Columbia River Project Water Use Plan

LOWER COLUMBIA RIVER FISH

Reference: CLBMON-44

Lower Columbia River Physical Habitat and Ecological Productivity Monitoring – Modelling Updates (2019)

Study Period: 2019

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Lower Columbia River Fish

Monitoring Program No. CLBMON-44

Lower Columbia River Physical Habitat and Ecological Productivity – Modelling Updates

2019 Summary Report

Prepared for

BC Hydro Generation
Water Licence Requirements

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Cover photos:

From left to right: 2017 Genelle; 2016 winter deployment (S7); 2019 bathymetry survey; 2018 spring deployment (S2)

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1.0 INTRODUCTION

A twelve-year study of the physical habitat and ecological productivity on the Lower Columbia River (LCR) (CLBMON-44), between the outflow of the Hugh L. Keenleyside (HLK) Dam and the Birchbank gauging station (BBK) near the southern British Columbia border was finalized in 2019. A final summary report of hydrological and benthic productivity data collected between 2008 and 2019 was issued to BC Hydro and Power Authority (BC Hydro) in August 2019 (Olson-Russello et al. 2019).

Discharges from the HLK Dam during winter and spring have the potential to affect salmonid spawning and rearing habitats. To minimize impacts, BC Hydro altered operations of HLK Dam to include: 1) rainbow trout protection flows which stabilize or increase HLK discharges from April 1 through June 30, to reduce redd dewatering and subsequent egg loss of rainbow trout, and 2) mountain whitefish flows which limit maximum discharges during peak spawning in January and later stabilizes discharges to reduce egg dewatering until mountain whitefish emerge in late March (BC Hydro 2007).

The objective of CLBMON-44 was to examine the influence of the managed flow periods (Mountain Whitefish (MWF) Jan 1 - Mar 31; and Rainbow Trout (RBT) Apr 1 - Jun 30; and a control fall fluctuating flow (FFF) Sep 1 - Oct 31) period on select physical habitat components and ecological productivity measures. Benthic productivity, inclusive of periphyton and benthic invertebrates, are a primary food source for fish. Physical habitat components are important variables that influence the benthic productivity of a river.

The Physical Habitat component involved monitoring water temperature, stage, electrochemistry and nutrient levels in LCR to allow tracking of potential changes in physical habitat and ecological health due to flow conditions. The Ecological Productivity component involved monitoring periphyton and benthic invertebrates to assess potential changes in trophic productivity and overall ecological health of LCR resulting from the continued implementation of MWF, RBT and FFF (BC Hydro, 2005a,b).

Despite the implementation of RBT protection flows, it is unclear as to how these flows have affected the local RBT population abundance (BC Hydro 2018). To reduce uncertainty, an experimental approach where RBT protection flows would be stopped and re-implemented in alternating years was initiated in 2019 (e.g. no RBT protection flows in 2019, but protection flows in 2020) for a maximum duration of five years, until 2023.

The objective of this 2-year contract is to assess how the RBT protection flows or lack there of, may affect the ecological productivity of Norn's Creek fan, an important spawning and rearing habitat for Rainbow Trout. Because the lack of RBT protection flows are likely to generate increased variability in water levels, there is a potential for altered primary production. To address this question, the following work plan was developed:

- Continue the maintenance and collection of water level logger data for all pre-established sampling locations in 2019 and 2020;
- Undertake a bathymetric survey of LCR between water level loggers S2 and S3 (inclusive of Norn's Creek fan);
- Develop a hydraulic model for the area using Telemac-2D software;

- Utilize the historic water elevation data at S2 and S3 to calibrate the hydraulic model;
- Produce a productivity model to quantify total productivity estimates of invertebrate biomass and chlorophyll-a of the Norn's Creek fan with and without RBT protection flows.

This summary report outlines the work that has been undertaken in 2019 and provides an overview of next steps that will be completed in 2020.

2.0 STUDY AREA

The study area is on LCR downstream of HLK Dam near Castlegar, BC at the confluence with Norn's Creek (Figure 2-1). Water quality index station 2 (WQIS2) is located approximately 1 km upstream of Norns Creek, and WQIS3 is about 800 m downstream of Norns Creek. The hydraulic model extent is inclusive of the whole river between WQIS2 and 3. The productivity model extent only includes the Norn's Creek fan where Rainbow Trout redds have been documented (Figure 2-1).

