and Appendix: 4, Figure: A4-1 respectively), as well as May and October 2010 (Appendix 4, Figures A4-2 and A4-3 respectively). Consequently, water level and, thus, stranding potential is directly influenced by change in discharge from the Revelstoke Dam even when such changes have short durations.

In some years, ALR influence can affect the degree of change in water levels at the Highway Bridge site, specifically on the lower end of the hydrograph (in times of low discharge from the dam). As observed in 2011, the partial inundation of the Highway Bridge site by high ALR levels prevented water levels from dropping to their normal, low discharge levels (Appendix 1, Photo 20) and rather maintained water levels at an artificial low (Appendix 1, Photo 18). This occurrence had a mitigating effect at the site by reducing the area that would dewater until such a time that the ALR level receded and minimum water depth would return to normal, riverine levels.

Consequently, Revelstoke Dam discharge does influence stranding risk at the Highway Bridge site due primarily to its proximity to the dam and the short lag time between changes in discharge at the dam and observed changes in water level at the site. However, high ALR levels occasionally have a mitigating effect on the site by increasing the minimum water level and thus, as discussed in Section 4.3, decreasing the stranding potential at the site for a portion of the season.

4.6 Rev 5 Effects

Year 4 (2013) was the second year of sampling following the completion of Rev 5. As such, the results were expected to address the second management question for the project: "*If fish strandings are found to occur in these side channels under the present* [four unit] *regime, are they likely to increase in extent, magnitude, duration or frequency under the five-unit operations?*" The addition of a fifth generator at the Revelstoke Dam increases the potential peak daily discharge of the facility by up to 20 per cent (from a maximum of 1,700 m^3/s to 2,125 m^3/s) (BC Hydro, 2009). It was hypothesized that this increase could be sufficient to flood side channel areas not affected by pre-Rev 5 operations. None of these potential effects were observed during the 2011 or 2013 field surveys. However conditions in the system during the 2011 and 2013 study period were observed to be not substantially different from those that could occur under the four unit operation. Discharge during the pre-Rev 5 years of the study peaked at 1,792 in 2009 (July 25) and 1,804 m^3/s in 2010 (August 25). In 2011 (Year 1 post-Rev 5), from May 1 to October 16 (169 days), discharge peaked at 1,779 m^3/s while in 2013, (Year 5 post-Rev 5), from May 1 to October 31 (184 days) discharge peaked at 1,805 m^3/s. Further, the pre-Rev 5 maximum of 1,700 m^3/s was exceeded on only 23 days (13% of the time) in 2013 and only 21 days (12% of the time) in 2011, generally for periods of less than one hour.

Consequently, because of their short duration, increases in the maximum discharge observed during the post-Rev 5 study periods did not appear to have any effect on stranding risk downstream of the Revelstoke Dam. Further, reconnaissance surveys did not identify any new areas of stranding concern resulting from the increased maximum discharge.

In addition, it was hypothesized that the higher discharge could result in even more extreme changes in water levels in the system, thereby increasing stranding risk. This, however, was not shown to be the case during the 2011 or 2013 field surveys as conditions in the system were observed to be not substantially different from those that could occur under the four unit operation. Lastly, there was the possibility that post-Rev 5 peak flows would be sufficient to mobilize channel bed and/or bar materials, resulting in a reconfiguration of bars and associated side channels over time. Prior studies have suggested that mainstem bed materials are stable under the current flow regime and should remain as such post Rev 5, but an increase in the rate of removal of fine-grained sediments that have accumulated at the base of unstable or steep river banks may occur (Northwest Hydraulic Consultants, 2006). Similarly, fine materials associated with current side channel areas and bars could also be mobilized.

Another change following completion of Rev 5 was the establishment of a minimum base flow of 142 m^3/s. It was hypothesized that this would help mitigate the stranding risk by ensuring that at least some of the high-risk habitats remain wetted. However, in 2013 Revelstoke Dam discharge still dropped below the 142 m^3/s threshold on 12 days (7% of the time) from May 1 to Oct 18 (171 days) and generally for periods of less than one hour. In 2011 sampling results were confounded by the influence of the ALR on the study area; therefore, it is not possible to determine what effect, if any, the minimum base flows had on stranding risk in the system. In addition, Revelstoke Dam discharge dropped below the 142 m^3/s threshold on 59 days (35% of the time) from May 1 to October 16 (169 days) and generally for periods of more than one hour. Despite the confounding factors that occurred in 2011 and 2013, it seems reasonable to speculate that implementation of the minimum base flows would reduce stranding risk in the system by ensuring that less habitat dewaters. At the very least, the minimum flows should not exacerbate the stranding that is occurring in the system.

4.7 Stranding Risk vs. Observed Mortalities

The results show that risk of fish stranding typically increases as proximity to the dam increases. However, it is important to understand that, since stranding risk is defined as a probability of stranding based on the three key physical factors (distance from the dam, ramping rates and ALR influence), high stranding risk does not necessarily result in a higher stranding rate. Consider the stranding risk at the Begbie and Highway Bridge Sites compared to the stranding rates ($fish/m^2$). Although stranding risk is less at the Begbie site (Moderate) than at the Highway Bridge site (High), stranding rate at the Begbie site (0.006 $fish/m^2$) is higher than at the Highway Bridge site (0.0003 $fish/m^2$).

