Bridge-Seton Water Use Plan

Monitoring Program Terms of Reference

BRGMON-1 Lower Bridge River Aquatic Monitoring

Revision 2
March 28, 2022

BRGMON-1 – Lower Bridge River Aquatic Monitoring Monitoring Program Terms of Reference Revision 2

1.0 MONITORING PROGRAM RATIONALE

1.1 Introduction

This BRGMON-1 Terms of Reference (TOR) Revision 2 is submitted in support of a submission package for an Interim Flow Decision and subsequent Order(s) anticipated from the Comptroller of Water Rights in addition to the Bridge River Project Water Use Plan Order (Bridge WUP Order) dated March 30, 2011, Schedule A, Clause 9 as follows:

a. Monitor influence of the flow regime on the physical conditions in aquatic and riparian habitats of lower Bridge River ecosystem;

b. Monitor how changes in aquatic habitat from the flow regime influences community composition and primary and secondary productivity of producers in lower Bridge River; and

c. Monitor how flow changes influence the recruitment of fish populations in lower Bridge River.

1.2 Background

1.2.1 Water Use Planning

In 1998 an agreement between BC Hydro and regulatory agencies was adopted in response to public, First Nations, and agency concerns about the lack of continuous flow releases from the Terzaghi Dam into the Lower Bridge River. The agreement specified that an instream flow release and monitoring program be developed and implemented to resolve uncertainty about response of the Lower Bridge River aquatic ecosystem to reservoir releases. The agreement specified that an experimental flow release program was to be initiated and continued until a Water Use Plan (WUP) was developed for the Bridge-Seton watershed.

On July 28, 2000, the Comptroller of Water Rights issued an Order under the *Water Act* (now the *Water Sustainability Act*) to initiate an annual water budget of three m^3/s shaped into a seasonal hydrograph plus associated monitoring studies to estimate the effect of that flow treatment on the aquatic ecosystem. Previous flow assessment studies (1993-1995) and ecological monitoring (1996-2000) provided some baseline data on zero flow from Terzaghi Dam into the Lower Bridge River to compare with the 3 m^3/s flow trial.

Based on the recommendations of the WUP Consultative Committee, a WUP Order was issued by the Comptroller of Water Rights on March 30, 2011 requiring a second treatment with an increase in the annual water budget to six m^3/s shaped into a seasonal hydrograph. This WUP Order also included the implementation of monitoring studies to inform future flow decision.

Aquatic productivity was to be monitored, including juvenile salmonid abundance (within BRGMON-1), the analysis of which would be supported by adult salmon and steelhead enumeration (within BRGMON-3) to examine the relationship between juvenile abundance and the instream flow regime, independent of external factors such as adult escapements.

1.2.2 Long-Term Flow Decision

The results from WUP studies on the Lower Bridge River were intended to inform a long-term flow release strategy recommendation by 2015.

In 2015 and in subsequent years leading up to 2022 when a request for an Interim Flow Decision was submitted by BC Hydro, the Comptroller of Water Rights conditionally approved delaying decision on the long-term flow release strategy.

The water management challenges posed since 2016 (see Section 1.2.3) necessitated further deferral of the long-term flow release strategy until an interim flow strategy could be developed. The Interim Flow Decision requested by BC Hydro in 2022 considers the flexibility needed for flows from Terzaghi Dam until BC Hydro infrastructure upgrades are substantially complete and water management capacity in the Bridge River-Seton system is restored.

1.2.3 High Flow Challenges in the Lower Bridge River

In 2016, BC Hydro Dam Safety issued a directive to reduce storage capacity of Downton Reservoir by ~50% to manage seismic risk. In the same year, BC Hydro advanced critical infrastructure upgrades at the Bridge River 1 and 2 Generating Stations to address the added water management risks associated with reduced storage in Downton Reservoir. The infrastructure upgrades affected the volume of water that could be diverted through Bridge River 1 and 2 from Carpenter Reservoir to Seton Lake. As a result, releases higher than the annual average six m^3/s (specifically in the springtime freshet period) may be discharged from Terzaghi Dam down Lower Bridge River in some years based on inflows into the reservoirs and the capacity of Bridge 1 and 2 to pass those inflows. This increased risk of higher flows into the Lower Bridge River is expected to continue until water management capacity in the Bridge River-Seton system is restored through completion of major infrastructure upgrades.

