Duncan Dam Project Water Use Plan

Adaptive Stranding Protocol Development Program

Implementation Year 5

Reference: DDMMON-16

Lower Duncan River: Fish Stranding Impact Monitoring: Year 5 Data Report

Study Period: April 2012 to April 2013

Golder Associates Ltd.
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January 31, 2014

REPORT

January 31, 2014

DDMMON-16: LOWER DUNCAN RIVER

Lower Duncan River Fish Stranding Impact Monitoring: Year 5 Data Report (April 2012 to April 2013)

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Cover Photo: Upstream view of the lower Duncan River at RKm 3.5, September 27, 2012.

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Executive Summary

Although natural flow fluctuations in unregulated tributaries are known to cause fish stranding, fish stranding in the lower Duncan River (LDR) can be exacerbated by Duncan Dam (DDM) operations that influence the frequency and magnitude of flow fluctuations. The current program, initiated under the BC Hydro Water License Requirements (WLR) Program, includes the continuation of the DDMMON-16 Lower Duncan River Fish Stranding Impact Monitoring Program.

The results from this monitoring program will help inform flow management decisions that may impact on fish stranding in the LDR. Based on the current state of knowledge, the flow reduction measures implemented under the Water Use Plan (WUP) are effective at reducing fish stranding. When possible, flow reductions at DDM follow recommendations made by the DDMMON-15 Lower Duncan River Stranding Protocol Development and Finalization Program. Based on collected data and the life history of species present in the system, DDM operations increase the risk of stranding in certain seasons and during periods of longer wetted histories. At this time, stranding rate assessment methods and dewatered area estimations are still in development and impacts of stranding events cannot be linked to evaluated population effects at this time. Such predictions are within the scope of this monitoring program and the methodology is anticipated for completion in Year 6. At that time, results from Years 1-5 are expected to be evaluated to provide an estimate of historic stranding impacts as well as annual impacts.

The current status of management questions for DDMMON-16 is presented in the table below. Because of the high degree of variation in stranding rates, high uncertainty of abundance and interstitial stranding estimates, and the many variables that could potentially contribute to stranding, these results should be treated as preliminary as they are somewhat sensitive to assumptions.

Table EI: DDMMON-16 Year 5: Status of Management Questions and Objectives.

DDMMON-16 Management Question	DDMMON-16 Specific Hypothesis	DDMMON-16 Year 5 (2011-2012) Status Summary
1) How effective are the operating measures implemented as part of the Adaptive Stranding Protocol Development Program (ASPD) program?	N/A	- Based on the current state of knowledge, the flow reduction measures implemented under the WUP are effective at reducing fish stranding. - When possible, flow reductions at DDM follow recommendations made by the DDMMON-15 Lower Duncan River Stranding Protocol Development and Finalization Program. The current WUP protocol reduces stranding rates by requiring daytime reductions at rates that result in slow stage changes rates (< 10 cm/hr) at the majority of identified stranding sites. - Variables related to stranding that are not currently addressed in the ASPD are wetted history and season.
2) What are the levels of impact to resident fish populations associated with fish stranding events on the lower Duncan River?	*Ho_1: Fish stranding observed at index sites along the lower Duncan River floodplain is representative of overall stranding.*	- Index sites were not originally selected to be representative of the entire LDR, but to focus on sites believed to have the highest amounts of stranding based on amount dewatered area and suitable habitat. - Index sites tend to be of lower gradient and wider than the non-index sites, therefore more area dewaters at these sites. - In the Year 4 analysis, the number of pools per unit area of exposed habitat did not vary between index and non-index sites nor did the number of fish per pools. Stranding rates per lineal distance do not differ between index and non-index sites, but differ due to greater dewatered area within index sites. Therefore, the greater area dewatered in index sites strands higher numbers of fish in comparison to non-index sites. Index sites appear to provide an estimate that is biased high. Therefore, hypothesis Ho_1 is rejected.
	Ho_2: Fish populations in the lower Duncan River are not significantly impacted by fish stranding events.	- In the Year 4 analysis, estimates for the number of rainbow trout fry stranded in pools were relatively precise and relatively low. The estimated numbers of interstitially stranded fish in the lower Duncan River had very high uncertainty. While interstitial stranding is likely to be biologically important, the current estimates may be upwardly biased and are uncertain. There was a seasonal component to pool stranding, but at this point it cannot be determined whether this was due to less fish in the system in the spring vs. the fall or to a decreased risk of stranding. - The most recent abundance estimates for the rainbow trout fry in the LDR are uncertain. - We are unable to test hypothesis Ho2 until the stranding indexing and dewatered area estimates are refined (planned for Year 6). - Several factors affect fish populations including: predation, out migration, food availability, availability of suitable rearing habitats, winter mortality, as well as inter- and intra-species competition. Whether stranding events kill the fish that would succumb to these factors, or kill fish which would survive these factors is unknown. - Mountain Whitefish encounters have been minimal in all study years. This consistently low level of stranding was not considered significant and will likely not result in a population level effect.

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Table of Contents

1.0 INTRODUCTION 1

1.1 Background 1

1.2 Report Scope 2

1.3 Objectives, Management Questions, and Hypotheses 2

1.4 Study Design and Rationale 3

1.4.1 Site Selection 3

1.4.2 Pool Sampling 4

1.4.3 Interstitial Sampling 4

1.4.4 Abundance Estimate Methodology 4

1.4.5 Data Analysis 4

2.0 METHODS 5

2.1 Study Area 5

2.2 Study Period 5

2.3 Physical Parameters 7

2.3.1 Water Temperature 7

2.3.2 River Discharge 7

2.4 Fish Stranding Assessment Methodology 7

2.4.1 Year 5 Stranding Site Selection 8

2.4.2 Year 5 Sampling Protocol 8

2.4.2.1 Isolated Pools 8

2.4.2.2 Dried Pool 9

2.4.2.3 Interstitial Sampling 9

2.4.2.4 Fish Life History Data 9

2.5 Duncan Stranding Database and Data Management 10

2.6 Data Analysis 10

3.0 RESULTS 11

3.1 Duncan Dam Discharge Reductions and Ramping Rates 11

3.2 Fish Stranding Assessment Results (2006 to Present) 12

3.3 Differences between Pre-WUP and Post-WUP Operations 17

4.0 DISCUSSION 19

4.1 Current Duncan Dam Operations in Relation to Fish Stranding 19

4.1.1 Pre- and Post-WUP Operating Regimes 19

4.1.2 Variables Affecting Fish Stranding 19

4.2 Fish Stranding Summary 20

4.2.1.1 Rainbow Trout 20

4.2.1.2 Mountain Whitefish 21

4.2.2 Stranding Mechanism Classification 21

4.3 Summary 21

5.0 RECOMMENDATIONS 22

6.0 REFERENCES 23

7.0 CLOSURE 25

TABLES

Table EI: DDMMON-16 Year 5: Status of Management Questions and Objectives. E3

Table 1: Chronology of sampling activities for the 2012 - 2013 Lower Duncan River Fish Stranding Impact Monitoring, Year 5 Program. 5

Table 2: Summary of DDM flow reduction events, from April 1, 2012 to March 31, 2013, for those events when fish stranding assessments were conducted. 12

Table 3: Scientific names of fish species encountered during fish stranding assessments on the lower Duncan River, September 2006 to January 2012. 13

Table 4: Sampling effort during reductions of each study year that were included in the present analysis. 14

Table 5: Total number and relative composition of fish species captured or observed during all stranding assessments conducted on the lower Duncan River from September 2006 to April 2013. 15

FIGURES

Figure 1: Lower Duncan River Fish Stranding Impact Monitoring Program: Overview of Study Area. 6

Figure 2: Hourly discharge at the Duncan Dam (DDM, red line) and at the Duncan River below the Lardeau River (DRL, blue line) from April 1, 2012 to April 1, 2013. Vertical dotted lines represent the timing of fish stranding assessments. 11

Figure 3: Abundances of sportfish species, separated by life stage, observed in stranding assessments between 2006 and 2012. Note the different y-axis scales among panels. On the uppermost panel, the numbers of sampled sites and pools are provided in the first and second lines, respectively. 16

Figure 4: Total area exposed by all annual reductions in the LDR by year of operations. The vertical line denotes the beginning on WUP flows in 2008. 17

Figure 5: Minimum, maximum (grey ribbon) and mean (black line) discharge as measured at the WSC DRL gauge in the LDR by month during pre-WUP operations (2002 - 2007) and post-WUP operational implementation (2008 - 2012). 18

APPENDICES

APPENDIX A
Year 6 Abundance Estimation Methodology

APPENDIX B
Summary of Identified Stranding Sites

APPENDIX C
Photographic Plates

1.0 INTRODUCTION

1.1 Background

The lower Duncan River (LDR) originates from Duncan Dam (DDM), and runs for approximately 11 km before flowing into the north end of Kootenay Lake. Below DDM, the river flows through a man-made channel for 1 km to the confluence of the Lardeau River. Downstream from the confluence, the Duncan River is comprised of a series of single and braided channel sections with continually changing morphology that includes: debris jams, bars, and islands. Although natural flow fluctuations from unregulated rivers are known to cause fish stranding, fish stranding in the Duncan River can be exacerbated by DDM operations (Golder 2002) by influencing the frequency and magnitude of flow fluctuations. Formal assessments of fish stranding impacts related to changes in operations at DDM began in the fall of 2002. In 2004, BC Hydro developed a fish stranding assessment protocol that includes communication protocols, recommended flow reduction rates, and fish stranding assessment methodologies (BC Hydro 2004). An assessment of fish stranding impacts on the Duncan River related to DDM operations from November 2002 to March 2006 was previously completed (Golder 2006). In 2008, an annual summary of DDM related stranding events was completed for BC Hydro (Golder 2008).

One of the main objectives of the Duncan Dam Water License Requirements (WLR) Program is to evaluate the effectiveness of the operating regime defined in the Water Use Plan (WUP) and to identify opportunities to improve dam operations to maximize fish abundance and diversity in the Duncan River Watershed in consideration of other values. This involves assessing the influence of flow reductions on migrating, resident and/or rearing fish populations in the LDR. The DDM water license requires a minimum average daily flow from DDM of 3 m^3/s and has seasonal targets for discharge, based on Columbia River Treaty discharge requirements. The water license also requires that a minimum flow of 73 m^3/s be maintained at the Duncan River below the Lardeau River Water Survey of Canada (WSC) discharge monitoring station (DRL). In addition, the maximum hourly flow reduction allowed under the WUP is 28 m^3/s, and the maximum daily flow change allowed is 113 m^3/s. All LDR water license discharge requirements are subject to available inflows into Duncan Reservoir and are dependent on tributary inflows.