As observed by Korman and Campana (2009), fish use within the immediate shoreline areas (areas which dewater regularly) of modified systems is often limited. Their results show that habitat use by juvenile Rainbow Trout at daily minimum flow can be up to four-fold higher than at daily maximum flows. At the Highway Bridge site, the limited use of the near-shore habitat is likely a behavioral response related to the frequency of dewatering at the site. Therefore, although the risk of stranding at the Highway Bridge site is inherently high, the limited fish use of the near-shore habitat in response to frequent dewatering may precludes actual fish strandings. Conversely, at the Begbie site, since the frequency and magnitude of dewatering events are less extreme, fish use would assumedly be higher while response to changes in water levels may be reduced. So although stranding risk at the Begbie site is only considered Moderate, higher stranding rates observed at this site may result from a lack of conditioning to frequent de-watering events. Sykes and Liebe, (2013) also observed that fish use, by coarse fish species in particular, is generally limited in reaches closest to the dam. At the Highway Bridge site, observed mortalities consisted of 2 species; one sport fish and one coarse fish. When considering the Begbie site however, mortalities from 6 species were recorded, 4 of which were coarse fish species. It is likely that the higher stranding rate at the Begbie site is, at least in part, also a result of the greater presence of coarse fish species compared to the Highway bridge site.

By ranking stranding risk solely at the three sites within the study area, because the Highway Bridge site is the upper limit of the study area, 7 km of the Columbia River upstream of the Bridge remain un-sampled. However, the observed trend of increasing stranding risk with increasing proximity to the dam is likely still applicable as ramping rates will be highest near the dam while ALR influence will virtually non-existent. Sykes and Liebe (2013) observed that, fish species composition between the dam and Highway Bridge comprises primarily of sport fish species, which are less susceptible to stranding than coarse fish species. So although the stranding risk within the upper section of the river, based on physical features is likely high, it is also likely that stranding rates will be low, resulting in few mortalities. Additionally, as sampling was restricted to three specific sites over a 24 km length of the river, conditions between sites cannot be determined with certainty. However, considering that the river conditions between each site remain relatively constant during a sample season, it is reasonable to assume stranding risk likely continues to decreases as distance from the dam increases.

The Greenslide Creek Side Channel is excluded from comparisons because, although strandings and mortalities are occurring within the side channel, they are not a result of Revelstoke Dam operations, but rather a result of ALR operations. Though out of the scope of the Middle Columbia River Juvenile Fish Stranding Assessment, stranding rates within the Greenslide Creek Side Channel suggest that ALR operations may be responsible for killing large numbers of fish on a yearly basis, although further, in depth study into this is required.

5.0 Management Question Summary

Based on Years 1 to 4 of the Middle Columbia River juvenile fish stranding assessment, the following conclusions can be drawn in relation to each of the four key management questions:

1. *Are fish strandings occurring in side channels near Greenslide Creek under the current four units operations in the area of influence of Rev 5?*

- Daily fish strandings resulting from fluctuating water levels due to Revelstoke Dam releases are not occurring at the Greenslide Creek Side Channel. However, seasonal isolation of habitat in the Greenslide Creek Side Channel does occur as the reservoir elevation drops in the fall, which potentially results in fish mortalities. Based on 2009, 2010, and 2013 sampling results, juvenile carp, Prickly Sculpin, tench, chub, and suckers are the most susceptible species. The absence of important habitat features including but not limited to: gravel substrates, cover and flow limit the potential to encounter sport fish within the Greenslide Creek Side Channel (sport fish captures were limited to one juvenile Rainbow Trout).

2. *If fish strandings are found to occur in these side channels under the present regime, are they likely to increase in extent, magnitude, duration or frequency under the five-unit operations?*

- Fish strandings will increase if additional high-risk areas (e.g., low-gradient sites where shallow channels and depressions form) not currently wetted during daily flow fluctuations become wetted as a result of the expected 20 per cent increase in daily peak flow magnitude. However, this was not observed in 2011 or 2013 (first and third year following installation of Rev 5) because discharge during the sample period did not approach the maximum forecasted levels.

3. *What is the relationship between abundance of stranded fishes (stranding risk) and time of day, wetted history, substrate and cover type in the area of influence of Rev 5?*

Findings from Year 4 were similar to those of Years 1 to 3:

Fish strandings – time of day

- Fish strandings typically occur in the early morning (3:00 a.m. to 5:00 a.m.) on nights when the discharge from the dam is ramped down (Rates ranging from 7.9 - 132.5 cm/hr.). There is a delay of approximately 20 minutes before the drop in flows is noticeable at the Highway Bridge site and 3 hours before they are noticeable at the Begbie site.

Fish strandings – time of year

- Stranding potential is highest from fall to spring when the reservoir elevation is lower and a greater proportion of the river is influenced by flow regulations from the dam.

Fish strandings – wetted history

- Fish strandings occur over a wide range of discharge on the falling limb of the hydrograph. Site conditions (e.g., channel morphology and bank slope) and rates of change will affect overall stranding risk. Sites frequently wetted and dewatered may be avoided by fish due to unpredictable conditions, thereby reducing stranding in those areas.

Fish strandings – substrate type

- Fish strandings resulting from dam operations occur primarily at low-gradient sites where multiple narrow and shallow channels, depressions, and pools form as water levels drop. These narrow and shallow channels and depressions typically have gravel and cobble substrates.

Fish strandings – cover type

- Fish strandings resulting from dam operations occur primarily at low-gradient sites where multiple narrow and shallow channels, depressions, and pools form as water levels drop. These narrow and shallow channels and depressions typically lack cover such as large woody debris.

4. *What species and life stages are most likely to be stranded?*

- **Species** – Sampling results from CLBMON-17 in the vicinity of the Highway Bridge site from 2009 to 2011 and 2013 suggested that based on abundance, sculpin and Mountain Whitefish were most likely to be stranded. 2010 stranding sampling results identified three Mountain Whitefish mortalities at the site, which supports the CLBMON 17 data. 2009 stranding results showed coarse fishes such as Peamouth Chub, Largescale Sucker, Redside Shiner, and sculpin were most likely to be stranded in the area downstream of the Illecillewaet River. In general, sport fishes at the study sites were associated primarily with deeper pools that would not be expected to dewater, or were associated with areas that remain connected to the main channel. These fishes also have a high velocity preference, which would enable them to detect reduction in velocities associated with decreasing flows; therefore they would move out of potential stranding areas.
- **Life stages** – Captured fishes and observed mortalities were typically juveniles, with the exception of the occasional adult Redside Shiner and sculpin. In 2010, several adult Kokanee were observed building redds in areas that became dewatered as flows ramped down.