BC Hydro received variance approvals (March 14, 2016, February 16, 2017, February 22, 2018, December 19, 2018 and May 4, 2021) from the Comptroller of Water Rights to vary the Terzaghi Dam discharges from those specified in the WUP, and to implement a more flexible flow regime at Terzaghi Dam following a set of *Guiding Principles* to inform within season flow release decisions. The discharge variance approvals permitted BC Hydro to exceed the annual average six m^3/s treatment hydrograph and specifically the 15 m^3/s maximum peak discharge during the annual freshet flow period (~March to August). Outside of the freshet flow period, BC Hydro has been able to operate Terzaghi Dam according to the seasonal WUP hydrograph limits. These actions to pre-emptively release higher flows during the freshet period substantially reduce the risk of a late summer/fall high flow release which would pose a much greater impact to the aquatic life in the Lower Bridge River (i.e., spawning salmon).

1.2.4 Joint Water Management

From 2016 to 2018 the hydrograph peak and duration during the high flow period were shaped by inflow volumes, with Terzaghi Dam discharges reaching 97 m^3/s in 2016, 127 m^3/s in 2017, 100 m^3/s in 2018 and 25 m^3/s in 2021. Spring freshet flows in these years were managed using the *Guiding Principles* developed jointly in meetings with representatives from St'át'imc, BC Hydro and regulatory agencies where water management options and risks to aquatic life were discussed collaboratively.

The planning meetings were formalized in late 2019 into what is now known as the Joint Planning Forum (JPF) with membership from St'át'imc and BC Hydro, invited participants from regulatory agencies, and occasionally also invited guests from the St'át'imc communities and other supporting parties.

The JPF meets on a monthly basis (or more frequently as required) and has a mandate that includes reviewing water conveyance operations and flow management at the Bridge-Seton Generation Facilities, both on a near and long-term basis, and as part of a potential *interim long-term flow strategy*. The JPF has been successful in providing joint recommendations for water management decisions ultimately made by BC Hydro. The JPF has provided a venue for joint problem solving between St'át'imc and BC Hydro for water management and environmental mitigation projects associated with the impacts of BC Hydro operations.

Revision 2 of this Terms of Reference outlines environmental monitoring associated with the interim flow recommendations provided by the JPF to support BC Hydro's request to the Comptroller of Water Rights for an interim flow decision on the Lower Bridge River.

1.2.5 Learning from the Past

Revision 2 of this TOR seeks to streamline monitoring approaches to address both the original WUP Order objectives and the Interim Flow Decision by building on the information gathered during the first ten years of the WUP studies and acknowledging the completion of monitoring task for which management questions have been resolved or will continue under other separately funded programs. For example, fish stranding monitoring and salvage originally included with the scope of BRGMON-1 will continue to address stranding risks separate from the TOR as a routine BC Hydro Environmental Field Operations monitoring program. Management Question four (relating to ramp-down operations and fish stranding) remains within the scope of BRGMON-1 but is already answerable with the current data set, so it no longer remains within the budget and scope BRGMON-1.

Similarly, in recognition of the flexibility needed for flow management at Terzaghi Dam until infrastructure upgrades are substantially complete, Revision 2 is also more focussed than the original TOR on filling gaps in knowledge that relate to variable flows (i.e., instream releases that have not previously been monitored). Additional monitoring tasks implemented during periods of high flows in 2016 to 2021 provide a template for high flow conditional monitoring that continue under Revision 2.

The relevant aquatic productivity monitoring scope outlined in the original BRGMON-1 TOR will continue largely unchanged in Revision 2, particularly for the fall timing of productivity monitoring methods that remain unaffected by the high flow freshet period and will continue to detect changes in aquatic productivity occurring under variable flow for the reaches of the river that had been previously monitored.

Reflecting on the results from BRGMON-1 analyses in 2012 to 2017, monthly juvenile growth sampling and annual habitat surveys specified in the original BRGMON-1 TOR are no longer required in Revision 2; however, additional monitoring of off-channel habitats implemented following the period of high flows will continue.

Finally, the approach for studying Chinook salmon emergence timing was also reviewed, and recommendations for future assessments have also been included in Revision 2.

1.3 Revision Rationale and Summary of Key Changes

The principal changes in BRGMON-1 Revision 1 and Revision 2 are as follows:

- Revision 1 remained largely focused on the comparison of the response of the aquatic ecosystem to the WUP six m^3/s and the pre-WUP three m^3/s annual average flow treatments but included some changes in wording to compare all instream flow conditions including those encountered in years where higher flows were necessary; however, Revision 2 shifts the focus further toward management of year-by-year variable flow conditions and potential refinements to the Guiding Principles.
- Management questions were added in Revision 1 to address uncertainty in how Terzaghi Dam flow releases affect the emergence timing, survival and early life history (rearing habitat use) of Chinook salmon and these remain relevant under Revision 2.
- In Revision 2, minor adjustments in the wording of management questions and hypotheses were made to focus on flow conditions rather than a flow regime.
- Monthly juvenile growth sampling and annual habitat surveys were removed from aquatic productivity monitoring methods in Revision 1 and will not be applicable in Revision 2 either.