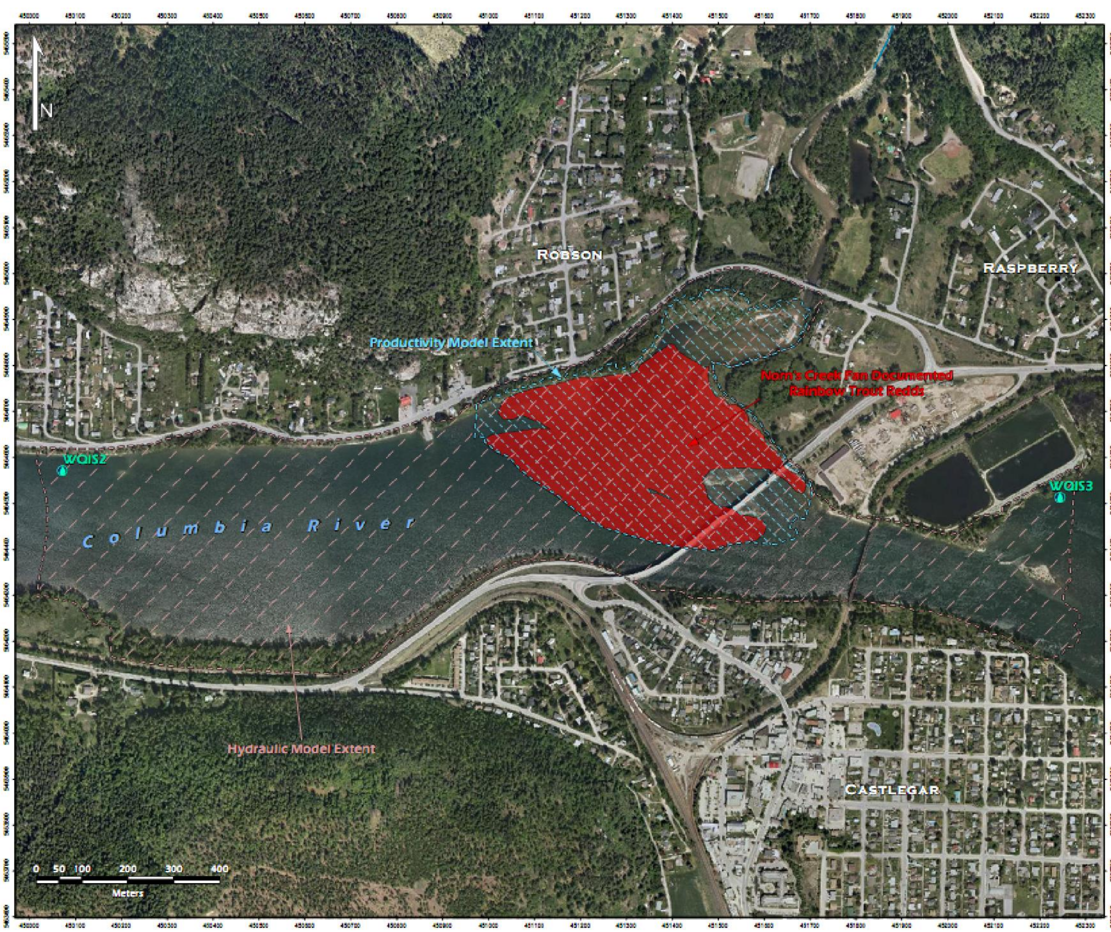

Figure 2-1: Map of the Lower Columbia River study area.

3.0 METHODS

3.1 Water Level Loggers Data Download and Maintenance

Level loggers that were installed as part of the CLBMON-44 program (Olson-Russello et al. 2019), were left in place and data was downloaded in March, June and October of 2019. There are five LCR water quality index stations (WQIS1-5) on LCR and a single station on Kootenay River (WQC2) (Table 3-1). Physical parameters collected in 2019 included water temperature and water elevation data.

Table 3-1: Monitoring Stations, Sample Types and UTM Coordinates (UTM 11).

