Columbia River Project Water Use Plan

Lower Columbia River Fish Management Plan

Lower Columbia River Fish Stranding Assessment and Ramping Protocol

Implementation Year 15

Reference: CLBMON-42A

Annual Monitoring Report

Study Period: April 2021 to April 2022

Golder Associates Ltd.
201 Columbia Avenue
Castlegar, BC

October 19, 2022

REPORT

Annual Summary Report

Lower Columbia River (CLBMON-42[A]) and Kootenay River Fish Stranding Assessments: Annual Summary (April 2021 to April 2022)

Submitted to:

BC Hydro

601 18th Street
Castlegar, BC
V1N 4G7

Submitted by:

Golder Associates Ltd.
201 Columbia Avenue, Castlegar, British Columbia, V1N 1A8, Canada

+1 250 365 0344

21508219-002-R-Rev1

19 October 2022

Cover Photo: Pool formed at Trail Bridge (RUB) during flow reduction event RE2021-28 on 20 November 2021 (see Appendix A; Figure A7 for location).

Suggested Citation: Golder Associates Ltd. 2022. Lower Columbia River (CLBMON-42[A]) and Kootenay River Fish Stranding Assessments: Annual summary (April 2021 to April 2022). Report prepared for BC Hydro. Golder Report No. 21508219-002-R-Rev1: 31 p. + 3 app.

Executive Summary

Discharge reductions and from Hugh L. Keenleyside Dam/Arrow Lakes Generating Station (HLK/ALH) and Brilliant Dam/Expansion (BRD/X) can result in fish stranding on the lower Columbia and Kootenay rivers downstream of these facilities. To address this concern, the Lower Columbia River Fish Stranding Assessment and Ramping Protocol (CLBMON-42) was implemented in 2007 as part of BC Hydro's Water Use Plan for the Columbia River (BC Hydro 2007). The primary objective of CLBMON-42 was to collect fish stranding data to assess the impact of flow reductions and flow ramping rates from HLK on the native fish species of the lower Columbia River. In 2020, upon completion of the 13-year Water Use Plan for the Columbia River, an analysis was conducted on a 20-year dataset of fish stranding assessments to address the five management questions of CLBMON-42 (Table ES1).

The present study is an extension (Year 15) on the Lower Columbia River and Kootenay River Fish Stranding Assessments (CLBMON-42[A]), which summarizes the results of stranding assessments collected following flow reductions at HLK/ALH and BRD/X at sites on the lower Columbia and Kootenay rivers between 1 April 2021 and 1 April 2022.

At total of 32 reduction events (RE) occurred between 1 April 2021 and 1 April 2022 (the present study period). Of these, 28 reduction events occurred at HLK/ALH and 4 occurred at BRD/X. Stranding assessments were determined to be required for 9 of the 32 reduction events. Of those 9 stranding assessments, 5 occurred during the High Risk period (1 June to 30 September) and 4 occurred during the Low Risk period (1 October to 31 May).

An estimated 2,199 stranded fish were encountered during the 9 stranding assessments, with the majority (76%) stranded in isolated pools. Of the total fish stranded, 51% were salvaged and successfully relocated to the mainstem Columbia or Kootenay rivers. A total of 20 sites were assessed at least once during the study period. The majority (69%) of stranded fish were found at Genelle Mainland (LUB), Bear creek (RUB), and Gyro Boat launch (RUB).

Sportfish accounted for 1% of the total stranded fish and were limited to YOY and juvenile Rainbow Trout (*Oncorhynchus mykiss*). Stranded invasive species, not native to the lower Columbia or Kootenay rivers included 3 Common Carp (*Cyprinus carpio*), 1 Tench (*Tinca tinca*), and 1 Yellow Perch (*Perca flavescens*). The remainder of stranded fish were non-sportfish; the most abundant being Sucker species (*Catostomidae spp.*), Longnose Dace (*Rhinichthys cataractae*) and Sculpin species (*Cottidae* spp.) which combined accounted for 70% of all stranded fish. Stranded species at risk were limited to 149 Umatilla Dace (*Rhinichthys umatilla*), of which 85% were successfully salvaged and returned to the mainstem of the Columbia or Kootenay rivers.

Table ES1: Summary of status on the management questions of CLBMON-42.

Objective	Management Questions [1]	Summary of Key Results
To assess the impact of flow reductions and flow ramping rates from HLK on the native species of the lower Columbia River.	MQ1: Is there a ramping rate (fast vs. slow, day vs. night) for flow reductions from HLK that reduces the number of fishes stranded (interstitially and pool) per flow reduction event in the summer and winter?	A statistical analysis conducted on the 20-year dataset of fish stranding assessments indicated little or no evidence of an effect of ramping rate within the range of operational ramping rates currently used at HLK/ALH on fish stranding in the lower Columbia River (Golder 2020a). Flow ramping studies conducted prior to CLBMON-42 also found no effect of ramping rate (Golder 2005, 2006, 2007). Previous analyses indicated that time of day was not a strong predictor of fish stranding risk; however, there were few night ramping experiments conducted, and no night-time stranding assessments were conducted (Golder 2005; Golder and Poisson 2010; Irvine et al. 2009; Irvine et al. 2014). Currently, there is insufficient data to determine whether time of day is a significant predictor of the probability of fish stranding. Additional night-time ramping experiments, or night-time reduction events and stranding assessments would be required to balance the dataset and determine if there is any difference in the probability of fish stranding between day and night.
	MQ2: Does wetted history (length of time the habitat has been wetted prior to the flow reduction) influence the number of fishes stranded (interstitially and pool) per flow reduction event for flow reductions from HLK?	In a statistical analysis conducted on the 20-year dataset of fish stranding assessments in the lower Columbia and Kootenay Rivers, wetted history had a statistically significant positive effect on both the probability and number of fish stranding (Golder 2020a). Modelling indicated that the predicted number of fish stranded per site increased from 21 fish at 1 day of wetted history to 52 fish at 50 days of wetted history. These findings were consistent with previous analyses conducted on lower Columbia and Kootenay River fish stranding assessment data (Golder and Poisson 2010; Irvine et al. 2014). This supports the idea that substrate that has been inundated for a longer period is more likely to strand fish if dewatered, compared to substrate that is inundated for a shorter period. Given these findings, wetted history is a key variable to assess prior to initiating a fish stranding assessment or fish salvage response to an operational flow reduction. An analysis conducted on historical fish stranding data for the Lower Columbia River: Fish Stranding Protocol (Golder 2021a) identified that a wetted history of 30 days represents an appropriate threshold between high (≥30 day wetted history) and low (<30 day wetted history) stranding risk.
	MQ3: Can a conditioning flow (temporary, one step, flow reduction of approximately 2 hours to the final target dam discharge that occurs prior to the final flow change) from HLK reduce the stranding rate of fishes?	Experimental flow ramping studies conducted in the summers and winters of 2004, 2005 and 2006 (prior to CLBMON-42) indicated that the use of a conditioning flow reduction appears to reduce the incidence of pool stranding on the Columbia River; however, this relationship was not statistically significant. The analysis was based on limited results and further conditioning flow experiments were recommended (Golder 2007; Irvine et al. 2009). A literature review in 2010 did not identify conclusive evidence regarding the effectiveness of a conditioning flow as a mitigation strategy for reducing fish stranding (Golder and Poisson 2010). During the 15-year period of CLBMON-42, conditioning flows have not been conducted and there is still considerable uncertainty regarding the efficacy of a conditioning flow at reducing the probability of stranding. Given the limited experiments conducted, a definitive answer regarding whether a conditioning flow can reduce the stranding rate cannot be determined.
	MQ4: Can physical habitat works (i.e., recontouring) reduce the incidence of fish stranding in high risk areas?	Six fish stranding sites on the lower Columbia River were recontoured between 2001 and 2021. To assess the effectiveness of recontouring, a statistical analysis was conducted on 20 years of lower Columbia River fish stranding data to model the probability of stranding and number of fish stranded before vs. after recontouring (Golder 2020a). Results indicate a significant reduction in both probability and number of fish stranding after recontouring compared to before recontouring. These results agree with previous analyses (Golder and Poisson 2010, Irvine et al. 2014) on recontouring and suggest that recontouring sites that pose a high stranding risk to fish is an effective mitigation strategy to reduce overall stranding.
	MQ5: Does the continued collection of stranding data, and upgrading of the lower Columbia River stranding protocol, limit the number of occurrences when stranding crews need to be deployed due to flow reductions from HLK?	During the 15-year period of CLBMON-42, the number of annual stranding assessments conducted in response to reduction events from HLK/ALH [2] has been variable (range = 8 to 15, median = 12, average = 12), with no clear increasing or decreasing trends. The response rate (i.e., the percent of annual HLK/ALH reduction events that are responded to with a field-based stranding assessment) has decreased in recent years. In 2021/2022, the response rate for HLK/ALH reduction events was 29%, which is the lowest in the 15-year period (range = 29 to 92%, median = 81%, average = 73%). Reasons for the atypically low response rate during the 2021/2022 study period were due to a variety of factors including HLK/ALH flow reductions being offset by co-occurring flow increases from BRD/X and flows in the Columbia River being well above historical average from December 2021 to March 2022 thereby limiting the risk of stranding and the requirement to conduct assessments. Overall, the continued collection of stranding data has reduced the number of stranding assessments required; however, a variety of additional factors (ex., reduction event timing, magnitude of reduction event, wetted history, discharge levels) influence whether any given reduction event will result in a stranding assessment response.

[1] The CLBMON-42 monitoring program is specific to operations at HLK; however, this facility operates in association with Arrow Lakes Generating Station (ALH) and will be referred to as the combined operation of HLK/ALH. The management questions of the program are presented as written in the CLBMON-42 Terms of Reference (BC Hydro 2007a).

[2] Flow reductions from BRD/X and/or both facilities (when a discharge reduction occurred at HLK/ALH and BRD/X) not included.

Key Words

CLMBON-42

Discharge

Fish Stranding

Flow Ramping

Flow Reduction

Kootenay River

Lower Columbia River

Re-contouring

Water Use Planning

Acknowledgements

Golder Associates Ltd. would like to thank the following individuals for their contributions to this program:

BC Hydro

Matt Casselman	Castlegar, BC
Marco Marrello	Castlegar, BC
Mark Sherrington	Burnaby, BC
Guy Martel	Burnaby, BC

Poisson Consulting Limited

Evan Amies-Galonski	Nelson, BC

Okanagan Nation Alliance

Evan Smith	Castlegar, BC
Eleanor Duifhuis	Castlegar, BC

The following employees of **Golder Associates Ltd.** contributed to the collection of data and preparation of this report.

Kevin Little	Biologist/Author
Chris King	Senior Biological Technician/Project Manager
Shawn Redden	Senior Biologist/Editor/Project Director
Dustin Ford	Senior Biologist//Editor/Database Manager
Paul Grutter	Senior Fisheries Biologist
Brad Hildebrand	Biologist
David Roscoe	Biologist
Geoff Sawatzky	Biological Technician
Natasha Audy	Biological Technician
Jamie Goodier	GIS Analyst
Carrie McAllister	Project Coordinator

Table of Contents

TABLES

FIGURES

APPENDICES

APPENDIX A
Site Maps

APPENDIX B
Database Query Example

APPENDIX C
Fish Stranding Frequency by Site

1.0 INTRODUCTION

1.1 Background

Fish stranding has been broadly recognized as a factor contributing to fish mortality. Fish can become stranded when water levels recede within the varial zone (the zone subject to seasonal inundation) of riverine habitats. When this occurs, fish can become stranded in habitats that are disconnected from the main channel (pool stranding) or become stranded between substrate particles in dewatered habitat (interstitial stranding).

Hydroelectric facilities have direct influences on water levels and thus, can affect fish stranding downstream of their operations. The Columbia River water levels below Hugh L. Keenleyside Dam and Arrow Lakes Generating Station (HLK/ALH) and the lower Kootenay River below Brilliant Dam and Brilliant Expansion Powerplant (BRD/X) are influenced by the operations of these facilities.

Fish stranding was raised as an environmental issue associated with Hugh L. Keenleyside Dam (HLK) operations by the regulatory agencies in the mid-1990's, at which time environmental monitoring began. Since that time, fish stranding assessments and flow ramping studies have been conducted, dam operations have been reviewed, flow smoothing (reductions in magnitude and frequency of reductions) has occurred, and habitat recontouring of high risk fish stranding sites has been conducted. In addition, since the mid-1990's fish stranding assessment methods have been improved, standardized, and adapted to include Kootenay River operations (BRD/X).

To continue studies related to fish stranding and dam operations, the Lower Columbia River Fish Stranding Assessment and Ramping Protocol (CLBMON-42) was implemented in 2007 as part of BC Hydro's Water Use Plan for the Columbia River (BC Hydro 2007). The primary objective of CLBMON-42 was to continue the collection of fish stranding data to assess the impact of flow reductions and flow ramping rates from HLK [3] on the native fish species of the lower Columbia River.

The approach to the monitoring program included three components:

- The continued collection of fish stranding data due to flow reduction events that occurred due to HLK/ALH (CLBMON-42[A]), and the subsequent establishment of a lower Columbia River stranding protocol;
- Conduct flow ramping studies designed to determine the effect of different flow reduction strategies on the stranding rates of fish; and
- Conduct physical habitat works in the form of gravel bar recontouring at locations where high rates of fish stranding occurs.

[3] The CLBMON-42 monitoring program is specific to operations at HLK; however, this facility operates in association with Arrow Lakes Generating Station (ALH) and will be referred to as the combined operation of HLK/ALH. The management questions of the program are presented as written in the CLBMON-42 Terms of Reference (BC Hydro 2007).

The monitoring program identified five management questions (BC Hydro 2007) which are as follows:

1) Is there a ramping rate (fast vs. slow, day vs. night) for flow reductions from HLK that reduces the number of fish stranded (interstitially and pool) per flow reduction event in the summer and winter?

2) Does wetted history (the length of time the habitat has been wetted prior to the flow reduction) influence the number of fish stranded (interstitially and pool) per flow reduction event for flow reductions from HLK?

3) Can a conditioning flow (a temporary, one step, flow reduction of approximately 2 hours to the final target dam discharge that occurs prior to the final flow change) from HLK reduce the stranding rate of fish?

4) Can physical habitat works (i.e., re-contouring) reduce the incidence of fish stranding in high risk areas?

5) Does the continued collection of stranding data, and upgrading of the lower Columbia River stranding protocol, limit the number of occurrences when stranding crews need to be deployed due to flow reductions from HLK?

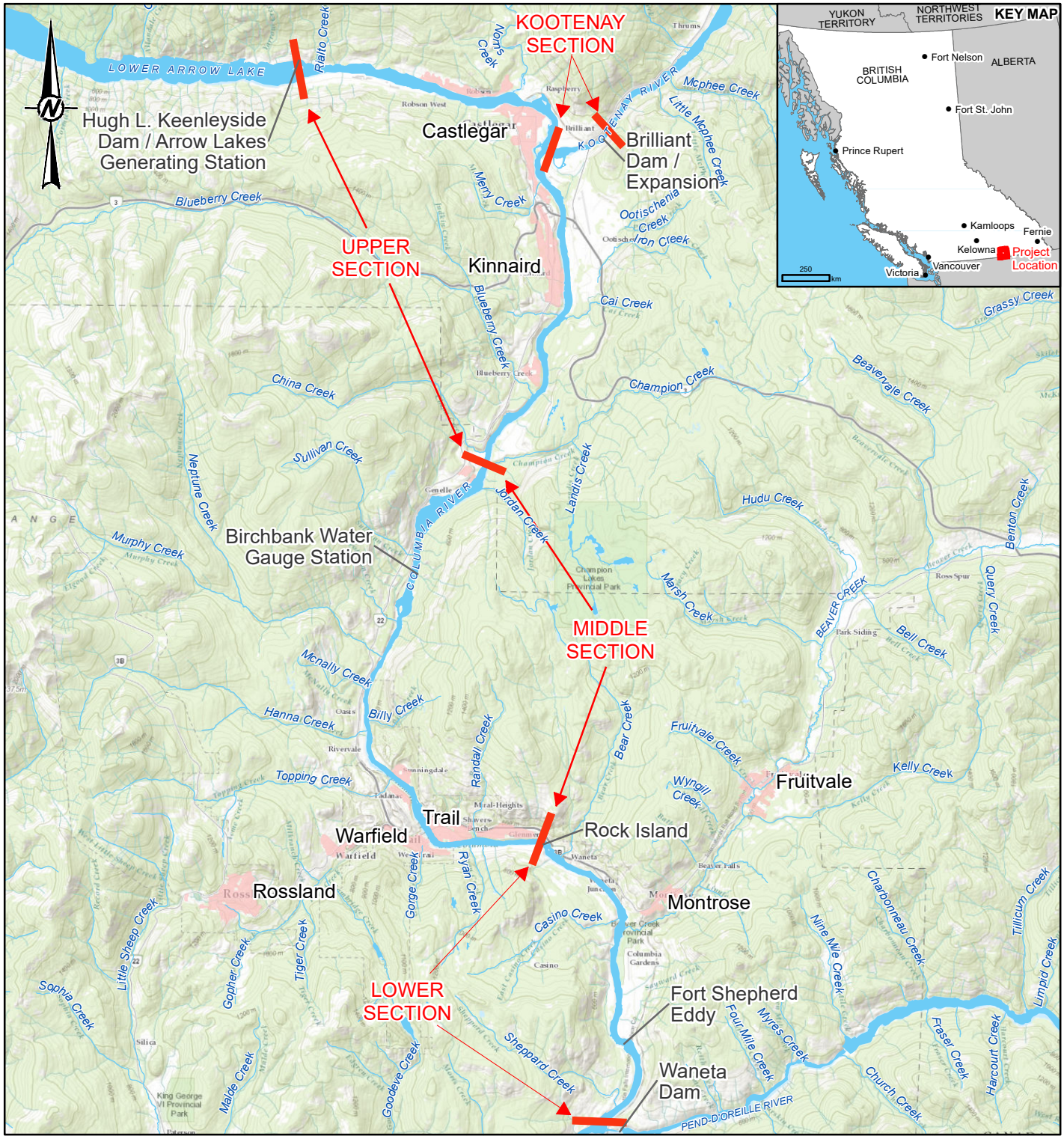
In 2020, an analysis was conducted on a 20-year dataset of fish stranding assessments conducted on the Lower Columbia and Kootenay rivers due to flow reductions from HLK/ALH and BRD/X operations to address the above management questions (Golder 2020a). This dataset included 13 years (2007/2008 to 2019/2020; study period of 1 April to 1 April annually) of fish stranding assessments conducted under CLBMON-42 and 7 years (2000 to 2007) of fish stranding assessments that were conducted in response to flow reduction events from HLK/ALH and BRD after stranding assessment methods were standardized in 1999. The status of the CLBMON-42 management questions, including a summary of the Golder (2020a) analysis and additional studies related to CLBMON-42 (Golder 2005, 2006, 2007, Golder and Poisson 2010, Irvine et al. 2009, Irvine et al. 2014), are included in Table ES1.

1.2 Scope and Objectives

The present study is an extension (Year 15) of the Lower Columbia River and Kootenay River Fish Stranding Assessments (CLBMON-42[A]), which summarizes the results of stranding assessments conducted in response to operational flow reductions at HLK/ALH and BRD/X. Stranding assessment were conducted at pre-determined stranding site (Appendix A) on the lower Columbia and Kootenay rivers between 1 April 2021 and 1 April 2022 (the present study period). The primary objective of conducting fish stranding assessments was to collect information on the effects of flow reductions on fish stranding, and the secondary objective was to conduct fish salvage (thereby also acting as a mitigation measure for fish stranding) (Golder 2021a). Field crews assess sites where stranding is expected, then isolated pools and de-watered interstitial habitat are sampled using the most appropriate methods to provide data on the number of fish stranded. When stranded fish are encountered, effort is made to salvage as many fish as possible and return those fish to the mainstem of the Columbia or Kootenay rivers. In certain cases, it is not possible to salvage all fish encountered (i.e., when pools are too large and/or deep or fish are too numerous). When this occurs, the locations are noted and prioritized for salvage during the next stranding assessment.

