# Columbia River Project Water Use Plan

# Revelstoke Flow Management Plan

# Monitoring Program Terms of Reference

- **CLBMON-15a Middle Columbia River Physical Habitat Monitoring**

**Revision**
**January 29, 2015**

# Monitoring Program No. CLBMON-15a
# Middle Columbia River Physical Habitat Monitoring

## 1.0 MONITORING PROGRAM RATIONALE

### 1.1 Background

The fundamental fish objective for the Columbia River Water Use Plan is to maximize the abundance, diversity and condition of wild, indigenous fish stocks in the Columbia River system (BC Hydro 2005). The Consultative Committee (CC) developed several sub-objectives, one of which was to maximize large river habitat in the mid Columbia River (MCR) between Revelstoke Dam and Arrow Lakes Reservoir, for the purpose of maximizing ecological productivity, increasing juvenile fish use, maximizing adult fish abundance, condition, and growth and fecundity spawning (BC Hydro 2005).

To monitor the effectiveness of the minimum flow in meeting the environmental objectives, the WUP CC recommended the implementation of a program to document physical habitat characteristics of the Middle Columbia River to compare how the implementation of a minimum flow affects physical habitat conditions for benthic organisms and fishes. The collection of physical habitat data was also anticipated by the WUP CC as a fundamental information requirement for supporting other monitoring programs associated with the Revelstoke Flow Management Program (RFMP). The intent was to ensure that it would be possible to construct a logical linkage between the operation of Revelstoke Dam and ecological response indicators for the productivity of the benthic community, changes in fish habitat use, and productivity of fish populations.

In 2007, BC Hydro received approval for the construction of a fifth unit (REV 5) at the Revelstoke Generating Station. REV 5, which entered in operation in December, 2010, adds 500 MW to the station's generating capacity and its operation allows for peak discharge of 2124 cms, an additional 425 cms over current operations. The in-service date for full operation of REV 5 coincided with the start of the minimum flow. Some of the predicted trends with REV 5 operations include: a general increase in the frequency of high flows with corresponding increases in river elevations and velocities immediately downstream of the dam, and a general increase in average daily discharge during low demand periods (BC Hydro 2006). An addendum to the WUP includes the provision to include monitoring of REV 5 operations in these Terms of Reference. Therefore, **references to evaluating the minimum flow releases or operational changes should be interpreted as including REV 5 operations**.

The CLBMON-15 monitoring program was initiated in 2007. The Terms of Reference (ToR) were subsequently revised in 2010 (BC Hydro 2010) to take into account the effects of REV 5. As per the recommendations of the CC, a technical review of the RFMP occurred in early 2014 (RFMP Review). At the RFMP Review, BC Hydro recommended changes to the scope and tasks associated with this monitoring program. The present ToR takes into account these changes. Please refer to **Table 15a-3** for key changes and the rationale for their inclusion.

## 1.2 Management Questions

The key management questions addressed by this monitoring program are:

1) How does the implementation of the 142 cms minimum flow affect water temperature in the flowing reach of the Middle Columbia River? What is the temporal scale (diel, seasonal) of water temperature changes? Are there spatial differences in the pattern of water temperature response?

2) *Original Question 2 deleted*[1]

3) How does the implementation of the 142 cms minimum flow affect the range and variability in river level fluctuation in the Middle Columbia River? Are there temporal (seasonal scale) or spatial (reach scale) differences in the pattern of response?

4) Does the implementation of the 142 cms minimum flow affect water quality in terms of electrochemistry and biologically active nutrients?

5) How do flow releases from Revelstoke Dam affect the total area of river channel that is permanently wetted[2]? Are there biologically significant differences in changes in velocity and depth of large river habitats? Where and when do those hydraulic changes occur?

## 1.3 Management Hypotheses

There are three key monitoring hypotheses addressed in this program. These hypotheses are associated with the response of: a) the water temperature regime, b) fluctuation of river levels, and c) the area of continuously flowing (wetted) river channel, to the minimum flow releases from Revelstoke Dam. The hypotheses and related sub-hypotheses are:

$H_{01}$: Implementation of a 142 cms minimum flow release from Revelstoke Dam will not significantly alter the water temperature regime of the Middle Columbia River.

- $H_{01A}$: The implementation of a 142 cms minimum flow release from Revelstoke Dam does not significantly change the diel variation of water temperature of the Middle Columbia River.
- $H_{01B}$: The implementation of a 142 cms minimum flow release from Revelstoke Dam will not significantly alter the seasonal pattern of mean temperature of the Middle Columbia River.

