Columbia River Project Water Use Plan

Monitoring Program Terms of Reference

LOWER COLUMBIA RIVER
FISH MANAGEMENT PLAN

- **CLBMON-44 Lower Columbia River Physical Habitat and Ecological Productivity Monitoring**

24 October 2007

TERMS OF REFERENCE FOR THE COLUMBIA RIVER PROJECT WATER USE PLAN MONITORING PROGRAMS LOWER COLUMBIA RIVER FISH MANAGEMENT PLAN

1.0 OVERVIEW

This document presents Terms of Reference for the effectiveness monitoring programs for the Lower Columbia River Fish Management Plan (Table 1). These programs will evaluate the effects of whitefish and rainbow trout flow conditions on the lower Columbia River and provide a physical and ecological health barometer against which the lower Columbia River monitoring programs can be evaluated.

This document provides detailed Terms of Reference for the following programs:

1) CLBMON-42 Lower Columbia River Fish Stranding Assessment and Ramping Protocol: a 13-year program to monitor planned and opportunistic flow reductions to establish impacts of flow reductions on fish populations in the lower Columbia River and the required operational procedures to mitigate ramping impacts.

2) CLBMON-43 Lower Columbia River Sculpin and Dace Life History Assessment: a 5-year program to monitor the life history and habitat use of sculpin and dace, in particular species listed under the federal Species at Risk Act and the BC Wildlife Act, in the lower Columbia River in relation to seasonal operations at Keenleyside Dam.

3) CLBMON-44 Lower Columbia River Physical Habitat and Ecological Productivity Monitoring: a 12-year program to monitor physical habitat parameters, periphyton and benthic invertebrates below Keenleyside Dam to evaluate net change in trophic productivity and overall ecological health in relation to rainbow trout and mountain whitefish flow regimes.

4) CLBMON-45 Lower Columbia River Fish Population Indexing Surveys: a 13-year program to monitor trends in the biological characteristics, distribution and abundance of mountain whitefish, rainbow trout and walleye populations in the lower Columbia River in relation to rainbow trout and mountain whitefish flow regimes.

5) CLBMON-46 Lower Columbia River Rainbow Trout Spawning Habitat Assessment: a 10-year program to monitor the relative abundance, distribution, spawning site selection and timing of rainbow trout spawning in the lower Columbia River in relation to rainbow trout and mountain whitefish flow regimes.

6) CLBMON-47 Lower Columbia River Whitefish Spawning Ground Topographic Surveys: a 3-year program to monitor spawning locations of whitefish in the lower Columbia River using detailed topographic surveys to improve the effectiveness of the whitefish flow regime in the lower Columbia River.

7) CLBMON-48 Lower Columbia River Whitefish Life History and Egg Mat Monitoring: a 5-year program to monitor whitefish life history, including spawning and egg mat sampling in the lower Columbia River, to establish the effectiveness of the current whitefish flow regime on egg survival, juvenile recruitment, and adult populations.

8) CLBMON-49 Lower Columbia River Effects on Great Blue Heron: a 4-year program to determine the importance of Waldie Island as an overwintering site for juvenile and adult heron from the Revelstoke colony.

Table 1 Lower Columbia River Fish Management Plan Monitoring Program Terms of Reference Submission Information

Name of Monitoring Program	Order Clause Fulfilled	Submitted with this Package	Previously Submitted To CWR	Submission Date	Leave to Commence
CLBMON-42 Lower Columbia River Fish Stranding Assessment and Ramping Protocol	Schedule E: 2.a	No	Yes	10 September 2007	No
CLBMON-43 Lower Columbia River Sculpin and Dace Life History Assessment	Schedule E: 2.b	Yes	No	26 October 2007	No
CLBMON-44 Lower Columbia River Physical Habitat and Ecological Productivity Monitoring	Schedule E: 2.c	Yes	No	26 October 2007	No
CLBMON-45 Lower Columbia River Fish Population Indexing Surveys	Schedule E: 2.d	No	Yes	10 September 2007	No
CLBMON-46 Lower Columbia River Rainbow Trout Spawning Habitat Assessment	Schedule E: 2.e	Yes	No	26 October 2007	No
CLBMON-47 Lower Columbia River Whitefish Spawning Ground Topographic Surveys	Schedule E: 2.f	Yes	No	26 October 2007	No
CLBMON-48 Lower Columbia River Whitefish Life History and Egg Mat Monitoring	Schedule E: 2.g	Yes	No	26 October 2007	No
CLBMON-49 Lower Columbia River Effects on Great Blue Heron	Schedule E: 2.h	Yes	No	26 October 2007	No

2.0 MONITORING PROGRAM RATIONALE

The trophic productivity and ecological health of the lower Columbia River and, therefore, the quality and quantity of large river habitat are partially dependent on the operation of Hugh L. Keenleyside (HLK) Dam. As such, the Columbia River Water Use Plan Consultative Committee (WUP CC) recognized operational impacts of the dam on fish productivity of the lower river as a key environmental concern to be addressed during the water use planning process.

The WUP CC initially explored ways of achieving specific elements of a preferred fish hydrograph for the lower Columbia River through modifying operation of Arrow Lakes Reservoir. However, it became apparent that BC Hydro would have only limited operational flexibility to unilaterally change flows in the lower Columbia River given the need to meet prescribed weekly flow releases at the border under the Columbia River Treaty (CRT). The WUP CC did not consider the existing flexibility to be biologically significant and, therefore, focused on more substantial flow changes that could be made by deviating from CRT flows through annual negotiations with the U.S. These included:

- rainbow trout protection flows, which involve stabilizing or increasing flows from 01 April to 30 June to minimize dewatering and potential egg losses of mid-timed spawning rainbow trout, and
- mountain whitefish flow, which involve limiting maximum flows during the peak spawning period (1 to 20 January) and smoothing flows until hatch (end March) to minimize subsequent egg dewatering and mortality, and maintaining February/March total stage changes less than 0.5 m.

