Columbia River Project Water Use Plan

Lower Columbia River Fish Management Plan

Lower Columbia River Fish Stranding Assessment and Ramping Protocol

Implementation Year 11

Reference: CLBMON-42A

Lower Columbia River Assessments (CLBMON-42A) and Kootenay River Fish Stranding Assessments

Study Period: April 1, 2017 to April 1, 2018

Golder Associates Ltd. 201 Columbia Ave. Castlegar, BC. V1N 1A8

July 13, 2018

13 July 2018

ANNUAL SUMMARY REPORT

Lower Columbia River (CLBMON#42[A]) and Kootenay River Fish Stranding Assessments: Annual Summary (April 2017 to April 2018)

Submitted to:
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REPORT

Golder Associates

Cover Photo: Shallow pools formed at Norns Creek Fan (RUB) during flow reduction event RE2017-16 on 2 October 2017 (see Appendix A; Figure A4 for location).

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Executive Summary

Discharge reductions and flow ramping from Hugh L. Keenleyside Dam/Arrow Lakes Generating Station (HLK/ALH) and Brilliant Dam/Expansion (BRD/X) can result in the stranding of fish species of the lower Columbia and Kootenay rivers. The Lower Columbia River Fish Stranding Assessment and Ramping Protocol Monitoring Program (CLBMON#42) has been carried out under the 13-year Columbia River Water Use Plan (BC Hydro 2007). The primary objective of CLMBON#42 is to continue to collect fish stranding data to assess the impact of flow reductions and flow ramping rates from HLK/ALH on the native fish species of the Lower Columbia River and includes two field data collection components: 1) Lower Columbia River and Kootenay River Fish Stranding Assessments (CLMBMON#42[A], and 2) Lower Columbia River Flow Ramping Studies. The present study is Year 11 of 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 pre-determined sites (Appendix A) on the Columbia and Kootenay rivers between 1 April 2017 and 1 April 2018.

At total of 19 reduction events (RE) occurred between 1 April 2017 and 1 April 2018 (the present study). Of those 19 RE, 9 occurred during the High Risk period (1 June to 30 September) and 10 occurred during the Low Risk period (1 October to 31 May). Stranding assessments were conducted for 16 of the 19 RE. Of the 16 stranding assessments, 15 were conducted in response to RE at HLK/ALH, and 1 assessment was conducted in response to a RE at both HLK/ALH and BRD/X.

An estimated 11,922 isolated or stranded fishes were observed during the 16 stranding assessments. Approximately 54% of these fishes were salvaged (successfully relocated to the mainstem Columbia or Kootenay rivers). Nineteen sites were assessed at least once during the study period and the bulk (48.9%) of stranded fishes were found at the Blueberry Creek (LUB) site. Sportfishes accounted for 1.3% of the total stranded fishes and included Rainbow Trout (*Oncorhynchus mykiss*), Mountain Whitefish (*Prosopium williamsoni*), Northern Pike (*Esox lucius*), and Kokanee (*Oncorhynchus nerka*). Of the non-sportfishes stranded, the most common were young-of-the-year and juvenile sucker species (*Catostomidae* spp.) accounting for 42.6% of the non-sportfishes stranded.

In addition to salvaging stranded fishes, the stranding assessments from 2017/2018 provided data for the Lower Columbia River Fish Stranding Database, particularly at discharges where previous stranding data were limited, thereby improving the resolution of database queries that help predict the effects of RE at HLK/ALH and BRD/X.

Secondary objectives of CLBMON#42 include addressing five key management questions identified under the Columbia River Project Water Use Plan (BC Hydro 2007). Analyses necessary to address the first three management questions were not conducted during the present study. These management questions were addressed using data from flow ramping studies conducted on the Columbia River from 2004 to 2006 (Golder 2005, 2006, 2007) and from a literature data review and analysis of the Lower Columbia River Fish Stranding Database conducted in 2010 (Golder and Poisson 2010). Recommendations have been made regarding the first three management questions in the present study. Data collected during the present study, along with a generalized linear mixed model analysis on the effects of re-contouring based on data in the Lower Columbia River Fish Stranding Database, focus on answering Management Question #4 and #5 (Table ES1).

Table ES1: CLBMON#42 Status of Lower Columbia River Fish Stranding Assessment and Ramping Protocol Program Objectives, Management Questions and Hypotheses

Primary Objective	Secondary Objectives	Management Questions	Management Hypotheses	Year 11 (2017/2018) Status
To assess the impact of flow reductions and flow ramping rates from HLK/ALH on the native species of the lower Columbia River.	To determine ramping rates for flow reductions which reduce the stranding rate of fish at different times of the year.	MQ1: Is there a ramping rate (fast vs. slow, day vs. night) for flow reductions from HLK/ALH that reduces the number of fish stranded (interstitially and pool) per flow reduction event in the summer and winter?	Ho1: The number of stranded fish is independent of either the ramping rate or time of day of flow reductions in the summer and winter.	Ramping rates within the range of variability experienced in the previous years of study were not a statistically significant predictor of fish stranding in the Columbia and Kootenay river systems (Golder 2005, 2006, 2007; Golder and Poisson 2010). Given these results, the ramping rate component of this hypothesis is not rejected. Previous studies indicate that time of day (day vs night) was not a significant variable for stranding risk (Golder 2005, 2006, 2007; Golder and Poisson 2010); however, this finding is based on limited data. Time of day ramping studies were not conducted during the present study. The time of day component of this hypothesis cannot be rejected and must be deferred until additional time of day ramping experiments are conducted. Additional ramping experiments are outside of the scope of the present study; therefore, this component of the hypothesis will not be addressed.
	To determine whether the wetted history influences the stranding rate of fish for flow reductions.	MQ2: Does wetted history (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/ALH?	Ho2: Wetted history does not influence the stranding rate of fish (both interstitially and pool stranding) for flow reductions from HLK/ALH.	A significant increase in the number of stranded fish was observed after a 10-day wetted history, although the effect size (proportion of the population affected and the response to wetted histories of variable lengths greater than 10 days) was not accurately quantified by Golder and Poisson (2010). Based on this previous study, this hypothesis can be rejected. The feasibility of using River2D models from Golder (2013) was assessed during the present study; however, the high cost of running the model coupled with the coarse accuracy for determining wetted history limited the feasibility of this analysis. If this management question is to be investigated further, either a detailed analysis of data collected to date or additional flow ramping studies are suggested.
	To determine whether a conditioning flow reduction from HLK/ALH reduces the stranding rate of fish.	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/ALH reduce the stranding rate of fish?	Ho3: A conditioning flow from HLK/ALH does not reduce the stranding rate of fish in the lower Columbia River.	This hypothesis cannot be rejected at this time. Conditioning flow studies were not conducted during the present study. For a definitive answer to this management question an experimental conditioning flow study including manipulation of flows with substantial time between replicates is required. The cost of this experimental design would be high and may result in substantial fish mortalities, as indicated by similar studies on the Duncan River (Poisson and Golder 2010). The effectiveness of this management tool cannot be properly assessed without dedicated conditioning flow experiments.

Primary Objective	Secondary Objectives	Management Questions	Management Hypotheses	Year 11 (2017/2018) Status
	To determine whether physical habitat manipulation will reduce the incidence of fish stranding.	MQ4: Can physical habitat works (i.e., re-contouring) reduce the incidence of fish stranding in high risk areas?	Ho4: Physical habitat manipulation does not reduce the stranding rate of fish in the lower Columbia River.	Since 2000, six high risk stranding sites on the Columbia River have been re-contoured: Fort Shepherd Launch (RUB), Genelle Lower Cobble Island (MID), Genelle Mainland (LUB), Lions Head (RUB), Millennium Park (LUB), and Norns Creek Fan (RUB). Previous analyses suggest that this hypothesis can be rejected (Golder and Poisson 2010; Irvine et al. 2014). During the present study, a generalized linear mixed model analysis was conducted on previously re-contoured sites using data in the Lower Columbia River Fish Stranding Database. Results of this analysis suggest that the previous efforts of re-contouring sites on the lower Columbia River have been successful in decreasing the incidence of stranding and the number of fish stranded. Based on previous studies and the present study Management Hypothesis #4 is rejected.
	Reduce the number of occurrences when a stranding crew would be deployed for a flow reduction.	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/ALH?	Ho5: The number of fish salvage events can be reduced through adaptive adjustments made as a result of ongoing data collection.	Based on 11 years of data collection, this hypothesis is rejected. Continued collection of stranding data and updating the Lower Columbia River Fish Stranding Database has not decreased the number of stranding events where crews were deployed. During the previous 8 years, 84% of HLK/ALH reduction events initiated stranding assessments. During the present study (1 April 2017 to 1 April 2018), 83% of HLK/ALH reduction events initiated a stranding assessment.

Key Words

Lower Columbia River

Kootenay River

Water Use Planning

Fish Stranding

Flow Reduction

Discharge Regulation

Re-contouring

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1.0 INTRODUCTION

1.1 Scope and Objectives

The Lower Columbia River Fish Stranding Assessment and Ramping Protocol Monitoring Program (CLBMON#42) has been carried out under the 13-year Columbia River Project Water Use Plan (BC Hydro 2007). The monitoring program includes two field data collection components:

- Lower Columbia River and Kootenay River Fish Stranding Assessments; and
- Lower Columbia River Flow Ramping Studies.

The main objective of the Lower Columbia River Fish Stranding Assessment and Ramping Protocol Monitoring Program was to collect fish stranding data to assess the impact of flow reductions and flow ramping rates from Hugh L. Keenleyside Dam/Arrow Lakes Generating Station (HLK/ALH) on native fish species of the lower Columbia and Kootenay rivers. Secondary objectives include the following: 1) determining ramping rates for flow reductions that reduced incidences of fish stranding at different times of the year; 2) determining whether wetted history influenced the stranding rate of fishes during flow reductions; 3) determining whether a conditioning flow reduction from HLK/ALH reduced the stranding rate of fishes; 4) determining whether physical habitat manipulation (e.g., re-contouring the shoreline) reduced incidences of fish stranding in the lower Columbia River; and 5) reducing (through risk management strategies) the number of occurrences when stranding crews need to be deployed during flow reductions (BC Hydro 2007).

Flow ramping studies at HLK/ALH were conducted in the summer and winter of 2004, 2005 and 2006 and the results were previously reported (Golder 2005, 2006, 2007). In 2010, a literature data review and an analysis of data in the Lower Columbia River Fish Stranding Database were conducted to address Management Questions #1-3 (Golder and Poisson 2010). Based on these previous studies, recommendations regarding Management Questions #1-3 have been made in the present study.

The present study provides the results of Year 11 (2017/2018) of the Lower Columbia River and Kootenay River Fish Stranding Assessments (CLBMON#42[A]) and contributes data and analyses designed to address Management Questions #4 and #5. The present study summarizes the results of fish stranding assessments at pre-determined sites (Appendix A) on the lower Columbia and Kootenay rivers between 1 April 2017 and 1 April 2018. Results are compared to data from previous years of monitoring and are discussed in relation to the objectives, Management Questions #4 and #5, and associated hypotheses outlined below.

1.2 Management Questions

The management questions identified under the Columbia River Project Water Use Plan and addressed under the Lower Columbia River Fish Stranding Assessment and Ramping Protocol Monitoring Program are summarized as follows (BC Hydro 2007):

1) Is there a ramping rate (fast vs. slow, day vs. night) for flow reductions from HLK/ALH 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/ALH?

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/ALH 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/ALH?

1.3 Management Hypotheses

Five hypotheses that correspond to the management questions detailed above were tested using data collected during the Lower Columbia River Fish Stranding Assessment and Ramping Protocol Monitoring Program (BC Hydro 2007):

Ho_1: The number of stranded fish is independent of either the ramping rate or time of day of flow reductions in the summer and winter.

Ho_2: Wetted history does not influence the stranding rate of fish (both interstitially and pool stranding) for flow reductions from HLK/ALH.

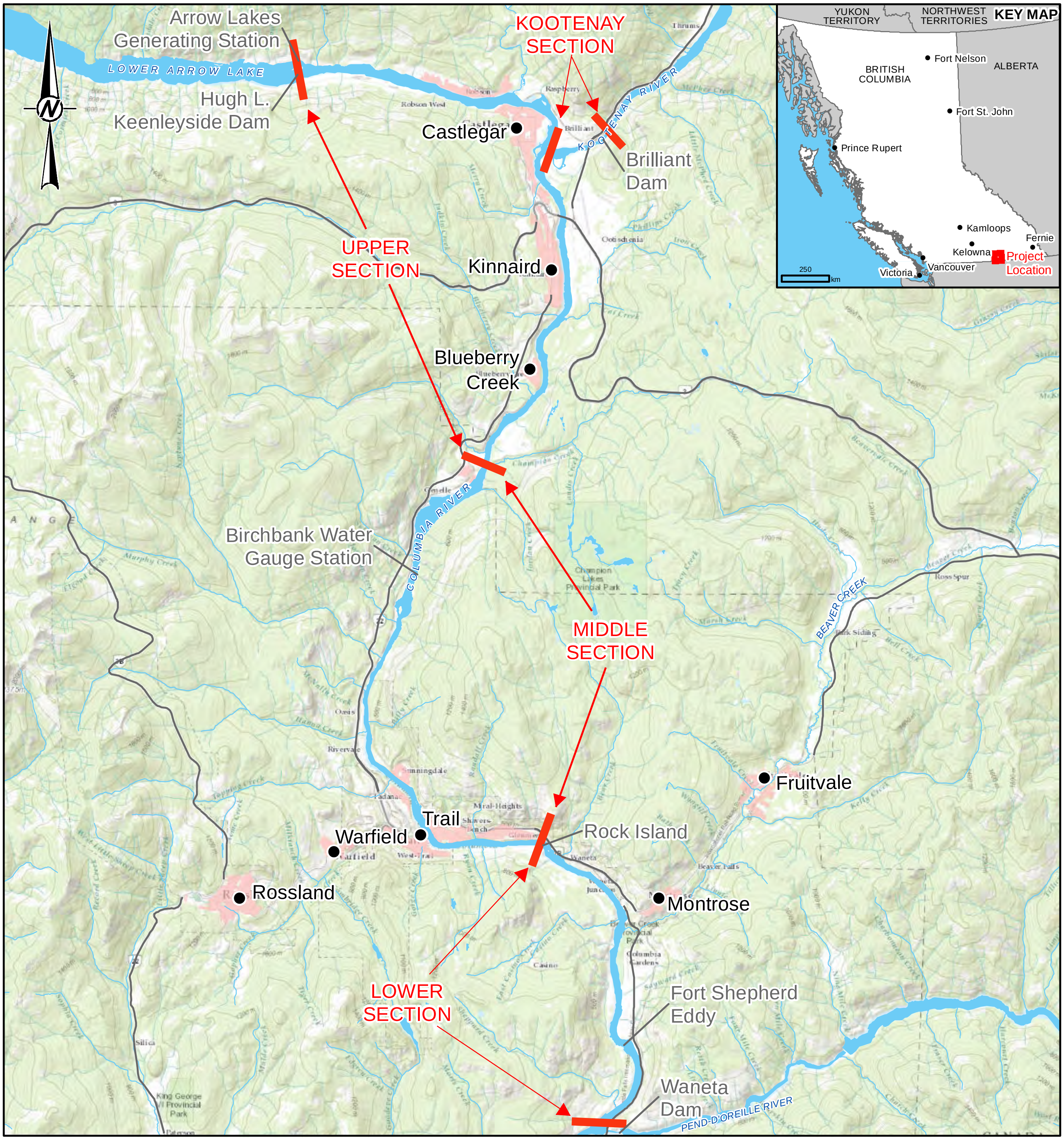
Ho_3: A conditioning flow from HLK/ALH does not reduce the stranding rate of fish in the lower Columbia River.

Ho_4: Physical habitat manipulation does not reduce the stranding rate of fish in the lower Columbia River.

Ho_5: The number of fish salvage events can be reduced through adaptive adjustments made as a result of ongoing data collection.

1.4 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).



LEGEND

- ● TOWN
- HIGHWAY
- WATERCOURSE
- RESIDENTIAL AREA
- WATERBODY

0 5 10

1:200,000 KILOMETERS

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PROJECT
LOWER COLUMBIA RIVER (CLBMON#42[A]) AND KOOTENAY RIVER FISH STRANDING ASSESSMENTS: ANNUAL SUMMARY (APRIL 2017 TO APRIL 2018)

TITLE
STUDY AREA OVERVIEW

CONSULTANT
GOLDER

YYYY-MM-DD	2018-07-17
DESIGNED	KL
PREPARED	CD
REVIEWED	DF
APPROVED	KL

PROJECT NO.	PHASE	REV.	FIGURE
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2.0 METHODS

2.1 Fish Stranding Risk Assessment

Owners and operators (BC Hydro, Columbia Power Corporation (CPC), and FortisBC) of hydroelectric facilities located on the lower Columbia and Kootenay rivers within BC have direct or indirect influences on water levels. *Canadian Lower Columbia River: Fish Stranding 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, and outlines the roles and responsibilities pertaining to flow reductions for owners and operators of hydroelectric facilities on the lower Columbia and Kootenay rivers. Golder (2011) also outlines the roles and responsibilities of the environmental monitor (Golder) and the protocols to be followed while conducting fish stranding assessments.

During the present study, the protocols developed in the *Canadian Lower Columbia River: Fish Stranding Risk Assessment and Response Strategy* were implemented preceding each reduction event and during all stranding surveys conducted. Fish stranding risk and response was based on current knowledge of factors known to influence fish stranding in regulated systems and the results of previous stranding assessments (Vonk 2003; BC Hydro 2005; Golder and Poisson 2010).

Once a potential flow reduction requirement is identified for HLK/ALH or BRD/X, the BC Hydro Operations Planning Engineer (OPE) for the facility consults with the BC Hydro Environmental Discharge Change Coordinator (DCC) regarding the potential flow reduction. The consultation includes information on the following:

- The timing and magnitude of the planned discharge change;
- The drivers of the discharge change;
- Flexibility of the system to modify discharge change expectations;
- Benefits of implementing the discharge change vs. consequences of not implementing the change;
- Current operations and/or planned changes at related hydroelectric facilities (HLK/ALH or BRD/X) to assist in deciding the most appropriate implementation/response strategy. It is important to ensure that there is knowledge of system operations for both the Columbia and Kootenay rivers to avoid potential incremental impacts; and
- A forecast of future changes for the following two weeks.