1.3 Study Area

The study area encompassed the approximately 56 km long section of the lower Columbia River from HLK/ALH to the Canada/USA border and included the lower Kootenay River (approximately 2.8 km) from downstream of BRD/X to the Columbia River confluence (Figure 1). The Columbia River study area is further delineated into the upper section (HLK/ALH to Genelle), middle section (Genelle to Rock Island downstream of Trail), and lower section (Rock Island downstream of Trail to the confluence of the Pend d'Oreille River). See Appendix A; Figures A1 through A11 for specific fish stranding site locations.



LEGEND

- WATERCOURSE
- WATERBODY
- RESIDENTIAL AREA

0 5 10

1:200,000 KILOMETERS

REFERENCES

1. WATERCOURSE AND WATERBODY DATA OBTAINED FROM IHS INC.
2. ROAD AND RESIDENTIAL AREA DATA OBTAINED FROM CANVEC © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.
3. BASEMAP IMAGE SOURCES: ESRI, HERE, GARMIN, INTERMAP, INCREMENT P CORP., GEBCO, USGS, FAO, NPS, NRCAN, GEOBASE, IGN, KADASTER NL, ORDNANCE SURVEY, ESRI JAPAN, METI, ESRI CHINA (HONG KONG), (C) OPENSTREETMAP CONTRIBUTORS, AND THE GIS USER COMMUNITY

DATUM: NAD 1983 UTM ZONE 11N

CLIENT
BC HYDRO

PROJECT
LOWER COLUMBIA RIVER (CLBMON#42[A]) AND KOOTENAY RIVER FISH STRANDING ASSESSMENTS: ANNUAL SUMMARY (APRIL 2021 TO APRIL 2022)

TITLE
STUDY AREA OVERVIEW

CONSULTANT
GOLDER
MEMBER OF WSP

YYYY-MM-DD	2022-05-03
DESIGNED	KL
PREPARED	JG
REVIEWED	SR
APPROVED	SR

PROJECT NO.	PHASE	REV.	FIGURE
21508219	2022-4	0	1

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A

25mm

0

PATH: \\golder.gds\vat\burnaby\CAD-GIS\Client\BC Hydro\Lower Columbia River\99_PROJECTS\19-1174\00\02\102_PRODUCTION\MXD\Report\2022\FIG1_21508219_2022_STUDY_AREA_REV0.mxd

2.0 METHODS

As part of the CLBMON-42 program, *The Canadian Lower Columbia River: Risk Assessment and Response Strategy* (Golder 2011) was developed with the primary objective to mitigate the effects of flow reductions from HLK/ALH and BRD/X on native fish species through flow reduction planning. This document outlines the roles and responsibilities pertaining to flow reductions for owners and operators of hydroelectric facilities on the lower Columbia and Kootenay rivers. In addition, it outlines the standardized protocols for conducting fish stranding risk assessments, and field-based fish stranding assessments. In 2021, this protocol was updated based on the findings of Golder 2020a and was re-titled *The Canadian Lower Columbia and Kootenay River: Fish Stranding Protocol* (Golder 2021a). This document currently exists as a living document which continues to be updated based on results of fish stranding assessments and input from the Columbia Operations Fish Advisory Committee (COFAC) members.

During the present study period, the protocols described in *The Canadian Lower Columbia and Kootenay River: Fish Stranding Protocol* (Golder 2021a) were followed and are summarized below.

2.1 Fish Stranding Risk Assessment

Whenever an operational flow reduction from HLK/ALH or BRD/X was proposed, the BC Hydro local Natural Resource Specialist (NRS) conducted a fish stranding risk assessment with input from the Golder Stranding Assessment Supervisor to determine the appropriate environmental response (i.e., whether to conduct a field-based fish stranding assessment or not). The fish stranding risk assessment process is illustrated in Figure 2 and described below.

The first step in the risk assessment process is to review three variables which are known to affect the severity of fish stranding in the lower Columbia and Kootenay rivers.

- Variable 1. Reduction Timing: Fish stranding risk (i.e., the probability of stranding) differs based on the time of year when flow reductions occur (Golder 2020a). The year can be divided into two fish stranding risk periods; the High Risk period occurs from 1 June to 30 September and the Low Risk period occurs between 1 October and 30 May (Golder 2021a).
- Variable 2. River Stage: The river stage is defined as the water level in the Columbia River. The discharge at the Water Survey of Canada Birchbank Hydrometric Station (Station Number 08NE049) is used as an indicator of river stage for the Lower Columbia and Kootenay rivers. The Birchbank station is located downstream of HLK/ALH and BRD/X facilities and therefore reflects adjustments in flow from all operations. During the risk assessment process, the current discharge at Birchbank, and what the discharge at Birchbank will be after a proposed flow reduction (i.e., resultant discharge) are considered. If the resultant Birchbank discharge is equal to or below 60 kcfs (thousands of cubic feet per second), then fish stranding risk is greater than if the resulting Birchbank discharge is above 60 kcfs (Golder 2021a).

- Variable 3. Wetted History – The wetted history is defined as the number of days that habitat had been inundated with water before dewatering. Substrate that has been inundated for a longer period are more likely to strand fish when dewatered, compared to substrate that has been inundated for a shorter period (Golder 2020a). A statistical analysis conducted to determine an appropriate High Risk vs. Low Risk cut-off determined that a wetted history of less than 30 days was considered to be Low Risk for stranding and a wetted history of greater than or equal to 30 days was considered to be High Risk for stranding (Golder 2021a).

Once the above variables were defined, the next step in the risk assessment process was to conduct a query on the Lower Columbia River Fish Stranding Database (the database), which stores all data from previous fish stranding assessments conducted on the lower Columbia and Kootenay rivers. The database query requires the following inputs:

- The current discharge at Birchbank (in kcfs);
- The resulting discharge at Birchbank after the proposed flow reduction (in kcfs);
- The current water temperature at Birchbank (in Celsius);
- The date of the proposed reduction; and
- The facility responsible for the proposed reduction (HLK/ALH, BRD/X, or reduction at both facilities).

Based on the above input values, the database query output (example provided in Appendix B) provides a fish stranding concern category for individual fish stranding sites on the lower Columbia and Kootenay rivers downstream of HLK/ALH and BRD/X based on previous fish stranding assessment data (year 2000 to present). The concern categories and their definitions are as follows:

- No Pools – Isolated pools (pools no longer connected to the mainstem of Columbia or Kootenay river) have not been identified during previous assessments;
- Reconnaissance – Fewer than five stranding assessments have been conducted since year 2000;
- Minimal Effect – Less than 200 fish and no species at risk stranded during each previous reduction; and
- Effect – Greater than 200 fish and/or greater than one species at risk stranded during a previous reduction.

In addition to the database query output, the NRS also reviews the historic fish stranding summary table (Table 8), which identifies maximum and average number stranded fish per reduction event by site, risk period and discharge. This table is updated annually and provides an important visual tool to estimate expected fish stranding risk for a proposed reduction event.

After determining the variables of timing, river stage and wetted history and reviewing results of previous stranding assessments (i.e., the database query output and Table 8), the NRS will decide whether or not a field-based stranding assessment should be conducted in response to the proposed flow reduction.

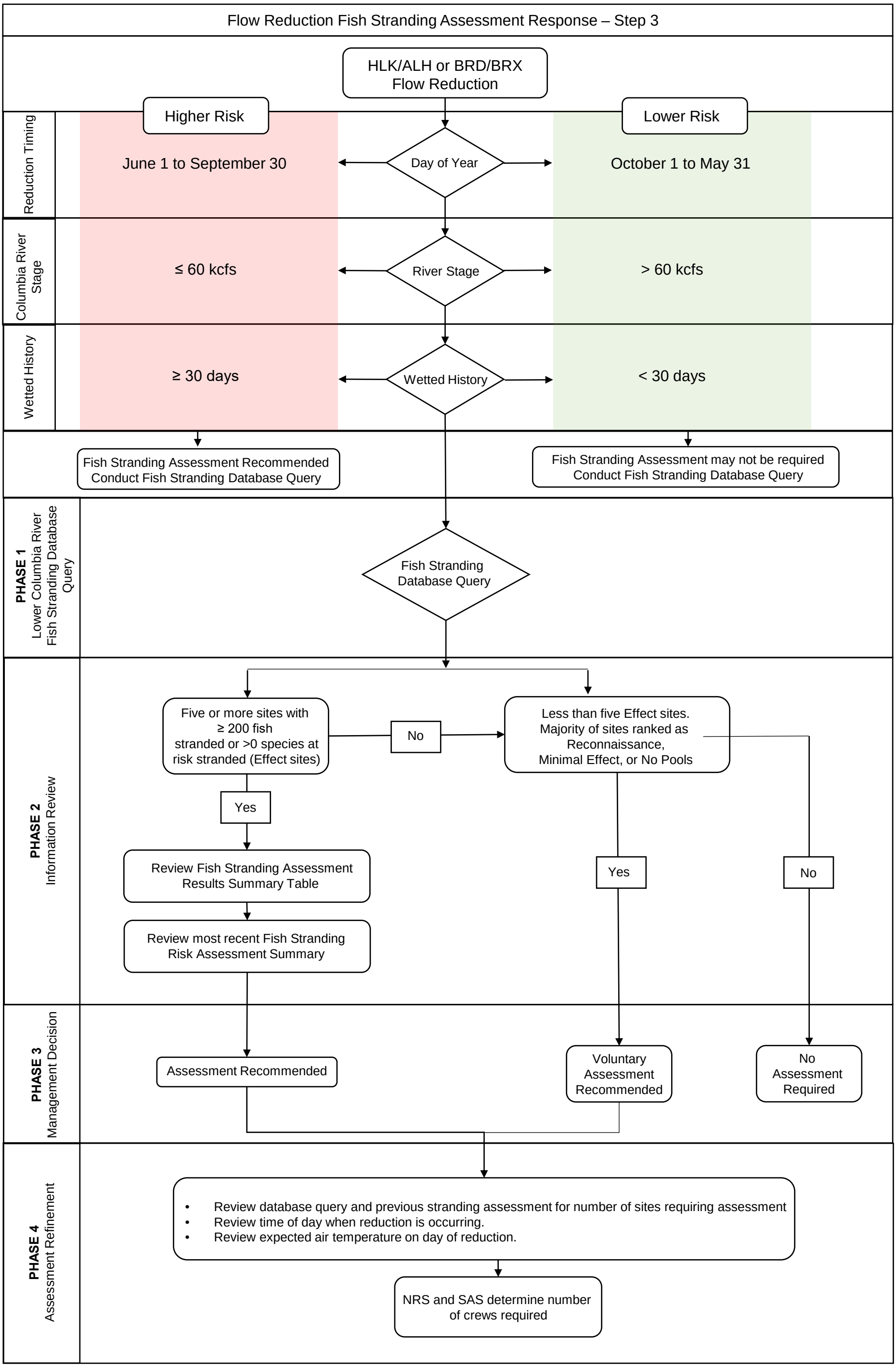


Figure 2: Fish Stranding Risk Assessment Process (Golder 2021a).

2.2 Fish Stranding Assessment and Salvage Methods

Fish stranding assessments are typically conducted by a single two-person crew. However, for some reduction events with a high number of 'Effect' sites identified in the database query, two two-person crews are used to accommodate the need for a greater number of site assessments. All fish stranding assessments were conducted at sites accessible by truck.

Stranding assessment crews arrived at the first stranding site no later than one hour after the final staged reduction from HLK/ALH or BRD/X. Fish stranding and salvage assessments began at the most upstream 'Effect' site identified by the database query. Throughout the day, site assessments were conducted from upstream to downstream following the stage recession. This standardized order of site assessment ensured that no site would be assessed prior to the effects of the flow reduction reaching each site. Sites were also assessed in order from high to low priority based on the site ranking from the database query. Sites where an 'Effect' ranking was assigned were the highest priority, followed by 'Reconnaissance' sites. If time permitted, 'Minimal Effect' and/or 'No Pools' sites were assessed to confirm the site ranking identified by the database query.

At each site, the field crew conducted the following activities:

1) Habitat variables were recorded at each site to identify potential fish habitat, characterize the stranding mechanisms present (i.e., pool stranding or interstitial stranding), and characterize general site conditions (Table 1).

2) A broad scale search of the dewatered area was conducted. The total number of new isolated pools (pools no longer connected to the mainstem of the Columbia or Kootenay river) and dewatered pools that were present due to the current flow reduction were recorded. Pools isolated during previous reduction events were noted in the comments but were not included in the tally for total pools formed due to the current reduction event.

3) Each new isolated pool was inspected for stranded fish and crews attempted to salvage any fish present using Smith-Root™ model 12-B POW or LR24 backpack electrofishers (Smith-Root, Vancouver, WA, USA), dipnets (if pools were too shallow to use backpack electrofishers), or beach seines. Backpack electrofishing was conducted with one crew member operating the electrofisher and one crew member netting fish. All captured fish were transferred to 20 L buckets filled with water. The effort and number of pools sampled was recorded at each site depending on the method used for fish capture. Captured fish from previously isolated pools (i.e., previous reduction events), were recorded but were not included in the tally for total number of fish stranded during the current reduction event.

4) Interstitial stranding areas (i.e., habitat amongst dewatered substrate) were also searched to look for stranded fish. The total interstitial area searched (in m^2) was recorded.

5) Captured fish were identified to species when possible and classified into one of the following life stages; egg, YOY, juvenile, or adult. The total number of live stranded fish (including those observed during sampling, but not captured), dead fish, and salvaged fish were recorded for each species and life stage. The stranding mechanism (i.e., pool stranding or interstitial stranding) for each was recorded. If stranded fish were numerous (i.e., greater than 200 individuals), the total number of stranded was estimated, and a subsample were captured and identified to species to expedite the fish salvage process.

6) Fish length measurements were collected from up to 30 individuals of each species captured during each stranding assessment. Total length was measured for sculpin species and fork length was measured for all other species.

7) All salvaged fish were returned to the main channel of the Columbia or Kootenay rivers.

8) Representative photographs were taken at each site to document current conditions. Photographs of representative fish species were also taken where possible.

9) Invasive species captured during stranding assessments were euthanized and removed from the system as per permit requirements.

Table 1: Habitat variables recorded at each stranding site as part of the Lower Columbia River and Kootenay River Fish Stranding Assessments, 2021/2022.

Variable	Description
Site Names	Name of stranding site
Date	The date the site was sampled
Time	Arrival time on site
Air Temp	Air temperature at the time of sampling (to the nearest 1°C)
Water Temp	Water temperature at the time of sampling (to the nearest 0.1°C)
Conductivity	Water conductivity at the time of sampling (to the nearest 10 µS/cm)
Estimated Vertical Drop	The estimated change in water level due to the current flow reduction
Slope	Estimated slope percent of dewatered area at site (less than or greater than 4%)
Cloud Cover	A categorical ranking of cloud cover (Clear = 0-10% cloud cover; Partly Cloudy = 10-50% cloud cover; Mostly Cloudy = 50-90% cloud cover; Overcast = 90-100% cloud cover); Fog
Instream Cover Type	Interstices, Woody Debris, Aquatic Vegetation, or Terrestrial Vegetation (% of 100)
Substrate	Boulder, Cobble, Gravel, Sand (% of 100)
New Pools Present	Total number of new pools isolated due to the current reduction
New Pools Sampled	Total number of new pools assessed for presence of stranded fish
De-watered Pools	Total number of de-watered pools due to the current reduction
Interstitial Area Sampled	Estimated area of interstitial (i.e., dewatered substrate) sampled for stranded fish (m^2)
Electrofisher Model	The model of electrofisher used during sampling
Volts	The voltage (V) used during sampling
Frequency	The frequency (Hz) used during sampling
Pulse Width	The pulse width (ms) used during sampling
Crew	The field crew that conducted the sampling
Sample Comments	Any additional comments regarding the stranding site or sampling conditions
Future Flow Reduction Problems	Identify whether new stranding pools will form if water level were to drop another 0.5 m
Photographs	Representative photographs documenting site conditions or fish species captured.

3.0 RESULTS

3.1 Operations Overview 2021/2022

During the present study period (1 April 2021 to 1 April 2022), the discharge in the Columbia River at the Birchbank Gauging Station ranged from 27.6 kcfs on 2 April 2021 to 128.2 kcfs on 28 December 2021 (Figure 3). Discharge at Birchbank generally increased from April to July, and from mid-October to the end of December. Discharge at Birchbank generally decreased from July to mid-October and from January through March. The annual trend in discharge at Birchbank in 2021/2022 was typical of previous years (Golder 2018, 2019, 2020b, 2021b); however, Birchbank discharge was above the historical average (2001 to 2020) from December to March.

The mean hourly discharge from HLK/ALH ranged from 10.3 kcfs on 23 November to 85.6 kcfs on 25 January (Figure 3). During the High Risk stranding period, discharge from HLK/ALH generally increased through June and July, then operational discharge reductions began to occur in August. During the Low Risk stranding period, discharge reductions from HLK/ALH were intermittently dispersed.

The mean hourly discharge from BRD/X ranged from 10.2 kcfs on 7 October to 66.4 kcfs on 7 June (Figure 3). Discharge from BRD/X were typical of previous years (Golder 2020b, 2021b), and generally follow the same seasonal pattern as unregulated systems. This is partly due to the limited capacity of BRD/X to store water upstream compared to HLK/ALH operations. During the High Risk stranding period, discharge from BRD/X exhibited a steady decline from June to August and remained relatively constant through September at approximately 18 kcfs. Kootenay River system operation can be more dynamic in certain situations due to the need to meet system load requirements. Load factoring at BRD/X, which results in shaping average daily inflows into peak discharge during the high load hours (typically 0600 to 2200 hrs) and minimum discharge during low load hours (typically 2200 to 0600 hrs), can occur when Kootenay River inflows are between 18 and 43 kcfs. Flow reductions associated with load factoring were not considered individual reduction events.

