Columbia River Project Water Use Plan

Middle Columbia River Juvenile Fish Stranding Assessment (Year 3 of 4)

Reference: CLBMON#53

Columbia River Water Use Plan Monitoring Program:
Middle Columbia River Juvenile Fish Stranding Assessment

Study Period: 2011-2012

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MIDDLE COLUMBIA RIVER JUVENILE FISH STRANDING ASSESSMENT

CLBMON-53 – 2011 REPORT (YEAR 3 OF 4)

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Executive Summary

This report summarizes the Year 3 results of a multi-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 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 2 years of pre-Rev 5 data collection as well as 2 years of post-Rev 5 data collection, with this report representing the first year of post-Rev 5 data collection.

Year 3 of the study involved water level monitoring of the Greenslide side channel site as well as sampling and water level monitoring at the Year 1 site (Begbie Creek gravel bar – June 1-2, 2011), and Year 2 site (Highway Bridge gravel bar – October 5-6, 2011). Pressure transducers were installed at all three 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 side channel 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 mortalities of fish at the site associated with dewatering would be the result of ALR operation as opposed to Revelstoke Dam operation.

In Year 3, prolonged, high ALR elevation was thought to have a mitigative effect on the risk of stranding at each of the three sites. In general, as the ALR elevation increases, water levels at the sites fluctuate less in response to changes in dam discharge. Further the effect of the ALR increases with distance from the dam. In Year 3, the ALR resulted in reduced stranding risk for approximately 75% of the growing season (May – September) at each of the three sites monitored. Further, discharge form the dam in Year 3 (post-Rev 5) was not found to differ substantially from that of Years 1 and 2 (pre-Rev 5). General findings from Years 1 – 3 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 they are noticeable at the Begbie Creek gravel bar site (located 12 km downstream of the dam). Water level changes associated with the dam are negligible at the Greenslide Creek site 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. Further, the presence of increased numbers of young-of-year and spawning fish in the system in the fall can increase the likelihood that water level changes will effect fish 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 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.

Year 4 will be the last year of the study and if possible it is recommended to time sampling to coincide with a time when the ALR is forecasted to remain low and when dam discharge will differ from that of pre-Rev 5 conditions.

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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 flood plain (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). Specifically, the Greenslide Creek side channel located 25 km downstream of the Revelstoke Dam was identified as an area that experiences rapid channel shifting and therefore poses a risk to fish stranding (BC Hydro 2009).

1.1 Management Objectives, Questions, and Hypotheses

The primary objective of this program, as outlined in the Request for Proposal (RFP) is:

> to assess the risk of fish stranding in a discrete portion of the Columbia River potentially influenced by the forecasted operations 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 fish and collect relevant data on these fishes in the Greenslide Creek 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 to be 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 REV5?*

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 REV5?*

4. *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-REV5 and post-REV5 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 3 (post-Rev 5) results and provides recommendations for future years of the study. Details on Year 1 and 2 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*).

2.0 Methodology

Year 3 was the first of the post-Rev 5 sampling events, and sampling 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 Year 1 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 reconnaissance survey, fish sampling to quantify stranding risk was proposed to be completed at the Year 1 sample site located on a right margin gravel bar complex approximately 600 m upstream of Begbie Creek. As in Year 1, sampling of the site was to be completed in both spring and fall. However, due to prolonged high ALR elevations in 2011, only the spring sampling could be completed at the site. Therefore, the fall sampling had to be completed at the Year 2 site (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. The assessment at the sites occurred at night and involved electrofishing (Begbie) and surveys of recently dewatered areas to locate stranded fish (Begbie and Highway bridge site). Water level loggers were also installed at both locations to quantify the degree and rate of dewatering at each site.

Lastly, as in Year 1 and 2, the Greenslide Creek side channel water levels were monitored because this was the site specifically identified for sampling in the RFP (BC Hydro 2009). Observations of the site were made throughout the spring, summer, and fall to assess seasonal stranding risk, and a water level logger was installed in the fall to document the rate of dewatering (changes in water levels per hour).

A chronology of field activities for Year 3 of the study is provided in Table 2-1, and a detailed description of the field work conducted is provided in the following sections.

[1] The Highway 1 Bridge was identified in the Terms of Reference (BC Hydro 2009) as the upstream limit of survey for the study.

Table 2-1: Chronology of field activities associated with the 2011 fish stranding program

Activity	Date
Reconnaissance Survey	May 24, 2011
Begbie Creek site	
Sampling and transducer (water level logging)	June 1–3, 2011
Highway bridge site	
Visual surveys for fish	October 5–7, 2011
Transducer (water level logging)	
Greenslide Creek side channel	
Transducer (water level logging)	October 5–7, 2011

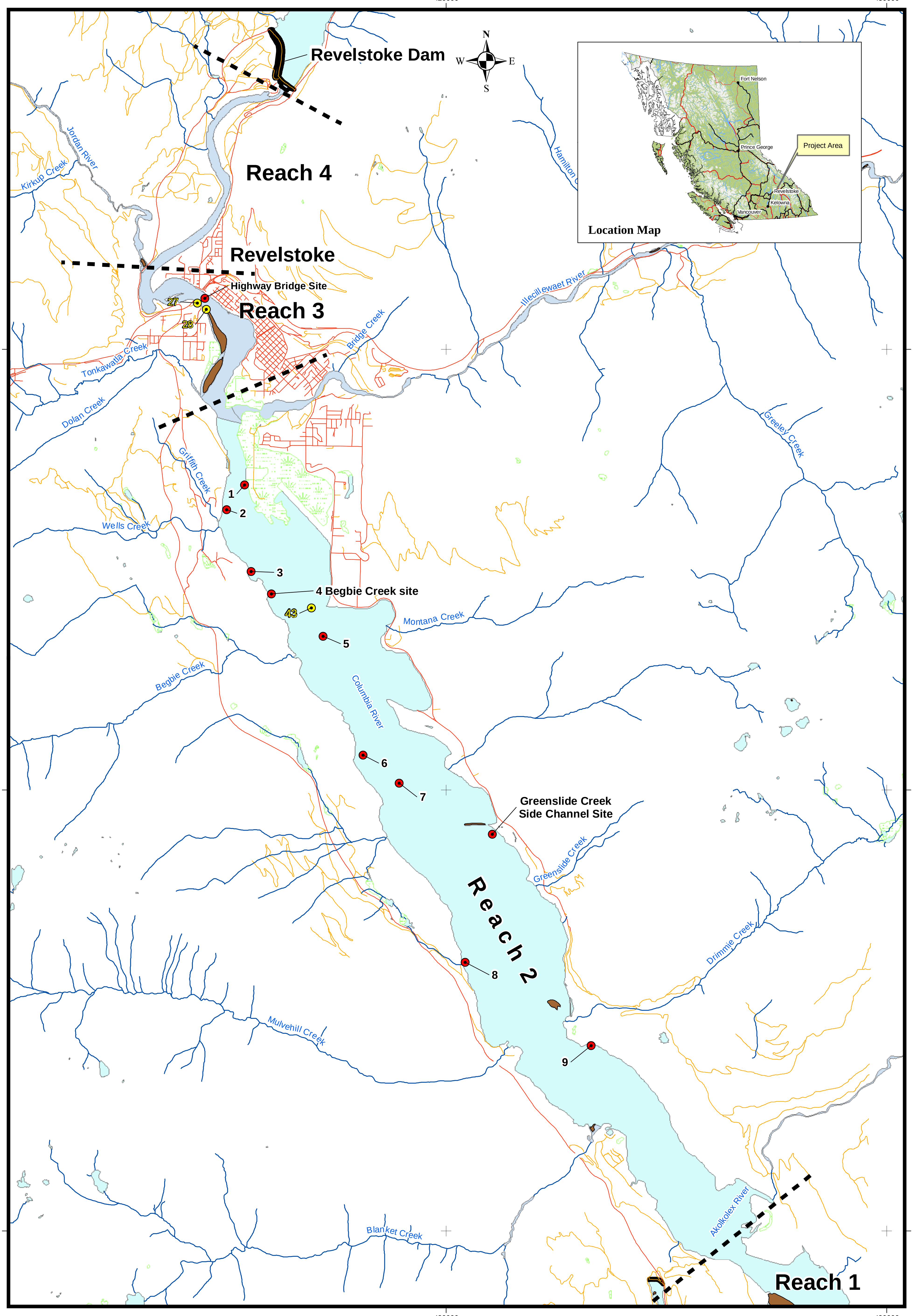
2.1 Field Surveys

2.1.1 Reconnaissance Survey

A reconnaissance trip was completed during the day on May 24, 2011 to revisit each of the 10 sites originally assessed during the reconnaissance surveys in Year 1 (2009) (Figure 2-1). During the Year 1 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 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 such that a regular cycle of watering and dewatering would be expected?

The goal of the reconnaissance survey in Year 3 was to confirm that the Year 1 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 assessed by boat, with the crew completing surveys by foot at the sites, as required.



MIDDLE COLUMBIA FISH STRANDING

Figure 2-1. - Overview of study area.

NO.	DATE (yyyy/mm/dd)	REVISION	BY
1	2011/12/15	Rev. 2	SA

0 500 1,000 2,000 3,000 4,000 Meters

Scale: 1:80,000

Legend

- Reconnaissance Trip Sites
- Juvenile Fish Sampling Sites for CLBMON#17

Basemap Source: 1:20,000 CWB & TRIM Data

Map Datum: UTM NAD 83 Zone 11

Project No: 4472

File No: N:\ACTIVE\4472_Middle_Columbia_Fish_Stranding_2011\MXD\Loaction_Fig1_11x17_2011.mxd

Date: Dec 15, 2011

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2.1.2 Sites Descriptions

Begbie Creek Site – spring sampling site

The Begbie Creek site was identified during the Year 1 reconnaissance survey as having the highest potential for stranding among the sites surveyed. The site is located approximately 12 km downstream of the Revelstoke Dam. The site consists of a low-gradient gravel and cobble dominated bar with multiple channels and depressions that could result in fish stranding. Two large pools containing large woody debris (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 1–4). Stranding risk at the site was considered to be high due to the size of the area that can dewater, frequency of depressions in which fish can become trapped, and habitat complexity.

