# Columbia River Project Water Use Plan

# Monitoring Program Terms of Reference

# LOWER COLUMBIA RIVER FISH MANAGEMENT PLAN

- **CLBMON-48 Lower Columbia River Whitefish Life History and Egg Mat 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$m^3s^{-1}$ 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.

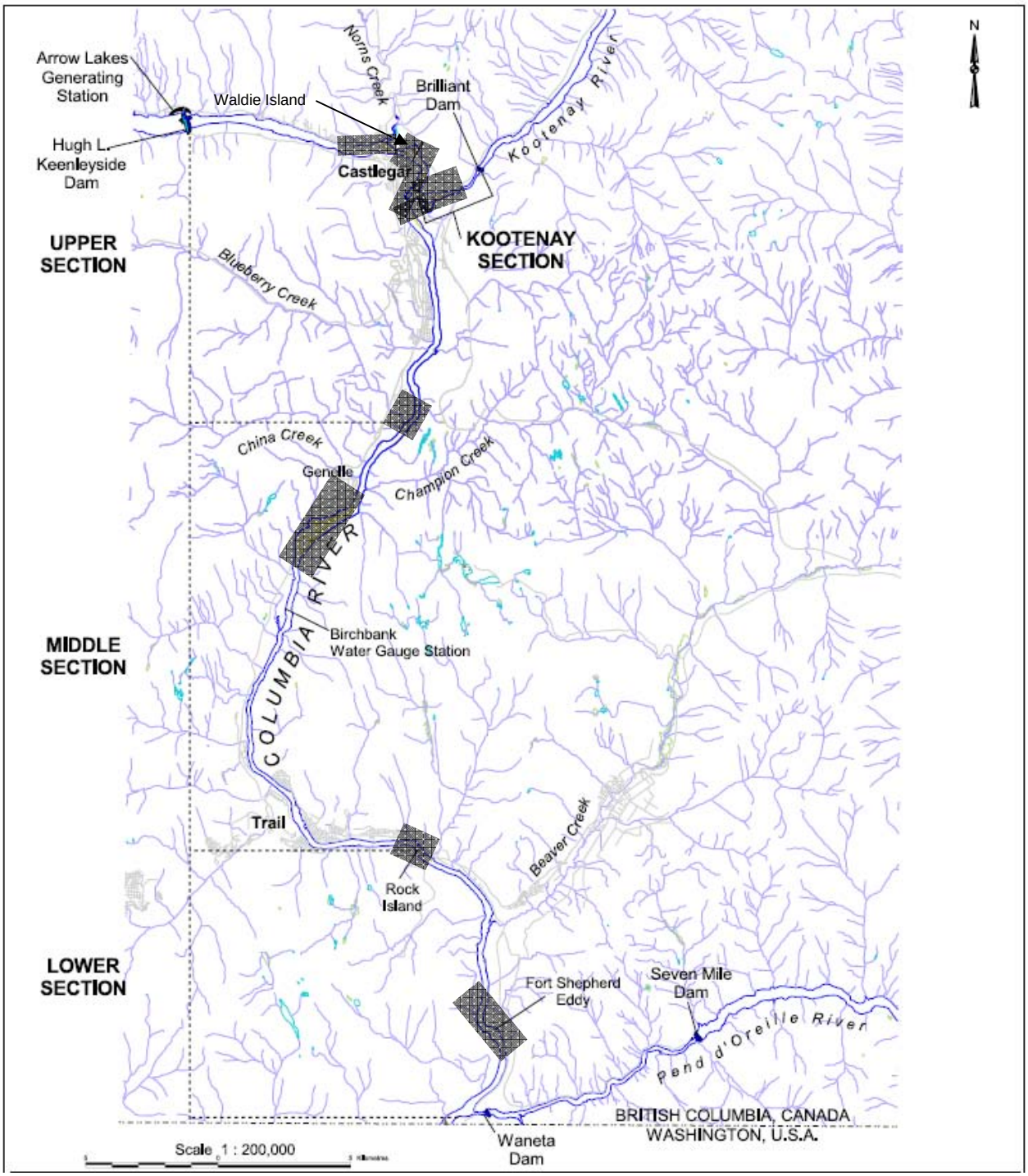
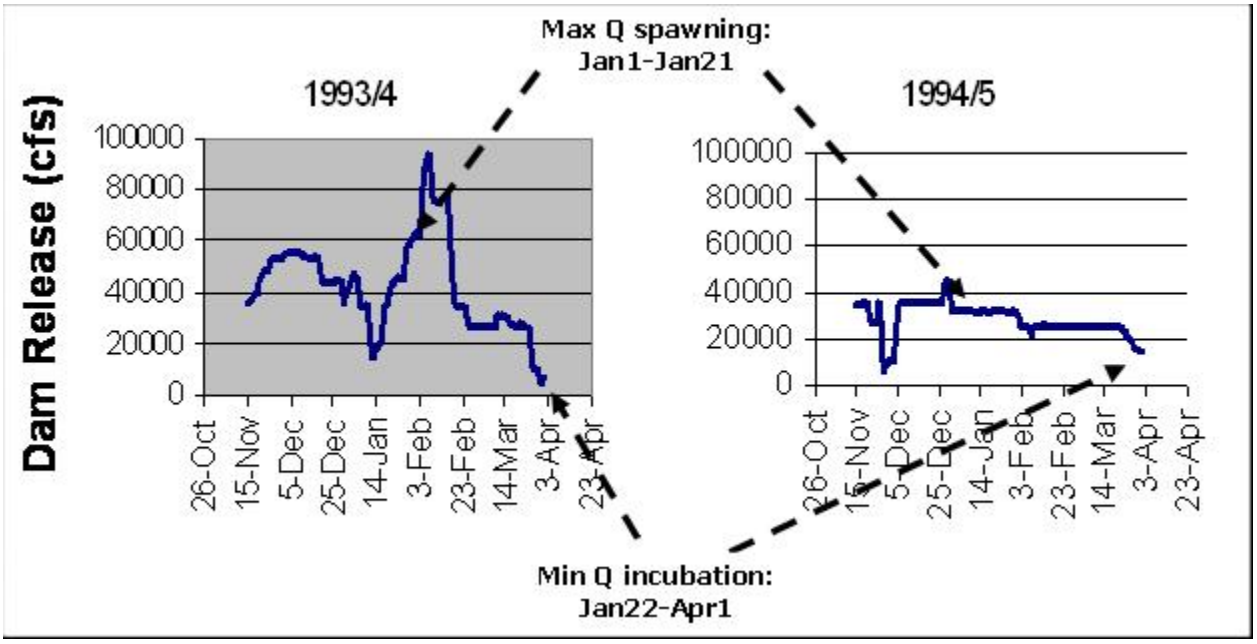