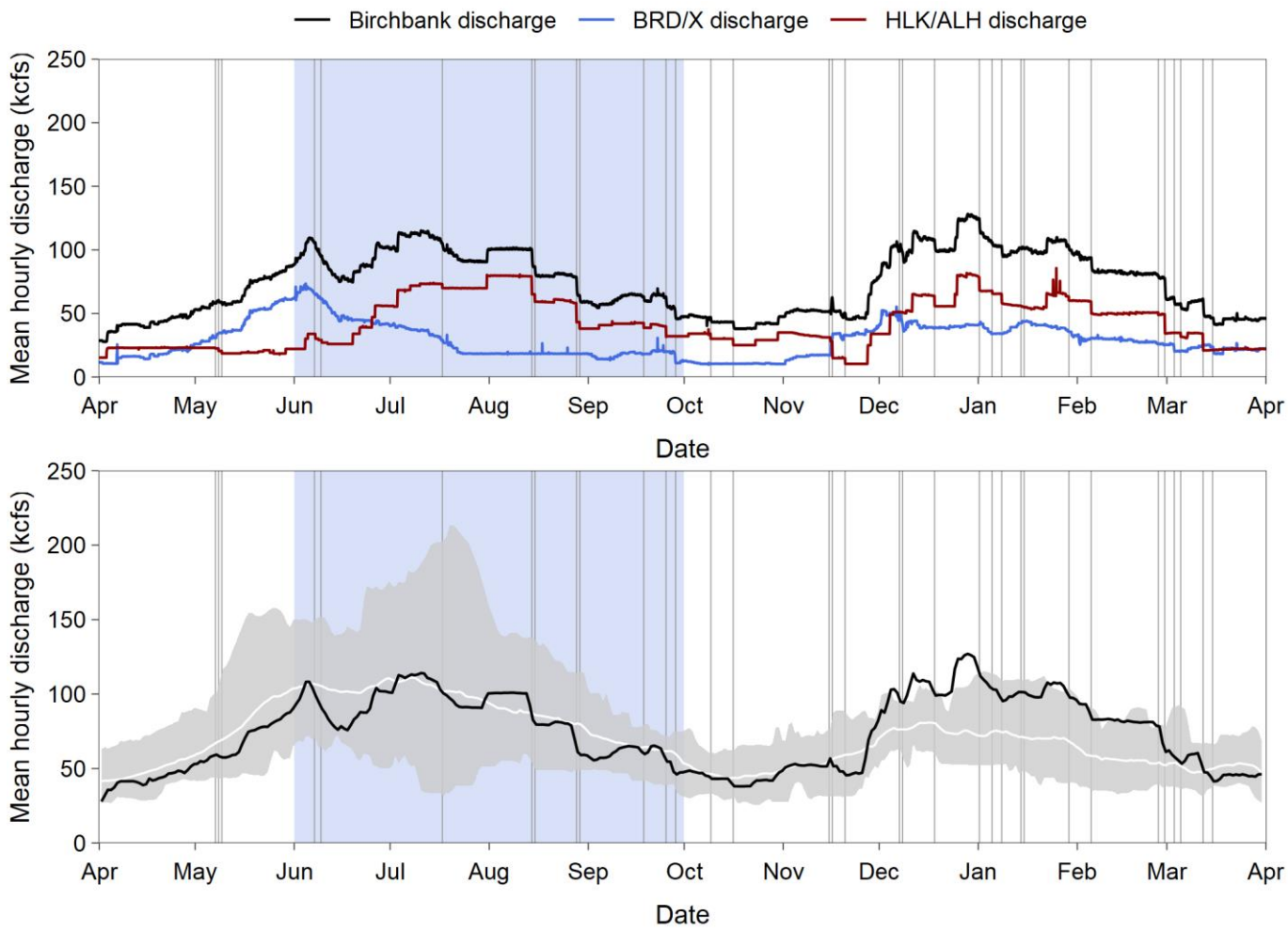


Figure 3: Mean hourly discharge from HLK/ALH, BRD/X, and the WSC Birchbank Gauging Station 1 April 2021 to 1 April 2022 (top panel). Mean hourly discharge from WSC Birchbank Gauging Station 1 April 2021 to 1 April 2022 with historical (2000 to 2021) range (grey shaded area) and mean (white line) (bottom panel). Blue shaded area represents High Risk stranding period (1 June to 30 September). Vertical lines represent 2021/2022 reduction events. Data provided by Water Survey of Canada and BC Hydro's Columbia Basin Hydrological Database.

3.2 Reduction Events and Fish Stranding Assessments

During the present study period there were a total of 32 operational flow reduction events (Figure 3); 28 occurred at HLK/ALH and 4 occurred at BRD/X, (Table 2). A total of 10 reductions events occurred during the High Risk period, while the remaining 22 occurred during the Low Risk period. The reduction events from HLK/ALH and BRD/X corresponded to reductions in discharge in the Columbia River at Birchbank Gauging Station that ranged from 1.5 to 16.6 kcfs (Table 2). All reduction events occurred on a single day, except for RE2021-29 and RE2022-04 which occurred over a two-day period. RE2021-29 occurred at BRD/X and was conducted over two days to provide a more gradual reduction to allow fish more time to escape shallow areas.

The magnitude of flow reduction for each reduction event at HLK/ALH ranged from 0.5 to 15.0 kcfs (Table 2). All reduction events from HLK/ALH were carried out with a maximum ramping rate of 5 kcfs per hour. For example, if the planned reduction had a total magnitude of 15 kcfs, then the reduction would be conducted as 3 reductions of 5 kcfs, separated by an hour between each reduction. All reduction events at HLK/ALH were required to fulfill Columbia River Treaty Coordination Agreements.

The magnitude of flow reduction for each reduction event at BRD/X ranged from 4.8 to 8.5 kcfs. All reduction events at BRD/X had a ramping rate of 1 kcfs or less per hour.

Fish stranding assessments were conducted for 9 of the 32 reduction events (Table 2) resulting in a response rate (percent of total reduction events that initiated a stranding assessment) of 28%. The response rate during the present study period was lower than all previous study periods, but there was a greater number of recorded reduction events than all previous study periods, thereby resulting in a lower than typical response rate. Part of the reason response rate was lower in 2021/2021 compared to previous years, was that some reduction events at HLK/ALH were offset by flows that were increasing at BRD/X (i.e., 2021-11, RE2021-12, RE2021-13, RE2021-26, and RE2021-27). Furthermore, Columbia River flows were well above the historical average (Figure 3) and above the high stranding risk threshold (60 kcfs) from December to March. This was partially due to extreme precipitation events that occurred in interior BC in the late fall of 2021. As a result of these atypically high flows in the Columbia River, stranding risk was low and the operational reductions that occurred during these months did not warrant a stranding response.

Between study year 2007/2008 and the current study year (2021/2022), the total number of annual stranding assessments due to reductions at HLK/ALH ranged from 8 to 15 (median = 12, average = 12). Over the same time period, the total number of annual stranding assessments regardless of which facility conducted the reduction (i.e., includes reductions from HLK/ALH, BRD/X, and reductions that occurred at both facilities on the same day) ranged from 9 to 21 (median = 16, average = 16) (Figure 4).

Table 2: Summary of Reduction Events from HLK/ALH and BRD/X 1 April 2021 to 1 April 2022.

Reduction Event Number	Reduction Date	Risk Period	Crew Dispatched?	Facility Responsible for Reduction	Magnitude of Facility Reduction (kcfs)	Magnitude of Birchbank Reduction (kcfs)	Maximum Birchbank Discharge (kcfs)	Minimum Birchbank Discharge (kcfs)	Birchbank Average Ramping Rate (kcfs/hr)	Number of Fish Stranded [a]
RE2021-11	7-May-21	Low	No	HLK/ALH	0.5	N/A [d]	59.7	57.9	N/A [d]	-
RE2021-12	8-May-21		No	HLK/ALH	1.9	1.8	60.4	58.6	0.3	-
RE2021-13	9-May-21		No	HLK/ALH	2.0	2.1	59.0	56.9	0.4	-
RE2021-14	7-Jun-21	High	No	HLK/ALH	3.8	6.1	106.7	100.6	0.3	-
RE2021-15	9-Jun-21		No	HLK/ALH	2.1	5.2	96.7	91.5	0.2	-
RE2021-16	17-Jul-21		No	HLK/ALH	3.1	6.7	106.3	99.6	0.3	-
RE2021-17	14-Aug-21		Yes	HLK/ALH	14.1	14.2	100.7	86.5	1.2	302
RE2021-18	15-Aug-21		Yes	HLK/ALH	5.9	7.4	86.9	79.5	0.7	44
RE2021-19	28-Aug-21		Yes	HLK/ALH	15.0	14.9	78.8	63.9	1.2	1,011
RE2021-20	29-Aug-21		No	HLK/ALH	5.2	5.7	64.3	58.6	0.4	-
RE2021-21	18-Sep-21		Yes	HLK/ALH	3.8	3.5	63.2	59.7	0.5	0
RE2021-22	25-Sep-21		No	HLK/ALH	8.1	8.5	63.2	54.7	0.6	-
RE2021-23	28-Sep-21		Yes	BRD/X	8.0	8.8	54.4	45.6	0.5	61
RE2021-24	9-Oct-21	Low	No	HLK/ALH	4.0	3.9	47.0	43.1	0.5	-
RE2021-25	16-Oct-21		Yes	HLK/ALH	5.1	5.6	43.4	37.8	0.4	73
RE2021-26	15-Nov-21		No	HLK/ALH	2.9	2.9	52.3	49.4	0.8	-
RE2021-27	16-Nov-21		No	HLK/ALH	13.4	10.9	62.5	51.6	0.8	-
RE2021-28	20-Nov-21		Yes	HLK/ALH	4.5	4.9	50.5	45.6	0.4	48
RE2021-29	7-Dec-21		No	BRD/X	5.6	4.2	104.5	100.3	0.6	-
	8-Dec-21		No	BRD/X	8.5	10.5	100.6	90.1	0.6	-
RE2021-30	18-Dec-21		No	HLK/ALH	7.9	9.2	108.1	98.9	0.8	-
RE2022-01	1-Jan-22		No	HLK/ALH	10.4	11.7	124.7	113	1.4	-
RE2022-02	5-Jan-22		No	HLK/ALH	2.3	4.3	107.4	103.1	0.3	-
RE2022-03	8-Jan-22		No	HLK/ALH	7.2	8.5	103.1	94.6	0.9	-
RE2022-04	14-Jan-22		No	HLK/ALH	0.9	N/A [d]	102.4	100.6	N/A [d]	-
	15-Jan-22		No	HLK/ALH	0.5	1.5	102.1	100.6	0.1	-
RE2022-05	29-Jan-22		No	HLK/ALH	3.1	5.0	104.2	99.2	0.2	-
RE2022-06	5-Feb-22		No	HLK/ALH	9.3	10.6	93.9	83.3	0.9	-
RE2022-07	26-Feb-22		No	HLK/ALH	1.9	2.8	80.5	77.7	0.2	-
RE2022-08	28-Feb-22		No	HLK/ALH	14.9	16.6	77.7	61.1	1.5	-
RE2022-09	3-Mar-22		No	BRD/X	5.1	6.0	62.9	56.9	0.6	-
RE2022-10	5-Mar-22		Yes	HLK/ALH	3.1	4.6	57.9	53.3	1.0	263
RE2022-11	12-Mar-22		Yes	HLK/ALH	13.1	14.1	61.4	47.3	0.9	359
RE2022-12	15-Mar-22		No	BRD/X	4.8	5.3	46.6	41.3	0.5	-

Notes

[a] Does not include a total of 38 fish that were captured/observed within pools that had been isolated during a previous unknown reduction.

[b] Birchbank discharge increased on day of facility reduction. No value for Birchbank reduction or average ramping rate.

Birchbank Gauge Station flow data provided by Water Survey of Canada Birchbank Guage Station No. 08NE049. Accessed on 4 April 2022 at: https://wateroffice.ec.gc.ca/report/real_time_e.html?stn=08NE049

BRD/X and HLK/ALH flow data provided by BC Hydro's Columbia Basin Hydrological Database.

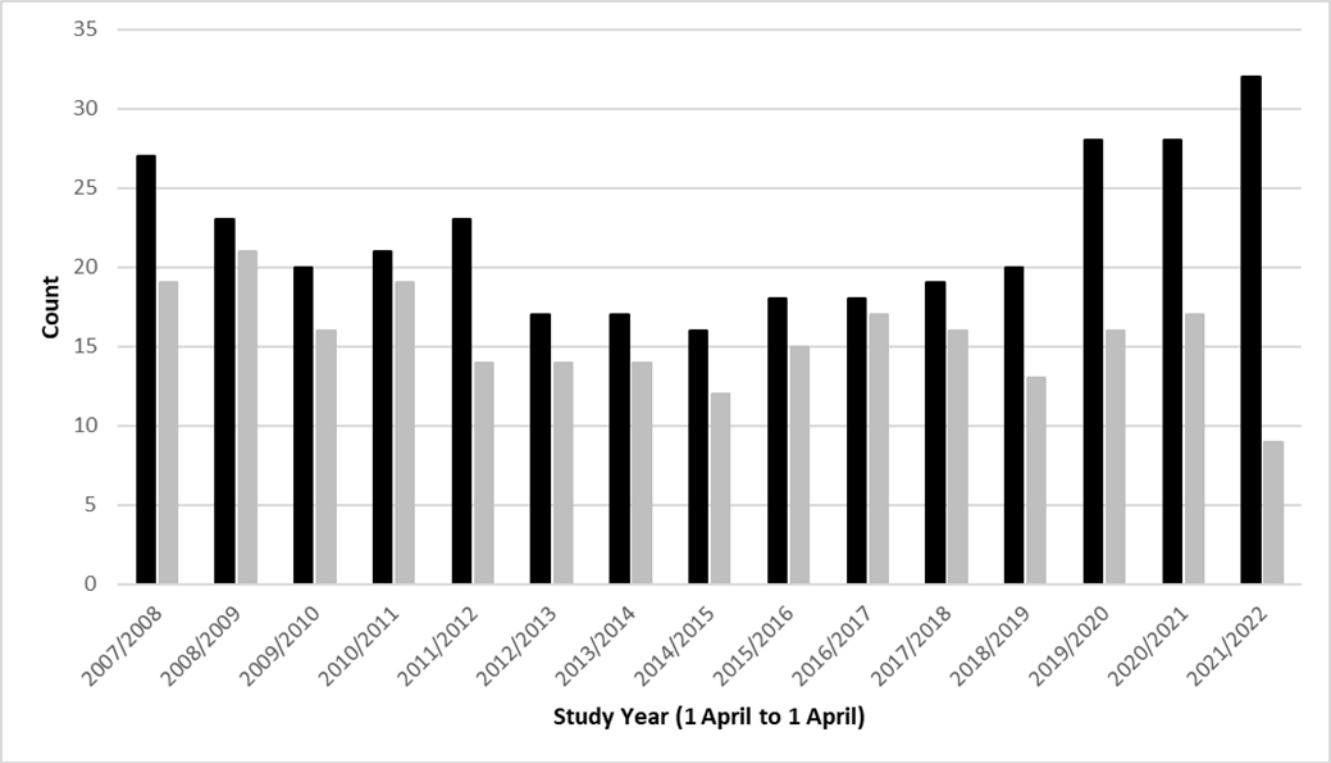


Figure 4: Count of annual reduction events (black bars) and stranding assessments (grey bars) conducted during each study period of the Lower Columbia River and Kootenay River Fish Stranding Assessments, 2007/2008 to 2021/2022.

As in previous years, sites ranked as 'Effect' sites in the database queries were prioritized during stranding assessments since these sites were most likely to strand fish. A total of 67 site assessments were conducted during the present study period. Of these, the database queries ranked 29 sites (43%) as 'Effect' sites, 35 sites (52%) as 'Reconnaissance' sites, and 3 sites (5%) as 'Minimal Effect' sites (Table 3). To provide an evaluation of the database query (Section 2.1), Table 3 identifies each database query site designation and categorizes each into the 'Effect', 'Minimal Effect' or 'No Pools' ranking based on the results from site assessments conducted during the present study period. Overall, results of the 67 sites assessments resulted in 9 sites (13%) that met the 'Effect' designation, 44 sites (66%) that met the 'Minimal Effect' designation, and 14 sites (21%) that met the 'No Pools' designation.

Three 'Minimal Effect' sites were assessed to verify the Database query designation. These sites were Norn's Creek Fan (RUB) and Tin Cup Rapids (RUB) assessed during RE2021-18 and Fort Shepherd Launch (RUB) assessed during RE2022-11. No pools or stranded fish were identified at Norn's Creek Fan (RUB), and 13 isolated pools and 25 stranded fish were identified at Tin Cup Rapids (RUB). At Fort Shepherd Launch (RUB) seven isolated pools were identified and one stranded fish was found. The results of these assessments were consistent with the designation provided in the database query.

Table 3: Comparison of site designation from database query and site designation based on results of fish stranding assessments, 1 April 2021 to 1 April 2022.

Site Designation from Database Query (Section 2.1)	Site Designation Based on Results of Stranding Assessments			Total (% of total)
	Effect [a]	Minimal Effect [b]	No Pools [c]	
Effect [a]	6	19	4	29 (43%)
Reconnaissance	3	23	9	35 (52%)
Minimal Effect [b]	0	2	1	3 (5%)
Total (% of total)	**9 (13%)**	**44 (66%)**	**14 (21%)**	**67 (100%)**

[a] ≥ 200 fish or > 1 species of concern stranded.

[b] < 200 fish stranded and no species of concern stranded.

[c] No fish stranded and no isolated pools identified.

During the present study period, 20 out of 25 stranding sites were assessed at least once over the nine fish stranding assessments (Table 4). Five sites (Birchbank Snye [LUB], Casino Road Bridge U/S [LUB], Casino Road Bridge D/S [LUB], Korpack [LUB], and Beaver Creek [RUB]) were not assessed because they were either ranked as 'Minimal Effect,' 'Reconnaissance', or 'No Pools' in the database queries, or assessments were limited by time constraints (i.e., a greater number of 'Effect' sites required assessment in the Upper and Middle sections).

The sites most frequently assessed were Genelle Mainland (LUB), Kootenay River (RUB), and Norn's Creek Fan (RUB). All three sites are common locations where fish stranding occurs and are ranked as an 'Effect' site in Database queries at a variety of discharge levels. Furthermore, BC Hydro conducted physical habitat recontouring at Genelle Mainland (LUB) in March 2021. This involved filling in depressions where isolated pools commonly form and grading the substrate to minimize habitat where stranding may occur. Therefore, this site was an area of focus to monitor the effectiveness of the physical habitat recontouring.

In general, sites in the Upper Section and Kootenay Section of the study area (Figure 1) were more frequently assessed than sites in the Middle and Lower Sections. This was due to sites within the Upper and Kootenay Sections frequently being ranked as 'Effect' sites in the Database query. Furthermore, crews could not begin to assess sites in the Lower Section of the Columbia River until the reduction reached those sites, limiting the number of sites that could be assessed in the Lower Section during a typical 10-hour field day. The stage reduction generally reaches Norn's Creek Fan (RUB) within 1-2 hours, Genelle Mainland (LUB) within 6 hours, and Fort Shepherd Launch (RUB) within 10 hours (Golder 2021a).

3.3 Fish Encountered During 2021/2022 Stranding Assessments

Stranded fish were identified during all stranding assessments conducted in response to flow reduction events except for RE2021-21. During the nine fish stranding assessments conducted, an estimated total of 2,199 fish were stranded (Table 4). This total includes 38 fish that were identified in isolated pools that had been isolated during a previous unknown reduction event (i.e., these stranded fish could not be definitively associated with a particular reduction event). The total number of fish observed or captured during each stranding assessment ranged from 0 to 1,011 (Table 2). Pool stranding accounted for 76% of all fish stranded, while the remaining 24% were stranded interstitially within dewatered substrate.

On a temporal scale, 66% of fish in 2021/2022 were stranded during the High Risk period (1 June to 30 September) and 34% of fish were stranded during the Low Risk period (1 October to 31 May). Consistently, a greater number of fish are stranded during the High Risk period compared to the Low Risk Period (Golder 2017, 2018, 2019, 2020a, 2020b, 2021b). During this period, larval and YOY fish are known to inhabit near shore habitat, and the risk of stranding is elevated (Golder and Poisson 2010, Golder 2020a).

The majority (69%) of stranded fish were found in pools and dewatered substrate located at Genelle Mainland (LUB), Bear Creek (RUB), and Gyro Boat Launch (RUB) (Table 4). Genelle Mainland (LUB) has been one of the top three site, in terms of total fish stranded for the previous five years (Golder 2017, 2018, 2019, 2020b, and 2021b). Bear Creek (RUB) and Gyro Boat Launch (RUB) have also stranded a high number of fish in previous years, particularly in study years 2015/ 2016 (*n* = 2,015) and 2019/2020 (*n* = 2,089) for Bear Creek (RUB) and in study years 2014/2015 (*n* = 1,025), 2015/2016 (*n* = 401), and 2020/2021 (*n* = 338) for Gyro Boat Launch (RUB) (Golder 2016, 2016, 2020b and 2021b).

Additional sites where high numbers of fish (≥ 100 individuals) were stranded during the present study period were Norns Creek Fan (RUB), Blueberry Creek (LUB), and Kootenay River (RUB) (Table 4). Norns Creek Fan (RUB) is a large creek fan characterized by gravel substrate with undulations that form isolated shallow pools at a wide range of river stages. This site also provides preferred habitat for sculpin species, which are frequently encountered in dewatered substrate or in isolated pools during stranding assessments. During the present study period the greatest number of stranded fish at Norn's Creek Fan (*n* = 177) occurred during RE2021-19 (28 August 2021). During this reduction event, stranded species included Torrent Sculpin, Slimy Sculpin, Longnose Dace, and Peamouth.

