Site C Clean Energy Project

Site C Fish Stranding Monitoring Program (Mon-12)

Construction Year 5 (2019)

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Site C Fish Stranding Monitoring Program (Mon-12) 2019 Data Report

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Executive Summary

BC Hydro is constructing the Site C Clean Energy Project (the Project), including dam and generating station, on the Peace River near Fort St. John, BC. The Project will be the third dam and generating station on the Peace River providing an additional 1,100 megawatts of capacity. Dam construction includes backwatering of an estimated 18-km Diversion Headpond, immediately upstream of the new dam and formation of an 83-km reservoir. The Site C Fish Stranding Monitoring Program (Mon-12) is intended to determine the magnitude of baseline fish stranding along the Peace River, from the Diversion Headpond (upstream of Site C) to the Many Islands area in Alberta, and to compare these baseline conditions to construction and operations phases of the Project. The program methods are based upon the "Canadian Lower Columbia River: Fish Stranding Risk Assessment and Response Strategy" (Golder 2011) and adaptations from fish stranding programs along the Columbia (CLBMON) and Duncan Rivers (DDMON). The primary management questions of Mon-12 are:

What is the magnitude of fish stranding in the Diversion Headpond relative to baseline conditions?

Which species and life stages of fish are most affected by stranding in the Diversion Headpond relative to baseline conditions?

During Project operation, what is the magnitude of fish stranding by species and life stage in the Peace River downstream of the Project relative to baseline conditions?

Do mitigation strategies (i.e., fish salvage and habitat enhancement) reduce fish stranding rates relative to baseline conditions?

The fourth consecutive year of sampling for Mon-12 was completed between July and October 2019. Ten (10) sampling days were conducted within three reaches of the study area: the Diversion Headpond (Wilder Creek to Site C), Reach 1, and Reach 2 (between Site C and the Alces River). Sampling was conducted during five 2-day sampling trips, each of which was coordinated with BC Hydro operations at the Peace Canyon Dam to ensure sampling occurred following a reduction in discharge (i.e., ramping) and to account for the time it takes the flow change to reach the study area. A total of 167 sampling events were completed using interstitial sampling of dewatered substrates (110 surveys) and pool sampling using backpack electrofishing methods in isolated pools (57 surveys) at both targeted and randomly selected sites.

Twenty-one (21) of the sampling events resulted in observations of isolated or stranded fish and 79 individual fish were observed. Of these, 63 fish (i.e., 80%) were considered isolated (i.e., fish collected during sampling in pools or in shallow surface water) and 16 fish (i.e., 20%) were considered stranded (i.e., fish found out of water and either dead or at imminent risk of mortality). The most commonly observed fish were sculpin (27 fish observed), which represented 34% of the total number of fish collected. The next most common fish observed were minnows (24 fish observed) and suckers (21 fish observed), representing 30% and 27% of total fish observations, respectively. Together, these three groups represented 91% of all fish observations. Approximately 92% of all fish collected were identified in the young-of-the-year and juvenile life history stages. Data collected in 2019 will be combined with the previous three years of baseline data collection and provided to Ecofish Research Ltd. for subsequent analysis and to test the management hypotheses summarized in Table ES.1.

Table ES.1 Summary of Mon-12 Management Hypotheses and Year 3 Results

Objective	Management Hypotheses	2019 Results
To monitor the effects of flow fluctuations associated with the construction and operation of the Project on fish communities.	During Project construction, fish stranding in the Diversion Headpond increases relative to baseline conditions.	Sampling in 2019 represents the fourth consecutive year of baseline data collection for the Diversion Headpond, identified as the area between Wilder Creek and the Project.
	During Project operation, fish stranding in the Peace River between the Project and the Pine River confluence increases relative to baseline conditions.	Sampling in 2019 represents the fourth year of baseline data collection for Reach 1, identified as the area between the Project and the Pine River confluence.
	During Project operation, fish stranding in the Peace River between the Pine River confluence and the Many Islands area in Alberta is similar to baseline conditions.	Sampling in 2019 represents the third year of baseline data collection in Reach 2, identified as the area between the Pine River confluence and the Alces River confluence. Previous baseline sampling was conducted in 2016 and 2017. Sampling in 2019 did not include Reach 3, identified as the area between the Alces River confluence and the Many Islands area in Alberta. One year of baseline data collection has been completed to date in Reach 3, which occurred in 2017.
	Proposed mitigation measures in the Headpond during the river diversion phase of Project construction and side channel enhancement and contouring in the Peace River downstream of the Project during operations are effective in reducing fish stranding rates.	Sampling in 2019 contributes to the previous two years of baseline data for the Diversion Headpond and Reach 1.

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Appendices

1. Introduction

Ecora Engineering & Resource Group Ltd. (Ecora) was retained by BC Hydro (BCH) to implement the Site C Fish Stranding Monitoring Program (Mon-12), included as Appendix M of the Fisheries and Aquatic Habitat Monitoring and Follow-up Program, FAHMFP (BCH 2015). The scope of Mon-12 includes a field data collection program and data summary report summarizing the results of the assessment of flow fluctuations associated with the construction and operation of the Site C Clean Energy Project (the Project) on stranding and isolation of fish communities (BCH 2016). Mon-12 was initiated in 2016 to compare the pre-construction (baseline) conditions to construction and operation conditions associated with the Project, including the creation of the Diversion Headpond. The methodology described for the program follows the methods developed for similar projects in other regulated rivers in BC, including the Columbia and Duncan rivers in the Kootenay region. Ecora partnered with Halfway River Ventures Ltd. (HRVL) to conduct the field component of the program. Ecofish Research Ltd. (Ecofish) was independently retained by BCH to provide technical oversight, including support in the development of field methodologies and completion of the statistical data analyses to test the Mon-12 management hypotheses.

This report provides a summary of results from sampling conducted in 2019 (Construction Year 5), which represents the fourth year of baseline data collection. The results are provided as a data summary and discussed in relation to the Mon-12 program objectives, management questions, and hypotheses defined by BCH (2016). Data analysis and testing of the management hypotheses will be addressed in a separate report prepared by Ecofish. The primary objectives of Mon-12 are to collect baseline fish stranding data to quantify the magnitude of fish stranding throughout the study area and to determine the species and life stages most commonly affected. This data enables comparison with future conditions during the construction and operation phases of the Project. The results will be used to develop strategies to mitigate the potential effects of stranding on identified species and/or life stages of concern. The Mon-12 schedule outlines the study area reaches to be assessed in each study year. The study area for 2019 included the Diversion Headpond, Reach 1, and Reach 2, as described further below.

1.1 Background

Fish stranding generally occurs when fish habitat becomes isolated from the main channel during flow reductions associated with ramping events (Golder 2014). The magnitude of stranding is usually closely associated with the magnitude and rate of ramping (Irvine et al. 2014). Fish are considered stranded when they are found dead or are at imminent risk of death from the dewatering of aquatic habitats, including within the interstitial spaces of coarse substrates (Golder 2014). Isolation is another form of stranding that occurs when fish become trapped in waterbodies that have become separated from the stream flow (i.e., fish are unable to leave the isolated waterbody). Isolated fish may not be at imminent risk of death, but depending on the physical characteristics of the waterbody, may be at higher risk of predation and subjected to the adverse effects of increased water temperatures, reduced dissolved oxygen, and other factors that increase the likelihood of mortality (Nicholl and Lewis 2016). The relative level of risk for isolated fish typically depends on physical characteristics of the waterbody (size, depth, substrates, and presence of cover), weather conditions (effects of evaporation, temperature, and dissolved oxygen), and the length of time the pool remains isolated (i.e., until mainstem flows rise and reconnect the isolated waterbody).

Isolation and stranding of fish may occur during natural river level fluctuations, but effects are typically exacerbated by hydroelectric activity due to increases in frequency, rate, and magnitude of water level fluctuations (Irvine et al. 2014). Young-of-the-year (YOY) and juvenile fish are generally more likely to be stranded by flow reductions due to their preference for shallow waters and near-shore habitats (Triton

2009). The risk of fish stranding is affected by several factors including proximity to the dam, the extent and duration of water level reduction, duration of inundation prior to water level reduction (i.e., wetted history), the rate at which reductions occur (i.e., ramping), and a site's physical characteristics, including slope, substrates, and the presence of depressions or other areas that may collect water during water level reduction events (Golder 2010a, 2010b). The potential adverse effects of isolation and stranding on fish include reduced growth rates, increased stress, and mortality (Irvine et al. 2014; Nagrodski et al. 2012).

During the four years of baseline sampling completed to date, the flow regime within the study area has been directly influenced by operation of the Peace Canyon Dam (PCN), located approximately 85 km upstream of the Project near Hudson's Hope, BC. As such, sampling efforts have focused on the ramping initiated at PCN, the effects of which are observed throughout the study area.

1.2 Program Objectives

The Mon-12 objectives and management questions were outlined in the Site C Fish Stranding Monitoring Program (BCH 2016). The main objective of the program is to collect data that address four primary fisheries management questions:

- What is the magnitude of fish stranding in the Diversion Headpond relative to baseline conditions?

Which species and life stages of fish are most affected by stranding in the Diversion Headpond relative to baseline conditions?

During Project operation, what is the magnitude of fish stranding by species and life stage in the Peace River downstream of the Project relative to baseline conditions?

Do mitigation strategies (i.e., fish salvage and habitat enhancement) reduce fish stranding rates relative to baseline conditions?

1.3 Management Hypotheses

To address the management questions, Mon-12 intends to test the following hypotheses (BCH 2016):

H1: During Project construction, fish stranding in the Diversion Headpond increases relative to baseline conditions.

H2: During Project operation, fish stranding in the Peace River between the Project and the Pine River confluence increases relative to baseline conditions.

H3: During Project operation, fish stranding in the Peace River between the Pine River confluence and the Many Islands area in Alberta is similar to baseline conditions.

H4: Proposed mitigation measures in the Diversion Headpond during the river diversion phase of Project construction and side channel enhancement and contouring in the Peace River downstream of the Project during operations are effective in reducing fish stranding rates.

According to the Mon-12 schedule, data from 2019 represents the fourth consecutive year of the planned four-year baseline data collection program. Results from 2019 will be compiled with those of previous program years to contribute to the overall baseline data collected to date and improve the statistical power of future analyses.

2. Methods

2.1 Study Area

The 139-kilometre Mon-12 study area is comprised of the Peace River, from the Wilder Creek confluence, downstream to the Many Islands area in Alberta (Figure 2.1). The study area is broadly divided into two sections, as defined in the Mon-12 monitoring plan (BCH 2016):

- The Site C Diversion Headpond, which is expected to extend 18 km from the dam site upstream to the Wilder Creek confluence. Hereafter, this area is referred to as 'the Headpond'.

The Peace River, from the dam site downstream to the Many Islands area in Alberta (approximately 121 km).

The portion of the Peace River downstream of the dam site is further divided into three reaches:

Reach 1 – Site C dam site downstream to the Pine River confluence (approximately 16 km).

Reach 2 – Pine River confluence downstream to the Alces River confluence (approximately 42 km).

Reach 3 – Alces River confluence to the Many Islands area in Alberta (approximately 63 km).

The total length of each reach is summarized in Table 2.1. The results of 2D modelling provided by BCH (2013) cover portions of Reach 2 and Reach 3, including areas expected to be the highest risk for stranding. Reach 2 includes three modelled areas, referred to as Upper (Taylor Bridge), Mid (Pallings Flat), and Lower (Raspberry Island). The Reach 3 modelled area is at Many Islands, at the downstream end of the reach. Sampling in 2019 focused on the Headpond, Reach 1, and Reach 2, which comprised approximately 76 km of river length.

Table 2.1 Summary of Study Area Reach Breaks

Site Strata	Reach Description	Reach Length (km)
1	Headpond	18
2	Reach 1	16
3	Reach 2	42
4	Reach 3	63
Total Length		139

An approximately 8-km portion of the study area surrounding the dam site is unavailable for sampling due to active construction and subsequent health, safety, and security-related concerns. This area increased from previous years due to expanded construction limits associated with contouring and side channel enhancements within Reach 1, immediately downstream of the Project. The area unavailable for sampling in 2019 occurs approximately between kilometre markers (KM) 103 to 110, as measured downstream of the Gordon M. Shrum Generating Station (GMS), at the WAC Bennett Dam. Of this, approximately 3 km is within the Headpond and 5 km is within Reach 1.