Highway Bridge Site – fall survey site

The study site selected in Year 2 was 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). The site is approximately 6 km downstream of the Revelstoke Dam. 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):

- *Area #1* is located between the Highway bridge and the CP Rail bridge. This area 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 frequency of depressions in which fish can become trapped.
- *Area #2* is located between the CP Rail bridge and the single lane bridge. This area is characterized by a steeper shoreline (5–10 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 fish as water levels recede. Stranding risk is considered to be moderate due to steeper slopes and fewer depressions than 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.

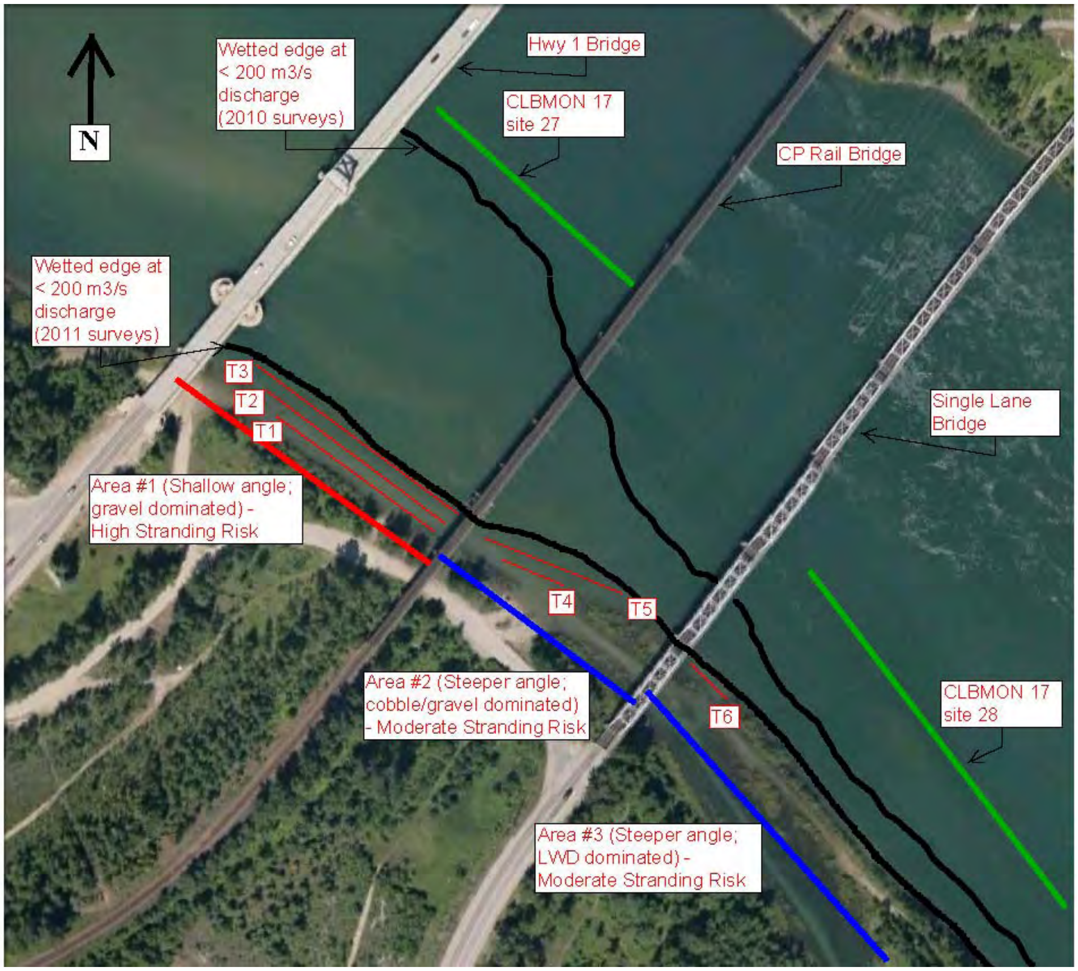

Figure 2-2: Overview of the Highway 1 gravel bar site. Numbers identify transect survey sites completed in 2011. The approximate wetted edge (2010 and 2011) is shown for comparison. CLBMON-17 sites are associated with a separate juvenile index sampling program completed in the spring, summer and fall of 2008-2013.

<u>*Greenslide Creek Side Channel*</u> – fall survey site

The Greenslide Creek side channel is a broad, U-shaped depression (Figure 2-3) on the left side of the river (when facing downstream) approximately 24 km downstream of the Revelstoke Dam. This site was specifically identified for monitoring in the RFP (BC Hydro, 2009) and therefore has been included in the field assessments in each of the first three years of study. It is dominated by fine substrates and it dewaters completely through the winter. In 2009 and 2011 (Years 1 and 3 of the study) the channel was dewatered in May, rooted vegetation was present throughout the channel, and there were no signs of scour or recent flow (Appendix 1: Photo 5). In 2010 (Year 2 of the study) the site became wetted at the end of April. As the ALR elevation increases in the spring, the channel becomes wetted from its downstream end and becomes fully inundated by the reservoir during the summer months (Appendix 1: Photo 6). When wetted, cover is limited to that provided by flooded vegetation, and there is limited habitat complexity. The channel dewaters over the winter and is dry by early spring. Results from Year 1 and 2 of the program showed that conditions at the Greenslide site are influenced by the seasonal changes in ALR elevation as opposed to daily flow changes associated with operation of the Revelstoke Dam. As a result stranding risk associated with the dam is considered low.

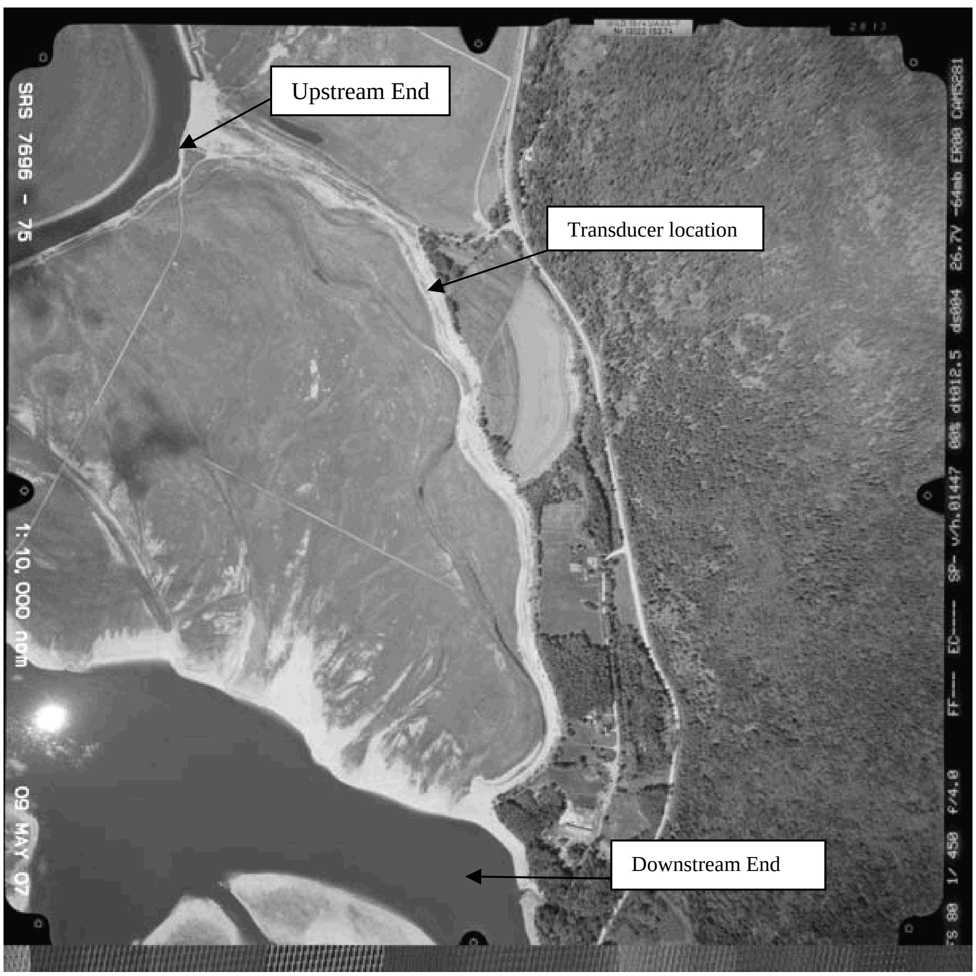

Figure 2-3: Overview of the Greenslide Creek side channel site showing transducer location

2.1.3 Water Level Loggers

Water depths at the Begbie Creek site (June 1–3, 2011), Highway 1 gravel bar site (September 7–October 7, 2011), and Greenslide Creek side channel (October 5–7, 2011) were continuously monitored using OnSet® HOBO water level loggers with an accuracy of +/- 2 cm over a range of 0–9 m. Two loggers were installed at each site: one was submerged in an area expected to remain continuously wetted, the second was installed above water level to collect baseline barometric pressure data which were later used to correct water level data. 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. Figure 2-3 shows the location of the transducer at the Greenslide Creek side channel site. At the Begbie Creek site, the transducer was installed along a bedrock outcrop at the downstream end of the site. At the Highway bridge site, the transducer was installed on the rip-rap bank underneath the bridge on the east side of the river.

2.1.3.1 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 are reduced to near zero during the night when the turbines are typically shut down. The lower the daily minimum discharge and the faster the rate of dewatering, the higher the stranding risk. 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.

2.1.4 Fish Sampling

Table 2-2 provides a summary of the fish sampling completed at each of the monitoring sites during years 1 to 3 of CLBMON-53.