6.0 References

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APPENDIX 1

PHOTOGRAPHS

Photo 1. Greenslide Creek Side Channel south view on May 30, 2011 prior to being inundated by the Arrow Lakes Reservoir

Photo 2. Greenslide Creek Side Channel north view on May 30, 2011 prior to being inundated by the Arrow Lakes Reservoir

Photo 3. Greenslide Creek Side Channel south view on June 19, 2009. The site is inundated by the Arrow Lakes Reservoir.

Photo 4. Greenslide Creek Side Channel north view on June 19, 2009. The site is inundated by the Arrow Lakes Reservoir.

Photo 5. North view of Greenslide Creek Side Channel on September 23, 2013 isolated from the ALR and in the process of dewatering

Photo 6. Greenslide Creek Side Channel on September 23, 2013 isolated and in the process of dewatering. View midway along the length of the channel.

Photo 7. Greenslide Creek Side Channel, south section, on September 23, 2013 isolated from ALR and in the process of dewatering

Photo 8. Greenslide Creek Side Channel on October 16, 2013 isolated dewatered. View looking north toward area of the connection point to reservoir

Photo 9. Greenslide Creek Side Channel on October 16, 2013 isolated and dewatered. South view midway along its length.

Photo 10. Greenslide Creek Side Channel area north view on October 5, 2011. The site remains inundated by the Arrow Lakes Reservoir with the Revelstoke Dam having little to no measurable influence on water levels.

Photo 11. Overview of the side channel site upstream of Begbie Creek on May 12, 2009, at typical mid-day discharge levels

Photo 12. Overview of the side channel site upstream of Begbie Creek on May 12, 2009, during daily low discharge levels

Photo 13. Overview of Pool #1 within the side channel site upstream of Begbie site on May 24, 2011, Revelstoke dam discharge of 1,120 m^3/s

Photo 14. Overview of Pool #1 at Begbie site during the physical habitat collection phase on May 28, 2009; Revelstoke Dam discharge of 780 m^3/s

Photo 15. Overview of small isolated pool at Begbie site on May 24, 2011; Revelstoke dam discharge of 1,120 m^3/s

Photo 16. Overview of Pool #2 at Begbie site during the physical habitat collection phase on May 28, 2009; Revelstoke Dam discharge of 1,125 m^3/s

Photo 17. Overview of Highway Bridge site at Area #1 on October 6, 2011 at a discharge of approximately 800 m^3/s. The site is inundated by the Arrow Lakes Reservoir.

Photo 18. Overview of Highway Bridge site at Area #1 on October 6, 2011 at a low discharge of approximately 200 m^3/s. The site is inundated by the Arrow Lakes Reservoir.

Photo 19. Overview of the Highway Bridge site on October 3, 2010 at approximately 1,000 m^3/s discharge with no Arrow Lakes Reservoir inundation

Photo 20. Overview of the Highway Bridge site on October 3, 2010 at approximately 400 m^3/s discharge with no Arrow Lakes Reservoir inundation

Photo 21. Overview of the Highway Bridge site on October 29, 2013 at approximately 400 m^3/s discharge with no Arrow Lakes Reservoir inundation

Photo 22. Overview of the Highway Bridge site on October 29, 2013 at approximately 200 m^3/s discharge with no Arrow Lakes Reservoir inundation

Photo 23. Overview of the Highway Bridge site at Area #3 on Oct 5, 2010 at approximately 400 m^3/s discharge. The site is inundated by the Arrow Lakes Reservoir.

Photo 24. Overview of the Highway Bridge site at Area #3 on May 26, 2010 at approximately 800 m^3/s discharge with no Arrow Lakes Reservoir inundation

Photo 25. Overview of the Highway Bridge site at Area #3 on May 26, 2010 at approximately 400 m^3/s discharge with no Arrow Lakes Reservoir inundation

APPENDIX 2

2013 FISH SAMPLING SUMMARY

Table A2-1. Summary of sampling effort and results for June 4–5, 2013 sampling at the Highway Bridge site

Site	Sampling Method	Effort (EF seconds; MT hours)	Results	Comment (G = Gravel %, C = Cobble %, F = Fines %, B = Boulder%; LWD = large woody debris)
T1	VO	n/a		Transect #1 from main Highway Bridge pier to 3rd CP Rail bridge pier. 0-10 m: gravel bar (NFC); 10-20 m: pool and draining channel (NFC); 20-70 m: C/G/B dewatered bar (NFC)
T2	VO	n/a		Transect #2: CP Rail bridge 3rd pier to single lane bridge 1st pier; G(60)C(40).
T3	EF	489	BT: 131, 127; CAS: 80, 89, 100; KO: 72	Transect #3: Single land bridge 1st pier downstream approximately 140 m. LWD and gravel shoreline; connected to main river at time of survey. All fish captured in areas that would allow escape and therefore not considered potential mortalities.
T4	EF	1,210	BT: 133; CAS: 89	Sampling along river edge (non-stranding zone).
1	EF/VO	858	NFC	Large pool between Highway and CP Rail bridge, 1-2 pieces of LWD; low habitat complexity; 0.5 m max depth when isolated.
2	EF/VO	87	NFC	2nd CP Rail Bridge pier; G(60), C(10), F(30); 1 piece LWD; site will dewater completely
3	EF/VO	52	NFC	3rd rail bridge pier; C(40)F(30)G(30); 2 pc LWD; site will dewater completely
4	EF/VO	45	NFC	Small depression between 3rd and 4th CP Rail pier. G(60)F(30)C(10)
5	EF/VO	80	NFC	Small depression on exposed bar downstream of CP Rail bridge; F(70)G(30); no cover; 20 cm deep; will dewater completely.
6	EF/VO	40	NFC	Small pool 5 m upstream of single lane bridge; F(60)G(40); no cover; 30 cm deep; will dewater.
7	VO	n/a	NFC	Small depression under LWD cover; less than 10 cm deep; likely will dewater completely.
8	VO	n/a	NFC	Dewatered shoreline with abundant LWD; F(70)C(30); 10% gradient.
9	EF/VO	60	NFC	Small pool with LWD cover; F(60)G(15)C(25); 20-30 cm deep and still connected at time of survey (potentially allowing escape).
10	EF/VO	30	NFC	Pool located 10 m downstream of large Highway bridge pier; F(80)B(10)G(5); 30 cm deep, isolated and likely to dewater completely.
11	MT	42.5	CAS: 86	Large Highway Bridge pier; LWD cover; G(60)F(40); 1 m deep and remains wetted.
15	MT	82.7	NFC	Small pool at 1st pier of single lane bridge; G(70)F(25)C(5); LWD and SWD present.
16	EF/VO	n/a	NFC	4.99 m radius plot; coarse substrate B(50)C(30)G(15)F(5);
17	EF/VO	n/a	NFC	Recently dewatered gravel bar G(60)C(30)F(10); downstream point of survey.
18	MT		NFC	2nd Highway Bridge pier; 0.5 m deep with LWD