**Figure 1** **Map of the Columbia River below Hugh Keenleyside dam showing the study area boundaries, known whitefish spawning areas (grey hatched boxes), Great Blue heron overwintering habitats at Waldie Island, and reach breakdown used for whitefish population index monitoring program initiated in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

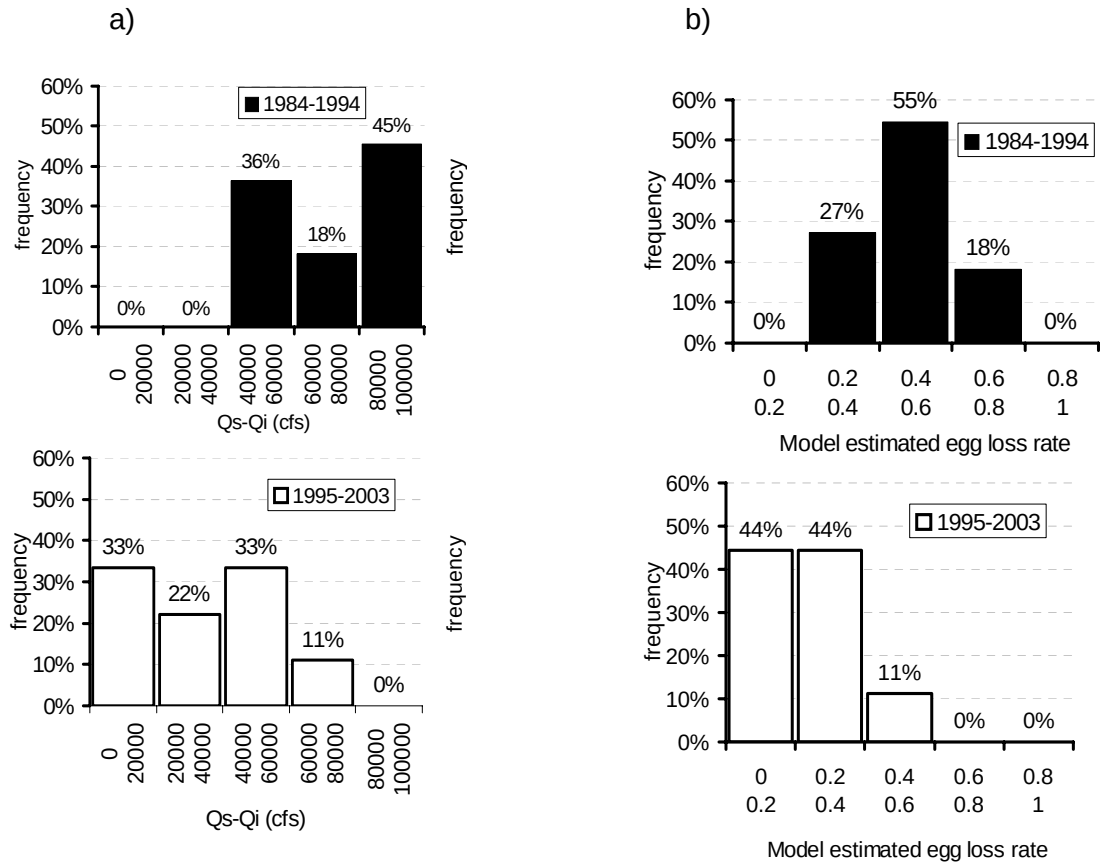



**Figure 3** **Distributions of flow stabilization index ($Q_{Smax} - Q_{Imin}$) and modelled egg losses for periods before and after the implementation of WFM. a) $Q_{Smax} - Q_{Imin}$ is difference between the maximum spawning flows during peak spawning (Jan 1 – Jan 21, $Q_{Smax}$) and the minimum 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.