1.4 Monitoring Variable Flow Conditions

While operating under the CWR approved variances, BC Hydro implemented additional monitoring (from 2016 to 2021) in response to the variable flows during freshet that was managed separately from BRGMON-3 in Revision 1.

Revision 2 rolls together approaches from both the original WUP monitoring and the supplemental high flow monitoring to create a monitoring strategy that will allow for continued variable freshet flow conditions for future years and help to inform the Guiding Principles for management of year-by-year flow conditions.

The monitoring that is conditional on high flows (initiated upon recommendation of the JPF) is as follows:

- monitoring the short-term effect of high flows including water quality, erosion, habitat use, and fish entrainment at Terzaghi Dam;
- quantifying substrate mobilization and changes in substrate composition;
- assessing juvenile salmonid habitat availability during the modified flow regime hydrograph using BC Hydro's Telemac2D model; and
- assessing off-channel habitat use by juvenile salmonids

1.5 Management Questions

Aquatic Productivity Monitoring

Management questions one to three address how instream flow affects the physical habitat, primary and secondary productivity, and fish populations in the Lower Bridge River:

1. How do instream flow conditions alter the physical conditions in aquatic and riparian habitats of the Lower Bridge River ecosystem?
2. How do differences in physical conditions in aquatic habitat resulting from instream flow conditions influence community composition and productivity of primary and secondary producers in Lower Bridge River?
3. How do changes in physical conditions and trophic productivity resulting from instream flow conditions influence the recruitment of fish populations in Lower Bridge River?

Management question three will use BRGMON-3 Adult Salmon and Steelhead Enumeration data to account for variation in adult salmon returns when estimating the relationship between the instream flow regime and juvenile fish populations.

Fish Salvage and Stranding Risk Assessment

Management question four addresses the timing and magnitude (or 'shape') of flow changes during the descending limb of the hydrograph from peak flow to three m^3/s. This question is intended to address both uncertainty in fish stranding risk across ramp downs and the risk of stranding relative to the abundance of fish in the Lower Bridge River. While peak discharge under a flexible flow regime will vary during the high flow period, the Guiding Principles necessitate ramp down protocol to manage fish stranding risks. Under Revision 1, management question four was revised to the following:

4. What is the appropriate 'shape' of the descending limb of any annual hydrograph, particularly down to 3 m^3/s?

While the question remains unchanged in Revision 2, sufficient data is already available to provide an answer; however, the proposed approach is to reduce scope under BRGMON-1 and collect requisite data under routine ramp-down assessments carried out separately by BC Hydro in order to continue to manage potential fish stranding risks (this data can still contribute to analyses of management question four).

Chinook Salmon Emergence Timing and Early Life History

Monitoring results from 2001 to 2021 identified increased fall water temperatures associated with minimum flow releases (under the three $m^3/s/y$ treatment, six m^3/s annual average flow treatment, and the variable flow regime hydrographs in recent years) that have the potential to advance the emergence timing of Chinook salmon fry, which could impact juvenile life history strategies and survival. However, there is also uncertainty on the extent to which early emergence occurs, how it affects the survival of Chinook salmon, and whether observed declines in juvenile Chinook salmon abundance across flow trials coincides with reduced adult returns to the Lower Bridge River. Energetic requirements at the time of early emergence would be low, and fry could potentially migrate to, and rear in, downstream non-natal habitats such as the Fraser River.

The original BRGMON-1 TOR management questions did not address early Chinook salmon emergence timing and survival or if the early life history rearing habitat use by Chinook salmon changes in response to the instream flow regime. Revision 1 of this TOR posed additional management questions to determine if flow conditions influence early emergence for Chinook salmon, and to evaluate impacts to survival and early life history. These same management questions will be included in Revision 2:

5. Do increased water temperatures and early emergence associated with Terzaghi Dam flow releases affect the survival of juvenile Chinook salmon in the Lower Bridge River?
6. What freshwater rearing habitats are used by Lower Bridge River juvenile Chinook salmon and is rearing habitat use influenced by Terzaghi Dam flow releases?

Relationships between early emergence and juvenile Chinook salmon survival and recruitment will be examined as part of management question three and can be used to address management question five. Understanding rearing habitat use in management question six will help inform the response of Chinook salmon to flow management and future flow recommendations.

1.6 Management Hypothesis

Hypotheses have been developed for each management question and are intended to guide the selection of response variables. The hypotheses presented here are not an exhaustive list and other hypotheses could be examined. Alternative hypotheses were not developed because explanatory variables may change with the implementation and development of monitoring.