A total of 185 fish were stranded at Blueberry Creek (LUB) (Table 4). Of these, 82% were found in a single pool that isolated during RE2022-10 (5 March 2022). This pool has boulder substrate and when inundated it often contains aquatic vegetation, providing appropriate rearing habitat for cyprinids, suckers, and Rainbow Trout. During RE2022-10 this pool isolated when Birchbank discharge reached 53.3 kcfs. Stranded species included Northern Pikeminnow, Longnose Dace, Redside Shiner, Rainbow Trout, and Sculpin species.

A total of 100 fish were stranded at Kootenay River (RUB) during the present study period. This site is large in area and isolated pools frequently form during reduction events. This site is also an area of focus since species of concern (i.e., Umatilla Dace) inhabit the nearshore area at Kootenay (RUB) (See Section 3.3.1.5).

The remaining sites stranded less than 50 individuals over all stranding assessments conducted during the present study period (Table 4).

Table 4: Count of site assessments and fish stranded by site during reduction events, 1 April 2021 to 1 April 2022.

Site a	Number of Site Assessments	Number of Fish Stranded	Median and Range of Fish Stranded per Assessment	% of Total Stranded Fish
Lions Head (RUB)	3	1	0 (0 - 1)	< 1
Norns Creek Fan (RUB)	7	231	1 (0 - 177)	10.5
CPR Island (MID)	5	23	2 (0 - 16)	1.0
Millennium Park (LUB)	1	0	0	0
Tin Cup Rapids (RUB)	4	40	7 (1 - 25)	1.8
Kootenay River (LUB)	3	46	18 (0 - 28)	2.1
Kootenay River (RUB)	7	100	15 (0 - 33)	4.5
Zuckerberg Island (LUB)	2	11	6 (0 - 11)	< 1
Kinnaird Rapids (RUB)	1	2	2	< 1
Waterloo U/S (RUB)	5	13	0 (0 - 13)	< 1
Waterloo Eddy (RUB)	2	0	0	0
Blueberry Creek (LUB)	5	185	1 (0 - 152)	8.4
Blueberry Creek D/S (LUB)	3	0	0	0
Sandbar Eddy (LUB)	1	0	0	0
Birchbank Snye (LUB)	0	-	-	-
Gyro Park (RUB)	1	0	0	0
Gyro Boat Launch (RUB)	5	371	0 (0 - 275)	16.9
Trail Bridge (RUB)	1	30	30	1.4
Casino Road Bridge U/S (LUB)	0	-	-	-
Casino Road Bridge D/S (LUB)	0	-	-	-
Korpack (LUB)	0	-	-	-
Bear Creek (RUB)	2	492	246 (3 - 489)	22.4
Beaver Creek (RUB)	0	-	-	-
Fort Shepherd Launch (RUB)	2	1	< 1 (0 - 1)	< 1
Total	**67**	**2,199**	**-**	**100.0**

[a] Sites ordered from upstream to downstream; Appendix A; Figures A1 through A11.
LUB = left bank as viewed facing upstream
RUB = right bank as viewed facing upstream
MID = island in mid-channel

3.3.1 Fish Species

3.3.1.1 Sportfish

Sportfish accounted for approximately 1% of total fish stranded and were limited to a total of 18 Rainbow Trout (*Oncorhynchus mykiss*) (Table 5). All stranded Rainbow Trout were either Young-of-Year (YOY) or juvenile age class. Rainbow Trout were found stranded at Bear Creek (RUB) (*n* = 1), Blueberry Creek (RUB) (*n* = 7), CPR Island (RUB) (*n* = 2), Gyro Boat Launch (RUB) (*n* = 2), and Tin Cup Rapids (RUB) (*n* = 6).

YOY and juvenile Rainbow Trout are most often found at stranding sites with coarse (i.e., cobble and boulder) substrate, which provides shelter and adequate rearing habitat preferred by Rainbow Trout (McPhail 2007). During the present study period, 33% of Rainbow Trout were stranded during the High Risk period (RE2021-17, RE2021-18, and RE2021-19 on 14, 15, and 28 August 2021, respectively). The remaining 67% of Rainbow Trout were stranded during the Low Risk period (RE2022-10 and RE2022-11 on 5 and 12 March 2022, respectively). This finding opposes the typical timing of Rainbow Trout stranding. Between 2000 and 2022, 82% of all stranded Rainbow Trout occurred during the High Risk period. The peak spawning period for Rainbow Trout typically occurs within the first two weeks of May (Thorley et. al. 2017), with emergence occurring approximately 4 to 6 weeks later depending on water temperature (McPhail 2007). Therefore, greater numbers of YOY Rainbow Trout are to be expected within near-shore habitat vulnerable to dewatering during the summer months as opposed to the winter months.

In previous years (i.e., 2016/2017 and 2019/2020), sportfish have comprised a higher percentage of total stranded fish; however, when this has been the case it has typically been due to a high number of YOY Mountain Whitefish (*Prosopium williamsoni*) being stranded (Golder 2017 and 2020b). In previous years, Mountain Whitefish have been most commonly stranded during the months of March to June, when newly emerged fry inhabit nearshore habitat. During the present study period, Mountain Whitefish were not encountered, likely because only two stranding assessments (RE2022-10 on 5 March 2022, and RE2022-11 on 12 March 2022) were conducted during the March to June time frame, and they may have occurred prior to Mountain Whitefish emergence.

3.3.1.2 Non-sportfish

As in previous years, non-sportfish accounted for the majority (99%) of total fish stranded (Table 5). Of all non-sportfish species stranded, YOY and juvenile Sucker species were the most abundant. Sucker species (*Catostomus spp*.) often represent the highest number of stranded fish during yearly stranding assessments (Golder 2016, 2017, 2018, 2020b and 2021b). Of all stranded Sucker species, 87% were found at Bear Creek (RUB), Gyro Boat Launch (RUB), Genelle Mainland (LUB), and Kootenay River (RUB); however, Suckers are ubiquitous throughout the lower Columbia and Kootenay rivers and were found at 11 of the 20 sites assessed. During the present study period, 61% of Sucker species were stranded during the High Risk period, this is a time when newly emerged YOY Suckers are inhabiting shallow near-shore habitat and as a result are susceptible to stranding when water levels are reduced.

Longnose Dace (*Rhinichthys cataractae*) were the second most abundant non-sportfish stranded (Table 5). Approximately, 64% of stranded Longnose Dace were found in two pools that formed at Bear Creek (RUB) during RE2021-19 (28 August 2021). A high number of Longnose Dace (*n* = 116) were also found stranded in pools that formed along a double-track road used to access Genelle Mainland (LUB) on RE2021-17 (14 August 2021). During most of the year this access road is dry, but it does become inundated with water when flow in the Columbia River reach the annual peak (typically June and July). When flows recede in mid- to late-summer and

discharge at Birchbank reaches approximately 65 kcfs, large areas of dewatered habitat become exposed and pools with YOY and juvenile fish are known to form along the Genelle Mainland (LUB) access road. In addition to Longnose Dace, YOY and juvenile Sucker species (*n* = 112), Northern Pikeminnow (*n* = 37), Redside Shiner (*n* = 2), and Sculpin species (*n* = 1) were also stranded at Genelle Mainland (LUB) during RE2021-17.

Sculpin species are commonly observed during stranding assessments on the lower Columbia and Kootenay rivers. Torrent Sculpin (*Cottus rhotheus*), Prickly Sculpin (*Cottus asper*), and Slimy Sculpin (*Cottus cognatus*), were stranded during the present study period (Table 5). As in previous years (Golder 2016, 2017, 2018, 2019, 2020b, 2021b), Torrent Sculpin represented the highest number of all stranded sculpin species. In 2021/2022, a total of 95 juvenile and adult Torrent Sculpin were stranded, accounting for 85% of all sculpin that were identified to species. Torrent Sculpin were found predominantly at Norn's Creek Fan (*n* = 54) and CPR Island (MID) (*n* = 16). All remaining sites where Torrent Sculpin were encountered, stranded less than a total of six individuals (all assessments combined) during the present study period.

3.3.1.3 Unidentified Fish

A total of 30 unidentified fish and 463 unidentified Sculpin species were observed during stranding assessments. The majority of unidentified fish (*n* = 25) were mortalities found in a dewatered pool at Blueberry Creek during RE2022-11 (12 March 2022). Based on the location of the dewatered pool it was determined that the fish had become isolated from the Columbia River during the previous reduction (RE2022-10), then the pool had dewatered due to the drop in flows during RE2022-11. It was not possible to identify these 25 individuals because they had become desiccated; however, they were likely either Northern Pikeminnow or Longnose Dace, as these species were also found within the same dewatered pool. The remaining unidentified fish (*n* = 5) were visually observed at Gyro Boat Launch during RE2021-23 in a pool that had been isolated during a previous unknown reduction. These fish were not captured, therefore positive identification to species was not possible.

Of the total number of stranded Sculpin not identified to species, all were identified as YOY or juvenile life stage and of those measured, total lengths were 37 mm or less (Table 7). Due to the small size of YOY and juvenile Sculpin and widespread interspecific hybridization common in the Kootenay region (McPhail 2007), field identification of juvenile Sculpin to the species level can be challenging.

3.3.1.4 Exotic Fish Species

Exotic species (i.e., not native to the lower Columbia and Kootenay rivers) stranded during the present study period were Common Carp (*Cyprinus carpio*), Tench (*Tinca tinca*), and Yellow Perch (*Perca flavescens*) (Table 5). A total of three YOY Common Carp were found in pools that had formed within the oxbow at Kootenay (RUB) during RE2021-23 (28 Sept 2021). Since 2000, a total of 138 Common Carp have been identified during fish stranding assessments, with the greatest number (*n* = 68) occurring at Kootenay (RUB).

A single juvenile Tench was identified in an isolated pool at Bear Creek (RUB) during RE2022-11 (12 March 2022). Since 2000, a total of seven Tench have been identified during fish stranding assessments. They have been found at Kootenay (RUB), Genelle Mainland (LUB), and Bear Creek (RUB).

A single adult Yellow Perch was identified in an isolated pool at Kootenay (RUB) during RE20220-10 (5 March 2022). The pool where the Yellow Perch was found had been isolated during a previous unknown reduction event. Since 2000, there have been a total of five Yellow Perch identified during stranding assessments. They have been identified at Millennium Park (LUB), Zuckerberg Island (LUB), Kootenay River (RUB), and Genelle Mainland (LUB).

All stranded exotic species were euthanized as per Scientific Fish Collection Permit (Permit No. CB21-620538) conditions.

Table 5: Summary of fish species captured or observed during fish stranding assessments, 1 April 2021 to 1 April 2022.

Species		Total Stranded	Percent of Total Stranded	Total Mortalities	Total Salvaged	Species Classification
Sportfish	Rainbow Trout	18	0.8	10	8	CDC [a] – Yellow
Non-Sportfish	Sucker species	550	25.0	44	351	N/A [b]
	Longnose Dace	524	23.8	149	177	CDC – Yellow
	Sculpin species	463	21.1	272	114	N/A [c]
	Northern Pikeminnow	213	9.7	69	144	CDC – Yellow
	Umatilla Dace	149	6.8	10	127	SARA [d] – Schedule 3 Special Concern COSEWIC [e] – Threatened CDC – Red
	Redside Shiner	114	5.2	55	59	CDC – Yellow
	Torrent Sculpin	95	4.3	2	93	CDC – Yellow
	Unidentified [f]	30	1.4	25	0	N/A
	Peamouth	18	0.8	0	18	CDC – Yellow
	Prickly Sculpin	10	0.5	0	10	CDC – Yellow
	Slimy Sculpin	7	0.3	0	7	CDC – Yellow
	Largescale Sucker	3	0.1	0	3	CDC – Yellow
Exotic Fish	Common Carp	3	0.1	0	0	CDC – Exotic
	Tench	1	< 0.1	0	0	CDC – Exotic
	Yellow Perch	1	< 0.1	0	0	N/A
Total		**2,199**	**-**	**636**	**1,111**	

[a] BC Conservation Data Centre (CDC); Red = indigenous species or subspecies that have, or are candidates for, Extirpated, Endangered, or Threatened status in British Columbia; Blue = any indigenous species or subspecies considered to be of Special Concern in British Columbia. Yellow = species that are apparently secure and not at risk of extinction. Exotic = species that have been moved beyond their natural range because of human activity. (BC Conservation Data Centre 2022).
[b] No Sucker species are listed as species of concern in the Columbia and Kootenay rivers.
[c] Fish identified to family level may potentially be species of concern under the classification system listed.
[d] Species at Risk Act (SARA); Species that were designated at risk by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) before the creation of the *Species at Risk Act* must be reassessed according to the new criteria of the Act before they can be added to Schedule 1. These species are listed on Schedules 2 and 3 and are not yet officially protected under SARA (COSEWIC 2010).
[e] Committee on the Status of Endangered Wildlife in Canada (COSEWIC 2010).

3.3.1.5 Species of Concern

Umatilla Dace (*Rhinichthys umatilla*), Columbia Sculpin (*Cottus hubbsi*), Shorthead Sculpin (*Cottus confusus*), and White Sturgeon (*Acipenser transmontanus*) are the resident species of concern (i.e., designated at risk by the Committee on the Status of Endangered Wildlife in Canada [COSEWIC][4] and/or the BC Conservation Data Center [CDC][5]) in the study area. Umatilla Dace, Columbia Sculpin, and Shorthead Sculpin have been documented during previous study years (Golder 2016, 2017, 2018, 2019, 2020b, 2021b) and White Sturgeon have never been identified during lower Columbia River and Kootenay River fish stranding assessments.

During the present study period, the only species of concern that were identified were Umatilla Dace. A total of 149 Umatilla Dace were stranded (Table 6). The greatest number of stranded Umatilla Dace (*n* = 114) occurred in isolated pools at Gyro Boat Launch (RUB) during RE2022-10 (5 March 2022) and RE2022-11 (12 March 2022). Of the 149 Umatilla Dace stranded during the present study period, 85% were successfully salvaged and returned to the mainstem of the Columbia or Kootenay River. The remaining 15% were either mortalities (*n* = 10) or were observed during salvage efforts but avoided capture (*n* = 12).

Since 2000, a total of 2,617 Umatilla Dace have been identified during fish stranding assessments with 94% stranded during the Low Risk period. In particular, the highest numbers of stranded Umatilla Dace have occurred in February (*n* = 703) and March (*n* = 1,086) (Figure 5). These findings suggest that the summer months do not pose a higher stranding risk for Umatilla Dace, as is the case for other species (i.e., Sucker species and Redside Shiner). Based on studies in the Slocan River, Umatilla Dace likely spawn from early July to mid-September (AMEC 2014). Only sparse information is available regarding Umatilla Dace preferred spawning habitat, but adults may congregate in deeper water to spawn, then upon emergence, the YOY and juveniles use shallow habitat for rearing throughout the fall, winter, and spring. In a study conducted by R.L. & L. Environmental Services Ltd. (1995), YOY Umatilla Dace were recorded in the mainstem Columbia River in shallow nearshore areas throughout the year and juveniles (age 1+) were abundant in nearshore areas in the summer, but then moved to deeper water during the fall. Since 2000, it has become clear that there are certain stranding sites that are more likely to strand Umatilla Dace. The highest numbers of stranded Umatilla Dace have been found at Kootenay River (LUB; *n* = 675), Kootenay River (RUB; *n* = 508), Gyro Boat Launch (RUB; *n* = 430), and Bear Creek (RUB; *n* = 402) (Figure 6).

[4] https://www.cosewic.ca/index.php/en-ca/

[5] https://www2.gov.bc.ca/gov/content/environment/plants-animals-ecosystems/conservation-data-centre/explore-cdc-data

Table 6: Summary of Species of Concern identified during stranding assessments, 1 April 2021 to 1 April 2022.

Site [a]	Total Number of Assessments	Number of Site Assessments with Species of Concern	Risk Period when Stranding Occurred [b]	Number of Fish Stranded
Umatilla Dace (SARA: Schedule 3 Special Concern, COSEWIC: Threatened, CDC: Red)				
Genelle Mainland (LUB)	7	1	High	13
Gyro Boat Launch (RUB)	5	2	Low	114
Kootenay River (LUB)	3	2	High / Low	20
Kootenay River (RUB)	7	1	Low	1
Trail Bridge (RUB)	1	1	Low	1
Total				**149**

[a] Appendix A; Figures A1 through A11.
[b] High Risk period = 1 June to 30 September; Low Risk period = 1 October to 31 May.

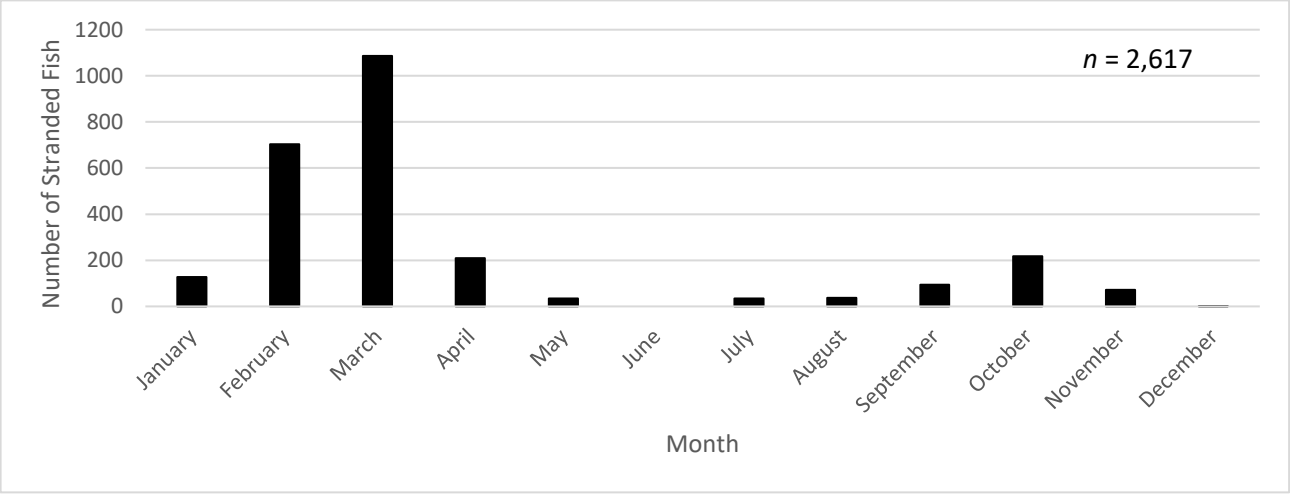


Figure 5: Number of Umatilla Dace stranded by Month from 1 January 2000 to 1 April 2022.