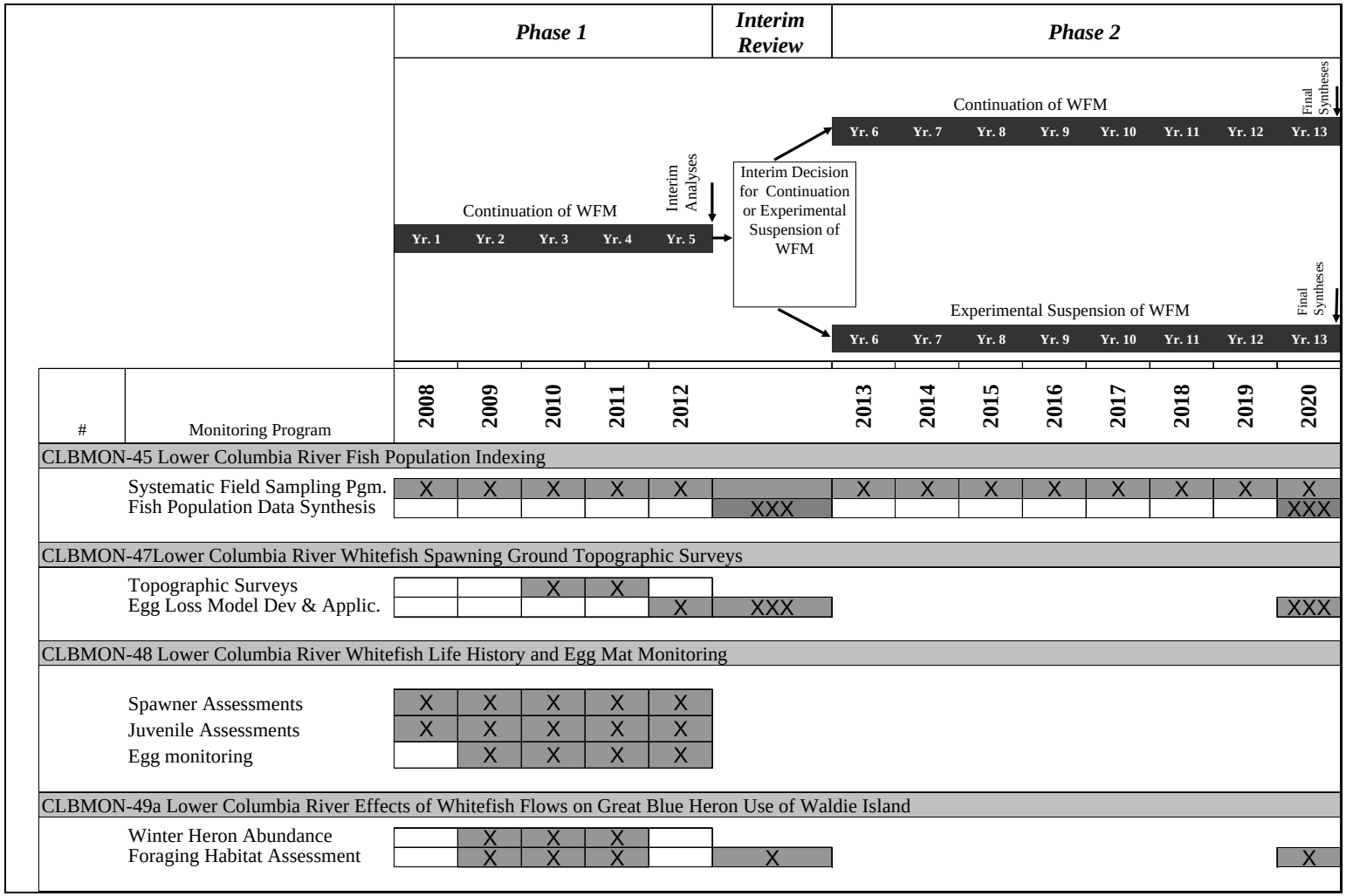



**Figure 4** **Conceptual approach and annual schedule for the implementation of monitoring programs and key activities for the evaluation of the biological effectiveness of WFM for the conservation of the mountain whitefish population in the lower Columbia River.**

# Monitoring Study No. CLBMON-48
# Lower Columbia River Whitefish Life History and Egg Mat Monitoring Program

## 1.0 MONITORING PROGRAM RATIONALE

### 1.1 Background

The Columbia River Water Use Plan Consultative Committee (WUP CC) supported the implementation of an adaptive management program to evaluate the effectiveness of the whitefish flow management (WFM) to conserve mountain whitefish populations of the lower Columbia River (BC Hydro 2005a, 2005b). An objective of this adaptive management program was to address outstanding biological uncertainties associated with the life history and habitat use of different life stages of whitefish in the lower Columbia and Kootenay rivers.

Monitoring has confirmed that whitefish eggs are dewatered by flow changes in the lower Columbia River (Golder 2003). However, egg loss estimates derived from field data were not precise enough to support trade-off decision making processes surrounding WFM implementation. In 2003, a process-based model was developed on limited field data to improve estimates of the relative risk of egg loss under alternative flow scenarios for WFM planning purposes (the “WF Egg Loss Model”, Golder 2003). The WF Egg Loss Model is now the primary analytical tool for quantifying egg losses that occur as a consequence of observed flow patterns. The model utilizes daily flow data and river cross-section information at index spawning locations to model river stage at index spawning areas during spawning and egg development periods. Biological assumptions of the seasonal timing of spawning, development rates of ova and the vertical distribution of deposited eggs in the river channel are incorporated to estimate daily losses of eggs