Table 2-2. Summary of fish sampling by site for Years 1 – 3 of CLBMON-53.

Site	Year 1 (2009)	Year 2 (2010)	Year 3 (2011)
Greenslide Creek Side Channel	X	X	
Begbie Creek Gravel Bar	X		X
Highway Bride Gravel Bar		X	X

2.1.4.1 Greenslide Creek Side Channel

Fish sampling in the Greenslide Creek side channel could not be completed in 2011. During the May reconnaissance survey the channel was dry, but by the first sampling event in June, the ALR had already inundated the site. The site remained inundated through October. Water level data were collected at the site in 2011, and fish sampling was completed in both 2009 and 2010 (Sykes and Liebe 2010*a*, 2011*a*).

2.1.4.2 Begbie Creek Gravel Bar

Fish sampling at the Begbie Creek site (June 1–2 2011) 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 of exposed gravel bars that had previously been wetted were conducted to detect the presence of stranded fishes. Wherever possible, the crew sampled the same sites originally sampled in 2009. Fish carcasses on exposed gravel bars were documented as mortalities. Fishes captured in shallow, isolated pools that were likely to dewater later were also considered to be mortalities. Data recorded included site location, date, set and retrieval time for traps, depth of traps, and habitat. Captured fishes were enumerated and identified to species, fork lengths were measured, and they were released.

2.1.4.3 Highway Bridge Gravel Bar

Fish sampling could not be conducted at the Highway bridge gravel bar during the October 5–7, 2011 survey because the fish collection permit issued by the B.C. Ministry of Forests, Lands, and Natural Resource Operations stated that electrofishing was not permitted after September 15 in streams that contain Bull Trout. As a result, the crew was limited to completing visual surveys of exposed gravel bars that had previously been wetted. A total of six transects with an approximate width of 3 m each were surveyed. Transects 1–3 were located in Area #1 (Highway bridge to CP Rail bridge), while transects 4 and 5 were located in Area #2 (CP Rail bridge to single lane bridge) (Figure 2-2). Only one transect (6) could be competed in Area #3 since most of that area remained inundated throughout the sampling period.

2.2 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.

2.3 Reporting

Fish species codes used in this report and in the associated database follow those outlined in the *Fish Collection Methods and Standards* (B.C. Ministry of Environment, Lands and Parks 1997), and are summarized in Table 3-2.

3.0 Results

3.1 Reconnaissance Survey

The reconnaissance trip showed that, in general, the results of the 2009 assessment (Table 3-1) were still accurate and that conditions at the identified sample sites were still appropriate to assess stranding (see section 2.1.1 for assessment criteria). No new side channel sites were identified, and there were no observations of new areas being flooded under the Rev 5 flow regime.

Table 3-1: Site summary from the 2009 and 2011 reconnaissance surveys. Refer to Figure 2-1 for locations.

Site	Location	UTM	Risk of Standing	2009 Comment	2011 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)
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
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
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
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 1–4)

Site	Location	UTM	Risk of Standing	2009 Comment	2011 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
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
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
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
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
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.

3.2 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 (Table 3-2). Prickly Sculpin, Redside Shiner, Mountain Whitefish and Kokanee are the species most commonly captured (Sykes and Liebe, 2009, 2010*b*, 2011*b*).

Table 3-2: 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*

Several CLBMON-17 sample sites overlap the fish stranding sites. Specifically, sites 27 and 28 of CLBMON-17 overlap the Highway bridge fish stranding sampling site. Site 27 is located between the Highway bridge and the CP Rail bridge (Area #1; Figure 2-2); site 28 is located downstream of the single lane bridge (Area #3; Figure 2-2). Site 43 of CLBMON-17 is in the same general area as the Begbie Creek site.

A review of the CLBMON-17 data from 2008 to 2011 showed that 52 fishes of eight different species were caught at site 43 in the vicinity of the Begbie Creek site during spring sampling (Table 3-3). Slightly more than half of them were juveniles (54 per cent). Prickly Sculpin was the most commonly encountered species. Other species frequently encountered included Mountain Whitefish, Redside Shiners, and Peamouth Chub. Additional sport fish species encountered included Rainbow Trout and Kokanee.

At site 27 a total of 204 individuals of five species were captured during the fall sampling. Most of these were juveniles (79 per cent). Prickly Sculpins and Mountain Whitefish dominated the catch at the site; other species encountered were Burbot, Bull Trout, and Kokanee.

At site 28 a total of 119 individuals of nine species were captured. Only 28 per cent of the catch was comprised of juveniles; however, the data are slightly skewed by the presence of adult Kokanee (representing 53 per cent of the catch), which spawn in the area in the fall. Coarse fish species captured included Prickly Sculpin, Redside Shiner, and Yellow Perch while sport fish included Mount Whitefish, Brook Trout, Rainbow Trout, Burbot and Bull Trout.

Table 3-3: Fishes captured by boat electrofishing as part of CLBMON-17 (2008–2011) in the vicinity of the 2011 fish stranding site. J = juvenile, A= adult. Refer to Table 3-2 for species codes and to Figure 2-1 for approximate location of sites.

CLBMON-17 Site #	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)	Total (J/A)
May												
43 (Begbie)			6/17	1/0	7/0		3/0	3/6	2/0	6/0	0/1	28/24
September												
27 (Highway Area #1)	1/0	3/0	66/33	7/8	84/2							161/43
28 (Highway Area #3)	1/0	1/2	3/28	12/58	4/0	2/0	5/0	0/1	2/0			30/89

3.3 Water Level Monitoring

3.3.1 Begbie Creek Site

Figure 3-1 shows 10-minute mean discharge from the Revelstoke Dam and recorded water levels at the Begbie Creek site for June 1–3, 2011. In general, discharge during the sampling period remained relatively low. The minimum discharge of 22.8 m^3/s occurred on June 2 between 1:20 p.m. and 3:50 p.m., while the maximum (399.4 m^3/s) occurred on June 1 at 10:10 p.m. Water depths at the site ranged from a maximum of 1.08 m on June 2 at 6:58 p.m. to a low of 0.81 m on June 2 at 3:58 a.m., a variation of 0.27 m. The maximum dewatering rate during the period was 7.9 cm/h. By comparison, during the 2009 surveys at the same site, daily maximum discharges typically exceeded 1200 m^3/s, while daily minimums were typically close to 0 m^3/s. The maximum dewatering rate recorded at the site on May 28/29, 2009 was 18 cm/h (Sykes and Liebe, 2010*a*). Comparison of the discharge data and water level data from 2009 and 2011 suggests a lag time of approximately three hours between dam discharge and observed changes in water level 12 km downstream at the Begbie Creek site. The reduced influence of the Revelstoke Dam on water levels at the Begbie Creek site in 2011 can be attributed to a combination of discharge remaining low through the day and the ALR influence on the site. Therefore, the risk of stranding at the site will be greater when the daily fluctuations in Revelstoke Dam discharge are greater and in years where the period of ALR influence on the site is shorter. In 2009 the ALR inundated the site for a total of 121 days, compared to 147 days in 2010, and 185 days in 2011 (see Section 3.4).

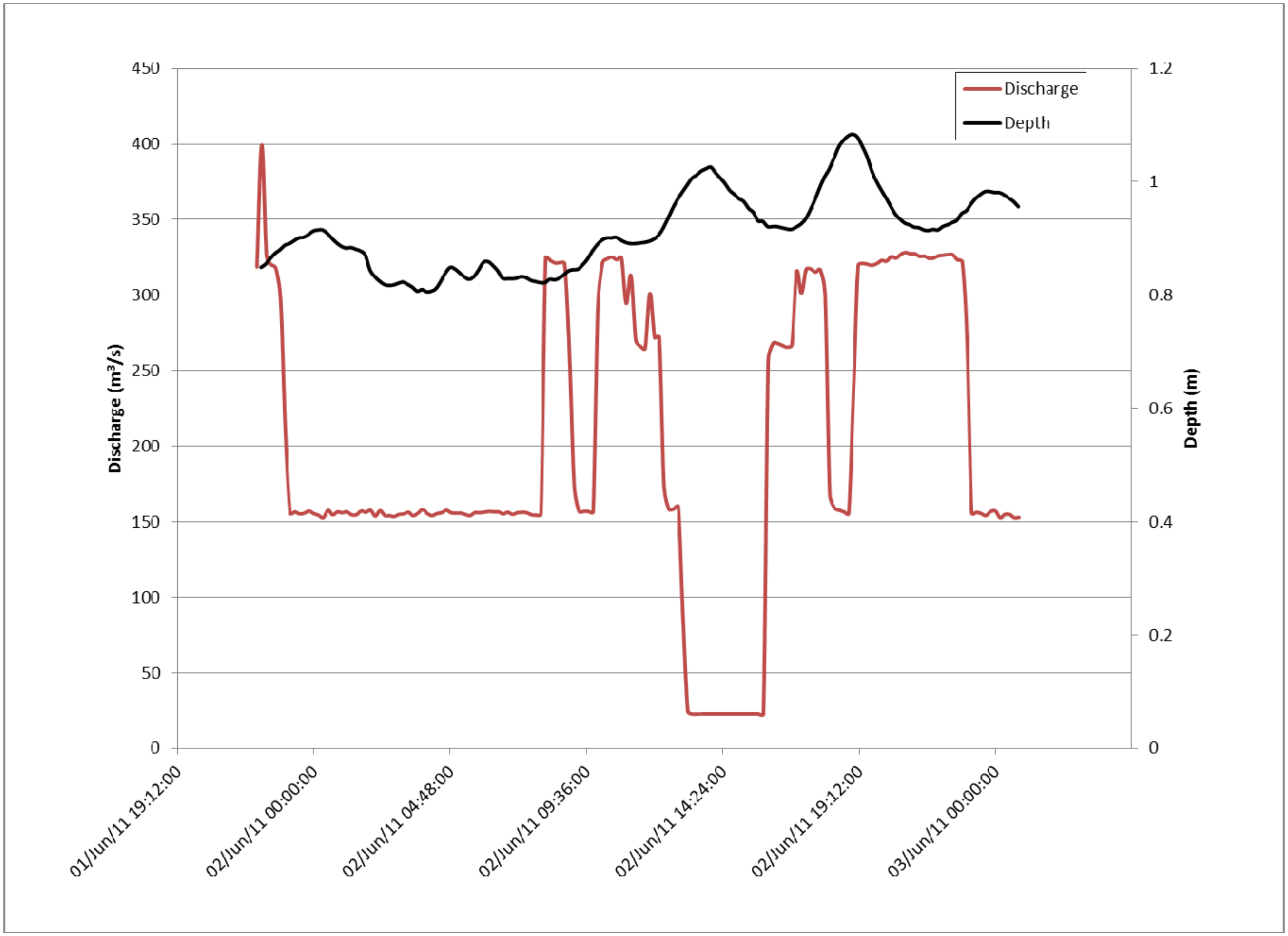

Figure 3-1: Ten-minute mean discharge from the Revelstoke Dam and water levels at the Begbie Creek site (June 1–3, 2011)