Once a flow change decision is made, a fish stranding risk assessment is conducted. The assessment is based on both the current environmental conditions, as well as the results of past stranding assessments. Figure 2 summarizes the five phases in the fish stranding risk assessment process for defining fish stranding risk, as well as guiding assessment/salvage response decisions.

- **Phase 1 - Timing of Reduction:** The timing of the proposed reduction is the first factor which is taken into consideration when deciding to initiate a stranding assessment. The stranding High Risk period occurs from 1 June to 30 September; the Low Risk period occurs from 1 October to 31 May (Golder and Poisson 2010). Stranding risk is greatest in the summer months because newly emerged juvenile fishes occupy shallow near-shore habitats where they are more susceptible to stranding (Golder and Poisson 2010).
- **Phase 2 - River Stage:** Defines the current and proposed base flow level at the Water Survey of Canada Birchbank Gauging Station (Station Number 08NE049) as a result of the proposed flow reduction. Previous fish stranding assessment data is used to define risk for the proposed flow reduction change. The probability of fish stranding is typically inversely related to water levels. Low angle river bank and the presence of shallow depressions that are more common at lower water levels result in greater risk of fish stranding when compared to conditions present at higher water levels. During the High Risk period (1 June to 30 September), fish stranding risk decreases when discharge is greater than 110 kilo cubic feet per second (kcfs) (based on limited data). During the Low Risk period (1 October to 31 May), stranding risk decreases when discharge is greater than 60 kcfs (Golder and Poisson 2010).
- **Phase 3 - Info Review:** The Lower Columbia River Fish Stranding Database was developed to store and manage historic flow reduction and stranding assessment data (discharge levels, ramping rates, sites, number of pools isolated, number and species of fishes/eggs stranded either interstitially or within pools, etc.) for use in predicting the potential impacts of a proposed RE. This database is updated a minimum of quarterly throughout the year to include all results from stranding assessments. Prior to a new RE from HLK/ALH or BRD/X, the database is queried to help define fish stranding risk at 22 known stranding sites, based on historical RE data (year 2000 to current) collected during similar times of the year under similar flow conditions. Data queried include current discharge from HLK/ALH and BRD/X, proposed resultant discharge from HLK/ALH and BRD/X on the day of reduction, the Columbia River water temperature at Birchbank, and the date of the proposed reduction. Based on these data, the database provides a ranking of predicted stranding risk at individual sites. From high to low stranding risk priority, the rankings are as follows: '**Significant Stranding Event'** (greater than 5000 fishes stranded during any of the previous RE), **'Effect'** (greater than 200 fishes stranded during any of the previous RE), '**Minimal Effect'** (less than 200 fishes stranded during any of the previous RE), '**Reconnaissance'** (less than five previous stranding assessments conducted), and '**No Pools'** (No pools were recorded at the site during assessments conducted at previous water levels).
- **Phase 4 – Management Decision:** After timing, river stage, and results of the database query have been considered, the DCC will develop an appropriate environmental response recommendation for the proposed RE. A stranding assessment will be required at sites where the results from any previous stranding assessment indicated the following:
  - The flow reduction is likely to result in an 'Effect' (greater than 200 fish stranded at any given site) during the flow reduction under similar conditions based on the database query results.
  - The reduction is likely to strand potential species at risk (Umatilla Dace [*Rhinichthys Umatilla*], Columbia Sculpin [*Cottus hubbsi*], Shorthead Sculpin [*Cottus confusus*], and White Sturgeon [*Acipenser transmontanus*]) or there is uncertainty in the presence of these species.

- The range of operations projected are outside those routinely undertaken for the time of year or few assessments have occurred at the flow range in the past two years.
- No monitoring will be required when past survey data indicates operation will be within the range of normal operations, the anticipated stranding effects are minimal, and listed species are not likely to be stranded. Effects are considered to be minimal when results from query in the Lower Columbia River Fish Stranding Database indicates either no pools are likely to form, or pools are likely to form but less than 200 fish have been stranded at any given site during previous surveys and listed species are not likely to be stranded under similar conditions.
- The hydroelectric utilities will undertake periodic non-mandatory assessments throughout the range of operations and risk levels over time in order to collect data that can be analysed to confirm or alter the state of knowledge about stranding risks. The number and timing of fish stranding assessments undertaken during periods when low numbers of fish are expected to become stranded will be at the discretion of the DCC.

- **Phase 5 – Assessment Refinement:** The DCC and the Golder Stranding Assessment Supervisor (SAS) will define crew requirements based on the following:
  - Review of database query results and total number of potential sites ranked as ‘Effect” and ‘Significant Stranding Event’.
  - The assessment results from the last flow reduction, which can help to indicate which species may be occupying near-shore habitats.
  - Wetted history based on water levels recorded at the Birchbank gauging station. Habitat that has a wetted history of greater than 10 days has a greater risk of stranding fish (Golder and Poisson 2010), which must be considered in flow reduction planning and response. During the High Risk period, YOY (young-of-year) fishes typically inhabit near-shore shallow water habitats and wetted history is less relevant to defining stranding risk.
  - Air Temperature – air temperatures greater than 25˚C or less than 0˚C can influence fish survival in isolated habitats by warming/cooling pool habitats and must be considered when fish salvage is anticipated.


Flow Reduction Fish Stranding Assessment Response
HLK /ALH or BRD/BRX Flow Reduction
PHASE 1 Timing
Day of Year
June 1 – September 30
October 1 – May 31
PHASE 2 Stage
Minimum River Stage during reduction (BB)?
<110 kcfs
>110 kcfs
<60 kcfs
>60 kcfs
Query Stranding Database
PHASE 3 Info Review
> 200 fish (effect) at one site or listed species expected?
<5 assessments at Individual sites at Risk (query), non-routine stage or ramping rate, no assessment in past 2 years at this stage?
No
Yes
PHASE 4 Management Decision
Assessment Recommended
Voluntary Assessment Recommended
No Assessment Required
PHASE 5 Assessment Refinement (Considerations)
1. Review database query results and number of potential sites with effects.
2. Review previous reduction results for significant stranding (> 5000 fish).
3. Estimate wetted history at Birchbank, >10 days wetted history – anticipate more fish stranded.
4. Define daytime air temperature. If air temperature is greater than 25ºC or less than 0ºC, increase crews may be deployed to high risk sites.
5. Consider time of last reduction and ability to assess all potential stranding sites before dark.
If review suggests minimal risk of stranding and limited value in additional information collection an assessment is not necessary.
Undertake Assessment Baseline = 1 crew of 2 can assess approximately 7 sites per day. Consider additional crew on standby if you answered YES to questions 1 – 5 above.
Undertake Assessment

2.2 Salvage Methods

Standard methodology used during the field component for each fish stranding assessment were outlined in the *Canadian Lower Columbia: River Fish Stranding Risk Assessment and Response Strategy* (Golder 2011) and are summarized below. The primary objective was to collect information on effects of flow reduction on fish stranding with fish salvage as a secondary objective.

Stranding assessment crews were on 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 site identified for assessment by the Lower Columbia River Fish Stranding Database query and assessments continued downstream following the stage recession. Sites were also assessed in order from high to low priority based on the site ranking from the database query. Sites where a ‘Significant Fish Stranding’ or ‘Effect’ ranking was assigned were assessed first. The next priorities were ‘Reconnaissance’ sites, and, if time permitted, ‘Minimal Effect’ or ‘No Pools’ sites to confirm information in the database.

At each site the crew conducted the following activities:

1) The current conditions were documented (date, time, weather, air temperature, water temperature, approximate vertical drawdown of the water level, and substrate material) on stranding field forms. The formation of new pools with future flow reductions (next 0.5 m stage decrease) was indicated for each site. Comments were also noted on the stranding field forms indicating success of the salvage and any other pertinent information regarding the stranding assessment.
2) The number of new isolated pools that were created as a result of the flow reduction was recorded. Pools isolated during previous RE were noted in the comments but were not included in the total pools formed from the current RE.
3) Each pool was inspected for fishes and crews attempted to salvage any fishes present using dipnets, backpack electrofishers (Smith-Root Model LR 24 or 12-B POW), or beach seines. The effort and number of pools sampled was recorded at each site depending on the method used for fish capture. Salvaged fishes from previously isolated pools (i.e. different RE), were recorded but were not included in the total number of fish stranded during the current RE.
4) Captured fishes were transferred to a bucket of water where each fish was identified to species if possible. Fishes were classed into one of the following life stages; egg, YOY, juvenile, and adult. If stranded fishes were numerous (greater than 200 individuals), a subsample were captured and identified to species. The total number of live fishes, dead fishes, and salvaged fishes were recorded for each species and life stage. Salvaged fishes were returned to the main channel of the Columbia or Kootenay rivers.
5) The number of larvae and fry stranded was estimated if sample methods were ineffective at capturing these life stages.
6) Interstitial stranding areas were inspected any fishes observed were salvaged.
7) Representative areas of the site at the time of sampling were photographed. Photographs of representative or unusual fish species where also taken as appropriate.
8) Fish length data were collected from up to 20 individuals of each species identified during each RE. Total length was measured for sculpin species and fork length was measured for all other species.

9) Invasive species (Northern Pike, Smallmouth Bass [*Micropterus dolomieu*], Brook Trout [*Salvelinus fontinalis*], Yellow Perch [*Perca flavescens*], Common Carp [*Cyprinus carpio*] and Tench [*Tinca tinca*]) found stranded were euthanized with clove oil and removed from the system based on recommendation from the Ministry of Forests, Lands, Natural Resource Operations and Rural Development (FLNRORD) (Pers. Comm., Matt Neufeld, FLNRO, 22 February 2016).

2.3 Statistical Analysis on Re-contouring Efforts on the Lower Columbia River

To address Management Question #4 (Can physical habitat works [i.e., re-contouring] reduce the incidence of fish stranding in high risk areas?) an analysis of all RE between 2000 and 2018 from the Lower Columbia River Fish Stranding Database was conducted for stranding sites that had been previously re-contoured. Previously re-contoured sites included the following:

- Millennium Park (LUB); re-contoured in 2001;
- Genelle Lower Cobble Island (MID); re-contoured in 2001;
- Norns Creek Fan (RUB); re-contoured in 2002;
- Genelle Mainland (LUB); re-contoured in 2003;
- Fort Shepherd Launch (RUB); re-contoured in 2012/2013; and
- Lions Head (RUB); re-contoured in 2015.

Stranding assessment data from before and after re-contouring was used in the analysis for all sites except Genelle Lower Cobble Island (MID). This site was not included in the analysis due to the limited amount of data available for this site. In recent years, stranding assessments for Genelle Lower Cobble Island (MID) have been conducted from Highway 22, which provides data regarding the presence/absence of pools formed as a result of RE, but does not provide data on the total number of fishes stranded during each RE. Therefore, recent stranding assessment data for this site is not applicable for an analysis on the effects of re-contouring. The effects of re-contouring were analyzed using generalized linear mixed models to estimate the probability of fish stranding events and the number of fishes stranded before and after re-contouring.

2.3.1 Probability of Fish Stranding

The probability of fish stranding events before and after re-contouring was analyzed using generalized linear mixed models assuming a binomial distribution (i.e., mixed-effects logistic regression). Two different binary response variables were analyzed:

1) Fish stranding (zero fish vs. one or more fishes were stranded)

2) Fish stranding 'Effect' (<200 or >200 fishes were stranded)

The number 200 was selected as a binary response because greater than 200 fishes stranded per RE represents the designation of an 'Effect' site in the Lower Columbia River Fish Stranding Database. The number of fishes of all species was summed for each site at each RE when assigning a value to the binary response variable. Fixed effects in the model included re-contouring (before/after), risk period (High/Low), and minimum discharge at Birchbank on the day of the RE. Discharge at Birchbank was centered by subtracting the mean from each observation before analysis. Random effects in the model were site and year. For each of the two response variables, two candidate models were run, one that included the interaction between risk period and re-contouring, and one without the interaction. The model with the lowest Aikake's Information Criterion (AIC) score was selected for interpretation. Models with AIC scores within 2 units were considered to have similar levels of support, and the model with fewer variables was selected for interpretation (Arnold 2010). Significance of fixed effects in the model was assessed at the 0.05 level. If the interaction between risk period and re-contouring was significant, then the lsmeans package (Lenth 2016) in R v.3.4.1 (R 2017) was used to assess significant differences in the marginal means (on the log odds ratio scale) for the two comparisons of interest: before vs. after re-contouring during the Low Risk period, and before vs. after during the High Risk period. Model-predicted probabilities of stranding with 95% confidence intervals for each site and year were calculated with discharge held constant at the mean value across all observations. The confidence intervals were calculated using parametric bootstrap resampling, which accounted for the uncertainty in both the fixed and the random (site and year) effects. Models were estimated in R using the lme4 package (Bates et al. 2015) and confidence intervals were estimated using the bootMer function.

2.3.2 Number of Fishes Stranded

The number of fishes stranded before and after re-contouring was analyzed using a generalized linear mixed model assuming a zero-inflated, negative binomial distribution. This distribution is suitable for count data with a large number of zeroes. The response variable was the total number of stranded fishes of all species recorded at each site at each RE. Fixed effects in the model were re-contouring (before/after), risk period (high/low), and minimum discharge (centered) at Birchbank on the day of the RE. Random effects in the model were site and year. Candidate models were run with and without the interaction between risk period and re-contouring. In addition, candidate models with different effects on the zero-inflation component were considered, including re-contouring, risk period, additive or multiplicative effects of re-contouring and risk period, or a single parameter applying to all observations (intercept only). Models with different effects on zero inflation can be used to interpret whether the proportion of zeroes (site visits with no fish stranded) is best described by a single parameter across all observations, or is affected by risk period or re-contouring. Candidate models were compared using AIC and the model with the lowest score was selected for interpretation. Models with AIC values within 2 units were considered to have similar levels of support, and the model with fewer variables was selected for interpretation. Significance of fixed effects in the model was assessed at the 0.05 level. If the interaction between risk period and re-contouring was significant, then the lsmeans package in R was used to assess significant differences in the marginal means for the two comparisons of interest: before vs. after re-contouring in the Low Risk period, and before vs. after during the High Risk period. Model-predicted mean values with Wald-type 95% confidence intervals were calculated for each site and year, with discharge held at the mean value across all observations.

For all of the candidate models, 12 observations (site visits) with more than 4000 fish were considered outliers data and omitted from the analysis, to resolve issues with model convergence. The analysis was performed using the package glmmTMB (Brooks et al. 2017) in the statistical environment R.

3.0 RESULTS

3.1 Operations Overview 2017/2018

During the present study, the discharge in the Columbia River at Birchbank ranged from 27.4 kcfs recorded on 3 November 2017 to 153.6 kcfs on 10 June 2017 (Figure 3). As in previous years, discharge at Birchbank increased from April to June and November to January, while discharge generally decreased from June to October and January to March. The mean hourly discharge from HLK/ALH ranged from 15.0 kcfs on 30 March 2017 to 75.2 kcfs on 9 January 2017 and the BRD/X mean hourly discharge ranged from a minimum of 9.23 kcfs on 17 October 2017 to a maximum of 103.4 kcfs on 2 June 2017 (Figure 3).

During the study period, there were a total of 19 operational flow RE (Figure 3). A total of 18 flow RE occurred at HLK/ALH, and one RE (RE2017-08) was in response to a flow reductions at both HLK/ALH and BRD/X (Table 1). Nine RE occurred during the High Risk period (1 June to 30 September) and the remaining ten RE occurred during the Low Risk period (1 October to 31 May). The magnitude of flow reductions ranged from 2.0 to 33.0 kcfs. The largest reduction event occurred at HLK/ALH from 29 September 2017 to 1 October 2017 (RE2017-16), when flows dropped from 58.0 to 25.0 kcfs over a three-day period. This decrease in flow from HLK/ALH resulted in a discharge drop at Birchbank from 70.4 to 38.3 kcfs over the same three-day period. RE2017-16 was conducted in response to Columbia River Treaty obligations. One RE (RE2017-16) from this study period involved a reduction in operational flows over a three-day period and four RE (RE2017-20, RE2017-21, RE2018-01 and RE2018-02) occurred over two-day periods. All remaining RE occurred on single days.