Water levels in the lower Columbia River are typically managed to limit high flows in January and to stabilize or increase flows through to the end of June; flows increase through the summer and flow fluctuations are allowed in the fall as a treaty trade-off for whitefish flows.

During the development of flow management recommendations, it was recognized that there are significant data gaps regarding the effects of flow shaping on the physical environment and ecological productivity of the lower Columbia River. Monitoring projects were designed to examine the effectiveness of these flow options, and to address existing data gaps between flows and other endpoints of interest[1] (Table 1).

The key objectives of the Lower Columbia Monitoring Program are to: 1) evaluate the effects of whitefish and rainbow trout flow conditions on the lower river and, 2) provide a physical and ecological health barometer against which the Middle Columbia monitoring program can be evaluated.

Rainbow Trout Protection Flows

Prior to 1992, the typical flow regime below HLK Dam was characterized by declining discharge over the March to May period, and increasing discharge over the June to July period. This discharge pattern resulted in reduced water levels at Norns Creek Fan (a primary rainbow trout spawning area), causing a significant number of rainbow trout redds constructed at higher elevations to become dewatered when flows were subsequently reduced. Since 1993, BC Hydro has successfully negotiated Non-Power Use Agreements with the U.S., in consultation with the fish agencies, with the aim of providing better flow regimes for rainbow trout spawning below HLK Dam than would normally occur under the CRT operations. BC Hydro has secured these flow changes by providing 1 MAF of storage from Arrow Lakes Reservoir in July-August for U.S. salmon flow augmentation.

An important objective of rainbow trout protection flow is to maintain minimum river levels at Norns Creek Fan between 1 April and 30 June to ensure that eggs deposited after 1 April

[1] A parallel study in the Middle Columbia River will assess the environmental benefits of the establishment of a year-round $142 m^3 s^{-1}$ minimum flow release from Revelstoke Dam.

remain wetted until fry emergence occurs, which is typically by the end of June. These flows are designed to minimize potential egg losses for the mid-timed rainbow spawners (April and May) by providing stable or increasing discharge over this period. This is typically achieved by delivering flows between 15 and 20 kcfs from HLK Dam. The initial discharge is set so that there is a high probability that the downstream river level can be maintained until the end of the spawning and incubation period without causing Treaty storage to draft below planned levels under the CRT.

The implementation of the rainbow trout flow policy in the lower Columbia River has coincided with a general increasing trend in rainbow trout population abundance over the past 10 years. While there may be many reasons for this population increase, BC Hydro and the fish agencies view this as a successful management strategy in protecting rainbow trout populations in the lower river. However, the WUP CC recognized that a significant tradeoff exists between providing protection flows in the lower Columbia to protect rainbow trout spawning and incubation, and its negative impact on other interests upstream in Arrow Lake Reservoir and mid Columbia River (i.e., vegetation, wildlife, large river habitat) due to the additional 1 MAF of storage in spring. Because of potential benefits that could be achieved upstream if annual provision of the protection flows were halted, the WUP CC discussed whether it is essential that this flow management be implemented every year to maintain or enhance these populations. It was recognized that a long-term commitment to monitoring would be required to better understand the linkage between rainbow trout flow implementation and population abundance.

Whitefish Flow Management

Despite over a decade of implementing whitefish flow management actions in the lower Columbia River, there remains uncertainty regarding the relationship between flow conditions and egg mortality, and the significance of egg loss to the productivity of the whitefish population. The WUP CC recognized that resolution of this uncertainty is critical for establishing winter flow release regimes for HLK and Brilliant dams.

Mountain whitefish spawn in the lower Columbia and Kootenay rivers during early winter with peak spawning typically occurring during the first three weeks of January each year (see Figure 1, RLL 2001). Eggs are broadcast into the water column, and are distributed throughout a variety of locations and depths depending on river flow conditions during spawning. Flows supplied to the river from HLK and Brilliant dams into the lower Columbia River during whitefish reproductive period are typically high during the peak mountain whitefish spawning period and decline to an annual minimum by 01 April. Flows can vary widely during the spawning and egg incubation periods, and have been observed to dewater whitefish eggs.

The conceptual approach to whitefish flow management is to stabilize (to the degree possible) regulated flow releases into the lower Columbia River during whitefish reproduction. This requires additional agreements outside of the CRT, including 1) the Whitefish Operating Agreement, which allows storage at Kinbasket and Arrow Lakes reservoirs during the January to reduce Arrow outflow, and 2) the Fall Provisional Storage Agreement and March Whitefish Flow Agreement, which allows for a provisional draft of Arrow Lakes Reservoir and higher releases during the fall in compensation to the U.S. for lost energy benefits associated with stabilization of winter flow.