resulting from flow changes. Although the model provides a transparent quantitative framework for evaluating egg loss risk, the WUP CC expressed concern associated with reliability of the WF Egg Loss Model for quantifying egg losses resulting from regulated flow changes during the adaptive management program.

To reduce this uncertainty the WUP CC recommended a biological monitoring program to: a) improve the understanding of whitefish life history and reproductive ecology; b) document topographic characteristics of representative whitefish spawning locations; and, c) improve the understanding of seasonal changes in the distribution of eggs in the river channel. This information is required in the adaptive management program for the refinement of the WF Egg Loss Model, and to provide auxiliary data and information to support the interpretation of the more systematically collected population time series data obtained through the ongoing Lower Columbia Fish Population Index Surveys (CLBMON-45). Physical data collection and actions to refine the egg loss model are included in the terms of reference for a related monitoring program (CLBMON-47 Lower Columbia River Mountain Whitefish Spawning Ground Topographic Survey).

The overarching objective of this monitoring program is to collect and refine data regarding the location, timing and depth distribution of mountain whitefish spawning in the lower Columbia River below Hugh L. Keenleyside (HLK) Dam to improve the annual estimate of egg mortality.

## 1.2 Management Questions

There are six key management questions addressed by this monitoring program. The first four are aimed at creating an understanding of the general life history, reproductive biology and habitat use by adult whitefish. This information is required to validate and/or refine key assumptions used in the egg loss model. The last two management questions relate to interpretation and measurement of the response of the whitefish population using adult and juvenile index monitoring approaches.