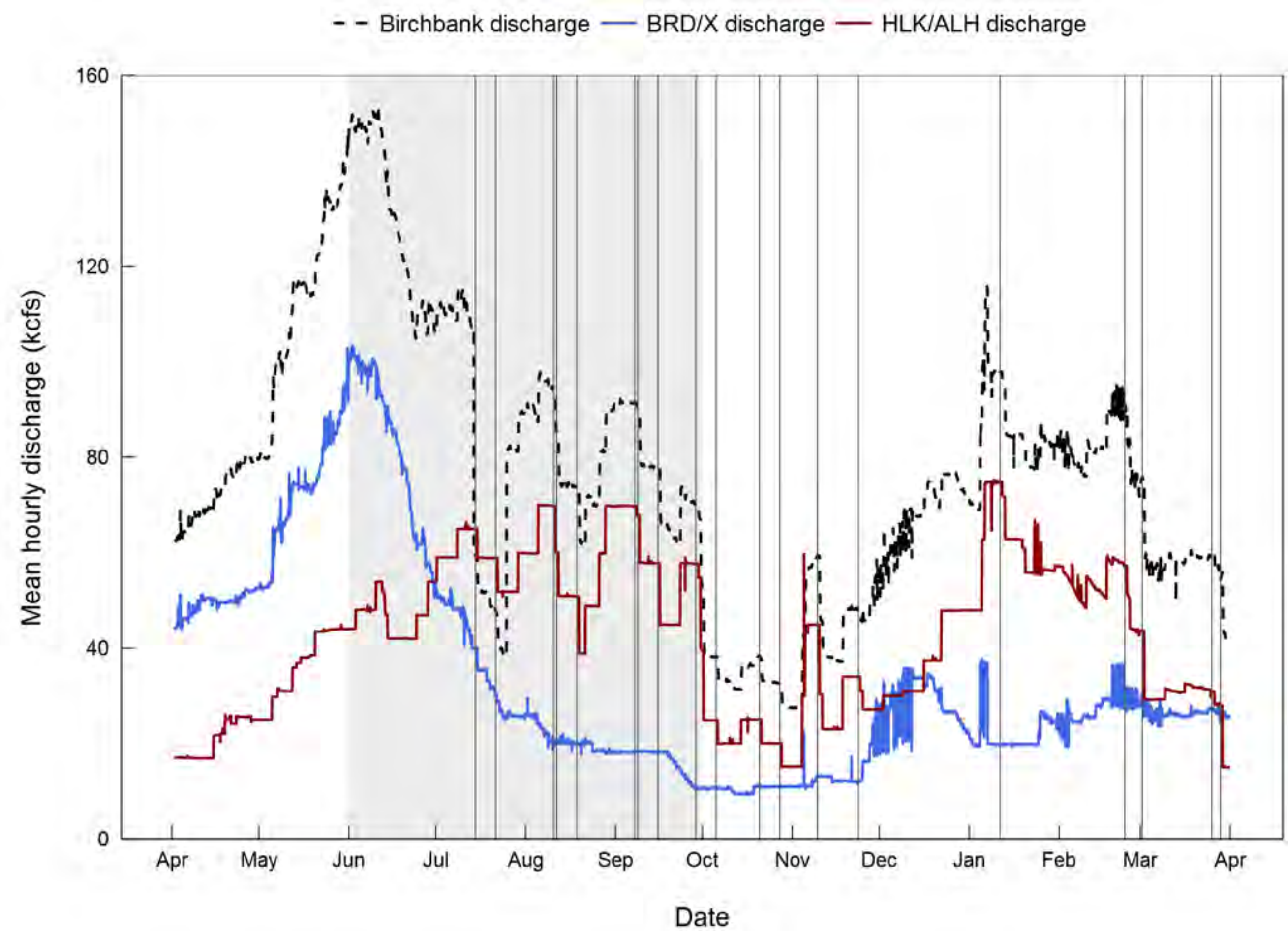

Figure 3: Mean hourly discharge from HLK/ALH (red line), BRD/X (blue line), and at the WSC Birchbank Gauging Station (dotted black line), 1 April 2017 to 1 April 2018. The solid vertical lines indicate RE. RE were numbered from RE2017-08 to RE2018-05 (left to right on the figure).

3.2 Reduction Events and Fish Stranding Assessments

Fish stranding assessments were conducted for 16 of the 19 RE (84%) that occurred between 1 April 2017 and 1 April 2018 (Table 1). Between 2009 and 2018 the median number of stranding assessments was 15, and the median number of RE was 18 (Figure 4; Table 2). Year to year, the number of RE and stranding assessments have been variable, although since 2014/2015 the total number of reduction events have generally increased.

Since 2009, the number of RE from HLK/ALH have ranged between 11 and 18, with a median of 13 RE (Table 2). Reductions from BRD/X have ranged from 0 to 6 over the same period, with a median of 2 RE. Since 2009, the median response rate (percent of total RE that initiate a stranding assessment) has been 83%. In the present study period, stranding assessments were conducted for 84% of the RE. The highest response rate was in 2013/2014 when 100% of RE initiated a stranding assessment (Figure 4; Table 2).

A stranding assessment was not required by Golder for RE2017-13 on 8 September 2017 since no 'Effect' sites were identified in the database query. However, two sites (Lions Head [RUB] and Fort Shepherd Launch [RUB]) were identified as 'Reconnaissance', having less than five previous stranding assessments. These sites were assessed on 8 September 2017 by BC Hydro (James Baxter pers. comm.), and have therefore been included in total number of stranding assessments in Figure 4.

No stranding assessments were conducted for RE2017-21, RE2018-02, and RE2018-04. The decision not to conduct a stranding assessment for RE2017-21 on 24-25 November 2017 was made because on 24 November the decrease in discharge from HLK/ALH was minimal (3 kcfs over 3 hours) and the 4 kcfs (1kcfs/hour) decrease in discharge from HLK/ALH on 25 November was associated with a 4kcfs increase in discharge from BRD/X. A stranding assessment was not conducted for RE2018-02 on 24-25 February 2018 because the database query revealed minimal pools forming and no fish were stranded during the last reduction of a similar magnitude. A stranding assessment was not conducted for RE2018-04 because the decrease in discharge was considered minimal (3 kcfs) and no 'Effect' sites were anticipated (pers. comm. Dean Den Biesen, BC Hydro). Additionally, a stranding assessment was to be conducted three days later on 29 March 2018 (RE2018-05) to facilitate Rainbow Trout spawning protection flows.

Environmental conditions during stranding assessments were generally adequate for fish salvage purposes.

Table 1: Summary of Reduction Events (RE) from HLK/ALH and BRD/X 1 April 2017 to 1 April 2018.

Reduction Event No.	Reduction Date	Concern Category	Crew Dispatched?	Birchbank				Brilliant Dam/BRX					HLK/ALGS									
				Mean Daily Water Temp (°C)	Max. Q (kcfs)	Min. Q (kcfs)	Magnitude of Reduction (kcfs)	Prev Q (kcfs)	Resulting Q (kcfs)	Magnitude of Reduction (kcfs)	No. Ramped Flow Reductions	Avg. Ramping Rate (kcfs/hr)	Prev Q (kcfs)	Resulting Q (kcfs)	Magnitude of Reduction (kcfs)	No. Ramped Flow Reductions	Avg. Ramping Rate (kcfs/hr)	Pools Formed	Interstitial Stranding	Fish Stranded	Sites Visited	Purpose of flow reduction
Both[a] 2017-08	July 15, 2017	High	Yes	N/A	59.4	51.7	7.7	40.0	35.0	5.0	3	1.7	65.0	59.0	6.0	2	3.0	Yes	Yes	1222	8	Operational Requirement under Treaty and Non-Treaty Coordination Agreement
HLK/ALH 2017-09	July 22, 2017	High	Yes	N/A	47.5	41.1	6.4	28.6	28.6	0.0	N/A	N/A	59.0	52.0	7.0	2	3.5	Yes	No	4,505	9	Operational Requirement under Treaty and Non-Treaty Coordination Agreement
HLK/ALH 2017-10	August 11, 2017	High	Yes	N/A	94.1	83.8	10.3	18.7	18.7	0.0	N/A	N/A	70.0	60.0	10.0	2	5.0	Yes	Yes	138	7	Operational Requirement under Treaty and Non-Treaty Coordination Agreement
HLK/ALH 2017-11	August 12, 2017	High	Yes	N/A	83.8	74.8	9.0	19.5	19.5	0.0	N/A	N/A	60.0	51.0	9.0	2	4.5	Yes	Yes	1,306	8	Operational Requirement under Treaty and Non-Treaty Coordination Agreement
HLK/ALH 2017-12	August 19, 2017	High	Yes	N/A	73.9	62.1	11.8	20.0	20.0	0.0	N/A	N/A	51.0	39.0	12.0	3	4.0	Yes	No	2,999	5	Operational Requirement under Treaty and Non-Treaty Coordination Agreement
HLK/ALH 2017-13	September 8, 2017	High	Yes[b]	N/A	91.3	89.4	1.9	18.1	18.1	0.0	N/A	N/A	70.0	68.0	2.0	1	2.0	No	No	0	2	Operational Requirement under Treaty and Non-Treaty Coordination Agreement
HLK/ALH 2017-14	September 9, 2017	High	Yes	N/A	89.5	78.2	11.3	18.1	18.1	0.0	N/A	N/A	68.0	58.0	10.0	2	5.0	Yes	No	25	8	Operational Requirement under Treaty and Non-Treaty Coordination Agreement
HLK/ALH 2017-15	September 16, 2017	High	Yes	N/A	78.2	65.9	12.3	18.1	18.1	0.0	N/A	N/A	58.0	45.0	13.0	3	4.3	Yes	No	426	7	Operational Requirement under Treaty and Non-Treaty Coordination Agreement
HLK/ALH 2017-16	September 29, 2017	High	Yes	N/A	70.4	67.1	3.3	10.5	10.5	0.0	N/A	N/A	58.0	55.0	3.0	1	3.0	N/A	N/A	N/A	0	Operational Requirement under Treaty and Non-Treaty Coordination Agreement
	September 30, 2017	High	No	N/A	67.1	52.9	14.2	10.5	10.5	0.0	N/A	N/A	55.0	40.0	15.0	3	5.0	Yes	No	33	4	
	October 1, 2017	High	Yes	N/A	52.9	38.3	14.6	10.5	10.5	0.0	N/A	N/A	40.0	25.0	15.0	3	5.0	Yes	No	457	10	
HLK/ALH 2017-17	October 6, 2017	Low	Yes	N/A	38.1	33.1	5.0	10.5	10.5	0.0	N/A	N/A	25.0	20.0	5.0	1	5.0	Yes	Yes	77	8	Operational Requirement under Treaty and Non-Treaty Coordination Agreement
HLK/ALH 2017-18	October 21, 2017	Low	Yes	N/A	38.0	33.0	5.0	11.0	11.0	0.0	N/A	N/A	25.0	20.0	5.0	1	5.0	Yes	No	25	7	Operational Requirement under Treaty and Non-Treaty Coordination Agreement
HLK/ALH 2017-19	October 28, 2017	Low	Yes	N/A	32.7	27.6	5.1	11.0	11.0	0.0	N/A	N/A	20.0	15.0	5.0	1	5.0	Yes	Yes	28	5	Operational Requirement under Treaty and Non-Treaty Coordination Agreement
HLK/ALH 2017-20	November 10, 2017	Low	Yes	N/A	59.4	45.7	13.7	15.0	15.0	0.0	N/A	N/A	45.0	30.0	15.0	3	5.0	Yes	No	46	7	Operational Requirement under Treaty and Non-Treaty Coordination Agreement
	November 11, 2017	Low	Yes	N/A	45.7	38.2	7.5	15.0	15.0	0.0	N/A	N/A	30.0	23.0	7.0	2	3.5	Yes	No	12	11	
HLK/ALH 2017-21	November 24, 2017	Low	No	6.6	48.4	45.6	2.8	14.0	14.0	0.0	N/A	N/A	34.0	31.0	3.0	3	1.0	N/A	N/A	N/A	0	Operational Requirement under Treaty and Non-Treaty Coordination Agreement
	November 25, 2017	Low	No	6.6	48.4	45.5	2.9	14.0	18.0	-4.0	N/A	N/A	31.0	27.0	4.0	1	4.0	N/A	N/A	N/A	0	
HLK/ALH 2018-01	January 12, 2018	Low	No	4.4	97.9	94.9	3.0	19.8	19.8	0.0	N/A	N/A	75.0	72.0	3.0	2	1.5	N/A	N/A	N/A	0	Operational Requirement under Treaty and Non-Treaty Coordination Agreement
	January 13, 2018	Low	Yes	4.4	94.8	84.7	10.1	19.8	19.8	0.0	N/A	N/A	72.0	63.0	9.0	2	4.5	Yes	No	1	11	
HLK/ALH 2018-02	February 24, 2018	Low	No	2.7	89.6	82.5	7.1	30.0	30.0	0.0	N/A	N/A	57.0	51.0	6.0	2	3.0	N/A	N/A	N/A	0	Operational Requirement under Treaty and Non-Treaty Coordination Agreement
	February 25, 2018	Low	No	2.8	83.7	74.4	9.3	30.0	30.0	0.0	N/A	N/A	51.0	45.0	6.0	2	3.0	N/A	N/A	N/A	0	
HLK/ALH 2018-03	March 2, 2018	Low	Yes	3.1	74.6	58.8	15.8	27.1	27.1	0.0	N/A[c]	N/A[c]	43.5	29.0	14.5	3	4.8	Yes	Yes	63	4	Operational Requirement under Treaty and Non-Treaty Coordination Agreement
HLK/ALH 2018-04	March 26, 2018	Low	No	3.8	60.2	56.3	3.9	26.0	26.0	0.0	N/A	N/A	31.0	28.0	3.0	1	3.0	N/A	N/A	N/A	0	Operational Requirement under Treaty and Non-Treaty Coordination Agreement
HLK/ALH 2018-05	March 29, 2018	Low	Yes	4.2	55.9	43.0	12.9	26.0	26.0	0.0	N/A	N/A	28.0	15.0	13.0	3	4.3	Yes	Yes	559	12	Operational Requirement under Treaty and Non-Treaty Coordination Agreement (Rainbow Trout spawning protection flows)

Notes

a = Both indicates reduction from both HLK/ALH and BRD/X.

b = Golder crew not deployed for RE2017-13. Two sites (Lions Head [RUB], and Fort Shepherd Launch [RUB]) visited by James Baxter of BC Hydro.

c = Brilliant Dam was load factoring at this time.

N/A = not applicable (Birchbank water temperature guage was not operational between April 1, 2017 and November 15, 2018).

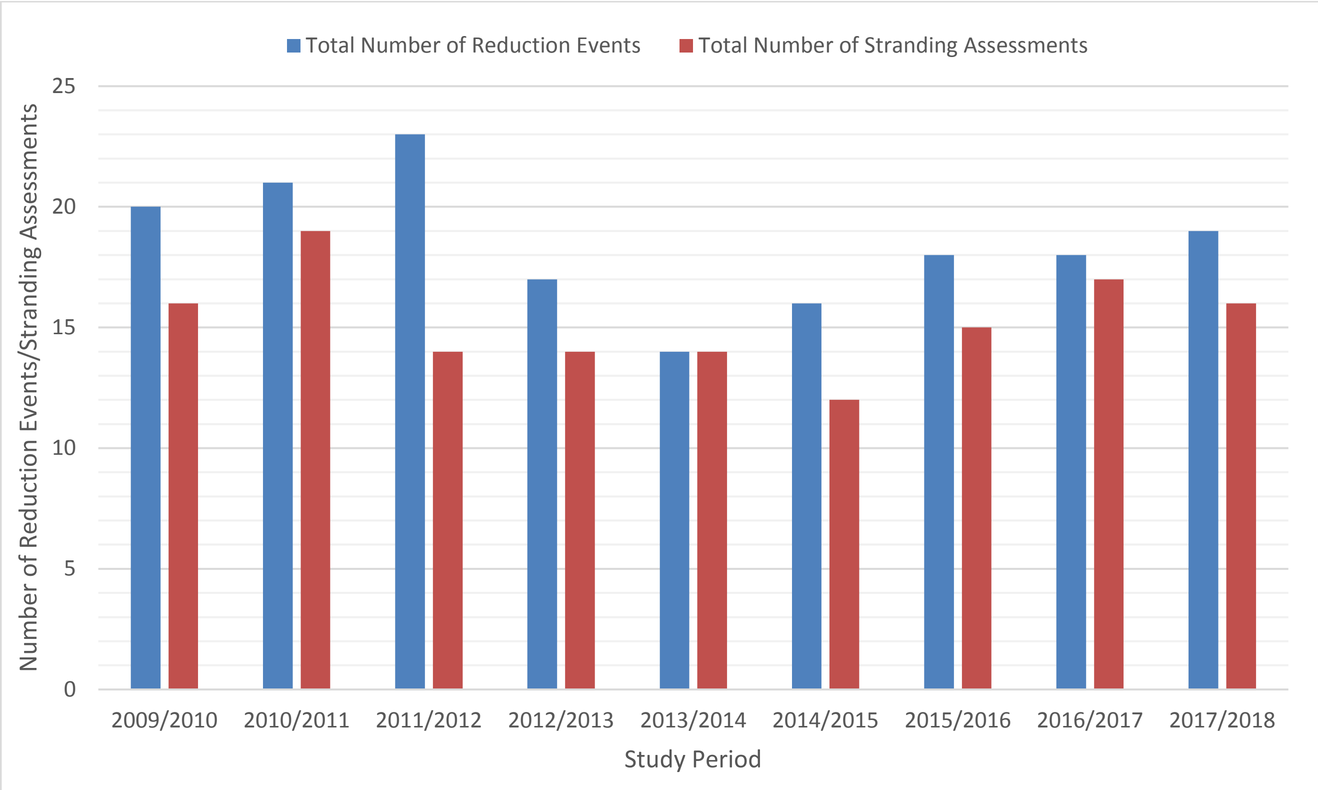

Figure 4: Total number of Reduction Events and Stranding Assessments conducted during each study period from 2009/2010 to 2017/2018.

Table 2: Breakdown of Reduction Events by hydroelectric facility (HLK/ALH, BRD/X or Both) from study period 2009/2010 to 2017/2018.

Study Period	Reduction Events from HLK/ALH	Reduction Events from BRD/X	Reduction Events from both HLK/ALH and BRD/X	Total Reduction Events	Total Stranding Assessments	Response Rate (%)
2009/2010	11	6	3	20	16	80
2010/2011	16	5	0	21	19	90
2011/2012	13	7	3	23	14	61
2012/2013	14	2	1	17	14	82
2013/2014	13	1	0	14	14	100
2014/2015	15	1	0	16	12	75
2015/2016	18	0	0	18	15	83
2016/2017	12	3	3	18	17	94
2017/2018	18	0	1	19	16	84
Median	**14**	**2**	**1**	**18**	**15**	**83**

In total, 19 different sites were assessed at least once during the 2017/2018 study period (Table 3). As with previous study years, fish stranding assessment efforts were concentrated on sites listed as 'Effect' or 'Significant Fish Stranding' as identified from a query of the Lower Columbia River Fish Stranding Database.

