Bridge-Seton Water Use Plan

Monitoring Program Terms of Reference

BRGMON-1 Lower Bridge River Aquatic Monitoring

Revision 1
November 30, 2018

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

1.0 MONITORING PROGRAM RATIONALE

1.1 Introduction

This BRGMON-1 Terms of Reference (TOR) Revision 1 is submitted in compliance with the Bridge River Project Water Use Plan Order (Bridge WUP Order) dated March 30, 2011, Schedule A, Clause 9 (a, b and c) 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

The lack of continuous flow releases from the Terzaghi Dam into the Lower Bridge River had until recently been a long standing concern of the public, First Nations, and regulatory agencies. In 1998, an agreement between BC Hydro and regulatory agencies specified that an instream flow test release and monitoring program be developed and implemented in an attempt 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.

As a result, on July 28, 2000, the Comptroller of Water Rights (CWR) under Section 39 of the *Water Act* ordered BC Hydro to initiate instream flow releases as of August 2, 2000, with an annual water budget of 3 m^3/s (3 m^3/s/y treatment) plus continued monitoring studies. Previous flow assessment studies (1993-1995) and ecological monitoring (1996-2000) had provided some data on the baseline, no flow conditions in the Lower Bridge River (0 m^3/s). BC Hydro was also ordered to continue monitoring to estimate the effect of increased 3 m^3/s/year treatment flows on the aquatic ecosystem.

Beginning in 1999, BC Hydro embarked on developing Water Use Plans across the province. The WUP Consultative Committee for Bridge River recommended that BC Hydro evaluate the relationship between different flow releases at Terzaghi Dam and key physical and biological indicators of productivity. The Bridge River WUP Order under Section 80 of the *Water Act* issued March 30, 2011 required a second treatment with an increase in the annual water budget to 6 m^3/s (6 m^3/s/y treatment) and a maximum discharge of 15 m^3/s.

Additionally, the WUP Order included monitoring and CWR approved BRGMON-1 TOR on April 12, 2012. The results from BRGMON-1 plus other related WUP studies were intended to inform the long-term flow release strategy recommendation by 2015.

In 2015 and 2016, BC Hydro received CWR approval to delay the flow recommendation to allow more time for further consultation. The long-term flow strategy recommendation continues to be deferred while consultation is ongoing.

In 2016, 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 Generating Station which affected the volume of water that could be diverted through the generating station from Carpenter Reservoir to Seton Lake. As a result, releases higher than the annual average 6 m^3/s would need to be discharged from Terzaghi Dam down Lower Bridge River in some years, until the critical upgrades are complete.

BC Hydro received a variance (March 14, 2016 and February 16, 2017) from the CWR to vary the Terzaghi Dam discharges from those specified in the WUP, and to implement a modified flow regime at Terzaghi Dam. The discharge variance permitted BC Hydro to exceed the 6 m^3/s/y treatment hydrograph and the previous 15 m^3/s maximum discharge during the annual high flow period (~March to August). Outside of the high flow period, Terzaghi Dam has been operated according to the seasonal hydrograph limits. On February 21, 2018, the CWR confirmed that BC Hydro can continue to operate under the February 2017 variance order, while consultation is underway and until a decision is made. The CWR also recognized that BC Hydro is not currently in a position to meet Clause 9 of the WUP Order.

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, and 100 m^3/s in 2018.

As part of BC Hydro's variance requests, BC Hydro noted that the aquatic productivity monitoring outlined in the BRGMON-1 TOR would continue largely unchanged for the remainder of the WUP monitoring period. The fall timing of productivity monitoring meant methods would be unaffected by the high flow period and would be able to detect changes in aquatic productivity occurring under the modified flow regime for reaches of the river that had been previously monitored. Aquatic productivity monitoring, as well as fish salvage during the descending limb of the 6 m^3/s/y hydrograph (15 to 3 m^3/s), was therefore recommended to continue for the remainder of the WUP monitoring period following the methods outlined in original BRGMON-1 TOR. Separate from the modified flow regime, reflecting learnings and results from BRGMON-1 analyses in 2012-2017, monthly juvenile growth sampling and annual habitat surveys specified in the original BRGMON-1 TOR were identified as no longer required. Additionally, the approach for studying Chinook salmon emergence timing was also reviewed and a revised study design was identified as needed to better assess how the early emergence timing affects the survival and early life history/rearing habitat selection of juvenile Chinook salmon.