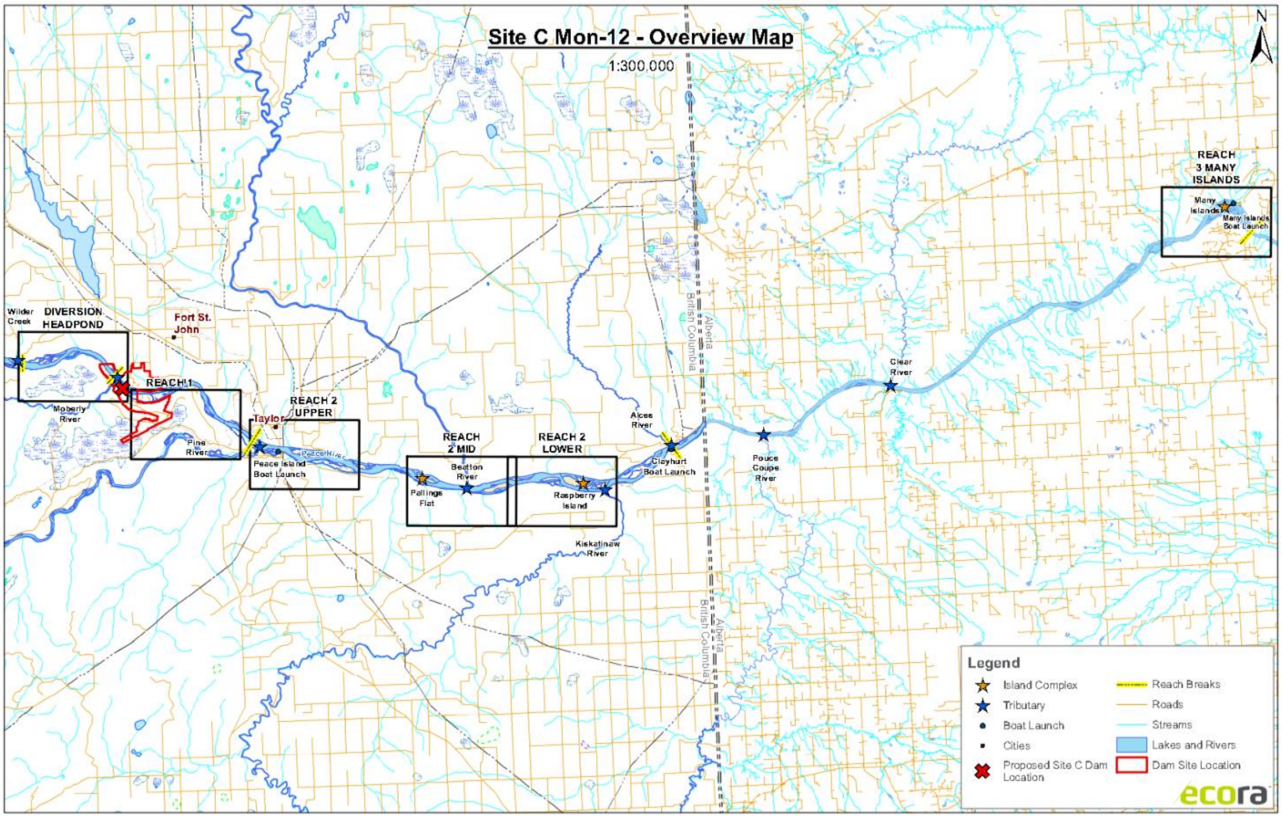

Figure 2.1 Overview Map

2.2 Site Selection

The initial site selection completed in 2016 was based on reviews of other studies of fish stranding in regulated river systems and the results of stranding assessments along the Lower Columbia River downstream of the Hugh Keenleyside Dam (Golder 2014) and the Duncan River downstream of the Duncan Dam (Golder 2013), which are based on adaptations to the Canadian Lower Columbia River Fish Stranding Risk Assessment and Response Strategy (Golder 2011). Sites were selected using physical habitat characteristics that increase stranding and/or isolation risk, as identified in the monitoring plan, which are consistent with other BCH fish stranding monitoring programs. High risk site selection characteristics were defined as areas with:

- Shorelines with gradient of < 4%;
- Large relative area (large areas increase risk of fish stranding);
- Presence of physical cover (woody debris and/or large substrates such as cobble and boulder, with low embeddedness); and
- Side Channel or Main Channel habitats.

In the first year of data collection for Mon-12 (2016), the sampling focus on high risk sites had the potential to bias the data and, when extrapolated across the entire study area, may suggest that stranding risk is higher than it is. As such, it was agreed through discussions with BCH and Ecofish that sampling efforts in 2017 would be undertaken in both high and low risk sites to provide a better estimate of total stranding from extrapolation of sampling data. To achieve this, BCH requested that Ecofish provide recommendations for site selection and stranding assessment planning for 2017. The recommendations included a combination of targeted high-risk sites (from experience gained during the 2016 surveys and knowledge of the study area) and random sites (generated from Ecofish modelling), which include both high and low-risk sites.

2.3 Site Stratification

Prior to the 2017 field season, Ecofish provided linear mapping to Ecora that categorized the modelled shoreline areas as Multi-thread or Single-thread channel type and High Risk or Low Risk. A third category called Negligible Risk was deemed unsuitable for sampling. The modelling included the entire Headpond and Reach 1 areas, and portions of Reach 2 and Reach 3. The delineation of channel type and risk category was completed using the inventory of side channels (NHC 2013), downstream modelled data (Knight-Piésold 2011), and Headpond modelling (Mainstream Aquatics 2012). The methodology used to determine the channel type and risk category was completed by Ecofish. In general, risk categories were defined using gradient between the modelled minimum and maximum wetted shorelines:

- High Risk (≤ 5% gradient);
- Low Risk (> 5% to 20% gradient); and
- Negligible Risk (> 20% gradient).

In 2017, random sites were generated by Ecofish along the modelled shoreline, with sampling order determined using a random number generator. As per the protocol provided by Ecofish, the sampling strategy was recommended as follows:

- Targeted high risk – consistent with sampling in 2016, focus of sampling effort to remain on areas with the highest risk of stranding. Focus on previously sampled sites from 2016 and new targeted sites, selected based on judgment of the field crew and knowledge of the study area.
- Random high risk (Multi-thread channels) – randomly select one waypoint per day in habitat designated high risk based on slope analysis.
- Random high risk (Single-thread channels) – randomly select one waypoint per day in habitat designated high risk based on slope analysis.
- Random low risk (Multi-thread channels) – randomly select one waypoint per day in habitat designated low risk based on slope analysis.
- Random low risk (Single-thread channels) – randomly select one waypoint per day in habitat designated low risk based on slope analysis.
- Negligible risk – no sampling unless potential stranding is suspected or observed.

This approach was implemented in 2017 and maintained through 2018 and 2019. Ecofish provided a new dataset of random point locations in a randomized order prior to the start of each field season. To address the recommendations of Ecofish and BCH, Ecora undertook a mapping exercise to create polygons from the linear mapping provided by Ecofish. The polygons were intended to quantify discrete habitat areas of similar channel and risk types and to give a measurable spatial area to distinct 'sites' throughout each of the study area reaches, as was done for similar programs elsewhere in BC, such as the Duncan Dam Monitoring Program (DDMON) and the Columbia River Monitoring Program (CLBMON). This mapping was completed for both the Headpond and Reach 1, as these were the focus for the sampling in 2018. In 2019, the mapping was expanded to include the modelled portions of Reach 2.

The mapping process adapted the existing risk classification lines, closing them to form discrete polygons (typically at the level of an entire gravel bar) that retained the risk classification from the parent risk modelling lines. Mapping was conducted initially in Google Earth, with line work subsequently refined and finalized in ArcGIS. Each polygon was applied a unique identifier (based upon Reach - Channel Type – Risk Type – Numeric ID) to allow consistent reference to a common site in the field and to enable a linkage between multiple field sites within the same bar. The identifier was recorded on every field form.

Each risk type was verified in the field during sampling events based on the slopes and habitat characteristics (e.g., substrates, vegetation) observed in the field. To avoid confusion with the Ecofish analysis, changes to the modeled channel type and/or risk category were not made to the mapping or the database. Instead, field-verified risk was recorded to identify sites where the risk of stranding based on habitat conditions (e.g., substrates, vegetation, topography) appeared low and there were limited opportunities to conduct sampling.

2.4 Trip Planning

Sampling trips were planned to sample flow reductions during the summer and fall seasons (generally July to October), as this is the period when energy demands typically result in ramping activity at PCN. The overall approach was to coordinate the sampling trips to align with the ramping forecast provided by PCN Operations. Trips were timed to capture ramping events that best enable the program objectives to be met. This approach contrasts with other sampling approaches (e.g., DDMON, CLBMON) which have crews ready to be deployed following a ramping event that may not be forecasted to occur.

Recommendations from Ecofish and BCH in 2018 were to target ramping events with a relatively long ‘wetted history’, which includes a period of high rates of discharge (i.e., >1,000 cubic metres per second or cms) for at least a one day and one night cycle, or 48 hours minimum, prior to the initiation of a ramping event. The targeted magnitude of each sampled ramping event was a reduction to 500 cms (or less) to allow sampling during a period of maximized exposed habitats. In 2019, BCH advised that a mix of large and small ramping events should be targeted for sampling, including a mix of long and short wetted histories. This was intended to reduce the bias associated with targeting only large-magnitude events.

Each sampling trip was coordinated with the BCH Operations Planning Engineers at PCN using operations forecasts at different time scales. Longer range operating forecasts (i.e., several months) were reviewed to determine when suitable ramping events might occur. The operating forecasts for 2019 indicated that discharge from PCN would be maintained at low levels between May and July. As a result, field surveys were planned to start in August, when anticipated ramping conditions would enable the sampling objectives to be met.

At a shorter timescale (hours to days), each trip was coordinated with the BCH Operations Planning Engineers at PCN to ensure sampling occurred following a reduction in discharge at PCN and to account for the lag time between PCN and the study area. For each ramping event, BCH advised Ecora of the planned timing, magnitude, and duration of the event. Ecora avoided influencing the overall timing, duration, or magnitude of each ramping event to prevent introducing bias associated with increasing or decreasing the risk of stranding.

To help coordinate the timing of crew arrival at each reach, BCH provided Ecora with a Peace River flow report via email every six hours which showed discharge rates over the previous four days and a twelve--hour forecast. An example of a typical report is provided in Figure 2.2.

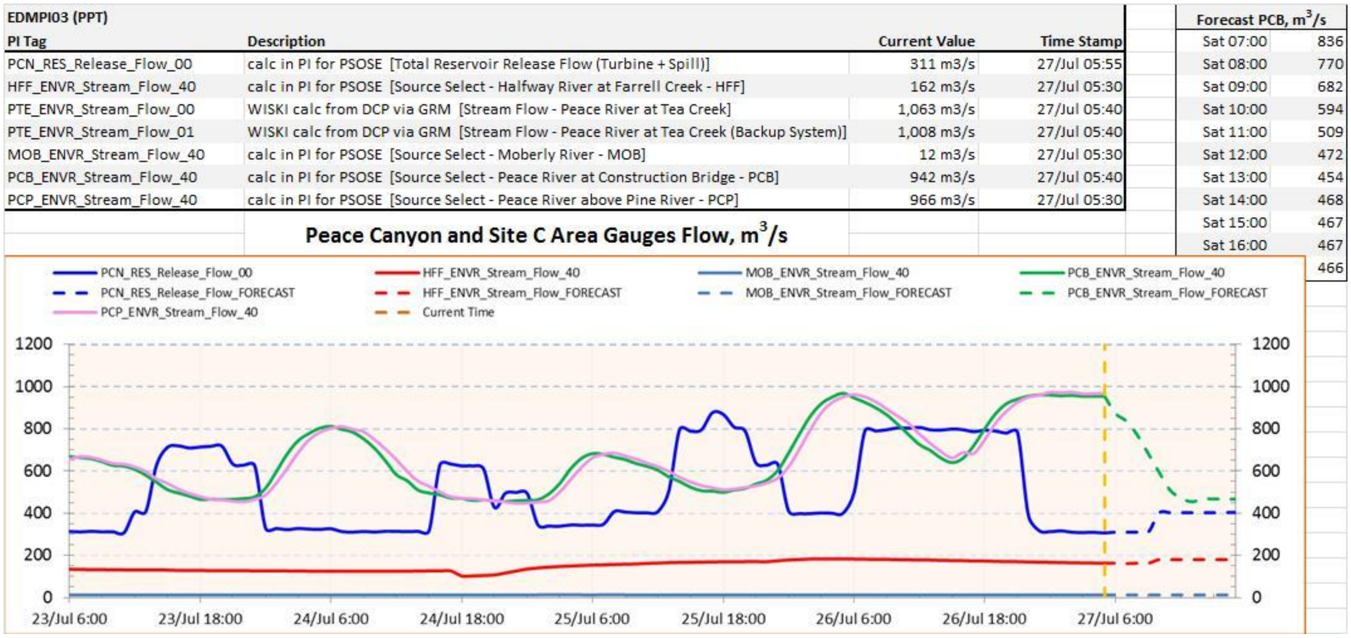

Figure 2.2 **Example of typical flow report provided by BCH showing the forecasted reduction event (dashed lines) at PCN prior to Trip 1 on July 27, 2019.**

The Peace River above Pine River Water Survey of Canada hydrometric station (07FA004) data were used to determine discharge rates within the study area as it occurs within Reach 1 (between the Moberly River and Pine River confluences) and represents approximate discharge conditions in the Headpond and Reach 1. The timing of reduction events in Reach 2 were determined using the approximate known lag time for the reduction event to arrive at the lower reaches.

2.5 Field Sampling

Consistent with previous project years, ten days of fish stranding surveys were completed over five separate trips (i.e., two sampling days per trip) between July 27 and October 20, 2019. A summary of the sampling methods completed during each trip is provided in Table 2.2. Maps of sampling locations within each reach are provided in Appendix A.