Fort Shepherd Launch (RUB) and Lions Head (RUB) were areas of focus during the present study since they were recently re-contoured (Fort Shepherd Launch in 2014 and Lions Head in April 2015). Reconnaissance stranding assessments at these sites during various discharge volumes and risk periods are beneficial to fill in data gaps in the dataset and to assess the effectiveness of re-contouring efforts. Some remote sites along the left downstream bank of the Columbia River, including Beaver Creek (LUB) and Fort Shepherd (LUB), were not assessed in 2017/2018 due to a permanent motorized vehicle closure of this area by the Fort Shepherd Conservancy (managed by the Trail Wildlife Association). Golder has been in contact with the Trail Wildlife Association to determine when site access might be granted to this area in the future. Based on the database queries conducted during the present study period, there were only two occurrences of an 'Effect' designation at Beaver Creek (LUB) or Fort Shepherd (LUB) sites. All other designations were either 'Reconnaissance' or 'No Pools'.

The most commonly assessed sites were Genelle Mainland (LUB) and Norns Creek Fan (RUB) with 14 stranding assessments conducted at each location (Table 3). Genelle Mainland (LUB) was commonly assessed because it is known to be an 'Effect' site at a variety of discharge volumes and is therefore a high priority for most stranding assessments. Truck access to Genelle Mainland site was limited during the present study due to a land owner's request. BC Hydro informed Golder of the limited access to this site on 20 October 2017. Permission to access the site was granted to BC Hydro and subcontractors, including Golder, on 1 March 2018 (pers. comm. Dean den Biesen, BC Hydro). During the limited access period the site was accessed by climbing down from the top of the bank or was assessed from the top of the bank when snow created slippery conditions and accessing from the top of the bank became a health and safety concern. When Genelle Mainland was assessed from the top of the bank observed pools were noted, but fish sampling was not conducted. Genelle Lower Cobble Island (MID) was assessed from Highway 22; only the presence or absence of pools were recorded. A boat is required to access Genelle Lower Cobble Island (MID), since this site is surrounded by the Columbia River year-round. See Appendix A; Figures A1 through A8 for site locations.

The Korpack (LUB) site is located on a large cobble bar downstream of Trail, BC (Appendix A; Figure A8). This site is not commonly assessed for stranding. Prior to the present study, this site had not been assessed since 2004. Korpack (LUB) was sampled on 28 October 2018 at the request of BC Hydro after receiving a call from a local angler who reported a number of adult rainbow trout stranded in two pools at this location.

3.2.1 Fish Captured or Observed During 2017/2018 Stranding Assessments

Isolated pools and stranded fishes were observed during all stranding assessments in 2017/2018 with the exception of RE2017-13. The stranding assessment for RE2017-03 consisted of two site assessments (Norns Creek Fan [RUB] and Fort Shepherd Launch [RUB]) conducted by James Baxter of BC Hydro.

None of the stranding assessments conducted during the present study were classified as a Significant Fish Stranding event (greater than 5000 fishes observed). Blueberry Creek (LUB) had the highest total number of stranded fishes (all assessments combined; 5825 individuals) (Table 3). This site was assessed during RE2017-09

(4505 stranded individuals), RE2017-11 (1299 stranded individuals), and RE2017-14 (21 stranded individuals). Pools were recorded during all three assessments. These RE occurred during the High Risk period when larval and juvenile fish are known to inhabit near shore habitat, and the risk of stranding is elevated. Most of the species stranded at Blueberry Creek (LUB) during these RE were larval sucker species (77%) and juvenile Longnose Dace (*Rhinichthys cataractae*) (21%).

Genelle Mainland (LUB) had the second highest number of stranded fish with 3905 individuals being stranded over 14 assessments conducted during the present study. The highest incident of stranding at Genelle Mainland (LUB) occurred during RE2017-12 (19 August 2017). During that RE, 2888 individuals were stranded within 7 isolated pools and 2 de-watered pools. Pools were sampled using a backpack electrofisher and a beach seine and 154 individuals were salvaged. A total of 234 Longnose Dace and sucker species mortalities were found in one of the dewatered pools. Two large pools at the site were too large to be sampled effectively with the backpack electrofisher and beach seine. An estimated 2500 YOY individuals remained in the pools. Based on the 154 individuals that were caught and identified at Genelle Mainland (LUB) during RE2017-12, it is likely that the remaining 2500 YOY were sucker species and Longnose Dace; however, since they were not caught and positively identified to species level, these individuals were identified in the database as ‘unidentified’.

The total number of fishes stranded per site for the remaining sites accounted for less than 4% of total fishes stranded during the present study (all sites combined) (Table 3).

Table 3: Percentage of the Total Number of Fishes Stranded at each site during Reduction Events from 1 April 2017 to 1 April 2018.

Site[a]	Total Number of Assessments	Total Number of Fishes Stranded	Median Number of Fishes Stranded per Assessment	% of Total Stranded Fishes per Site
Blueberry Creek (LUB)	3	5825	1299	48.8
Genelle (Mainland) (LUB)	14	3905	6	32.8
Norns Creek Fan (RUB)	14	460	3	3.9
Gyro Boat Launch	9	383	0	3.2
Beaver Creek (RUB)	4	358	0	3.0
Tin Cup Rapids (RUB)	13	262	2	2.2
Fort Shepherd Launch (RUB)	9	165	0	1.4
Kootenay River (RUB)	12	138	6	1.2
Korpack Trail (LUB)	2	122	61	1.0
Lions Head (upstream of Norns Fan) (RUB)	12	82	0	0.7
Bear Creek (RUB)	6	64	0	0.5
Millennium Park (LUB)	7	53	0	0.4
Zuckerberg Island (LUB)	6	51	0	0.4
CPR Island (MID)	5	40	0	0.3
Kootenay River (LUB)	8	14	1	0.1
Casino Road Bridge, Trail (LUB) (Downstream)	1	0	0	0.0
Casino Road Bridge, Trail (LUB) (Upstream)	1	0	0	0.0
Genelle Lower Cobble Island (MID)	4	0	0	0.0
Trail Bridge (RUB) (Downstream)	2	0	0	0.0
Total	**132**	**11922**		**100.0**

[a]Appendix A; Figures A1 through A8.
LUB = left bank as viewed facing upstream; RUB = right bank as viewed facing upstream.

3.2.1.1 Fish Species

3.2.1.1.1 Sportfishes

Sportfishes accounted for 1.3% (n = 156) of total fishes stranded in 2017/2018 (Table 4). This total is lower when compared to the 2016/2017 study period, where sportfishes accounted for 24.4% of total fishes stranded. The median yearly percent of sportfishes stranded since 2009 is 5.4%.

A total of 128 Rainbow Trout were stranded, accounting for 82% of all sportfish stranded in 2017/2018. Since 2009, the median yearly percentage of Rainbow Trout is 16.7% of all sportfishes stranded. Of the 128 Rainbow Trout stranded during the 2017/2018 study period, 103 were salvaged. The greatest number of stranded Rainbow Trout at a single site were found at Korpack (LUB) on 28 October 2018 (n = 41). The stranded Rainbow Trout were reported by a local angler to BC Hydro on 25 October 2017. BC Hydro contacted Golder regarding the stranded fish and a crew was deployed to assess this site while conducting a stranding assessment for RE2017-19 (28 October 2017). Based on the elevation and location of the pools at Korpack (LUB) it was estimated that these Rainbow Trout became isolated during RE2017-16 on 1 October 2017. A total of 36 adult and 4 juvenile Rainbow Trout were salvaged from Korpack (LUB) during RE2017-16. Methods of capture included backpack electroshocking and beach seine. Additional sportfish species that were stranded during the present study include Mountain Whitefish (*n* = 23), Northern Pike (*n* = 3) and Kokanee (*n* = 2) (Table 4).

3.2.1.1.2 Non-sportfishes

Non-sportfishes accounted for 98.7% of total fishes stranded. The most commonly stranded non-sportfishes were juvenile and YOY sucker species (*n* = 5081), which accounted for 43.2% of non-sportfishes recorded (Table 4). A total of 3968 sucker species were salvaged during the present study. The largest stranding event for sucker species occurred at Blueberry Creek (LUB) on 22 July 2017 during RE2017-09. During this stranding assessment, an estimated total of 4500 YOY sucker species were stranded within 4 isolated pools. Using a backpack electroshocker and dip net, 3500 were salvaged, and an estimated 1000 remained in the pools and could not be salvaged. Historically, Genelle Mainland (LUB) is a common stranding site for juvenile and YOY sucker species. During the present study, 182 sucker (3.6%) were stranded at Genelle Mainland (LUB). Fork lengths ranged from 16 to 82 mm with a median value of 38 mm (*n* = 157).

Longnose Dace accounted for 15.0% of all non-sportfishes stranded (*n* = 1769), and a total of 1154 individuals were salvaged during the present study. Longnose Dace were most commonly stranded at pools formed at Blueberry Creek (LUB) (*n* = 1214), Genelle Mainland (LUB) (*n* = 475), Fort Shepherd Launch (RUB) (*n* = 35), and Norns Creek Fan (RUB) (*n* = 21). Longnose Dace had the highest number of mortalities (*n* = 592) of all species stranded in 2017/2018. The majority (61.3%) of Longnose Dace mortalities occurred at Blueberry Creek (LUB) on 12 August 2017 during RE2017-11. An estimated, 250 individuals were found in two de-watered pools and an additional 113 mortalities were found in 4 isolated pools on the site. High daily air temperatures (30°C) likely contributed to the mortalities experienced at Blueberry Creek (LUB) during RE2017-11. Fork lengths taken from a sub-sample of Longnose Dace ranged from 15 to 44 mm with a median value of 24 mm (*n* = 96).

Sculpin species are bottom-dwellers, remaining close to the substrate throughout their life stages, and are commonly observed during stranding assessments in the Columbia River. Torrent Sculpin (*Cottus rhotheus*), Prickly Sculpin (*Cottus asper*), Slimy Sculpin (*Cottus cognatus*), and Columbia Sculpin (*Cottus bairdii*) were stranded during the present study. Similar to previous years, Torrent Sculpin were the most commonly stranded sculpin species. In 2017/2018, a total of 243 Torrent Sculpin were stranded, accounting for 45% of all sculpin species observed. Total length measurements were collected for all sculpin species and both adult and juvenile life stages were observed. Of the measured sculpin species (n = 262), total lengths ranged from 15 to 101 mm. Adults accounted for 68% of all measured sculpin species based on total lengths greater than 45 mm (AMEC 2014).

Table 4: Summary of Fish Species Captured or Observed during Fish Stranding Assessments Subsequent to Reductions in Discharge from HLK/ALH or from BRD/X, 1 April 2017 to 1 April 2018.

Species		**Total Stranded and/or Captured**	**Percent of Total Stranded and/or Captured (%)**	**Number of Mortalities**	**Number Salvaged**	**Species Classification**		
						SARA[a]	**COSEWIC[b]**	**CDC[c]**
Sportfishes	Rainbow Trout (*Oncorhynchus mykiss*)	128	1.1	13	103	N/A	N/A	Yellow
	Mountain Whitefish (*Prosopium williamsoni*)	23	0.2	2	21	N/A	N/A	Yellow
	Northern Pike (*Esox lucius*)	3	0.0	3	0	N/A	N/A	Yellow/ Exotic
	Kokanee (*Oncorhynchus nerka*)	2	0.0	1	1	N/A	N/A	Yellow
Non-Sportfishes	Sucker species *(Catostomidae spp.)*	5081	42.6	69	3968	N/A[d]	N/A[d]	N/A[d]
	Unidentified[e]	4051	34.0	70	433	N/A[f]	N/A[f]	N/A[f]
	Longnose Dace (*Rhinichthys cataractae*)	1769	14.8	592	1154	N/A	N/A	Yellow
	Torrent Sculpin (*Cottus rhotheus*)	243	2.0	14	223	N/A	N/A	Yellow
	Peamouth (*Mylocheilus caurinus*)	218	1.8	27	191	N/A	N/A	Yellow
	Sculpin species (*Cottus spp.*)	154	1.3	3	79	N/A[f]	N/A[f]	N/A[f]
	Northern Pikeminnow (*Ptychocheilus oregonensis*)	78	0.7	3	75	N/A	N/A	Yellow
	Redside Shiner (*Richardsonius balteatus*)	64	0.5	4	50	N/A	N/A	Yellow
	Prickly Sculpin (*Cottus asper*)	34	0.3	0	34	N/A	N/A	Yellow
	Slimy Sculpin (*Cottus cognatus*)	33	0.3	0	33	N/A	N/A	Yellow
	Umatilla Dace (*Rhinichthys umatilla*)	32	0.3	1	31	Schedule 3 Special Concern	Threatened	Red
	Columbia Sculpin (*Cottus hubbsi)*	9	0.1	0	9	Schedule 1 Special Concern	Special Concern	Blue
Total		**11,922**		**802**	**6,405**			

[a]Species at Risk Act; Species that were designated at risk by COSEWIC (the Committee on the Status of Endangered Wildlife in Canada) 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).
[b]Committee on the Status of Endangered Wildlife in Canada (COSEWIC 2010).
[c]Conservation Data Centre; Red=any 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 (formerly Vulnerable) 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 as a result of human activity. (B.C. Conservation Data Centre. 2018).
[d]No species are listed from this region that are found under any of the classification criteria for species of concern.
[e]Not identified to species because they were YOY life stage or observed but not captured.
[f]Fish identified to family level or other high level taxa may potentially be species of concern under the classification system listed.

3.2.1.1.3 Unidentified Fishes

During this study period 4051 fishes were unidentified. Of these unidentified fish, the majority (61.7%; *n* = 2500) were fishes that remained in two large pools located at Genelle Mainland (LUB) after sampling on 19 August 2017 during RE2017-17. These pools were sampled using a beach seine and backpack electroshocker but sampling was ineffective due to the large size of the pools and the early life stage (YOY) of the stranded fishes. Since these fishes were observed but not captured and identified to species they were listed as 'unidentified'. Based on fishes that were salvaged from these pools, it is likely that most of the remaining fishes were YOY sucker species and Longnose Dace. Additionally, 1190 fishes were listed as 'unidentified' during RE2017-08 at Genelle Mainland (LUB), Beaver Creek (RUB), and Tin Cup Rapids (RUB). These fishes were all larval life stage, making field identification more difficult. Salvage of larval fishes was attempted during this stranding assessment using backpack electroshocker, beach seine, and dipnet; however, due to their small size salvage rates were low. Larval fishes were easily lost within coarse substrate and algal material during salvage efforts.

During this study period, 154 sculpin were not identified to species. Of these, 48.7% (*n* = 75) were observed during salvage efforts but were not caught. The captured sculpin listed as Sculpin species were juveniles with measured total lengths between 21 and 36 mm with a median of 27 mm. Due to the small size of juvenile sculpin, field identification of sculpin to the species level was difficult. Additionally, widespread interspecific hybridization is common in the Kootenay region (McPhail 2007). If positive identification of sculpin to the species level could not be determined in the field, these fishes were listed as Sculpin species.

3.2.1.1.4 Listed Fish Species

Currently, four resident fish species in the study area are considered at risk: Columbia Sculpin (COSEWIC: Special Concern, CDC: Blue), Shorthead Sculpin (COSEWIC: Special Concern, CDC: Blue), Umatilla Dace (COSEWIC: Threatened, CDC: Red), and White Sturgeon (*Acipenser transmontanus*) (COSEWIC: Endangered, CDC: Red). During the 2017/2018 stranding assessment period Columbia Sculpin and Umatilla Dace were stranded (Table 5). Shorthead Sculpin were observed during previous years but were not observed in 2017/2018. White Sturgeon have never been observed during lower Columbia River fish stranding assessments.

Table 5: Summary of Listed Species Captured or Observed during Stranding Assessments, 1 April 2017 to 1 April 2018.

Site[a]	Risk Period[b]	Total Number of Assessments	Number of Assessments with Listed Species Present	Number of Listed Fish Stranded
Umatilla Dace (COSEWIC: Threatened, CDC: Red)				
Gyro Boat Launch	Low	9	1	1
Kootenay River (RUB)	Low	12	1	31
Columbia Sculpin (COSEWIC: Special Concern, CDC: Blue)				
Norns Creek Fan (RUB)	High and Low	14	3	5
CPR Island (MID)	Low	5	1	2
Zuckerberg Island (LUB)	Low	6	1	2
Total				**41**

[a]Appendix A; Figures A1 through A8.
[b]High Risk period = 1 June to 30 September; Low Risk period = 1 October to 31 May.

From 2000 to present, the majority (95%) of listed species recorded during stranding assessments were captured during the Low Risk period; however, it is possible that listed fishes were also stranded during the High Risk period but were not identified to species because of their life stage (i.e., YOY or larvae) or because they were simply incidentally observed during electrofishing efforts.

Umatilla Dace spawn in the late spring or early summer similar to closely related species (McPhail 2007); therefore, larval stage Umatilla Dace may be included in the numbers of unidentified larval fish observed during RE2017-08 (15 July 2017) and RE2017-10 (11 August 2017). Likewise, the sculpin that were not identified to species during stranding assessments could have been Columbia Sculpin or Shorthead Sculpin.

3.2.1.1.5 Exotic Fish Species

The only exotic fish species observed during the present study was Northern Pike. Two juvenile Northern Pike were captured from an isolated pool at Kootenay (RUB) on 19 August 2017 during RE2017-12. An additional juvenile Northern Pike was observed, but not caught during RE2017-12 at Kootenay (RUB). The two captured Northern Pike were measured for fork length and euthanized using clove oil as requested by the Ministry of Forests, Lands, Natural Resource Operations & Rural Development (FLNRORD) (Pers. Comm., Matt Neufeld, FLNRORD, 22 February 2016). The present study is the first time Northern Pike have been captured or observed during stranding assessments.

Exotic fish species have been identified and recorded during stranding assessments since 2002 in varying numbers. Species composition has remained constant. The majority (98%) of all of the exotic fish species recorded during stranding assessments were Smallmouth Bass. The remaining 2% in order of abundance were Common Carp, Yellow Perch, Northern Pike, Brook Trout, Tench, and Walleye (*Sander vitreus*).