1.3 Revision Rationale and Summary of Key Changes

The objectives of this BRGMON-1 TOR Revision are to: 1) improve the capacity of the TOR to address existing management questions and support a long-term flow recommendation through focused management hypotheses; and 2) improve the program by adding new management questions and refining the approach for studying Chinook salmon early emergence.

The principal changes resulting in this TOR Revision 1 are as follows:

- The wording in the TOR has been revised to focus on a long-term flow recommendation and ensure comparability across all flow regimes implemented in the Lower Bridge River.
  - The original BRGMON-1 TOR (January 23, 2012) specified comparison of the response of the aquatic ecosystem to the WUP 6 m^3/s/y treatment and the pre-WUP 3 m^3/s/y treatment. Wording has been updated throughout to compare all instream flow regimes.
  - In this Revision, the management hypotheses have been refined to define the response variables to be tested. The original hypotheses compared the pre-WUP and WUP flow regimes. The revised hypotheses can be better applied to a long-term flow recommendation.
  - The management questions, approach, and methods are unchanged as they are applicable across all flow regimes. Continuation of the current monitoring approach under any flow regime will help inform a long-term flow recommendation.
- Monthly juvenile growth sampling and annual habitat surveys have been removed from aquatic productivity monitoring methods.
  - Timing for growth surveys has varied across years and river temperature regimes have varied with flow treatments. These factors have confounded comparison of growth and monthly growth data have not been used to date to assess the effects of the instream flow regime.
  - Past habitat surveys quantified changes in the wetted area of aquatic meso-habitats with the 3 m^3/s/y and 6 m^3/s/y flow treatment hydrographs. Stable hydrographs from 2011-2015 allowed two annual field surveys to characterize wetted area at each hydrograph stage. However, the field survey approach is not suited to the variable hydrographs expected under the modified flow regime. In place of habitat surveys, hydraulic modeling as part of modified operations monitoring will be used to quantify changes in habitat.
- Management questions have been added to address uncertainty in how Terzaghi Dam flow releases and the early emergence of Chinook salmon affect survival and early life history (rearing habitat use). An approach to addressing these questions will be developed as part of this TOR.

- Management questions addressing Chinook salmon early were not included in the original BRGMON-1 TOR and two questions have been added.

- The approach proposed in the original TOR was to use juvenile otolith microchemistry analyses to determine the rearing locations of juvenile Chinook salmon within the Lower Bridge River to determine dispersal and survival for different emergence locations and timing. However, water chemistry across reaches was too similar to differentiate rearing locations using otoliths.

- A new approach to assessing the effects of early emergence on survival, rearing habitat selection and potential population-level consequences is needed. The new approach will be developed as part of this Revision and, if required, will include a combination of desktop and field studies.

- Collection of adult and juvenile Chinook salmon otoliths – that may be required for future studies - will continue during development of the new approach.

Appendix A provides more detail on the key changes made to in this revision compared to the BRGMON-1 TOR dated January 23, 2012.

1.4 Modified Operations Monitoring not included in this Revision

While operating under the CWR approved variances, BC Hydro has implemented additional monitoring in response to the modified flow regime (from 2016 to present) that is not included in this TOR Revision. Separately, we have defined specific management questions and scope for these modified operations monitoring programs that will assess effects of the modified flow regime and monitor additional explanatory variables that could explain any observed changes in aquatic productivity monitored under BRGMON-1. This modified operations monitoring will be responsive in the short term to adapt to the results obtained and will help inform the mitigation required to address any negative effects of the modified flow regime.

The additional monitoring programs implemented include:

- monitoring the short-term effect of high flows including water quality, erosion, and fish entrainment at Terzaghi Dam;
- carrying out stranding assessments and fish salvage during high flow ramp downs;
- assessing juvenile salmon habitat availability during the modified flow regime hydrograph using BC Hydro's Telemac2D model;
- quantifying substrate mobilization and changes in substrate composition; and
- assessing the feasibility of expanding aquatic productivity monitoring to Reach 1.

This additional modified operations monitoring is complementary to BRGMON-1 monitoring and the results of both programs will be integrated into a single comprehensive annual report to help inform future flow regime decisions. Reporting costs will be appropriately pro-rated to WUP and modified operations according to the scope of each of the programs. Modified operations monitoring will also support assessments outside of BRGMON-1 reporting including comprehensive data reviews of BRGMON-1, related program (e.g. BRGMON-3), and modified operations monitoring results to assess the limiting factors for aquatic productivity in the Lower Bridge River under the various flow regimes. Such assessment will assist with future monitoring and mitigation planning and development of the long-term flow recommendation.