Table 2.2 **Summary of 2019 Sampling Dates, Methods, and Total Sampling Events**

Trip	Sampling Day	Date (2019)	Sampling Methods		Total Sampling Events
			Pool Sampling	Interstitial Sampling	
Trip 1	Day 1	July 27	7	12	19
	Day 2	July 28	7	11	18
Trip 2	Day 3	August 10	5	12	17
	Day 4	August 11	6	14	20
Trip 3	Day 5	September 6	10	12	22
	Day 6	September 7	5	11	16
Trip 4	Day 7	September 19	5	11	16
	Day 8	September 20	5	8	13
Trip 5	Day 9	October 19	6	11	17
	Day 10	October 20	1	8	9
Total			**57**	**110**	**167**

Surveys were conducted following the observation of the reduction event at each subject reach, generally between 8:00 am and 5:00 pm by four crews of two to four people (two electrofishing crews and two interstitial survey crews). Sampling locations were accessed using two jet boats (two crews per boat) launched at Peace Island Park, near Taylor, BC. Field navigation was completed through PDF-enabled mapping software (Avenza) on iPad minis. Upon arrival at each targeted or random site, the crews decided whether to initiate sampling based on availability of recently dewatered substrates and/or formation of isolated pools.

Once a site was deemed suitable for sampling, the spatial coordinates were recorded (waypoint) using the iPad. Location data were obtained by dropping a virtual pin on the PDF map using the GPS-enabled iPad (consumer model A1490 with GPS accuracy of approximately 3 to 5 m). At each site, the following information were recorded on waterproof data forms:

- Date and time arrived;
- Reach (Headpond, Reach 1, or Reach 2);
- Sampling Event ID: Year-Crew-Survey Day-Site Number (sequential from first sample);
- Crew names;
- Method of sampling;
- Method of site selection (Targeted or Random);
- Random site ID (if Random Site being sampled);
- Site slope (estimate of slope at sampling area);
- Weather; and
- Air temperature.

Representative site photos were taken using the iPads and referenced with the GPS waypoint. Based on the site conditions and habitat availability, either interstitial sampling or pool sampling (using electrofishing equipment) was completed, as described below.

2.6 Interstitial Sampling

Interstitial transect sampling methods for 2019, described below, are consistent with the methods developed by Ecofish in 2017 and refined during sampling in 2018.

- At each selected site, the crew leader recorded sampling location, start time, site conditions, etc. using the iPad and data sheet. Location data were obtained by dropping a virtual pin on the PDF map using the GPS-enabled iPad. A pin was dropped at the start location and another pin dropped at the end locations for each of the sampling transects.

- An overview (‘Broad-based’) search was completed by the crew over a portion of the site to search for obvious fish presence (i.e., readily observable without overturning substrates). The crew searched at least 100 m length transect along the shoreline in an upstream direction or as the available sampling area allowed. Crews completed the overview sampling by walking side by side over the entire area (Plate 1).

- During the Broad-based search, areas believed to have the highest likelihood of fish stranding (i.e., ‘Hot-spots’) were identified. These generally included shallow depressions, small pools of residual water, and/or areas with habitat cover (e.g., coarse cobble substrates, woody debris, or vegetation). If fish were found during the overview search, procedures were followed as described below (see ‘Fish Processing’).

- Once the Broad-based search was complete, five Hot-spot locations were selected for detailed sampling. Hot-spot locations were selected using professional judgement and included areas where fish were anticipated to be at highest risk of stranding, such as depressions and recently dewatered pools.

- At each Hot-spot, a measuring tape was laid out to delineate two sides of a sampling area, typically 4-m by 5-m or 10-m by 2-m for a total of 20 m^2 of sampling area per Hot-spot (with a target of 100 m^2 of total Hot-spot sampling per site). Within each Hot-spot, crews worked low to the ground (on hands and knees) and overturned all rock substrates and other cover (e.g., vegetation, woody debris) to search for fish (Plate 2).
- Photos were taken of each Hot-spot using the iPad showing the tape measure for reference and scale. Sketches were included on the data forms to show the Hot-spot locations within the overall sampling area.
- Quality assurance/quality control (QA/QC) reviews were conducted by having a different crew periodically re-assess a Hot-spot immediately following the initial sampling to confirm that fish were not overlooked and to calibrate crew effort.
- Collected fish were placed in buckets with river water and processed as described in Section 2.8.

2.7 Pool Sampling

Pool sampling was conducted by two crews of two to three people using backpack electrofisher units (Smith-Root LR-24) within waterbodies that became isolated from the main river during the reduction event. A variety of pool sizes were sampled to address the assumption that fish isolated in pools, while not necessarily at imminent risk of mortality, are at elevated risk from predation and from extreme temperatures (high and low) and low dissolved oxygen. Isolated fish may also become stranded if the isolated pool dries prior to river levels rising and inundating the pool. Trail cameras were used to monitor sites where pools form during ramping events and where fish were collected or expected to be collected based on previous experience. The cameras were set to record time-lapse photos for a subset of pools at ten sites, as described in Section 2.9.

The general approach to pool sampling was based on the assumption that although some isolated pools may not be at imminent risk of drying out or heating during that particular sampling trip (depending on weather or flow fluctuations), under other circumstances, the isolation may lead to fish stranding and/or mortality (e.g., if flows remained low for an extended period of time or flow increases do not raise water levels sufficient to inundate the pool). As such, sampling was completed at sites where pools form during ramping events to determine what species and life history stages became isolated. The pool sampling methodology is summarized below:

- Upon arrival at each selected site, a brief reconnaissance was completed to determine presence of isolated pools and suitability for sampling, based on relative size, depth, and complexity.
- Pools selected for sampling were required to have no clear fish passage to the mainstem or other adjacent waterbodies (i.e., isolated) and no evidence of a constant water source (from upstream surface water or subsurface upwelling). Targeted sites with pools generally occurred along mid-stream or side-channel bars, were larger than 1 m in diameter, and deeper than 5 cm (Plate 3). Cover within sampled pools was generally low and provided by coarse substrates with occasional vegetation or woody debris present.

- The crew leader recorded sampling location, start time, and site conditions using the iPad and data sheet. The map pin represents the approximate location of the pools being sampled within the site.
- If one to three pools were observed at a site, each pool was sampled. At sites where more than three pools suitable for sampling had formed, a subset of three pools was selected for sampling (Plate 4). Pools with the greatest likelihood of containing fish were selected for sampling, based on habitat suitability, including relative size and depth, coarse substrates, and low embeddedness.
- Sampled pools were searched visually, and backpack electrofishing was used to confirm fish presence and collect fish, where possible (Plate 5). Multi-pass electrofishing techniques (i.e., minimum two passes per pool; typically, three were conducted) were used to collect all fish present within each pool. The LR-24 quick setup was used to automatically set the initial settings of voltage, frequency and duty cycle, based on the water conditions, with manual adjustments made to optimize capture success, where necessary.
- Electrofishing settings and seconds were recorded to measure time spent actively electrofishing.
- Pool characteristics, including approximate size (length and width) of the wetted area. The 'bankfull' area of the pool was also estimated, which was intended to represent the total amount of each pool area that forms at the moment of isolation (i.e., as the water level lowers and pools initially form, thereby isolating fish within the bankfull area of the pool). Other characteristics such as average depth, temperature, conductivity, and substrates (using Modified Wentworth Scale) were recorded at each sampled pool.
- All other pools (beyond the three selected for sampling) were enumerated, and primary substrates and pool size (wetted and bankfull dimensions) were estimated. Each pool was visually inspected for presence of fish and where possible the electrofisher was used to confirm fish presence.
- Based on correspondence with Ecofish midway through the 2019 field sampling program, it was determined that an estimate of the total dewatered area of the site at the time of the sampling event should be collected. This method was implemented on Trips 4 and 5. The approximate dimensions and total dewatered area were estimated visually and/or using the measuring tool on the iPad mapping software. In some cases, warm temperatures causing evaporation and/or precipitation made the estimate of the limits of the dewatered area difficult to determine. As such, the total dewatered area is considered a rough, coarse-level estimate.
- Photos were taken of each pool sampling site and all sampled pools using the iPad. Sketches were included on the data forms to show the approximate pool locations within the site.
- Collected fish were placed in buckets with river water and processed as described in Section 2.8.

2.8 Fish Processing

Fish were placed in buckets of river water until processing and each fish was identified to species, where possible. All fish were classified as stranded or isolated at the time of collection. Fish that were immersed in water at the time of collection were considered 'isolated'. Fish that were completely out of water were considered ‘stranded’. Fish condition (live or dead) was recorded and, for dead fish, a descriptor was added to identify whether the fish was found dead or if mortality resulted from sampling or handling.

Fish fork length was recorded to the nearest millimeter using a measuring board and/or fish viewer and the life history stage (adult, juvenile, YOY) was determined based on relative size compared to average adult and/or juvenile sizes determined from reference material (McPhail 2007; McPhail and Carveth 1993) and professional judgment (McAllister pers. comm.). Table 2.3 summarizes the life history stage for species observed in 2019.

Table 2.3 Summary of Life History Stage Categories for Fish Observed in 2019

Group	Species	YOY (mm)	Juvenile (mm)	Adult (mm)
Sportfish (Cold)	Mountain Whitefish	<100	100-200	>200
Sportfish (Cool)	Northern Pike	<130	130-350	>350
	Walleye	<110	110-300	>300
Sucker	Sucker spp.	<50	50-300	>300
Sculpin	Slimy Sculpin	<40	40-60	>60
Minnow	Lake Chub	<30	30-80	>80
	Longnose Dace	<30	30-60	>60

All fish (live or dead) were released into the mainstem of the Peace River following the sampling event. Photos were taken of representative fish at each site using a fish viewer (Plate 6). Voucher specimens were not collected.

2.9 Remote Monitoring

Time-lapse cameras (Browning Command Ops Model BTC-4-14) were set up at ten sites throughout the 2019 study area (Plate 7). The intended use of the images from the remote cameras was to provide information about the total approximate dewatered area at selected sites, the timing of pool formation, and/or the timing of pool dewatering (i.e., infiltrating to ground or drying out through evaporation), where possible. Each sampling event where isolated fish were observed during pool sampling at a camera location was cross-referenced to estimate the time the pool became isolated until the time the pool became inundated (i.e., until the river level ramped up and re-connected the pool to the mainstem) or the time until the pool dried out.

Camera locations were selected based on known formation of pools during ramping events and presence of stranded and/or isolated fish observed during previous surveys. Cameras were generally installed on trees, shrubs, root wads, or on makeshift posts and oriented towards the subject pools. Each camera was given a unique ID and programmed to take high-resolution time-lapse images on a 10-minute interval during daylight hours (Plate 8). During the night the cameras took motion-triggered photos.

Cameras were checked routinely for battery life, condition, and orientation. At each inspection, the SD card was removed and replaced with a blank SD card. The removed SD card was returned to the Ecora office in Kelowna after each trip to download the photos onto the Ecora server. The cameras were retrieved on the last trip.

2.10 Safe Work Procedures and Permits

The Site C Fish Stranding Monitoring Program Safe Work Procedures (SWP) document for 2019 was approved on July 23, 2019. The SWP outlines safe work practices to be followed during work on boats and around flowing water, electrofishing equipment, dangerous wildlife, and operating vehicles. Prior to each day of sampling, Ecora contacted Peace River Hydro Partners (PRHP) to ensure the crew’s plans, especially for travel through the active construction zone, was communicated. The crews (Ecora and

HRVL) and boat operators met each sampling day at the Peace Island Park boat launch and completed a tailboard safety meeting to review potential hazards, emergency procedures, and other health and safety related concerns. All members participated and signed the daily meeting form. HRVL staff also discussed and signed their own forms to accommodate requirements under their internal safety program.

Cellular phone and data service are available although patchy throughout the Headpond and Reach 1. HRVL provided each crew with a handheld radio for communication. Boat operators kept SPOT and/or Garmin inReach GPS devices for emergency communication. Boats generally travelled together, and crews maintained line of sight and/or radio contact during the day. Ecora conducted check-in and check-out procedures with Ecora personnel in Kelowna, as well as PRHP safety personnel. Digital and hardcopies of fish collection permits were kept with the field crews and Ecora provided 48 hours' notice of fish collection activities prior to each sampling trip. Following each trip, Ecora provided a trip summary to BCH outlining any near miss, good catch, and/or incidents that occurred. A general summary of safe practices that were followed and other observations of interest were also included.

2.11 Data Management

Field data were entered on waterproof data sheets and spatial data were recorded using the GPS-enabled iPads. Upon completion of each trip, data from the field forms were entered into a Microsoft Excel database, saved on the Ecora network server, and checked for gaps, errors, and other inconsistencies. Data forms were reviewed and cross-referenced with the database during data entry to ensure consistency and identify potential sources of error. All hardcopy field data were scanned and saved as PDF files on the Ecora server, with the original field forms saved in a project binder at the Kelowna office. Calculations in the database were limited to unit area for broad-based search areas and bankfull area estimates to provide a measure of relative sampling effort.

Broad-based search area was calculated using the assumption that each person walking the transect searches a 3-m wide band. Therefore, each broad-based sampling area was determined using the calculation [(transect length) x (number of persons walking transect x 3)].