The management questions are:

1) What is the spatial distribution of whitefish spawning activities in the lower Columbia and lower Kootenay rivers? Is there inter-annual variation in spawning habitat use? Is the spatial distribution of spawning locations associated with flow management?

2) What are the physical and hydraulic characteristics of whitefish spawning and egg incubation habitats?

3) What is the seasonal timing of whitefish spawning in the lower Columbia and lower Kootenay rivers? To what extent does the timing and intensity of spawning vary from year to year? Is the timing or intensity of spawning associated with flow management?

4) What is the pattern of egg dispersal at spawning locations? What is the vertical distribution of eggs in the river channel? Is the spatial distribution of eggs related to flow management?

5) What are the pre-spawning and post-spawning seasonal movement patterns of whitefish? How do patterns of sub-adult and adult migration affect the interpretation of annual index monitoring programs?

6) What habitats are juvenile whitefish using in the lower Columbia and lower Kootenay rivers? Is it possible to develop and implement a reliable program for indexing the young of the abundance as a measure of fish cohort strength?

## 1.3 Management Hypotheses

Six key hypotheses, corresponding to the management questions above, will be tested using data collected during the lower Columbia River Whitefish Life History and Egg Mat monitoring Program. The first four are stated as null hypotheses to test current assumptions of the Golder (2003) egg loss model. The model currently uses time averaged historical data about the spatial distribution and physical characteristics of spawning habitats, the timing of spawning events, and the resulting vertical distribution of eggs used by the egg loss model. These hypotheses are:

$Ho_1$: The distribution of spawning habitat used by mountain whitefish in the lower Columbia and lower Kootenay rivers does not differ significantly between years.

$Ho_2$: The physical habitat characteristics of spawning habitats of mountain whitefish in the lower Columbia and lower Kootenay rivers do not differ significantly between years.

$Ho_3$: The seasonal timing of spawning by mountain whitefish in the lower Columbia and lower Kootenay rivers does not differ significantly between years.

$Ho_4$: The vertical distribution of mountain whitefish eggs in the river channel in the lower Columbia and lower Kootenay rivers does not differ significantly between years.

The final two hypotheses are stated more generally to support interpretation and development of effective monitoring approaches for adults and juvenile life stages. These hypotheses are:

$Ho_5$: Whitefish undertake significant migrations in the lower Columbia and lower Kootenay rivers during pre-spawning and spawning periods, such that stock assessment conducted in Sept/Oct does not accurate reflect the spawning population abundance/characteristics.

$Ho_6$: Young of the year whitefish consistently use near-shore habitats and can be monitored to provide a reliable index of survival in the first year of life in the lower Columbia and Kootenay rivers.

## 1.4 Key Water Use Decision Affected

The key operating decision that will be affected by the implementation of the whitefish adaptive management program is the long-term continuation or suspension of WFM actions in the lower Columbia. Results from the completed study and associated inferences from other monitoring programs in the lower Columbia River will determine whether these flows improve or maintain the population status of mountain whitefish in the study area. In particular, the monitoring programs will determine whether implementing minimum flows during the peak spawning period (Jan 1-21) significantly reduces egg dewatering, subsequent egg mortality, and ultimately recruitment to the juvenile mountain whitefish population. Results from this study and related programs will be used to establish the long-term operating release requirements for the HLK Dam.

Decisions around whitefish flow management for the conservation of whitefish populations will be based on a synthesis of outputs from: 1) an integrated physical and biological model to estimate relative egg loss associated with alternative flow management scenarios (the WF Egg Loss Model), and 2) explicit fish population dynamics modeling to provide a comprehensive assessment of fish population response to flow changes. This monitoring program will, therefore, support future water use decisions in two ways: 1) it will supply information needed for improving and validating key biological assumptions about the life history, reproductive ecology, and egg dispersal used in the egg loss modeling, and 2) it will provide critical information regarding the seasonal patterns of movement and habitat use of juvenile, sub-adult and adult whitefish. These data are required to reliably interpret monitoring data, and determine where refinements to the model would improve overall monitoring program reliability.

# 2.0 MONITORING PROGRAM PROPOSAL

## 2.1 Objective and Scope

The objectives of the Lower Columbia River Mountain Whitefish Life History and Egg Monitoring Program are to:

1) Quantify the periodicity (timing), intensity and distribution of mountain whitefish spawning in the lower Columbia River and lower Kootenay rivers during the December, January, and February spawning period.