3.3 Statistical Analysis on Re-contouring Efforts on the Lower Columbia River

During the High Risk period, the proportion of RE where fishes were stranded decreased after re-contouring at all sites (Table 6). Similarly, during the High Risk period the proportion of RE where more than 200 fishes were stranded decreased after re-contouring at all sites except Genelle Mainland (LUB). For Genelle Mainland (LUB), no change was observed. During the Low Risk period, the proportion of RE where fish were stranded decreased after re-contouring for all sites except Fort Shepherd Launch (RUB). The proportion of RE where more than 200 fishes were stranded decreased after re-contouring for all sites except Millennium Park (LUB). The total number of RE at Millennium Park (LUB) during the Low Risk period was 19 before re-contouring compared to 120 RE after re-contouring.

Table 6: Summary of RE based on risk period before and after re-contouring. Summary includes RE between 2000 and 2018.

Site	Risk Period	Before/After Re-contouring	Total Number of RE	Number of RE (>0 fishes stranded)	Proportion of RE (>0 fishes stranded)	Number of RE (>200 fishes stranded)	Proportion of RE (>200 fishes stranded)
Fort Shepherd Launch (RUB)	High Risk	Before	51	27	0.53	6	0.12
		After	17	4	0.24	0	0
	Low Risk	Before	81	15	0.19	3	0.04
		After	28	11	0.39	0	0
Genelle Mainland (LUB)	High Risk	Before	21	15	0.71	6	0.29
		After	99	68	0.69	29	0.29
	Low Risk	Before	47	32	0.68	11	0.23
		After	146	63	0.43	8	0.05
Lions Head (RUB)	High Risk	Before	52	20	0.38	1	0.02
		After	17	1	0.06	0	0
	Low Risk	Before	102	52	0.51	9	0.09
		After	22	9	0.41	0	0
Millennium Park (LUB)	High Risk	Before	14	7	0.5	3	0.21
		After	63	13	0.21	1	0.02
	Low Risk	Before	19	6	0.32	0	0
		After	120	35	0.29	5	0.04
Norns Creek Fan (RUB)	High Risk	Before	24	17	0.71	4	0.17
		After	94	43	0.46	5	0.05
	Low Risk	Before	36	22	0.61	5	0.14
		After	160	90	0.56	10	0.06

3.3.1 Probability of Stranding

For the analysis of stranding probability (>0 fish), the model that did not include the interaction of risk period and re-contouring (AIC = 1453.6) was better supported than the model including the interaction (AIC = 1455.4) and was selected for interpretation. The odds of stranding was significantly greater before than after re-contouring (*P* = 0.0008; odds ratio [OR] with 95% confidence interval: 0.52 [0.35-0.76]; Table 7). The odds of stranding was significantly greater during the High Risk than the Low Risk period (*P*<0.0001; OR: 0.28 [0.20-0.39]) and had a significant negative relationship with discharge at Birchbank (*P*<0.0001; OR: 0.95 [0.94-0.96]). These results suggest re-contouring reduced the risk of stranding at all sites during the High and Low Risk periods, which is shown by the model predicted values (Figure 5). For instance, at Fort Shepherd Launch (RUB) during the High Risk period, the predicted probability of stranding during a reduction event decreased from approximately 60% before re-contouring to approximately 45% after re-contouring (Figure 5).

For the analysis of the probability of a stranding 'Effect' (>200 fishes), the model that included the interaction of risk period and re-contouring (AIC = 610.1) was better supported than the model without the interaction (AIC = 615.8) and was selected for interpretation. The interpretation of the significant interaction is that the effect of re-contouring depends on the risk period. Therefore, the odds ratios for fixed effects of re-contouring and risk period (Table 7) should not be interpreted, and instead the before/after effect of re-contouring was assessed during the High Risk and Low Risk periods separately. The odds of stranding was significantly greater before than after re-contouring during the Low Risk period (*P*<0.0001; OR: 5.51 [2.38-11.17]) but not different before and after re-contouring during the High Risk period (*P* = 0.4). The odds of stranding had a significant negative relationship with discharge at Birchbank (*P*<0.0001; OR: 0.93 [0.92-0.95]). The results suggest that the effect of re-contouring varied by risk period, with a reduction of stranding 'Effect' (>200 fishes) only during the Low Risk period. The effect of re-contouring also varied by site (Figure 6). Based on model predictions, re-contouring had resulted in the greatest decreases in probability of stranding effect at Genelle Mainland (approximately 14% before to approximately 4% after) and Norns Creek Fan (approximately 6% before to 1% after) (Figure 6).

Table 7: Coefficients and P-values for fixed effects in models of probability of stranding (>0 fish) and probability of stranding 'Effect' (>200 fishes).

Response Variable	Fixed Effect	Odds Ratio (Exponentiated Coefficient Estimates)	P-value
Probability of Stranding (>0 fish)	Intercept (Before, High Risk)	2.34	0.008
	Re-contouring	0.52	0.0008
	Risk Period	0.28	<0.0001
	Discharge	0.95	<0.0001
Probability of Stranding 'Effect' (>200 fishes)	Intercept (Before, High Risk)	0.18	0.0002
	Re-contouring	0.7	0. 4
	Risk Period	0.31	0.001
	Re-contouring: Risk Period	0.28	0.006
	Discharge	0.93	<0.0001

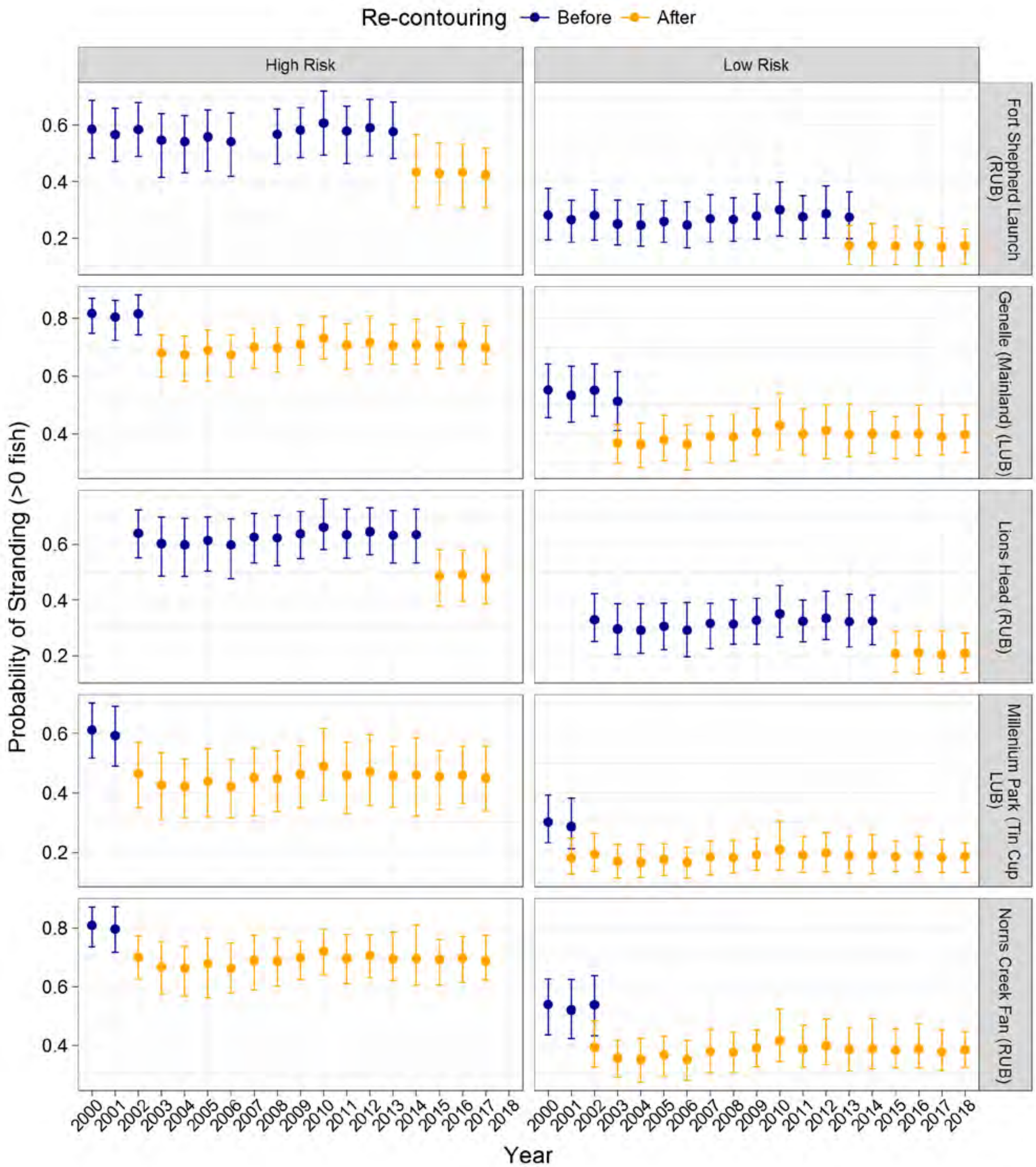

Figure 5: Model-predicted probability of fish stranding (>0 fish). Values are means and 95% confidence intervals from bootstrap resampling.

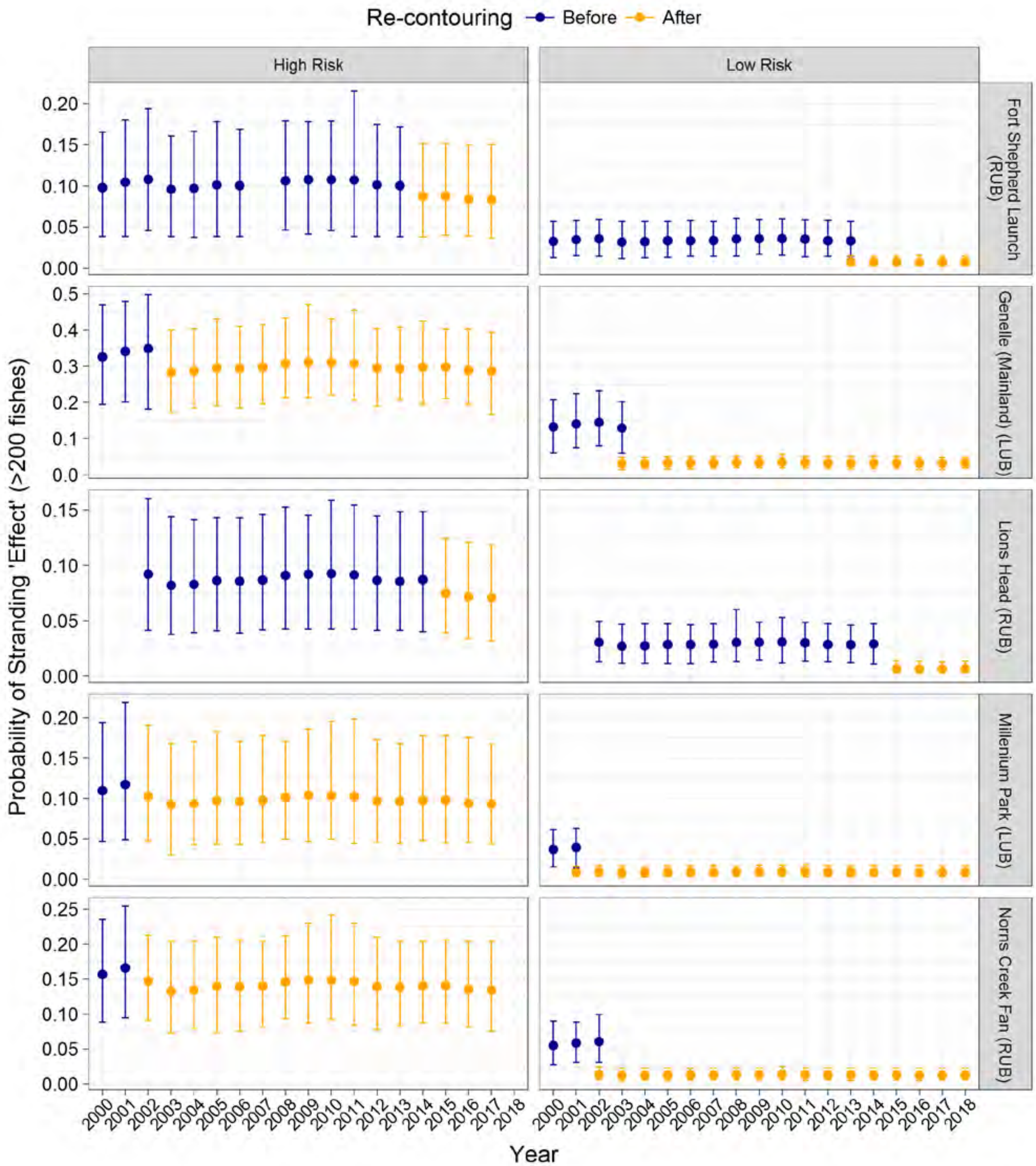

Figure 6: Model-predicted probability of stranding 'Effect' (>200 fishes). Values are means and 95% confidence intervals from bootstrap resampling.

3.3.2 Number of Fishes Stranded

Model 3 had the lowest AIC but Model 4 was within two AIC units and was simpler (Table 8). Therefore Model 4 was selected for interpretation. The selected model included re-contouring, risk period, and discharge at Birchbank as fixed effect predictor variables, all of which were statistically significant (P<0.05; Table 9). The zero-inflation component of the model included the effect of re-contouring, although the effect was not significant (P>0.9; Table 9). The model suggested that significantly more fish were stranded before than after re-contouring (*P* = 0.002), and during the High Risk period than the Low Risk period (*P*<0.0001). The coefficient on the log-scale for re-contouring was -0.51 (Table 9), which is equivalent to an incidence rate ratio of 0.6 (exponential of -0.51). This suggests that there were 0.6 times as many fishes stranded after re-contouring as before, with all the other variables held constant, based on the selected model and observed data-set. Discharge had significant negative relationship with number of fish stranded (*P*<0.0001). Predicted numbers of fish stranded suggest the greatest benefit of re-contouring was at Genelle Mainland (LUB) during the High Risk period, with predicted mean values of approximately 300 fishes stranded before and approximately 100 to 150 fishes stranded after re-contouring (Figure 7).

Table 8: Aikake's Information Criterion (AIC), which was used for model selection, for candidate models predicting the number of fish stranded at each site visit.

Model Number	AIC	Fixed Effects Included in Model				Effects on Zero-Inflation			
		Re-contouring	Risk Period	Re-contouring: Risk Period	Discharge	Re-contouring	Risk Period	Re-contouring: Risk Period	Single parameter (intercept)
3	6934.9	X	X	X	X	X			
4[a]	6935.2	X	X		X	X			
2	6937.6	X	X						X
1	6937.6	X	X	X	X				X
7	6937.8	X	X	X	X	X	X	X	
5	6938.7	X	X	X	X		X		
6	NA	X	X		X	X	X		

[a]indicates the model selected for interpretation. Value of NA for AIC indicates that model did not converge therefore no AIC is available.

Table 9: Coefficients and P-values for selected model predicting the number of fishes stranded.

Model Component	Fixed Effect	Coefficient Estimate[a]	P-value
Conditional Model (Number of Fishes Stranded)	Intercept (Before, High Risk)	4.862	<0.0001
	Re-contouring	-0.509	0.002
	Risk Period	-1.118	<0.0001
	Discharge	-0.046	<0.0001
Zero-Inflation Model	Intercept (Before)	-13.730	>0.9
	Re-contouring	11.965	>0.9

[a]indicated coefficients are on the link scale, which was log-scale for the conditional model and logit-scale for the zero-inflation model.

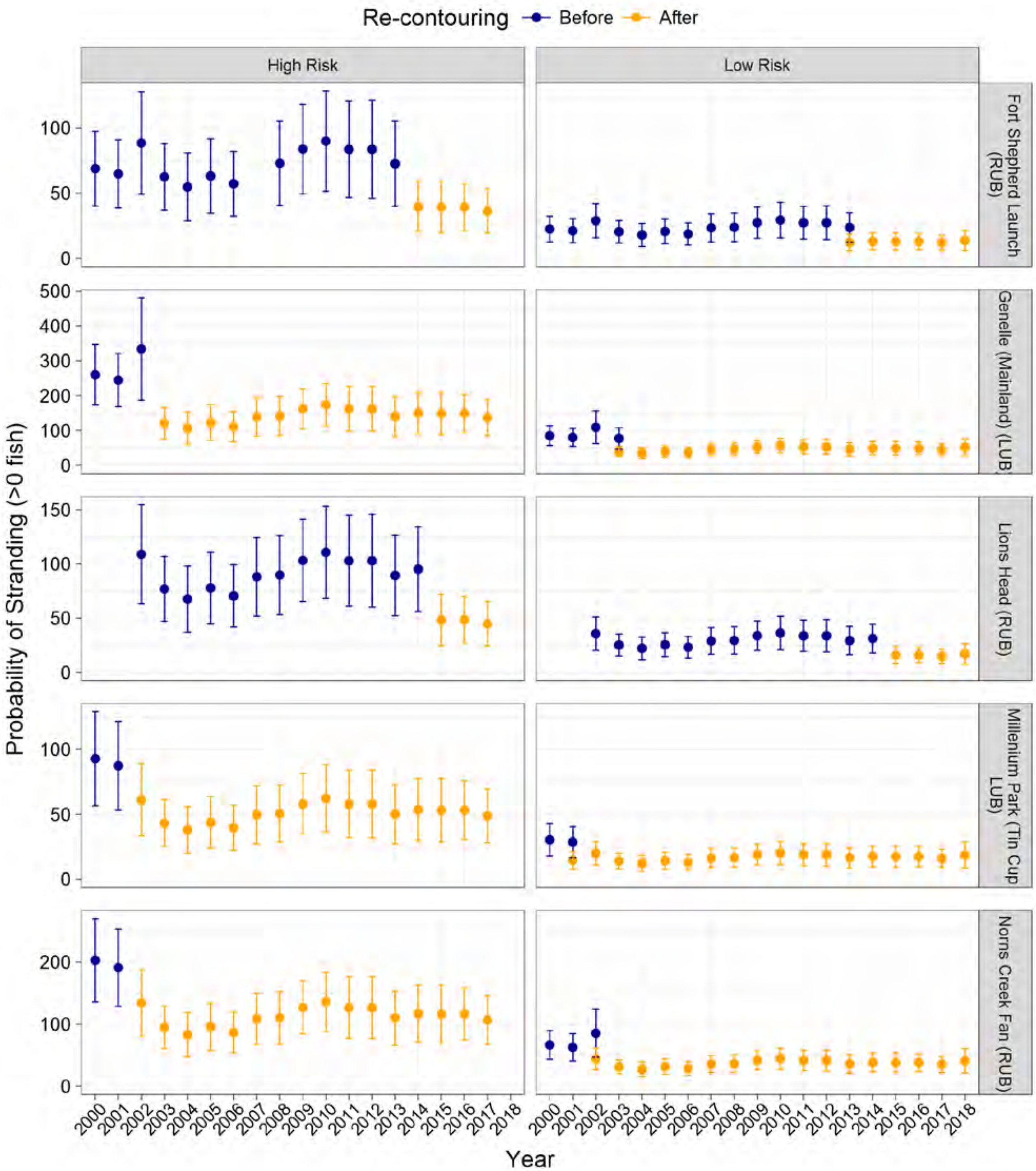

Figure 7: Predicted number of fishes stranded per site visit by year and site. Mean values with 95% confidence intervals are from a zero-inflated negative binomial generalized linear mixed model.