As a result of several uncertainties in WUP assumptions, the Adaptive Stranding Protocol Development Program (ASPD) was developed to address the impacts of flow reductions on fish. This adaptive management program will be implemented over the WUP review period based on the results from a collective group of monitoring studies. One component of the broader program is DDMMON -16: the Lower Duncan River Fish Stranding Impact Monitoring Program (FSIMP). In conjunction with other assessment tools being developed during the monitoring period, the FSIMP will assess population level impacts associated with dam operations during the review period. The information generated by these assessments will ultimately form the rationale for the implementation of a final operating protocol for DDM discharge releases that minimizes impacts on fish.

The fish stranding impact monitoring program conducted this year (Year 5) builds on the historic methodology, expands the program’s data sets, updates the boundaries of identified sites where stranding occurs, and analyzes pre-WUP DDM operations and how they relate to fish stranding. The monitoring program was created to develop and refine LDR stranding estimates that can be used to determine population level impacts. To accomplish this objective, extrapolation of fish stranding rates for the entire length of the river using information from the LDR Hydraulic Model (DDMMON-3) and other interrelated studies (DDMMON-1 – Lower Duncan River Ramping Rate Monitoring, DDMMON-2 – Lower Duncan River Habitat Use Monitoring, DDMMON-4 – Lower Duncan River Kokanee Spawning Monitoring, and DDMMON-15 – Lower Duncan River Stranding Protocol Review) is planned. The information obtained during the first four years of data collection and synthesis activities, combined with the information that will be obtained from other research activities internal and external to the Duncan WUP monitoring programs, is expected to have a significant influence on the design of this stranding impact monitoring program into the future.

1.2 Report Scope

The following document provides information on fish stranding observed over all assessed flow reductions from the timing of the last report on January 20, 2012 (Golder and Poisson 2012) to April 14, 2013. At the time the present document was prepared, the LDR Hydraulic Model was being updated and data from the model were not available. Therefore, this report does not include in-depth analyses of new and previously collected data and analyses. Instead, this report presents brief analysis of the Year 5 fish stranding assessments, with some comparisons between study years. More detailed statistical analysis in relation to the multi-year program objectives will be undertaken Year 6 (next year), after the hydraulic model update is complete. The report synthesizing the first four years of this program (2008 to 2012) provides an in-depth description of the state of knowledge regarding the relationship between operations and fish stranding (Golder and Poisson 2012).

1.3 Objectives, Management Questions, and Hypotheses

As stated in the Lower Duncan River Water Use Plan Terms of Reference (BC Hydro 2008), the overall management question to be addressed within the ASPD program is:

What are the best operating strategies at Duncan Dam to reduce fish stranding in the lower Duncan River?

The specific management questions associated with this monitoring program are:

1. *How effective are the operating measures implemented as part of the ASPD program?*
2. *What are the levels of impact to resident fish populations associated with fish stranding events on the lower Duncan River?*

To address the specific management questions associated with this monitoring program, the primary objectives of the FSIMP are:

1. To determine the effectiveness of the operating measures implemented as part of the ASPD program.
2. To determine the levels of impact to resident fish populations associated with fish stranding events on the lower Duncan River.

These objectives directly reflect the uncertainties facing the DDM WUP Consultative Committee when making decisions regarding BC Hydro operations on the LDR. It is anticipated that by addressing these objectives, an understanding of fish stranding impacts and the potential for making operating/monitoring improvements at DDM can be applied in future. The Terms of Reference did not state specific hypotheses to address primary objective 1. Therefore, objective 1 was addressed by assessing DDM operations in relation to stranding variables (Golder and Poisson 2012) within and outside of direct management control. To address the second primary objective, the TOR stated two hypotheses that the FSIMP must test, which are related to the assumptions to be used in the monitoring program. The specific hypotheses that are addressed in this report as part of the second objective are:

Ho_1: Fish stranding observed at index sites along the lower Duncan River floodplain is representative of overall stranding.

Ho_2: Fish populations in the lower Duncan River are not significantly impacted by fish stranding events.

Years 1 (2008 – 2009) and 2 (2009 – 2010) of the FSIMP worked toward addressing primary objective 1) the effectiveness of operating measures, and addressing Hypothesis Ho_1, fish stranding at index sites is representative of overall stranding (Golder 2009 and 2010). Sampling efforts focused on monitoring and calibrating fish stranding impacts associated with DDM flow reduction within the LDR from the Duncan/Lardeau confluence downstream to Kootenay Lake under different temporal variations and variable ramping rates.

The second objective, to empirically assess the influence of stranding events on resident and/or rearing fish population levels in the LDR, was the focus of Year 3 (2010 – 2011), Year 4 (2011 – 2012) and the present study year (Year 5; 2012 - 2013) of the FSIMP. Recommendations to refine study methodology and to better address both objectives and hypotheses in future years of the FSIMP have been developed (Section 5).

1.4 Study Design and Rationale

Since 2002, Golder has conducted fish stranding assessments on the LDR. A wide variety of fish capture/observation techniques have been utilized to ensure the study design in each sample year met BC Hydro's objectives. Recommendations made in Years 3 and 4 (2010 – 2011 and 2011 – 2012 respectively) on changes to study design to address gaps in the data set identified during the data analysis (Golder 2011, Golder and Poisson 2012) were implemented in the present study year.

1.4.1 Site Selection

In previous study years, fish stranding assessments focused on index sites, as these sites have the largest dewatered areas during flow reductions, and are also believed to strand the highest numbers of fish. Due to this focused methodology, limited assessments of non-index sites were conducted and therefore in-depth statistical analysis of stranding rates at both index and non-index sites were unable to be conducted. In turn, estimates of stranding rates may have been upwardly biased. To allow for comparisons of stranding rates between index and non-index sites, increased sampling effort during the present study assessed non-index sites. Further information on site selection details is provided in Section 2.0.

1.4.2 Pool Sampling

As pool sampling was the primary focus of previous study years, relatively precise pool stranding estimates for Rainbow Trout were obtained in Years 3 and 4 (Golder 2011, Golder and Poisson 2012). Therefore, sampling effort that focused on pools in the previous study was refocused in the present study to assess interstitial stranding in more detail.

After the Year 4 data analysis, it was recommended that dried pools be classified as a third stranding mechanism to further refine the fish stranding data set. It was determined that there is a possibility that fish trapped in an isolated pool which subsequently drains could be classified as interstitially stranded during assessments. This new mechanism category will remove the possibility of misidentifying the mechanism that stranded observed fish and will allow for more accurate future estimates of fish stranding in the LDR.

1.4.3 Interstitial Sampling

During data analysis in Year 3, estimates of both interstitial stranding per unit area (m^2) and total interstitial stranding, showed high uncertainty (Golder 2011). To reduce this uncertainty and obtain a more complete representation of fish stranding in the LDR, interstitial sampling effort in Year 4 and in the present study was increased.

1.4.4 Abundance Estimate Methodology

When the contract for this program was awarded to Golder in the fall of 2012, there was not enough time to develop and implement a program to estimate the abundance of the target species within the study area before the onset of Kokanee Protection Flows. Therefore, after discussions with BC Hydro, the Year 5 abundance estimate program was delayed until Year 6. This allowed for sufficient time to review past estimation methodology and develop a reliable program to meet the needs of this study. The abundance methodology for Year 6 is provided in Appendix A.

1.4.5 Data Analysis

At the time this document was prepared, the RIVER-2D Hydraulic Model created as part of the DDMMON-3 was undergoing an update to incorporate changes in the channel and to transition to the TELEMAC-2D river modeling platform. Once the update is complete, the wetted areas and stranding locations predicted in the model at various flow elevations are expected to provide the basis for extrapolation of stranding rates defined in this study.

2.0 METHODS

2.1 Study Area

The geographic scope of the study area for the FSIMP was the 11 km of mainstem LDR from DDM to the mouth of Kootenay Lake (Figure 1). This study area (collectively known as the LDR) includes the Duncan-Lardeau rivers confluence, as well as the Meadow, Hamill and Cooper Creek mouths. For the purpose of this study, 50 potential fish stranding sites were identified based on previous studies (AMEC 2004 and Golder 2006, 2008, 2009, 2010, and 2011; Golder and Poisson 2012). These stranding sites include 11 index stranding assessment sites and 39 non-index sites (Appendix B, Figures 1 to 7). The remaining habitats outside of the identified sites consist of steep banks with extreme gradient that would not be considered to strand fish.

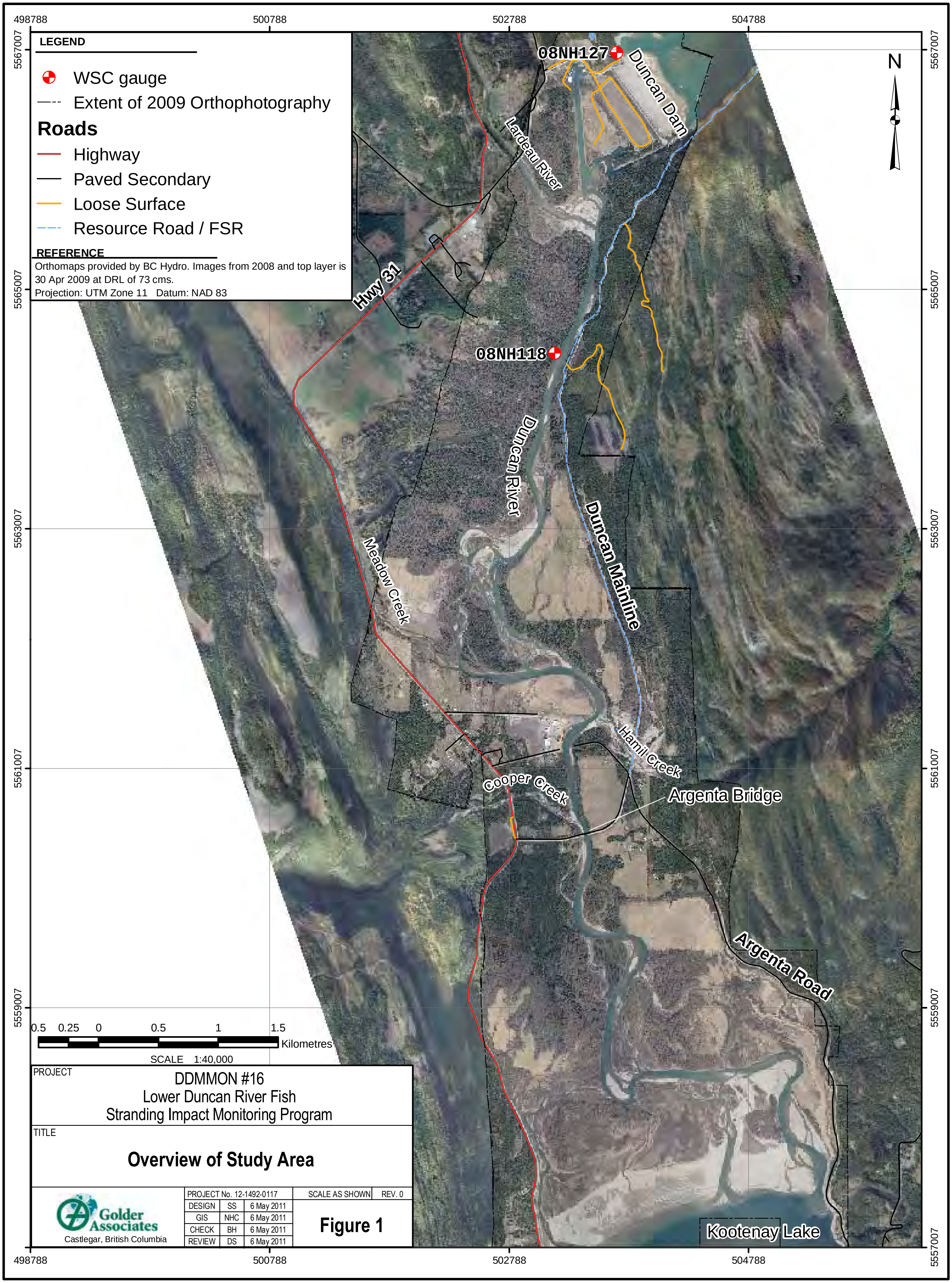
For the purpose of all WLR studies, the mainstem Duncan River was divided into five sections; these were termed Reach 1 (RKm 0.0 – at DDM spill gates to RKm 0.8), Reach 2 (RKm 0.8 to RKm 2.6), Reach 3 (RKm 2.6 to RKm 5.7), Reach 4 (RKm 5.7 to RKm 6.7), and Reach 5 (RKm 6.7 to RKm 11.0 – at the mouth to Kootenay Lake).

