Columbia River Project Water Use Plan

Lower Columbia River Fish Management Plan
Monitoring Programs Annual Report: 2011
Implementation Period: August 2010 to July 2011

- CLBMON-42 Lower Columbia River Fish Stranding Assessment and Ramping Protocol
- CLBMON-43 Lower Columbia River Sculpin and Dace Life History Assessment
- CLBMON-44 Lower Columbia River Physical Habitat and Ecological Productivity Monitoring
- CLBMON-45 Lower Columbia River Fish Population Indexing Surveys
- CLBMON-46 Lower Columbia River Rainbow Trout Spawning Habitat Assessment
- CLBMON-47 Lower Columbia River Whitefish Spawning Ground Topographic Survey
- CLBMON-48 Lower Columbia River Whitefish Egg Monitoring & Life History Study
- CLBMON-49 Lower Columbia River Effects of Whitefish Flows on Great Blue Heron & Winter Use of Waldie by Great Blue Heron

Conditional Water Licences for Kinbasket storage (27068 and 39432), Mica diversion (39431), Revelstoke diversion and storage (47215), and Arrow storage (27066)

August 31, 2011
1 Introduction

This document provides a summary of the status and results of monitoring programs and physical works being implemented under the Lower Columbia River Fish Management Plan of the Columbia River Water Use Plan (WUP) to 31 July 2011, as per the Columbia River Order under the Water Act, dated 26 January 2007. There are eight monitoring programs included within this Management Plan:

- CLBMON-42 Lower Columbia River Fish Stranding Assessment and Protocol
- CLBMON-43 Lower Columbia River Sculpin and Dace Life History Assessment
- CLBMON-44 Lower Columbia River Physical Habitat and Ecological Productivity Monitoring
- CLBMON-45 Lower Columbia River Fish Population Indexing Surveys
- CLBMON-46 Lower Columbia River Columbia Rainbow Trout Spawning Habitat Assessment
- CLBMON-47 Lower Columbia River Whitefish Spawning Ground Topographic Survey
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2 Background

The water use planning process for BC Hydro’s Columbia River project was initiated in August 2000 and completed in June 2004. The conditions proposed in the WUP for the operation of the project reflect the June 2004 consensus recommendations of the Columbia River WUP Consultative Committee (CC).

In July 2006, the Columbia River Draft WUP was submitted to the Comptroller of Water Rights (CWR). The draft WUP was sent out to regulatory agencies, First Nations and interested stakeholders for review. In January 2007, the CWR approved the final WUP and issued an Order to BC Hydro to implement the conditions proposed in the Columbia River WUP and prepare the monitoring programs and physical works Terms of Reference (TOR).

An addendum to the Columbia River WUP was submitted to the CWR in July 2007 after an Environmental Assessment Certificate was issued for the Revelstoke Unit 5
Project. The addendum proposes additional terms and conditions for the Columbia River WUP, as recommended by the Revelstoke Unit 5 Core Committee in December 2006, to address incremental impacts of the operation of the fifth generating unit at Revelstoke Dam.

In August 2007, the CWR accepted the Columbia River Project WUP Addendum resulting from the Revelstoke Unit 5 Project, and issued amendments to the Columbia River Implementation Order to include the commitments made by BC Hydro to undertake additional monitoring programs and physical works associated with the Revelstoke Unit 5 Project.

The following table outlines the dates that TOR for the Lower Columbia River Fish Management Plan were submitted to and approved by the CWR.

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<th>Monitoring Programs/ Physical Works TOR</th>
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As outlined in the Columbia River WUP, the CC recommended a full review of the Plan 13 years after implementation, unless results of the monitoring program suggest an earlier review is appropriate or significant risks are identified that could result in a recommendation to change operations.

BC Hydro will convene a multi-party panel five years after commencing the implementation of this WUP to evaluate the effectiveness of operations and physical works in meeting the stated objectives for Arrow Lakes Reservoir and the lower Columbia River. The outcomes from this process will be used to assess any potential need to review the Arrow Lakes Reservoir component of this WUP. If a replacement Non-Treaty Storage Agreement (NTSA) is negotiated within this 5-year period, it is
also recommended that agreement provisions and implications be reported out through this panel. Signing of a new NTSA is not a trigger for panel evaluation or a review of this Water Use Plan recommendation to change operations.

3 Schedule

The following table (Table 3-1) outlines the current schedule for the monitoring programs being delivered under the Lower Columbia River Fish Management Plan of the Columbia River WUP.

Table 3-1: Schedule of Columbia River WUP Monitoring Program Implementation under the Lower Columbia River Fish Management Plan

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Legend: * = Program to be undertaken/initiated in identified year
u/w = Project is underway
✓ = Program completed for the year
× = Program started, but encountered operational or hydrological delays

4 Columbia River WUP Monitoring Programs – Lower Columbia River Fish Management Plan

This section summarizes the status of the monitoring programs being implemented under the Lower Columbia River Fish Management Plan of the Columbia River Water Use Plan, as per the Order under the Water Act, dated January 26, 2007.