3.4 Historic Fish Stranding Summary

The results of fish stranding assessments conducted between January 2000 and 1 April 2018, are summarized by site, resultant Birchbank discharge, and risk period (Table 10). This table is used by the DCC to determine if the proposed RE has occurred historically for the time of year and what sites resulted in high stranding risk. The numbers of fishes are presented as the maximum number of fishes stranded at each site during a single RE. The classification of sites where listed species have been previously identified is included (yellow highlighted cells). In 2017/2018, Norns Creek Fan (RUB) was newly designated as an 'Effect' site at a resultant discharge of 60-70 kcfs during the High Risk period. This designation change was a result of three Shorthead Sculpin observed at this site during RE2017-12 on 19 August 2017. Other instances where listed species were observed during the present study occurred at sites that were already designated 'Effect' sites for the associated resultant discharge.

During the High Risk period, 'Effect' sites were identified at resultant discharges between 30 and greater than 120 kcfs with high stranding numbers from single historic RE occurring between 40 and 60 kcfs. During the low risk period, 'Effect' sites were identified between less than 30 and 70 kcfs with high stranding numbers from single historic RE occurring between 30 and 40 kcfs. This suggests that the highest stranding risk occurs between a resultant Birchbank discharge of 30 to 60 kcfs. Genelle Mainland (LUB) and Tin Cup Rapids (RUB) commonly strand fish at various discharge volumes in both High Risk and Low Risk periods. Kootenay River (LUB) and Kootenay River (RUB) have historically stranded a number of listed species at various discharge volumes during the Low Risk period and are therefore priority sites during stranding assessments between 1 October and 31 May (Table 10). Blueberry Creek (LUB) has been infrequently assessed compared to other sites, however the recent high number of fishes stranded during the High Risk period (4505 individuals stranded on 22 July 2017 [RE2017-09]), and 1299 individuals stranded on 12 August 2017 [RE2017-11]) suggests this site should be more frequently assessed during this risk period in the future. Conducting surveys at sites with no previous data or insufficient data (surveyed less than five times) will continue to help identify sites that pose a high risk of fish stranding during flow reductions.

Based on data in the Lower Columbia River Fish Stranding Database there have been a total of 2375 listed fish species stranded within the lower Columbia River since 2000 (2277 Umatilla Dace, 72 Columbia Sculpin, and 26 Shorthead Sculpin). Of this total, 2109 have been salvaged and successfully returned to the mainstem during stranding assessments. Figure 8 illustrates sites in the lower Columbia River where the highest numbers of listed species have been stranded. Since 2000, there have been 606 listed species stranded at Kootenay River (LUB), 490 listed species stranded at Kootenay River (RUB), 399 listed species stranded at Bear Creek (RUB), and 257 listed species stranded at Gyro Boat Launch (Figure 8). Most listed species stranded at Kootenay River (RUB) and Bear Creek (RUB) occurred during a single reduction event. At Kootenay River (RUB) a total of 357 Umatilla Dace were stranded during RE2002-05 on 27-28 March 2002. At Bear Creek (RUB) a total of 349 Umatilla Dace were stranded during RE2016-03 on 5 February 2016. The yearly total of listed species stranded at Kootenay River (LUB) and Gyro Boat Launch have been more consistent year-to-year since 2000. The yearly total listed species stranded at Kootenay River (LUB) has ranged from 0 to 91 (median = 33), and the yearly total listed species stranded at Gyro Boat Launch has ranged from 0 to 98 (median = 0).

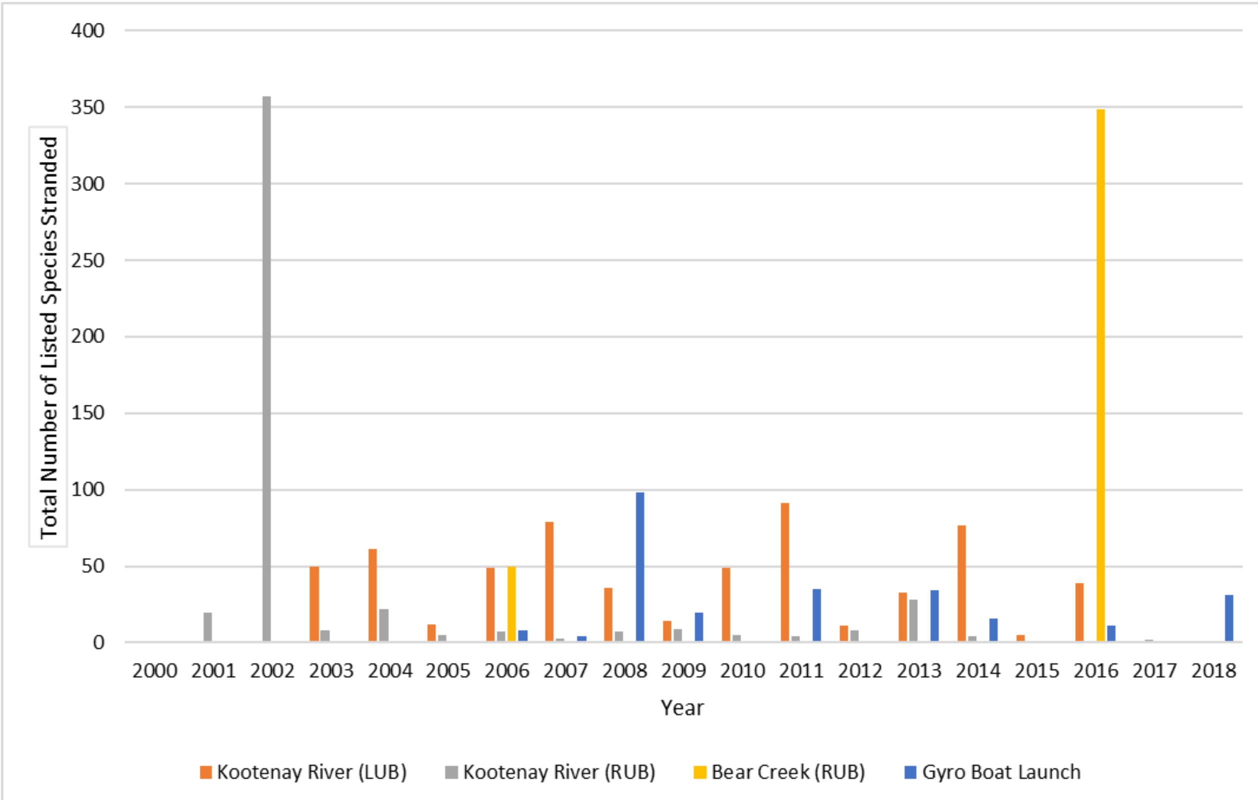

Figure 8: Total number of listed fish species (Umatilla Dace, Columbia Sculpin, and Shorthead Sculpin) stranded at Kootenay River (LUB), Kootenay River (RUB), Bear Creek (RUB), and Gyro Boat Launch sites since 2000.

Since 2000, 95% of listed species stranding occurred during the Low Risk period. This may be a result of the High Risk period being only four months of the year and therefore a greater number of yearly stranding assessments occur during the Low Risk period. For the majority of sites upstream of Trail Bridge, higher total fish numbers were recorded during the High Risk period irrespective of resultant discharge levels (Table 10).

During the present study, 52% of total stranding assessments were conducted at 'Effect' sites and 38% were conducted at 'Reconnaissance' sites. To confirm the accuracy of the database, six 'No Pools' sites and two 'Minimal Effect' sites were assessed. Newly formed isolated pools were found at two 'No Pools' sites (Beaver Creek [RUB], and Fort Shepherd Launch), and greater than 200 stranded fishes were found at one of the 'Minimal Effect' sites (Genelle Mainland [LUB]). These findings suggest that the lower Columbia River is dynamic and substrate size and topography at stranding sites can change over time resulting in areas of new pool formation. It is beneficial to continue conducting stranding assessments at some 'No Pool' and 'Minimal Effect' sites to verify the site designation from the database query.

Table 10: Summary of effects and corresponding responses for fish stranding on the lower Columbia River from flow reductions at HLK/ALH and BRD/BRX sorted by time of year. (Based on data collected between 2000 and 2018).

Observed Effect

Risk Period	Resultant Birchbank Discharge (kcfs)	Columbia River										Kootenay River			
		Lions Head		Norn's Creek Fan		CPR Island		Tin Cup Rapids		Millennium Park		Kootenay River (LUB)		Kootenay River (RUB)	
		Max. # of fish	# of visits	Max. # of fish	# of visits	Max. # of fish	# of visits	Max. # of fish	# of visits	Max. # of fish	# of visits	Max. # of fish	# of visits	Max. # of fish	# of visits
High Risk (1 June to 30 September)	≤30														
	≥30 to <40					0	1	13500	1					0	3
	≥40 to <50	0	1	312	5	191	5	76	4	15	2	94	3	81	8
	≥50 to <60	1	2	150	12	1	2	253	15	7	6	58	13	3901	18
	≥60 to <70	0	4	423	28	0	5	258	27	34	10	3172	33	5737	32
	≥70 to <80	0	6	56	17	0	1	219	14	0	12	1	10	35	14
	≥80 to <90	No Pools		88	20	No Pools		34	19	24	21	No Pools		12	9
	≥90 to <100	No Pools		5	11	0	4	563	13	26	11	No Pools		No Pools	
	≥100 to <110			2	3	2	1	10307	4	7521	3	No Pools		No Pools	
	≥110 to <120			No Pools		No Pools		1500	5	60	3	No Pools		No Pools	
	≥120			No Pools		No Pools		1200	3	100	1	No Pools		0	3
Low Risk (1 October to 31 May)	≤30			29	5	6	2	68	5	601	4	0	3	643	5
	≥30 to <40	48	8	5071	39	110	11	228	25	358	30	286	23	1168	33
	≥40 to <50	14	6	623	51	337	39	117	39	526	26	517	49	1450	69
	≥50 to <60	33	2	146	27	12	15	86	23	52	21	193	27	340	34
	≥60 to <70	0	3	700	29	16	13	11	28	2	22	122	39	529	42
	≥70 to <80	0	2	79	15	2	4	3	17	2	18	0	14	10	18
	≥80 to <90	No Pools		0	2	No Pools		1	3	0	4	No Pools		0	4
	≥90 to <100	No Pools		0	1	0	1	0	1	0	1	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		No Pools		0	1	0	1	No Pools		0	1

Risk Period	Resultant Birchbank Discharge (kcfs)	Columbia River															
		Zuckerberg Island		Kinnaird Rapids		Blueberry Creek		Genelle Mainland		Genelle Upper Cobble Island		Genelle Lower Cobble Island		Gyro Boat Launch		Trail Bridge	
		Max. # of fish	# of visits	Max. # of fish	# of visits	Max. # of fish	# of visits	Max. # of fish	# of visits	Max. # of fish	# of visits	Max. # of fish	# of visits	Max. # of fish	# of visits	Max. # of fish	# of visits
High Risk (1 June to 30 September)	≤30			No Pools		No Pools								No Pools			
	≥30 to <40	620	2	No Pools		No Pools				No Pools		0	1				
	≥40 to <50	0	1			4505	1	14302	6	No Pools				464	3		
	≥50 to <60	18	8	No Pools		No Pools		37964	18					0	3	0	3
	≥60 to <70	55	16	0	1	1	3	3118	30	1	1	20	2	0	3	No Pools	
	≥70 to <80	48	11	No Pools		1299	8	1503	17	54	2	0	4	No Pools		No Pools	
	≥80 to <90	0	13	No Pools		269	9	6000	18	0	8	3	9	500	7	No Pools	
	≥90 to <100	No Pools		No Pools		No Pools		900	12	No Pools		0	3	500	6	No Pools	
	≥100 to <110	0	3			No Pools		0	3					500	2		
	≥110 to <120	No Pools		No Pools		0	2	No Pools		No Pools		No Pools		No Pools		No Pools	
	≥120	0	1			0	2	0	2	No Pools		No Pools		No Pools		No Pools	
Low Risk (1 October to 31 May)	≤30	0	2	No Pools		No Pools		1	2					No Pools		8	3
	≥30 to <40	95	30	No Pools		No Pools		1414	28	No Pools		0	4	2024	13	19	9
	≥40 to <50	298	39	0	3	0	4	210	46	No Pools		0	6	755	36	5	11
	≥50 to <60	71	31	No Pools		No Pools		400	30	0	6	0	7	48	13	0	9
	≥60 to <70	109	29	0	5	1	7	520	35	1	5	0	4	351	16	No Pools	
	≥70 to <80	0	19	No Pools		0	5	7	11	0	3	0	5	No Pools		No Pools	
	≥80 to <90	0	3	No Pools		0	3	1	4	0	2	0	4	0	3	No Pools	
	≥90 to <100	No Pools		No Pools		No Pools		0	1	No Pools		0	1			No Pools	
	≥100 to <110					No Pools											
	≥110 to <120	No Pools		No Pools				No Pools		No Pools		No Pools		No Pools		No Pools	
	≥120	0	1					0	1	No Pools		No Pools		No Pools		No Pools	

Risk Period	Resultant Birchbank Discharge (kcfs)	Columbia River													
		Casino Road Bridge, Trail (u/s)		Casino Road Bridge, Trail (d/s)		Bear Creek		Beaver Creek (RUB)		Beaver Creek (LUB)		Fort Shepherd Eddy		Fort Shepherd Launch	
		Max. # of fish	# of visits	Max. # of fish	# of visits	Max. # of fish	# of visits	Max. # of fish	# of visits	Max. # of fish	# of visits	Max. # of fish	# of visits	Max. # of fish	# of visits
High Risk (1 June to 30 September)	≤30							No Pools		No Pools					
	≥30 to <40			0	1							7500	2		
	≥40 to <50			207	2	0	1							0	1
	≥50 to <60	0	3	11	3	0	4	358	3			0	2	0	2
	≥60 to <70	0	7	5	8	500	9	6	8	0	1	0	2	2	4
	≥70 to <80	No Pools		0	5	0	7	8	10	No Pools		0	2	1	6
	≥80 to <90	No Pools		No Pools		0	4	62	5	No Pools		0	4	134	5
	≥90 to <100	No Pools		No Pools		No Pools		251	7	No Pools		0	4	No Pools	
	≥100 to <110														
	≥110 to <120	No Pools		No Pools		No Pools		No Pools		No Pools		0	2		
	≥120	No Pools		No Pools		No Pools		No Pools		No Pools		0	1		
Low Risk (1 October to 31 May)	≤30	0	3	0	3	2063	4	No Pools		No Pools		0	1		
	≥30 to <40	0	9	1	11	12	9	38	8	0	3	80	3	9	7
	≥40 to <50	4	12	2	10	2015	13	44	9	0	7	8	7	5	12
	≥50 to <60	0	15	21	20	1	11	0	5	20	4	2	4	29	2
	≥60 to <70	1	19	3	22	0	16	4	6	0	2	0	2	46	6
	≥70 to <80	No Pools		0	8	3	15	0	6	No Pools		0	1	0	1
	≥80 to <90	No Pools		No Pools		0	2	0	4	No Pools		0	1	0	1
	≥90 to <100	No Pools		No Pools		No Pools				No Pools		0	1	No Pools	
	≥100 to <110														
	≥110 to <120	No Pools		No Pools		No Pools		No Pools		No Pools					
	≥120	No Pools		No Pools		No Pools		No Pools		No Pools					

Code	Description	Definition and Response
	No Pools	Site has been previously surveyed; pools have not been recorded at or near these flows. No Response.
	Minimal Effect	Site has been previously surveyed at least five time under similar flow conditions and isolated pools were observed; less than 200 fish were recorded during a single reduction event under similar conditions. No Response.
	No Data or Insufficient Data	Site has been previously surveyed less than five times under similar flow conditions; less than 200 fish were recorded during a single reduction event under similar conditions. Reconnaissance Survey.
	Effect	Site has been previously surveyed under similar flow conditions and isolated pools were observed; greater than 200 fish were recorded during a single reduction event under similar flow conditions. Stranding Survey.
	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 2018).
	Listed species were captured or observed.	During at least one stranding assessment under similar flow conditions listed species were captured or observed.

Does not include data pre-recontouring.

Includes all stranding assessments and stranded fish between 1 January 2000 and 1 April 2018.

4.0 DISCUSSION

4.1 Lower Columbia River Fish Standing Assessment and Ramping Protocol (CLBMON#42) Management Questions

Analyses necessary to address Management Question #1, #2, and #3 from the Lower Columbia River Fish Stranding Assessment and Ramping Protocol Monitoring Program (BC Hydro 2007) were not conducted during the current study period. These management questions were addressed using data collected during 2004, 2005, and 2006 flow ramping studies at HLK and a literature and data review and analysis of the Lower Columbia River Fish Stranding Database (Golder 2005, 2006, 2007; Golder and Poisson 2010). The present study has contributed data to address Management Question #4 and #5. Management questions and hypotheses to be addressed by the Lower Columbia River Fish Stranding Assessment and Ramping Protocol include:

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

   Ho_1: The number of stranded fish is independent of either the ramping rate or time of day of flow reductions in the summer and winter.