Station Name & General Location	Station Characteristics	Sample Type	UTM Coordinates	
			Northing	Easting
WQIS1 (across from Zellstoff Celgar Ltd.)	Upstream of Celgar outfall	Water temperature/water elevation	5,465,742	445,693
WQIS2 (upstream of boat launch)	Downstream of Celgar outfall	Water temperature /water elevation	5,464,573	450,072
WQIS3 (downstream of railway bridge)	Within back channel area	Water temperature /water elevation	5,464,517	452,244
WQIS4 (~7 km downstream of Kootenay River confluence)	Left bank off of bedrock face	Water temperature /water elevation	5,455,332	452,653
WQIS5 (~ 2.2 km upstream of Birchbank)	Right bank off of bedrock face	Water temperature /water elevation	5,450,221	448,514
WQ C2 (Kootenay River)	Right bank, off of bedrock face	Water temperature /water elevation	5,462,911	454,114

3.2 Bathymetric Survey

Ecoscape completed a bathymetric survey of LCR between WQIS2 and WQIS3 on June 6-7, 2019. A multibeam sonar and real time kinemetric (RTK) GPS base station was used to scan the bottom of the riverbed and relate it to the real-world location. Ecoscape used a multibeam system that collects point data in a swath as a function of depth. The sounder was set at an 8:1 ratio which allowed an 8-meter-wide swath for every 1 metre of water depth with at least a 50% overlap of coverage. This setup facilitated an extremely dense point cloud to be collected in a time efficient manner. Unfortunately, the day before the survey, water levels dropped by approximately 1 metre, which limited our ability to collect data in shallow water.

Our intention was to use LIDAR to infill the shallow water and land portion of the survey, however, when trying to get access to the LIDAR data, the Province indicated that it would not be available in the short-term. Because it was anticipated that the model creation and simulation time would be a time constraint, it was decided to complete a second survey to fill in the bathymetric data gaps and the topographic component. The second survey was conducted on July 30-31, 2019. This survey was completed using a single beam sonar to record riverbed elevations and a RTK base station to integrate it to a the first survey. The single bean sonar was chosen, as there was no benefit to the more expensive multibeam setup when surveying in very shallow water (1-2 metres). During this survey the water depth was much higher and coverage of the entire Norn's Creek fan and many of the gravel bars were surveyed with the bathymetric setup. The remaining topographic data was collected on foot using a RTK Rover connected to the common GPS base station.

3.3 PAR Readings

On October 10, 2019, light intensity, turbidity and depth were recorded in LCR to eventually model light availability. Additional data collection of light intensity, turbidity and depth will occur during the RBT flow period (Apr 1 – Jun 30) and modeling of the entire dataset will be subsequently undertaken. Reporting on this aspect of the project will occur in the fall of 2020.

3.4 Hydraulic Model Development

TELEMAC-2D is a hydraulic modelling software that provides water depth and velocity for each discrete model cell. Saint-Venant equations are used with the finite-element method and a computation mesh to model depth and velocity based on discharge (NHC 2016). The computation mesh is usually generated from bathymetric data. The implementation of a TELEMAC-2D model requires a mesh, model parameters, discharge and elevation data for the area of interest.

The mesh for the TELEMAC-2D model was generated by processing the bathymetric survey data in ArcGIS and BlueKenue. ArcGIS was used to clean the points collected from the survey and generate a raster with a 0.5 metre resolution. A 0.5 metre point cloud of the bathymetric and topographic elevations was generated from the raster to be imported into Blue Kenue. Blue Kenue was developed by the National Research Council of Canada and is used for model data preparation, simulation results analysis, visualization and animation. The resulting mesh with 7,183 nodes and 13,709 elements was used in TELEMAC-2D for the model simulation.

The TELMAC-2D model requires hourly discharge data and elevation from the downstream limits of the model. Model simulations were run on individual months and required hourly discharge data from HLK Dam and hourly elevations from the WQIS3 level logger. When WQIS3 logger data was un-available, a discharge and elevation relationship from existing data was used to predict hourly elevations at WQIS3.

Default model parameters were used for the TELEMAC-2D, except for Manning's n. Manning's n values represent the roughness of the channel which corresponds to channel bottom friction applied to flow. Model calibration was run to determine the most suitable Manning's n during the RBT flow period (Apr 1 – Jun 30). Calibration of the TELEMAC-2D model required the selection of years that had a typical range of discharges during the RBT flow period. To calibrate the model, the TELEMAC-2D models for April 2010 and 2012, and June 2015 and 2017 were run with four different Manning's n values: 0.046, 0.048, 0.050, and 0.052. The TELEMAC-2D predicted elevations, at WQIS2 and WQIS3, were compared to the logged elevations using each model simulation with a different Manning's n. A Manning's n of 0.048 was determined to be the most suitable value, as the simulated water levels aligned most closely to logged levels at WQIS2 and WQIS3.