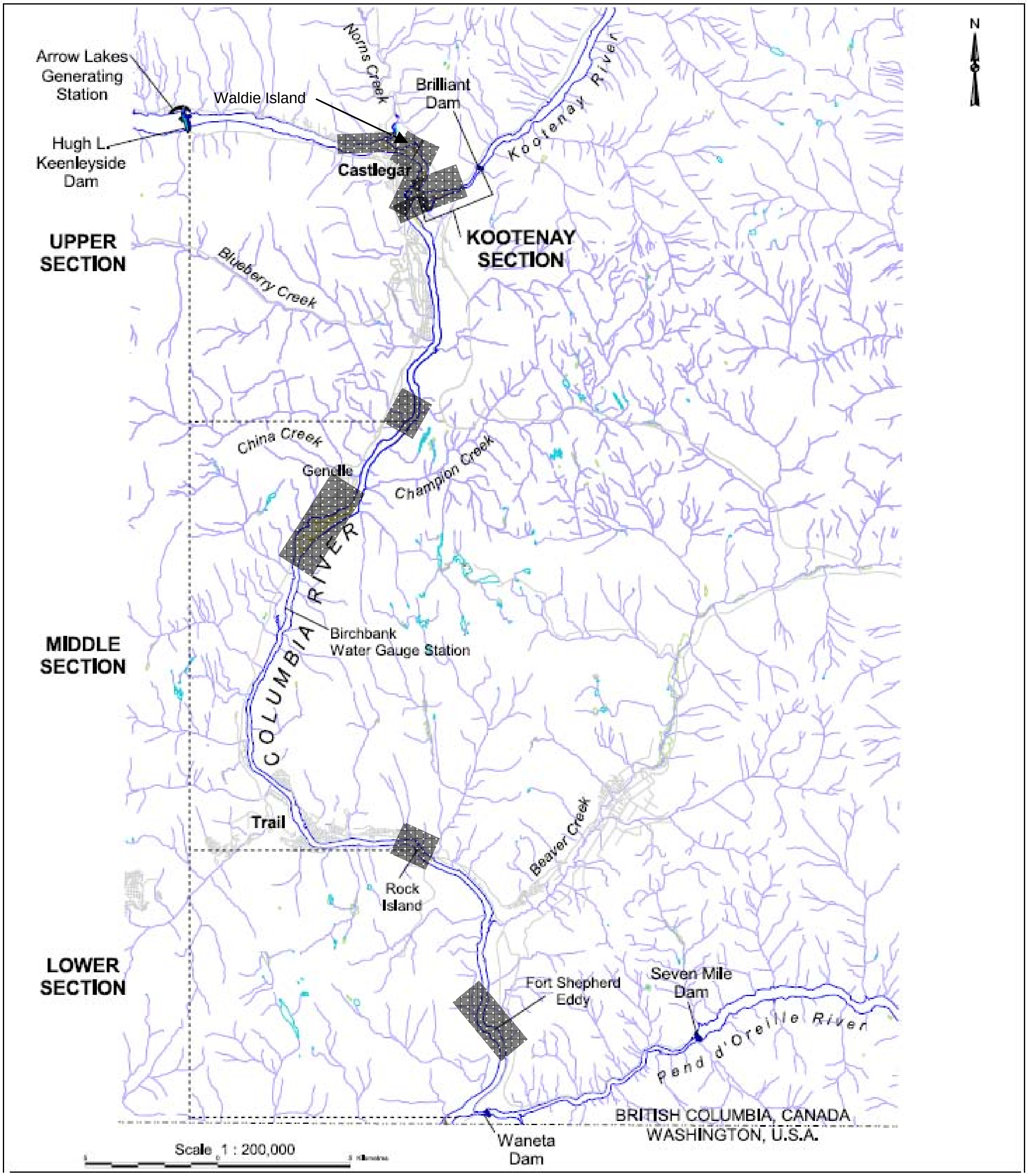
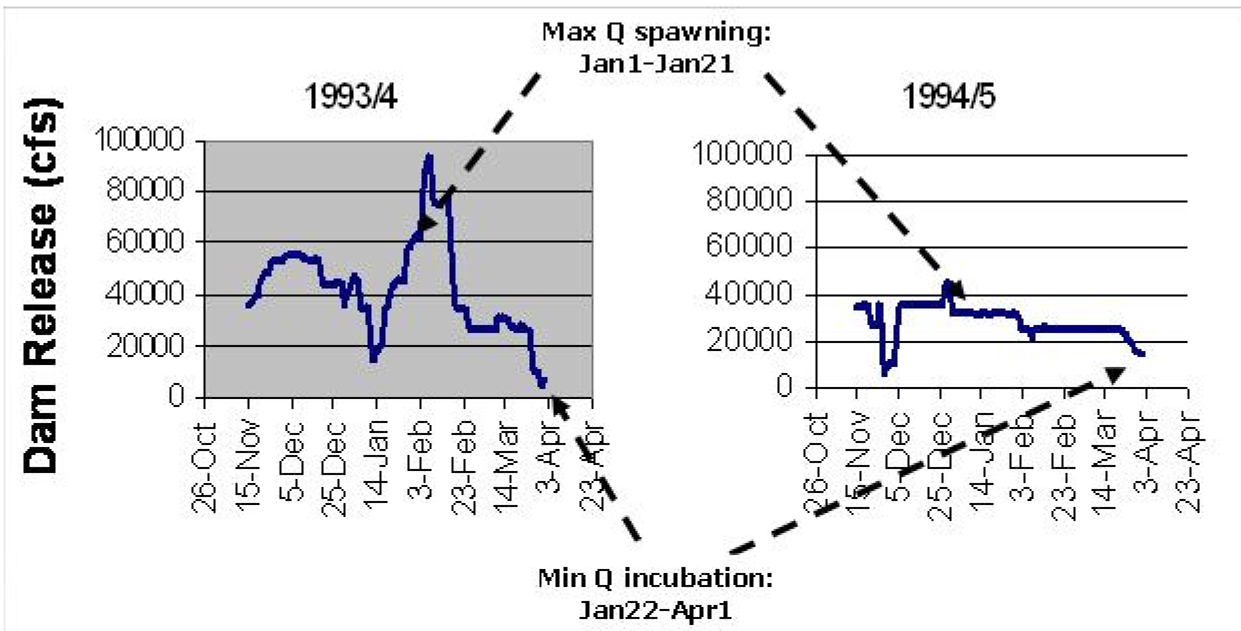


Figure 1 **Map of the Columbia River below Hugh Keenleyside dam showing the study area boundaries, known whitefish spawning areas (grey hatched boxes), Great Blue heron overwintering habitats at Waldie Island, and reach breakdown used for whitefish population index monitoring program initiated in 2001, and proposed for the whitefish adaptive management program.**

Operationally, whitefish flow management is achieved by minimizing the difference between the maximum flow during the peak spawning period (January 1 -21, Q_{Smax}) and the minimum flow prior to egg hatch (January 22 – Apr 1, Q_{Imin}). The relative degree of flow stabilization (and risk of egg loss) is indexed by a simple hydrologic metric, Q_{Smax}-Q_{Imin} (see Figure 2). As a result of annual variation in hydrology, power demand, dam operating conditions, and other factors that govern the flow regime of the Columbia River, there is variation in the success of stabilization efforts. Figure 3 shows the relative degree of stabilization achieved prior (1984-1994) to and after (1995-2005) implementation of whitefish flow management actions.