Notes: Sites were visually assessed (VO) and electrofished (EF) if possible. MT= minnow trapping
NFC: No Fish Caught. Fish species codes are provided in Table 2.5-1. Total length in mm measured for sculpin (CAS), fork length in mm measured for remainder of species captured. **Bold records are potential or observed mortalities due to stranding.**

Table A2-2. Summary of the results from the June 4–5, 2013 surveys at the Highway Bridge site

Site	Sampling Method[1]	Description of Survey Transects	Results
T1	VO	Transect #1 between Highway bridge and CP Rail bridge: 50 m transect with gravel and fine dominated substrates	No fish observed
T2	VO	Transect #2 between Highway bridge and CP Rail bridge: 70 m transect with gravel dominated substrates	No fish observed
T3	VO	Transect #3 between Highway bridge and CP Rail bridge: 90 m transect with gravel dominated substrates	No fish observed
T4	VO	Transect #4 between CP Rail bridge and single lane bridge: 30 m transect along steep shore dominated by gravel and cobble	No fish observed
T5	VO	Transect #5 between CP Rail bridge and single lane bridge: 50 m transect along steep shore dominated by gravel and cobble	No fish observed
T6	VO	Transect #6 downstream of single lane bridge: 15 m transect dominated by fines and small gravel with large woody debris	No fish observed

VO: Visual Observation

Refer to Figure 2.2-2 for location of sites

Table A2-3. Summary of the results from the September 23-25, 2013 minnow trapping at Greenslide side channel

Site	Sampling Method[1]	Description of Sample Site at Greenslide side channel[1]	Results
September 23/24 overnight set			
T1	MT	Site #1 50m downstream of side channel inlet. 1 MT was set. 19 hour soak	CSU; 12@ 55mm – 65mm FL[2], CAS; 4 @ 32mm – 48mm TL[3]
T2	MT	Site #2 250m downstream of side channel inlet. 1 MT was set. 19 hour soak	No fish caught or observed
T3	MT	Site #3 300m downstream of side channel inlet. 1 MT was set. 19 hour soak	CAS; 1 @ 34mm FL
T4	MT	Site #4 350m downstream of side channel inlet. 1 MT was set. 19 hour soak	No fish caught or observed
September 24/25 overnight set			
T1	MT	Site #1 50m downstream of side channel inlet. 1 MT was set. 21 hour soak	CSU; 9 @ 60mm - 66mm FL
T2	MT	Site #2 250m downstream of side channel inlet. 1 MT was set. 21 hour soak	CSU; 1 60mm FL
T3	MT	Site #3 300m downstream of side channel inlet. 1 MT was set. 21 hour soak	CAS; 6 @ 50mm – 60mm TL, CSU; 1 62mm FL
T4	MT	Site #4 350m downstream of side channel inlet. 1 MT was set. 21hour soak	CAS; 9 @ 50mm – 60mm TL, CSU; 1 65mm FL

1. The side channel was isolated from the Reservoir at the time of assessment. The Reservoir level was approximately 2 m below Greenslide channel upstream inlet.
2. Fork length
3. Total length

Refer to Figure 2.2-1 for location of site

Table A2-4. Summary of the results from the September 23-25, 2013 surveys at the Highway Bridge site

Site	Sampling Method[1]	Description of Survey Transects at Highway Bridge Site	Results
Evening of Sept 23 2013			
T1	EF	Transect #1 between Highway bridge and CP Rail bridge: 25m Transect with gravel dominated substrates. One isolated pool, 25m^2, just downstream of RB Hwy bridge pier; 35 sec.	CAS; 1 67mm total length
T2	EF	Transect #2 between Highway bridge and CP Rail bridge: 40 m transect with gravel dominated substrates. Main large pool, 100m^2; 330 sec.	No fish caught or observed
T3	EF	Transect #3 between Highway bridge and CP Rail bridge: 20 m transect with gravel dominated substrates. No isolated pools present.	No fish observed
T4	EF	Transect #4 between CP Rail bridge and single lane bridge: 30 m transect along the base of the CN bridge piers. 2 small isolated pools around the pier bases, 15m^2 combined area; 94 sec	No fish caught or observed
T5	EF	Transect #5 between CP Rail bridge and single lane bridge: 50 m transect along shallow shore dominated by gravel and cobble. 3 small isolated shallow pools, 25m^2 combined area; 257 sec	No fish caught or observed
Afternoon of Sept 24 2013			
T1	EF	Transect #1 between Highway bridge and CP Rail bridge: 25m Transect with gravel dominated substrates. One isolated pool, 25m^2, just downstream of RB Hwy bridge pier; 30 sec	No fish caught or observed
T2	EF	Transect #2 between Highway bridge and CP Rail bridge: 40 m transect with gravel dominated substrates. Main large pool, 100m^2; 650 sec	No fish caught or observed
T3	EF	Transect #3 between Highway bridge and CP Rail bridge: 20 m transect with gravel dominated substrates. 2 small isolated pools present; 45 sec	No fish caught or observed
T4	EF	Transect #4 between CP Rail bridge and single lane bridge: 30 m transect along the base of the CN bridge piers. 2 small isolated pools around the pier bases, 15m^2 combined area; 80 sec	No fish caught or observed
T5	EF	Transect #5 between CP Rail bridge and single lane bridge: 50 m transect along shallow shore dominated by gravel and cobble. 3 small isolated shallow pools, 25m^2 combined area; 170 sec	No fish caught or observed