3.3.2 Highway Bridge Site

Figure 3-2 shows 10-minute mean discharge from the Revelstoke Dam and recorded water levels at the Highway bridge site for September 7–October 7, 2011. During that period, the discharge ranged from a maximum of 1,769 m^3/s on September 23 (10:40 a.m.) to a low of 9.3 m^3/s on October 6 (6:50 a.m.). During the period when fish surveys were completed (October 5–7, 2011), the discharge ranged from a maximum of 1,231 m^3/s to a low of 9.3 m^3/s. Water depths at the site ranged from a high of 2.5 m on October 2 at 7:40 p.m. to a low of approximately 0.75 m on September 25 at 4:20 a.m. The maximum dewatering rate during the sampling period was 27 cm/h. The estimated lag time between dam discharge and observed changes in water level at the site was approximately 20 minutes. By comparison, in October 2010, the discharge from the Revelstoke Dam ranged from a high of 1,193 m^3/s to a low of 20.8 m^3/s during the sampling period (October 4–6, 2010). During the same period, water depths at the site 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 during the 2010 sampling period was 132.5 cm/h (Sykes and Liebe, 2011*a*). Figure 3-3 shows the discharge and water level during the period when field surveys were completed (October 5-6, 2011).

Photos 7 and 8 (Appendix 1) show an overview of the Highway bridge site in 2011 at discharges of 800 m^3/s and 200 m^3/s, respectively. The minimal change in water level that resulted from the change in discharge can be attributed to the influence of the ALR on the site. By comparison, Photos 9 and 10 show the same site on October 3, 2010 at discharges of 1,000 m^3/s and 400 m^3/s, respectively. During that year, the ALR had already receded below the site; consequently, the fluctuation in water level that resulted due to discharge changes resulted in a much larger area becoming dewatered. Therefore, Revelstoke Dam discharge does influence stranding risk at the site due primarily to its proximity and the short lag time between changes in discharge at the dam and changes in water level at the site. In 2009 the ALR inundated the site for a total of 104 days compared to 112 in 2010 and 180 in 2011 (see section 3.4).

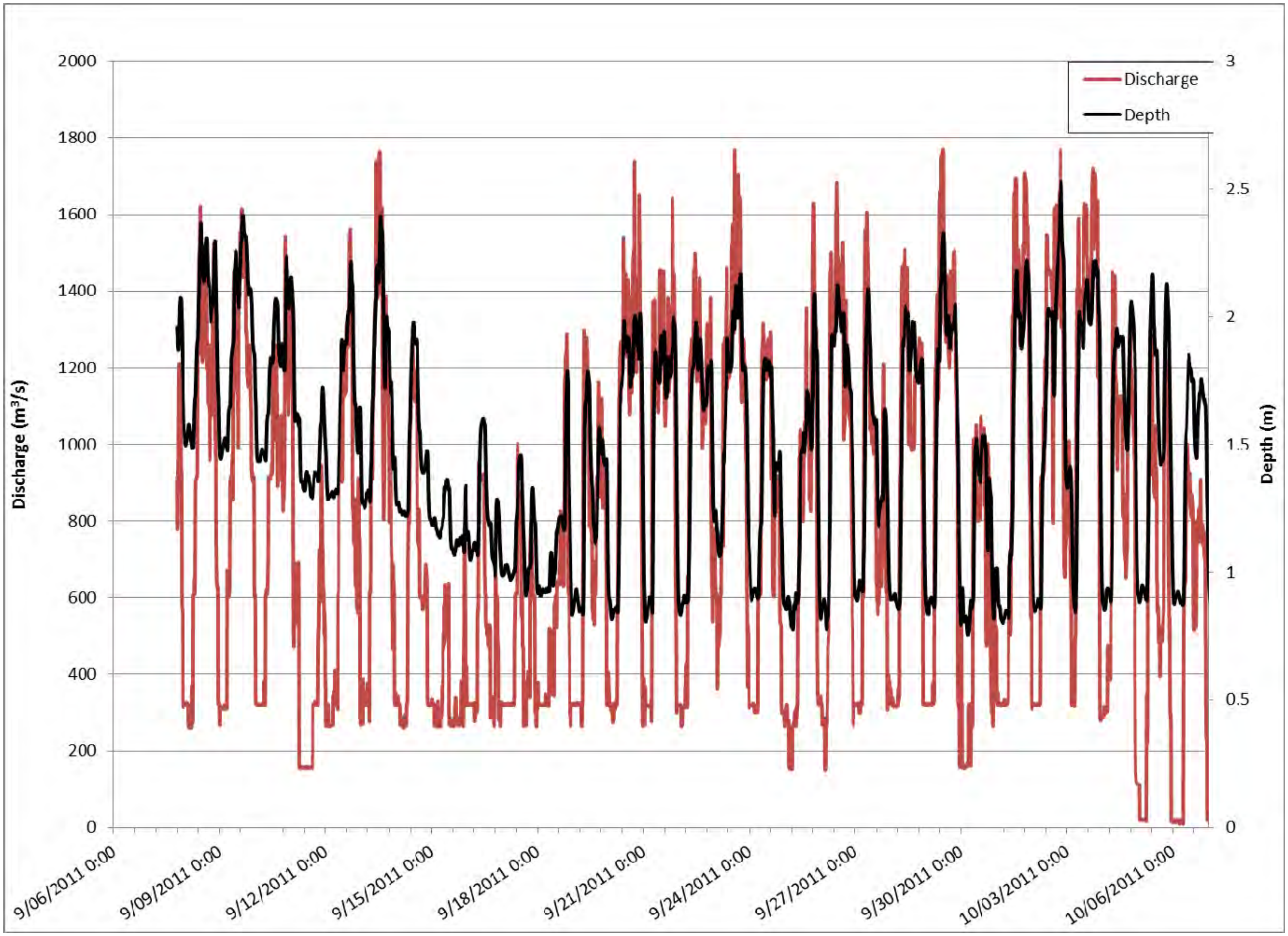

Figure 3-2: Ten-minute mean discharge from the Revelstoke Dam and water levels at the Highway 1 bridge site (September 7–October 7, 2011)

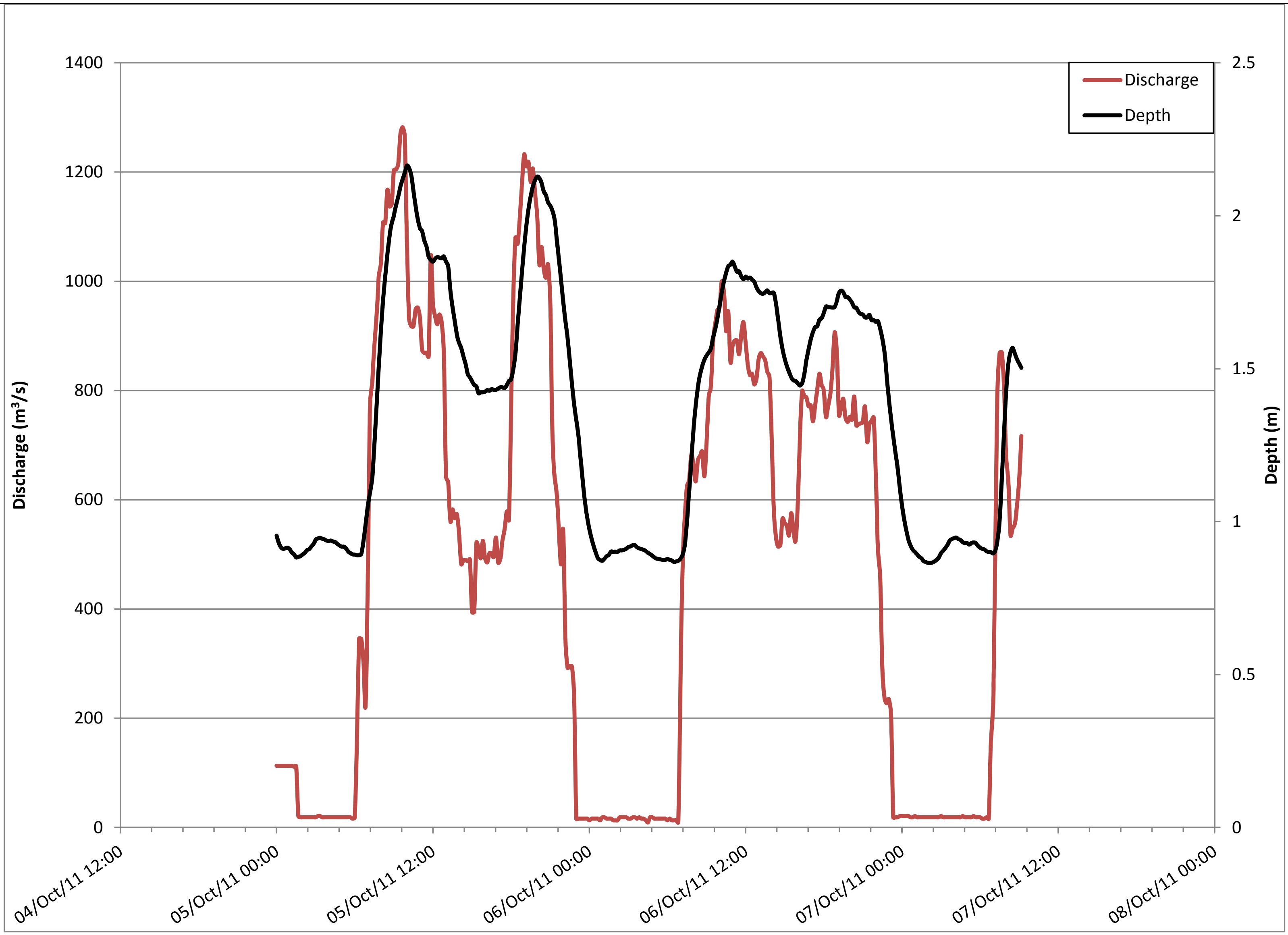

Figure 3-3: Ten-minute mean discharge from the Revelstoke Dam and water levels at the Highway 1 bridge site during field assessments (October 5–October 7, 2011)