$H_{o2}$: *This Management Hypothesis was removed*[3]

- $H_{o2A}$: *This Management Sub-Hypothesis was removed*[4]

[1] The original Management Question 2 was "How does the implementation of the 142 m3s-1 minimum flow affect total gas pressure (TGP) in the flowing reach of the Middle Columbia River?"

[2] For example, the performance measure associated with wetted habitat is Total Productive Area (in hectare-days), calculated as "the annual average of the minimum area continuously wetted each month for a period of 21 days or more, where productive area is calculated for each 0.25 m cross section slice that is considered productive over each month. The statistic reports the sum of monthly productive area across all cross sections that are riverine in nature" (BC Hydro 2005, p. 4-46)

[3] The original $H_{o2}$ was "The implementation of a 142 $m^3s^{-1}$ minimum flow release from Revelstoke Dam will not significantly alter TGP levels in the flowing reach of the Middle Columbia River."

[4] The original $H_{o2A}$ was "The implementation of a 142 m3 s-1 minimum flow release from Revelstoke Dam will not significantly alter TGP levels."

$H_{03}$: The implementation of a 142 cms minimum flow release from Revelstoke Dam will not significantly reduce the magnitude (i.e. range and variability) of river level fluctuation in the Middle Columbia River.

$H_{03A}$: The implementation of a 142 cms minimum flow release from Revelstoke Dam does not reduce the diel variation of river levels in Middle Columbia River.

$H_{03B}$: The implementation of a 142 cms minimum flow release from Revelstoke Dam will not alter the seasonal pattern of mean river level fluctuation in the Middle Columbia River.

$H_{04}$: The implementation of a 142 cms minimum flow release from Revelstoke Dam will not significantly increase the area of river channel that is continuously inundated in the Middle Columbia River.

$H_{04A}$: The implementation of a 142 cms minimum flow release from Revelstoke Dam does not increase the minimum total wetted channel area in Middle Columbia River.

$H_{04B}$: The implementation of a 142 cms minimum flow release from Revelstoke Dam does not increase the 'ecologically productive' area (minimum total wetted channel area inundated daily for a minimum of 21 days) in Middle Columbia River.

Given the complex interaction between the dam releases, tributary inflows, and Arrow Reservoir level on physical habitat characteristics, each hypothesis will be examined on a reach-specific basis and used to draw inferences regarding the cumulative physical habitat conditions over the entire study area.

### 1.4 Key Water Use Decision Affected

The key water use planning decision affected by the results of this monitoring program is the implementation of the 142 cms minimum flow release from Revelstoke Dam. The questions addressed in this monitoring program are directly related to estimating how Revelstoke Dam operations affect key physical monitoring indicators that describe large river habitat conditions. These physical habitat time series data and the associated inferences regarding effects on habitat conditions are a key component of the interpretation of four other integrated monitoring programs recommended for the Revelstoke Flow Management Program. This information is critical for constructing a logical linkage between the operation of Revelstoke Dam and response indicators for the productivity of the benthic community, changes in fish habitat use, and productivity of fish populations.

## 2.0 MONITORING PROGRAM PROPOSAL

### 2.1 Objective and Scope

The goal of the Middle Columbia River Physical Habitat Monitoring program is to provide empirical information on the response of key physical habitat variables to the implementation of minimum flow releases from Revelstoke Dam and operation of REV 5. Physical habitat data are required to test hypotheses about the observed changes in large river habitat conditions and to support the logical chain of inference for explaining observed changes in key ecological productivity indicators in each of the monitoring programs of the Revelstoke Flow Monitoring Program.

The objectives of the Middle Columbia River Physical Habitat Monitoring program are:

1) To measure spatial and temporal differences in the daily and seasonal river water temperature regimes between current operations and the 142 cms minimum flow regime.
2) To measure spatial and temporal differences in the daily and seasonal range of river level fluctuation between current operations and the 142 cms minimum flow regime.
3) To estimate changes in water quality (nutrient and electrochemistry) resulting from 142 cms minimum flow releases at the reach scale.
4) To estimate changes in the quantity and spatial distribution of permanently inundated river channel resulting from Revelstoke Dam flow releases.