2.2 Study Period

In Year 3 (2010 – 2011), the study period for each year was set between April 15 of that year, and continued until the following April 14. Stranding assessment activities in the present study year were conducted from April 15, 2012 to March 1, 2013. Each assessed reduction from DDM was assigned a reduction event number (RE; see Section 2.4) and Table 1 outlines all assessment activities during Year 5.

Table 1: Chronology of sampling activities for the 2012 - 2013 Lower Duncan River Fish Stranding Impact Monitoring, Year 5 Program.

Date(s)	Reduction Event Number	Number of Index Sites Assessed	Number of Non-Index Sites Assessed
April 15, 2012	RE2012-03	2	0
June 1, 2012	RE2012-04	Assessment was planned, but cancelled by BC Hydro prior to reduction date	
September 26, 2102	RE2012-05	5	4
September 27, 2012	RE2012-06	3	2
October 1, 2012	RE2012-07	3	3
January 21, 2013	RE2013-01	6	5
March 1, 2013	RE2013-02	3	2



LEGEND
WSC gauge
Extent of 2009 Orthophotography
Roads
Highway
Paved Secondary
Loose Surface
Resource Road / FSR
REFERENCE
Orthomaps provided by BC Hydro. Images from 2008 and top layer is 30 Apr 2009 at DRL of 73 cms.
Projection: UTM Zone 11 Datum: NAD 83
498788
500788
502788
504788
5567007
5565007
5563007
5561007
5559007
5557007
N
08NH127
Duncan Dam
Lardeau River
Hwy 31
08NH118
Duncan River
Duncan Mainline
Meadow Creek
Hamil Creek
Cooper Creek
Argenta Bridge
Argenta Road
Kootenay Lake
0.5 0.25 0 0.5 1 1.5
Kilometres
SCALE 1:40,000
PROJECT
DDMMON #16
Lower Duncan River Fish
Stranding Impact Monitoring Program
TITLE
Overview of Study Area
Golder Associates
Castlegar, British Columbia
PROJECT No. 12-1492-0117
SCALE AS SHOWN
REV. 0
DESIGN SS 6 May 2011
GIS NHC 6 May 2011
CHECK BH 6 May 2011
REVIEW DS 6 May 2011
Figure 1

2.3 Physical Parameters

2.3.1 Water Temperature

Water temperatures for the LDR were obtained from the Duncan River below Lardeau River Water Survey of Canada gauging station (DRL) located downstream of the Duncan-Lardeau confluence at River Km (RKm) 2.1. The DRL station uses Lakewood™ Universal temperature probes (accuracy ± 0.5°C).

Spot measurements of water temperature were also obtained at all stranding assessment sites at the time of sampling using an alcohol handheld thermometer (accuracy ± 1.0ºC).

2.3.2 River Discharge

The DRL gauging station was selected as the compliance monitoring station for LDR discharge, as it provides information on the magnitude of flow reductions along the majority of the river channel. All DDM releases and discharge data for the LDR were obtained from BC Hydro Power Records.

2.4 Fish Stranding Assessment Methodology

A formalized fish stranding assessment methodology was developed for the Duncan River in 2004, entitled "Strategy for Managing Fish Stranding Impacts in the lower Duncan River Associated with Flow Reductions at Duncan Dam" (BC Hydro 2004). This protocol provided the standard methodology for conducting fish stranding assessments on the Duncan River prior to the present study. The protocol was updated in 2012 (Golder 2012) and addressed up to date sampling methodologies, protocols related to fish stranding and DDM operations. Based on the protocol, when DDM flow reduction is planned, BC Hydro will contact the organization responsible for conducting stranding assessments. The planned flow reduction is assigned a RE and a list of criteria is followed to determine if a stranding assessment is required (Golder 2012).

Because of the remote location of the LDR and limited development, access to the river must occur by boat or on foot. Boat launches exist at the confluence of the Duncan and Lardeau rivers (BC Hydro private launch), at Argenta near the mouth of the river into Kootenay Lake, and at Lardeau on Kootenay Lake, 3.5 km downstream of the mouth of the LDR on Kootenay Lake. Since late 2007, debris jams have formed just between RKm 4.1 and 4.5, preventing continuous boat access along the river. At the time this document was created, a log jam at RKm 4.5 could not be navigated at any discharge level. However, the downstream portions of the river can be accessed at higher river elevations by boat through a side channel located at RKm 4.2 and flows into Meadow Creek near its outlet into the LDR. As the river nears the mouth to Kootenay Lake, the channel meanders on a yearly basis, and access to the LDR from Kootenay Lake remains in question at lower DRL discharges.

In 2010, DDMMON-15 reviewed all LDR aquatic study reports and provided recommendations on the data collection methodology used during fish stranding assessments. This lead to the modification of the assessment methodology at the onset of Years 3 and 4 to improve the accuracy of fish stranding estimates, and to increase the amount of long-term data available for stranding impact analysis on the lower Duncan River (Golder 2011, Golder and Poisson 2012). In Year 5, the assessment methodology was modified further to address data gaps identified in Year 3 (Section 2.4.2.2).

2.4.1 Year 5 Stranding Site Selection

Utilizing the methodology developed in Year 4 (Golder and Poisson 2012), prior to each fish stranding assessment, 10 sites were randomly selected from all identified stranding sites. This was accomplished by creating two strata (index and non-index) and then randomly selecting sites from each stratum to sample. The number of sites in each stratum selected for sampling was proportionate to the area dewatered in each stratum as a result of the assessed DDM flow reduction. The dewatered area at all sites was calculated using the site area regressions that were completed in Year 3 (Golder 2011). At each site assessed for stranding, isolated pools and interstitial habitat that formed as a result of the decrease in DDM discharge were sampled for fish stranding.

2.4.2 Year 5 Sampling Protocol

2.4.2.1 Isolated Pools

Following the methodology used in Year 4, once sampling commenced, isolated pools within individual stranding sites (that formed as a result of the DDM flow reduction) were enumerated and the area (m^2) of each pool was estimated and recorded. The field crews then randomly sampled up to 50% of the pools at each assessed site, up to a maximum of three pools, using single pass electrofishing, dip nets and/or visual inspection. In addition, to determine the observer (capture) efficiency during stranding assessments, multi-pass electrofishing (two passes) was conducted at a subset of randomly selected pools. The effort for each subsequent pass was as consistent as possible with the first pass. The fish salvaged and effort for each pass were recorded separately. As observer efficiency can differ with the amount of cover present in each pool, the complexity of each sampled pool was classified into one of the following two categories:

1) Zero to Low complexity (0% – 10% total cover); and,

2) Moderate to High complexity (>10% total cover; Appendix C, Plate 1).

Pools with 0% – 10% cover were classified at Zero to Low complexity if surface area was 5 m^2 or less. Zero to Low Complexity pools are generally smaller in size so that fish could be captured readily by backpack electrofishing. Moderate to High Complexity pools are likely to have: larger surface areas, larger substrate that could provide cover to fish including larger cobble and gravel or boulder, and some portions of the pool that are not visible because of woody debris or other cover types.

For each pool, associated cover types (and percentages within the pool) were recorded from the following list:

- Large woody debris (woody debris with diameter of >10 cm);
- Small woody debris (woody debris with diameter of <10 cm; Appendix C, Plate 2);
- Aquatic vegetation;
- Overhanging vegetation;
- Submerged Terrestrial Vegetation;

- Organic debris (leaves, bark etc.);
- Cut bank;
- Shallow pool (Appendix C, Plate 3);
- Deep pool; and,
- Other (metal, garbage, etc.).

To be consistent with past studies (fish stranding assessments and ramping experiments), if time allowed, the dominant and subdominant substrate in each pool were recorded using a Modified Wentworth Scale.

2.4.2.2 Dried Pool

As a result of recommendations made in Year 4, a third class of stranding mechanism, dried pools, was incorporated into the project methodology. The working field definition of a dried pool is a low point which when disconnected from the mainstem would create a wetted pool but was drained at the time of assessment. The life history data for fish found stranded in dried pools was recorded (see Section 2.4.4). Unlike isolated pools, the habitat parameters described in Section 2.4.2.1 were not recorded for dried pools as field crews were unable to accurately determine the areal extent of pool at time of isolation from the mainstem river.

2.4.2.3 Interstitial Sampling

Dewatered habitat at each site was assessed by conducting a maximum of 20 randomly placed grids (each grid has area of 0.5 m^2). The substrate and all cover were removed from each grid, and the stranded fish enumerated (Appendix C, Plate 4). To be consistent with past studies (fish stranding assessments and ramping experiments), the dominant and subdominant substrate in each grid were recorded using a Modified Wentworth Scale.