[1] EF: Electrofishing

Refer to Figure 2.2-2 for location of site

Table A2-5. Summary of the results from the October 16 to 18, 2013 minnow trapping at Greenslide side channel.

Site	Sampling Method[1]	Description of Sample Site at Greenslide side channel[1]	Results
October 16/17 overnight set			
T1	MT	Site #1 50m downstream of side channel inlet. 1 MT was set. 23 hour soak	CAS; 1 @ 37mm TL[2]
T2	MT	Site #2 250m downstream of side channel inlet. 1 MT was set. 23 hour soak	No fish caught or observed
T3	MT	Site #3 300m downstream of side channel inlet. 1 MT was set. 23 hour soak	No fish caught or observed
T4	MT	Site #4 350m downstream of side channel inlet. 1 MT was set. 23 hour soak	No fish caught or observed

1. The side channel was isolated from the Reservoir at the time of assessment. The Reservoir level was approximately 2.3 meters below Greenslide channel upstream end. Since the September trip, the water level in the side channel has dropped approximately 0.18m and
2. Total length

Refer to Figure 2.2-1 for location of site.

Table A2-6. Summary of sampling effort and results for Oct 16-17, 2013 sampling at the Begbie site

Site	Sampling Method[1]	Sampling Effort (EF = s; MT = hr)	Area (m^2)	Fish caught:[2,3] fork length (mm)	Description
Pool 1	EF	173	40	KO: 62, 64, 59	Gravel and cobble dominated substrates upstream of side channel area. Pool likely doesn't completely dewater.
Pool 2	EF	330	50	NFC	Gravel and cobble dominated substrates just downstream of Pool 1.
Pool 2	MT	72	50	NFC	Gravel and cobble dominated substrates just downstream of Pool 1. Pool was dry at the time of MT retrieval 18 hours after set time.
Pool 3	EF	105	80	CAS: 43 mm	Larger gravel dominated pool 15 m downstream of Pool 2. Still connected during field work via shallow riffle. Likely will isolate but will stay wetted.
Small pool 1	EF	35	5	NFC	Cobble/gravel substrate with no LWD. Likely to dewater completely.
Small pool 2	EF	28	6	NFC	Cobble/gravel substrate with LWD present. Likely to dewater completely.
Small pool 3	EF	47	8	NFC	Gravel dominated with some fines. LWD present. Likely to dewater completely.
Small pool 4	EF	78	9	CSU: 57mm, 42mm, CCG: 39mm	Fines dominated pool, likely to dewater completely.
Small pool 5	EF	35	6	NFC	Gravel and cobble pool and channel that become isolated and pose a high risk for stranding and mortality. Pool is approximately 0.25 m deep
Transect	VO	Duration 1 hour	8,000	**2 RSC**	Surveyed throughout the general dewatered area – approximately 8000 m^2. The 2 observed RSC mortalities were stranded immediately downstream of Pool 2 between the hours of 20:00 and survey time of 23:00 to 23:59, Oct 16, 2013. Flows had been at 400 m^3/s for approximately 2 hours.

[1] EF: Electrofishing; MT: Minnow trap; NFC: No Fish Caught.

[2] **Bolded** fish records are mortalities as a result of stranding.

[3]CAS: Prickly Sculpin; CSU: Largescale Sucker; RSC: Redside Shiner. Total length in mm measured for sculpin (CAS) fork length in mm measured for remainder of species captured.

Table A2-7. Summary of the results from the October 16, 2013 sampling at Highway Bridge Site.

Site	Sampling Method[1]	Description of Sample Site at Hwy Bridge Site	Results
Afternoon of October 16 2013			
T1	EF	Transect # between Highway bridge and CP Rail bridge: 40 m transect with gravel dominated substrates. Main large pool, 100m^2; 1282 sec.	CAS; 1 @ 31 mm TL[2]
T2	EF	Transect #2 was the two isolated pools at the CP bridge piers. Pier 1, 104 sec, Pier 2, 33 sec	NFC at Pier 1; KO, 255mm FL female, spawned out caught at Pier 2. Released in MCR.
T3	EF	Transect #3 between CP Rail bridge and single lane bridge: 50 m transect along shallow shore dominated by gravel and cobble. No other isolated pools observed.	No fish caught or observed

Refer to Figure 2.1-1 for location of sites.