3.5 Datasets

The primary data collected as part of the CLBMON-44 modelling updates is summarized in Table 3-2.

Table 3-2: Predominant physical datasets.

Name/Description	Source	Frequency of Collection
Physical Datasets		
LCR / Kootenay River Elevation / Water Temperature	Data collected at 5 stations (LCR) and 1 station (Kootenay River)	3-4 times annually
Mean Daily Discharge at Hugh L. Keenleyside (HLK)	Data obtained from Poisson Consulting	Continuous
Light Intensity, turbidity and depth	Field data	Collected once in 2019, additional collections planned for 2020
Bathymetric survey data	Bathymetric and topography survey of area of interest	Multiple days in summer of 2019

4.0 RESULTS AND DISCUSSION

4.1 Flow Context

Figure 4-1 illustrates the mean daily flow below HLK Dam during the Rainbow Trout flow period (Apr 1 – Jun 30) when RBT flows were in affect (1992-2018), and for 2019, the first year RBT flows were not implemented. Even though BC Hydro indicated that 2019 may not be that different from years when RBT flows were undertaken, there were two sizable drops in HLK discharge during late May and early June that could impact the riverine productivity and spawning redds (Figure 4-1). In addition, the flows during April of 2019 were lower compared to years when RBT flows were implemented (Figure 4-1).

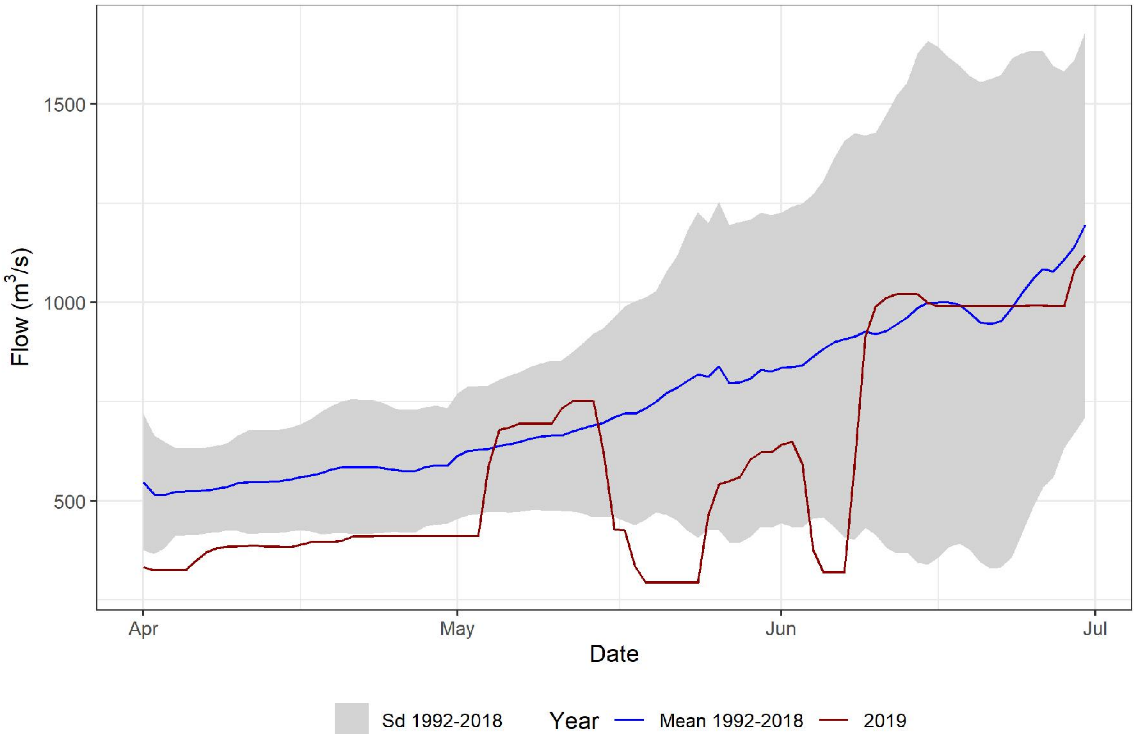

Figure 4-1: **HLK mean daily flow for 2019 and during managed RBT flows (1992-2018).** The red line depicts the mean daily flow at HLK in 2019. The blue line is the mean daily flow from 1992-2018 and the grey shaded area is the standard deviation of the mean daily flows from 1992-2018.