2.4.2.4 Fish Life History Data

Following the methodology used in Year 4, for each fish captured during pool and interstitial sampling, the following life history data were recorded:

- Species;
- Length (mm);
- Condition (alive or dead);
- Salvaged (Yes/No); and,
- Habitat association (if possible).

Observed fish that were not captured and remained in the pool after sampling was completed were also documented. If the number of captured fish from a pool was high and time did not allow for the measuring of all fish, an estimate of the number of fish by species captured in the pool was recorded and individuals from a subsample (30-50) of each species from the salvaged fish were measured for length and the species recorded.

2.5 Duncan Stranding Database and Data Management

The MS Access database (referred to as the LDR stranding database) created in Year 2 was populated with all available stranding data collected during the present study year. The database underwent several refinements during the analysis to facilitate data entry and queries. Presently, 61 individual stranding assessments are into the database. Results from 14 assessments prior to September 15, 2006 were not included in the dataset, as sampling methodology was not consistent with more recent assessments.

Protocols for information management for data collected during this program have been created by DDMMON-15: Lower Duncan River Protocol Development and Finalization and are presented in the revised document: “Adaptive Stranding Protocol for Managing Fish Impacts in the Lower Duncan River Associated with Flow Reductions at Duncan Dam” (Golder 2012).

2.6 Data Analysis

To compare pre- and post-WUP operations and to address the first management question regarding whether the operational measures of the ASPD are effective at reducing fish stranding, the Year 5 DDM and DRL flow data was added to the discharge data set. The modelling conducted in Year 4 (Golder and Poisson 2012) was then repeated with the updated data set. For the purposes of the historical comparison, discharge reduction events were defined as a decline in the hourly discharge caused by DDM operations as measured at the WSC gauge at DRL. The difference in discharge when a reduction event occurred was then multiplied by the slopes estimated for the high and low slope habitat and summed together in order to obtain a total riverine area exposed for each reduction. These total areas were summed over the entire year in order to estimate the total area exposed by year.

3.0 RESULTS

3.1 Duncan Dam Discharge Reductions and Ramping Rates

Hourly discharge at DRL during the study period ranged from 70.7 m^3/s on Oct 15, 2012 to 576.5 m^3/s on July 22, 2012. Hourly discharge from DDM ranged from 0 m^3/s on several days between early June and early July 2012, to 369.0 m^3/s on July 23, 2012 (Figure 2). Lowest DDM flows typically occur during the spring/summer recharge of Duncan Reservoir. During this period there are temporary pulses of flow to meet Bull Trout (*Salvelinus confluentus)* migration requirements of daily average discharge. While DDM discharge is at its lowest during reservoir recharge, the Lardeau River discharge is typically high, which satisfies flow requirements for the protection of fish.

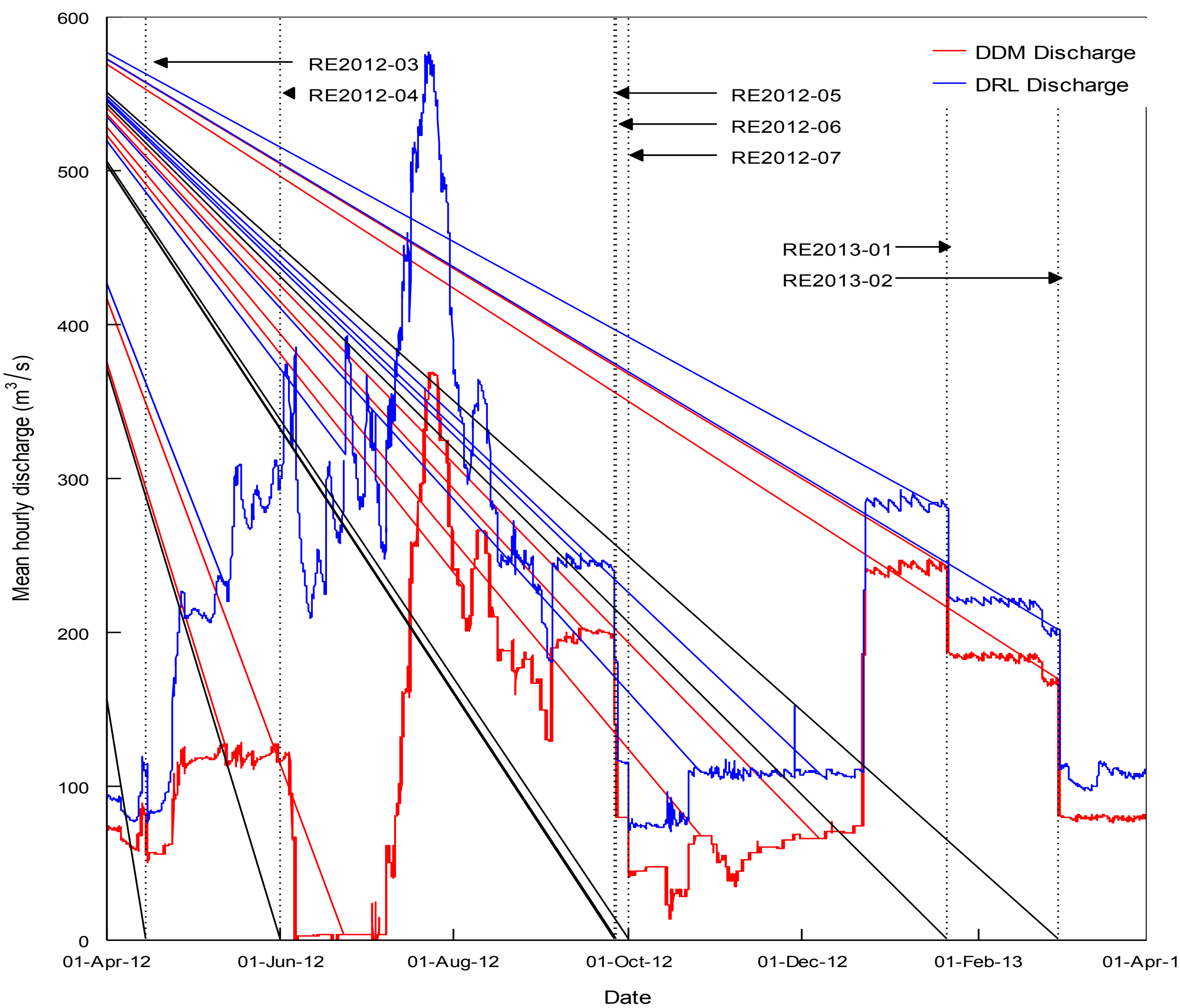


Figure 2: Hourly discharge at the Duncan Dam (DDM, red line) and at the Duncan River below the Lardeau River (DRL, blue line) from April 1, 2012 to April 1, 2013. Vertical dotted lines represent the timing of fish stranding assessments.

During the present study, seven REs occurred at DDM. The REs used a variety of flow ramping strategies, dependent upon water levels at the onset of the REs (Figure 2 and Table 2). During the REs, DDM decreases of discharge ranged between 39 and 90 m^3/s (Table 2). These decreases represent the discharge reductions at DDM, rather than flow changes at particular downstream fish stranding sites.

Table 2: Summary of DDM flow reduction events, from April 1, 2012 to March 31, 2013, for those events when fish stranding assessments were conducted.

Date	Reduction Event (RE)	Initial DDM Discharge	Resulting DDM Discharge	Magnitude of DDM Reduction	Ramping Description[a]	Flow Reduction Rationale
Apr 15, 2012	RE 2012-03	90 m^3/s	46 m^3/s	44 m^3/s	Down 20 m^3/s at 14:00, and down 14 m^3/s at 15:00.	Discharge reduced to compensate for low inflows.
Jun 1, 2012	RE 2012-04	Assessment cancelled.				
Sep 26, 2012	RE 2012-05	196 m^3/s	140 m^3/s	56 m^3/s	Down 20 m^3/s at 06:30, 07:30, and 08:30.	Onset of Kokanee protection flows.
Sep 27, 2012	RE 2012-06	140 m^3/s	80 m^3/s	60 m^3/s	Down 20 m^3/s at 06:30, 07:30, and 08:30.	Kokanee protection flows.
Oct 01, 2012	RE 2012-07	80 m^3/s	41 m^3/s	39 m^3/s	Down 20 m^3/s at 05:30 and 06:30.	Final transition to Kokanee protection flows.
Jan 21, 2013	RE 2013-01	244 m^3/s	185 m^3/s	59 m^3/s	Down 7 m^3/s every 15 minutes from 06:00 to 07:45.	Discharge reduced to meet reservoir targets.
Mar 01, 2013	RE 2013-02	170 m^3/s	80 m^3/s	90 m^3/s	Down 7 m^3/s every 15 minutes from 06:00 to 08:45, and a final drop of 5 m^3/s at 09:00.	Discharge reduced to meet flow target at DRL.

[a] The flow decreases reflect the net total decrease in flows over specific intervals at DDM. Actual ramping rates (rate of stage or discharge decrease per unit time) at particular stranding sites may be significantly higher over a shorter time interval or possibly attenuated to a lower rate at the downstream locations where stranding was observed.

3.2 Fish Stranding Assessment Results (2006 to Present)

Fish stranding assessment results have been presented from 2006 to present during a period of consistent assessment methodology. Therefore, results from assessments prior to September 15, 2006 have been excluded from the dataset. Stranding assessments were conducted following seven flow reductions during the present study. All fish encountered during the assessments have been split into sportfish and non-sportfish categories for analysis. The scientific names of all species in these categories are presented in Table 3.

Table 3: Scientific names of fish species encountered during fish stranding assessments on the lower Duncan River, September 2006 to January 2012.

Category	Species	Scientific Name	Species Code[a]
Sportfish	Rainbow Trout	*Oncorhynchus mykiss*	*RB*
	Bull Trout	*Salvelinus confluentus*	*BT*
	Mountain Whitefish	*Prosopium williamsoni*	*MW*
	Pygmy Whitefish	*Prosopium coulteri*	*PW*
	Kokanee	*Oncorhynchus nerka*	*KO*
	Burbot	*Lota lota*	*BB*
Non-sportfish	Longnose Dace	*Rhinichthys cataractae*	*LNC*
	Dace spp.	*Cottus species*	*DC*
	Slimy Sculpin	*Cottus cognatus*	*CCG*
	Torrent Sculpin	*Cottus rhotheus*	*CRH*
	Prickly Sculpin	*Cottus asper*	*CAS*
	Sculpin spp.	*Cottus species*	*CC*
	Sucker spp.	*Catostomus species*	*SU*
	Redside Shiner	*Richardsonius balteatus*	*RSC*
	Northern Pikeminnow	*Ptychocheilus oregonensis*	*NSC*
	Peamouth Chub	*Mylocheilus caurinus*	*PCC*
	Lake Chub	*Couesius plumbeus*	*LKC*

[a] As defined by the BC *Ministry of Environment*.