Flow Stabilization Index (Q_{Smax}-Q_{Imin}) = Maximum Flow (Jan 1 to Jan 21) - Minimum Flow (Jan 22 to Apr 1)

Figure 2 **Example of computation of the Q_{smax}-$Q_{i\ min}$ flow stabilization index and patterns of daily flow releases from Hugh Keenleyside Dam during whitefish reproduction periods before (1993/4) and after (1994/5) the implementation of WFM practices.**

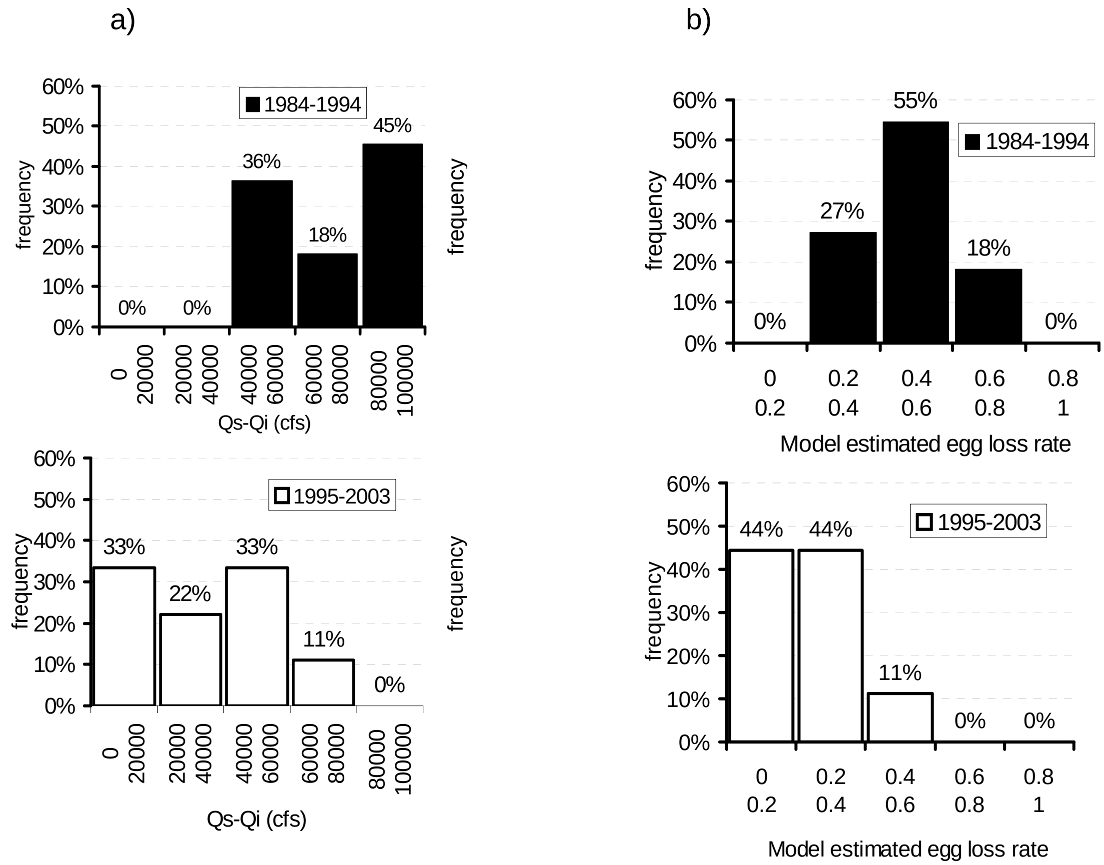


Figure 3 **Distributions of flow stabilization index ($Q_{Smax} – Q_{Imin}$) and modelled egg losses for periods before and after the implementation of WFM. a) $Q_{Smax} – Q_{Imin}$ is difference between the maximum spawning flows during peak spawning (Jan 1 – Jan 21, Q_{Smax}) and the minimum egg incubation flows (Jan 22- Apr 1, Q_{Imin}) for historical operation (1984-1994, black bars) and during WFM implementation (1995-2005, white bars); b) Estimated egg loss observed prior to (black bars) and after (white bars) the implementation of WFM .**

The biological rationale for whitefish flow management is based on three hypotheses that link the physical effects of flow variation to inter-annual abundance of the adult population:

H_1: Management of flow in the lower Columbia River during peak spawning (Jan 1- Jan 21) and stabilization of post spawning flows (22 Jan -01 Apr) will reduce egg losses resulting from dewatering.

H_2: Reduced egg losses increase the recruitment of young-of-the-year whitefish

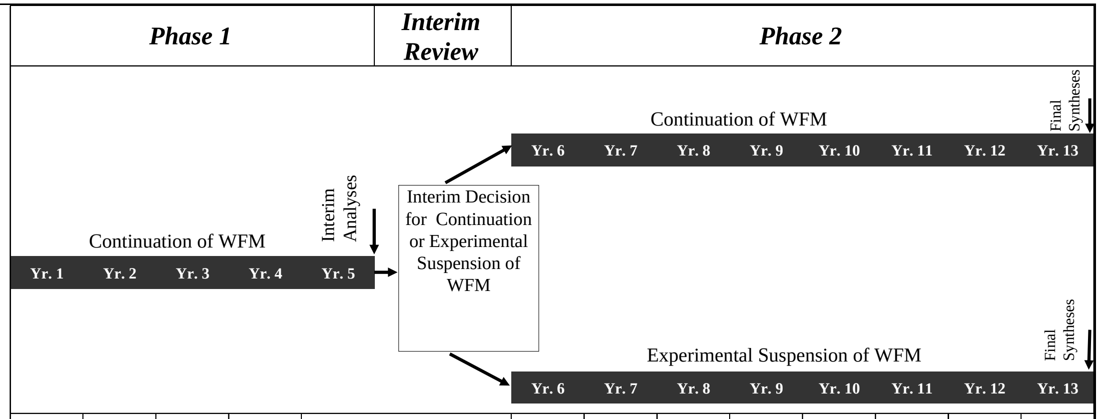
H_3: Increased young-of-the-year recruitment results in a stable or increasing abundance of the reproductively active adult whitefish population (i.e., F.L. >250 mm)