APPENDIX 3

SITE SUMMARY COMMENTS FROM THE 2009, 2011 AND 2013 RECONNAISSANCE SURVEY

Table A3.1. Site summary comments from the 2009, 2011 and 2013 reconnaissance surveys

Site	Location	UTM	Risk of Standing	2009 Comment	2011 Comment	2013 Comment
Greenslide	left margin	11.421053. 5639001	low	Broad channel dominated by fine substrates and vegetated by grass in several locations. No sign of scour or evidence of flow. No functional cover for fish observed. No defined inlet or outlet. Likely inundated from downstream end as reservoir fills. Does not pose a stranding risk under current flow regime because is not regularly wetted and dewatered.	Dry at time of survey (May 24)	The channel morphology and substrate characteristics are unchanged since 2009. During Sept surveys, the channel was completely isolated from the ALR. The elevation of the reservoir was approximately 2 m below the inlet of Greenslide channel. Fish were captured during sampling and released into the mainstem/reservoir. Remaining fishes will most likely not survive through to spring 2014 when the ALR will inundate the channel again. During surveys conducted in October, water levels had dropped approximately 18 cm with the remaining water being fractured into isolated shallow pools. Fishes captured were released into the mainstem. Remaining fishes will likely not survive through the winter.
1	left margin	11.415435. 5646920	low	Channel >20 m wide and >2 m deep. Upstream end dewaters at daily low flow but downstream remains connected. Large, deep pool would provide stable habitat, and dissolved oxygen (DO) and temperature likely not an issue during periods of low flow. Low stranding risk.	Conditions similar to 2009. Risk of stranding still considered to be low	Conditions similar to 2009. Risk of stranding still considered to be low

Site	Location	UTM	Risk of Standing	2009 Comment	2011 Comment	2013 Comment
2	right margin	11.415042. 5346327	low	Upstream end of site dewaters at low flows but downstream end remains connected due to discharge from Griffith Creek. Large, deep pool at upstream end would provide stable habitat, and DO and temperature likely not an issue. Low stranding risk.	Conditions similar to 2009. Risk of stranding still considered to be low	Conditions similar to 2009. Risk of stranding still considered to be low
3	right margin	11.415582. 5644960	low	Upstream end of site dewaters at low flows but downstream end remains connected due to deep bedrock controlled channel. Deep channel would provide stable habitat, and DO and temperature likely not an issue. Low stranding risk.	Conditions similar to 2009. Risk of stranding still considered to be low	Conditions similar to 2009. Risk of stranding still considered to be low
4 (Begbie Creek Gravel Bar)	right margin	11.416045. 5644451	high	High stranding risk due to several channels and pools that become isolated and dewatered daily during low flow periods. Presence of functional large woody debris (LWD) cover in some pools could increase potential for fish use.	Still considered high risk for stranding due to large area of low-gradient shoreline with frequent depressions that can form isolated pools. LWD still present (Photos 1 to 4)	Similar to 2009, there is a high stranding risk due to several channels and pools that become isolated and dewatered daily during low flow periods. Presence of functional large woody debris (LWD) cover in some pools could increase potential for fish use.

Site	Location	UTM	Risk of Standing	2009 Comment	2011 Comment	2013 Comment
5	left margin	11.417216. 5643487	low	Defined channel with continuous discharge as a result of ponding and tributaries (Montana Creek) located upstream. Good connectivity to river even at low discharge due to flow. Low stranding risk.	Conditions similar to 2009. Risk of stranding still considered to be low	Conditions similar to 2009. Risk of stranding still considered to be low
6	right margin	11.418120. 5640796	low	Channel >20 m wide and >2 m deep. Upstream and downstream likely remains connected even at low flows. Low stranding risk.	Conditions similar to 2009. Risk of stranding still considered to be low	Conditions similar to 2009. Risk of stranding still considered to be low
7	left margin	11.418943. 5640159	low	Wide channel that potentially dewaters at upstream end but likely remains connected at downstream end. Width and depth of channel suggest DO and temperature likely not an issue. Low stranding risk.	Conditions similar to 2009. Risk of stranding still considered to be low	Conditions similar to 2009. Risk of stranding still considered to be low
8	right margin	11.420435. 5636092	low	Main part of side channel has a waterfall tributary that would prevent dewatering at downstream end. Large pond connected to the side channel via a 20 m long 0.65 m deep channel likely remains connected due to depth of channel. No functional cover within the pond. Low stranding risk.	Conditions similar to 2009. Risk of stranding still considered to be low	Conditions similar to 2009. Risk of stranding still considered to be low

Site	Location	UTM	Risk of Standing	2009 Comment	2011 Comment	2013 Comment
9	left margin	11.423294. 5634203	low	Broad channel dominated by fine substrates with no sign of scour or evidence of flow. No functional cover for fish observed. No defined inlet or outlet. Likely inundated from downstream end as reservoir fills. Does not pose a stranding risk under current flow regime because channel is not regularly wetted and dewatered. Low stranding risk.	Conditions similar to 2009. Risk of stranding still considered to be low	Conditions similar to 2009. Risk of stranding still considered to be low
Highway Bridge Gravel Bar	right margin	11.414418. 5651054	high	Area not assessed in 2009.	High stranding risk due to presence of large area of low gradient with several large pools that become isolated and dewatered daily during low flow periods. Presence of functional large woody debris (LWD) and mix of small and coarse substrates could increase potential for fish use.	Similar to 2011, the is a high stranding risk due to presence of large area of low gradient with several large pools that become isolated and dewatered daily during low flow periods. Presence of functional large woody debris (LWD) and mix of small and coarse substrates could increase potential for fish use.