3.3.3 Greenslide Creek Side Channel

Figure 3-4 shows 10-minute mean discharge from the Revelstoke Dam and recorded water levels at the Greenslide Creek side channel site for October 5–7, 2011. During that period, water levels were relatively stable with only a slight variation of approximately 10 cm or less. During the same period, Revelstoke Dam discharge ranged from a high of 1,234 m^3/s on October 5 at 7:00 p.m. to a low of 9.3 m^3/s on October 6, at 4:30 a.m. These results suggest that releases from the Revelstoke Dam have little to no influence on water levels at the Greenslide Creek side channel site. Photo 9 (Appendix 1) shows an overview of Greenslide Creek side channel in May prior to the channel being inundated. Photo 10 shows an overview of the site in October during the period when water levels were being monitored. In 2009 the ALR inundated the site for a total of 161 days in 2009, more than 180 days in 2010 and more than 193 days in 2011.

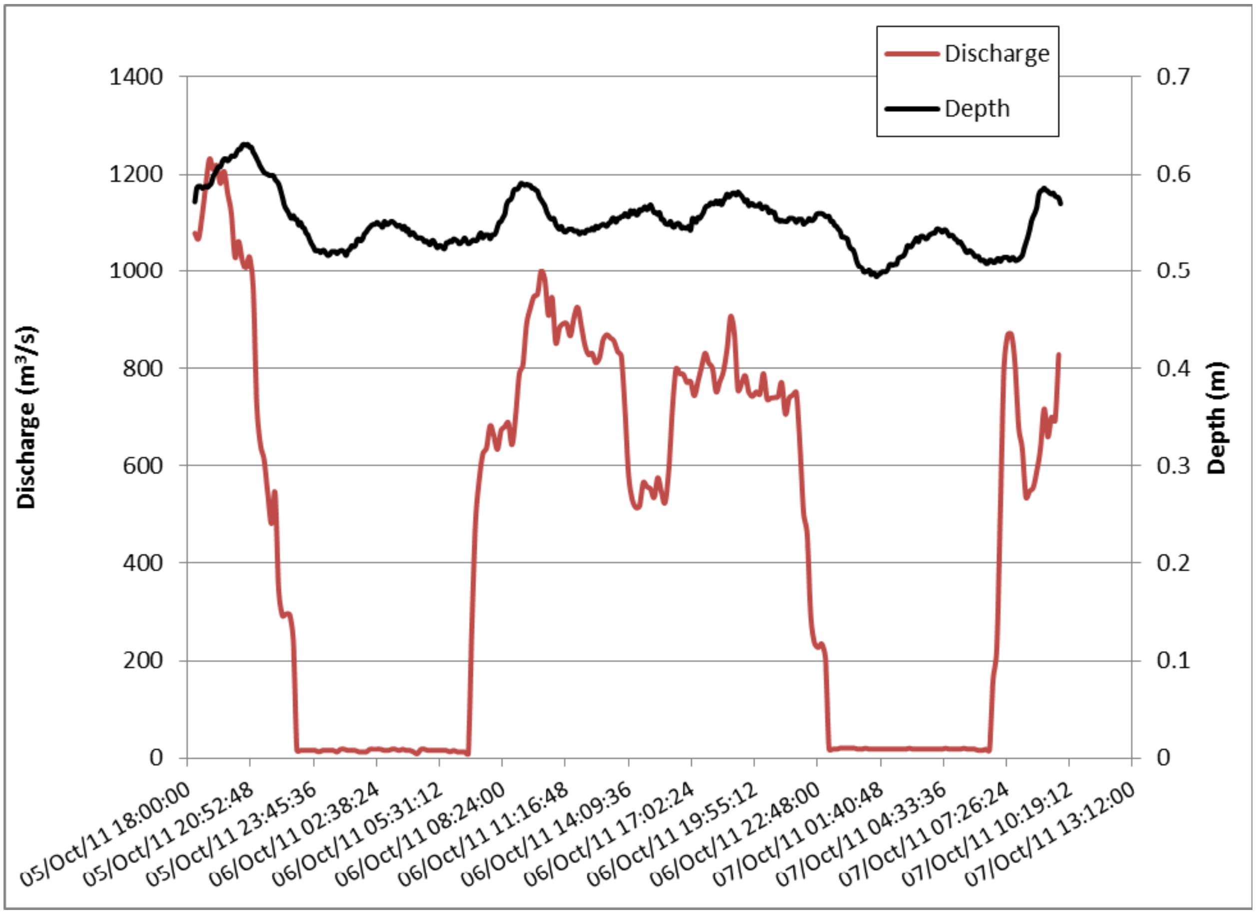

Figure 3-4: Ten-minute mean discharge from the Revelstoke Dam and water levels at the Greenslide Creek side channel site (October 5–7, 2011)

3.4 Influence of the Arrow Lakes Reservoir

The Arrow Lakes Reservoir daily mean elevation for 2009-2011 was compared with the approximate elevations of the Greenslide Creek side channel site (433 m; Figure 3-5), Begbie Creek site (434 m; Figure 3-6), and the Highway bridge site (435 m; Figure 3-7)[2] to determine when ALR levels most likely influenced each site in 2011. The risk of fish stranding was considered to be lower during the period of ALR inundation since the changes in water levels are both slower and less extreme. Data from 2009 and 2010 area also presented for comparison.

In 2011 the Greenslide Creek side channel site began to be influenced by ALR levels on approximately May 29, which was similar to results from 2009 (June 1). In 2010 the site was inundated on May 5. The site remained inundated beyond December 7 in 2011 (> 193 days) and beyond October 31 (> 180 days) in 2010. In 2009 the ALR receded below Greenslide on November 8 for a total of 161 days of inundation.

At the Begbie Creek site, the ALR began to influence the site on approximately June 6 in 2009 and 2011 and on May 21 in 2010. The elevation receded below that of the Begbie Creek site on October 4 and 14 in 2009 and 2010, respectively. The site remained inundated beyond December 7 in 2011. Therefore, stranding risk at the site was at least partially mitigated by the ALR for a total of 121 days in 2009, 147 days in 2010, and more than 185 days in 2011.

At the Highway bridge site, influence of the ALR began on approximately June 4 in 2010, June 11 in 2011, and June 13 in 2009. The site remained inundated until approximately September 23 and 24 in 2010 and 2009, respectively, and beyond the period on record (December 7) in 2011. Therefore, stranding risk at the site was at least partially mitigated by the ALR for a total of 104 days in 2009, 112 days in 2010, and more than 180 days in 2011.

[2] In 2010 the reported elevation of the Highway 1 bridge site was 438 m; however, this was corrected in 2011 based on discussion with Karen Bray, BC Hydro.

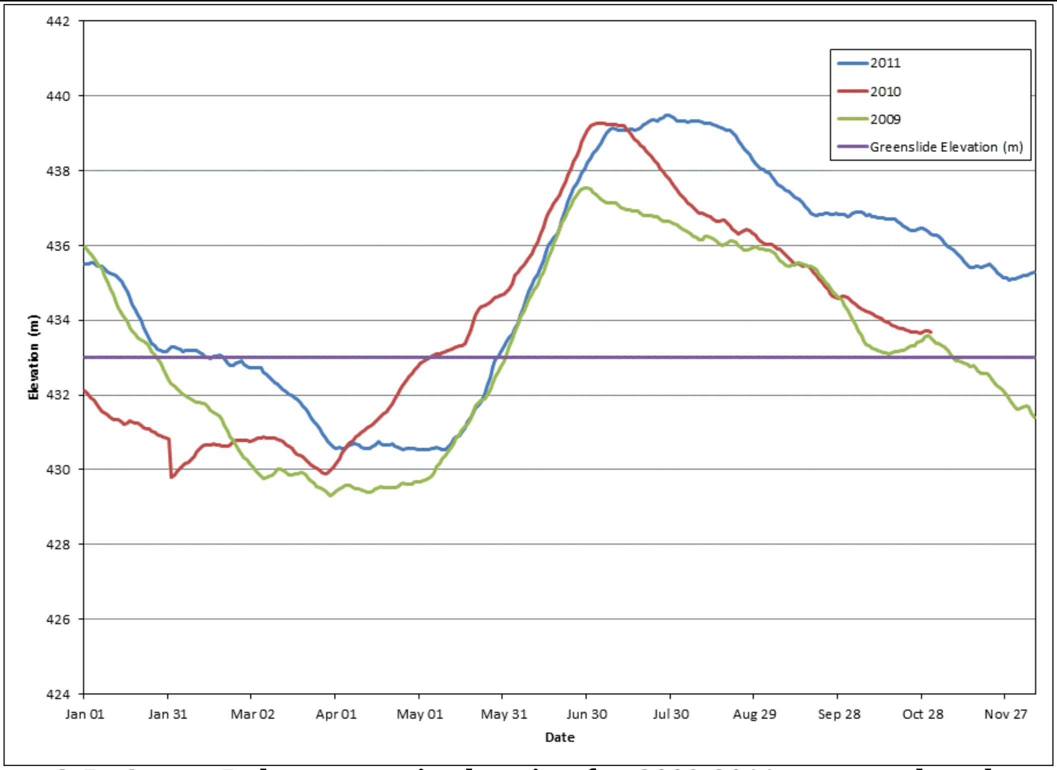

Figure 3-5: Arrow Lakes reservoir elevation for 2009-2011 compared to the approximate elevation of the Greenslide Creek side channel. During periods when reservoir elevation is above that of the site, the stranding risk at the site is reduced.