Within the dataset analyzed, the number of reduction events assessed for fish stranding per study year ranged from two (2006 - 2007) to eight (2008 - 2009; Table 4). As discussed above, the focus of sampling shifted from index sites to non-index sites, which accounted for a larger proportion of sites sampled in the present study year. The number of pools sampled in the present year was also reduced to allow for more intensive interstitial sampling effort. This resulted in the minimum number of pools (n = 78), and the second most number of interstitial grids (n = 331) assessed in a single study year (Table 4).

Table 4: Sampling effort during reductions of each study year that were included in the present analysis.

Study Year	Number of Reductions Assessed	Number of Index Sites Assessed	Number of Non-Index Sites Assessed	Total Number of Pools Sampled	Total Number of Interstitial Grids Conducted
2006-2007	2	16	0	144	15
2007-2008	7	56	0	346	40
2008-2009	8	42	0	233	34
2009-2010	6	33	14	221	40
2010-2011	7	50	22	346	96
2011-2012	7	29	21	92	411
2012-2013	7	20	18	78	331

In the present year of study (2012 - 2013), a total of 896 fish were observed, representing 10 species [five sportfish and five non-sportfish species (Table 5)]. Juvenile Rainbow Trout were the most abundant sportfish, followed by Kokanee young-of-the-year (YOY), accounting for 37.1 and 28.7% of the total number of fish, respectively (Table 5, Figure 3). The most common non-sportfish taxa were Sculpin spp. and Longnose Dace, accounting for 14.5 and 3.6% of the total number of observed fish, respectively.

Table 5: Total number and relative composition of fish species captured or observed during all stranding assessments conducted on the lower Duncan River from September 2006 to April 2013.

Species and Life Stage			N Fish (% of Total) 2006-07	N Fish (% of Total) 2007-08	N Fish (% of Total) 2008-09	N Fish (% of Total) 2009-10	N Fish (% of Total) 2010-11	N Fish (% of Total) 2011-12	N Fish (% of Total) 2012-13
Sport Fish	Rainbow Trout	Adult	0 (0)	0 (0)	0 (0)	1 (0.1)	0 (0)	0 (0)	0 (0)
		Juvenile	130 (37.1)	278 (11.5)	530 (33.2)	113 (12.3)	343 (25.2)	452 (24.2)	332 (37.1)
	Bull Trout	Adult	0 (0)	0 (0)	0 (0)	4 (0.4)	0 (0)	0 (0)	0 (0)
		Juvenile	2 (0.6)	0 (0)	11 (0.7)	1 (0.1)	6 (0.4)	2 (0.1)	3 (0.3)
	Mountain Whitefish	Adult	0 (0)	1 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
		Juvenile	1 (0.3)	157 (6.5)	70 (4.4)	4 (0.4)	45 (3.3)	225 (12.1)	6 (0.7)
	Pygmy Whitefish	Adult	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
		Juvenile	0 (0)	0 (0)	0 (0)	1 (0.1)	3 (0.1)	55 (3)	0 (0)
	Kokanee	Adult	0 (0)	97 (4.0)	572 (35.8)	112 (12.2)	42 (3.1)	3 (0.2)	111 (12.4)
		Y-O-Y	0 (0)	1695 (70.4)	85 (5.3)	109 (11.9)	83 (6.1)	858 (46)	257 (28.7)
	Burbot	Adult	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	1 (0.1)	0 (0)
		Juvenile	0 (0)	0 (0)	1 (0.1)	0 (0)	0 (0)	0 (0)	1 (0.1)
Non-sport fish	Longnose Dace		117 (33.4)	15 (0.6)	103 (6.5)	273 (29.7)	551 (40.5)	30 (1.6)	32 (3.6)
	Dace spp.		0 (0)	0 (0)	0 (0)	12 (1.3)	1 (0.1)	0 (0)	0 (0)
	Slimy Sculpin		0 (0)	13 (0.5)	11 (0.7)	62 (6.8)	39 (2.9)	6 (0.3)	0 (0)
	Torrent Sculpin		0 (0)	1 (0)	1 (0.1)	0 (0)	0 (0)	3 (0.2)	0 (0)
	Prickly Sculpin		0 (0)	0 (0)	0 (0)	0 (0)	2 (0.1)	0 (0)	0 (0)
	Sculpin spp.		23 (6.6)	16 (0.7)	65 (4.1)	62 (6.8)	165 (12.1)	99 (5.3)	130 (14.5)
	Sucker spp.		2 (0.6)	4 (0.2)	26 (1.6)	166 (18.1)	54 (4.0)	9 (0.5)	16 (1.8)
	Redside Shiner		0 (0)	112 (4.6)	8 (0.5)	15 (1.6)	0 (0)	0 (0)	7 (0.8)
	Northern Pikeminnow		0 (0)	0 (0)	2 (0.1)	0 (0)	15 (1.1)	7 (0.4)	1 (0.1)
	Peamouth Chub		0 (0)	0 (0)	6 (0.4)	6 (0.7)	0 (0)	0 (0)	0 (0)
	Lake Chub		0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
	Unidentified		75 (21.4)	20 (0.8)	105 (6.6)	4 (0.4)	13 (1.0)	114 (6.1)	0 (0)
All Species Total			**350**	**2409**	**1596**	**918**	**1361**	**1864**	**896**

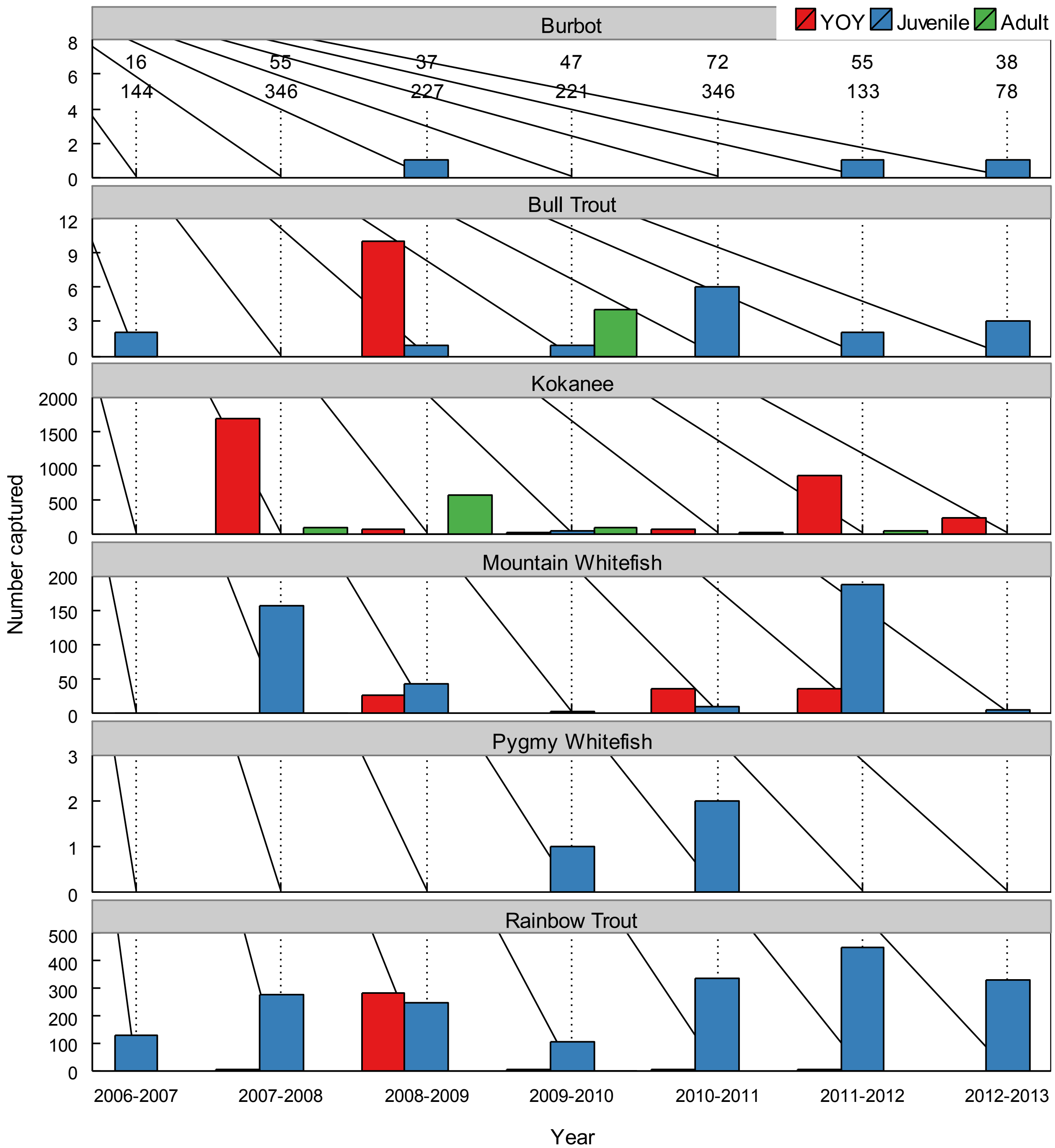


Figure 3: Abundances of sportfish species, separated by life stage, observed in stranding assessments between 2006 and 2012. Note the different y-axis scales among panels. On the uppermost panel, the numbers of sampled sites and pools are provided in the first and second lines, respectively.

3.3 Differences between Pre-WUP and Post-WUP Operations

Based on DDM flow data provided by BC Hydro, the DDMMON-3 model outputs, and subsequent analysis the overall mean area exposed during pre-WUP operations was 17.03 km², in comparison to 14.05 km² during the post-WUP operational regime (Figure 4). The area exposed is less variable from year to year in the post-WUP operational regime over the years assessed and is in general, lower (Figure 4). The maximum annual exposed area (20.91 km²) was observed in 2006, during pre-WUP operations. The minimum exposed area (12.5 km²) was observed in 2010 during post-WUP operations (Figure 4).