The scope of the Middle Columbia Physical Habitat monitoring program is:

1) To continuously monitor water temperature and river stage at index monitoring stations focusing on the upper two reaches of the Middle Columbia River (Reaches 3 and 4), and in key tributaries (Jordan and Illecillewaet Rivers).
2) To use existing water quality data and data available from other sources to assess the importance of minimum flow releases in affecting water quality in the Middle Columbia River, Reaches 3 and 4.
3) To use stage data collected during the monitoring program to calibrate existing 1-d steady and unsteady hydraulic models for the Middle Columbia River and to use those models to estimate total area, locations of and changes in inundated river channel.
4) To use the empirical data and hydraulic modeling results to test hypotheses about the influence of minimum flow releases on hydraulic characteristics and temperature of the Middle Columbia River.
5) To develop an electronic data base system for systematic storage and retrieval of physical habitat data for the Middle Columbia.

The geographic scope of the Middle Columbia River is the ~30 km long section from the Akolkolex River to the tailrace of Revelstoke Dam (Reaches 4, 3 and 2; **Table CLBMON-15a-1**). While not excluding Reach 2 where possible and applicable, the upper two reaches (3 and 4) are the main focus of sampling and modeling.

**Table CLBMON-15a-1 Proposed common reach breakdown recommended for the Revelstoke Flow Management Program (Physical Habitat monitoring program)**

| Reach | Description of Reach Boundaries |
|---|---|
| 1 | Beaton Flats to Akolkolex River confluence |
| 2 | Akolkolex River to Illecillewaet River confluence. |
| 3 | Illecillewaet River confluence to Jordan River confluence. |
| 4 | Jordan River confluence to Revelstoke Dam tailrace |

## 2.2 Approach

The approach of this monitoring program is to establish index monitoring stations to collect physical habitat data focusing on the upper two reaches of the study area (Reaches 3 and 4) for a systematic time series on water temperature and water level conditions. These stations must coincide as much as possible with periphyton/benthic substrate locations for CLBMON-15b Ecological Productivity, since the data collected will be used to help understand the influence of physical habitat conditions on the benthic community.

The data will be used to provide a description of physical habitat conditions and to investigate how minimum flow releases, tributary inflows, and reservoir operations impact key physical habitat characteristics. Monitoring data will be used to test hypotheses about how minimum flow affects water temperature, water quality, and river level fluctuations. The empirical data will also be used to calibrate existing hydraulic models of the Middle Columbia River. These models will be applied to estimate how the observed pattern of dam releases, tributary inflows, and reservoir operations affect the total wetted area of flowing large river habitat. The results from these models will furthermore be integrated with adult and juvenile habitat suitability indices derived from monitoring programs CLBMON-16 (Middle Columbia River Fish Population Indexing Surveys) and CLBMON-17 (Middle Columbia River Juvenile Fish Habitat Use) respectively.

The data generated from this monitoring program will be archived in an electronic database and used as covariates in analyses conducted in other components of the RFMP, which investigate the influence of physical habitat on ecological productivity, fish population response measures, and fish habitat use.

## 2.3 Methods

### 2.3.1 Task 1: Project Management

Project management will involve the general administrative and technical oversight of the project. This task will include, but not be limited to: 1) budget management, 2) study team management, 3) logistic coordination, 4) technical oversight of field and analysis components, and 5) facilitation of data transfer among other investigators associated with the RFMP.

A safety plan must be developed and submitted to the BC Hydro contact for all aspects of the study involving field work, in accordance with BC Hydro procedures and guidelines. Specific safety training may be required.

### 2.3.2 Task 2: Temperature and Stage Monitoring

Water temperature and river stage monitoring will be conducted at index monitoring stations in each reach of the river. In addition to mainstem sites, continuous recording thermographs and river stage monitoring have also been installed and maintained in the primary tributaries to the Middle Columbia River (e.g., Jordan River, Illecillewaet River).

Given the accuracy of the predictions of the HEC-RAS model (Plate et al. 2014; cf.Task 4 for further details), further collection of river stage monitoring data is not judged to be necessary anymore. The level loggers will thus be removed from the existing stations as soon as possible. The standpipes will however be left in place, and thus be available for future monitoring, should this be required.

Four of the temperature monitoring stations will remain in effect (one in each of the two tributaries, one close to Revelstoke Dam, and one below the Illecillewaet), and their data will be downloaded by one of the other RFMP studies as dictated by schedules.