2) Document the spatial extent and physical characteristics of whitefish spawning areas in the lower Columbia and lower Kootenay rivers.

3) Document vertical distribution (depth) of mountain whitefish eggs in various locations in the lower Columbia and lower Kootenay rivers during the December, January, and February spawning period.

4) Document the seasonal patterns of migration, habitat use and biology of adult mountain whitefish in the lower Columbia and lower Kootenay rivers.

5) Collect seasonal data on the biology, life history and habitat use of juvenile mountain whitefish in the lower Columbia and lower Kootenay rivers.

The scope of the Lower Columbia River Mountain Whitefish Life History and Egg Mat Monitoring Program is to:

1) Capture adult mountain whitefish in the lower Columbia River and lower Kootenay River, and implant those fish with radio/acoustic transmitters. These fish will be tracked to allow the timing, location and habitat use of pre-spawning, spawning, and post-spawning mountain whitefish to be evaluated.

2) Conduct systematic sampling for mountain whitefish eggs in several index locations in the lower Columbia River and lower Kootenay River, as determined through radio telemetry investigations, to estimate local timing of spawning and spatial dispersal patterns of eggs.

3) To design and implement a field sampling program for juvenile mountain whitefish in the lower Columbia River and lower Kootenay River to quantify abundance, distribution and patterns of habitat use.

The geographic scope of the mountain whitefish monitoring program is the ~55 km long section of the lower Columbia River from HLK Dam to the US border. In addition, some work may occur in the lower Kootenay River downstream of Brilliant Dam (Figure 1).

## 2.2 Approach

The approach of this monitoring program is sequential, where results from the first and second years of implementation will be used to refine and establish monitoring details (location, timing) for the last three years of implementation.

During the first year of monitoring, a coordinated field program will be undertaken involving two main activities: 1) a radio/acoustic tagging program of adult mountain whitefish to track their movements to spawning locations in the lower Columbia and lower Kootenay rivers, and establish index spawning areas and proposed locations for monitoring egg dispersal patterns, and 2) a systematic field sampling program to improve the understanding of the biology, habitat use, relative abundance, and distribution of pre-adult life stages of whitefish. This program will be implemented for a period of five years to allow identification of key spawning times/locations and other life history characteristics, as well as to document inter-annual variation in these parameters.

The results from the first year of monitoring will be used to begin pilot implementation of detailed sampling protocols, aimed at assessing egg dispersal patterns at key spawning sites. A description of egg deposition patterns is needed for egg loss modeling in the second year. Results from this work will be used to finalize sampling protocols, and will be repeated annually for the remainder of Phase 1 of the adaptive management program. In the final year, the results from all five years will be assembled and synthesized, and a final report for use in the Interim Analyses will be prepared.

## 2.3 Tasks

### 2.3.1 Task 1: Project Coordination

Project coordination 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 Lower Columbia River Fish Management Plan.

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: Field Sampling Program

*Radio/Acoustic Tagging and Tracking*

The objective of the radio/acoustic tagging task is to design and implement a coordinated field program to document the seasonal pattern of migration, spawning timing, spawning distribution and habitat use of pre-spawning adult mountain whitefish in the lower Columbia River. The sampling program methodology will be designed to meet the following objectives:

- Capture pre-spawning adult mountain whitefish (FL>250 mm, minimum n=30) and implant them with radio/acoustic tags;
- Track and locate implanted mountain whitefish to quantitatively identify migration timing, spawning locations and timing, and seasonal habitat use;
- Collect seasonal biological data (fork length, weight, sexual state, aging structures) from all sampled fish; and,

- Analyze telemetry and fish sampling information to infer the spatial distribution of whitefish spawning areas in the lower Columbia River, and recommend index sites for egg monitoring and topographic surveys.

*Egg Mat Sampling*

Egg mats will be deployed in a strategic manner to quantify the spatial and temporal patterns of egg dispersal at key spawning locations. The sampling design will involve the selection of representative locations to establish temporal changes in the vertical distribution of whitefish eggs deposited on the river channel bottom. Egg mat sampling will be initiated in the second year of Phase 1 studies to allow completion of one year of telemetric assessment of spawning locations. The design of this program should also build upon experience gained during previous whitefish egg sampling activities conducted (e.g., Golder 2003). The key goals of the egg mat sampling are to:

- Investigate the distribution and abundance of mountain whitefish eggs within the cross-sectional channel profile

- Document the seasonal timing and intensity of spawning activity at key spawning locations.