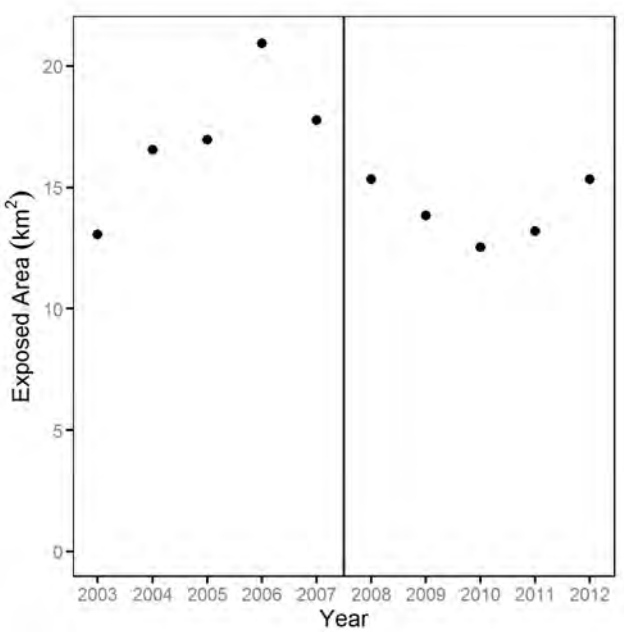


Figure 4: Total area exposed by all annual reductions in the LDR by year of operations. The vertical line denotes the beginning on WUP flows in 2008.

Interannual variability in discharge as assessed at the gauge at DRL overall is higher in the pre-WUP period, with the most radical difference seen in the October to January period. Under the current operational regime (i.e., 2008 to present), there is almost no interannual deviation during the October to January period (Figure 5). Decreased discharge variability post-WUP is also seen between January and March. An additional change in discharge patterns is seen between March and May, where discharge trend changed from gradual decrease pre-WUP to a gradual increase post-WUP (Figure 5).

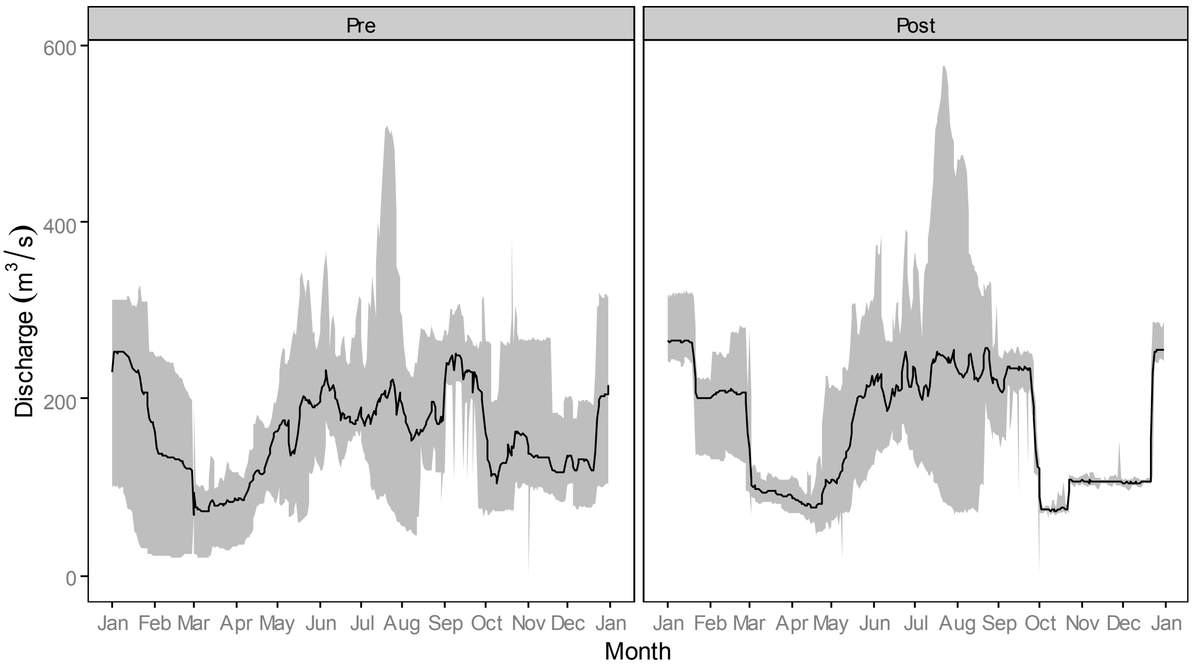


Figure 5: Minimum, maximum (grey ribbon) and mean (black line) discharge as measured at the WSC DRL gauge in the LDR by month during pre-WUP operations (2002 - 2007) and post-WUP operational implementation (2008 - 2012).

4.0 DISCUSSION

4.1 Current Duncan Dam Operations in Relation to Fish Stranding

4.1.1 Pre- and Post-WUP Operating Regimes

Management Question 1) (*How effective are the operating measures implemented as part of the ASPD program?)* was partially addressed by examining the differences between the pre- and post WUP flow regimes. Under the water license, two large flow reductions occur on an annual basis, in late September to early October for Kokanee protection and in late winter for support of Columbia River Mountain Whitefish management objectives. The purpose of the late winter flow reductions is to manage Duncan Reservoir flood control targets as defined under the Columbia River Treaty. In addition there are several smaller reductions that occur throughout the year to effectively manage water resources and power generation.

The assessment of the amount of area of exposed habitat per year due to LDR discharge reductions suggests that post-WUP flows have resulted in the dewatering of less habitat compared to pre-WUP operations. Interannual variability in discharge has also been reduced under post-WUP operations. Concurrently, DDM operations are required under the current water license, to reduce flows at a ramping rate that ensures a stage change of 10 cm/hr or less at the majority of identified stranding sites when possible. As recommended by the DDMMON-1 Program (Poisson and Golder 2010), this ramping rate is believed to minimize the risk of fish stranding and is supported by studies conducted in Norway (Halleraker et al. 2003), which recommended the same ramping rates to reduce stranding rates of salmonids, especially after an extended period of stable flows.

Total area dewatered during all annual flow reductions was used to determine differences in pre- and post-WUP operations, because the area exposed relates directly to the hydraulic and stranding analysis models. This comparison did not take into account the magnitude or rate of the discharge reductions that may affect the stranding risk. Also, the sampling program assessing the fish stranding levels through time has had different methodologies and varying study foci through the years so it is not possible to analyze fish stranding data from the pre-WUP and post-WUP periods. Therefore, only indirect assessments can be made on the effectiveness of the post-WUP operations.

4.1.2 Variables Affecting Fish Stranding

There are several environmental and operational variables of interest that could affect fish stranding. Within that suite of variables, those that are currently addressed by operational strategies to potentially reduce fish stranding rates are ramping rate (discussed above in Section 4.1.4) and time of day (Golder 2011, Golder and Poisson 2012). These variables were analysed and discussed as part of DDMMON-1 – Lower Duncan River Ramping Rate Monitoring (Poisson and Golder 2010).

DDMMON-1 showed a trend of increased fish stranding at night (Poisson and Golder 2010). For the LDR, there is evidence to suggest night time flow reductions in the autumn period lead to more stranding of the species of interest than daytime reductions. This is consistent with use and activity patterns for juvenile salmonids observed in past work (AMEC 2003 and Thorley et al. 2011). All flow reductions under present DDM operations occur in the daytime period, which follows the recommendations of DDMMON -1 & -15 and allows for fish stranding assessments immediately after the reductions.

Operational variables related to stranding that were identified in the DDMMON#1 program are wetted history and season. Wetted history defines the amount of time that a particular portion of the river downstream of DDM remained stable with respect to flow provision, and can correlate to stranding rate. Further study and analysis is required to confirm or deny this trend throughout the year, and to consider how it could be translated into a mitigation tactic. Time of year was a major variable in fish stranding with the highest observed rates of stranding occurring late summer/early fall, and late winter, which coincide both with the two large annual flow reductions that typically occur under the current DDM operating regime, and the escapement and emigration of kokanee in the system.

4.2 Fish Stranding Summary

Management Question 2) (*What are the levels of impact to resident fish populations associated with fish stranding events on the lower Duncan River?)* was not addressed in the current study year. As stated above in Section 1.3.5, with the updating of the DDMMON-3 Hydraulic Model and the postponement of the abundance several key components required for in-depth analysis of the data set were not available. Therefore, in-depth analysis of the data-set was not conducted and only preliminary interpretations of the results from the assessments are presented.

The species of interest for this study program are Rainbow Trout and Mountain Whitefish. During the Year 5 assessments, ten different species were encountered (five sportfish and five non-sportfish species), but only three species had substantial numbers of stranded individuals: rainbow trout, kokanee, and sculpin (Table 5).

Determining how estimates of mortality due to stranding affect the population is difficult (Golder 2011). Several factors affect fish populations including: predation, outmigration, food availability, availability of suitable rearing habitats, winter mortality, as well as inter- and intra-specific competition. Whether stranding events kill fish that would have died because of these factors, or kill fish which would survive these factors is unknown (Golder and Poisson 2012).

4.2.1.1 Rainbow Trout

The second specific hypothesis (H_{02}) to address Management Question 2 states*: Fish populations in the LDR are not significantly impacted by fish stranding events*. In Year 4, based on the likely overestimated interstitial stranding estimates, combined with relatively precise pool estimates, hypothesis H_{02} was rejected (Golder and Poisson 2012). Although interstitial and pool stranding estimates were not analyzed in Year 5, preliminary examination of the data collected showed the number of Rainbow Trout encountered during assessments was within the range documented in previous study years (Table 5).

There is high uncertainty related to the most recent abundance estimates for Rainbow Trout juveniles in the LDR (Thorley et al. 2012). The Habitat Conservation Trust Fund (HCTF) is conducting an ongoing stock assessment for the Duncan-Lardeau system, and as part of that program is an in-depth analysis of rainbow trout snorkel counts and mark-resighting data (J. Thorley, Statistician, Poisson Consulting., pers. comm., 2012). The HCTF analysis should help reduce this uncertainty (Thorley et al. 2012).

As in-depth analysis to address the Management Questions was not conducted in the present study year, we are unable to re-examine hypothesis H_{02}. In order to address hypothesis H_{02} more confidently, it is critical that the uncertainties associated with the abundance and interstitial stranding estimates be refined.

4.2.1.2 Mountain Whitefish

Over the course of the study year, only six stranded Mountain Whitefish were documented, five of which were observed in the fall season (RE2012-05 and 06). Mountain Whitefish encounters have been minimal in all study years. This consistently low level of stranding was not considered ecologically significant and will likely not result in a population level effect. However, previous experimental stranding investigations indicated that large numbers of mountain whitefish could be stranded during rapid night time reductions in flow (Poisson and Golder 2010).

4.2.2 Stranding Mechanism Classification

The estimated numbers of interstitially stranded fish in the lower Duncan River for low slope habitats obtained in Years 3 and 4 were relatively high and uncertain (Golder 2011, Golder and Poisson 2012). Random sampling of interstitial habitat began in August 2011, and is comparatively new to the program. While interstitial stranding is likely to be biologically important, the previous estimates may be upwardly biased as some dewatered pools that contained stranded fish may have been considered to be interstitial habitat. This potential bias has been removed with the addition of the third, “dried pool” stranding mechanism category.