To determine the effectiveness of whitefish flow management for conserving whitefish populations, the WUP CC recommended a 13-year phased adaptive management program (Figure 4). In Phase 1 of the program, standard whitefish flows will be implemented for five years to provide a total of 12 continuous years (2000-2012) of population index monitoring coincident to implementation of this flow regime (Years 1–7 Pre-Water Use Plan; Years 8-12 under the Water Use Plan). The objectives of this phase of the program are to: 1) extend time series of systematic whitefish population monitoring to allow quantitative assessment of the influence of WFM on the whitefish population, and 2) fill critical gaps in understanding about the life history, biology, and spawning habitats of whitefish to support management hypotheses testing. Winter flows will be actively managed through the existing flow management framework with the objective of providing an egg loss risk exposure consistent with that observed during the period of implementation (1995-2003, Figure 3). Continuation of fish population index surveys will provide uninterrupted time series of population data. Biological monitoring will be implemented to improve understanding of the whitefish life history and reproductive biology, as well as better description of the physical characteristics of key spawning locations. These data will be combined with historical information for the refinement of the existing egg loss model, to test key model assumptions, or to, where possible, modify the model to provide more reliable egg loss estimates.

The CC was also concerned with potential negative effects of whitefish flow management on overwintering habitats used by Great Blue herons in the lower Columbia River. Monitoring has indicated a heron aggregation during the fall and early winter periods near to and upstream of the confluence of the Kootenay and Columbia rivers. This period corresponds to a period of high and variable flow releases prior to whitefish spawning, which are operationally required to allow stabilized flows during the peak of whitefish reproduction. To address this concern, a monitoring program was recommended to better understand seasonal patterns of heron movement and how the whitefish flow management effects shallow-water foraging habitat utilization by Great Blue heron.

At the end of Phase 1, an Interim Analysis of the biological effectiveness of whitefish flows will be conducted. Annual flow data, egg loss risk estimates, patterns of young of the year recruitment, and trends in abundance of the adult population will be analyzed to test the three primary conceptual hypotheses linking flow management to biological effects on whitefish populations. The primary objectives of the Interim Analysis will be to: 1) document the relationship between winter flow conditions, egg dewatering and the population response of whitefish under the WFM regime, and 2) support a decision regarding experimental suspension of whitefish flow management in Phase 2 of the adaptive management program (see Figure 4).

In Phase 2 of the program, an experimental suspension of flow management was recommended as option by the CC, where deemed safe and informative to do so. The objective will be to increase the contrast in annual egg loss conditions more aggressively to test the biological response of the population without flow protection. The target level of winter flow stabilization is that observed prior to implementation of whitefish flow management (Figure 3). During Phase 2 of the program, adult population index monitoring will continue for an additional 7 years to provide a total of 20 years of systematically collected population data. In the final year of Phase 2, a comprehensive data synthesis will be undertaken. A Final Synthesis will integrate results from all aspects of the program to re-test the three conceptual hypotheses underpinning whitefish flow management, and to contrast biological responses of whitefish under the two alternative winter flow management regimes. The Final Synthesis will be used to inform the decision regarding the long-term continuation of protection flows during the planned review of the Columbia River Water Use Plan.



#	Monitoring Program	2008	2009	2010	2011	2012		2013	2014	2015	2016	2017	2018	2019	2020
CLBMON-45 Lower Columbia River Fish Population Indexing															
	Systematic Field Sampling Pgm.	X	X	X	X	X		X	X	X	X	X	X	X	X
	Fish Population Data Synthesis						XXX								XXX
CLBMON-47Lower Columbia River Whitefish Spawning Ground Topographic Surveys															
	Topographic Surveys			X	X										
	Egg Loss Model Dev & Applic.					X	XXX								XXX
CLBMON-48 Lower Columbia River Whitefish Life History and Egg Mat Monitoring															
	Spawner Assessments	X	X	X	X	X									
	Juvenile Assessments	X	X	X	X	X									
	Egg monitoring		X	X	X	X									
CLBMON-49a Lower Columbia River Effects of Whitefish Flows on Great Blue Heron Use of Waldie Island															
	Winter Heron Abundance		X	X	X										
	Foraging Habitat Assessment		X	X	X		X								X

Figure 4 **Conceptual approach and annual schedule for the implementation of monitoring programs and key activities for the evaluation of the biological effectiveness of WFM for the conservation of the mountain whitefish population in the lower Columbia River.**

Monitoring Study No. CLBMON-44
Lower Columbia River Physical Habitat and Ecological Productivity Monitoring

1.0 MONITORING PROGRAM RATIONALE

1.1 Background

Over the past decade, BC Hydro has attempted to stabilize water releases from the Hugh L. Keenleyside (HLK) Dam during whitefish and rainbow trout spawning seasons (January through March and April through June, respectively) to minimize egg losses in the lower Columbia River. To address existing uncertainties around the effectiveness of these flows to whitefish and rainbow trout populations in the lower Columbia River, the Water Use Plan Consultative Committee (WUP CC) supported continued implementation of the current flow management strategies (contingent on successful negotiations with the U.S.), as well as the option of testing the effectiveness of whitefish flows by re-introducing the historical flow regime after a total of 12 continuous years of systematic baseline data collection (BC Hydro 2005a).