1.5 Management Questions

Aquatic Productivity Monitoring

Management questions 1 to 3 address how the instream flow regime affects the physical habitat, primary and secondary productivity, and fish populations in the Lower Bridge River:

1) How does the instream flow regime 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 the instream flow regime 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 the instream flow regime influence the recruitment of fish populations in Lower Bridge River?

Management question 3 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 4 addresses the timing and magnitude (or 'shape') of flow changes during the descending limb of the 6 m^3/s/y treatment hydrograph from 15 m^3/s to 3 m^3/s. This 'appropriate' aspect of 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 discharge under the modified flow regime will exceed 15 m^3/s during the high flow period, the 6 m^3/s/y treatment hydrograph will be implemented outside of this period and ramp downs from 15 m^3/s to 3 m^3/s will occur as prescribed. Therefore, management question 4 is still applicable:

4) What is the appropriate 'shape' of the descending limb of the 6 m^3/s hydrograph, particularly from 15 m^3/s to 3 m^3/s ?

Chinook Salmon Emergence Timing and Early Life History

Monitoring results from 2001 to 2017 identified increased fall water temperatures associated with minimum flow releases under the 3 m^3/s/y treatment, 6 m^3/s/y treatment, and the modified flow regime hydrographs as advancing the emergence timing of Chinook salmon fry and potentially reducing juvenile abundance. However, there is uncertainty if early emergence affects the survival of Chinook salmon as the observed decline in juvenile Chinook salmon abundance following minimum flows coincided 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. New management questions to determine if early emergence affects survival and early life history are:

5) **New Question:** 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) **New Question:** 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 3 and can be used to address management question 5. Understanding rearing habitat use in management question 6 will help inform the response of Chinook salmon to current or future flow regimes and support a long-term flow regime recommendation.

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 take into account variation between the flow regime but also inter-annual variation within flow regimes to assess how various explanatory variables might affect aquatic productivity. Testing hypotheses associated with juvenile salmonid abundance will need to use data from BRGMON-3 to take into account adult escapement to isolate the effect of the flow regime. This approach is intended to inform a long-term flow recommendation for the Lower Bridge River.

Null hypotheses associated with Management Question 1 (physical conditions) are:

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

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

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

Null hypotheses associated with Management Question 2 (primary and secondary productivity) are:

$H_{2.1}$: Periphyton accumulation and diversity in the Lower Bridge River are independent of the instream flow regime.

$H_{2.2}$: Invertebrate abundance and diversity in the Lower Bridge River are independent of the instream flow regime.

Null hypotheses associated with Management Question 3 (juvenile recruitment) are:

$H_{3.1}$: Juvenile salmonid recruitment in the Lower Bridge River is independent of the instream flow regime.

$H_{3.2}$: Juvenile salmonid abundance and distribution in the Lower Bridge River are independent of the instream flow regime.

Fish Salvage and Stranding Risk Assessment

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:

$H_{4.1}$: Juvenile salmonid stranding risk in the lower Bridge River during the annual flow reduction from 15 m^3/s to 3 m^3/s is independent of hydrograph shape.

$H_{4.2}$: Juvenile salmonid productivity in the Lower Bridge River is independent of stranding mortality during the annual flow reduction from 15 m^3/s to 3 m^3/s.

Chinook Salmon Emergence Timing and Early Life History

The null hypothesis associated with Management Question 5 (emergence/survival) is:

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

The null hypothesis associated with Management Question 6 (rearing location) is:

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

1.7 Key Water Use Decision Affected

Results of the BRGMON-1 Lower Bridge River Aquatic Monitoring program will be contribute to the development of a long-term flow recommendation for the Lower Bridge River. Results of all flow regimes (0 m^3/s, 3 m^3/s, 6 m^3/s, and the modified flow regime) will be analyzed to develop a recommendation that may include refinements to the timing, magnitude and duration of different discharges (hydrograph ‘shape’).

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 regimes to determine which variables explain any changes in aquatic productivity. Monitoring will continue for the remainder of the WUP monitoring period and the results used to inform short-term (during the modified operations) and long-term (following completion of works requiring the modified operations) flow release strategies for the Lower Bridge River. 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;
- Reconnaissance surveys of fish stranding and carrying out fish salvage during WUP ramp downs (<15 m^3/s); and
- Updating and implementing a program to assess Chinook salmon emergence timing, survival, rearing habitat use, and the potential effects on recruitment.