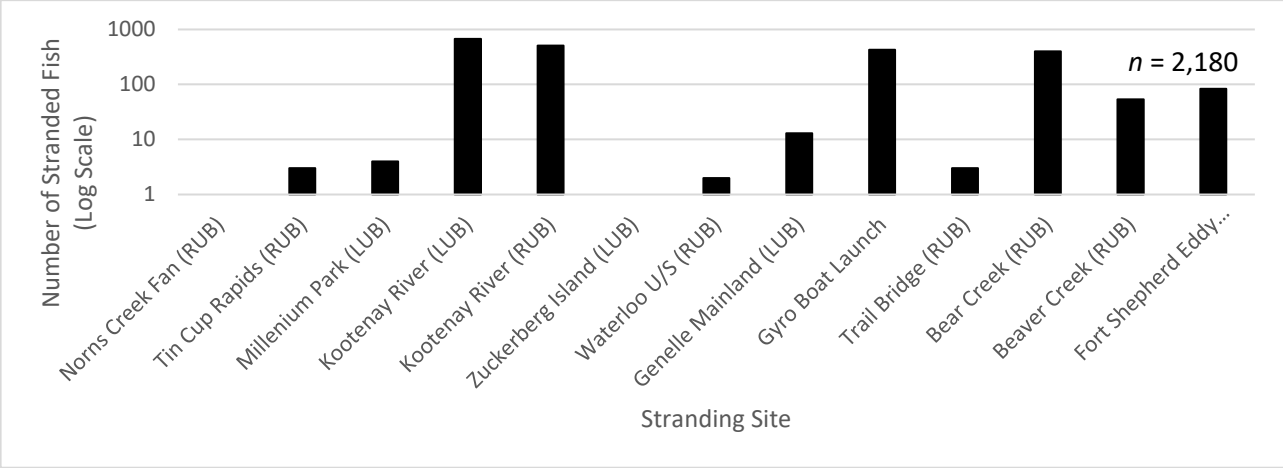


Figure 6: Number of Umatilla Dace stranded by site from 1 January 2000 to 1 April 2022. Sites ordered from upstream to downstream. Figure does not include Umatilla Dace stranded at Lions Head (RUB), Genelle Mainland (LUB), and Fort Shepherd Launch (LUB) before the most recent recontouring at these sites.

3.3.1.6 Fish Length Analysis

A total of 589 fish captured during fish stranding assessments were measured for either fork length or total length. The average length (mm) of all measured individuals is shown in Table 7. Length measurements were taken to provide a representative sample of the size of fish encountered, and were used to determine life stage.

Of the large-bodied fish captured during the present study period (i.e., Common Carp, Largescale Suckers, Northern Pikeminnow, Rainbow Trout, and Tench), all individuals were either YOY or juvenile life stage, except the single Tench captured at Bear Creek (RUB). This individual had a fork length of 270 mm. Based on a study of this species in Kayabogazi Dam Lake in Turkey, Tench reached sexual maturity at an age of 3 or 4, corresponding to fork length within the range of 152 to 226 mm (Alas and Solak 2004).

Of the small-bodied fish captured during the present study period (Longnose Dace, Peamouth, Sculpin Species, and Umatilla Dace), juvenile and adult life stages were captured.

Table 7: Descriptive statistics of fork length and total length by species, 1 April 2021 to 1 April 2022.

Species	Average Length ± SD (mm)	Range (mm)	*n*
Common Carp	19.3 ± 0.6	19 – 20	3
Largescale Sucker	48.7 ± 5.0	44 - 54	3
Longnose Dace	30.0 ± 9.7	10 - 45	59
Northern Pikeminnow	35.7 ± 9.0	20 – 73	94
Peamouth	28.0 ± 9.5	19 - 61	17
Prickly Sculpin	49.5 ± 12.9	35 – 81	10
Rainbow Trout	66.6 ± 16.5	50 – 108	11
Redside Shiner	33.4 ± 7.8	16 – 61	48
Sculpin species	27.4 ± 4.9	19 - 37	33
Slimy Sculpin	68.8 ± 7.5	64 – 80	4
Sucker species	46.2 ± 11.8	15 - 79	168
Tench	270.0 ± 0	N/A	1
Torrent Sculpin	66.3 ± 18.1	35 – 110	75
Umatilla Dace	31.0 ± 5.1	22 - 42	63
Total			**589**

Total length (mm) represented for all sculpin species; fork length (mm) represented for all remaining species. SD = standard deviation.

3.4 Historic Fish Stranding Summary

The results of fish stranding assessments conducted between January 2000 and 1 April 2022 are summarized by site, risk period and resultant Birchbank discharge (classified into 10 kcfs ranges) in Table 8. To provide an additional visualization of historic fish stranding the percent frequency of fish stranded between January 2000 and 1 April 2022 has been summarized for each stranding site by month and by resultant Birchbank discharge in Appendix C (Figure C1 and C2).

Table 8 can be used by BC Hydro during the risk assessment process (Section 2.1) to determine if a proposed reduction event has occurred historically at a given time of year, and which sites are most likely to have high stranding risk based on historical fish stranding data. The maximum and average number of fish stranded per reduction event are presented. Sites where species of concern (i.e., Columbia Sculpin, Shorthead Sculpin, and Umatilla Dace) have been previously stranded are also identified.

During the High Risk period, Tin Cup Rapids (RUB) has a high stranding risk, with both maximum and average number of fish per reduction event being greater than 200 fish at a variety of discharge ranges (Table 8). Additionally, species of concern have been stranded at this site during the High Risk period. Given these findings, Tin Cup Rapids (RUB), should be a focus of stranding surveys during the summer months. Historically, Genelle Mainland (LUB) has also stranded a high number of fish at a variety of discharge ranges (Golder 2021b). Since recontouring, there have been two reduction events at Genelle Mainland (LUB) that have resulted in greater than 200 fish being stranded (RE2021-19 and RE2021-17). Table 8 indicates that Genelle Mainland (LUB) still poses a stranding risk during the High Risk period when discharge is above 60 kcfs. Other sites of concern for stranding during the High Risk period are Norn's Creek Fan (RUB) and Kootenay River (RUB) when resultant discharge is between 30 and 70 kcfs. Blueberry Creek (LUB), has also stranded a high number of fish during the

High Risk period, specifically when resultant discharge reaches 40 to 50 kcfs or between 70 and 90 kcfs. Approximately 75% of all fish historically stranded at Blueberry Creek (LUB) have been stranded during August (Appendix C; Figure C1).

During the Low Risk period, all sites in the Kootenay River and in the Columbia River upstream of the Kootenay River confluence pose an elevated risk of stranding, and species of concern have been found at all of these sites (Table 8). The majority of sites downstream of the Kootenay River confluence appear to have generally lower fish stranding risk; however, Gyro Boat Launch (RUB) has had relatively high numbers of stranded fish and Umatilla Dace are often found at this site during the Low Risk period when resultant discharge is between 30 and 70 kcfs. Overall, there has been a greater occurrence of species of concern during the Low Risk period than the High Risk period. Stranding risk during the Low Risk period appears to decrease sharply when discharge is greater than 70 kcfs. This finding is further supported by Appendix C (Figure C2), which indicates a higher percent frequency of stranded fish at discharges lower than 70 kcfs for most sites.

Table 8: Summary of fish stranded by site, risk period and discharge on the lower Columbia and Kootenay rivers due to reduction events at HLK/ALH and BRD/X, 1 January 2000 to 1 April 2022.

Observed Effect

Risk Period	Resultant Birchbank Discharge (kcfs)	Columbia River														
		Lions Head (RUB) [a]			Norns Creek Fan (RUB) [a]			CPR Island (MID)			Tin Cup Rapids (RUB)			Millennium Park (LUB) [a]		
		# of Fish Max.	# of Fish Avg.	# of RE	# of Fish Max.	# of Fish Avg.	# of RE	# of Fish Max.	# of Fish Avg.	# of RE	# of Fish Max.	# of Fish Avg.	# of RE	# of Fish Max.	# of Fish Avg.	# of RE
High Risk (1 June to 30 September)	≤30															
	≥30 to <40	8	8	1	455	228	2	60	22	3	13500	4508	3	38	19	2
	≥40 to <50	0	0	1	312	125	6	191	84	6	76	19	4	15	15	1
	≥50 to <60	17	5	4	150	29	16	112	30	4	253	51	14	17	3	7
	≥60 to <70	5	1	5	423	68	29	0	0	6	258	14	27	34	3	10
	≥70 to <80	8	1	11	56	7	16	0	0	2	219	25	16	0	0	12
	≥80 to <90	No Pools			88	6	17	No Pools			34	4	19	24	2	16
	≥90 to <100	2	1	4	12	2	12	0	0	5	563	120	14	26	2	11
	≥100 to <110	50	50	1	2	1	3	2	2	1	10307	2579	4	7521	1893	4
	≥110 to <120				No Pools			No Pools			1500	536	4	60	20	3
	≥120				No Pools			No Pools			1200	406	4	100	56	2
Low Risk (1 October to 31 May)	≤30	7	7	1	46	22	5	6	3	2	68	44	4	6	3	5
	≥30 to <40	953	77	14	5071	167	42	110	21	18	228	12	27	358	35	30
	≥40 to <50	201	23	10	623	42	50	337	22	38	117	12	41	526	40	29
	≥50 to <60	33	6	8	146	16	32	20	3	18	86	5	24	601	33	22
	≥60 to <70	177	30	6	700	44	33	16	2	16	11	1	33	2	0	23
	≥70 to <80	0	0	2	79	6	13	2	1	4	3	0	14	2	0	15
	≥80 to <90	No Pools			0	0	2	No Pools			1	0	3	0	0	3
	≥90 to <100				0	0	1	0	0	1	0	0	1	0	0	1
	≥100 to <110															
	≥110 to <120				No Pools			No Pools								
	≥120				No Pools			No Pools			0	0	1	0	0	1

Risk Period	Resultant Birchbank Discharge (kcfs)	Kootenay River						Columbia River								
		Kootenay River (LUB)			Kootenay River (RUB)			Zuckerberg Island (LUB)			Kinnaird Rapids (RUB)			Waterloo U/S (RUB)		
		# of Fish Max.	# of Fish Avg.	# of RE	# of Fish Max.	# of Fish Avg.	# of RE	# of Fish Max.	# of Fish Avg.	# of RE	# of Fish Max.	# of Fish Avg.	# of RE	# of Fish Max.	# of Fish Avg.	# of RE
High Risk (1 June to 30 September)	≤30															
	≥30 to <40	129	76	2	641	160	4	620	221	3	No Pools					
	≥40 to <50	94	28	5	81	31	8	0	0	1				13	13	1
	≥50 to <60	58	5	14	3901	257	18	18	5	6	0	0	1	0	0	1
	≥60 to <70	3172	130	31	5737	219	29	55	4	14	0	0	1	No Pools		
	≥70 to <80	1	0	11	35	3	15	48	4	12	No Pools					
	≥80 to <90	No Pools			12	2	10	0	0	14	No Pools			No Pools		
	≥90 to <100	No Pools			No Pools			No Pools			No Pools					
	≥100 to <110	No Pools			No Pools			0	0	3						
	≥110 to <120	No Pools			No Pools			No Pools			No Pools					
	≥120	No Pools			0	0	2	0	0	1						
Low Risk (1 October to 31 May)	≤30	0	0	2	382	146	5	5	2	3	1	1	2			
	≥30 to <40	286	17	26	1168	55	37	95	12	26	No Pools			5	3	2
	≥40 to <50	517	52	50	1450	113	62	298	26	38	2	1	3	24	12	2
	≥50 to <60	193	17	34	2839	122	37	7	1	30	10	3	4			
	≥60 to <70	122	9	44	529	15	48	109	4	31	0	0	8	No Pools		
	≥70 to <80	0	0	12	10	1	15	0	0	17	No Pools					
	≥80 to <90	No Pools			0	0	4	0	0	3	No Pools			No Pools		
	≥90 to <100	No Pools			No Pools			No Pools			No Pools					
	≥100 to <110	No Pools			No Pools											
	≥110 to <120	No Pools			No Pools			No Pools			No Pools					
	≥120	No Pools			0	0	1	0	0	1						

Risk Period	Resultant Birchbank Discharge (kcfs)	Columbia River														
		Waterloo Eddy (RUB)			Blueberry Creek (LUB)			Blueberry Creek D/S (LUB)			Sandbar Eddy (LUB)			Genelle Mainland (LUB) [a]		
		# of Fish Max.	# of Fish Avg.	# of RE	# of Fish Max.	# of Fish Avg.	# of RE	# of Fish Max.	# of Fish Avg.	# of RE	# of Fish Max.	# of Fish Avg.	# of RE	# of Fish Max.	# of Fish Avg.	# of RE
High Risk (1 June to 30 September)	≤30				No Pools											
	≥30 to <40	0	0	1	0	0	0									
	≥40 to <50				4505	4505	1							5	5	1
	≥50 to <60	No Pools			0	0	3							0	0	1
	≥60 to <70	No Pools			1	0	6	No Pools						333	333	1
	≥70 to <80				1299	121	12	No Pools						18	18	1
	≥80 to <90				269	42	11				No Pools			268	268	1
	≥90 to <100	No Pools			No Pools											
	≥100 to <110				0	0	2									
	≥110 to <120				0	0	2									
	≥120				0	0	2									
Low Risk (1 October to 31 May)	≤30				No Pools											
	≥30 to <40				0	0	2	0	0	1						
	≥40 to <50	0	0	2	0	0	5	0	0	1				1	1	2
	≥50 to <60	No Pools			152	30	5									
	≥60 to <70	No Pools			1	0	8	No Pools			0	0	1			
	≥70 to <80				0	0	5	No Pools								
	≥80 to <90				0	0	2									
	≥90 to <100	No Pools			No Pools											
	≥100 to <110															
	≥110 to <120															
	≥120															

Risk Period	Resultant Birchbank Discharge (kcfs)	Columbia River														
		Birchbank Snye (LUB)			Gyro Park (RUB)			Gyro Boat Launch (RUB)			Trail Bridge (RUB)			Casino Road Bridge, Trail (U/S)		
		# of Fish Max.	# of Fish Avg.	# of RE	# of Fish Max.	# of Fish Avg.	# of RE	# of Fish Max.	# of Fish Avg.	# of RE	# of Fish Max.	# of Fish Avg.	# of RE	# of Fish Max.	# of Fish Avg.	# of RE
High Risk (1 June to 30 September)	≤30															
	≥30 to <40							152	152	1						
	≥40 to <50				0	0	1	464	95	5						
	≥50 to <60							0	0	5	0	0	3	0	0	4
	≥60 to <70							0	0	4	No Pools			6	1	8
	≥70 to <80							0	0	8	No Pools			No Pools		
	≥80 to <90							500	78	10	No Pools			No Pools		
	≥90 to <100							500	120	6	No Pools			No Pools		
	≥100 to <110							500	250	2						
	≥110 to <120							No Pools			No Pools			No Pools		
	≥120							No Pools			No Pools			No Pools		
Low Risk (1 October to 31 May)	≤30							0	0	3	2	1	2	0	0	3
	≥30 to <40	0	0	1				2024	228	18	20	5	13	0	0	10
	≥40 to <50							658	66	38	30	5	11	4	0	10
	≥50 to <60	0	0	1				273	31	19	8	1	11	0	0	15
	≥60 to <70	2000	667	3	0	0	1	351	21	17	No Pools			1	0	19
	≥70 to <80							0	0	4	No Pools			No Pools		
	≥80 to <90							0	0	2	No Pools			No Pools		
	≥90 to <100										No Pools			No Pools		
	≥100 to <110															
	≥110 to <120							No Pools			No Pools			No Pools		
	≥120							No Pools			No Pools			No Pools		

Risk Period	Resultant Birchbank Discharge (kcfs)	Columbia River														
		Casino Road Bridge, Trail (D/S)			Korpack (LUB)			Bear Creek (RUB)			Beaver Creek (RUB)			Fort Shepherd Launch (RUB) [a]		
		# of Fish Max.	# of Fish Avg.	# of RE	# of Fish Max.	# of Fish Avg.	# of RE	# of Fish Max.	# of Fish Avg.	# of RE	# of Fish Max.	# of Fish Avg.	# of RE	# of Fish Max.	# of Fish Avg.	# of RE
High Risk (1 June to 30 September)	≤30										No Pools					
	≥30 to <40	0	0	1							31	31	1			
	≥40 to <50	207	74	3				0	0	1				0	0	1
	≥50 to <60	11	5	4				0	0	5	358	96	4	0	0	2
	≥60 to <70	5	1	6	0	0	3	2030	250	13	21	4	7	2	1	5
	≥70 to <80	0	0	4				57	9	11	21	3	10	1	0	9
	≥80 to <90	No Pools			No Pools			0	0	5	62	10	6	134	27	5
	≥90 to <100	No Pools						No Pools			251	55	6	No Pools		
	≥100 to <110													0	0	1
	≥110 to <120	No Pools						No Pools			No Pools					
	≥120	No Pools						No Pools			No Pools					
Low Risk (1 October to 31 May)	≤30	0	0	2				0	0	2	No Pools			0	0	1
	≥30 to <40	1	0	13	122	16	8	18	3	12	44	12	9	9	2	10
	≥40 to <50	2	0	9	0	0	4	2015	126	16	4	1	10	5	1	12
	≥50 to <60	21	1	20	0	0	5	2063	138	15	17	3	7	29	6	7
	≥60 to <70	3	0	23	0	0	3	2	0	19	4	1	6	46	7	7
	≥70 to <80	0	0	7	No Pools			3	0	12	0	0	5	0	0	1
	≥80 to <90	No Pools			No Pools			0	0	2	0	0	3	0	0	1
	≥90 to <100	No Pools						No Pools						No Pools		
	≥100 to <110															
	≥110 to <120	No Pools						No Pools			No Pools					
	≥120	No Pools						No Pools			No Pools					

Code	Description	Definition
	No Pools	Site has been previously surveyed; pools have not been recorded at or near these flows.
	Minimal Effect	Site has been previously surveyed at least five times under similar flow conditions and isolated pools were observed; maximum number of fish or average number of fish (all RE combined) was less than 200.
	No Data or Insufficient Data	Site has been previously surveyed less than five times under similar flow conditions and isolated pools were observed; maximum number of fish or average number of fish (all RE combined) was less than 200.
	Effect	Site has been previously surveyed under similar flow conditions; maximum number of fish or average number of fish (all RE combined) was less than 200.
	Unlikely Discharge Range	Birchbank discharge has not been recorded at these levels during the specified time period (based on discharge data collected between 2000 and 2022).
	Species of Concern were stranded	During at least one stranding assessment under similar flow conditions species of concern (i.e., Columbia Sculpin, Shorthead Sculpin, or Umatilla Dace) were captured or observed.

Notes

RE = reduction event; Max. = maximum number of fish stranded per RE; Avg. = average number of fish stranded per RE; RUB = right bank as viewed facing upstream; LUB = left bank as viewed facing upstream; MID = mid channel site.

When multiple day assessments were conducted for one RE fish numbers were summed.

a. Sites have been physically recontoured. Data from pre-recontouring not included.

Includes all stranding assessment data collected from the lower Columbia and Kootenay rivers from flow reductions at HLK/ALH and BRD/X between 1 January 2000 and 1 April 2022.

4.0 SUMMARY

The present study provides the results of fish stranding assessments conducted on the Lower Columbia and Kootenay rivers in response to flow reductions at HLK/ALH and BRD/X between 1 April 2021 and 1 April 2022. The main findings of these assessments are as follows:

- Discharge in the Columbia River at the Birchbank Gauging Station was typical of previous years and ranged from 27.6 to 128.2 kcfs.
- There were 32 operational flow reduction events; 28 from HLK/ALH, 4 from BRD/X. Stranding assessments were conducted for 9 of the 32 reduction events, resulting in a response rate of 28%.
- During the 9 fish stranding assessments conducted, an estimated total of 2,199 fish were stranded. Of these stranded fish, 51% were successfully salvaged and returned to the Columbia or Kootenay river. The majority of stranded fish (66%) were observed during the High Risk period. Genelle Mainland (LUB), Bear Creek (RUB), and Gyro Boat Launch (RUB) accounted for 69% of all stranded fish identified.
- Sportfish accounted for approximately 1% of all stranded fish and all were YOY and juvenile Rainbow Trout. Non-sportfish accounted for the remaining 99% of stranded fish with Sucker spp. and Longnose Dace representing the highest abundance.
- Stranded exotic species included 3 Common Carp, 1 Tench and 1 Yellow Perch. All exotic species encountered were euthanized and removed from the lower Columbia or Kootenay River at the request of FLNRORD.
- Stranded species of concern included 149 Umatilla Dace. The majority (77%) were found at Gyro Boat Launch (RUB) in 2021/2022. Despite their listed status, Umatilla Dace are regularly encountered during stranding assessments in the lower Columbia and Kootenay rivers, particularly at Kootenay River (LUB), Kootenay River (RUB), Gyro Boat Launch (RUB), and Bear Creek (RUB).