The WUP CC considered monitoring of flows and other habitat variables to be essential for supporting future decisions on water release strategies at HLK Dam, and recommended the implementation of a monitoring program to document physical habitat characteristics and ecological productivity of the lower Columbia River. The goal of the monitoring program is to use the resulting data to make inferences about the linkage between the implementation of whitefish and rainbow trout flows, and overall ecological health of the river. In addition, the collection of physical habitat and ecological productivity data was anticipated by the WUP CC as a fundamental information requirement for supporting other monitoring programs associated with the lower Columbia River Fish Management Plan (LCRFMP). The physical habitat and ecological productivity studies complement parallel monitoring programs in the mid Columbia River, as well as ongoing large river fish indexing programs that provides an annual metric on the ecological productivity of the mid and lower Columbia River.

The objective of the Physical Habitat component of this monitoring program is to monitor water temperature, stage, electrochemistry and nutrient levels in the lower Columbia River to allow tracking of potential changes in physical habitat and ecological health as a result of flow conditions. The Ecological Productivity component will monitor periphyton and benthic invertebrates to assess potential changes in trophic productivity and overall ecological health of the lower Columbia River resulting from the continued implementation of mountain whitefish and rainbow trout flow agreements (BC Hydro 2005b).

1.2 Management Questions

The data collected will be used to generate time series data of habitat variables that can be used to form a logical chain of inference from flow to habitat and ecological productivity to fish populations. The data collected will be combined with data from related monitoring programs in the lower Columbia River and used to examine primary hypotheses about change in fish populations.

1.2.1 Physical Habitat Monitoring

The key management questions addressed by the physical habitat monitoring program are:

1) How does continued implementation of whitefish and rainbow trout flows during winter and spring, and fluctuating flows during fall affect water temperature in the lower 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) How does continued implementation of whitefish and rainbow trout flows during winter and spring, and fluctuating flows during fall affect the seasonal and inter-annual range and variability in river level fluctuation in the lower Columbia River?

3) How does continued implementation of whitefish and rainbow trout flows during winter and spring, and fluctuating flows during fall affect electrochemistry and biologically active nutrients in the lower Columbia River?

1.2.2 Ecological Productivity Monitoring

The key management questions addressed by the ecological productivity monitoring program are:

1) What is the composition, abundance, and biomass of epilithic algae and benthic invertebrates in the lower Columbia River?

2) What is the influence of the whitefish and rainbow trout flows during winter and spring, and fluctuating flows during fall on aquatic that determine the abundance, diversity, and biomass of benthic invertebrates?

3) Are organisms that are used as food by juvenile and adult whitefish and rainbow trout in the lower Columbia River supported by benthic production in the lower Columbia River?

1.3 Management Hypotheses

1.3.1 Physical Habitat Monitoring

This monitoring program addresses three key hypotheses associated with the effects of continued implementation of whitefish and rainbow trout flows during winter and spring, and fluctuating flows during fall, on water temperature, fluctuation of river levels and nutrient levels in the lower Columbia River. The hypotheses and related sub-hypotheses are as follows:

Ho_1: Continued implementation of whitefish and rainbow trout flows during winter and spring, and fluctuating flows during fall does not alter the seasonal water temperature regime of the lower Columbia River.

Ho_2: Continued implementation of whitefish and rainbow trout flows does not affect seasonal water levels in the lower Columbia River.

Ho_{2A}: Continued implementation of whitefish flows does not reduce the river level difference between the maximum peak spawning flow (1 January to 21 January) and the minimum incubation flow (21 January to 31 March).

Ho_{2B}: Continued implementation of rainbow trout flows does not maintain constant water level elevations at Norns Creek fan between 1 April and 30 June.

Ho_3: Continued implementation of whitefish and rainbow trout flows during winter and spring, and fluctuating flows during fall does not alter the water quality of the lower Columbia River.

Ho_{3A}: Continued implementation of whitefish and rainbow trout flows during winter and spring, and fluctuating flows during fall does not alter the electrochemistry of the lower Columbia River.

Ho_{3B}: Continued implementation of whitefish and rainbow trout flows during winter and spring, and fluctuating flows during fall does not alter the availability of biologically active nutrients of the lower Columbia River.

1.3.2 Ecological Productivity Monitoring

The three key monitoring hypotheses addressed in this program are associated with the effects of continued implementation of whitefish and rainbow trout flows during the winter and spring, and fluctuating flows during fall, on the abundance, diversity biomass and distribution of benthic invertebrates in the lower Columbia River. The hypotheses and related sub-hypotheses are as follows:

Ho_1: Continued implementation of whitefish and rainbow trout flows during winter and spring, and fluctuating flows during fall, do not affect the biomass, abundance and composition of benthic invertebrates in the lower Columbia River.

Ho_{1A}: Continued implementation of whitefish flows does not affect the biomass, abundance and composition of benthic invertebrates in the lower Columbia River.

Ho_{1B}: Continued implementation of rainbow trout flows does not affect the biomass, abundance and composition of benthic invertebrates in the lower Columbia River.

Ho_{1C}: Continued fluctuations of flow during the fall do not affect the biomass, abundance and composition of benthic invertebrates in the lower Columbia River.

Ho_2: Continued implementation of whitefish and rainbow trout flows during winter and spring, and fluctuating flows during fall, do not increase total biomass accrual of periphyton in the lower Columbia River.

Ho_{2A}: Continued implementation of whitefish flows does not increase total biomass accrual of periphyton in the lower Columbia River.

Ho_{2B}: Continued implementation of rainbow trout flows does not increase total biomass accrual of periphyton in the lower Columbia River.

Ho_{2C}: Continued fluctuations of flow during the fall do not increase total biomass accrual of periphyton in the lower Columbia River.

Ho_3: Continued implementation of whitefish and rainbow trout flows during winter and spring, and fluctuating flows during fall, do not increase the availability of fish food organisms in the lower Columbia River.