Bankfull area (length and width) was estimated in the field surrounding each sampled pool (i.e., the estimated area that would define the pool at the time of isolation from the mainstem of the river). For consistency, the bankfull estimates from the first sampling event were used for subsequent sampling events at pools that were sampled multiple times. Although pools vary in shape and complexity, most of the pools sampled are roughly oval-shaped. As such, the estimate of pool size (both wetted and bankfull) used the formula for the area of an oval ($A = \pi(\mathrm{R} * \mathrm{r})$, where R is the major radius and r is the minor radius). This estimate does not account for pool depth, substrates, or complexity.

GPS data and digital photos were downloaded to the Ecora server and organized using ESRI ArcGIS version 10.2.2. Raw, preliminary hydrometric data (discharge and primary water level) for this report were provided by BCH Operations at PCN for the following stations:

- PCN Total Reservoir Release Flow;
- Peace River at Site C Construction Bridge;
- Peace River above Pine River (Water Survey Canada Hydrometric Station 07FA004); and
- Peace River above Alces River (Water Survey Canada Hydrometric Station 07FD010).

2.12 Quality Assurance

The Ecora and HRVL crews spent the first survey of the first day of each trip working together as a group to review project background and objectives, calibrate surveyor techniques and level of effort, and to train new crew members. Data forms were reviewed by crew leaders following each day of surveying and all sheets were transported to the Kelowna Ecora office at the end of each trip for QA/QC review and data entry. Data from hardcopy forms were entered manually into an Excel database and reviewed. Corrections to errors and omissions were addressed. During the review of the data collected following each trip, inconsistent and/or missing field data were noted and addressed using review of photos, notes, and discussions with field crew members.

3. Results

3.1 Hydrometric Operations

The Peace River above Pine River (PRPR) Water Survey of Canada hydrometric station data shows that during the sampling period (June to October 2019), maximum discharge of 1,960 cms occurred on October 16, shortly prior to Trip 5. Minimum discharge of 394 cms occurred on July 18 and 19. The timing of sampling days are indicated by the red vertical lines in Figure 3.1.

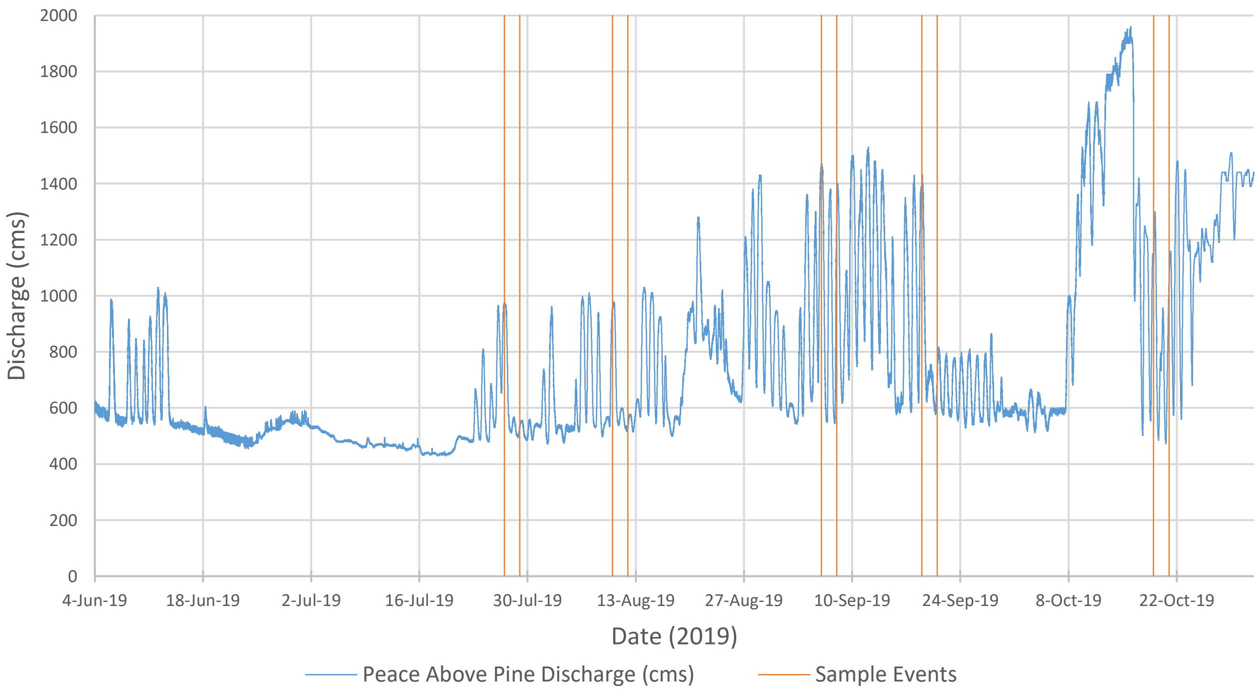

Figure 3.1 Summary of discharge recorded at the Peace River above Pine River (07FA004) Water Survey of Canada Hydrometric Station and sampling days (vertical lines) between June 1 and October 31

Base flows remained low through April, May and June (i.e., approximately 500 to 600 cms) and peak discharge events were generally short in duration (i.e., preceded by low flows and therefore short period of wetted history). According to PCN the low flow period was related to the filling of the Williston Reservoir, upstream of PCN.

Ramping was not occurring regularly during early to mid July, which led to the initial sampling trip being planned for July 27. The initial sampling trip occurred during the first planned ramping event following a period of extended low discharge in July. PCN informed Ecora that there were no plans to maintain high discharge with occasional major reduction events until spring of 2020. This contrasts with previous years, where discharge from PCN was generally high (e.g., 1,200 to 1,400 cms) during the summer months with occasional reduction events to low flow (e.g., 300 to 500 cms). In 2019, sampling trips were generally coordinated with ramping events that resulted in a peak discharge following a period of low flow.

Appendix C includes discharge data from PRPR during the two-day period for each of the five sampling trips. The figures show the approximate timing of the arrival at the upstream end of each reach in relation to the discharge recorded at PRPR.

3.2 Ramping Rates

Table 3.1 summarizes the ramping events recorded at PRPR during each sampling day. Water level and discharge data for the beginning and end of each ramping event were interpreted from the discharge data. Table 3.1 shows data for the period between the peak water level prior to the ramping event associated with each trip as well as the low water level observed following the ramping event.

Table 3.1 Summary of ramping conditions from the Peace River above Pine River hydrometric station

Trip	Date	Start Time	Water Level (m)	Discharge (cms)	End Time	Water Level (m)	Discharge (cms)	Ramping Period (hr)*	Stage Change (m)	Discharge Change (cms)	Stage Change Rate (cm/hr)	Ramping Rate (cms/hr)
1	27-Jul	5:20	406.97	956	16:50	406.09	523	11:30	0.88	433	0.08	38
	28-Jul	7:20	406.21	564	15:50	406.02	499	8:30	0.19	65	0.02	8
2	10-Aug	5:25	407.00	974	15:50	406.17	549	10:25	0.83	425	0.08	41
	11-Aug	8:25	406.30	596	14:35	406.12	530	6:10	0.18	66	0.03	11
3	9-Sep	7:05	407.18	1090	13:55	406.52	701	6:50	0.66	389	0.10	57
	10-Sep	4:00	407.76	1500	14:50	406.61	748	10:50	1.16	752	0.11	69
4	19-Sep	3:10	407.64	1400	14:50	406.38	631	11:40	1.26	769	0.11	66
	20-Sep	4:05	406.61	750	17:55	406.25	578	13:50	0.36	172	0.03	12
5	19-Oct	4:30	407.50	1300	14:10	406.02	497	9:40	1.48	803	0.15	83
	20-Oct	5:10	406.98	957	13:55	405.94	472	8:45	1.03	485	0.12	56

*time between peak flow and low water level during the ramping event

The greatest overall stage change (1.48 m) occurred during Trip 5 on October 19. The greatest discharge reduction and ramping rate were also observed on October 19, when discharge was reduced by 803 cms over a period of approximately 9 hours and 40 minutes at an approximate rate of 83 cms/hour. In general, there was a greater change in discharge and stage on the first day of sampling with a smaller change observed on the second day. The exception to this occurred during Trip 3 on September 9 and 10.

3.3 Fish Stranding Monitoring Surveys

A total of 167 sampling events were completed during ten trips between July 27 and October 20, 2019. These included 110 interstitial surveys and 57 pool surveys using electrofishing methods. The number of each type of survey is summarized by reach, channel type, and risk type in Table 3.2. The number of targeted and random sample events for each survey type is also shown in Table 3.2.

Table 3.2 Summary of Targeted and Random Sampling for each Method by Reach, Channel Type, and Risk Type

Reach	Channel Type	Risk Type	Interstitial Method		Pool Method		Total
			Targeted	Random	Targeted	Random	
Headpond	Multi-thread	High Risk	16	2	13	0	**31**
		Low Risk	0	4	0	0	**4**
	Single-thread	High Risk	2	1	0	0	**3**
		Low Risk	1	1	0	0	**2**
Reach 1	Multi-thread	High Risk	16	1	12	0	**29**
		Low Risk	0	3	0	0	**3**
	Single-thread	High Risk	5	2	5	0	**12**
		Low Risk	2	5	0	0	**7**
Reach 2	Multi-thread	High Risk	30	2	20	1	**53**
		Low Risk	0	2	0	0	**2**
		Unclassified	8	0	5	0	**13**
	Single-thread	High Risk	4	0	1	0	**5**
		Low Risk	0	3	0	0	**3**
		Unclassified	0	0	0	0	**0**
Total			**84**	**26**	**56**	**1**	**167**

Approximately 24% of the 110 interstitial surveys were randomly selected and approximately 2% of the 57 pool samples were randomly selected (Table 3.2). The low number of randomly sampled pool sites is attributed to the low likelihood that pools form at random site locations. Approximately 68% of the samples were completed in Multi-thread High Risk sites and approximately 12% of the samples were completed in Single-thread High Risk sites.

This is roughly proportionate to the availability of those habitat types throughout the study area. There were no pool sampling events in Low Risk Types as those areas are generally higher gradient with low potential for pool formation during reduction events. There were no sampling events completed in Negligible Risk Types.

Samples within Unclassified Risk Type are associated with targeted sampling events in Reach 2 that have not been modeled for Risk Type. These samples generally occurred in low-gradient gravel bars within island complexes and tributary fans between upper Reach 2 and mid Reach 2 and would be considered high risk for stranding potential (based on low slope, formation of pools, and substrates).

3.4 Fish Observations

Information for fish observations included condition (live/dead) and whether the fish was considered ‘stranded’ or ‘isolated’ at the time of collection. Isolated fish include all fish that were collected during sampling in pools or were found alive in residual pools or small pockets of water during interstitial sampling. Only fish collected out of water were recorded as stranded (Table 3.3).

Table 3.3 Summary of Sampling Events and Fish Observations

Method	Number of Sample Events	Samples with Fish Collected	Isolated Fish (Live/Dead)	Stranded Fish (Live/Dead)	Total Fish Collected (Live/Dead)
Interstitial Sampling	110	5	6 (6/0)	16 (10/6)	22 (16/6)
Pool Sampling	57	16	57 (53/4)	0	57 (53/4)
Total	**167**	**21**	**63 (59/4)**	**16 (10/6)**	**79 (69/10)**

Fish encounter rates were higher during pool sampling (28% of samples resulted in fish observations) than during interstitial sampling (5% of samples resulted in fish observations). All fish observed during pool sampling were considered isolated and approximately 79% of the total fish collected during interstitial sampling were considered isolated at the time of sampling (i.e., were immersed in water).

Most of the fish observations were isolated fish that were alive at the time of sampling (53 fish or 67%). There were ten instances of observed fish (13%) that were dead at the time of sampling or the result of incidental mortality during sampling.

3.5 Fish Species

Table 3.4 shows the fish species and life history classes for isolated fish collected during both interstitial and pool sampling. Table 3.5 shows the same information for stranded fish collected during interstitial sampling. YOY and/or dead fish in various states of decomposition were identified to species or group (i.e., Family), where possible. Sportfish species were divided into coldwater and coolwater species, as defined in the Environmental Impact Statement Volume 2 Appendix O (Fish and Fish Habitat Technical Data Report).

Table 3.4 Summary of Isolated Fish Species and Life History Classes

Group	Species	YOY	Juvenile	Adult	Unknown	Totals	Group Total	Percent of Total
Sportfish (Cold)	Mountain Whitefish	1	0	0	0	1	1	**2**
Sportfish (Cool)	Northern Pike	1	0	0	0	1	2	**3**
	Walleye	1	0	0	0	1		
Sucker	Longnose Sucker	3	4	0	0	7	14	**22**
	Sucker sp.	7	0	0	0	7		
Sculpin	Slimy Sculpin	22	1	4	0	27	27	**43**
Minnow	Lake Chub	1	2	1	0	4	15	**24**
	Longnose Dace	10	1	0	0	11		
Unknown	Unknown	1	0	0	3	4	4	**6**
Totals		47	8	5	3	**63**	**63**	**100**
Percent of Total		**75**	**13**	**8**	**4**			

There were 63 isolated fish, comprised of seven identified species and two unknown or uncertain species. Sculpin were the most numerous fish observed (n=27). Three groups (Suckers, Sculpins and Minnows) represented 89% of all isolated fish collected. Most fish collected were YOY and juvenile, together representing 88% of isolated fish.