5.0 RECOMMENDATIONS

The following recommendations are provided for consideration for future fish stranding assessments in the lower Columbia and Kootenay rivers:

- As in the current study period, Genelle Mainland (LUB) should be a focus of fish stranding assessments in 2022/2023. Historically, this site has had a high risk of fish stranding at various discharges (Golder 2021b). Because of this, BC Hydro conducted physical habitat recontouring at Genelle Mainland (LUB) in March 2021. Recontouring efforts included infilling of depressions where isolated pools were likely to form and adjusting gradient to reduce the likelihood of stranding. During stranding assessments in 2021, fish stranding crews noticed that much of the recontoured area has changed due substrate movement during the spring 2021 freshet, when flows in the Columbia River inundated the recontoured area. Due to the movement of substrate, two large depressions have been created at the site which will likely form isolated pools and pose a stranding risk when flows are reduced in the summer of 2022. It is recommended that Genelle Mainland be assessed during most stranding assessments in 2022/2023.
- To maximize the potential for fish salvage, ‘Effect’ sites (as identified in the Database query) should remain the focus of fish stranding assessments. These sites represent the highest number of stranded fish based on historical stranding data for a given time of year and Columbia River discharge value. If time permits, it is recommended that ‘Reconnaissance’ sites be visited to continue to fill in data gaps that remain in Table 8.

6.0 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.

Kevin Little, BSc Biology
Aquatics Scientist

Shawn Redden, BSc, RP Bio
Associates, Senior Fisheries Biologist

KL/SR/cmc

https://golderassociates.sharepoint.com/sites/104258/project files/6 deliverables/draft report annual summary 2021_2022/21508219-002-r-rev1-2021_2022_lcr_stranding_report 19oct_22.docx

7.0 REFERENCES

Alas A, K Solak. 2004. The reproductive biology of the Tench (*Tinca tinca* L., 1758). In Kayabogazi (Kutahya, Turkey) Dam Lake. The Turkish Journal of Veterinary and Animal Science. 28. 879-885.

AMEC. 2014. Lower Columbia River Sculpin and Dace Life History Assessment (CLBMON-43). Year 5 Technical Report. Report Prepared for BC Hydro, Burnaby, BC. Prepared by: AMEC Environment & Infrastructure Ltd. 117 pp. + 8 App.

B.C. Conservation Data Centre. 2022. BC Species and Ecosystems Explorer. B.C. Ministry of Environment Victoria, B.C. Available: http://a100.gov.bc.ca/pub/eswp/ (accessed Apr 25, 2022).

BC Hydro. 2007. Columbia River Project Water Use Plan, Monitoring Program Terms of Reference: Lower Columbia River Fish Management Plan. 37 p + 2 appendices.

Golder Associates Ltd. (Golder) 2005. Columbia River Ramping rate Assessment: Phase I and II Investigations, Winter and Summer 2004. Report prepared for BC Hydro, Castlegar, B.C. Golder report No. 04-1480-053F: 46 p. + 6 app.

Golder Associated Ltd. 2006. Columbia River Ramping Rate Assessment: Phase III and IV Investigations, Winter and Summer 2005. Report prepared for BC Hydro, Castlegar, B.C. Golder Report No. 05-1480-039F: 33 p. + 5 app.

Golder Associates Ltd. 2007. Columbia River Flow Reduction and Fish Stranding Assessment: Phase V and VI Investigations, Winter and Summer 2006. Report prepared for BC Hydro, Castlegar, B.C. Golder report No. 06-1480-030F: 59 p. + 5 app.

Golder Associates Ltd. 2011. Canadian Lower Columbia River: Fish Stranding Risk Assessment and Response Strategy. Report prepared for BC Hydro, Columbia Power Corporation, Fortis BC, Columbia operations Fish Advisory Committee (COFAC) and Canal Plant Agreement Operating Committee, Golder Report No. 09-1480-0055F: 31 p. + 4 appendices.

Golder Associates Ltd. 2016. Lower Columbia River (CLBMON#42[A]) and Kootenay River Fish Stranding Assessments: Annual summary (April 2015 to April 2016). Report prepared for BC Hydro. Golder Report No. 1407618: 28 p. + 2 app.

Golder Associates Ltd. 2017. Lower Columbia River (CLBMON#42[A]) and Kootenay River Fish Stranding Assessments: Annual summary (April 2016 to April 2017). Report prepared for BC Hydro. Golder Report No. 1407618: 28 p. + 1 app.

Golder Associates Ltd. 2018. Lower Columbia River (CLBMON#42[A]) and Kootenay River Fish Stranding Assessments: Annual summary (April 2017 to April 2018). Report prepared for BC Hydro. Golder Report No. 1407618: 42 p. + 1 app.

Golder Associates Ltd. 2019. Lower Columbia River (CLBMON#42[A]) and Kootenay River Fish Stranding Assessments: Annual summary (April 2018 to April 2019). Report prepared for BC Hydro. Golder Report No. 1895371: 29 p. + 1 app.

Golder Associates Ltd. 2020a. CLBMON 42 Lower Columbia River Fish Stranding Assessment and Ramping Protocol Final Summary Report – 2020. Report prepared for BC Hydro Generations, Water License Requirements, Burnaby, BC. 33 pp + 5 app.

Golder Associates Ltd. 2020b. Lower Columbia River (CLBMON#42[A]) and Kootenay River Fish Stranding Assessments: Annual summary (April 2019 to April 2020). Report prepared for BC Hydro. Golder Report No. 19117420: 27 p. + 1 app.

Golder Associated Ltd. 2021a. Canadian Lower Columbia River: Fish Stranding Protocol - Draft. Report prepared for BC Hydro. Golder Report No. 19117420-006-R: 38 pp + 6 app.

Golder Associated Ltd. 2021b. Lower Columbia River (CLBMON-42[A] and Kootenay River Fish Stranding Assessments: Annual summary (April 2020 to April 2021). Report Prepared for BC Hydro. Golder Report No. 19117420-010-R-Rev0: 33 pp + 3 app.

Golder Associates Ltd. and Poisson Consulting Ltd. 2010. Columbia and Kootenay River Fish Stranding Protocol Review: Literature Review and Fish Stranding Database Analysis. 34 p + appendices. Irvine R.L., Oussoren T., Baxter J.S., Schmidt, D.C. 2009. The effects of flow reduction rates on fish stranding in British Columbia, Canada. River Research and Applications. 25: 405-415.

Irvine RL, T Oussoren, JS Baxter, and DC Schmidt. 2009. The effects of flow reduction rates on fish stranding in British Columbia, Canada. River Research and Applications. 25: 405-415.

Irvine RL, JL Thorley, R Westcott, D Schmidt, and D DeRosa. 2014. Why do fish strand? An analysis of ten years of flow reduction monitoring data from the Columbia and Kootenay Rivers, Canada. River Research and Applications. DOI: 10.1002/rra.2823

McPhail JD. 2007. The Freshwater Fish of British Columbia. The University of Alberta Press. Edmonton, AB.

R.L. & L. Environmental Services Ltd. 1995. Shallow-water habitat use by dace spp. and sculpin spp. in the lower Columbia River Basin Development Area. Report prepared for BC Hydro, Environmental Resource Division, Vancouver. R.L. & L. Environmental Services Ltd., Edmonton AB.

Thorley JL, RL Irvine, JTA Baxter. 2017. WLR Monitoring Study No. CLBMON-46 (Year 9) Lower Columbia River Rainbow Trout Spawning Assessment Study Period: January to July 2016. Columbia River Water Use Plan. BC Hydro, Castlegar. A Mountain Water Research and Poisson Consulting Ltd. Final Report.

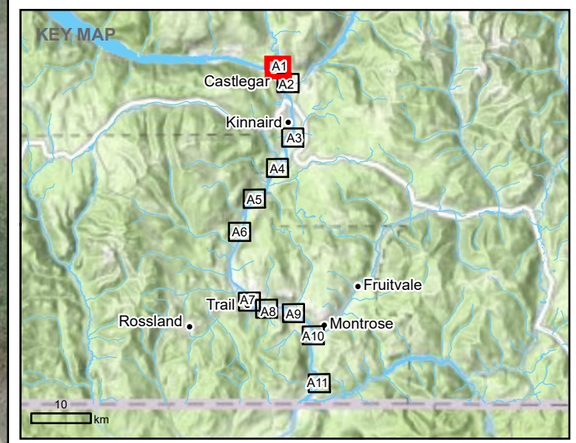
APPENDIX A

Site Maps

LEGEND

- STRANDING SITE

KEY MAP



0 125 250

1:7,500 METRES

REFERENCE

1. BASE IMAGERY SOURCE: SOURCES: ESRI, HERE, DELORME, INCREMENT P CORP., NPS, NRCAN, ORDNANCE SURVEY, © OPENSTREETMAP CONTRIBUTORS, USGS, NGA, NASA, CGIAR, N ROBINSON, NCEAS, NLS, OS, NMA, GEODATASTYRELSEN, RIJKSWATERSTAAT, GSA, GEOLAND, FEMA, INTERMAP AND THE GIS USER COMMUNITY SOURCE: ESRI, MAXAR, EARTHSTAR GEOGRAPHICS, AND THE GIS USER COMMUNITY DATUM: NAD83 PROJECTION UTM 11

CLIENT
BC HYDRO

PROJECT
LOWER COLUMBIA RIVER (CLBMON#42[A]) AND KOOTENAY RIVER FISH STRANDING ASSESSMENTS: ANNUAL SUMMARY (APRIL 2021 TO APRIL 2022)

TITLE
STRANDING SITES: UPPER SECTION - COLUMBIA RIVER

CONSULTANT
GOLDER
MEMBER OF WSP

YYYY-MM-DD	2022-08-23
DESIGN	KL
PREPARED	JG
REVIEW	KL
APPROVED	SR

PROJECT No.	PHASE	Rev.	FIGURE
21508219	2022-4	A	**A1**

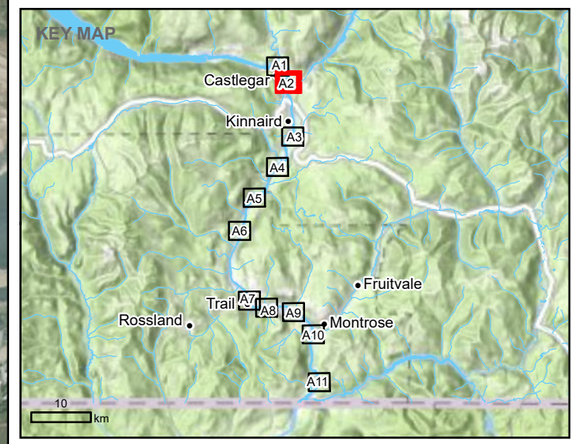
IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: 0 25mm

Path: \\golder.gds\gal\burnaby\CAD-GIS\Client\BC_Hydro\Lower_Columbia_River\99_PROJECTS\19117420\2021\02_PRODUCTION\MXD\Report\2022\AppA_21508219_2022_SITE_LOCATIONS_REVA.mxd

LEGEND

- STRANDING SITE

KEY MAP



0 125 250

1:7,500 METRES

REFERENCE

1. BASE IMAGERY SOURCE: SOURCES: ESRI, HERE, DELORME, INCREMENT P CORP., NPS, NRCAN, ORDNANCE SURVEY, © OPENSTREETMAP CONTRIBUTORS, USGS, NGA, NASA, CGIAR, N ROBINSON, NCEAS, NLS, OS, NMA, GEODATASTYRELSEN, RIJKSWATERSTAAT, GSA, GEOLAND, FEMA, INTERMAP AND THE GIS USER COMMUNITY SOURCE: ESRI, MAXAR, EARTHSTAR GEOGRAPHICS, AND THE GIS USER COMMUNITY DATUM: NAD83 PROJECTION UTM 11

CLIENT
BC HYDRO

PROJECT
LOWER COLUMBIA RIVER (CLBMON#42[A]) AND KOOTENAY RIVER FISH STRANDING ASSESSMENTS: ANNUAL SUMMARY (APRIL 2021 TO APRIL 2022)

TITLE
UPPER SECTION - COLUMBIA AND KOOTENAY RIVER

CONSULTANT
GOLDER
MEMBER OF WSP

YYYY-MM-DD	2022-08-23
DESIGN	KL
PREPARED	JG
REVIEW	KL
APPROVED	SR

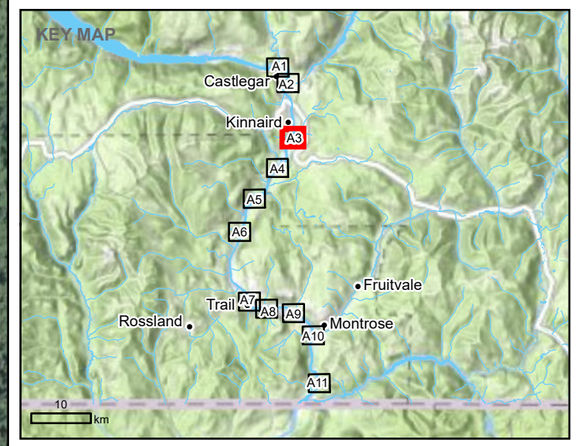
PROJECT No.	PHASE	Rev.	FIGURE
21508219	2022-4	A	**A2**

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM:
25mm
0

Path: \\golder.gds\gal\burnaby\CAD-GIS\Client\BC_Hydro\Lower_Columbia_River\99_PROJECTS\19111742\20221102_PRODUCTION\MXD\Report\2022\AppA_21508219_2022_SITE_LOCATIONS_REVA.mxd

LEGEND

- STRANDING SITE



0 125 250

1:7,500 METRES

REFERENCE

1. BASE IMAGERY SOURCE: SOURCES: ESRI, HERE, DELORME, INCREMENT P CORP., NPS, NRCAN, ORDNANCE SURVEY, © OPENSTREETMAP CONTRIBUTORS, USGS, NGA, NASA, CGIAR, N ROBINSON, NCEAS, NLS, OS, NMA, GEODATASTYRELSEN, RIJKSWATERSTAAT, GSA, GEOLAND, FEMA, INTERMAP AND THE GIS USER COMMUNITY SOURCE: ESRI, MAXAR, EARTHSTAR GEOGRAPHICS, AND THE GIS USER COMMUNITY DATUM: NAD83 PROJECTION UTM 11

CLIENT
BC HYDRO

PROJECT
LOWER COLUMBIA RIVER (CLBMON#42[A]) AND KOOTENAY RIVER FISH STRANDING ASSESSMENTS: ANNUAL SUMMARY (APRIL 2021 TO APRIL 2022)

TITLE
STRANDING SITES: UPPER SECTION - COLUMBIA RIVER

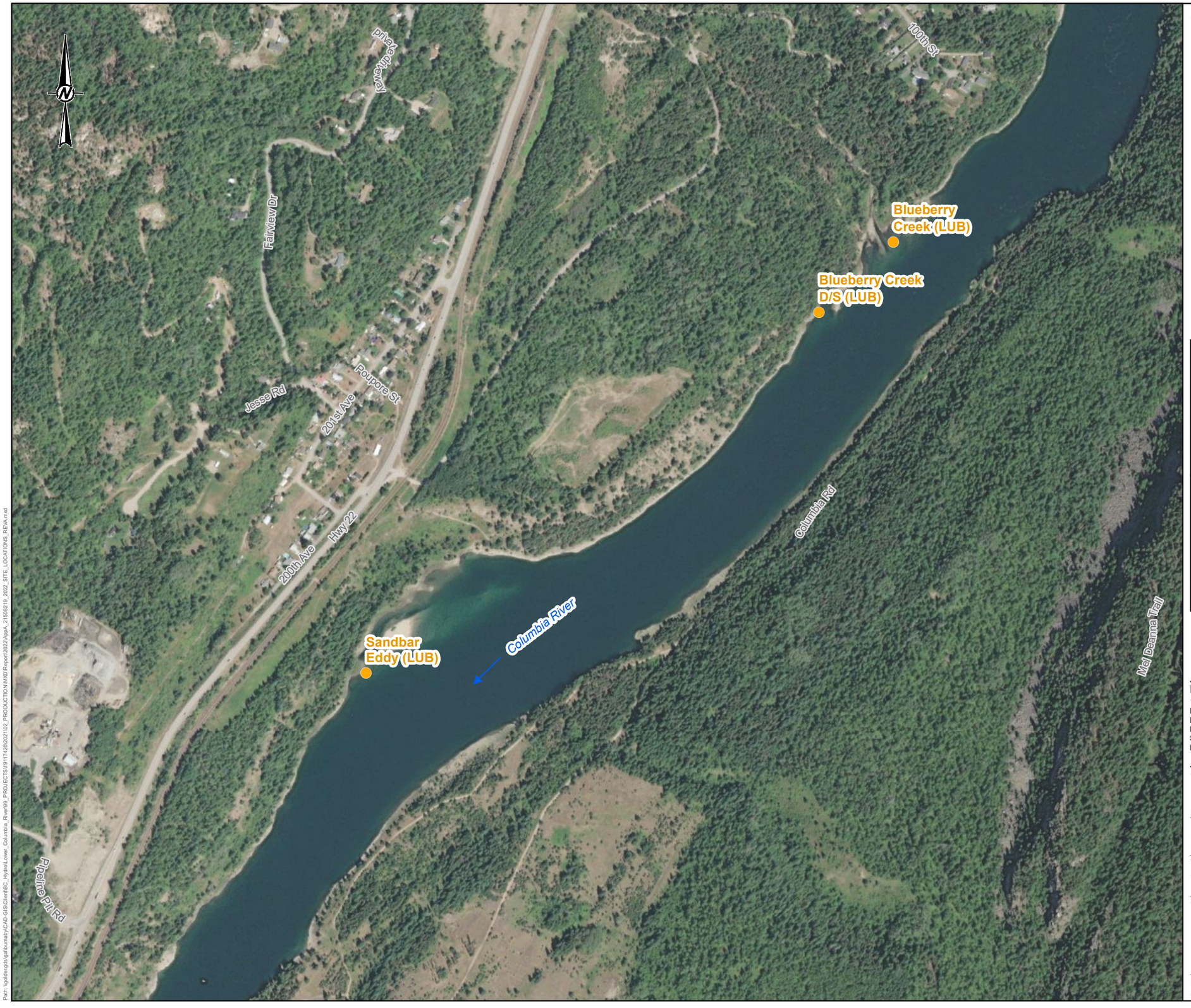
CONSULTANT
GOLDER
MEMBER OF WSP

YYYY-MM-DD	2022-08-23
DESIGN	KL
PREPARED	JG
REVIEW	KL
APPROVED	SR

PROJECT No.	PHASE	Rev.	FIGURE
21508219	2022-4	A	**A3**

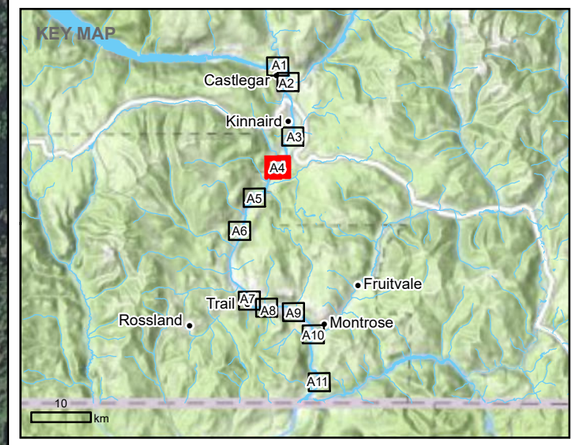
IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM:
25mm
0