### 2.3.3 Task 3: Water Quality

Seasonal water quality samples (point samples) have been collected at the index monitoring stations and primary tributaries from 2007 to 2014. Results indicate that water quality indicators sampled (point samples of nutrients and electrochemistry) are thus far insensitive to variations in flow changes (Golder Associates 2013). Consequently one of the RFMP technical review recommendations was to decrease the effort devoted to sampling water quality. The data collected so far will be analyzed, in conjunction with other databases as available, to finalize the assessment of the influence of minimum flow releases on water quality (nutrients and electrochemistry).

### 2.3.4 Task 4: Hydraulic Model Calibration and Application

Given the dynamic and complex nature of the regulated flow regime and the geographic extent of the Middle Columbia River study area, it is not feasible to directly measure changes in hydraulic parameters of the river. To facilitate a standardized approach to quantifying the hydraulic parameters of the Middle Columbia River study area during the RFMP, a hydraulic modeling approach is required. River stage data collected during the monitoring program at index stations in each reach have been applied to calibrate existing 1-d steady and unsteady state hydraulic (HEC RAS) models (Korman et al. 2002). Stage data collected in the MCR, Illecillewaet and Jordan River index stations over the last seven years were used to calibrate the HEC-RAS model to predict flows, water depths and wetted width for the MCR Reaches 2, 3 and 4. Based on this extended calibration phase, it appears that the predictive power of the HEC-RAS model is now highly accurate (Plate et al., 2014).

The calibrated hydraulic model will be applied to estimate specific conditions produced during the implementation of RFMP monitoring program. Hydraulic conditions of the study area will be simulated by driving the calibrated hydraulic model with observed annual flow regime (dam releases + tributary flow estimates + reservoir elevation) for the Middle Columbia to produce time series data on the average depth, velocity, and wetted channel area. Modeled estimates of critical hydraulic parameters will be simulated on an hourly time scale at each river cross-sections. These data are required to test the hypotheses about the extent of river level variation and inundation of river channel bed, to assess how changes in minimum flow affect water quality, and to estimate the area and location of permanently wetted large river habitat.

One of the main results will be the development of flow vs. wetted area relationships (flow vs. depth and velocity being key outputs) for Reaches 3 and 4. These relationships will be used by CLBMON-16 and CLBMON-17 in conjunction with Habitat Suitability Indices (HSIs) to develop flow vs habitat relationships for adults and juvenile fish species, and also by CLBMON-15b to assess the changes in benthic ecological productivity affected by flows.

The output of the model will be electronically archived in the Middle Columbia River Physical Habitat database.

### 2.3.5 Task 5: Develop Middle Columbia River Physical Habitat Database

An electronic database will be developed to facilitate archiving time series data of key physical habitat variables measured during the monitoring program (water temperature, river stage elevation, water quality), as well as storing output associated with hydraulic modeling to estimate depth, velocity, and wetted channel area characteristics.

An objective of developing this database system is to facilitate the testing of hypotheses about physical habitat changes, as well as facilitating access to physical habitat data for other monitoring program analyses within the RFMP.

A structured system of data query macros will be developed to extract raw and summary time series data. The query macros should also be developed to retrieve estimates of hydraulic conditions at each of the 245 river cross-sections and produce summary output across reaches. At a minimum these parameters will included depth (i.e., stage level), velocity, wetted width, and wetted area.

### 2.3.6 Task 6: Reporting

A technical report will be prepared each year of the program, which will describe the field and analytical methods, summary results of field measurements and modeled hydraulic parameters, data analysis, and interpretation. A synthesis report of data collected in the first five years of the monitoring program will be used in the interim review to provide recommendations for improving assessment methods in future years of the program. A final synthesis report shall be prepared upon completion of 13 years of monitoring.

Reports will follow the standard format developed for WUP monitoring programs. All reports will be provided in hard copy and as Microsoft Word and Adobe Acrobat (*.pdf) format, and all maps and figures will be provided either as embedded objects in the Word file or as separate files.

## 2.4 Interpretation of Monitoring Program Results

The data collected in this monitoring program will be used to test hypotheses about the changes in physical habitat conditions associated with the minimum flow releases at Revelstoke Dam. The data and inferences from these hypotheses are the first component in the logical chain of inference of how a minimum flow release from the dam affects large river fish habitat (flow releases $\rightarrow$ physical conditions $\rightarrow$ ecological productivity $\rightarrow$ fish populations) in the Middle Columbia River.