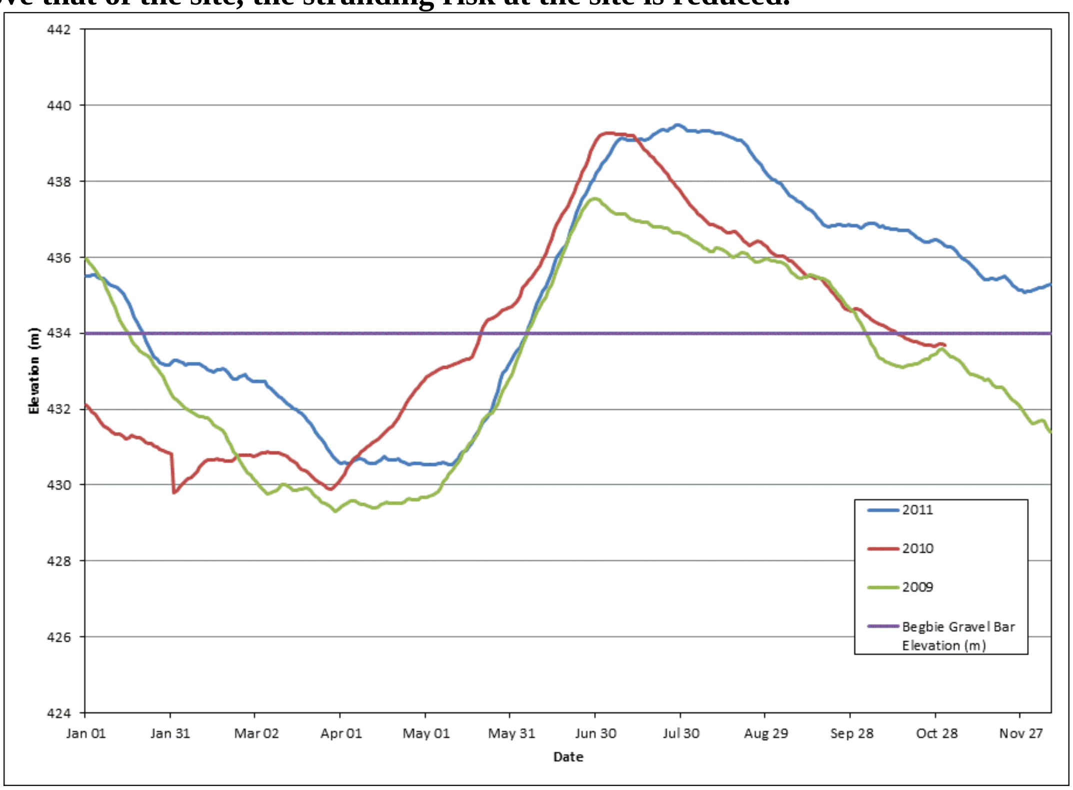

Figure 3-6: Arrow Lakes reservoir elevation for 2009-2011 compared to the approximate elevation of the Begbie side channel. During periods when reservoir elevation is above that of the site, the stranding risk at the site is reduced.

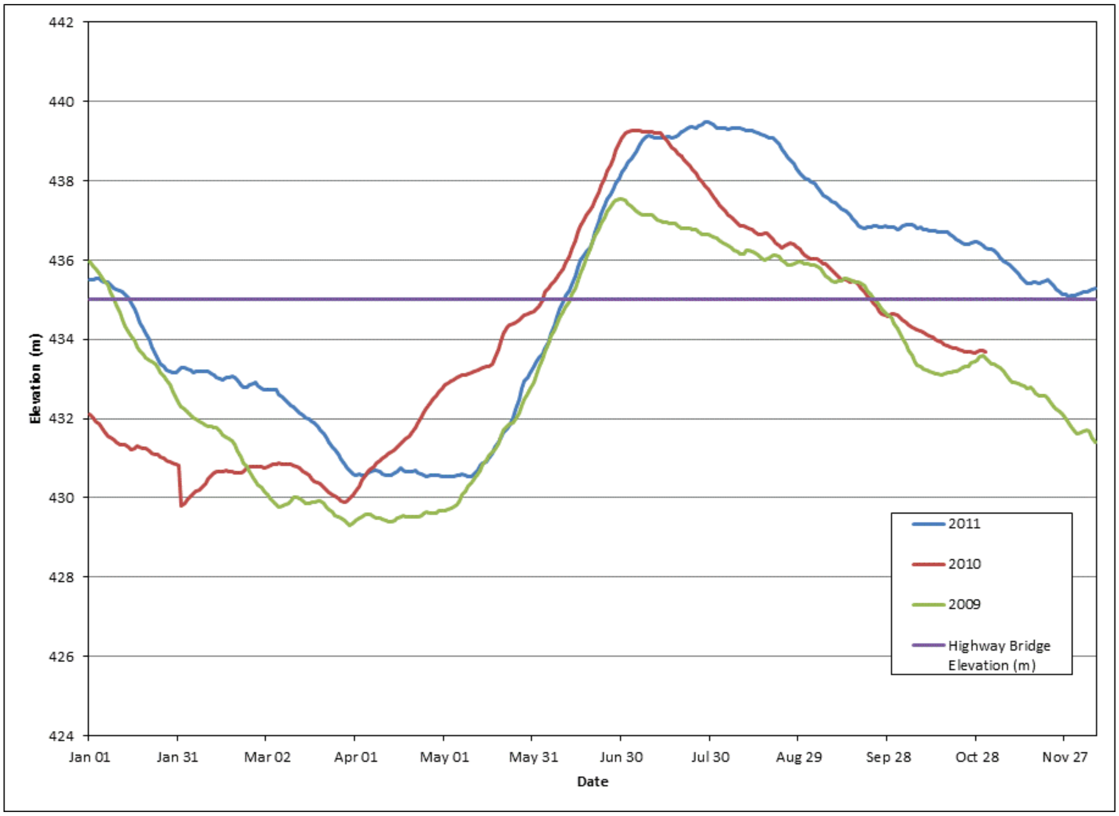

Figure 3-7: Arrow Lakes reservoir elevation for 2009-2011 compared to the approximate elevation of the Highway Bridge site. During periods when reservoir elevation is above that of the site, the stranding risk at the site is reduced.

3.5 Fish Sampling

Table 3-4 summarizes the potential strandings[3] observed at each of the sample sites during year 1-3 of CLBMON-53. Approximately 2,000 m^2 was estimated to have been surveyed at the Begbie Creek site in 2009 with 0 mortalities observed in May and 41 observed in October resulting in an estimated potential stranding rate of 0 and 0.0205 fish/m^2, respectively (Sykes and Liebe, 2010*a*). The site was not surveyed in 2010 and in May 2011 approximately 30% of the area surveyed in 2009 was inundated by the ALR. A total of five mortalities were observed resulting in an estimated potential stranding rate of 0.0036 fish/m^2. Approximately 6,000 m^2 was estimated to have been surveyed at the Highway bridge site in 2010 with 3 mortalities observed in May and 7 mortalities observed in October (Sykes and Liebe, 2011*a*). This corresponds to an

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

estimated potential stranding rate of 0.0005 and 0.0011 fish/m^2, for the May and October trips respectively. No mortalities were observed at the Highway bridge site during the October sampling in 2011 however the area surveyed was greatly reduced due to ALR inundation of the site.

Table 3-4: Potential strandings (fishes/m^2) observed at each sample site in each year of survey (NS = not sampled).

Sample Site	2009 (Year 1)		2010 (Year 2)		2011 (Year 3)	
	May	**Oct.**	**May**	**Oct.**	**May**	**Oct.**
Begbie Creek Site	0	0.0205	NS	NS	0.0036	NS
Highway Bridge Site	NS	NS	0.0005	0.0011	NS	0

3.5.1 Begbie Creek Site

Fish sampling at the Begbie Creek site in 2011 resulted in the capture or observation of 64 individuals from six different species (Table A2-1, Appendix 2). In addition, five desiccated coarse fishes that had presumably died as a result of stranding were observed but could not be identified to species. All individuals observed were less than 100 mm in length, and most were considered to be juveniles. Prickly Sculpin was the most commonly encountered species (n = 18) followed by Redside Shiner (n = 17). Other species encountered included Largescale Sucker (n = 11), Peamouth Chub (n = 10), Northern Pikeminnow (n = 4), and Mountain Whitefish (n = 4). In addition to the five unidentified coarse fish mortalities, one Redside Shiner mortality was observed in a recently dewatered pool.

By comparison, a total of 21 fishes of five species was captured at the site during the May 2009 (Year 1) sampling: 18 were coarse fish (11 Prickly Sculpin, two Longnose Sucker, and Redside Shiner) and three were sport fish (two Rainbow Trout and one Burbot). With the exception of the one Burbot that was captured, all fishes were less than 100 mm in length and most were juveniles. No mortalities were observed (Sykes and Liebe, 2010*a*).