   Between 2004 and 2006 six phases of flow ramping studies were conducted to address the potential effects of HLK operations on downstream interstitial and pool based fish stranding (Golder 2005, 2006, 2007). Ramping rate and time of day were primary variables for Phase I to Phase IV and secondary variables for Phases V and VI. Results of these studies showed that in both summer and winter studies ramping rate was not a statistically significant effect on the probability of interstitial or pool stranding. Further analysis regarding ramping rates and their effect on stranding risk was obtained through a review of fish stranding assessments between January 1999 and July 2009 from the Lower Columbia River Fish Stranding Database and presented in Golder and Poisson (2010). Results of this study reveal that there has been a consistent trend for increased stranding with increased ramping rates since the onset of experimentation in the Columbia and Kootenay river systems, however ramping rate as a variable has not been statistically significant. Based on these findings the recommendation was made to maintain ramping rates within the ranges tested (1 to 5 kcfs/hr for HLK/ALH and below 2 kcfs/hr for BRD/X) to allow fishes the greatest length of time to escape stranding habitats where possible. During the present study, the ramping rates for reduction events at HLK/ALH were maintained below 5 kcfs/hr for all reductions, and the ramping rate for the single BRD/X reduction (RE2017-08) was below 2 kcfs/hr (Table 1). Based on previous analysis, the ramping rate component of this hypothesis is not rejected. If further clarification on the effect of ramping rate on fish stranding is required, it is recommended that additional ramping studies be conducted.

   Results of the Phase I (winter sampling) showed that there was a trend for fish to strand more at night than during the day, however this trend was statistically weak (Golder 2005). Phase II to Phase VI studies showed that time of day did not show a statistically significant effect on the probability of interstitial or pool stranding (Golder 2005, 2006, 2007). However, it is important to note that the dataset from all phases (interstitial and pool stranding combined) was limited to seven night time net pens and 65 daytime net pens. Further analysis of the Lower Columbia River Fish Stranding Database by Golder and Poisson (2010) found that time of day of reduction on the stranding risk for juvenile fishes in the Columbia and Kootenay rivers, was not a highly significant variable, but did influence stranding risk. The highest risk period was in the afternoon; however, stranding assessment surveys did not occur during night time hours and therefore the dataset was completely biased towards daytime. Other studies on the effect of time of day on juvenile fish stranding have provided equivocal results. On some occasions, more fishes were stranded at night (e.g., Salveit 2001) while other studies noted greater stranding occurring during daytime (e.g., Bradford et al. 1995). Due to the limited data from night ramping experiments and the absence of night stranding assessments, the time of day component of the management hypothesis cannot be rejected. Additional ramping experiments are outside the scope of the Lower Columbia River and Kootenay River Fish Stranding Assessments (CLBMON#42[A]), therefore this component of the hypothesis is not addressed.

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

Ho_2: Wetted history does not influence the stranding rate of fish (both interstitially and pool stranding) for flow reductions from HLK/ALH.

During Phase V of the 2006 flow ramping studies, wetted history was a primary variable assessed for stranding risk. The analysis showed that there was a gradual increase in fish density with an increased duration of wetted history, however the analysis indicated that wetted history did not show a statistically significant effect on the proportion of interstitial stranded fish (Golder 2007). An analysis on the Lower Columbia River Fish Stranding Database based on data between January 1999 and July 2009 revealed that the risk of stranding increased with increased wetted history (Poisson 2010). Additionally, there was a statistically significant increase in the number of fishes stranded during assessments conducted after a wetted history of greater than 10 days versus a wetted history of less than ten days (Poisson 2010, Golder and Poisson 2010); however, there were insufficient data to define the size of the effect (proportion of the population affected and the response to wetted histories of variable lengths greater than 10 days). A wetted history of 10 days represents an appropriate cut-off level for differentiating between severity of stranding risk, however the determination of whether to initiate a stranding assessment due to a RE should continue to be based on factors such as time of year, river stage and database query results, in addition to wetted history. Previous studies suggest that this management hypothesis can be rejected, however in Year 10 of the Lower Columbia River and Kootenay River Fish Stranding Assessments (CLBMON#42[A]), a recommendation was made to consider the feasibility of using River2D models from Golder (2013) to further investigate the effects of wetted history on the number of fish stranded per flow reduction.

The River2D models incorporate 70 ADCP transects near CPR Island and the confluence area of the Columbia and Kootenay rivers which allow for quantification of fluctuations in river stage (water elevation). These models could be applied to the following stranding sites: Lions Head (RUB), Norn's Creek Fan (RUB), CPR Island (RUB), Kootenay LUB, and Kootenay RUB. While the River 2D models can provide a quantification of river discharge using discharge values for HLK/ALH and BRD/X, the number of model runs that would be required to determine wetted history would be very costly and outside of the scope of the current study. The River2D models are better designed to evaluate depth, velocity and total de-watered area at given facility discharge volumes rather than wetted history. Furthermore, the River2D models that were established in Golder (2013) include 99 model runs incorporating HLK/ALH discharge volumes ranging from 8.9 kcfs to 37.5 kcfs and BRD/X discharge volumes ranging from 8.9 kcfs to 57.4 kcfs, which provide a coarse estimate for quantification of fluctuations in river stage. Wetted history at stranding sites would need to be determined by 'best fit' with the established 99 model outputs. Therefore, determining wetted history during certain flow changes (i.e. flow ramping periods at BRD/X) may not be accurately represented when compared to these outputs. In previous ramping studies investigating the effect of wetted history on stranding rate, the Norns Creek Gauge was used to determine wetted history, which had to be reset for every experiment conducted requiring complicated coordination between HLK and BRD (Golder 2007). If this management question is to be investigated further either a detailed analysis of the data in the Lower Columbia River Fish Stranding Database (similar to Golder and Poisson 2010, taking into account recent data up to 2018) or additional flow ramping studies are suggested. Both are currently outside the scope of the present study. Furthermore, future investigations into wetted history would likely be required to use stage data from the Birchbank gauging station to determine wetted history since Norns Creek Gauge is no longer functioning.

3) *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/ALH reduce the stranding rate of fish?*

Ho_3: A conditioning flow from HLK/ALH does not reduce the stranding rate of fish in the lower Columbia River.

Previous studies have shown that the use of a conditioning reduction appears to reduce the incidence of pool stranding on the Columbia River (Golder 2007); however, this result was based on limited data and a recommendation was made that additional experiments be undertaken to verify the results. Currently, no additional conditioning flow experiments have been conducted and conditioning flow reductions from HLK/ALH are not being considered as a management tool to reduce fish stranding. The value of implementing conditioning flows requires further discussions regarding the operational risk versus biological rationale. Two key concerns regarding adopting conditioning flow reductions as a management tool to reduce fish stranding were identified in a literature review (Golder and Poisson 2010). The first concern was the limited amount of data collected and preliminary stages of research on the suitability of conditioning flows for use on the Columbia and Kootenay rivers. The second concern was with the actual effectiveness of the method. The initiation of conditioning flows may encourage some fishes to leave high stranding risk areas, but the conditioning flow reduction may cause significant mortality within a short period of time, which would reduce the practicality of the method (Golder and Poisson 2010). In observations made on the lower Duncan River during ramping experiments conducted in the fall of 2009, less than 10% of mountain whitefish that were aggregated in a pool that drained survived over the 30 minutes the water was absent (Poisson and Golder 2010). Due to limited data, this hypothesis cannot be rejected at this time. If conducting additional conditioning flow experiments at HLK/ALH is not practical abandonment of this management tool should be considered.

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

Ho_4: Physical habitat manipulation does not reduce the stranding rate of fish in the lower Columbia River.

Over the past 16 years, six previously identified high risk stranding sites have been re-contoured in an attempt to mitigate the occurrence and magnitude of fish stranding. The Genelle Lower Cobble Island (MID) site and Millennium Park (LUB) site were re-contoured in 2001, Norn's Creek Fan site was re-contoured in 2002, Genelle Mainland site was re-contoured in 2003, and most recently Lions Head (upstream of Norn's Fan) was re-contoured in April 2015. The Fort Shepherd Launch (RUB) site was re-contoured between fall of 2012 and spring of 2013 by Columbia Power Corporation (CPC) as a component of the CPC Owner's Commitment #39 ([Revised 10 November 2006] [CPC 2011]). This commitment included the development of a Shallow-water Habitat Compensation Plan which was designed as the "Fort Shepherd Bar-Shallow-water Habitat Compensation Site" at the Fort Shepherd Launch (RUB) site. Previous studies have shown significant benefits of re-contouring on reducing the rate of stranding using a data set from this system (Irving et al. 2014). Golder and Poisson (2010) identified a reduction in the incidence of fish stranding at Genelle Lower Cobble Island (MID), Millennium Park (LUB), Norns Creek Fan (RUB) and Genelle Mainland (LUB). However, the effect size (the proportion of the population or the relative number of fishes not stranded as a result of the physical habitat works) was not estimated due to limited data.

The effects of re-contouring were analyzed using generalized linear mixed models to estimate the probability of fish stranding events and the number of fishes stranded before and after re-contouring at Millennium Park (LUB), Norns Creek Fan (RUB), Genelle Mainland (LUB), Fort Shepherd Launch (RUB), and Lions Head (RUB). The probability of stranding (>0 fish) were significantly greater before than after re-contouring (Figure 5) for both High and Low Risk periods. The probability of stranding greater than 200 fishes were also significantly greater before than after re-contouring for the Low Risk period (Figure 6). Analysis conducted on the number of fishes stranded revealed that significantly more fishes were stranded before than after re-contouring (Figure 7). The analysis was also valuable in identifying that the odds of stranding and total fishes stranded had a negative relationship with Birchbank discharge values, suggesting higher stranding effects as Birchbank discharge decreases. The number of 'Effect' sites and total fishes stranded per RE (Table 10) show a similar trend. Results of the generalized linear mixed model's analysis suggest that the previous efforts of re-contouring sites on the lower Columbia River have been successful in decreasing the incidence of stranding and the number of fishes stranded. Based on previous studies and the present study, Management Hypothesis #4 is rejected.

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?*

Ho_5: The number of fish salvage events can be reduced through adaptive adjustments made as a result of ongoing data collection.

In the previous ten years, the continued collection of stranding data has not proven to limit the number of stranding assessments required due to reduction events from HLK/ALH, therefore this hypothesis is rejected. Since 2009, the number of stranding assessments conducted due to flow reductions from HLK/ALH has fluctuated from 8 to 15, with an average of 84% of HLK/ALH RE initiating a stranding assessment. During the present study 83% of HLK/ALH RE initiated a stranding assessment.

There are two potential reasons why the number of stranding assessments has not decreased:

- Due to recent re-contouring efforts at stranding sites including Fort Shepherd Launch (RUB) and Lions Head (RUB), additional 'Reconnaissance' stranding assessments were conducted to determine presence or absence of pool formation, stranding risk and to determine the effectiveness of re-contouring efforts.
- Since 2000, year after year there continues to be more stranding sites designated as 'Effect' sites within a given discharge range due to either greater than 200 fish found stranded from a single RE or from the identification of listed species (i.e., Umatilla Dace, Columbia Sculpin, Shorthead Sculpin) at sites where they had previously not been found. As the number of 'Effect' sites increase in the Lower Columbia River Fish Stranding Database, the more stranding assessments are required, since 'Effect' sites are a high priority (Golder 2011). Table 10 effectively illustrates the time of year and discharge volumes where 'Effect' sites have been identified.

Although the continued collection of stranding data has not shown to limit the number of stranding assessments required, the data has led to site designation changes from "Reconnaissance' to 'No Pools', 'Minimal Effect', 'Effect' or 'Significant Fish Stranding' and has therefore refined the precision of Lower Columbia River Fish Stranding Database queries. With additional site assessment data in the database, queries become more precise and the decision to initiate a stranding assessment becomes more effective. Additionally, more stranding assessment data will help to focus future stranding assessments on sites with a high likelihood of stranding fishes.

5.0 RECOMMENDATIONS

- Limited experimentation has been conducted to address whether 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/ALH will reduce the stranding rate of fish (Management Question #3). Currently the hypothesis cannot be rejected. If conducting additional conditioning flow experiments at HLK/ALH is not practical abandonment of this management tool should be considered.

- Opportunistically target sites designated as 'Reconnaissance' sites by database queries in order to fill in data gaps. Additional 'Reconnaissance' site data will lead to a site designation of 'No Pools', 'Minimal Effect', 'Effect' or 'Significant Fish Stranding', thereby increasing the precision of the query. As the dataset becomes more refined, so too will the decision to initiate stranding assessments. Specifically, additional emphasis should be made to conduct 'Reconnaissance' assessments at the following sites:

  - Lions Head (RUB) and Fort Shepherd Launch (RUB), due to recent re-contouring. The analysis conducted in the present study has identified that the re-contouring efforts at these two sites has been effective in limiting the probability of stranding fishes. However there are still some data gaps at certain discharge volumes identified in Table 10 where additional assessments would be beneficial.

  - Korpack (LUB), due to the large number ($n = 41$) of adult Rainbow Trout found stranded during a stranding assessment on 28 October 2017. This site has been infrequently assessed in past years, but due to the findings of the present study, it is recommended that this site be assessed more often, especially at flows between 30 and 70 kcfs as measured at Birchbank. It is estimated that the adult Rainbow Trout became isolated at these discharge volumes.

  - Blueberry Creek (LUB), due to the high number of stranded fish observed at this site during the High Risk period during the present study (4505 individuals stranded on 22 July 2017 [RE2017-09]), and 1299 individuals stranded on 12 August 2017 [RE2017-11]).

- The sites listed below have been previously recommended as candidates for re-contouring because of high stranding risk relative to other sites (Golder and Poisson 2010). Re-contouring at these sites could be conducted using a phased approach, with higher priority sites (based on stranding risk, cost, and other factors) being enhanced first and other sites being re-contoured in subsequent years. Sites recommended for re-contouring are:

  - Kootenay (RUB) - Kootenay (RUB) and the associated Kootenay Oxbow are inundated and dewatered as a result of flow regulation from BRD/X and HLK/ALH. Re-contouring of this site would assist in the draining of Kootenay Oxbow. Kootenay (RUB) is a good candidate for re-contouring because it is a common stranding site. Since 2000, this site has stranded a total of 21,567 fishes (third highest site for total stranded fish) including 490 listed species (Figure 8). Listed species have been stranded for 15 of the previous 18 years. Kootenay (RUB) has also been identified as an 'Effect' site at common discharge ranges (50 to 70 kcfs in High Risk period, and 30 to 70 kcfs in Low Risk period) (Table 10). Additionally, re-contouring efforts would help reduce stranding at a public and logistically difficult place to salvage fishes (very large, shallow pools with large cobble substrate).

- Genelle Mainland (LUB) - In 2003, two large pools at the downstream end of Genelle Mainland (LUB) were re-contoured. Since then, years of high flow (in particular 2012) have changed the site topography resulting in the formation of stranding pools at a variety of discharge volumes. This site is a good candidate for re-contouring because of a large abundance of fishes that are common in this area and a history of significant stranding events. Since 2000, Genelle Mainland (LUB) has had the highest total number of stranded fishes (88,939 fishes including 74 listed species, during 273 stranding assessments), followed by Tin Cup Rapids (RUB) (31,679 fishes including 17 listed species, during 253 stranding assessments). Additionally, Genelle Mainland (LUB) has been designated as an 'Effect' site for a large range of discharges (40 to 100 kcfs during the High Risk period, and 30 to 70 kcfs during the Low Risk period) (Table 10). Suggested modifications include improving drainage between the access road and the Whispering Pines Trailer Park and removing a depositional berm near the downstream end of the site that has formed since the original re-contouring.

- Gyro Boat Launch (RUB) – Since 2000, Gyro Boat Launch (RUB) has stranded a total of 9186 fishes including 257 listed species (Figure 8) during 125 stranding assessments. Listed species have been stranded at this site for 9 of the last 18 years. This site is a good candidate for re-contouring because it would be logistically easy place to bring equipment in to conduct re-contouring. Re-contouring efforts at Gyro Boat Launch (RUB) should include the removal of a large artificial depression (potential storm drain exit) that is prone to fish stranding.

- Abandonment of strictly visual assessments should be considered. Stranding assessments for Genelle Upper Cobble Island (MID) and Genelle Lower Cobble Island (MID) in recent years have been conducted from Highway 22, since these sites can only be accessed by boat. While assessments from the highway provide information regarding pool formation, they do not provide any specific details regarding total fish stranded or environmental conditions during REs.

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.