The results from this program will be integrated with the four other monitoring programs of the RFMP (Ecological Productivity, Fish Population Indexing Surveys, Juvenile Habitat Use, Adult Habitat Use) and will be used to support inferences regarding benefits of the minimum flow for fish. Results from the RFMP and associated inferences will be used to establish the long term minimum operating release requirements for the Revelstoke Dam.

### 2.5 Schedule

This program is being implemented annually over the period of the Columbia Water Use Plan (13 years), of which the first eight years (2007-2014) have now been completed.

### 2.6 Budget

Total Revised Program Cost for CLBMON-15a and CLBMON-15b: $3,788,278.

## REFERENCES

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BC Hydro. 2005. Consultative Committee report: Columbia River Water Use Plan, Volumes 1 and 2. Report prepared for the Columbia River Water Use Plan Consultative Committee by BC Hydro, Burnaby, BC.

BC Hydro. 2010. Columbia River Project Water Use Plan. Monitoring Program Terms of Reference. Revelstoke Flow Management Plan. CLBMON-15a Middle Columbia River Physical Habitat Monitoring. CLBMON-15b. Middle Columbia River Ecological Productivity Monitoring.

Golder Associates Ltd. 2013. CLBMON-15a Mid-Columbia River Physical Habitat Monitoring. Synthesis Report (Years 1 – 6). Report prepared for BC Hydro, Revelstoke, BC. Golder Report No. 12-1492-0084. 44 p. + 6 app.

Korman, J, Y. H. Lan, L. Hildebrand, and L. Failing. 2002. Fish Habitat Performance Measures to Evaluate Minimum Discharge Requirements For Revelstoke Canyon Dam. Prepared for Columbia Water Use Planning Fisheries Technical Committee, by Ecometric Research Ltd. November 8, 2002, 31 p.

Plate, E.M., Y. Imam, S. Dashti, L. Walker, N. Wright and M. Zimmer. 2014. CLBMON-15a Mid-Columbia River Physical Habitat Monitoring Project, 2013 (Year 7). Prepared for: BC Hydro, Revelstoke, BC. Prepared by: Okanagan Nation Alliance, LGL Limited and Ecofish Research Limited: 79 pp.

**Table 15a-3. CLBMON 15a MCR Physical Habitat Monitoring. Key changes and rationale for their inclusion.**

| Section | Change | Rationale |
|---|---|---|
| Background | Added in the history of ToR revisions and introduced the RFMP technical Review | To let the revised ToR to be a stand alone document while allowing the reader to understand the history for changes from the start of the program |
| Management Questions | Removed management question 2 about TGP.<br><br>Original Management Question (MQ) #2 was:<br><br>"How does the implementation of the 142 m3s-1 minimum flow affect total gas pressure (TGP in the flowing reach of the Middle Columbia River. " | The stochastic nature of spillway and synchronous condense operations at Revelstoke Dam (which have been shown increase TGP production in Middle Columbia River) could not be monitored within this program's scope.<br><br>Furthermore BC Hydro's Total Dissolved Gas Strategy (BC Hydro 2014) will endeavor to assess operational risks and identify opportunities for mitigation at all facilities, including Revelstoke Dam.<br><br>Consequently, Management Question 2 of the May 2010 ToR relating to Total Gas Pressure (TGP) and Task 3 from the May 2010 ToR were dropped. |
| Management Hypotheses | Minor changes – 'reduce' instead of 'alter' in some cases.<br>Removed hypothesis $Ho_2$ and $Ho_{2A}$. | More precise wording |
| Objectives and Scope | 1. Deleted reference to TGP<br>2. Removed requirement to collect seasonal samples of water quality; now objective is to estimate changes in water quality | 1. Cf. MQ above<br>2. Seasonal point samples in water quality do not reflect variation in these parameters; rationale also explained in Task 3 |
| Approach | Emphasized importance of linking study results to fish surveys | Study is to provide data to other RFMP programs |
| Tasks | Task 2: Removed the collection of water stage data through level loggers. | Replaced with a calibrated HECRAS Model. |
| | Task 3: TGP Monitoring was deleted and replaced with water quality (previously task 4) sampling which resulted in one less task from the original TOR. Furthermore, a decrease effort devoted to water quality data collection | Water quality indicators are insensitive to variations to flow |
| | Task 4: changed wording of first sentence, second paragraph<br><br>Added one paragraph about expected results of modelling. | Clarify intent of hydraulic model simulations |
| Schedule | Removed reference to Technical Review | Technical Review occurred |
| Budget | Budget reduced from the approved 2010 budget | Primarily due to a reduction in water quality sampling effort |