Aquatic Productivity Monitoring

Management hypotheses related to aquatic productivity have been developed to guide testing of key response variables related to physical conditions, primary and secondary productivity, and juvenile salmonid abundance. Assessment of these hypotheses will focus on inter-annual variation of flows to assess how various explanatory variables might affect aquatic productivity and, subsequently, how the effects could be mitigated by potentially making refinements to the Guiding Principles or considering alternate mitigation strategies if necessary.

Testing hypotheses associated with juvenile salmonid abundance will need to use adult escapement data from BRGMON-3 to isolate the effect of the Lower Bridge River flow conditions to other external variables affecting survival. This approach is intended to inform both annual and future flow recommendations for the Lower Bridge River.

Null hypotheses associated with Management Question one (physical conditions) are:

$H_{1.1}$: The thermal regime of the Lower Bridge River is independent of the observed instream flow conditions.

$H_{1.2}$: The water quality of the Lower Bridge River is independent of the observed instream flow conditions.

$H_{1.3}$: The distribution, suitability or availability of juvenile salmonid rearing habitat in the Lower Bridge River are independent of the observed instream flow conditions.

Null hypotheses associated with Management Question two (primary and secondary productivity) are:

$H_{2.1}$: <u>Periphyton accumulation and diversity</u> in the Lower Bridge River are independent of the observed instream flow conditions.

$H_{2.2}$: <u>Invertebrate abundance and diversity</u> in the Lower Bridge River are independent of the observed instream flow conditions.

Null hypotheses associated with Management Question three (juvenile recruitment) are:

$H_{3.1}$: <u>Juvenile salmonid recruitment</u> in the Lower Bridge River is independent of the observed instream flow conditions.

$H_{3.2}$: <u>Juvenile salmonid abundance and distribution</u> in the Lower Bridge River are independent of the observed instream flow conditions.

Fish Salvage and Stranding Risk Assessment (less relevant in Revision 2)

Null hypotheses associated with Management Question 4 (hydrograph 'shape') assess the potential variation in stranding risk across ramp downs and the potential for stranding to affect the productivity of juvenile salmonids:

$H_{4.1}$: <u>Juvenile salmonid stranding risk</u> in the lower Bridge River during the annual flow reduction is independent of hydrograph shape.

$H_{4.2}$: <u>Juvenile salmonid productivity</u> in the Lower Bridge River is independent of stranding mortality during the annual flow reduction.

Chinook Salmon Emergence Timing and Early Life History

The null hypothesis associated with Management Question five (emergence/survival) is:

$H_{5.1}$: Emergence timing and juvenile recruitment of Chinook salmon in the Lower Bridge River are independent of the observed instream flow conditions.

The null hypothesis associated with Management Question six (rearing location) is:

$H_{6.1}$: The diversity and relative frequency of Lower Bridge River Chinook salmon rearing strategies are independent of the observed instream flow conditions.

1.7 Key Water Use Decision Affected

Results of the BRGMON-1 Lower Bridge River Aquatic Monitoring program will contribute to the year-by-year review and refinement of the Guiding Principles and inform flow recommendations made by the JPF for the Lower Bridge under a flexible flow regime that minimizes impacts on aquatic life and habitat. Results of each year's flow conditions (expected to be variable over the study period) will be analyzed to develop annual recommendations that may include refinements to the timing, magnitude and duration of different discharges (hydrograph 'shape') for following years and flow management conditions.

2.0 Monitoring Program Proposal

2.1 Objective and Scope

The objective of the BRGMON-1 monitoring is to quantify the response of key physical and biological indicators in the Lower Bridge River to different instream flow conditions to determine which variables explain any changes in aquatic productivity. The results will continue to inform annual Terzaghi Dam operations and be used to help the JPF to make recommendations for annual operations and to potentially refine the Guiding Principles.

Following completion of capital upgrades and improvements requiring flexible operations, the data gathered will also be useful to inform future flow release strategies for the Lower Bridge River (i.e. during WUPOR).

The scope of this program includes:

- Monitoring of key physical, chemical, and biological productivity indicators;
- Annual standing stock assessments to estimate juvenile salmonid abundance and develop stock recruitment relationships using adult data from BRGMON-3;
- Developing and implementing a program to assess Chinook salmon emergence timing, rearing habitat use, and the potential effects on survival and recruitment.

2.2 Approach

As in the original BRGMON-1 TOR, the key approaches in this monitoring program are:

- Follow the standardized protocols for ecological sampling and data collection established through the monitoring programs from 1996 to 2021. This will ensure the continuity of productivity data across all instream flow conditions.
- Assessment of flow conditions on Chinook salmon early life history parameters (such as emergence timing, growth rate, and rearing habitat use) will be conducted through desktop assessment, and field or laboratory studies as required. Opportunities to leverage existing data sets, infrastructure, and collaborative research agreements will be evaluated to facilitate implantation of this program.