4.3 Summary

In summary, this monitoring program provides an understanding of fish stranding in relation to DDM operations and helps management to reduce the severity of fish stranding in the LDR. Based on the current state of knowledge, the flow reduction measures implemented under the WUP are effective at reducing fish stranding. Whenever possible, flow reductions at DDM follow recommendations made by the various studies conducted on the LDR. To better understand stranding related to the species of interest in the LDR, the abundance and interstitial stranding estimates for these species needs further refinement. The refinements and other recommendations discussed in Section 5.0 will work towards reducing the uncertainly around these estimates.

5.0 RECOMMENDATIONS

Recommendations for next year of the DDMMON-16 Lower Duncan River Fish Stranding Impact Monitoring Program are as follows:

1) Continue following current methodology in future stranding assessments, with the new classification of stranding mechanisms. This will continue to strengthen the existing dataset and allow more accurate estimates of fish stranding in the LDR.

2) Continue to build on the stranding site selected program to ensure that sites assessed are representative of the river;

3) Once the DDMMON-3 Hydraulic Model has been updated, conduct several model runs to determine the wetted area of the Duncan River at varying DRL discharges. From this we can update our dataset, calculate the dewatered area at each of our sites, and have the most up to date and representative data to conduct the stranding analyses in Years 6 and 7.

4) Conduct additional work on slopes within each identified stranding site. This can be achieved by obtaining the DDMMON-3 Digital Elevation Model (DEM) once it has been updated. Once the DEM is obtained, the slopes of each sample site can be recalculated and updated to better represent conditions in the LDR.

5) Use the updated DDMMON-3 Hydraulic Model to identify areas with certain velocity and depth criteria to select sites to sample for the abundance estimate program. This most likely can be completed when the model runs are conducted for point 3 above, but may require additional model runs as well.

6) As part of the abundance estimate program, explore the feasibility of obtaining spring fry abundance estimates to further refine annual stock assessments. As in Year 3 (Golder 2011), the Rainbow Trout surveys conducted by DDMMON-2 may be expanded to obtain abundance estimates for this program.

7) When finalized, incorporate the findings and recommendations of the ongoing HCTF's ongoing stock assessment of Rainbow Trout into this programs abundance estimate methodology.

These recommendations will focus sampling effort and are designed to build on the current data set. The focus of future study years should be on the refinement of interstitially stranded fish estimates throughout the system, as well as ensuring that the abundance estimates obtained in study Years 6 and 7 are as accurate as possible. Prior to abundance estimate sampling in Year 6, study leads for both DDMMON-3 and 16 will have to work closely to ensure that appropriate data sharing between the program occurs. As for future fish stranding assessments, sampling methods should remain such that comparisons with historical data can be maintained.

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7.0 CLOSURE

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

GOLDER ASSOCIATES LTD.

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APPENDIX A

Year 6 Abundance Estimation Methodology

Prior to Field work:

1) Consult the weather forecast prior to sampling.
2) Organize field work schedule and communication protocol with contract authority: James Baxter: 250-365-4593, and Duncan Dam staff: Len or Kris Wiens: 250-366-4257.

Field Sampling:

Field sampling during abundance assessments will be conducted as consistently as possible with previous fish abundance assessments performed by AMEC Environment & Infrastructure Ltd. And Poisson Consulting Ltd., with the following changes to methodology to ensure sampling robustness while addressing logistic difficulties:

1) If feasible, travel to Meadow Creek or Kaslo the day before the scheduled abundance assessment and stay overnight in staff house (arrangements to be made with Len Wiens 250-366-4257) or at the Kaslo Motel (Front Desk 250-353-2431). It is our experience that with the field crew staying overnight in Meadow Creek or Kaslo, fieldwork can be initiated earlier the following day.

2) To sample a similar length of river as in previous reports (5,700 and 3,600 m in fall 2010 and spring 2012 surveys, respectively), we will select 20 sites of approximately 250 m each. The longer sites, in comparison to the 2010 survey, will allow us to reduce the number of sites, and therefore logistic difficulties, in comparison to the 2010 survey, while maintaining random and robust coverage of the Duncan system.

3) Based on the results from the DDMMON-2 abundance estimate methodology (Thorley et. al. 2011), the RIVER-2D hydraulic model developed as part of the DDMMON-3 program will be used to divide the shorelines of the LDR mainstem and side channels into the following 4 strata:

   - Shallow (≤ 0.4 m) and Slack (≤ 0.02 m/s);
   - Shallow (≤ 0.4 m) and Flowing (> 0.02 m/s to 0.5 m/s);
   - Deep (> 0.4 m to 1.5 m) and Slack (≤ 0.02 m/s); and,
   - Deep (> 0.4 m to 1.5 m and Flowing (> 0.02 m/s to 0.5 m/s).

   Sampling effort in each strata will be proportionate to the amount of area in each strata that is available. Sites will be randomly selected using linear Generalized Random Tessellation Stratification (GRTS) along the thalweg. Sites will not be stratified by main and side channel, since previous reports found no significant differences in abundance among the two types of habitat (Thorley et al. 2010).

4) Due to the frequent changes in channel morphology and the high number of log jams, some of the pre-selected sites may not be accessible or safe. Therefore, GRTS sampling will include 10 oversampling sites, so that if a pre-selected site is deemed unsafe to sample, an oversampling site will be used instead.

5) Prior to the nighttime sample days, the crew will survey the GRTS-selected sampling sites by boat. The sites that are to be sampled will be marked using flagging tape at the downstream and the upstream boundaries of the site.

6) Snorkelling assessments of abundance will commence at least 30 minutes after sunset, to ensure sufficient darkness. Three snorkelers will survey each site, moving in the upstream direction. Depending on the width of the site, the third snorkeler will either swim or support the other snorkelers by recording data and holding lights. The snorkelers will record the numbers and estimated sizes of target species using underwater writing boards. Each snorkeler will have a throw bag to assist with rescue if needed.

7) Each site will be surveyed by snorkelers to a maximum depth of 1.5 m, as Thorley et al. (2012) reported that the vast majority of Mountain Whitefish and Rainbow Trout fry and parr are found in shallower depths. In the shallows (15 cm or less), fish will be observed by carefully walking and using a spotlight. Underwater visibility range will be estimated as the distance at which a snorkeler will no longer be able to discern the black-and-white pattern on a Secchi disk.

8) Field crews will record the following information for each site: date, time of beginning and end of sampling of each site, GPS location of the upstream and downstream boundaries of each site, and the number and estimated size of the observed target species.

9) During sampling, the validity of the predicted habitat characteristics (strata) at each site will classified based on visual estimation. A subset of measurements will be taken to calibrate observers and classify any uncertainties related to the model predictions of strata.

10) A safety boat with an experience operator and an assistant will be stationed at the downstream end of each site to allow for rescue of the snorkelers if needed. This boat will also be used to travel to each site.

Post Sampling:

1) Once the crew returns to the office, all relevant equipment with data (i.e. camera, GPS) will be downloaded, and data will be stored put in the corresponding analysis folder.
2) All data sheets will be placed in the 12-1492-0117 non-entered data folder in top drawer of right fireproof filing cabinet.

Analysis:

1) Separate abundance estimates will be conducted for each target species (Mountain Whitefish and Rainbow Trout) and life stage (juveniles and adult). Rainbow Trout and Mountain Whitefish with a fork length smaller 250 mm will be considered juveniles. Fish larger than this cut-off value will be considered adults.
2) Hierarchical Bayesian Models will be used to estimate total abundance. Fish counts will be assumed to be Poisson-distributed, with a mean expected density drawn from a log-normal distribution. Observer efficiency, derived from previous work on Rainbow Trout and Mountain Whitefish in the Duncan (Thorley et al. 2012), will be used to estimate total fish abundance at each site from the number of observed fish. The estimated site abundance and the sampled length of site will be used to estimate lineal density of fish. The hydrological RIVER-2D model will be used to estimate the total length of similar depths and velocities to those sampled in the field, and the lineal density of fish will be extrapolated to total abundance.

Equipment List:

The following equipment will be prepared for field work:

- Truck with proper hitch
- G3 boat and appropriate safety gear
- 3 hand-held, waterproof flashlights
- Spot lights
- Fish sample kit
- Level 1 First Aid kit
- Throwbags
- Bear kit
- Clipboard with Duncan River Fish Abundance Survey Form and Duncan Abundance Habitat and Fish Record datasheets on waterproof paper, HASP, BC Hydro South Interior Radio System Info sheet, WPP Local Component for Duncan Dam Info sheet, pencils, Fish ID key, Modified Wentworth Substrate Key, Duncan Stranding Protocol (2012), 12-1492-0117 Specific Work Instructions (this document)
- Underwater writing boards
- Satellite phone
- VHF Radio with BC Hydro frequencies (Provided by BC Hydro)
- Laser Rangefinder
- Digital Camera
- GPS (WAAS Enabled)
- Thermometer
- Laminated Maps for identification of snorkel sites (Duncan River Orthophotos)

Personal Gear:

- Lifejacket
- Dry suits
- Rain gear
- Dry bag with spare clothes
- Headlamps
- Personal First Aid kit

References:

Thorley, J., R. Irvine, J. Baxter, L. Porto, and C. Lawrence. 2012. Lower Duncan River habitat use (DDMMON-2). Year 3 final report. Report prepared for: BC Hydro, Castlegar. Prepared by: AMEC Environment & Infrastructure Ltd., Poisson Consulting Ltd., and Mountain Water Research.

Thorley, J., L. Porto, J. Baxter, and J. Hagen. 2010. Lower Duncan River habitat use monitoring; year 1 data report.