Ho_{3A}: Continued implementation of whitefish flows does not increase availability of fish food organisms in the lower Columbia River.

Ho_{3B}: Continued implementation of rainbow trout flows does not increase availability of fish food organisms in the lower Columbia River.

Ho_{3C}: Continued fluctuations of flow during the fall do not increase availability of fish food organisms in the lower Columbia River.

The hypotheses will also be examined for reach-specific differences in periphyton accrual rates and abundance/ biomass/ diversity of benthic invertebrates.

1.4 Key Water Use Decision Affected

The key operating decision that will be affected by this monitoring program is the continued annual provision of whitefish flow management and rainbow trout protection flows in the lower Columbia River and associated fluctuating flows during the fall. The questions addressed in this monitoring program directly relate to estimating how provisions of these flows improve or maintain the physical habitat and ecological productivity of the lower Columbia River. The physical habitat and ecological productivity time series data and the associated inferences regarding effects on fish habitat conditions are a key component of the interpretation of other integrated monitoring programs that will be implemented in the lower Columbia River. This information is critical for constructing a logical linkage between the operation of Hugh L. Keenleyside Dam and response indicators for the productivity of the benthic community, changes in fish habitat use, and productivity of fish populations in the lower Columbia River.

2.0 MONITORING PROGRAM PROPOSAL

2.1 Objective and Scope

The goal of the lower Columbia River Physical Habitat and Ecological Productivity monitoring programs is to provide empirical information on how the continued implementation of whitefish and rainbow trout flows during winter and spring, and associated fluctuating flows during fall, affect physical habitat and ecological productivity attributes in the river. Data are required to support inferences regarding observed seasonal and inter-annual changes in habitat conditions as a result of continued implementation of whitefish and rainbow trout flows, compared to key ecological productivity indicators from scientific literature. Results will also be compared with those of parallel monitoring programs in the mid Columbia River as a general indicator of the ecological health of the Columbia River downstream of Revelstoke dam.

The objectives of the lower Columbia River Physical Habitat monitoring program are to:

9) Collect time series data on the daily and seasonal river water temperature regimes under current whitefish and rainbow trout flow operations.
10) Measure spatial and temporal differences in the seasonal and inter-annual range of river level fluctuation during the continued implementation of whitefish and rainbow trout flow operations.
11) Provide physical habitat data for the lower Columbia River to which physical habitat data from the mid Columbia River can be compared qualitatively.

The scope of the lower Columbia River Physical Habitat monitoring program is:

1) Collect time series data on water temperature and river stage at index monitoring stations in three reaches of the lower Columbia River.
2) Conduct seasonal water quality sampling (electrochemistry and biologically active micronutrients) at index monitoring stations in three reaches of the lower Columbia River.
3) Systematically collect seasonal nutrient and electrochemistry data three reaches of the lower Columbia River to spatially characterize water quality conditions as they affect biological productivity of the benthic community.
4) Use the empirical data to test hypotheses about the influence of whitefish and rainbow trout flows on the water temperature, hydraulic characteristics and water quality in the lower Columbia River and to determine how these parameters compare to the mid Columbia River.
5) Develop an electronic data base system for systematic storage and retrieval of physical habitat data for the lower Columbia River.

The objectives of the lower Columbia River Ecological Productivity monitoring program are:

1) To design and implement a systematic long term program for indexing the productivity and diversity of key benthic community taxa (periphyton and invertebrates) in the lower Columbia River.
2) To assess the effects of whitefish flows, rainbow trout flows and fall flow fluctuations on the benthic community taxa (periphyton and invertebrates) of the lower Columbia River.
3) To investigate and quantify the relationship between habitat attributes and benthic composition, abundance, and biomass within the lower Columbia River to identify factors that are most important in determining the availability of fish food organisms.

The scope of the Lower Columbia Ecological Productivity monitoring program is to conduct annual monitoring of periphyton and benthic productivity in three reaches of the lower Columbia River. The geographic scope of the monitoring programs is the ~30 km long section of the lower Columbia River from Hugh L. Keenleyside Dam to the Birchbank Water Gauge station. The study area will be divided into three reaches as described in Table CLBMON-44-1.

Table CLBMON-44-1 Proposed common reach breakdown recommended for the Lower Columbia River Physical Habitat and Ecological Productivity monitoring program.

Reach	Description of Reach Boundaries
1	HLK to Norns Creek Confluence
2	Norns Creek Confluence to Kootenay River Confluence
3	Kootenay River Confluence to Birchbank

2.2 Approach

The approach of the physical habitat monitoring program is to establish index monitoring stations to collect physical habitat data in each reach of the study area for a systematic time series on water temperature, water quality and water level conditions. These stations must coincide with periphyton/benthic substrate locations for the ecological productivity monitoring, since the data will be used to help understand the influence of physical habitat conditions on the benthic community. Ecological productivity will be assessed by index monitoring of periphyton growth and benthic production during the peak growing season and during fluctuating flows in the fall. Artificial substrata will be used for all measurements of periphyton and benthic invertebrate community composition, abundance and biomass, using procedures consistent with Perrin et al. (2004).

The empirical data will be used to provide a fundamental description of physical habitat conditions and ecological productivity in each reach of the study area and to investigate how dam releases, tributary inflows, and reservoir operation impact key habitat characteristics. The data generated from this monitoring program will be archived in an electronic database and used as covariates in analyses conducted in other programs of the LCRFMP, which investigate the influence of physical habitat and ecological productivity on fish population response measures and fish habitat use (BC Hydro 2006).

2.3 Tasks

Eight tasks are required to complete the physical habitat and ecological productivity monitoring in the lower Columbia River.

2.3.1 Task 1: Project Management

Project management will involve the general administrative and technical oversight of the project, which 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 LCRFMP monitoring programs.