2.3 Methods

2.3.1 Task 1: Aquatic Productivity Monitoring

Physical parameters, primary and secondary productivity, and juvenile salmonid growth surveys occur around seven established index sites (Rkm 20.0, 23.6, 26.4, 30.4, 33.3, 36.5, 39.9) and the fall standing stock assessment will be carried out at the ~50 established survey sites.

Physical Parameter Monitoring and Water Quality Sampling

Temperature loggers are installed and maintained at each index site as well in the Yalakom River to continuously monitor water temperature. River stage are monitored using level loggers at a minimum of three sites: 1) in close proximity to Terzaghi Dam; 2) upstream of the Yalakom River confluence near the downstream end of Reach three; and 3) in Reach two downstream of the confluence with the Yalakom River. A real-time level logger is also maintained in Reach 2 to ensure continuity with past level data collection.

Water quality samples for nutrients are collected in September and November at each index site and in Carpenter Reservoir near Terzaghi Dam. Samples are also collected from the six tributaries (Mission, Yankee, Hell, Russell, Michelmoon, Yalakom, Antoine). Nutrient analysis includes but not be limited to total dissolve phosphorous, total phosphorous, soluble reactive phosphorous, nitrate, nitrite, ammonium, and total alkalinity. The water sampling methods, as well as techniques used for laboratory analysis of nutrients are described by Riley et al. (1997). Spot measurements of pH, conductivity, and temperature will also be taken at the time of sample collection.

Additional water quality monitoring scope may be included for high flow years upon recommendation of the JPF (see section 2.3.3).

Primary Productivity

To provide an index of primary productivity in the Lower Bridge River, periphyton accrual will be measured annually at each index site. Three one ft^2 artificial periphyton samplers will be installed approximately 20 m apart at each site to provide sample replication. Installations and data collection will begin near the start of the low-flow period with weekly periphyton samples collected during a six to eight-week series (~October - November). Depth and velocity measurements will be recorded at the time of plate installation and with each subsequent sample collection. Chlorophyll concentration will be used as an index of primary productivity over the sampling period. At the end of the series, a final sample will be taken and preserved for analysis of periphyton community abundance and species composition.

Additional primary productivity monitoring scope may be included for high flow years upon recommendation of the JPF (see section 2.3.3).

Secondary Productivity

To provide an index of secondary productivity, benthic invertebrate density and community composition will be estimated at each monitoring site using gravel-filled colonization baskets during the summer and fall (~September - November). Basket installations should occur at the same time as the periphyton plates for primary productivity. At each site, three baskets will be installed approximately 20 m apart to provide sample replication. Baskets will be removed at the end of the series and the abundance and diversity of invertebrates that colonized the baskets will be quantified.

Additional secondary productivity monitoring scope may be included for high flow years upon recommendation of the JPF (see section 2.3.3).

Fall Standing Stock Assessment

Fall standing stock assessments have been conducted in Bridge River in 1993, 1994, and from 1996 to 2021. Standing stock assessments are a comprehensive method to quantify how juvenile salmonid productivity responds to different instream flow regimes. To assess relative changes in fish productivity with the instream flow regime, the 50-site standing stock program, established in 1993 and then followed by BC Hydro from 1996 to present, will be repeated annually to estimate the abundance and biomass of fish. The assessment will be carried out each year in the first two weeks of September. Closed-site electrofishing depletion sampling with a minimum of three passes will be used to estimate salmonid populations by species and age class. The netted area of each site will be maintained as consistent as possible between years by referring to annual photographs of the netted area. All fish will be identified to species and age class, measured for weight and length, and returned to the river at the point of collection. Level one habitat assessments (substrate composition, water depth and velocity, netted site photographs) of each site will be carried out annually to inform habitat suitability of the site for juvenile salmonids.

Juvenile Off-Channel Habitat Use

Monitoring at the Bluenose and Applesprings sites will occur three times during the rearing period: 1) During the ascending limb of the hydrograph in May or early in the summer rearing period in June; 2) during the 15 m^3/s arearing period in June and July; and, 3) in the fall during the BRGMON-1 standing stock assessment. Areas sampled will be the same as previous years and include sites in the off-channel sites as well as in adjacent main-stem habitat. Sampling will be completed with single-pass electrofishing or another method (e.g. seine netting) to assess the species and age classes of salmon and other species in the sites. Area sampled, sampling effort, water temperature, and site photographs including the Bluenose entrance will be recorded. Fish sampling will include standard measurements (length, weight, representative photos of each species and age class) as carried out during the standing stock assessment. It is expected that off-channel habitat assessments can be largely completed by technicians with a qualified biologist providing field oversight and guidance.

Additional Juvenile Off-Channel Habitat Use monitoring scope may be included for high flow years upon recommendation of the JPF (see section 2.3.3).