4.2 Mean Daily Water Levels

This report includes water level elevation data collected between Jan - Oct 2019. The logger at WQ1S1 malfunctioned and unfortunately the data for 2019 was not accurate, and therefore has not been included (Figure 4-2). The level loggers in use have been deployed since 2008 and several of them have needed replacement batteries and have exhibited issues with accurate data collection. As concerns arise, the loggers have been sent back to the manufacturer for repair and/or battery replacement. We are now observing that recently repaired loggers are beginning to fail for a second time, likely indicating that their life span is limited.

The other level loggers collected accurate data in 2019, and Figure 4-2 illustrates the variability at each site compared to the mean daily water levels during previous years. In April 2019, the discharge from HLK was so low, that all the LCR level loggers were exposed and the water elevation at these sites could not be determined (Figure 4-2).

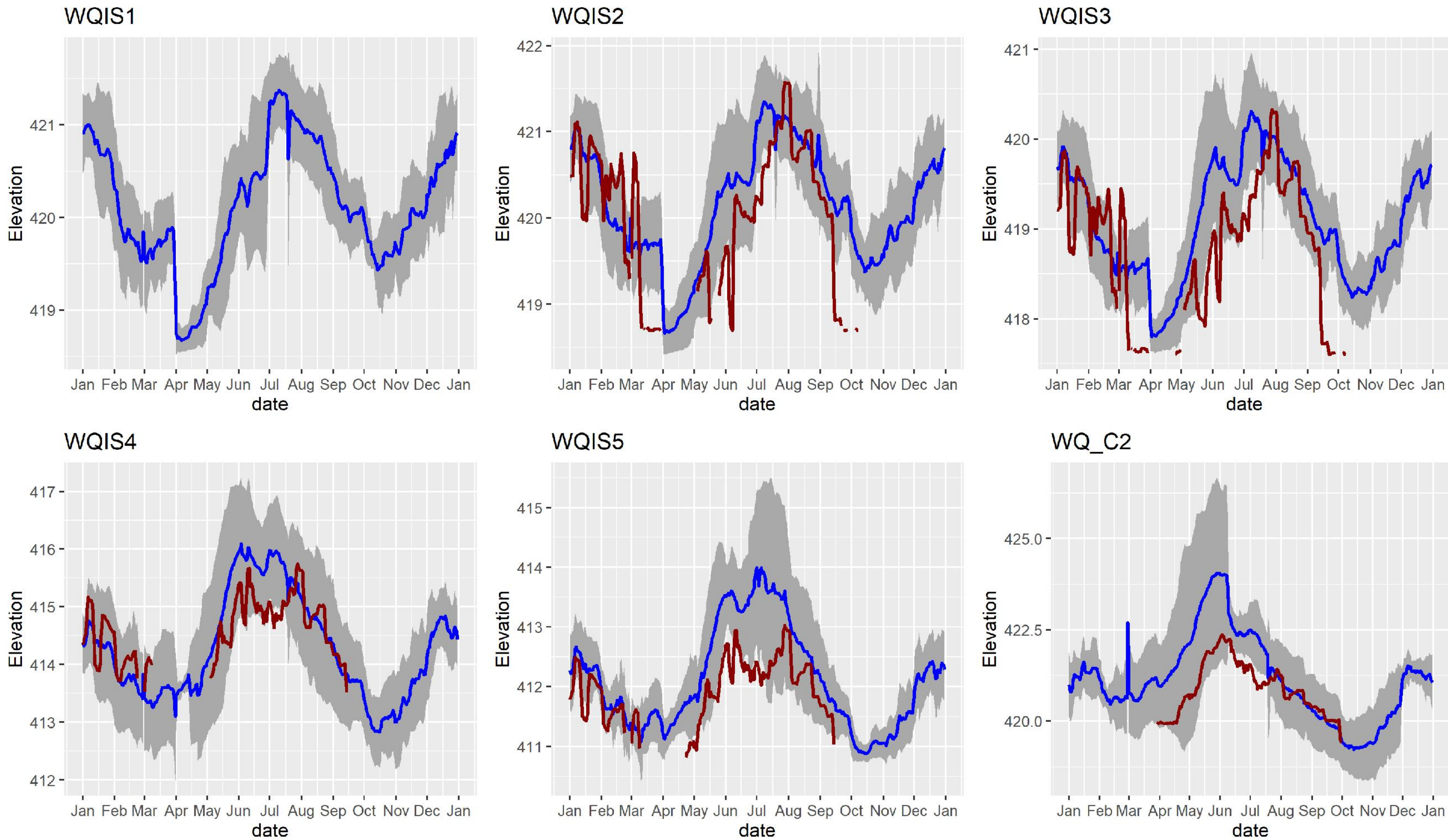

Figure 4-2: Mean daily water levels recorded at WQIS1 – 5 on LCR and at WQ C2 on Kootenay River. The red line depicts the mean daily water level recorded at each site in 2019. The blue line is the mean daily water level throughout the duration of the study for LCR sites (2008-2019± SD (gray shaded area)) and for an eight-year duration at the Kootenay River site (2011 - 2019± SD (gray shaded area)). The SD is shown to highlight the variation in the data over multiple years, but it could not be determined for all months due to gaps in the data.

4.3 Mean Daily Water Temperature

The 2019 daily water temperatures were generally similar to the mean water temperatures recorded throughout the study (Figure 4-3). However, it is interesting to note the higher water temperatures observed in May and June of 2019 occurred when HLK flows were reduced, indicating that water temperature is sensitive to the reduction in flow. Historically, WQIS4 and 5 exhibited a higher variability than sites WQIS1 - 3, due to the influx of flows from Kootenay River. This was not observed in 2019; rather the altered flows from HLK appeared to have a greater role on water temperature, even at sites downstream of the Kootenay confluence.