Whitefish eggs deposited on the mats will be enumerated and removed from the mats on a regular basis to document and test for temporal changes in the vertical distribution of eggs during the reproductive period. Representative samples of collected eggs will be preserved for subsequent examination of developmental stage to allow inference of development rates of eggs. Habitat measurements will also be taken at the locations where mats are deployed to characterize egg deposition habitats during egg collection periods.

The seasonal period of interest for egg sampling is the known whitefish spawning and egg development period (December through March). After completion of the egg sampling program at the end of Phase 1, a detailed analysis will be conducted to infer: a) seasonal changes in the timing of egg deposition (intensity of spawning), b) vertical distribution of whitefish eggs deposited in the cross-section profile of the river channel, and, where possible, c) effects of flow management on the vertical distribution of whitefish eggs in the river channel. These data are critical for testing the validity of assumptions or refining assumptions in the WF Egg Loss Model.

*Juvenile Sampling*

A systematic field sampling program will be undertaken to document seasonal patterns in the distribution, habitat use and general biological characteristics of juvenile and sub-adult stages of whitefish. Past sampling efforts to determine the biology of juvenile and sub-adult whitefish have been limited. The goal of this component of the program is to develop effective sampling procedures, provide information essential to interpretation of inferences from adult index monitoring, and attempt to develop a systematic unbiased index for quantifying the patterns of recruitment of young of the year whitefish.

### 2.3.3 Task 3: Data Analysis and Reporting

To facilitate effective management of data from the monitoring program and support of the Interim Analysis review, annual technical reports will be prepared to: 1) describe the methods used to address the statement of work; 2) present the data and results of field investigations; 3) discuss key findings of the investigations; and 4) provide recommendations for the refinement of field sampling protocols. A final synthesis report will be initiated and completed in the fifth year of Phase 1 of the adaptive management program, which will include:

- an executive summary;
- a description of the methods employed;
- a data summary;
- a detailed discussion of the findings as they relate to the management questions and hypotheses; and,
- any recommendations for the refinement of field sampling protocols

The report 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

This monitoring program is one component of an adaptive management program to assess the biological effectiveness of winter flow stabilization for conserving whitefish populations in the lower Columbia and lower Kootenay rivers. The results from this monitoring program are key inputs into the Interim Analysis for the adaptive management program, and are required to decide on the continuation or experimental suspension of WFM practices for winter flow management at HLK Dam.

The two key inputs are associated with a) refinement and testing of key biological assumption used in the WF Egg Loss Model (timing of spawning, seasonal variation in intensity of egg deposition, temporal variation in horizontal and vertical distribution of eggs deposited on the river channel bottom at known spawning areas), and, b) critical life history and biological data needed for the interpretation of results of adult population indexing and fish population dynamics modeling. Recent adult monitoring programs (Golder 2006) have demonstrated a high variability in population abundance over time, and variable patterns of recruitment in relation to WFM. It is anticipated that the interpretation of the life history results will lead to a more reliable understanding of the results of population monitoring, and more confidence in inferences regarding the impacts of winter flow variation on patterns of recruitment and adult whitefish abundance.

## 2.5 Schedule

The Lower Columbia River Mountain Whitefish Life History and Egg Mat Program will be conducted annually for five years during the 12-year implementation period of the Columbia River WUP (Figure 3).

## 2.6 Budget

The total annual cost for the monitoring program is estimated at $169,817 (in 2004 dollars), and an average annual cost of $169,979 (assuming a 2% rate of inflation and 5% contingency). The annual study budget recommended by the WUP CC in 2004 was $150,000.

Table CLBMON-48-1 provides a detailed breakdown of the costs of the monitoring program.

# 3.0 REFERENCES

BC Hydro. 2005a. Consultative Committee report: Columbia River Water Use Plan, Volumes 3 and 2. Report prepared for the Columbia River Water Use Plan Consultative Committee by BC Hydro, Burnaby, BC.

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Golder Associates Ltd. 2003. Estimates of Mountain Whitefish Egg Stranding Mortality for potential Columbia River Flow Reductions in 2002 - 2003. Report prepared for BC Hydro, Castlegar, BC. Golder Report No. 02-28-057D: 12 p.

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