2.2 Approach

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

- To follow the standardized protocols for ecological sampling and data collection established through the monitoring programs from 1996 to 2017. This will ensure the continuity of productivity data across all instream flow regimes.

- The approach for fish salvage and stranding risk assessment will follow the protocol for ramping assessments in other WLR programs including stage monitoring, identifying sites with a higher potential stranding risk, and carrying out fish salvage and habitat assessments at these sites during ramp downs.

- How early emergence of Chinook salmon affects the survival and early life history will be addressed with desktop and field or laboratory studies as required.

2.3 Methods

2.3.1 Task 1: Project Coordination

Project coordination will involve the general administration and technical oversight of the tasks addressing management questions. Project coordination is required for each task and will include but not be limited to budget management, staff selection, logistics planning, technical oversight in both field and analysis components, and liaison with regulatory agencies and First Nations.

2.3.2 Task 2: Aquatic Productivity Monitoring

Physical parameters, primary and secondary productivity, and juvenile salmonid growth surveys will 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 will be installed and maintained at each index site as well in the Yalakom River to continuously monitor water temperature. River stage will be 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 3; and 3) in Reach 2 downstream of the confluence with the Yalakom River. A real-time level logger will also be maintained in Reach 2 to ensure continuity with past level data collection.

Water quality samples for nutrients will be collected in September and November at each index site and in Carpenter Reservoir near Terzaghi Dam. Samples will also be collected from the six tributaries (Mission, Yankee, Hell, Russell, Michelmoon, Yalakom, Antoine). Nutrient analysis will include 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.

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 1 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 6-8 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.

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.

Fall Standing Stock Assessment

Fall standing stock assessments have been conducted in Bridge River in 1993, 1994, and from 1996 to 2017. 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 1 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.

2.3.3 Task 3: Chinook Salmon Emergence Timing and Early Life History

Terzaghi Dam releases under the 3 m^3/s/y and 6 m^3/s/y treatments increased fall water temperatures in the Lower Bridge River leading to the early emergence of Chinook salmon fry in the upper reaches. Monthly growth sampling between 2002 and 2010 collected early emergent Chinook salmon fry in November and December in reaches 2, 3, and 4 (Jeff Sneep, unpublished data). 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 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 the modified flow regime 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 sufficient to differentiate the in-river rearing locations of juvenile Chinook salmon (Clarke et al. 2014). Further, adult otolith collection had low effectiveness using streamwalk carcass surveys due to the low abundance of adult Chinook salmon.

Additional field studies may not be required to determine whether early emergence of Chinook salmon affects survival. For instance, past adult Chinook salmon abundance and spawning distribution data from BRGMON-3 could be used to estimate total annual egg deposition and the proportion of fry experiencing early emergence. Data from past fall standing stock assessment data could then be used to examine stock recruitment relationships and determine the effect of early emergence on juvenile survival. 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 modified operations.

Given the uncertainty in the success of future efforts to assess the effects of early Chinook salmon emergence on survival, the priorities for BRGMON-1 are: 1) a review of existing data from BRGMON-1 and a review of findings from other Chinook salmon systems with similar emergence issues (e.g. Nechako River, Bradford 1994) to assess the potential for survival and population level effects in the Lower Bridge River; 2) ongoing sample collection including adult Chinook salmon otolith collection and optional juvenile otoliths in the spring field to support potential future analyses; and, 3) implementing detailed field studies only if deemed necessary after a review of current findings and proposed monitoring scope.

Ongoing adult otolith collection will occur each fall for the remainder of the BRGMON-1 program through opportunistic collection during field work or dedicated streamwalks. Adult otolith collection will also be supported though related monitoring programs such as BRGMON-3 streamwalks or potentially a fish fence installed in the Lower Bridge River that would be collecting broodstock for a conservation hatchery program related to modified operation 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 long term flow recommendation for the Lower Bridge River, in particular, whether restoring the previous thermal regime during the fall incubation period will provide benefits to Chinook salmon.

2.3.4 Task 4: Fish Salvage and Stranding Risk Assessment

Fish salvage and stranding monitoring will be carried out at each Terzaghi Dam ramp down during the descending limb of the hydrograph. Ramp down at discharges <15 m^3/s will be considered part of BRGMON-1 while salvage at discharges >15 m^3/s will be part of the modified operations monitoring.