Table 3.5 Summary of Stranded Fish Species and Life History Classes

Group	Species	YOY	Juvenile	Adult	Unknown	Totals	Group Total	Percent of Total
Sucker	Longnose Sucker	7	0	0	0	7	7	**44**
	Sucker sp.	0	0	0	0	0		
Minnow	Lake Chub	0	6	0	0	6	9	**56**
	Longnose Dace	3	0	0	0	3		
Totals		10	6	0	0	**16**	**16**	**100**
Percent of Total		**63**	**37**	**0**	**0**			

There were 16 stranded fish observed, comprised of three confirmed species. All stranded fish observed were roughly split between Suckers (44%) and Minnows (56%) and there were no sportfish observed. All stranded fish were either YOY or juvenile life stages.

3.6 Fork Length Frequency

Fork length was measured for fish collected during the sampling events. A summary of the fork length frequency data for the three most commonly observed species or species groups (Suckers, Slimy Sculpin, and Longnose Dace) is provided in Figure 3.2.

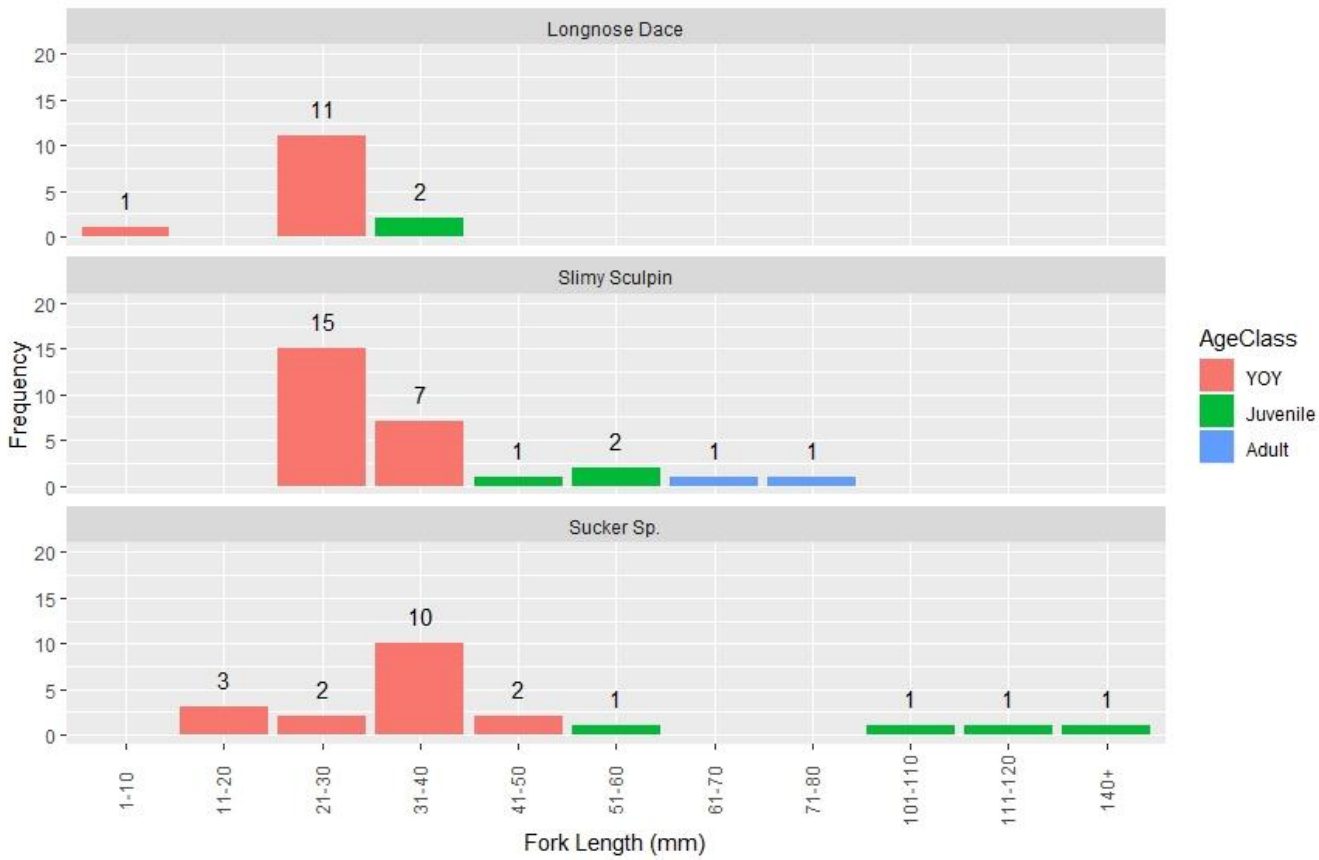

Figure 3.2 **Fork length frequency distribution and Sample Sizes for Sucker spp., Slimy Sculpin, and Longnose Dace, collected from stranding surveys in 2019.**

Figure 3.2 includes data from both isolated and stranded fish collected during the 2019 sampling. Longnose dace and Sucker life stages are dominated by YOY with some juveniles, while Slimy Sculpin includes adult life stages. These species and life stages are generally associated with the shallow and near-shore habitats that are most affected by the sampled ramping events.

3.7 Fish Stranding by Reach

The 78 fish collected in 2019 (isolated and stranded combined) were divided between 6 (8%) fish collected in the Headpond, 15 (19%) fish collected in Reach 1, and 57 (73%) fish collected in Reach 2. Tables 3.6 and 3.7 summarize the fish observations in each Reach for interstitial and pool sampling methods, respectively.

Table 3.6 **Summary of Interstitial Sampling Fish Observations by Reach**

Reach	Stranded Fish	Isolated Fish	Total Fish Observed	No. Surveys	No. Fish Observed per Survey
Headpond	0	0	0	28	0.00
Reach 1	1	0	1	34	0.03
Reach 2	15	6	21	48	0.44
Total	**16**	**6**	**22**	**110**	**0.20**

Interstitial sampling resulted in the collection of 22 fish during 110 sampling events. Approximately 73% of the fish collected during the interstitial sampling were considered stranded at the time of sampling. Almost all the fish observed during interstitial sampling were observed in Reach 2 (95%).

The 15 stranded fish observed in Reach 2 were all within the mid-Reach 2 area. Of those 15 fish, 12 were collected at a single sampling event (19-03-10-02 at site 2-M-H-4). The remaining 3 stranded fish were collected at 2 other sites (one fish at 2-M-H-286 and two fish at 2-M-H-239). Four of the six isolated fish observed in Reach 2 were collected at two sampling events in mid-Reach 2, while the other two isolated fish were collected at a single sampling event within lower Reach 2. There were no fish observed in upper Reach 2 during interstitial sampling.

There were no fish observed in the Headpond and only one in Reach 1 during 62 surveys in those reaches. As such, the number of fish observed per survey was much higher in Reach 2 (0.44 fish per survey) than the other two reaches combined (0.03 fish per survey).

Table 3.7 Summary of Pool Sampling Fish Observations by Reach

Reach	Stranded Fish	Isolated Fish	Total Fish Observed	No. Surveys	No. Fish Observed per Survey
Headpond	0	7	7	13	0.54
Reach 1	0	14	14	17	0.82
Reach 2	0	36	36	27	1.33
Total	**0**	**57**	**57**	**57**	**1.00**

All fish observed during pool sampling were considered isolated. Pool sampling resulted in 57 fish collected during 57 surveys. The total number of fish observations was greatest in Reach 2, as was the number of fish observed per survey (36 fish observations during 27 surveys or 1.33 fish per survey).

3.8 Fish Distribution

Estimation of stranding rates, including extrapolation of data to the reach scale, will be completed in a separate report by Ecofish. The section below provides a summary of the 2019 study area channel and risk types, the amount of area sampled, and the distribution of fish observations, based on the polygon mapping completed by Ecora in 2018 and 2019.

3.8.1 Risk Type Summary

A summary of the refined extents of polygons representing areas of each defined Channel/Risk Types is provided in Table 3.8. The total area of each Channel/Risk Type is expressed in square metres and is intended to represent the total amount of dewatered habitat that would be created from an event that began at the modelled high water level and ended at the modelled low water level (i.e., based on the spatial extents of the modeled high-low water elevation).

This information is based on the modelled information provided by BC Hydro and refined with polygons by Ecora in 2018 (Headpond and Reach 1) and 2019 (Reach 2). The area associated with Reach 1 decreased between 2018 and 2019 due to the extension of the dam construction footprint downstream into Reach 1 which made overlapping sites unavailable for sampling. The areas shown for Reach 2 only include the polygon areas that were created using the modelled data. Areas that were not modelled for Risk Type (Unclassified) are not represented in this table.

The spatial extents of the mapping may not accurately represent real-world conditions as the river environment is dynamic and the surface area and elevation of gravel bars change over time. For example, the mapped sites associated with the modeling at the Pine River fan do not appear to match the most current aerial imagery (e.g., Google Earth) or the conditions observed in the field in 2019.

Table 3.8 Summary of Channel and Risk Types within each Reach

Reach	Channel Type	Risk Type	Total Area (m^2)	Percent of Reach Total
Headpond	Multi-thread	High Risk	882,715	78
		Low Risk	181,245	16
		Negligible Risk	41,380	4
	Single-thread	High Risk	12,892	1
		Low Risk	8,611	1
		Negligible Risk	2,204	0
		Headpond Total	**1,129,047**	**100**
Reach 1	Multi-thread	High Risk	366,122	43
		Low Risk	206,765	24
		Negligible Risk	112,708	13
	Single-thread	High Risk	53,490	6
		Low Risk	79,270	9
		Negligible Risk	42,575	5
		Reach 1 Total	**860,930**	**100**
Reach 2	Multi-thread	High Risk	267,5921	71
		Low Risk	466,405	12
		Negligible Risk	362,285	10
	Single-thread	High Risk	161,141	4
		Low Risk	61,572	2
		Negligible Risk	64,382	2
		Reach 2 Total	**3,791,706**	**100**
		2019 Study Area Total	**5,781,683**	**100**

The 2019 study area was dominated by the Multi-thread, High Risk channel type (68%). The relatively small spatial extents of Single-thread Channel Type result in clustered random sites and reduced availability of suitable locations for targeted sampling. The areas modelled as Negligible risk are not selected for targeted sampling and do not have random sampling locations assigned to them.

3.8.2 Stranded Fish Distribution

A summary of the sampling results describing the distribution of fish collected during the Broad-based and Hot-spot sampling is provided in Table 3.9 and Table 3.10, respectively. The Channel Type and Risk Type were used to stratify the data and allow comparison among sites with similar characteristics. The spatial area sampled in each Channel and Risk Type is also provided to show the relative sampling effort in each habitat type. Effort was increased within Reach 2 sampling in 2019, since that area is not sampled every year.

Table 3.9 Summary of Fish Collected During Broad-based Sampling in 2019

Reach	Channel Type	Risk Type	Area Sampled (m²)	No. Isolated Fish	No. Stranded Fish
Headpond	Multi-thread	High Risk	23,060	0	0
		Low Risk	1,734	0	0
	Single-thread	High Risk	2,168	0	0
		Low Risk	2,370	0	0
Reach 1	Multi-thread	High Risk	30,752	0	0
		Low Risk	1,257	0	0
	Single-thread	High Risk	12,665	0	0
		Low Risk	6,143	0	1
Reach 2	Multi-thread	High Risk	38,678	2	15
		Low Risk	180	0	0
		Unclassified	8,892	0	0
	Single-thread	High Risk	11,625	2	0
		Low Risk	2,300	0	0
		Unclassified	0	0	0
Totals			**141,824**	**4**	**16**

Most of the Broad-based sampling occurred in Multi-thread, High Risk sites, representing 65% of the total area sampled. Almost all fish collected (17 of 20) were within Multi-thread, High Risk sites. Of the 15 stranded fish observed in Reach 2 Multi-thread, High Risk Type, 12 fish were observed at a single site (2-M-H-4) during sampling event 19-03-10-02 on October 20. These fish were all observed in a small depression (formerly a pool) that had dried out beneath a piece of large woody debris (rafted log). There was only one stranded fish observed during Broad-based sampling in the Headpond and Reach 1.

Table 3.10 Summary of Fish Collected During Hot-spot Sampling in 2019

Reach	Channel Type	Risk Type	Area Sampled (m²)	No. Isolated Fish	No. Stranded Fish
Headpond	Multi-thread	High Risk	1,640	0	0
		Low Risk	0	0	0
	Single-thread	High Risk	200	0	0
		Low Risk	100	0	0
Reach 1	Multi-thread	High Risk	1,700	0	0
		Low Risk	0	0	0
	Single-thread	High Risk	700	0	0
		Low Risk	200	0	0
Reach 2	Multi-thread	High Risk	3,040	2	0
		Low Risk	0	0	0
		Unclassified	780	0	0
	Single-thread	High Risk	200	0	0
		Low Risk	100	0	0
		Unclassified	0	0	0
Totals			**8,660**	**2**	**0**

Most of the Hot-spot sampling occurred within Multi-thread, High Risk sites (90% of the total sampled area). Only two fish were observed at a single site (2-M-H-286) during sampling event 19-02-05-04 on September 6. Hot-spot sampling was not completed at all sampling events, such as randomly selected sites where a Broad-based search was completed but the substrate was unsuitable for further surveying (e.g., fines or muddy substrates).