APPENDIX 4

ADDITIONAL REVELSTOKE DAM TEN-MINUTE DISCHARGE CHARTS FROM THE HIGHWAY BRIDGE SITE FOR THE 2013, 2011, AND 2010 SAMPLE SEASONS

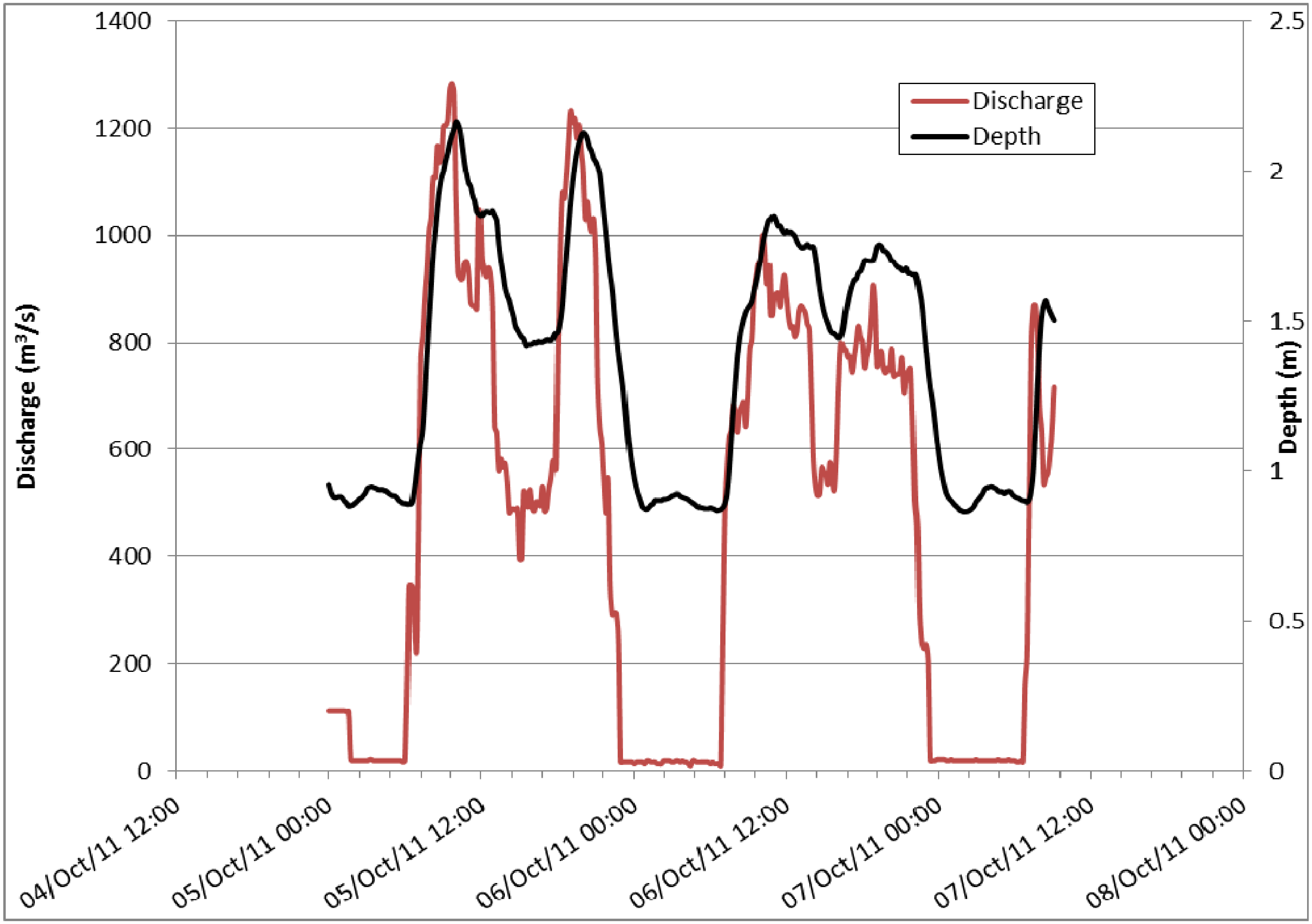

Figure A4-1. Ten-minute mean discharge from the Revelstoke Dam and water levels at the Highway Bridge site during field assessments (Oct 4 – 8, 2011)