APPENDIX B

Summary of Identified Stranding Sites

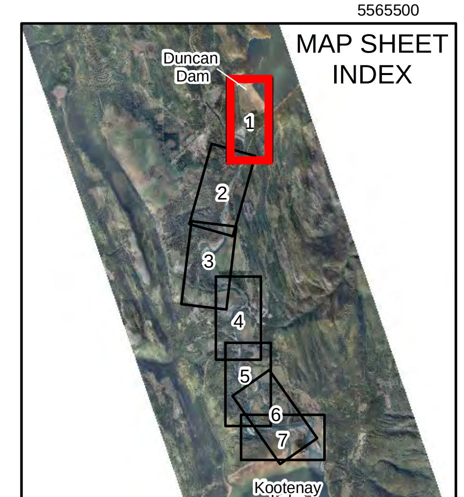
LEGEND

- RIVER KILOMETRE
- WSC GAUGE
- BOAT LAUNCH
- STRANDING SITE - INDEX
- STRANDING SITE - NON-INDEX

REFERENCE

1. IMAGERY FROM BC HYDRO, 2012

PROJECTION: UTM ZONE 11N DATUM: NAD 83



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SCALE 1:5,000

PROJECT: DDMMON-16
LOWER DUNCAN RIVER FISH STRANDING IMPACT MONITORING

TITLE: **LOWER DUNCAN RIVER STRANDING ASSESSMENT SITES**

Golder Associates

PROJECT No. 12-1492-0117			SCALE AS SHOWN	REV. 0
DESIGN	BH	9 Apr. 2013	FIGURE 1	
GIS	CD	9 Apr. 2013		
CHECK	BH	31 Jan. 2014		
REVIEW	GB	31 Jan. 2014		

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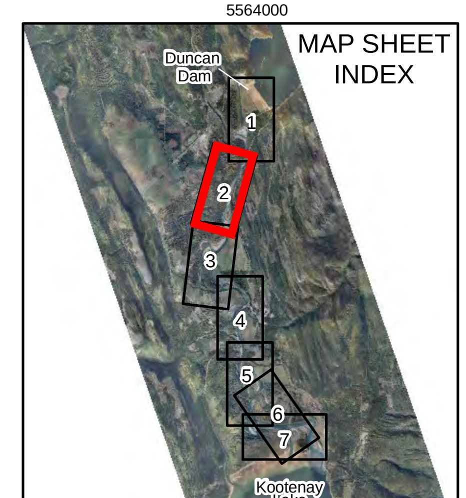

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SCALE 1:5,000

LEGEND

- RIVER KILOMETRE
- WSC GAUGE
- BOAT LAUNCH
- STRANDING SITE - INDEX
- STRANDING SITE - NON-INDEX

REFERENCE

1. IMAGERY FROM BC HYDRO, 2012

PROJECTION: UTM ZONE 11N DATUM: NAD 83

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PROJECT

DDMMON-16
LOWER DUNCAN RIVER FISH
STRANDING IMPACT MONITORING

TITLE

LOWER DUNCAN RIVER
STRANDING ASSESSMENT SITES

Golder Associates

PROJECT No. 12-1492-0117			SCALE AS SHOWN	REV. 0
DESIGN	BH	9 Apr. 2013	FIGURE 2	
GIS	CD	9 Apr. 2013		
CHECK	BH	31 Jan. 2014		
REVIEW	GB	31 Jan. 2014		

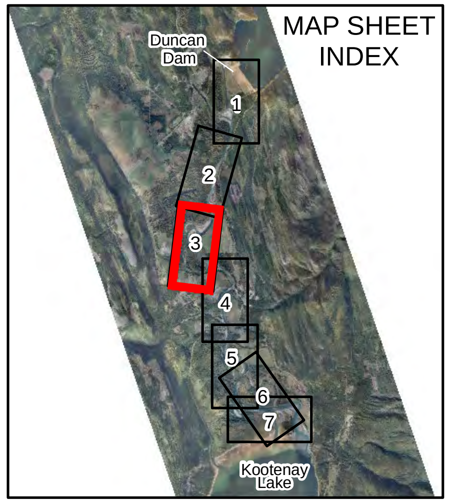
LEGEND

- RIVER KILOMETRE
- WSC GAUGE
- BOAT LAUNCH
- STRANDING SITE - INDEX
- STRANDING SITE - NON-INDEX

REFERENCE

1. IMAGERY FROM BC HYDRO, 2012

PROJECTION: UTM ZONE 11N DATUM: NAD 83



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PROJECT

DDMMON-16
LOWER DUNCAN RIVER FISH
STRANDING IMPACT MONITORING

TITLE

LOWER DUNCAN RIVER
STRANDING ASSESSMENT SITES

PROJECT No. 12-1492-0117			SCALE AS SHOWN	REV. 0
DESIGN	BH	9 Apr. 2013		
GIS	CD	9 Apr. 2013	FIGURE 3	
CHECK	BH	31 Jan. 2014		
REVIEW	GB	31 Jan. 2014		

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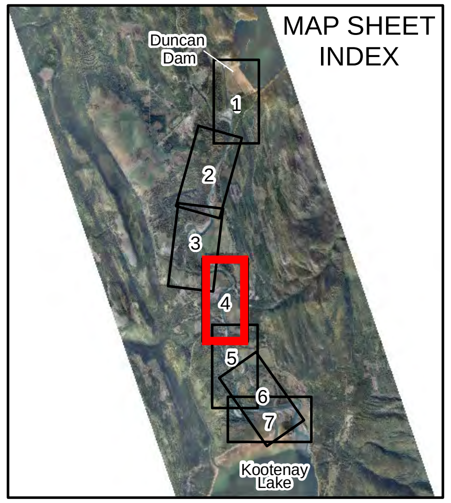
LEGEND

- RIVER KILOMETRE
- WSC GAUGE
- BOAT LAUNCH
- STRANDING SITE - INDEX
- STRANDING SITE - NON-INDEX

REFERENCE

1. IMAGERY FROM BC HYDRO, 2012

PROJECTION: UTM ZONE 11N DATUM: NAD 83



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PROJECT	DDMMON-16 LOWER DUNCAN RIVER FISH STRANDING IMPACT MONITORING
TITLE	**LOWER DUNCAN RIVER STRANDING ASSESSMENT SITES**

Golder Associates	PROJECT No. 12-1492-0117			SCALE AS SHOWN	REV. 0
	DESIGN	BH	9 Apr. 2013	FIGURE 4	
	GIS	CD	9 Apr. 2013		
	CHECK	BH	31 Jan. 2014		
	REVIEW	GB	31 Jan. 2014		

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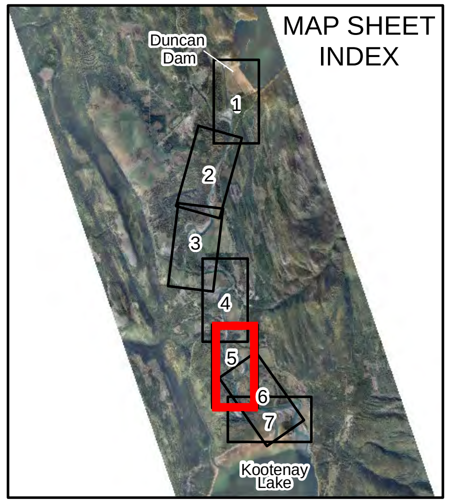
LEGEND

- RIVER KILOMETRE
- WSC GAUGE
- BOAT LAUNCH
- STRANDING SITE - INDEX
- STRANDING SITE - NON-INDEX

REFERENCE

1. IMAGERY FROM BC HYDRO, 2012

PROJECTION: UTM ZONE 11N DATUM: NAD 83



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PROJECT

DDMMON-16
LOWER DUNCAN RIVER FISH
STRANDING IMPACT MONITORING

TITLE

LOWER DUNCAN RIVER
STRANDING ASSESSMENT SITES

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PROJECT No. 12-1492-0117			SCALE AS SHOWN	REV. 0
DESIGN	BH	9 Apr. 2013		
GIS	CD	9 Apr. 2013		
CHECK	BH	31 Jan. 2014	FIGURE 5	
REVIEW	GB	31 Jan. 2014		

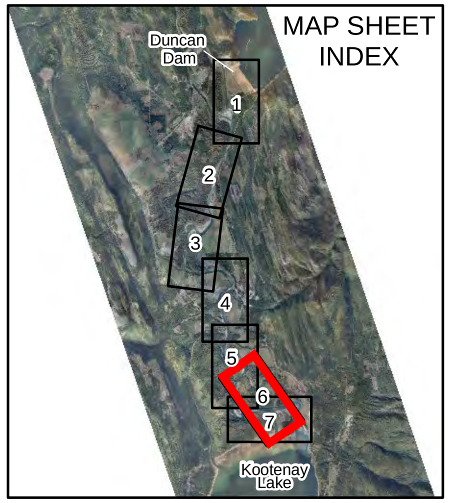
LEGEND

- RIVER KILOMETRE
- WSC GAUGE
- BOAT LAUNCH
- STRANDING SITE - INDEX
- STRANDING SITE - NON-INDEX

REFERENCE

1. IMAGERY FROM BC HYDRO, 2012

PROJECTION: UTM ZONE 11N DATUM: NAD 83



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PROJECT	DDMMON-16 LOWER DUNCAN RIVER FISH STRANDING IMPACT MONITORING
TITLE	**LOWER DUNCAN RIVER STRANDING ASSESSMENT SITES**

PROJECT No. 12-1492-0117			SCALE AS SHOWN	REV. 0
DESIGN	BH	9 Apr. 2013	FIGURE 6	
GIS	CD	9 Apr. 2013		
CHECK	BH	31 Jan. 2014		
REVIEW	GB	31 Jan. 2014		

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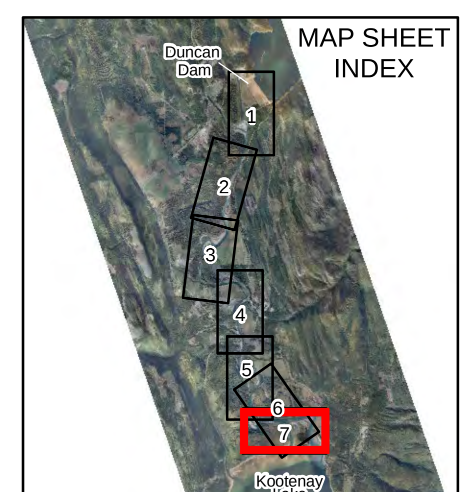
LEGEND

- RIVER KILOMETRE
- WSC GAUGE
- BOAT LAUNCH
- STRANDING SITE - INDEX
- STRANDING SITE - NON-INDEX

REFERENCE

1. IMAGERY FROM BC HYDRO, 2012

PROJECTION: UTM ZONE 11N DATUM: NAD 83



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PROJECT

DDMMON-16
LOWER DUNCAN RIVER FISH
STRANDING IMPACT MONITORING

TITLE

LOWER DUNCAN RIVER
STRANDING ASSESSMENT SITES

Golder Associates

PROJECT No. 12-1492-0117			SCALE AS SHOWN	REV. 0
DESIGN	BH	9 Apr. 2013	FIGURE 7	
GIS	CD	9 Apr. 2013		
CHECK	BH	31 Jan. 2014		
REVIEW	GB	31 Jan. 2014		

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APPENDIX C

Photographic Plates

Plate 1 Moderate to High complexity pool at site S3.5-4.0R, April 15, 2012.

Plate 2 Small woody debris cover in isolated pool, site S7.6L on September 26, 2012.

Plate 3 Shallow pool cover at site S3.5-4.0R on April 15, 2012.

Plate 4 Kokanee eggs found in interstitial grid, site S6.9R on September 26, 2012.

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