3.8.3 Isolated Fish Distribution

A summary of the distribution of isolated fish collected during pool sampling is provided in Table 3.11. Since pools do not always form in a uniform manner within each site, the total estimated bankfull area was used to represent the total amount of pool habitat that forms during a reduction event and therefore has the potential to isolate fish. The Channel and Risk Type were used to stratify the data and allow for comparison among sites with similar characteristics.

Table 3.11 Summary of Fish Collected During Pool Sampling in 2019

Reach	Channel Type	Risk Type	Bankfull Area Sampled (m²)	No. Isolated Fish
Headpond	Multi-thread	High Risk	3,263	7
		Low Risk	0	0
	Single-thread	High Risk	0	0
		Low Risk	0	0
Reach 1	Multi-thread	High Risk	3,574	8
		Low Risk	0	0
	Single-thread	High Risk	1465	6
		Low Risk	0	0
Reach 2	Multi-thread	High Risk	5,838	13
		Low Risk	0	0
		Unclassified	501	21
	Single-thread	High Risk	38	2
		Low Risk	0	0
		Unclassified	0	0
Totals			**14,680**	**57**

Most of the sampling occurred within Multi-thread, High Risk sites (89% of the total sampled area) and 28 fish were collected at Multi-thread, High Risk sites (49%). This relates to the fact that pools tend to most often form at High Risk sites. There were 21 fish collected during sampling within Unclassified Risk Type areas within Reach 2. These areas were not modeled for Risk Type but there are mid-stream island and bars that present a relatively high risk for stranding, as supported by the number of fish observed.

3.9 Remote Monitoring

The locations of the ten time-lapse cameras are shown on the figures in Appendix A. Overall, there were four cameras setup in the Headpond, two in Reach 1, and four in Reach 2. There were eight instances where isolated fish were observed in pools that were monitored by the trail cameras, with fish collected at six of these sites. There was only one instance where it appeared that fish isolated in pools either became stranded or were at increased risk of mortality based on the camera imagery.

- Sample Event 19-01-07-05 at site 2-M-H-259 (September 19, 2019) – Three fish collected and evidence that pools dried out (sampling was conducted prior to an extended low water period of over 19 days).

The use of cameras to confirm pool dewatering was limited due to changes in water elevations that occurred overnight (i.e., in the dark) and the opportunity to cross-reference with pools where fish were collected has been minimal. The prediction of the 'fate of fish' within isolated pools was difficult to determine conclusively based on the time-lapse imagery from the cameras and there are many assumptions, inferences, and other professional judgements required to draw conclusions. As such, estimates of fish stranding and/or mortality rates were not made with the 2019 camera data.

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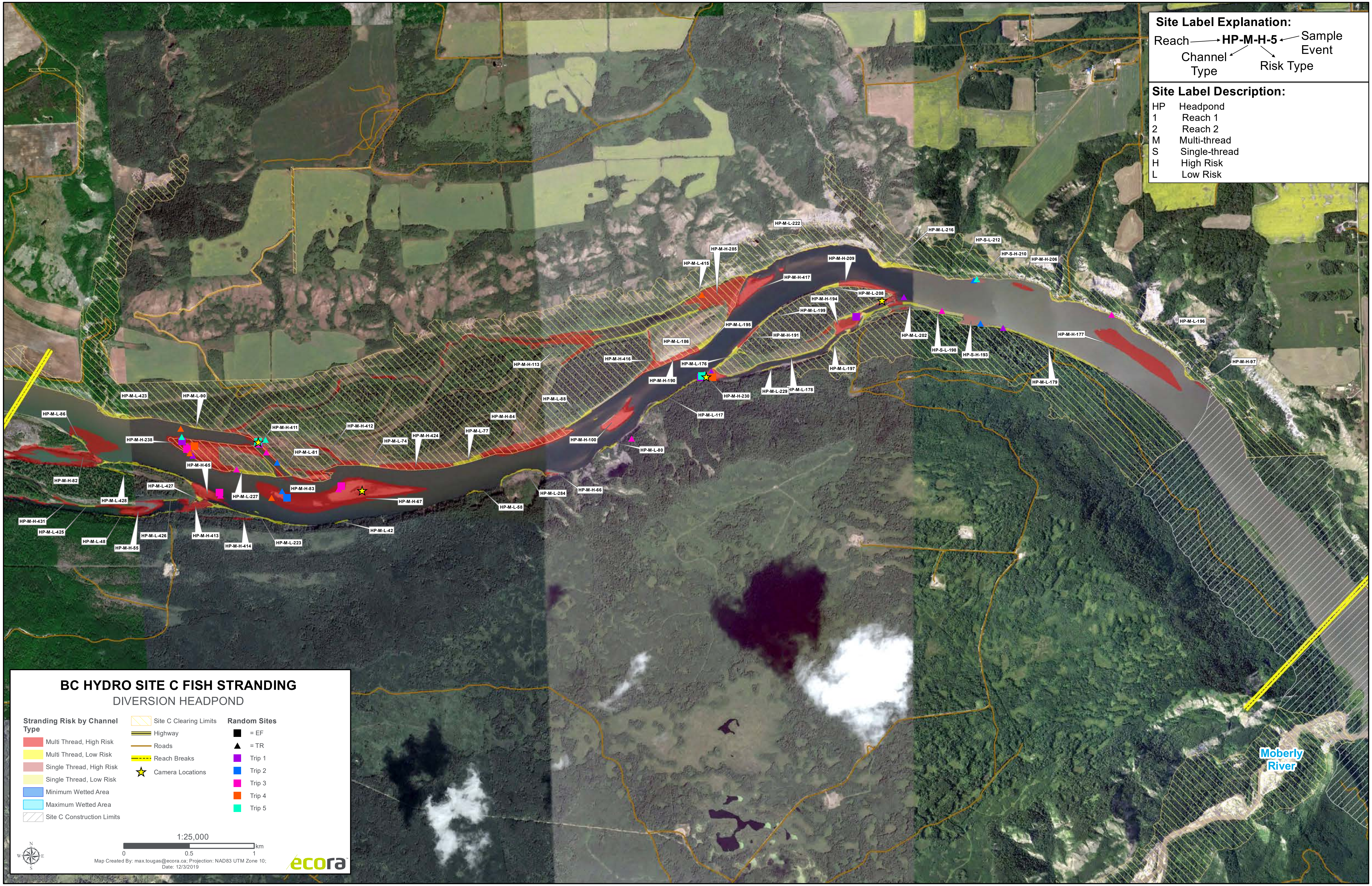
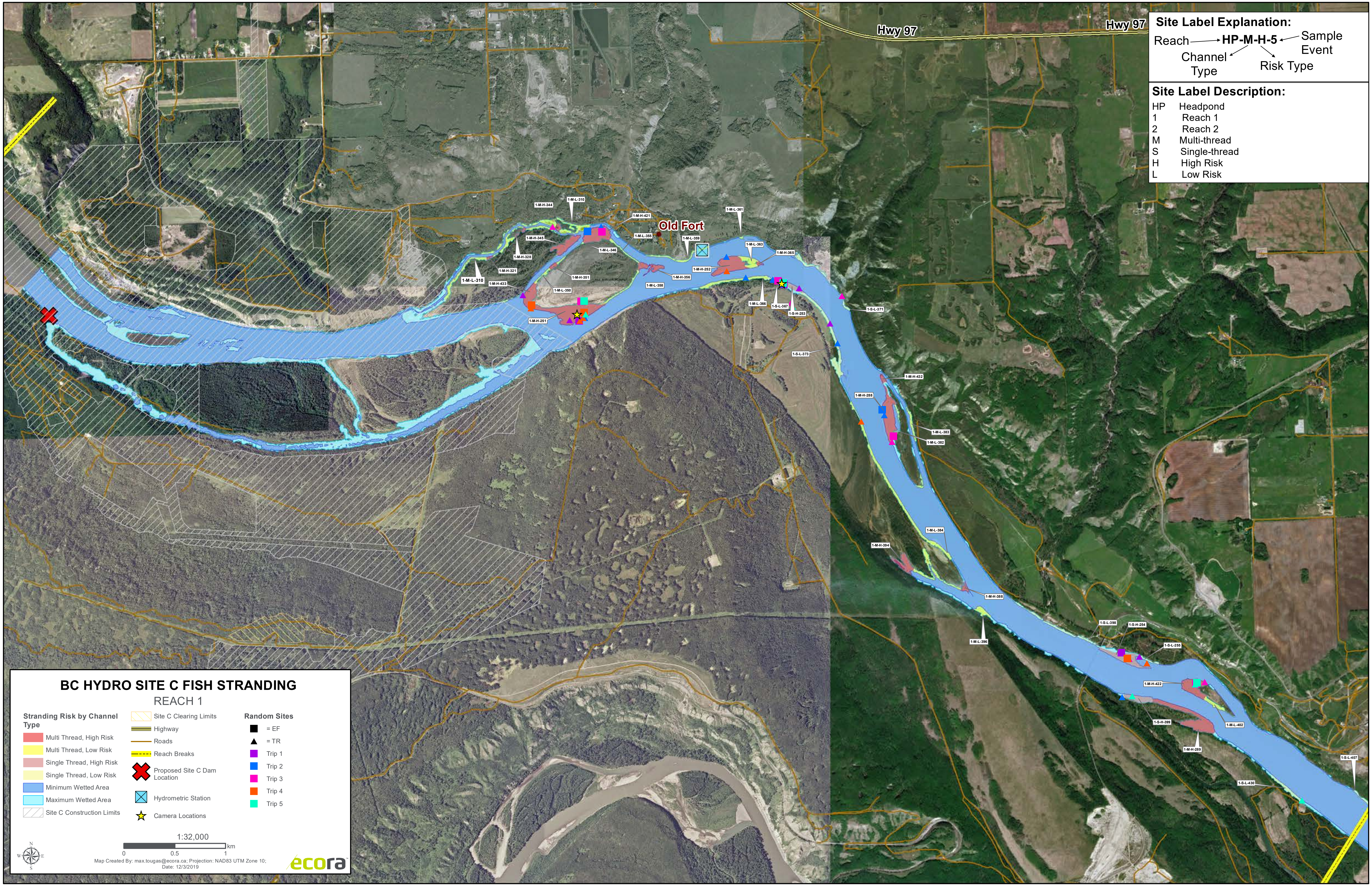
Appendix A

Study Area Maps and Sampling Locations



Site Label Explanation:
Reach
HP-M-H-5
Sample Event
Channel Type
Risk Type
Site Label Description:
HP Headpond
1 Reach 1
2 Reach 2
M Multi-thread
S Single-thread
H High Risk
L Low Risk
Moberly River
BC HYDRO SITE C FISH STRANDING
DIVERSION HEADPOND
Stranding Risk by Channel Type
Multi Thread, High Risk
Multi Thread, Low Risk
Single Thread, High Risk
Single Thread, Low Risk
Minimum Wetted Area
Maximum Wetted Area
Site C Construction Limits
Site C Clearing Limits
Highway
Roads
Reach Breaks
Camera Locations
Random Sites
= EF
= TR
Trip 1
Trip 2
Trip 3
Trip 4
Trip 5
1:25,000
0 0.5 1 km
N S E W
Map Created By: max.tougas@ecora.ca; Projection: NAD83 UTM Zone 10; Date: 12/3/2019
ecora