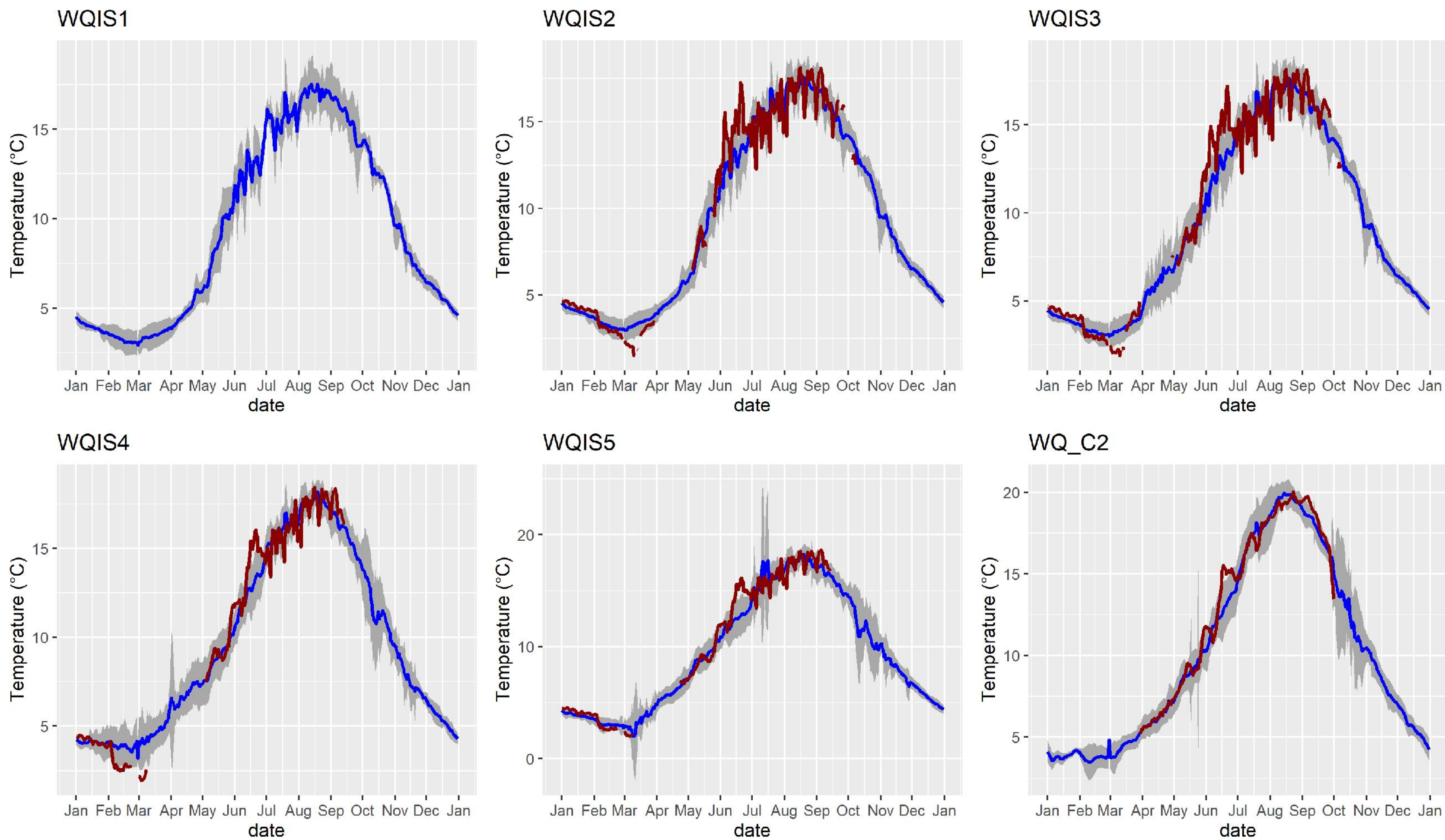

Figure 4-3: **Mean daily water temperatures recorded at WQIS1 – 5 on LCR and at WQ C2 on Kootenay River.** The red line depicts the mean daily water temperature recorded at each site in 2019. The blue line is the mean daily water temperature throughout the duration of the study (2008-19) ± SD (gray shaded area).

4.4 Hydraulic Model Outputs

Calibration of the hydraulic model required that elevations were available for both WQIS2 and WQIS3. The WQIS2 and WQIS3 level loggers have discontinuous datasets due to sensor malfunction and/or exposure. The years that had accurate level logger data for WQIS2 and WQIS3 during the RBT flow period are displayed in Figure 4-4, along with the range of mean hourly discharge from HLK Dam.

The years with available elevation data exhibited a range of flows during the RBT flow period. For example, flows in June 2015 were high compared to June 2017-2019 because of an earlier freshet. Exposure of the level loggers during the low flow period in April occurred in some years (i.e. 2015, 2017), resulting in lost data. There were only four years (2009 – 2010, 2012, 2014) that had available April elevation data at both WQIS2 and WQIS3. April 2010 had the lowest HLK flows, whereas April 2012 had the highest HLK flows (Figure 4-4).

April 2010, April 2012, June 2015 and June 2017 were selected for model calibration because these periods spanned the full range of HLK flows that had available data. May data was not included for calibration because it fell within the range of April and June data. The Root Mean Squared Error (RMSE) and Mean Bias Error (MBE) were calculated for the predicted WQIS2 elevations and the measured WQIS2 elevations. The most accurate hydraulic models that had the lowest RMSE were the models that used Manning's n of 0.046 and 0.048 (Table 4-1). The model with Manning's n of 0.048 had the lowest bias of all models with a MBE of 0.003 m.

Table 4-1: Model calibration results using WQIS2 level logger elevations from April 2010, April 2012, June 2015 and June 2017.

Manning's n	Root Mean Squared Error	Mean Bias Error
0.046	0.131	0.035
0.048	0.130	0.003
0.05	0.138	-0.027
0.052	0.152	-0.057