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

2.3.2 Task 2: Ecological Productivity - Preparation of Artificial Substrata and Associated Rigging

Artificial substrates will be prepared according to Perrin (2004) to allow for sampling under different velocity and depth conditions (including desiccated conditions). These substrates also support inter-site comparisons of endpoint measurements (e.g., abundance, diversity and biomass) without the risk of confounding by substrata size, or variation in sample collection by different field staff.

2.3.3 Task 3: Sampling and Measurements

As recommended in Perrin (2004), all three reaches will be intensively sampled during the peak growing season for three years to describe area biomass and community metrics at deep and shallow strata to establish a baseline data set. After the baseline is established, sampling consistent with the first three years will be conducted at the sample stations in Reach 2 to monitor potential changes over time.

To assess the potential effects of fall flow fluctuations, sampling consistent with the late summer sampling program will be conducted during late fall at the sample stations in Reach 2 only for the first three years of the monitoring program, then biannually for four additional years.

In each year of the study, periphyton substrates and benthic invertebrate substrates will be installed at each elevation strata within each of the river reaches. There will be two stations in R1, seven stations in R2 and two stations in R3. Each station will include a periphyton sampler and a benthic sampler in three depth strata. The depth strata should be shallow (surface to 2m), medium (2-5 m water depth), and deep (>5m). For Reach 2, sufficient replication will be required within each reach and depth strata to provide for a quantitative evaluation of endpoints. For Reaches 1 and 3, a qualitative evaluation of trends in growth and production is preferred. Within budget constraints, consistency with Perrin et al. (2004) is recommended to allow for data comparisons.

Periphyton biomass on the substrata should be sampled weekly for a period of 49 days (7 weeks). Weekly biomass samples should be used for measuring the rate of algal biomass accrual (slope of the line of change in biomass over time) and peak biomass (highest biomass attained on a substratum over the time series). On the last sampling day, an additional sample should be collected for the enumeration of cells by algal species.

The benthic invertebrate baskets should remain installed and undisturbed for 49 days. The basket contents should then be harvested and submitted to a laboratory for enumeration of all individuals, by genus (or other reliable taxonomic level) and measurement of biomass categorized by major taxonomic groups.

2.3.4 Task 4: Temperature and Stage Monitoring

Water temperature and river stage monitoring will be conducted in each of the reaches established for the ecological productivity monitoring. There will be three stations in Reach 2 and one station in each of Reaches 1 and 3.

2.3.5 Task 5: Seasonal Water Quality Sampling

Seasonal water quality sampling will be conducted at each index site established for the ecological productivity monitoring, as well as primary tributaries, at the beginning and end of the sample collection for the ecological productivity study, as well as three supplementary times throughout the year. Water samples will be collected and analyzed for nutrients, total suspended solids (TSS) and turbidity, and electrochemistry measurements will be recorded.

2.3.6 Task 6: Develop Lower Columbia River Physical Habitat and Ecological Productivity 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 ecological productivity variables. An objective of developing this database system is to facilitate the testing of hypotheses about physical habitat changes or ecological productivity, as well as facilitating access to data for other monitoring program analyses within the lower Columbia River monitoring program. Any database that is developed should be compatible with a similar system being developed for the mid Columbia.

2.3.7 Task 7: Data Analysis

Data analysis for physical habitat will be conducted each year for the first three years and summarized at the end of the third year to be included in an interim report of the baseline monitoring program. Subsequently, data will be summarized annually and reported bi-annually in conjunction with the results of the ecological monitoring program.

In each of the first three years, comparisons of benthic community composition and biomass will be made within and between the reaches. In subsequent years, comparisons of benthic community composition and biomass will be made within Reach 2 only. Physical habitat descriptions will accompany the biological community descriptions. A qualitative comparison will be made between the community of benthic invertebrates and the composition of food that is ingested by fish in the lower Columbia River.

In Year 2 of the program, a preliminary model will be advanced to examine the relative importance of the habitat attributes on the benthic invertebrate community groupings, abundance metrics and biomass. At the end of the study, multiple lines of evidence will be compiled to determine if the continued implementation of whitefish and rainbow trout flows influence the structure of the benthic community of the lower Columbia River.

2.3.8 Task 8: Reporting

A brief technical report will be prepared each year of the program, which will outline the field and analytical methods, summary results of key field measurements, data analysis and interpretations. A synthesis of data collected in the first three years will be provided in an interim report, which should include recommendations for improving assessment methods in future years of the program. A comprehensive report shall be prepared upon completion of the monitoring program, which will include:

- an executive summary;
- a description of the methods employed;
- a data summary;
- analysis results and a comparison of results among years;
- a detailed summary of the findings as they relate to the ecological hypotheses and the key management questions; and
- any recommendations for operational changes as a result of observed changes.

Reports will follow the standard format that is being 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 and ecological productivity associated with the whitefish and rainbow trout flows, and fluctuating flows during fall from Hugh L. Keenleyside Dam. It will be used to develop inter-annual indicators of ecological health that serve to document long term trends in the health of the aquatic ecosystem. The data and inferences from these hypotheses are the first component in the logical chain of inference of how physical influences from flow releases affect the fish habitat (flow releases → physical conditions → ecological productivity → fish populations) in the lower Columbia River.

2.5 Schedule

The Physical Habitat Monitoring program will be conducted annually over the period of implementation of the Columbia WUP (2008-2019). The Ecological Productivity Monitoring program will be implemented as described above in Section 2.3.3. A technical review of the study findings will occur after three years of the program.

2.6 Budget

The combined study cost recommended by the WUP CC in 2004 for the Physical Habitat and Ecological Productivity monitoring programs was $125,000. Although the budget for this study is considerably higher than the CC estimate in Years 1-3, 5, and 7, costs for the remaining years of the study are substantially less than the estimate. Over the duration of the study, the average annual cost of undertaking this work is $165,891. Table CLBMON-44-2 provides a detailed breakdown of the annual budget,

3.0 REFERENCES

BC Hydro. 2005a. 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, B.C.

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