Hwy 97
Hwy 97
Old Fort
Site Label Explanation:
Reach
HP-M-H-5
Sample Event
Channel Type
Risk Type
Site Label Description:
HP Headpond
1 Reach 1
2 Reach 2
M Multi-thread
S Single-thread
H High Risk
L Low Risk
BC HYDRO SITE C FISH STRANDING
REACH 1
Stranding Risk by Channel Type
Multi Thread, High Risk
Multi Thread, Low Risk
Single Thread, High Risk
Single Thread, Low Risk
Minimum Wetted Area
Maximum Wetted Area
Site C Construction Limits
Site C Clearing Limits
Highway
Roads
Reach Breaks
Proposed Site C Dam Location
Hydrometric Station
Camera Locations
Random Sites
= EF
= TR
Trip 1
Trip 2
Trip 3
Trip 4
Trip 5
1:32,000
0
0.5
1
km
N
S
E
W
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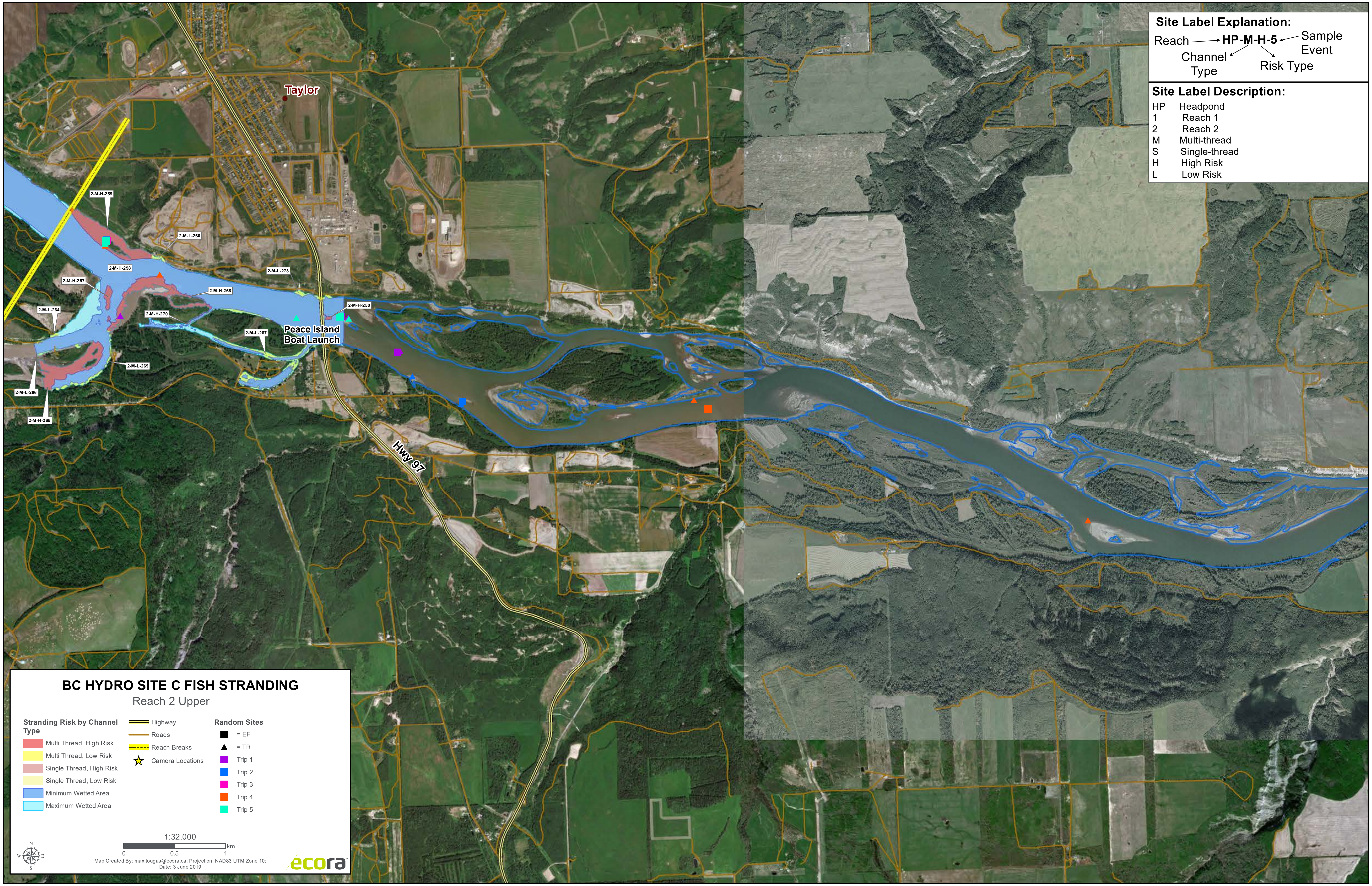
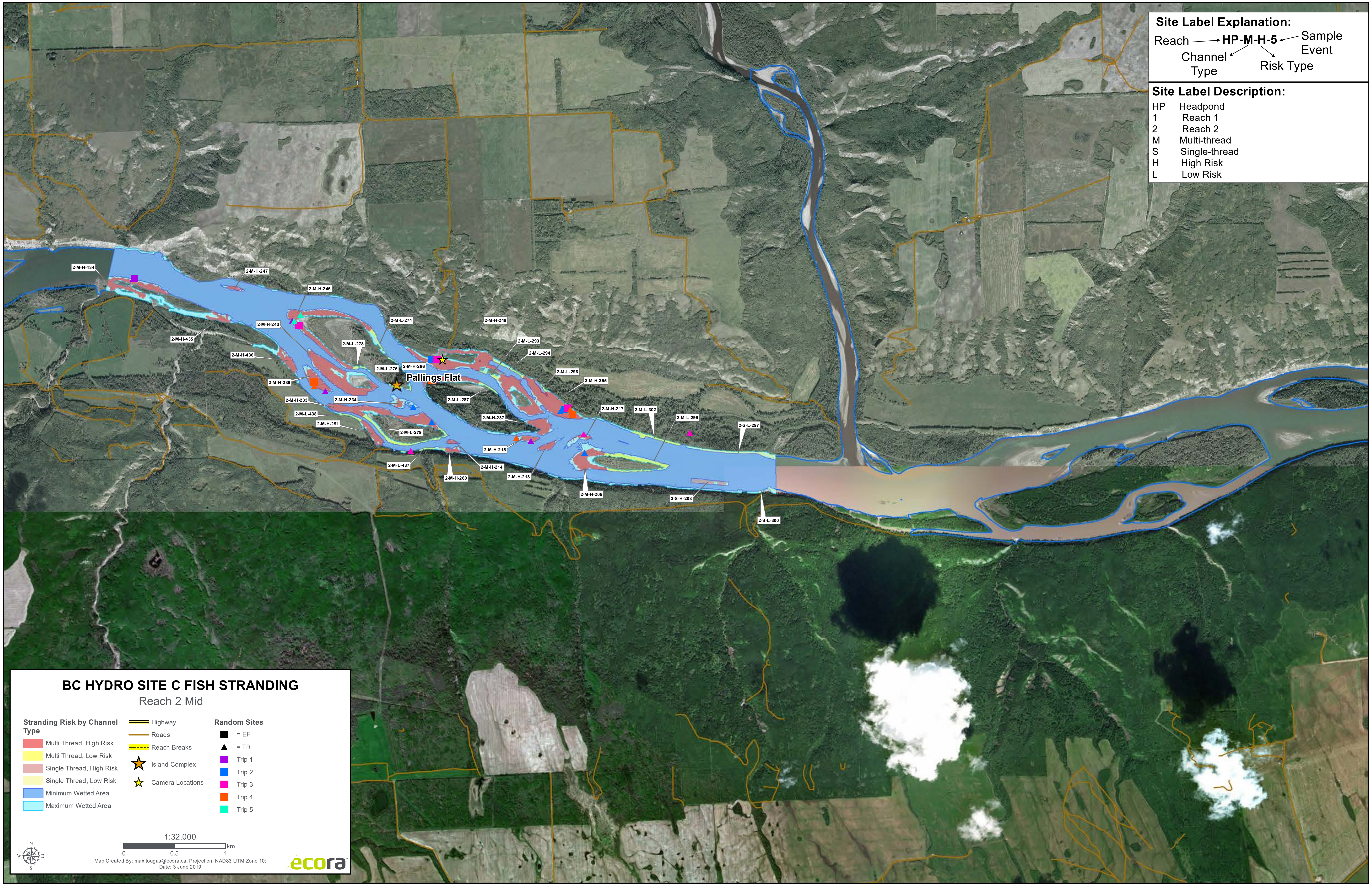


Site Label Explanation:
Reach
HP-M-H-5
Sample Event
Channel Type
Risk Type
Site Label Description:
HP Headpond
1 Reach 1
2 Reach 2
M Multi-thread
S Single-thread
H High Risk
L Low Risk
Taylor
2-M-H-259
2-M-L-260
2-M-H-258
2-M-L-273
2-M-H-257
2-M-H-268
2-M-H-250
2-M-L-264
2-M-H-270
2-M-L-267
Peace Island Boat Launch
2-M-L-269
2-M-L-266
2-M-H-265
Hwy 97
BC HYDRO SITE C FISH STRANDING
Reach 2 Upper
Stranding Risk by Channel Type
Multi Thread, High Risk
Multi Thread, Low Risk
Single Thread, High Risk
Single Thread, Low Risk
Minimum Wetted Area
Maximum Wetted Area
Highway
Roads
Reach Breaks
Camera Locations
Random Sites
= EF
= TR
Trip 1
Trip 2
Trip 3
Trip 4
Trip 5
1:32,000
0 0.5 1 km
N W E S
Map Created By: max.tougas@ecora.ca; Projection: NAD83 UTM Zone 10;
Date: 3 June 2019
ecora



Site Label Explanation:
Reach
HP-M-H-5
Sample Event
Channel Type
Risk Type
Site Label Description:
HP Headpond
1 Reach 1
2 Reach 2
M Multi-thread
S Single-thread
H High Risk
L Low Risk
2-M-H-434
2-M-H-247
2-M-H-246
2-M-H-243
2-M-L-274
2-M-H-249
2-M-H-435
2-M-L-278
2-M-L-293
2-M-L-294
2-M-H-436
2-M-L-276
2-M-H-286
Pallings Flat
2-M-L-296
2-M-H-295
2-M-H-239
2-M-H-233
2-M-H-234
2-M-L-287
2-M-L-438
2-M-H-237
2-M-H-217
2-M-L-302
2-M-L-299
2-M-H-291
2-S-L-297
2-M-L-279
2-M-H-215
2-M-L-437
2-M-H-214
2-M-H-280
2-M-H-213
2-M-H-205
2-S-H-203
2-S-L-300
BC HYDRO SITE C FISH STRANDING
Reach 2 Mid
Stranding Risk by Channel Type
Multi Thread, High Risk
Multi Thread, Low Risk
Single Thread, High Risk
Single Thread, Low Risk
Minimum Wetted Area
Maximum Wetted Area
Highway
Roads
Reach Breaks
Island Complex
Camera Locations
Random Sites
= EF
= TR
Trip 1
Trip 2
Trip 3
Trip 4
Trip 5
1:32,000
0
0.5
1
km
N
W
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S
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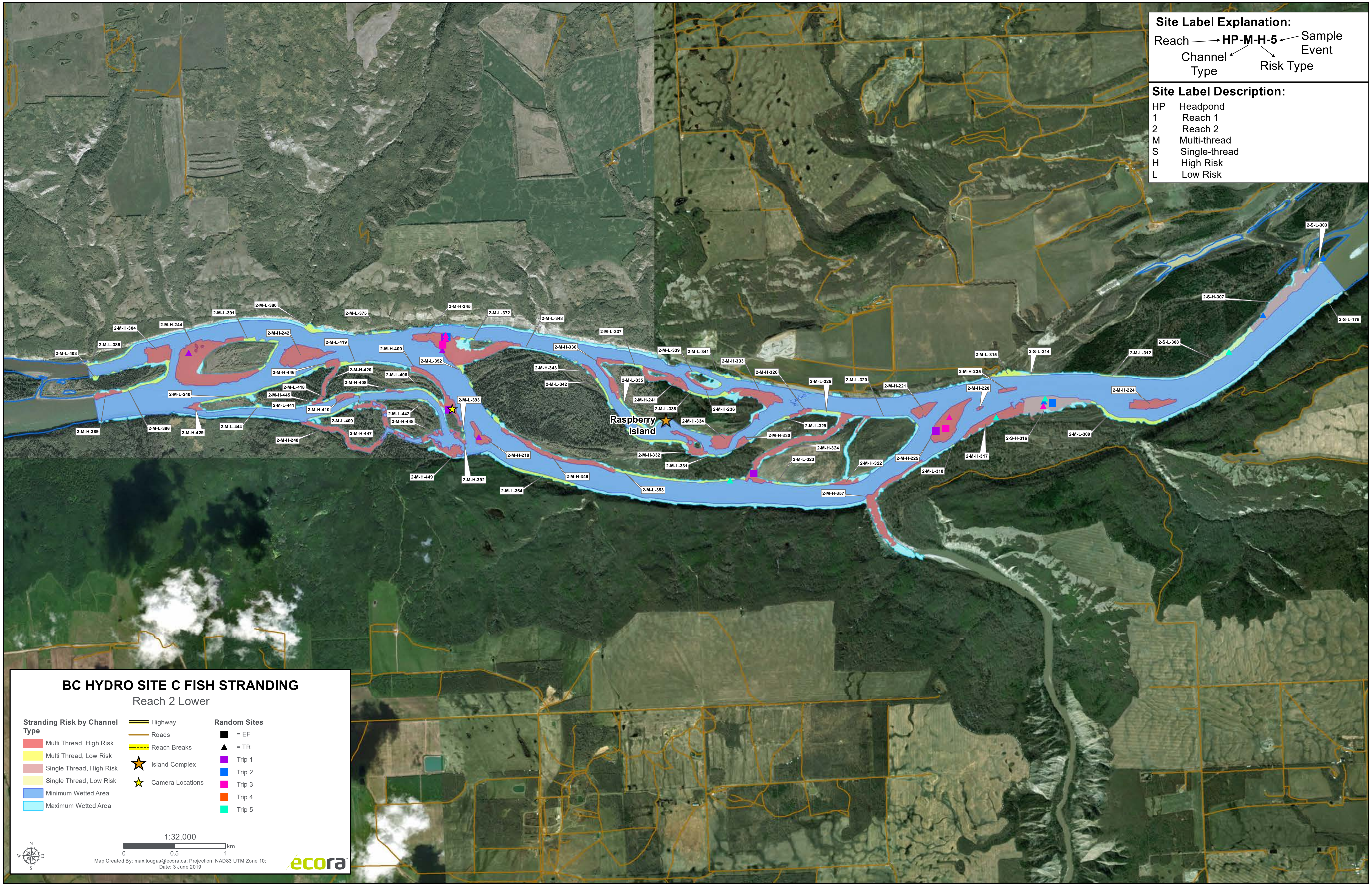
Date: 3 June 2019
ecora