Path: \\golder.gds\gal\burnaby\CAD-GIS\Client\BC_Hydro\Lower_Columbia_River\99_PROJECTS\191174202\2021\02_PRODUCTION\MXD\Report\2022\AppA_21508219_2022_SITE_LOCATIONS_REVA.mxd



LEGEND

STRANDING SITE



0 125 250

1:7,500 METRES

REFERENCE

1. BASE IMAGERY SOURCE: SOURCES: ESRI, HERE, DELORME, INCREMENT P CORP., NPS, NRCAN, ORDNANCE SURVEY, © OPENSTREETMAP CONTRIBUTORS, USGS, NGA, NASA, CGIAR, N ROBINSON, NCEAS, NLS, OS, NMA, GEODATASTYRELSEN, RIJKSWATERSTAAT, GSA, GEOLAND, FEMA, INTERMAP AND THE GIS USER COMMUNITY SOURCE: ESRI, MAXAR, EARTHSTAR GEOGRAPHICS, AND THE GIS USER COMMUNITY DATUM: NAD83 PROJECTION UTM 11

CLIENT
BC HYDRO

PROJECT
LOWER COLUMBIA RIVER (CLBMON#42[A]) AND KOOTENAY RIVER FISH STRANDING ASSESSMENTS: ANNUAL SUMMARY (APRIL 2021 TO APRIL 2022)

TITLE
STRANDING SITES: UPPER SECTION - COLUMBIA RIVER

CONSULTANT
GOLDER
MEMBER OF WSP

YYYY-MM-DD	2022-08-23
DESIGN	KL
PREPARED	JG
REVIEW	KL
APPROVED	SR

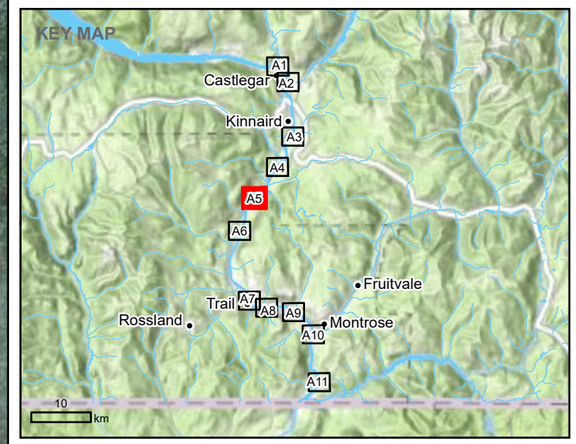
PROJECT No.	PHASE	Rev.	FIGURE
21508219	2022-4	A	**A4**

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: 25mm 0

Path: \\golder.gds.\gal\burnaby\CAD-GIS\Client\BC_Hydro\Lower_Columbia_River\99_PROJECTS\19117420\2021\02_PRODUCTION\MXD\Report\2022\AppA_21508219_2022_SITE_LOCATIONS_REV.mxd

LEGEND

STRANDING SITE



0 125 250

1:7,500 METRES

REFERENCE

1. BASE IMAGERY SOURCE: SOURCES: ESRI, HERE, DELORME, INCREMENT P CORP., NPS, NRCAN, ORDNANCE SURVEY, © OPENSTREETMAP CONTRIBUTORS, USGS, NGA, NASA, CGIAR, N ROBINSON, NCEAS, NLS, OS, NMA, GEODATASTYRELSEN, RUKSWATERSTAAT, GSA, GEOLAND, FEMA, INTERMAP AND THE GIS USER COMMUNITY SOURCE: ESRI, MAXAR, EARTHSTAR GEOGRAPHICS, AND THE GIS USER COMMUNITY DATUM: NAD83 PROJECTION UTM 11

CLIENT
BC HYDRO

PROJECT
LOWER COLUMBIA RIVER (CLBMON#42[A]) AND KOOTENAY RIVER FISH STRANDING ASSESSMENTS: ANNUAL SUMMARY (APRIL 2021 TO APRIL 2022)

TITLE
STRANDING SITES: MIDDLE SECTION - COLUMBIA RIVER

CONSULTANT
GOLDER
MEMBER OF WSP

YYYY-MM-DD	2022-08-23
DESIGN	KL
PREPARED	JG
REVIEW	KL
APPROVED	SR

PROJECT No.	PHASE	Rev.	FIGURE
21508219	2022-4	A	**A5**

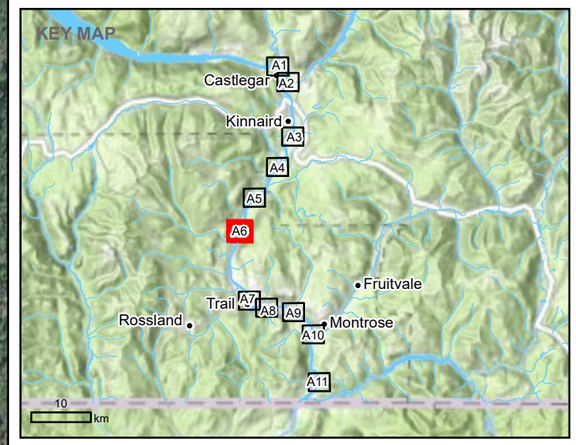
IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: 25mm 0

Path: \\golder\gds\gal\burnaby\CAD-GIS\Client\BC_Hydro\Lower_Columbia_River\99_PROJECTS\191174200\2021102_PRODUCTION\MXD\Report\2022\AppA_21508219_2022_SITE_LOCATIONS_REVA.mxd

LEGEND

STRANDING SITE

KEY MAP



0 125 250

1:7,500 METRES

REFERENCE

1. BASE IMAGERY SOURCE: SOURCES: ESRI, HERE, DELORME, INCREMENT P CORP., NPS, NRCAN, ORDNANCE SURVEY, © OPENSTREETMAP CONTRIBUTORS, USGS, NGA, NASA, CGIAR, N ROBINSON, NCEAS, NLS, OS, NMA, GEODATASTYRELSEN, RIJKSWATERSTAAT, GSA, GEOLAND, FEMA, INTERMAP AND THE GIS USER COMMUNITY SOURCE: ESRI, MAXAR, EARTHSTAR GEOGRAPHICS, AND THE GIS USER COMMUNITY DATUM: NAD83 PROJECTION UTM 11

CLIENT
BC HYDRO

PROJECT
LOWER COLUMBIA RIVER (CLBMON#42[A]) AND KOOTENAY RIVER FISH STRANDING ASSESSMENTS: ANNUAL SUMMARY (APRIL 2021 TO APRIL 2022)

TITLE
STRANDING SITES: MIDDLE SECTION - COLUMBIA RIVER

CONSULTANT
GOLDER
MEMBER OF WSP

YYYY-MM-DD	2022-08-23
DESIGN	KL
PREPARED	JG
REVIEW	KL
APPROVED	SR

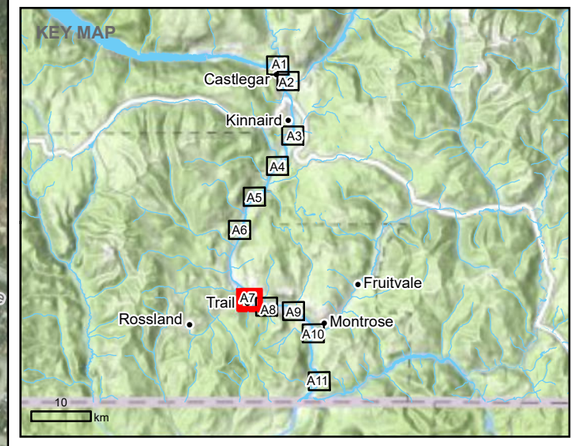
PROJECT No.	PHASE	Rev.	FIGURE
21508219	2022-4	A	**A6**

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: 25mm 0

Path: \\golder.gds\gal\burnaby\CAD-GIS\Client\BC_Hydro\Lower_Columbia_River\99_PROJECTS\19117420\20210\2_PRODUCTION\MXD\Report\2022\AppA_21508219_2022_SITE_LOCATIONS_REV

LEGEND

- STRANDING SITE



0 125 250

1:7,500 METRES

REFERENCE

1. BASE IMAGERY SOURCE: SOURCES: ESRI, HERE, DELORME, INCREMENT P CORP., NPS, NRCAN, ORDNANCE SURVEY, © OPENSTREETMAP CONTRIBUTORS, USGS, NGA, NASA, CGIAR, N ROBINSON, NCEAS, NLS, OS, NMA, GEODATASTYRELSEN, RUKSWATERSTAAT, GSA, GEOLAND, FEMA, INTERMAP AND THE GIS USER COMMUNITY SOURCE: ESRI, MAXAR, EARTHSTAR GEOGRAPHICS, AND THE GIS USER COMMUNITY DATUM: NAD83 PROJECTION UTM 11

CLIENT
BC HYDRO

PROJECT
LOWER COLUMBIA RIVER (CLBMON#42[A]) AND KOOTENAY RIVER FISH STRANDING ASSESSMENTS: ANNUAL SUMMARY (APRIL 2021 TO APRIL 2022)

TITLE
STRANDING SITES: MIDDLE SECTION - COLUMBIA RIVER

CONSULTANT
GOLDER
MEMBER OF WSP

YYYY-MM-DD	2022-08-23
DESIGN	KL
PREPARED	JG
REVIEW	KL
APPROVED	SR

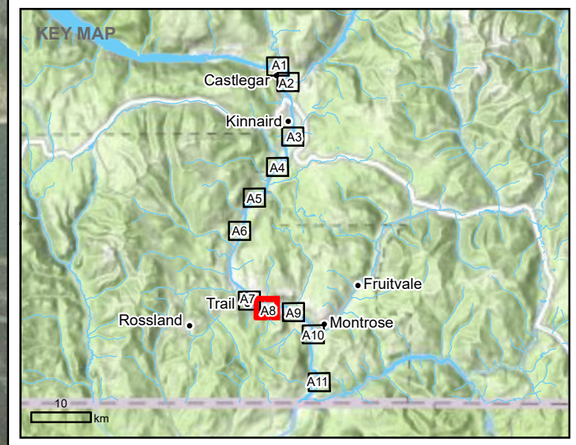
PROJECT No.	PHASE	Rev.	FIGURE
21508219	2022-4	A	**A7**

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: 25mm 0

Path: \\goldergds\gal\burnaby\CAD-GIS\Client\BC_Hydro\Lower_Columbia_River\99_PROJECTS\191174202\2021\02_PRODUCTION\MXD\Report\2022\AprA_21508219_2022_SITE_LOCATIONS_REVA.mxd

LEGEND

- STRANDING SITE



0 125 250

1:7,500 METRES

REFERENCE

1. BASE IMAGERY SOURCE: SOURCES: ESRI, HERE, DELORME, INCREMENT P CORP., NPS, NRCAN, ORDNANCE SURVEY, © OPENSTREETMAP CONTRIBUTORS, USGS, NGA, NASA, CGIAR, N ROBINSON, NCEAS, NLS, OS, NMA, GEODATASTYRELSEN, RIJKSWATERSTAAT, GSA, GEOLAND, FEMA, INTERMAP AND THE GIS USER COMMUNITY SOURCE: ESRI, MAXAR, EARTHSTAR GEOGRAPHICS, AND THE GIS USER COMMUNITY DATUM: NAD83 PROJECTION UTM 11

CLIENT
BC HYDRO

PROJECT
LOWER COLUMBIA RIVER (CLBMON#42[A]) AND KOOTENAY RIVER FISH STRANDING ASSESSMENTS: ANNUAL SUMMARY (APRIL 2021 TO APRIL 2022)

TITLE
STRANDING SITES: MIDDLE SECTION - COLUMBIA RIVER

CONSULTANT
GOLDER
MEMBER OF WSP

YYYY-MM-DD	2022-08-23
DESIGN	KL
PREPARED	JG
REVIEW	KL
APPROVED	SR

PROJECT No.	PHASE	Rev.	FIGURE
21508219	2022-4	A	**A8**

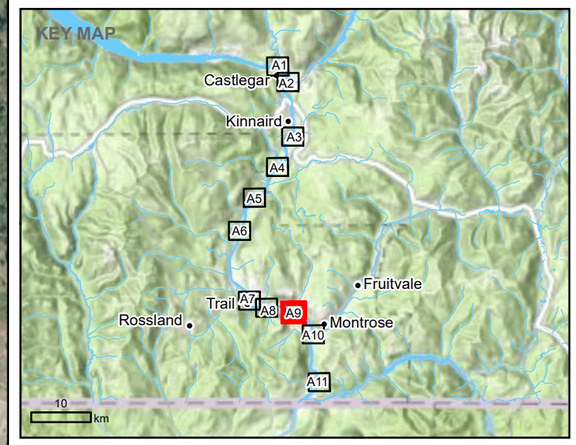
IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: 25mm 0

Path: \\golder.gds\gal\burnaby\CAD-GIS\Client\BC_Hydro\Lower_Columbia_River\99_PROJECTS\19117420\21102_PRODUCTION\MXD\Report\2022\AppA_21508219_2022_SITE_LOCATIONS_REV.mxd

LEGEND

STRANDING SITE

KEY MAP



0 125 250

1:7,500 METRES

REFERENCE

1. BASE IMAGERY SOURCE: SOURCES: ESRI, HERE, DELORME, INCREMENT P CORP., NPS, NRCAN, ORDNANCE SURVEY, © OPENSTREETMAP CONTRIBUTORS, USGS, NGA, NASA, CGIAR, N ROBINSON, NCEAS, NLS, OS, NMA, GEODATASTYRELSEN, RIJKSWATERSTAAT, GSA, GEOLAND, FEMA, INTERMAP AND THE GIS USER COMMUNITY SOURCE: ESRI, MAXAR, EARTHSTAR GEOGRAPHICS, AND THE GIS USER COMMUNITY DATUM: NAD83 PROJECTION UTM 11

CLIENT
BC HYDRO

PROJECT
LOWER COLUMBIA RIVER (CLBMON#42[A]) AND KOOTENAY RIVER FISH STRANDING ASSESSMENTS: ANNUAL SUMMARY (APRIL 2021 TO APRIL 2022)

TITLE
LOWER SECTION - COLUMBIA RIVER

CONSULTANT
GOLDER
MEMBER OF WSP

YYYY-MM-DD	2022-08-23
DESIGN	KL
PREPARED	JG
REVIEW	KL
APPROVED	SR

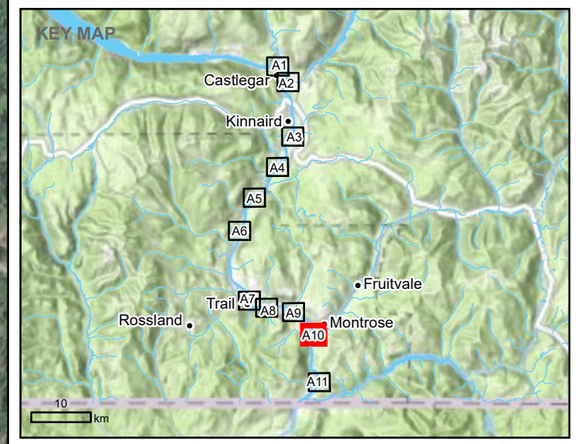
PROJECT No.	PHASE	Rev.	FIGURE
21508219	2022-4	A	**A9**

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: 25mm 0

Path: \\golder.gds\gal\burnaby\CAD-GIS\Client\BC_Hydro\Lower_Columbia_River\99_PROJECTS\191117420\20210102_PRODUCTION\MXD\Report\2022\AppA_21508219_2022_SITE_LOCATIONS_REV

LEGEND

STRANDING SITE



0 125 250

1:7,500 METRES

REFERENCE

1. BASE IMAGERY SOURCE: SOURCES: ESRI, HERE, DELORME, INCREMENT P CORP., NPS, NRCAN, ORDNANCE SURVEY, © OPENSTREETMAP CONTRIBUTORS, USGS, NGA, NASA, CGIAR, N ROBINSON, NCEAS, NLS, OS, NMA, GEODATASTYRELSEN, RIJKSWATERSTAAT, GSA, GEOLAND, FEMA, INTERMAP AND THE GIS USER COMMUNITY SOURCE: ESRI, MAXAR, EARTHSTAR GEOGRAPHICS, AND THE GIS USER COMMUNITY DATUM: NAD83 PROJECTION UTM 11

CLIENT
BC HYDRO

PROJECT
LOWER COLUMBIA RIVER (CLBMON#42[A]) AND KOOTENAY RIVER FISH STRANDING ASSESSMENTS: ANNUAL SUMMARY (APRIL 2021 TO APRIL 2022)

TITLE
LOWER SECTION - COLUMBIA RIVER

CONSULTANT
GOLDER
MEMBER OF WSP

YYYY-MM-DD	2022-08-23
DESIGN	KL
PREPARED	JG
REVIEW	KL
APPROVED	SR

PROJECT No.	PHASE	Rev.	FIGURE
21508219	2022-4	A	**A10**

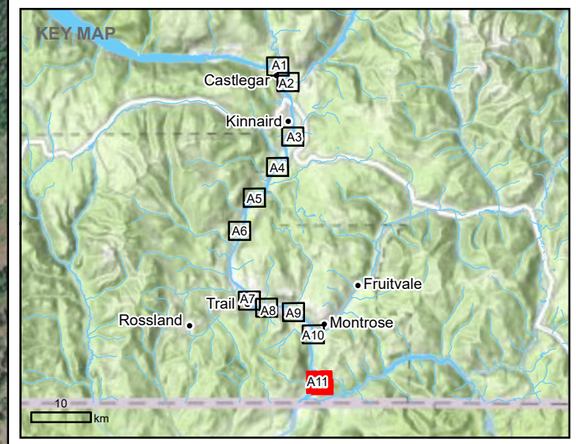
IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: 25mm 0

Path: \\goldergds\gal\burnaby\CAD-GIS\Client\BC_Hydro\Lower_Columbia_River\99_PROJECTS\19111742\20\20211102_PRODUCTION\MXD\Report\2022\AppA_21508219_2022_SITE_LOCATIONS_REVA.mxd

LEGEND

STRANDING SITE

KEY MAP



0 125 250

1:7,500 METRES

REFERENCE

1. BASE IMAGERY SOURCE: SOURCES: ESRI, HERE, DELORME, INCREMENT P CORP., NPS, NRCAN, ORDNANCE SURVEY, © OPENSTREETMAP CONTRIBUTORS, USGS, NGA, NASA, CGIAR, N ROBINSON, NCEAS, NLS, OS, NMA, GEODATASTYRELSEN, RIJKSWATERSTAAT, GSA, GEOLAND, FEMA, INTERMAP AND THE GIS USER COMMUNITY SOURCE: ESRI, MAXAR, EARTHSTAR GEOGRAPHICS, AND THE GIS USER COMMUNITY DATUM: NAD83 PROJECTION UTM 11

CLIENT
BC HYDRO

PROJECT
LOWER COLUMBIA RIVER (CLBMON#42[A]) AND KOOTENAY RIVER FISH STRANDING ASSESSMENTS: ANNUAL SUMMARY (APRIL 2021 TO APRIL 2022)

TITLE
LOWER SECTION - COLUMBIA RIVER

CONSULTANT
GOLDER
MEMBER OF WSP

YYYY-MM-DD	2022-08-23
DESIGN	KL
PREPARED	JG
REVIEW	KL
APPROVED	SR

PROJECT No.	PHASE	Rev.	FIGURE
21508219	2022-4	A	**A11**

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM:
25mm
0

Path: \golder.gds\gal\burnaby\CAD-GIS\Client\BC_Hydro\Lower_Columbia_River\9b_PROJECTS\19117420\20211102_PRODUCTION\MXD\Report2022\AppA_21508219_2022_SITE_LOCATIONS_REVA.mxd