3.5.2 Highway Bridge Site

Fish surveys at the Highway bridge gravel bar site were completed overnight on October 5 and 6, 2011. However, only approximately 20 per cent of the area that could be surveyed in 2010 became dewatered in 2011 (see Figure 2-2 for a comparison of wetted edge location at low discharge between the two years). This limited the 2011 survey to six transects that ranged in length from 15 m to 90 m and covered a combined area of 915 m^2 (Table A2-2, Appendix 2). No fishes were observed at any of the survey sites during either night. However, numerous adult Kokanee with spawning colours were observed from both the Highway bridge and the single lane bridge and in the shallow water between the bridges. The carcasses of two Kokanee were found along the shore, and it is assumed they were post-spawn mortalities as opposed to stranding mortalities. In addition there were several birds observed in the area presumably feeding on spawned-out individuals. Spawning was not observed in any of the areas that became dewatered during either night.

In 2010, a total of 88 fishes of four species was captured or observed during the October survey of the site. This included approximately 53 adult Kokanee displaying spawning colours and behaviour (pairing, redd building). One redd that had been excavated became dewatered as the discharge dropped. All remaining fishes were less than 100 mm in length and were either sculpins (n = 14), Mountain Whitefish (n = 1), or Redside Shiners (n = 20). Only seven mortalities were observed, all of which were Redside Shiners (Sykes and Liebe, 2011*a*).

4.0 Discussion

The results of Year 3 of the juvenile stranding assessment supported the findings of Year 1 and 2 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. However, Year 3 of the study also showed that in years of prolonged, high ALR elevation, the risk of stranding within the study area greatly decreased. This was 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 ALR influence at the sites monitored in 2011 resulted in changes in water levels that were both less extreme and occurred at a slower rate than that in previous years when ALR influence was absent. However, the extent of the ALR influence will vary from year to year and is dependent on how quickly the ALR fills in the spring and how long it remains high through the fall. It should be noted that receding of the ALR in the fall also results in stranding as flooded areas become isolated and dewater, but assessment of that situation was beyond the scope of this study.

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 each of the first three 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. In 2011 the influence of the ALR was observed at all three of the sites surveyed: the Greenslide site was inundated by May 29, the Begbie site by June 6, and the Highway bridge site by June 11. The ALR elevation remained above the elevation of each of the sites beyond December 7. This means that stranding risk was reduced at each site for more than half the year. Further, during the growing season (i.e., April to November—245 days), the ALR effectively reduced stranding risk at each of the three sites for approximately 75 per cent of the time.

The earliest inundation of each of the sites occurred in 2010 (Greenslide site: May 5; Begbie site: May 21; Highway site: June 4), but the ALR receded below the Highway and Begbie sites on September 23 and October 14, respectively. The elevation remained above that of Greenslide beyond October 31 (end of available data set). This translated into a reduced stranding risk for approximately 46 per cent (Highway site) to greater than 75 per cent (Greenslide) of the growing season. The results from Years 1–3 of the study suggest that stranding risk within the study area will be mitigated to some degree by the ALR for at least a portion of the growing season each year.

In 2009, inundation of the three sites occurred on approximately the same dates as in 2011, but the ALR receded sooner in the fall. As a result, the Highway site, Begbie site, and Greenslide site were above the ALR elevation on September 24, October 4, and November 8, respectively. Therefore, the period during which stranding risk was mitigated by the ALR ranged from 42 per cent (Highway site) to 66 per cent (Greenslide) of the growing season.

The following sections summarize the findings to date and provide additional details on the factors that contribute to stranding risk in the system.

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). The reconnaissance survey completed in Year 1 and repeated in Year 3 identified several side channels with stranding potential. However, when assessed in the field, most of those sites 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.

Both the Begbie Creek site and the Highway bridge site consisted of a large area of low- gradient gravel bar that has the potential to be wetted and dewatered daily for much of the year. Fish sampling results at the Begbie site (Year 1 and 3) and the Highway site (Year 2) 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. 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.

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). In managed systems such as the Middle Columbia, changes in discharge (termed “ramping”) are controlled by the operators. As in Year 1 and 2, the dewatering rates observed at the sites in 2011 exceeded those developed by Fisheries and Oceans Canada for British Columbia (KPC 2005; Table 4-1). Calculations of dewatering rates at the Begbie Creek site (June) showed a maximum of 7.9 cm/h, whereas the Highway bridge site (October) showed maximum of 27.0 cm/h. While both rates were higher than the provincial ramping rates guidelines, they were lower than those previously recorded at each site (Begbie: 18 cm/h May 2009; Highway bridge: 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.

Table 4-1: Summary of British Columbia ramping rate standards as defined by Fisheries and Oceans Canada (from KPC 2005)

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

Time of Year

Data collected in each of the first three years of the study suggest that the risk of fish stranding in the Middle Columbia River varies according to the time of year. 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. The ALR effects extended beyond the Highway bridge at Revelstoke during the summer months and into the fall, thus limiting the possibility of dewatering through the entire study area.

In Year 1 results suggested 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. Similarly, Year 2 results also identified some potential impact on Kokanee spawning as a result of water level changes in the fall. However, in Year 3 neither of these trends was observed due to high ALR elevation reducing stranding risk throughout the study area. Therefore, while there is the possibility of increased effects of stranding on fish in the Middle Columbia River in the fall, this is mitigated in some years by high ALR elevation.

Species and Life Stages Impacted

The fish catch at the Highway bridge site during the juvenile index sampling (CLBMON-17 site 27) in September 2008-2011 consisted primarily of Mountain Whitefish, Kokanee, and Prickly Sculpin (Table 3-3). This was comparable to the species composition at the site during the fall sampling in 2011, with Mountain Whitefish being the only species with observed mortalities. Therefore, these would be the species the most at risk of stranding at that site if the ALR was not reducing that risk.

In general, species composition at both the Highway and Begbie sites did not differ substantially between survey years. At the Begbie Creek site, Prickly Sculpin was the most commonly encountered species during the juvenile index sampling; other species frequently encountered included Mountain Whitefish, Redside Shiner, and Peamouth Chub. Species encountered during the spring stranding sampling included Prickly Sculpin, Largescale Sucker, Redside Shiner, Peamouth Chub, Northern Pikeminnow, and Mountain Whitefish. Redside Shiner was the only species with confirmed mortalities at the site in 2011; the remaining five mortalities could not be identified beyond being a coarse fish species. Sampling at the site in 2009 resulted in the capture of five species - Prickly Sculpin, Longnose Sucker, Redside Shiner, Burbot, and Rainbow Trout - but no mortalities were identified. In 2009 sport fish species constituted 14 per cent of the catch (3 of 21), but none were captured in 2011. This change is likely due to natural sampling variation rather than a species shift due to changes in the system.

Most fishes captured during the juvenile sampling at the Highway bridge site and all fishes captured at the Begbie Creek 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 riffles-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, quiet 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*). No redds were observed to be impacted in 2011, which suggests that stabilization of water levels by the ALR also helps mitigate impacts to Kokanee spawning at that location.

Dam Operations vs. Reservoir Operations

Year 3 data collected from the Greenslide Creek side channel further 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 and 2010 showed that once wetted, the Greenslide Creek channel provides fish habitat, primarily for juvenile coarse species such as carps, suckers, chub, and sculpins. Although these fishes are not at risk of stranding from daily flow fluctuations, any that remain in the channel once it has become isolated 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 Creek site is considered to be representative of many other flooded areas that become dewatered over the winter. 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.

Rev 5 Effects

Year 3 (2011) was the first year of sampling following the completion of Rev 5. Therefore, 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. In addition, the higher discharge could result in even more extreme changes in water levels in the system, thereby increasing stranding risk. 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.

None of these potential effects were observed during the 2011 field surveys. However conditions in the system during the 2011 study period were not substantially different from those that could occur under the four unit operation: from May 1 to October 16 (169 days) discharge peaked at 1,779 m^3/s. Further, the pre-Rev 5 maximum of 1,700 m^3/s was exceeded on only 21 days (12 per cent of the time) and generally for periods of less than one (1) hour.

The other change that occurred 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, the 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 still dropped below the 142 m^3/s threshold on 59 days from May 1 to October 16 (169 days or 35 per cent of the time) and generally for periods of more than one (1) hour. Despite the confounding factors that occurred in 2011, it seems reasonable to speculate that the implementation of the minimum base flow will 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.

5.0 Recommendations for the 2012 Field Program

Year 4 (2012) will be the second year of post-Rev 5 flows and the last year of the study. Based on data collected in Year 3 we were not able to assess the effects of discharges from the Revelstoke Dam due to ALR influence , as discharges did not differ from those of Year 1 or 2 (pre-Rev 5). Therefore, if the flow regime in 2012 is not likely to differ from that of Years 1–3 (i.e., a maximum discharge that does not substantially exceed 1,700 m^3/s and minimum flows that drop below 142 m^3/s), there may not be any value in completing the sampling. Similarly, if the ALR elevation is forecast to remain high for prolonged periods, it might also not be worthwhile to complete the sampling. While it is recognized that it is very difficult to predict discharge and ALR conditions in the Middle Columbia River, discussions should still be had in the early spring prior to sampling to assess the value of completing the work that year given the data available. If it is decided to proceed, the following sampling is recommended:

1. Complete sampling at both the Year 1 (Begbie) the Year 2 Highway bridge site in both the spring and fall in order to compare pre-Rev 5 conditions to post-Rev 5 conditions to determine if stranding has increased at this site under the modified flow regime.

2. Monitor water levels at Greenslide, Begbie and Highway sites during the spring, summer and fall to compare dewatering rates and change in water level during different times of year.

3. If periods of maximum discharge (i.e. approaching 2,125 m^3/s) a reconnaissance survey should be completed to identify new areas of stranding within the study area.