Fish salvage and stranding monitoring will accompany each Terzaghi Dam ramp down from 15 m^3/s to 1.5 m^3/s. Stage changes during ramp downs will be monitored and ramping rate confirmed post-season with water level loggers (installed under *Physical Parameter Monitoring and Water Quality Sampling*). Fish salvage will take place as required, between Terzaghi Dam and the Yalakom River confluence at sites identified during in-season reconnaissance (part of *Water Quality, Erosion, and Entrainment Monitoring*) or from previous data. Known off-channel habitats a short distance downstream of the Yalakom River confluence near Horseshoe Bend will be surveyed at a lower level of intensity (since these habitats are influenced by the natural hydrology and receding flows from the Yalakom River). Fish salvage will follow established methods (Higgins and Bradford 1996) but include methodological updates added in 2017-2018 designed to support improved assessment of stranding risk. Characteristics of each salvage site will be recorded (GPS location, area, habitat type) and standard methods (electrofishing, dip net, seine net) used to salvage stranded fish. Salvage effort of each method at each site will be recorded. Salvaged fish will be enumerated and identified to species and age-class and a sub-sample of each species and age-class measured for fork length and weight.

Fish salvage data will be used to inform a stranding risk assessment that will assess relative stranding risk across discharges, stage changes, river banks, river reaches, and ramp rates. The stranding risk assessment will be supported by BC Hydro Telemac2D hydrodynamic model estimates of changes in wetted area between discharges that will be used to estimate potential stranding risk between river banks, reaches, and stage changes.

2.3.5 Task 5: 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 and modified operations monitoring, as they relate to the aquatic productivity of the Lower Bridge River. 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 modified 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 of both BRGMON-1 and modified operations monitoring. At the end of the current BRGMON-1 monitoring program, a single synthesis report will summarize all BRGMON-1 and modified operations monitoring results.

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 regime, key aquatic productivity changes, and the response of juvenile salmonid populations. Upon completion of the works requiring the modified operations, these data will be interpreted to recommend a long-term flow release for the Lower Bridge River. However, for the period where modified operations are required, the approach for interpreting the monitoring program results, as they relate to the modified flow regime, 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 for the modified flow regime to affect the aquatic productivity of higher tropic levels (e.g. juvenile salmonid abundance). All comparisons will be relative to results during the 3 $m^3/s/y$ and 6 $m^3/s/y$ treatments. These short-term indicators will be used to recommend mitigation options or enhancements to avoid or mitigate for any negative effects of the modified flow regime.

As additional years of data are collected during the modified flow regime, interpretation of program monitoring results will involve using the results from long-term productivity indicators, such as juvenile salmonid abundance and biomass, to identify variables affecting aquatic productivity and any further mitigation or compensation required. Variables will be identified by formulating and testing alternative hypotheses to the null hypotheses associated with the WUP and modified operations management questions. The null hypotheses presented are not exhaustive and interpretation of results may include formulation of new null or alternative hypotheses to better explain relationships between the flow regime and aquatic productivity monitoring results. Testing the null and alternative hypotheses will inform importance of the different factors associated with the instream flow regime to aquatic productivity and identify where inferential and analytical powers are limited. Determining the importance and confidence level associated with the different factors associated with the instream flow regime will ultimately allow for the design of a long-term flow recommendation for the Lower Bridge River.

2.5 Schedule

The program will be implemented each year until the end of the BRGMON-1 monitoring program in 2021. The timing of individual components of the work is described within the WUP and modified operations tasks above.

2.6 Budget

Total revised program cost $3,303,715.