APPENDIX B

Database Query Example

Fish Stranding Data Query Results

Current Water Temp = **7.3 °C**

Current Birchbank Discharge = **48 kcfs**

Proposed Reduction Date = **20-Nov-21**

Resulting Birchbank Discharge = **43 kcfs**

Reduction Location = **Hugh L. Keenleyside Dam**

Site Name	Reduction Date	Reduction Event #	Max. BB Disch. (kcfs)	Min. BB Disch. (kcfs)	Water Temp. at BB (°C)	Total Number Unlisted Fish Stranded	Total Number of Stranded Listed Fish
Lions Head (upstream of Norns Fan) (RUB)	05-Nov-16	201616	50.5	45.9	8.5	0	
Maximum number of fish stranded at this site during a single reduction (based on 1 reduction) =						**0**	
Concern Category:						**Reconnaissance Survey**	
Norns Creek Fan (RUB)	07-Oct-06	200619	54.0	47.0	9.0	0	
	06-Oct-07	200725	51.8	43.6	14.2	25	
	07-Oct-09	200917	53.7	44.1	13.5	47	
	20-Nov-10	201019	48.1	45.2	5.0	3	
	30-Nov-14	201416	78.2	43.8	2.5	36	**2**
	01-Oct-16	201613	56.9	43.4	14.5	2	
	10-Nov-17	201720	59.4	45.7	7.5	5	
Maximum number of fish stranded at this site during a single reduction (based on 7 reductions) =						**47**	**2**
Concern Category:						**Effect**	
CPR Island (MID)	07-Oct-06	200619	54.0	47.0	13.0	10	**1**
	06-Oct-07	200725	51.8	43.6	14.2	39	
	02-Oct-08	200818	45.6	43.9	15.0	0	
	07-Oct-09	200917	53.7	44.1	13.5	147	
	20-Nov-10	201019	48.1	45.2	7.0	0	
	09-Nov-13	201314	53.3	43.0	8.0	0	
	30-Nov-14	201416	78.2	43.8	4.3	93	
Maximum number of fish stranded at this site during a single reduction (based on 7 reductions) =						**147**	**1**
Concern Category:						**Effect**	
Tin Cup Rapids (RUB)	05-Oct-01	200120	52.6	47.8	14.2	19	
	15-Oct-01	200121	47.1	43.6		0	
	07-Oct-06	200619	54.0	47.0		0	
	07-Oct-09	200917	53.7	44.1	13.5	70	
	20-Oct-10	201017	48.2	46.2	11.0	86	
	20-Nov-10	201019	48.1	45.2	7.0	10	
	30-Nov-14	201416	78.2	43.8	4.0	0	
	10-Nov-17	201720	59.4	45.7	8.3	2	
Maximum number of fish stranded at this site during a single reduction (based on 8 reductions) =						**86**	
Concern Category:						**Minimal Effect**	

Site Name	Reduction Date	Reduction Event #	Max. BB Disch. (kcfs)	Min. BB Disch. (kcfs)	Water Temp. at BB (°C)	Total Number Unlisted Fish Stranded	Total Number of Stranded Listed Fish
Millenium Park (Tin Cup LUB)	05-Oct-01	200120	52.6	47.8	14.2	0	
	07-Oct-06	200619	54.0	47.0	13.0	0	
	25-Nov-08	200819	47.6	43.6	7.0	0	
	20-Nov-10	201019	48.1	45.2	7.0	0	
	30-Nov-14	201416	78.2	43.8	4.0	0	
Maximum number of fish stranded at this site during a single reduction (based on 5 reductions) =						**0**	
Concern Category:						**Minimal Effect**	
Kootenay River (LUB)	15-Oct-01	200121	47.1	43.6		0	
	07-Oct-06	200619	54.0	47.0	14.0	0	
	27-Oct-12	201216	53.5	44.2	11.0	0	
	09-Nov-13	201314	53.3	43.0	4.5	0	
	30-Nov-14	201416	78.2	43.8	4.5	0	
	10-Nov-17	201720	59.4	45.7	7.2	0	
Maximum number of fish stranded at this site during a single reduction (based on 6 reductions) =						**0**	
Concern Category:						**Minimal Effect**	
Kootenay River (RUB)	05-Oct-01	200120	52.6	47.8	15.5	**1450**	
	15-Oct-01	200121	47.1	43.6		42	
	07-Oct-06	200619	54.0	47.0	13.0	124	**1**
	06-Oct-07	200725	51.8	43.6	14.2	68	
	01-Oct-08	200817	49.1	45.5	12.0	30	
	02-Oct-08	200818	45.6	43.9	13.0	117	
	25-Nov-08	200819	47.6	43.6	5.0	1	
	07-Oct-09	200917	53.7	44.1	15.5	**335**	
	20-Oct-10	201017	48.2	46.2	6.5	10	
	20-Nov-10	201019	48.1	45.2	6.5	0	
	27-Oct-12	201216	53.5	44.2	11.0	0	
	09-Nov-13	201314	53.3	43.0	4.5	0	
	10-Nov-17	201720	59.4	45.7	7.2	39	
Maximum number of fish stranded at this site during a single reduction (based on 13 reductions) =						**1450**	**1**
Concern Category:						**Effect**	

Site Name	Reduction Date	Reduction Event #	Max. BB Disch. (kcfs)	Min. BB Disch. (kcfs)	Water Temp. at BB (°C)	Total Number Unlisted Fish Stranded	Total Number of Stranded Listed Fish
Zuckerberg Island (LUB)	05-Oct-01	200120	52.6	47.8	14.3	0	
	15-Oct-01	200121	47.1	43.6		0	
	01-Oct-08	200817	49.1	45.5	14.0	10	
	02-Oct-08	200818	45.6	43.9	14.0	165	
	25-Nov-08	200819	47.6	43.6	7.0	0	
	07-Oct-09	200917	53.7	44.1	13.5	131	
	20-Nov-10	201019	48.1	45.2	7.0	0	
	30-Nov-14	201416	78.2	43.8	4.0	1	
Maximum number of fish stranded at this site during a single reduction (based on 8 reductions) =						**165**	
Concern Category:						**Minimal Effect**	
Kinnaird Rapids (RUB)							
Maximum number of fish stranded at this site during a single reduction (based on 1 reduction) =							
Concern Category:						**No Pools**	
Waterloo U/S (RUB)							
Maximum number of fish stranded at this site during a single reduction (based on 1 reduction) =						No Data	
Concern Category:						**Reconnaissance Survey**	
Blueberry Creek (LUB)	07-Oct-06	200619	54.0	47.0	9.0	0	
Maximum number of fish stranded at this site during a single reduction (based on 1 reduction) =						**0**	
Concern Category:						**Reconnaissance Survey**	
Blueberry Creek D/S (LUB)							
Maximum number of fish stranded at this site during a single reduction (based on 1 reduction) =						No Data	
Concern Category:						**Reconnaissance Survey**	
Sandbar Eddy (LUB)							
Maximum number of fish stranded at this site during a single reduction (based on 1 reduction) =						No Data	
Concern Category:						**Reconnaissance Survey**	

Site Name	Reduction Date	Reduction Event #	Max. BB Disch. (kcfs)	Min. BB Disch. (kcfs)	Water Temp. at BB (°C)	Total Number Unlisted Fish Stranded	Total Number of Stranded Listed Fish
Genelle Mainland (Before Recontouring 2021)	07-Oct-06	200619	54.0	47.0	14.0	0	
	06-Oct-07	200725	51.8	43.6	14.2	0	
	01-Oct-08	200817	49.1	45.5	15.5	0	
	02-Oct-08	200818	45.6	43.9	13.0	0	
	20-Oct-10	201017	48.2	46.2	11.0	1	
	20-Nov-10	201019	48.1	45.2	8.6	0	
	30-Nov-14	201416	78.2	43.8	4.5	27	**6**
	01-Oct-16	201613	56.9	43.4	15.5	0	
	10-Nov-17	201720	59.4	45.7		0	
Maximum number of fish stranded at this site during a single reduction (based on 9 reductions) =						**27**	**6**
Concern Category:						**Effect**	
Genelle Mainland (LUB)							
Maximum number of fish stranded at this site during a single reduction (based on 1 reduction) =						No Data	
Concern Category:						**Reconnaissance Survey**	
Genelle Upper Cobble Island (MID)							
Maximum number of fish stranded at this site during a single reduction (based on 1 reduction) =							
Concern Category:						**No Pools**	
Genelle Lower Cobble Island (MID)							
Maximum number of fish stranded at this site during a single reduction (based on 1 reduction) =						No Data	
Concern Category:						**Reconnaissance Survey**	
Gyro Park (RUB)							
Maximum number of fish stranded at this site during a single reduction (based on 1 reduction) =						No Data	
Concern Category:						**Reconnaissance Survey**	
Gyro Boat Launch	07-Oct-06	200619	54.0	47.0	13.0	89	**5**
	06-Oct-07	200725	51.8	43.6	13.9	**390**	**4**
	01-Oct-08	200817	49.1	45.5	15.5	0	
	02-Oct-08	200818	45.6	43.9	13.0	**650**	
	20-Oct-10	201017	48.2	46.2	13.0	1	
	27-Oct-12	201216	53.5	44.2	11.0	1	
	09-Nov-13	201314	53.3	43.0	5.7	32	
	30-Nov-14	201416	78.2	43.8	4.0	8	
Maximum number of fish stranded at this site during a single reduction (based on 8 reductions) =						**650**	**5**
Concern Category:						**Effect**	

Site Name	Reduction Date	Reduction Event #	Max. BB Disch. (kcfs)	Min. BB Disch. (kcfs)	Water Temp. at BB (°C)	Total Number Unlisted Fish Stranded	Total Number of Stranded Listed Fish
Trail Bridge (RUB) (Downstream)	30-Nov-14	201416	78.2	43.8	4.0	0	
Maximum number of fish stranded at this site during a single reduction (based on 1 reduction) =						**0**	
Concern Category:						**Reconnaissance Survey**	
Casino Road Bridge, Trail (LUB) (Upstream)	30-Nov-14	201416	78.2	43.8	4.2	0	
Maximum number of fish stranded at this site during a single reduction (based on 1 reduction) =						**0**	
Concern Category:						**Reconnaissance Survey**	
Casino Road Bridge, Trail (LUB) (Downstream)	30-Nov-14	201416	78.2	43.8	4.2	1	
Maximum number of fish stranded at this site during a single reduction (based on 1 reduction) =						**1**	
Concern Category:						**Reconnaissance Survey**	
Bear Creek (RUB)	30-Nov-14	201416	78.2	43.8	3.5	2	
Maximum number of fish stranded at this site during a single reduction (based on 1 reduction) =						**2**	
Concern Category:						**Reconnaissance Survey**	
Beaver Creek (RUB)							
Maximum number of fish stranded at this site during a single reduction (based on 1 reduction) =						No Data	
Concern Category:						**Reconnaissance Survey**	
Beaver Creek (LUB)	30-Nov-14	201416	78.2	43.8	3.1	0	
Maximum number of fish stranded at this site during a single reduction (based on 1 reduction) =						**0**	
Concern Category:						**Reconnaissance Survey**	
Fort Shepherd Eddy (LUB)	30-Nov-14	201416	78.2	43.8	3.1	3	**5**
Maximum number of fish stranded at this site during a single reduction (based on 1 reduction) =						**3**	**5**
Concern Category:						**Effect**	
Fort Shepherd Launch (RUB)	30-Nov-14	201416	78.2	43.8	4.0	5	
	01-Oct-16	201613	56.9	43.4	14.5	5	
Maximum number of fish stranded at this site during a single reduction (based on 2 reductions) =						**5**	
Concern Category:						**Reconnaissance Survey**	

APPENDIX C

Fish Stranding Frequency by Site

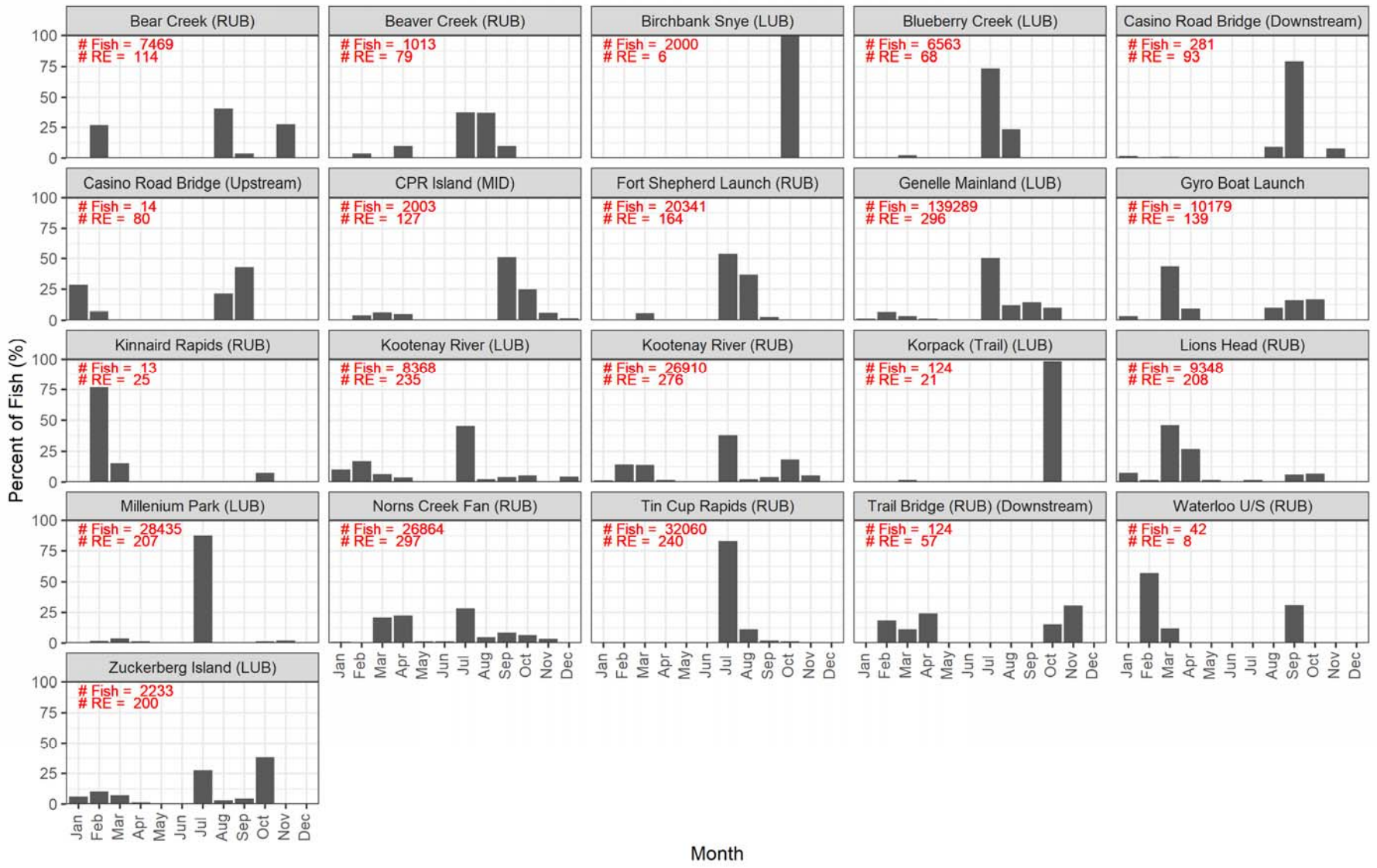


Figure C1: Percent frequency of fish stranded by site and by month. Includes all fish stranded between 1 January 2000 to 1 April 2022. For sites that have been recontoured (Fort Shepherd Launch [RUB], Genelle Mainland [LUB], Lions Head [RUB], Millennium Park [LUB], and Norn's Creek Fan [RUB]), the number of fish and number of reduction events (RE) is inclusive of before and after recontouring occurred.

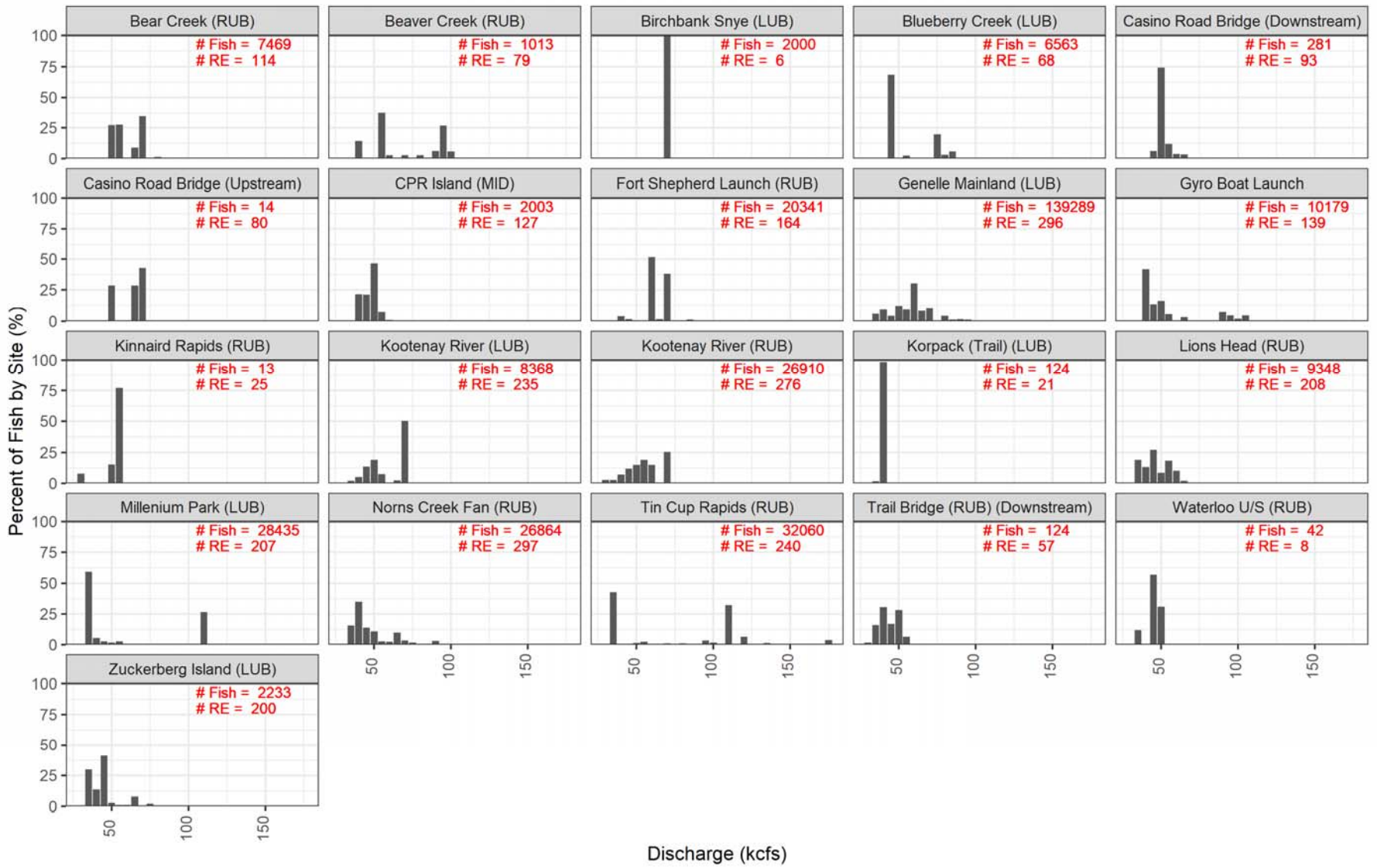


Figure C2: Percent frequency of fish stranded by site and by resultant Birchbank Discharge (Water Survey of Canada Station No. 08NE049). Includes all fish stranded between 1 January 2000 to 1 April 2022. For sites that have been recontoured (Fort Shepherd Launch [RUB], Genelle Mainland [LUB], Lions Head [RUB], Millennium Park [LUB], and Norn's Creek Fan [RUB]), the number of fish and number of reduction events (RE) is inclusive of before and after recontouring occurred.

golder.com