2.3.2 Task 2: Chinook Salmon Emergence Timing and Early Life History

Terzaghi Dam releases during the summer and fall period increase water temperatures in the Lower Bridge River leading to the potential for early emergence of Chinook salmon fry in the upper reaches. Monthly growth sampling between 2002 and 2010 documented Chinook salmon fry in November and December in reaches 2, 3, and 4 (Sneep & Evans, 2020). The presence of Chinook salmon fry in these months aligns with emergence timing predicted from water temperature at the established index sites (Sneep et al. 2018). However, the survival of early-emergent Chinook salmon fry has not been assessed. Coho salmon emergence timing was also estimated by Sneep et al. (2018); however, early Coho emergence has not been observed, was not predicted to occur, and as a result will not be studied.

The diverse early life histories and seasonal movements undertaken by juvenile Chinook salmon (Bradford and Taylor 1997) could allow fry to survive following early emergence by seeking downstream rearing habitats within the Lower Bridge River or Fraser River. Survival of juvenile Chinook salmon can be assessed by estimating recruitment using data from BRGMON-3 and the fall standing stock assessment results; however, movement to the Fraser River and displacement during high flow conditions may limit the power of this approach.

A better understanding of the early life history of Lower Bridge River Chinook salmon could help determine rearing habitat selection and survival. This approach was outlined in the original BRGMON-1 TOR (January 23, 2012) and focused on relating the microchemistry of otoliths collected from juvenile and adult Chinook salmon with water chemistry of the reaches of the Lower Bridge River. A model was to be developed to discriminate the rearing locations used by juvenile Chinook salmon to describe their early life history and dispersal. However, an initial analysis of juvenile Chinook salmon otoliths found that while water chemistry differed between reaches, the variation in otolith microchemistry was not enough to differentiate the in-river rearing locations of juvenile Chinook salmon (Clarke et al. 2014). Further, adult otolith collection had low effectiveness using stream walk carcass surveys due to the low abundance of adult Chinook salmon.

A review of existing data from BRGMON-1 and a review of findings from other Chinook salmon systems with similar emergence issues (Sneep and Evans, 2020) indicate the potential for effects to Chinook juveniles in the Lower Bridge River, however additional field studies are required to determine whether early emergence of affects survival or has population-level impacts. To date, data from past fall standing stock assessments has been insufficient to examine stock-recruitment relationships, as the proportion of Chinook that emerge early remains poorly understood.

Future investigations should seek to improve the understanding of year-round dynamics in juvenile Chinook distribution in the Lower Bridge River. However, applying this approach in future BRGMON-1 study years will likely encounter several challenges including low adult escapements and high spring discharges due to variable flow conditions.

Given the uncertainty in the success of future efforts to assess the effects of early Chinook salmon emergence on survival, BRGMON-1 should take a collaborative and opportunistic approach to data collection, employing a strategy that includes but is not limited to leveraging existing data collection, infrastructure and relationships in the Lower Bridge River. Research priorities for such a program include: 1) evaluation of Chinook emergence timing, outmigration timing, and seasonal habitat use in Lower Bridge River; and 2) ongoing sample collection including adult and juvenile Chinook salmon otolith and DNA to support potential future analyses.

Ongoing adult otolith collection will continue through opportunistic collection during field work or dedicated stream walks. Adult otolith collection will also be supported though related monitoring programs such as BRGMON-3 stream walks or potentially a fish fence installed in the Lower Bridge River that would be collecting broodstock for the conservation hatchery program related to flow impact mitigation. Juvenile otolith collection would be expected to occur in the spring prior to high flows associated with the modified flow regime. Any analysis of otoliths would be considered part of detailed field studies.

Estimating the survival of early emergent Chinook salmon fry will help inform the annual flow management recommendations for the Lower Bridge River whether a different thermal regime during the fall incubation period will provide benefits to Chinook salmon.

2.3.3 Task 3: Conditional Monitoring

Enhancement Site Monitoring and Reconnaissance

High flow monitoring of the Bluenose and Applesprings sites during high flows will inform if high discharges in 2020 affect site function and access for fish.

Bluenose will be assessed at >15 m^3/s at each discharge stage on the ascending limb of the hydrograph to record: 1) how high discharges are interacting with the site entrance i.e. if discharges are causing erosion or if substrate is being deposited; and, 2) measure the river elevation relative to the Bluenose site pond outlet to determine the approximate discharge stage that the Bluenose site connects with the main-stem. Photographs of the site entrance showing the river level relative to upstream ponds will be taken at each discharge from repeat photo points.