6.0 Management Question Summary

Based on Year 3 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 REV5?*
   - Daily fish strandings 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 sampling results, juvenile carp, prickly sculpin, tench, chub, and suckers are the most susceptible species (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. This was not observed in 2011 (first year following installation of Rev 5) because discharge 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 REV5?*

Findings from Year 3 were similar to those of Year 1 and 2:

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 and 3 hours before they are noticeable at the Begbie Creek gravel bar 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 1 bridge site in 2010 suggested that based on abundance, Mountain Whitefish and sculpin were most likely to be stranded. Year 2 stranding sampling results identified three mountain whitefish mortalities at the site, which supports the CLBMON 17 data. Year 1 (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 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. During Year 2, several adult Kokanee were observed building redds in areas that became dewatered as flows ramped down.

7.0 References

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APPENDIX 1

PHOTOGRAPHS

Photo 1. Overview of the side channel site upstream of Begbie Creek (site 4) on May 12, 2009, at typical mid-day discharge levels

Photo 2. Overview of the side channel site upstream of Begbie Creek (site 4) on May 12, 2009, during daily low discharge levels (4:00 a.m.)

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

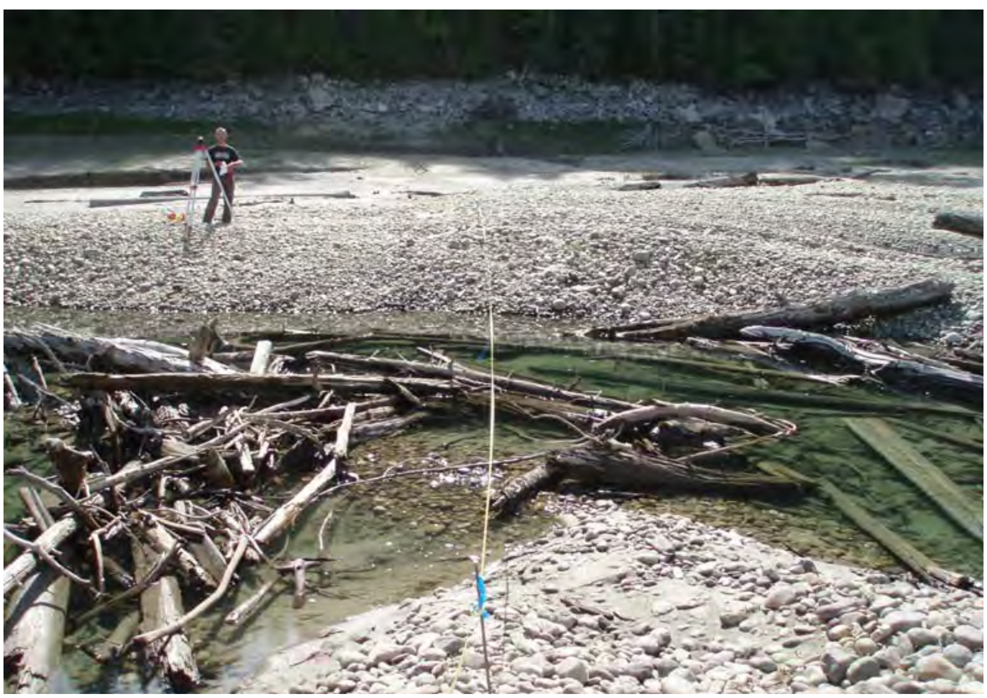

Photo 4. Overview of Pool #2 (Begbie Creek site) during the physical habitat collection phase (May 28, 2009). Revelstoke Dam discharge of 1,125 m^3/s

Photo 5. Greenslide Creek side channel on May 30, 2011 prior to being inundated by the Arrow Lakes Reservoir

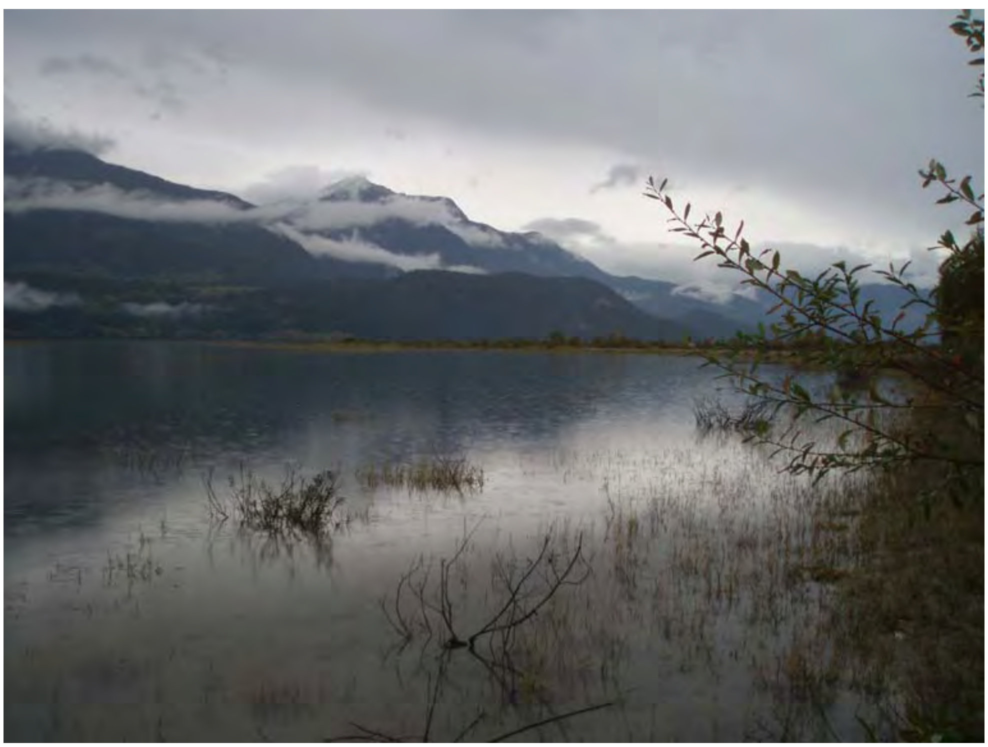

Photo 6. Greenslide Creek side channel area on October 5, 2011. The site remains inundated by the Arrow Lakes Reservoir with the Revelstoke Dam having little to no measurable influence on water levels

Photo 7. Overview of Highway bridge site (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 8. Overview of Highway bridge site (Area #1) on October 6, 2011 at a discharge of approximately 200 m^3/s. The site is inundated by the Arrow Lakes Reservoir.

Photo 9. Overview of the Highway bridge site at approximately 1000 m^3/s discharge on October 3, 2010 with no Arrow Lakes Reservoir inundation

Photo 10. Overview of the Highway bridge site at approximately 400 m^3/s discharge on October 3, 2010 with no Arrow Lakes Reservoir inundation

APPENDIX 2

2011 FISH SAMPLING SUMMARY

Table A2-1. Summary of sampling effort and results for June 1–2, 2011 sampling at the Begbie Creek site

Site	Sampling Method[1]	Sampling Effort (EF = s; MT = hr)	Area (m^2)	Fish caught:[2,3] fork length (mm)	Description
1	EF	245	300	MW: 75 (+ 3 observed but not captured); CAS: 68, 72; RSC: 45, 52, 63 60, 70	Gravel and cobble dominated shoreline upstream of side channel area. Never dewaters
2	EF	150	120	CAS: 50, 63, 52; PCC: 57, 63; RSC: 70, 73, 80, 55, 63	Gravel and cobble dominated channel that dewaters at the top but remains connected at the downstream end. Low risk of stranding because water drains from top to bottom as flows drop thereby allowing escape
3	EF	50	4	NFC	Shallow (0.1–0.2 m deep), isolated pools that dry up completely. Fish trapped in the pool are likely mortalities.
4	EF	30	1	NFC	
5	EF	66	10	NFC	
6	EF	60	4	NFC	
7	EF	15	3	NFC	
8	EF	95	20	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
9	EF	65	25	NFC	Gravel and cobble pool that become isolated and pose a high risk for stranding and mortality. Pool is approximately 0.25 m deep
10	VO	N/A	15	**RSC: 35**	Three small depressions that were wetted were surveyed, and one confirmed mortality was observed.
13	VO	N/A	20	CAS: 2 total CSU: 3 total	Isolated pool approximately 0.6 m deep. Pool may not completely dewater; however, it still poses moderate risk for mortality at lower discharge levels.
14	VO	N/A	10	NFC	Isolated pool approximately 0.3 m deep. Dewaters completely and therefore poses a high risk for stranding and mortality.
15	VO	N/A	2	**2 mortalities**	Isolated pool that dewaters completely. Mortalities observed on substrate: desiccated and not able to be identified to species
16	VO	N/A	4	**3 mortalities**	Isolated pool that dewaters completely. Mortalities observed on substrate: desiccated and not able to be identified to species
19	EF	200	200	CAS: 44; PCC: 55, 41, 55, 53, 50, 55; CSU: 51, 56	Pool #1: Pool did not completely isolate during either night of the survey. Maximum depth remained > 1 m and therefore poses a low risk for stranding.
20	EF	175	100	CAS: 10 total (50-60 mm);	Pool #2: Pool did not completely isolate during either night of the survey. Maximum depth remained > 1 m and therefore poses a low risk for stranding.

Site	Sampling	Sampling	Area	Fish caught:[2,3]	Description
21	MT	18 hr	200	CSU: 50, 47, 35, 65, 48, 47; NPM: 55, 67, 73, 66; RSC: 44, 40, 37, 50	Pool #1: 6 MT deployed
22	MT	18 hr	100	RSC: 44, 50; PCC: 47, 49	Pool #2: 6 MT deployed

[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; NPM: Northern Pikeminnow; PMC: Peamouth Chub; RSC: Redside Shiner. Total length in mm measured for sculpin (CAS) fork length in mm measured for remainder of species captured.
Note: Sites 11, 12, 17, and 18 from 2009 could not be accessed in 2011 due to water depth.

Table A2-2. Summary of the results from the October 5–7, 2011 surveys at the Highway bridge site. Refer to Figure 2-2 for location of sites.

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

[1] VO: Visual Observation