Site Label Explanation:
Reach
HP-M-H-5
Sample Event
Channel Type
Risk Type
Site Label Description:
HP Headpond
1 Reach 1
2 Reach 2
M Multi-thread
S Single-thread
H High Risk
L Low Risk
Raspberry Island
BC HYDRO SITE C FISH STRANDING
Reach 2 Lower
Stranding Risk by Channel Type
Multi Thread, High Risk
Multi Thread, Low Risk
Single Thread, High Risk
Single Thread, Low Risk
Minimum Wetted Area
Maximum Wetted Area
Highway
Roads
Reach Breaks
Island Complex
Camera Locations
Random Sites
= EF
= TR
Trip 1
Trip 2
Trip 3
Trip 4
Trip 5
1:32,000
0 0.5 1 km
Map Created By: max.tougas@ecora.ca; Projection: NAD83 UTM Zone 10;
Date: 3 June 2019
ecora

Appendix B

Photo Plates

Plate 1 **View of interstitial sampling crew conducting Broad-based survey within the recently dewatered area along the wetted edge of the river at site 2-M-H-259 on Trip 2 – Day 3 (August 10, 2019)**

Plate 2 **View of crew conducting Hot-spot interstitial sample at site HP-M-H-65 on Trip 3 – Day 6 (September 7, 2019)**

Plate 3 **View upstream towards the project site and typical pool sampling location at site 1-M-H-251 on Trip 5 – Day 9 (October 19, 2019)**

Plate 4 **View of pool sampling site 2-M-H-38 on Trip 3 – Day 6 with multiple shallow pools occurring throughout (September 7, 2019).**

Plate 5 **View of electrofishing sampling at an isolated pool at site HP-M-H-411 on Trip 5 – Day 9 (October 19, 2019)**

Plate 6 **Fish viewer used to measure and photograph a Walleye collected from a pool at site 2-S-H-316 on Trip 2 – Day 4 (August 11, 2019)**

Plate 7 **View of Camera 08 (indicated by red arrow) attached to the root wad of a piece of large woody debris at site HP-M-H-411 on Trip 2 – Day 3 (August 10, 2019)**

Plate 8 **View of image from Camera 10 at site 2-S-H-316 on September 19, 2019 at 15:02, showing pool formation following a reduction event that occurred during Trip 4**

Appendix C

Hydrometric Graphs

Summary of discharge recorded at the Peace River above Pine River (07FA004) Water Survey of Canada Hydrometric Station during each of the five sampling trips between July 27 and October 20, 2019 and the approximate survey start time at each reach (hydrometric data provided by operations staff at Peace Canyon Dam on November 29, 2019).

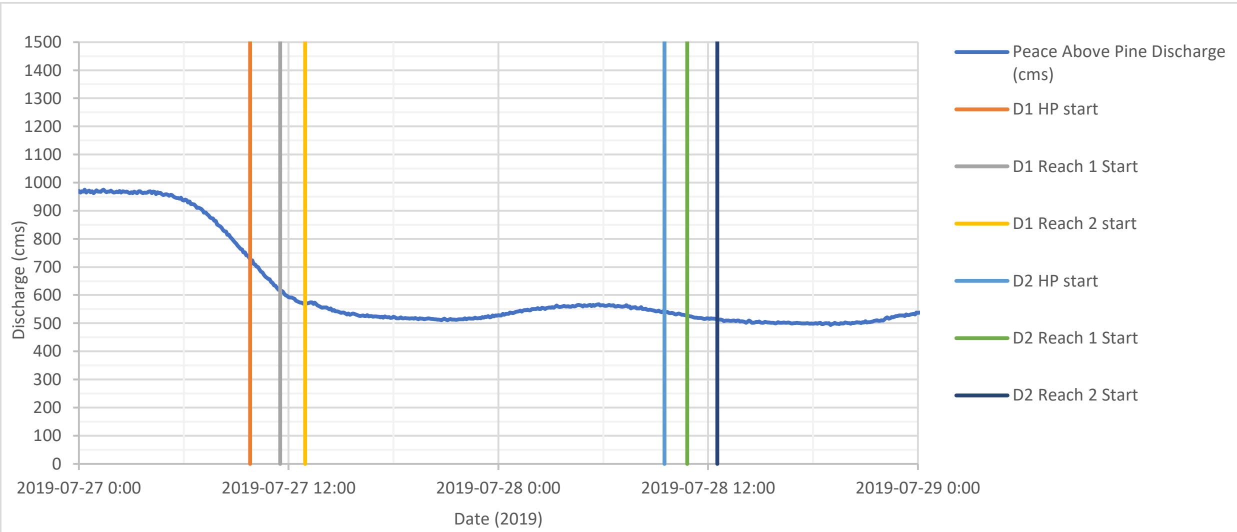


Figure C-1. **Trip 1 (Day 1 and 2) on July 27 and 28, 2019**

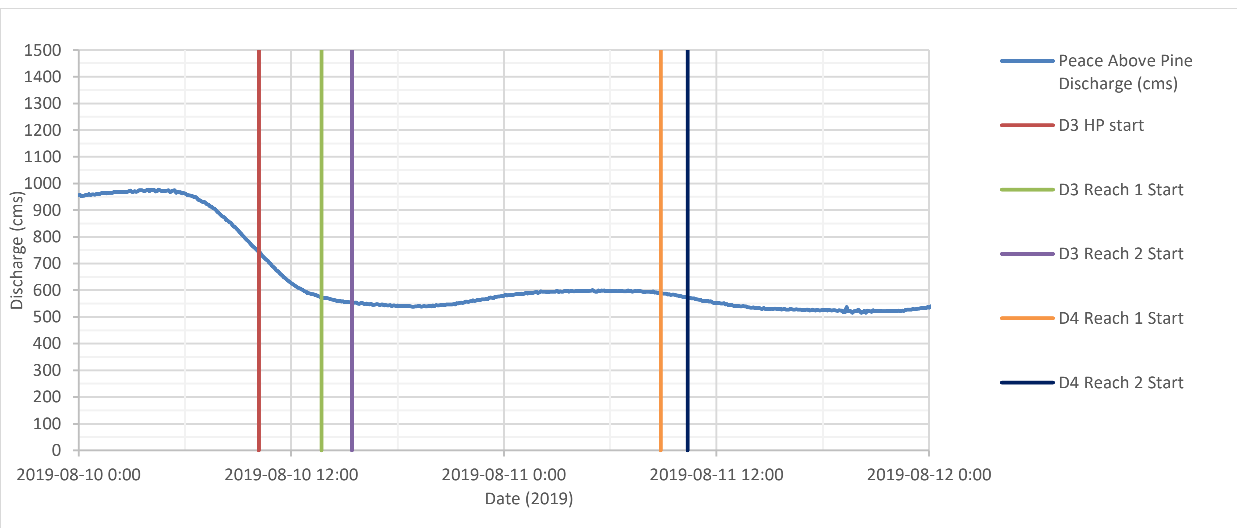


Figure C-2. **Trip 2 (Day 3 and 4) on August 10 and 11, 2019**

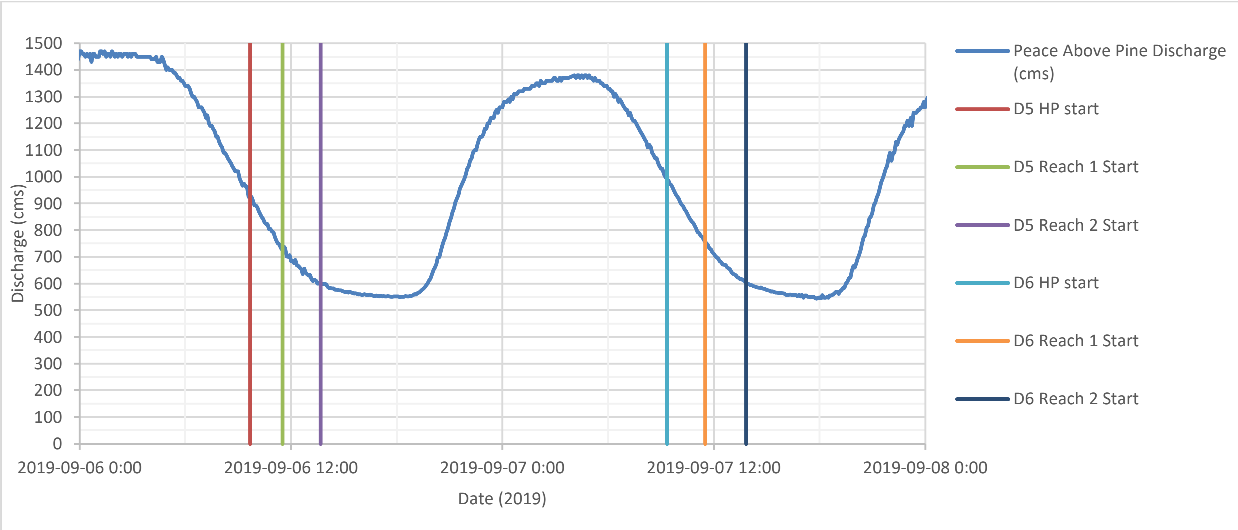


Figure C-3. **Trip 3 (Day 5 and 6) on September 6 and 7, 2019**

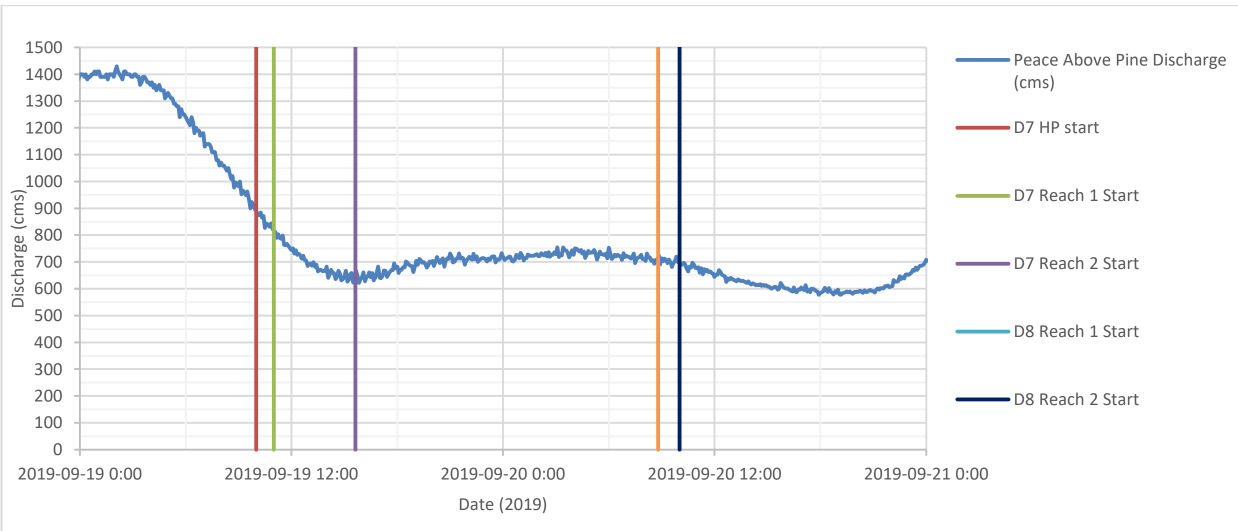


Figure C-4. **Trip 4 (Day 7 and 8) on September 19 and 20, 2019**

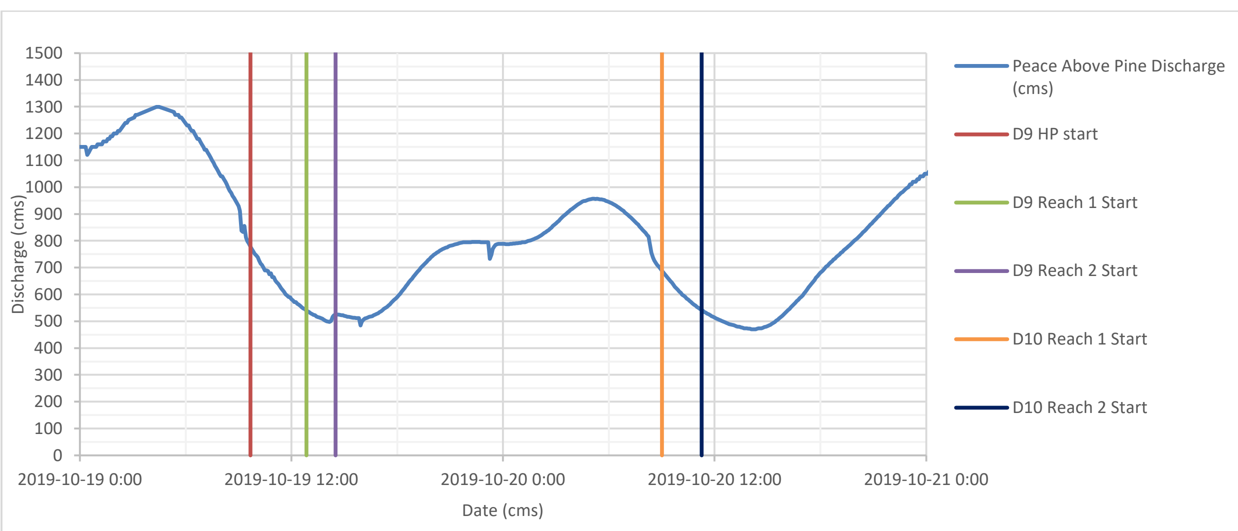


Figure C-5. **Trip 5 (Day 9 and 10) on October 19 and 20, 2019**