Applesprings assessments at > m^3/s will occur every one to four weeks, as required, to monitor sediment accumulation into the site and flow levels at the site outlet and in the ponds. If sediment is accumulating, the areal extent of accumulated sediment at the site will be recorded with photographs taken from photo points established during the baseline site visits. Maintenance at the intake pipe will also occur if required. Water depths should also be monitored to ensure flows into the site are maintained throughout the high flows. Sediment accumulation will inform the need for maintenance frequency or larger mitigation works to address any ongoing sediment issues.

Water Quality Measurements

Water temperature, air temperature, total dissolved gases (TDG), and turbidity measurements will be taken at the three established locations between the Yalakom River confluence and the Terzaghi Dam plunge pool. Measurements will also be taken from the Yalakom River. Measurements at all location should occur on each survey day, at consistent times of day, and GPS locations saved for future reference. Water temperature monitoring must occur at >0.6 m of water depth and TDG monitoring and turbidity test must be completed in accordance with standard collection protocols. A hand-held barometer will be used to provide site-specific atmospheric pressure readings for TDG meter calibration.

Kokanee Entrainment Monitoring

The two qualified fisheries technicians will carry out visual counts to enumerate any Kokanee entrained from Carpenter Reservoir. Observations will be made from the downstream left bank of the Terzaghi Dam plunge pool to ~1.5 km downstream. Each technician will conduct separate counts of Kokanee, with the two counts used to calculate a corrected mean abundance. Observations of individual Kokanee, or groups if multiple fish are together, will include photos, GPS location, condition (e.g. uninjured or uninjured), and fish size (age/maturity). Where it is possible to safety collect any mortalities, Kokanee will be individually sampled for length, weight and scale samples taken to support BRGMON-4.

2.3.4 Task 4: Analysis and Reporting

A single technical report will be prepared annually that summarizes the key qualitative observations and empirical results from the BRGMON-1 monitoring as they relate to the aquatic productivity of the Lower Bridge River. A component of the report will include key results synthesized annually and prepared in a simple format that summarizes data across the monitoring period and helps to support JPF recommendations and BC Hydro decision-making related to variability in annual flow conditions and to inform potential refinements to the Guiding Principles.

Quantitative results from each monitoring component will be drawn upon as required to carry out detailed statistical analyses and determine how physical conditions and productivity indicators vary with the magnitude and duration of discharges under the variable flow regime. Analyses may include but not be limited to: multivariate analyses to describe changes in the temporal and spatial variation of the periphyton and invertebrate community structure; comparison of fish growth by age class between reaches and instream flow regime; stock recruitment analysis to compare juvenile salmonid abundance and biomass across flow regimes and to control streams; Bayesian models to estimate juvenile salmonid abundance and densities with an uncertainty estimate. Analysis results will be used to address the management questions.

At the end of the current monitoring period, a final synthesis report summarizing all results will be prepared.

2.4 Interpretation of Monitoring Program Results

The long-term strategy of the BRGMON-1 Lower Bridge River Aquatic Monitoring program is to collect the data required to make a scientifically defensible linkage between the instream flow conditions, key aquatic productivity changes, and the response of juvenile salmonid populations.

Upon completion of the capital infrastructure improvements in the Bridge River-Seton system that require flexible operations at Terzaghi Dam, these data will be interpreted to recommend a flow release strategy for the Lower Bridge River. However, during the interim, the approach for interpreting the monitoring program will be to use habitat indicators that vary in the short-term, such as habitat suitability and availability or primary/secondary productivity, to assess the potential to affect the aquatic productivity of higher tropic levels (e.g. juvenile salmonid abundance). All comparisons will be relative to results during the original WUP three m^3/s/y and six m^3/s/y treatments. These shorter-term indicators will be used to recommend refinements to Guiding Principles and year-by-year flow management options, as well as mitigation options or enhancements to avoid or mitigate for any negative effects of a given year's flow regime.

2.5 Schedule

The program will be implemented each year until the end of the BRGMON-1 monitoring review period. The timing of individual components of the work is described within the WUP and modified operations tasks above.

Tasks	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
Physical Habitat Monitoring	x	x	x	x	x	x	x	x	x	x
Primary Productivity Monitoring	x	x	x	x	x	x	x	x	x	x
Juvenile Standing Stock Assessment	x	x	x	x	x	x	x	x	x	x
Juvenile Off-Channel Habitat Use	x	x	x	x	x	x	x	x	x	x
Chinook Early Emergence Monitoring	x	x	x	x	x	x	x	x	x	x
Enhancement Site Access Monitoring	*	*	*	*	*	*	*	*	*	*
Water Quality Monitoring	*	*	*	*	*	*	*	*	*	*
Kokanee Entrainment Monitoring	*	*	*	*	*	*	*	*	*	*
Workshops	x									
Interim Data Report	x	x	x	x	x	x	x	x	x	x
Final Analytical Report	x	x	x	x	x	x	x	x	x	x

*Conditional monitoring will be considered as warranted under variable flow conditions, as outlined in Section 1.4

2.6 Budget

Total revised program cost $6,576,084

3.0 REFERENCES

Bacon, C.R. 2004. Migration and rearing histories of Chinook Salmon (*Oncorhynchus tshawytscha*) determined by ion microprobe Sr isotope and Sr/Ca transects of otoliths. Canadian Journal of Fisheries and Aquatic Sciences. 61: 2425-2439.