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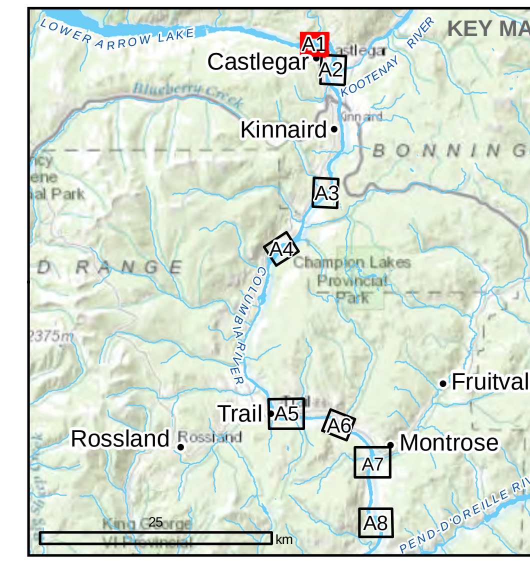
APPENDIX A

Site Maps

LEGEND

● STRANDING SITE



0 130 260

1:5,000 METRES

REFERENCE

1. WATERCOURSE AND WATERBODY DATA OBTAINED FROM IHS ENERGY INC.
2. BASE IMAGERY SOURCE: 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), SWISSTOPO, © OPENSTREETMAP CONTRIBUTORS, AND THE GIS USER COMMUNITY
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DATUM: NAD83 PROJECTION UTM 11

CLIENT
BC HYDRO

PROJECT
LOWER COLUMBIA RIVER (CLBMON#42[A]) AND KOOTENAY RIVER FISH STRANDING ASSESSMENTS: ANNUAL SUMMARY (APRIL 2017 TO APRIL 2018)

TITLE
STRANDING SITES: UPPER SECTION - COLUMBIA RIVER

CONSULTANT
GOLDER

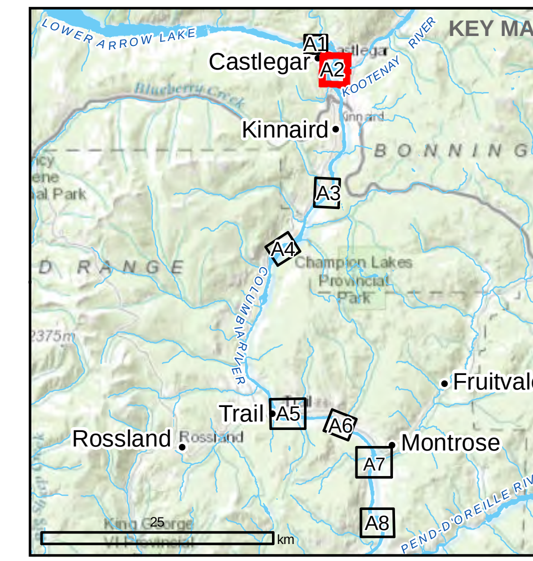
YYYY-MM-DD	2018-07-17
PREPARED	CD
DESIGN	KL
REVIEW	DF
APPROVED	KL

PROJECT No.	CONTROL	Rev.	FIGURE
1407618	4000	0	A1

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

LEGEND

● STRANDING SITE



0 170 340

1:6,500 METRES

REFERENCE

1. WATERCOURSE AND WATERBODY DATA OBTAINED FROM IHS ENERGY INC.
2. BASE IMAGERY SOURCE: 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), SWISSTOPO, © OPENSTREETMAP CONTRIBUTORS, 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 2017 TO APRIL 2018)

TITLE
STRANDING SITES: UPPER SECTION - COLUMBIA RIVER

CONSULTANT
GOLDER

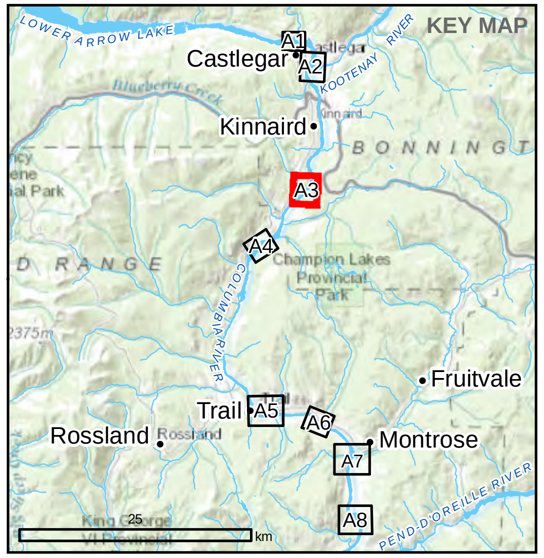
YYYY-MM-DD	2018-07-17
PREPARED	CD
DESIGN	KL
REVIEW	DF
APPROVED	KL

PROJECT No.	CONTROL	Rev.	FIGURE
1407618	4000	0	**A2**

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

LEGEND

STRANDING SITE



0 170 340

1:6,500 METRES

REFERENCE

1. WATERCOURSE AND WATERBODY DATA OBTAINED FROM IHS ENERGY INC.
2. BASE IMAGERY SOURCE: 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), SWISSTOPO, © OPENSTREETMAP CONTRIBUTORS, AND THE GIS USER COMMUNITY
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DATUM: NAD83 PROJECTION UTM 11

CLIENT
BC HYDRO

PROJECT
LOWER COLUMBIA RIVER (CLBMON#42[A]) AND KOOTENAY RIVER FISH STRANDING ASSESSMENTS: ANNUAL SUMMARY (APRIL 2017 TO APRIL 2018)

TITLE
STRANDING SITES: UPPER SECTION - COLUMBIA RIVER

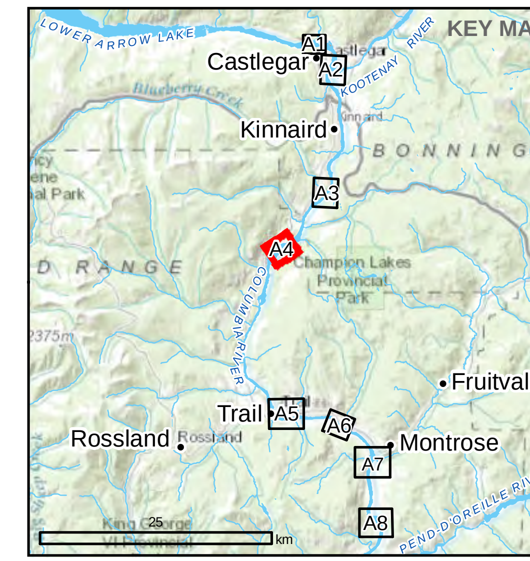
CONSULTANT		
GOLDER	YYYY-MM-DD	2018-07-17
	PREPARED	CD
	DESIGN	KL
	REVIEW	DF
	APPROVED	KL

PROJECT No.	CONTROL	Rev.	FIGURE
1407618	4000	0	A3

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

LEGEND

● STRANDING SITE



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1:6,000 METRES

REFERENCE

1. WATERCOURSE AND WATERBODY DATA OBTAINED FROM IHS ENERGY INC.
2. BASE IMAGERY SOURCE: 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), SWISSTOPO, © OPENSTREETMAP CONTRIBUTORS, AND THE GIS USER COMMUNITY
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CLIENT
BC HYDRO

PROJECT
LOWER COLUMBIA RIVER (CLBMON#42[A]) AND KOOTENAY RIVER FISH STRANDING ASSESSMENTS: ANNUAL SUMMARY (APRIL 2017 TO APRIL 2018)

TITLE
STRANDING SITES: MIDDLE SECTION - COLUMBIA RIVER

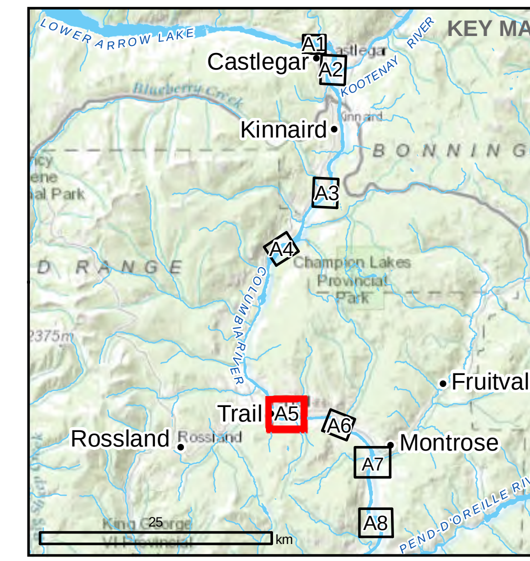
CONSULTANT
GOLDER

YYYY-MM-DD	2018-07-17
PREPARED	CD
DESIGN	KL
REVIEW	DF
APPROVED	KL

PROJECT No.	CONTROL	Rev.	FIGURE
1407618	4000	0	**A4**

LEGEND

● STRANDING SITE



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REFERENCE

1. WATERCOURSE AND WATERBODY DATA OBTAINED FROM IHS ENERGY INC.
2. BASE IMAGERY SOURCE: 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), SWISSTOPO, © OPENSTREETMAP CONTRIBUTORS, AND THE GIS USER COMMUNITY
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DATUM: NAD83 PROJECTION UTM 11

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PROJECT
LOWER COLUMBIA RIVER (CLBMON#42[A]) AND KOOTENAY RIVER FISH STRANDING ASSESSMENTS: ANNUAL SUMMARY (APRIL 2017 TO APRIL 2018)

TITLE
STRANDING SITES: LOWER SECTION - COLUMBIA RIVER

CONSULTANT

GOLDER

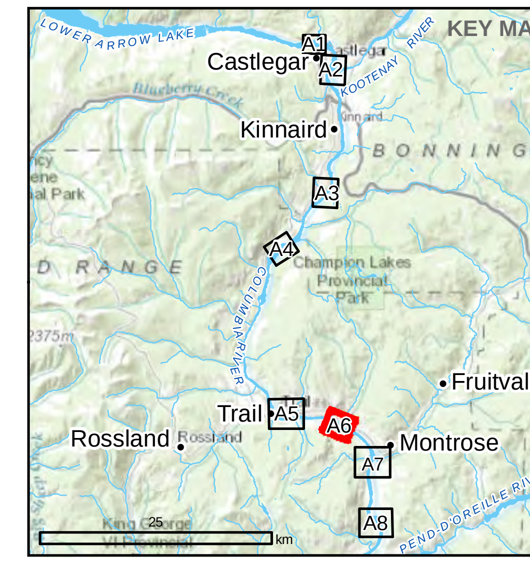
YYYY-MM-DD	2018-07-17
PREPARED	CD
DESIGN	KL
REVIEW	DF
APPROVED	KL

PROJECT No.	CONTROL	Rev.	FIGURE
1407618	4000	0	**A5**

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

LEGEND

● STRANDING SITE



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1:6,000 METRES

REFERENCE

1. WATERCOURSE AND WATERBODY DATA OBTAINED FROM IHS ENERGY INC.
2. BASE IMAGERY SOURCE: 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), SWISSTOPO, © OPENSTREETMAP CONTRIBUTORS, AND THE GIS USER COMMUNITY
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DATUM: NAD83 PROJECTION UTM 11

CLIENT
BC HYDRO

PROJECT
LOWER COLUMBIA RIVER (CLBMON#42[A]) AND KOOTENAY RIVER FISH STRANDING ASSESSMENTS: ANNUAL SUMMARY (APRIL 2017 TO APRIL 2018)

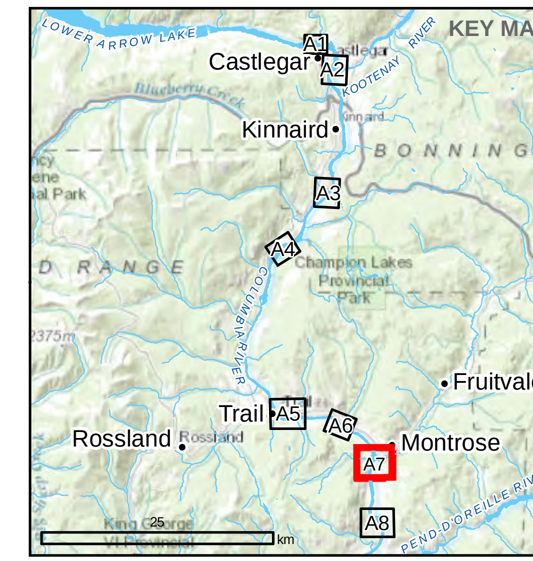
TITLE
STRANDING SITES: LOWER SECTION - COLUMBIA RIVER

CONSULTANT		
GOLDER	YYYY-MM-DD	2018-07-17
	PREPARED	CD
	DESIGN	KL
	REVIEW	DF
	APPROVED	KL

PROJECT No.	CONTROL	Rev.	FIGURE
1407618	4000	0	A6

LEGEND

● STRANDING SITE



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1:8,000 METRES

REFERENCE

1. WATERCOURSE AND WATERBODY DATA OBTAINED FROM IHS ENERGY INC.
2. BASE IMAGERY SOURCE: 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), SWISSTOPO, © OPENSTREETMAP CONTRIBUTORS, AND THE GIS USER COMMUNITY
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DATUM: NAD83 PROJECTION UTM 11

CLIENT
BC HYDRO

PROJECT
LOWER COLUMBIA RIVER (CLBMON#42[A]) AND KOOTENAY RIVER FISH STRANDING ASSESSMENTS: ANNUAL SUMMARY (APRIL 2017 TO APRIL 2018)

TITLE
STRANDING SITES: LOWER SECTION - COLUMBIA RIVER

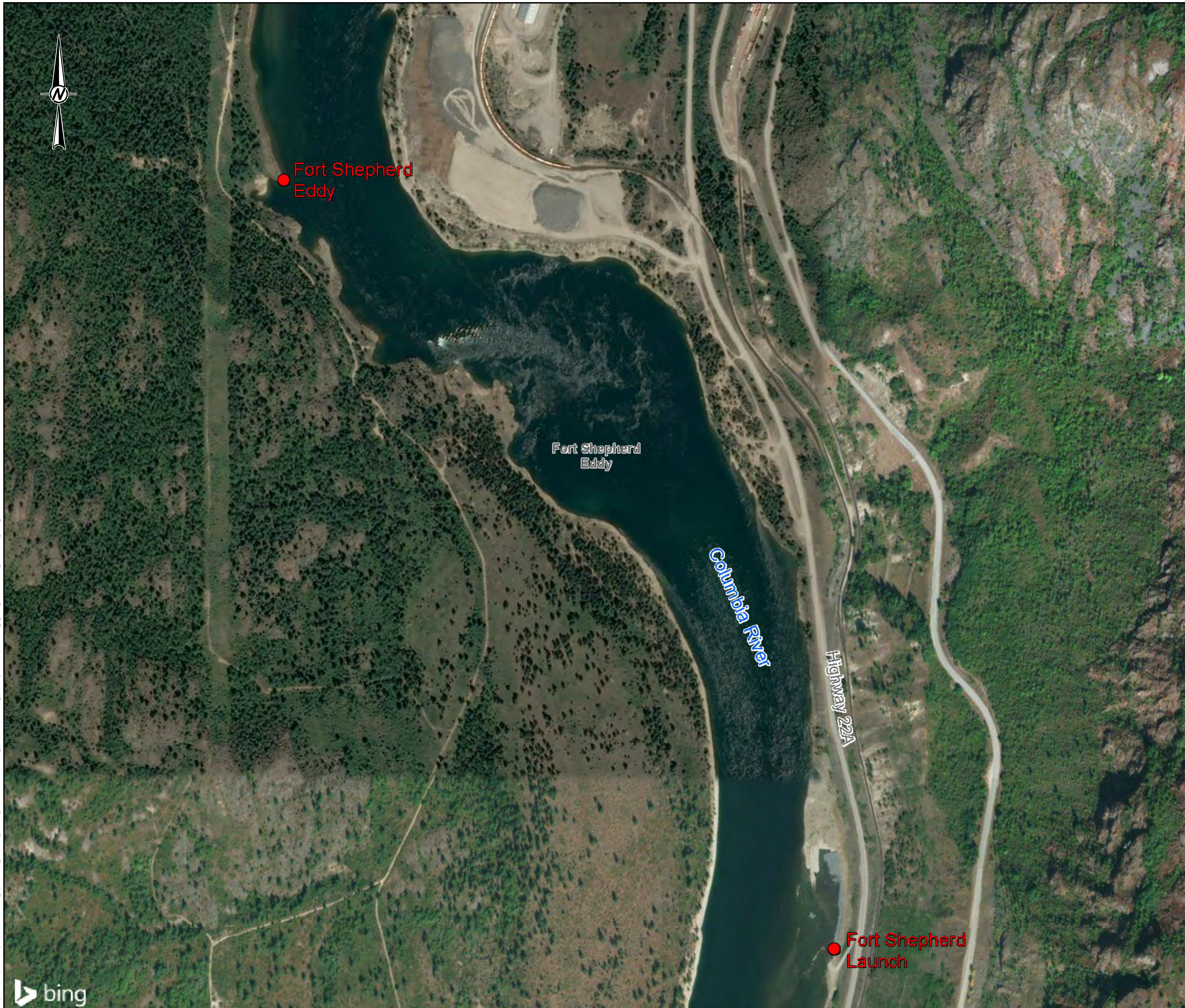
CONSULTANT

GOLDER

YYYY-MM-DD	2018-07-17
PREPARED	CD
DESIGN	KL
REVIEW	DF
APPROVED	KL

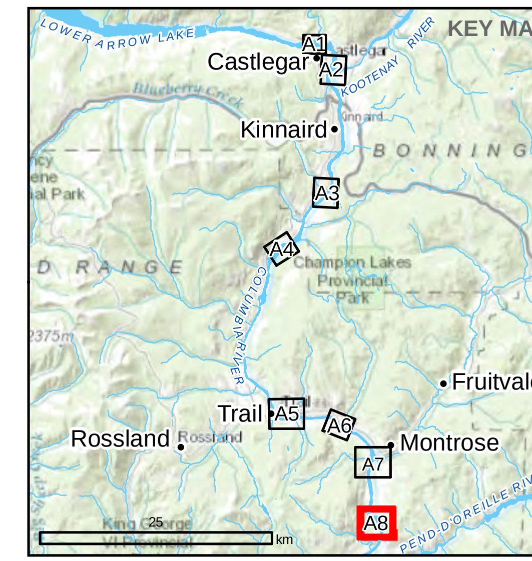
PROJECT No.	CONTROL	Rev.	FIGURE
1407618	4000	0	**A7**

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



LEGEND

● STRANDING SITE



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1:7,500 METRES

REFERENCE

1. WATERCOURSE AND WATERBODY DATA OBTAINED FROM IHS ENERGY INC.
2. BASE IMAGERY SOURCE: 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), SWISSTOPO, © OPENSTREETMAP CONTRIBUTORS, AND THE GIS USER COMMUNITY
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PROJECT
LOWER COLUMBIA RIVER (CLBMON#42[A]) AND KOOTENAY RIVER FISH STRANDING ASSESSMENTS: ANNUAL SUMMARY (APRIL 2017 TO APRIL 2018)

TITLE
STRANDING SITES: LOWER SECTION - COLUMBIA RIVER

CONSULTANT

GOLDER

YYYY-MM-DD	2018-07-17
PREPARED	CD
DESIGN	KL
REVIEW	DF
APPROVED	KL

PROJECT No.	CONTROL	Rev.	FIGURE
1407618	4000	0	**A8**

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