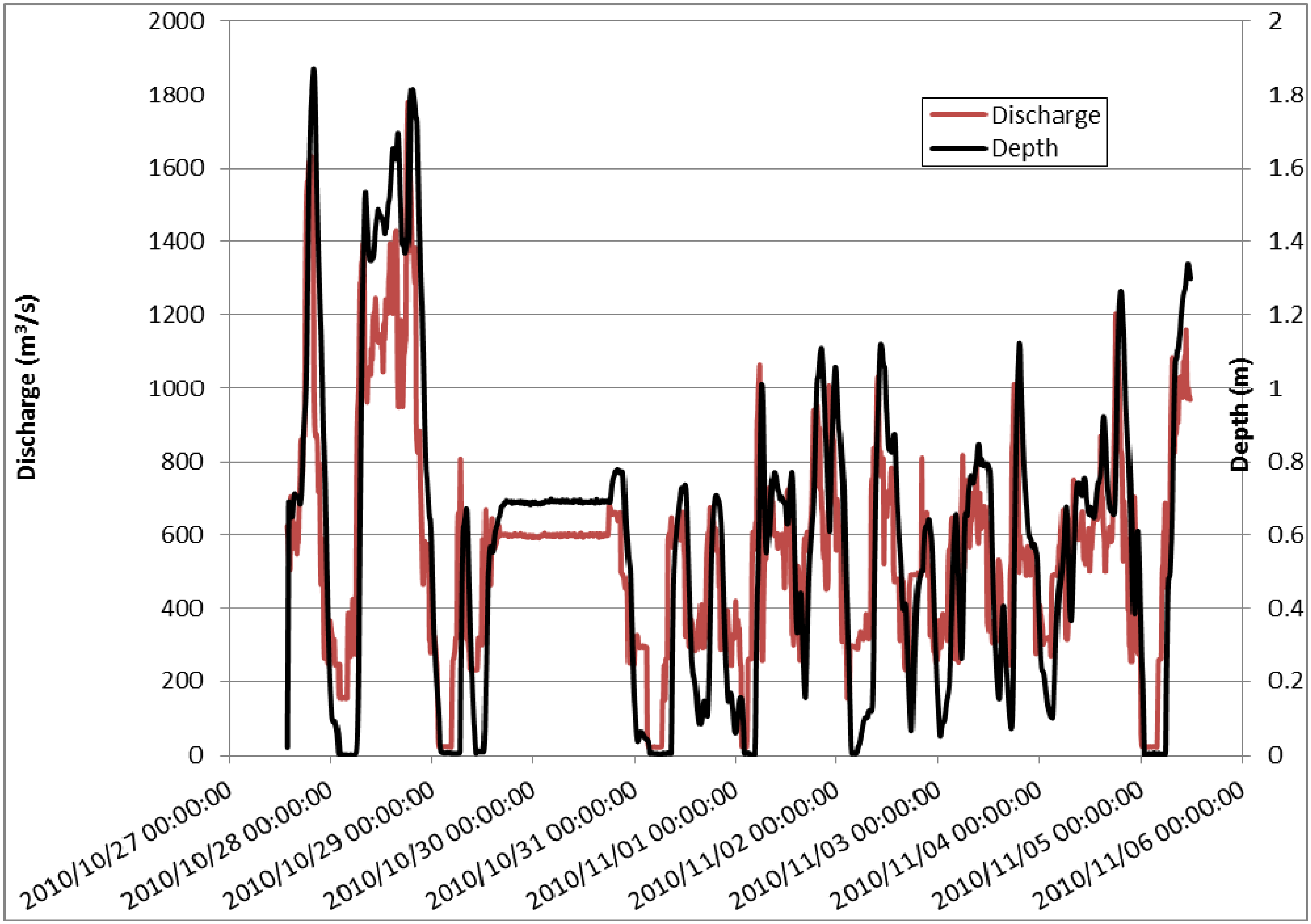

Figure A4-2. Ten-minute mean discharge from the Revelstoke Dam and water levels at the Highway Bridge site during field assessments (Oct 27 – Nov 6, 2010)

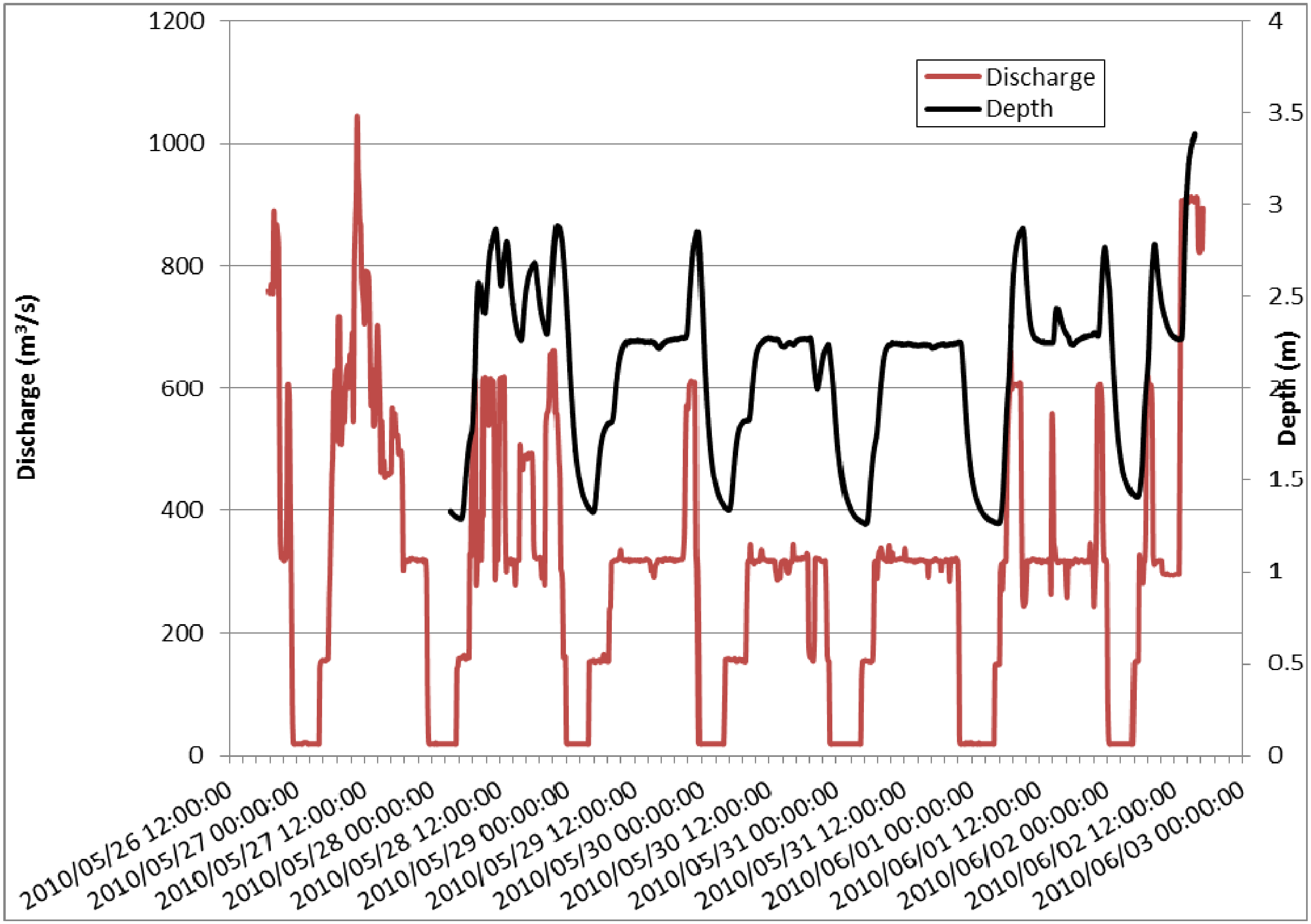

Figure A4-3. Ten-minute mean discharge from the Revelstoke Dam and water levels at the Highway Bridge site during field assessments (May 26 – June 3, 2010)