3.0 REFERENCES

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

Section	Changes	Rationale
1.1 Background	• Updated the background section summarizing the pre-WUP and WUP flow treatments. • Clarified references to the WUP Order. • Added background on the capital improvements requiring the modified flow regime.	• Added new relevant history and background since the original Terms of Reference from 2012.
1.2 Revision Rationale and Summary of Key Changes	• Summarized the changes in the Revision and the rationale. • Clarifies scope not included in this TOR related to only modified operations. • Clarified how the WUP and modified operations monitoring will be integrated in reporting.	• New section added.
1.3 Modified Operations Monitoring not included in this Revision	• Outlined the additional monitoring being implemented by BC Hydro as part of the variance applications for the modified flow regime.	• New section added.
1.4 Management Questions	• Two new management questions were added to address Chinook salmon emergence. No changes were made to the original management questions.	• Management questions specific to Chinook salmon emergence timing were not identified in the original TOR.
1.5 Management Hypothesis	• Refined the management hypotheses to specify the response variables to be tested.	• The management hypotheses contained in the original TOR restricted hypothesis testing to pre-WUP and WUP flow regimes comparison rather than identifying various attributes that could be applied to define a long-term flow recommendation.
1.6 Key Water Use Decisions Affected	• Shortened and simplified this section to focus the decision on the long term flow recommendation.	• This section previously cited competing management hypotheses. However, the results of all monitoring, regardless of the flow treatment, will help inform a long-term flow release recommendation. • A long term flow recommendation cannot be implemented until capital improvements are completed.
2.1 Objective and Scope	• Clarified this section to align the terminology with the rest of the TOR. The long-term objective of the program remains the same. • Short-term objectives have been noted.	• The focus of the program continues to be to define a long term flow release regime for the Lower Bridge River. • BRGMON-1 results will be used to inform the annual shape of the hydrograph during the period of the modified flow regime.
2.2 Approach	• Updated to provide a better overview of the monitoring approach and tasks.	• Chinook salmon emergence timing was not previously included in this section.

Section	Changes	Rationale
2.3 Methods	• *Task 2* '*Field Sampling*' renamed to '*Aquatic Productivity Monitoring*'. • *Ecology Sampling: Nutrients and Water Quality* component renamed to *Physical Parameter Monitoring and Water Quality Sampling*. Parameter monitoring previously under *Habitat Assessment* moved to this section. • *Fish Species Composition, Growth and Abundance* updated to remove growth sampling and biopsy sampling for BRGMON-12. • *Habitat Assessments* are have been removed and replaced with more-detailed habitat availability and suitability modeling to be carried out under the *Fish Salvage and Stranding Risk Assessment* task and modified flow regime modeling. • *Task 3: Chinook Salmon Emergence Timing and Early Life History* methods have been updated. The *Rampdown Assessment* task has been renamed to *Task 4: Fish Salvage and Stranding Risk Assessment* • In *Task 5: Analysis and Reporting,* replaced the requirement for a 2015 synthesis report with a 2021 synthesis report. • Added a requirement for an annual report that summarizes monitoring results to date from both WUP and modified operation monitoring and carries out detailed data analyses.	• All physical parameter monitoring combined into a single section for clarity. • Monthly growth sampling has not been used to inform aquatic productivity monitoring results to date. Comparison of growth can be made under the *Fall Standing Stock Assessment* task. Biopsies for BRGMON-12 are no longer required. • *Habitat Assessments* were completed over multiple years for a single flow treatment hydrographs to estimate the changes in wetted area for different meso-habitat types. However, the modified flow regime hydrograph will vary annually and the field surveys under past habitat assessments will be unable to capture the annual variability. Habitat modeling (Telemac2D model) will be able to provide annual estimates of habitat availability. • Previously proposed methods for studying Chinook salmon emergence were unable to determine the rearing location or survival of early-emerging Chinook salmon. The updated approach proposes developing a comprehensive program to assess Chinook survival and life history changes in response to warm fall water temperatures The collection of adult and juvenile otoliths will occur while this scope of developed to ensure samples are available if required by future studies. • A detailed report integrating WUP and modified operations monitoring will allow for improved confidence in the annual management of the LBR hydrograph (short term objective). • Annual reporting will need to take into account the modified flow regime to fully describe any observed changes in aquatic productivity.
2.4 Interpretation of Monitoring Program Results	• Analytical details were updated and moved to Section 2.3.5 *Task 5 Analysis and Reporting* as part of the annual reporting requirements. • Interpretation of the results was updated to reflect the need to have short and long-term indicators to determine any effects of the modified flow regime.	• Detail analyses will be required annually to improve the year-to-year management of the modified flow regime. Analysis updates reflect the most recent approach used. • Requirements for data interpretation have changed as a result of the modified flow regime.
2.5 Schedule	• No changes to the seasonal timing of WUP monitoring components.	

Section	Changes	Rationale
2.6 Budget	• Updated as required to incorporate the removal and addition of monitoring components. • Timing of the synthesis report shifted from prior to long term flow recommendation in 2015 to 2021 as described in 2.5 above. • Reporting budget has been included as a pro-rated proportion of WUP reporting and additional modified flow regime monitoring.	
3.0 References	• Updated as required.	