Bradford, M.J. 1994. Trends in the abundance of Chinook Salmon (*Oncorhynchus tshawytscha*) of the Nechako River, British Columbia. Canadian Journal of Fisheries and Aquatic Sciences. 51: 965-973.

Bradford, M.J. and G.D. Taylor. 1997. Individual variation in dispersal behaviour of newly emerged Chinook salmon (*Oncorhynchus tshawytscha*) from the Upper Fraser River, British Columbia. Canadian Journal of Fisheries and Aquatic Sciences. 54: 1585–1592.

Clarke, A., N. King, and K. Telmer. 2014. Use of otolith microchemistry to examine Chinook salmon life-history in the lower Bridge River. Unpublished report to Coldstream Ecology Ltd.

Higgins, P.S. and M.J. Bradford. 1996. Evaluation of a large-scale fish salvage to reduce the impacts of controlled flow reduction in a regulated river. North American Journal of Fisheries Management. 16: 666-673.

Riley, S.C., P.S. Higgins, and T. Nevin. 1997. Bridge River stream ecology and stock assessment: 1996 data report. Unpublished report prepared for B.C. Hydro, Strategic Fisheries, Burnaby, B.C.

Shrimpton, J.M., K.D. Warren, N.L. Todd, C.J. McRae, G.J. Glova, K.H. Telmer, and A.D. Clarke. 2014. Freshwater movement patterns by juvenile Pacific salmon *Oncorhynchus* spp. before they migrate to the ocean: Oh the places you'll go! Journal of Fish Biology. 85:987-1004.

Sneep, J. 2015. Fish Stranding Protocol for BC Hydro's Bridge-Seton Generation Area. Unpublished report prepared for BC Hydro, Burnaby, BC.

Sneep, J., C. Perrin, S. Bennett, and J. Korman. 2018. BRGMON-1 Lower Bridge River Aquatic Monitoring, Year 6 (2017) Results. Unpublished report prepared for B.C. Hydro. April 27, 2018.

Appendix A: Key changes to the BRGMON-1 Terms of Reference and rationale

Section/Task	Changes	Rationale
Throughout	• Shifted from a focus on flow regime to flow conditions • Introduced the Guiding Principles and a shift in monitoring focus to year-by-year variable flow conditions during freshet • Introduced the role of the Joint Planning Forum and their needs to inform annual decision based on the Guiding Principles • Consolidating scope that was formerly included in high flow and mitigation monitoring within the scope of the WUP Terms of Reference	• Although the flow regime concept will be revisited at the WUP Order review and this monitoring will continue to support that, the monitoring is shifting focus to better support variable freshet flow conditions on a year by year basis that we expect to continue until BC Hydro has substantially completed facility upgrades • Acknowledge the linkages between data collected under this monitoring program and its value to applying the Guiding Principles to year-by-year recommendations for water management • Identifying that this monitoring program will now be under more direct oversight and recommendations of the Joint Planning Forum in order to support year-by-year recommendations for water management
Fish Salvage and Stranding Assessment	• Becomes part of routine BC Hydro compliance protocol and service contracts • No longer needed to inform Management Questions	• Management Questions have been answered and fish stranding risks at various flows are well understood • Monitoring and salvage of stranded fish continues as per established protocols
Primary and Secondary Productivity	• No change to baseline monitoring approach	• Measure the change over time
Juvenile Productivity Monitoring	• Little or no change to baseline monitoring approach	• Measure the change over time
Chinook Early Emergence Monitoring	• Look to better understand the effects of early Chinook emergence on survival • Potentially look at juvenile distribution more broadly	• Understand better if Chinook early emergence that results in mortality is having a population level effect

Section/Task	Changes	Rationale
	over time	
Physical Habitat Conditions	• Confirm conditional monitoring scope • Continue to investigate critical thresholds when conditional monitoring is required and whether mitigation is warranted	• Continue to support a better understanding of the short-term effect of high flows including water quality, erosion, and fish entrainment at Terzaghi Dam • Scope under high flow conditions would be based on a JPF recommendation looking at flow thresholds that mobilize sediment, affect habitat and have the potential to entrain fish • Flow thresholds triggering actions may be refined over time
Budget	• Detailed budget table includes estimates for conditional high flow monitoring	• Document full program cost and clarify budget allocation between ONR and BC Hydro funded tasks.