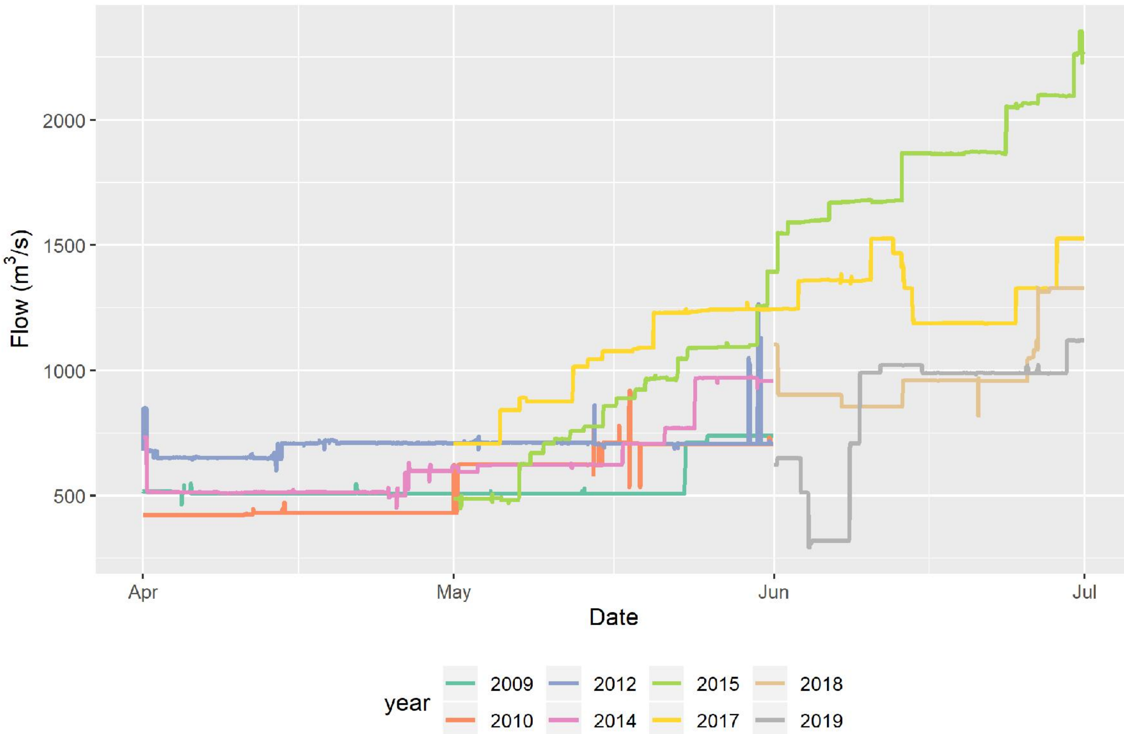

Figure 4-4: **Mean hourly discharge from HLK Dam when elevation data was available for WQIS2 and WQIS3 during the RBT flow period.**

5.0 NEXT STEPS

In 2020, level logger data will continue to be collected, as well as field data that will be used to model light availability. The hydraulic model will be finalized and run for the time frame of interest, but obstacles that must first be overcome include the need for hourly elevations at WQIS3 prior to 2009.

Hourly elevations for the WQIS3 logger are not available before 2009 but are required for the hydraulic model. In May and June, the Kootenay River frequently causes backwatering at the location of the WQIS3 logger. Backwatering effects during the RBT flow period make it difficult to predict the hourly elevation of WQIS3 from HLK discharges. As part of Brilliant Expansion Project (BRX) productivity assessment, a HEC RAS 1D hydraulic model was developed for the LCR and Kootenay River below Brilliant Dam (Schleppe et al. 2015). The HEC RAS 1D model accounts for backwatering from Kootenay because it includes HLK flows and Brilliant Dam flows as inputs to the model. The HEC RAS 1D model can be used to accurately predict hourly elevations for WQIS3 from 1984-2009. WQIS3 predicted elevations from HEC RAS 1D are available for 1992-2014. The HEC RAS 1D model will need to be run for April-June 1984-1992 to provide WQIS3 hourly elevations.

To determine hourly water depths (i.e. if a given area is wet or dry), the hydraulic model will be run for April to June 1984-2019. Years that are anomalies during the RBT flow period will not be included in the analysis. For example, the daily mean discharge from HLK was >2000 m^3/s for most of June 1992. June 1992 was an anomaly and had very high discharges because the 95% quantile for discharges during the RBT period was 2036 m^3/s. BlueKenue will be used to extract hourly water depths from the hydraulic model. PostgreSQL and R will be used to import all hourly depth data into a PostgreSQL database.

Finally, daily productivity estimates of chlorophyll-a and invertebrate biomass will be calculated by using the hourly water depths to determine hourly growth or death rates for each discrete cell in the Norm's Creek Fan area. The productivity models assume that if a given cell is exposed, then periphyton and benthic invertebrates are in a state of death. However, if a given cell is submerged, then the periphyton and benthic invertebrates are in a state of growth. The growth and death curves that will be used are from BRX productivity assessment and were developed for the LCR (Schleppe et al. 2015). The areal productivity of each cell in the Norn's Creek fan area will be summed to determine the total daily productivity.

The total productivity estimates of invertebrate biomass and chlorophyll-a will be compared between years that have managed RBT flows and years that have no RBT managed flows. Daily productivity or monthly productivity estimates could be compared. However, the statistical test and comparison will depend on the data distribution and the sample sizes.

6.0 REFERENCES

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7.0 APPENDIX 1. Timeline and Milestones of CLBMON-44 (Modelling Updates)

Table A1. Timeline and Milestones of CLBMON-44.

Year	Milestones
2019	Collection of water temperature / water elevation data, river bathymetry, development of a Telemac-2D model, status report
2020	Collection of water temperature / water elevation data, field data collection of light intensity, turbidity, and depth, productivity model development, final reporting