4.1 CLBMON-42 Lower Columbia River Fish Stranding Assessment and Ramping Protocol

4.1.1 Management Questions

The key management questions addressed by this monitoring program are:

1) Is there a ramping rate (fast vs. slow, day vs. night) for flow reductions from HLK that reduces the number of fish stranded (interstitially and pool) per flow reduction event in the summer and winter?

2) Does wetted history (the length of time the habitat has been wetted prior to the flow reduction) influence the number of fish stranded (interstitially and pool) per flow reduction event for flow reductions from HLK?

3) Can a conditioning flow (a temporary, one step, flow reduction of approximately 2 hours to the final target dam discharge that occurs prior to the final flow change) from HLK reduce the stranding rate of fish?
4) Can physical habitat works (i.e., recontouring) reduce the incidence of fish stranding in high risk areas?

5) Does the continued collection of stranding data, and upgrading of the lower Columbia River stranding protocol, limit the number of occurrences when stranding crews need to be deployed due to flow reductions from HLK?

4.1.2 Overview

The primary objective of this monitoring program is to collect fish stranding data to assess the impact of flow reductions and flow ramping rates from Hugh L. Keenleyside (HLK) Dam on the native fish species of the lower Columbia River. Secondary objectives include: (1) reducing (through risk management strategies) the number of occurrences when stranding crews need to be deployed with flow reductions; (2) determining ramping rates for flow reductions that reduce the stranding rate of fish at different times of the year; (3) determining whether the wetted history influences the stranding rate of fish for flow reductions; (4) determining whether a conditioning flow reduction from HLK reduces the stranding rate of fish; and (5) determining whether physical habitat manipulation reduce the incidence of fish stranding in the lower Columbia River.

The Columbia River WUP CC agreed on four actions that could provide the greatest potential gains to wild indigenous fish populations in the lower Columbia River (BC Hydro 2005a, 2005b). Two of these actions were related to fish impacts associated with flow regulation at HLK and included:

- Explore opportunities to minimize the frequency and magnitude of flow reductions and develop a flow reduction protocol and standard methods for assessment, data collection and mitigation responses to manage fish stranding impacts.

- Conduct flow ramping studies to determine appropriate ramping rates to minimize pool and interstitial stranding.

It was recommended that the above strategy and associated monitoring program was an acceptable approach to addressing the impacts of flow reductions at HLK on fish stranding in the lower Columbia River.

Monitoring Indicators:

a) Program will monitor the number of fish stranding incidences in the lower Columbia River (where dictated by the lower Columbia River Stranding Protocol) when flow reductions occur from HLK.

b) Program will monitor the number of fish stranded after utilizing various ramping rate experiments.

c) Program will monitor whether fish stranding continues to occur at locations where gravel bar re-contouring has been conducted.

The approach of this monitoring program is to continue stranding surveys within the study area over the period of the Columbia WUP. These stranding surveys will be undertaken as required through the implementation of the lower Columbia River Stranding Protocol – including future updates.
In addition, flow ramping studies will continue for a period of time as warranted by interpretation of the results. The flow ramping program was initiated through negotiation with Fisheries and Oceans Canada (DFO), and the program was further examined by the Columbia WUP CC. BC Hydro meets with the Columbia Operations Fish Advisory Committee (COFAC) annually to review the results of the flow ramping program and to receive direction on future study/monitoring requirements. As such, the primary objective of the monitoring program is to meet the requirements of the regulatory agencies, and, if agreed to by the regulatory agencies, to approach the Comptroller of Water Rights for sign off on meeting the requirements of this component of the Columbia WUP in an earlier time period.

Finally, where appropriate, physical habitat works in the form of gravel bar re-contouring will be considered for areas where a high rate of fish stranding occurs. Similar work has been undertaken previously in the study area, and further work will be considered if proposed flow ramp rates do not reduce the rate of stranding, or high risk areas are identified through the stranding surveys.

4.1.3 Status

This monitoring program was initiated in August 2007, and will be carried out over 13 years. Program reports for Year 1 (2007/2008), Year 2 (2008/2009), Year 3 (2009/2010) and Year 4 (2010/2011) have been received by BC Hydro. Attached is the Year 4 report.

A summary of the flow ramping studies conducted on the Lower Columbia and Kootenay rivers (2004 to 2007) was undertaken and presented to COFAC at their 24 June 2008 meeting. The presentation included a summary of the flow ramping data that has been collected to date, as well as a detailed power analysis to determine “where we are at” with regards to answering the objectives of the monitoring study. A summary of the annual stranding assessment results was also presented for both the lower Columbia and Kootenay rivers. Following the presentations, it was concluded by the committee that flow ramping studies in the lower Columbia River should cease until a full review of the all related information (e.g., ramping studies, stranding assessment data, and grey literature) could be completed.

The lower Columbia River Stranding Surveys component of the monitoring program will be conducted annually until 2019.

Feasibility to identify and assess potential areas for physical habitat manipulation will be conducted using information from the ramping studies and stranding surveys, with physical habitat manipulation being implemented (pending DFO approval) in eight of twelve years (from Years 3 to Year 13). Effectiveness monitoring would be conducted in Years 6 through 13.

4.1.4 Interpretation of Data

a) Lower Columbia Fish Stranding Assessment

During the April 2010 to April 2011 fish stranding assessment, the overall objectives were to: 1) reduce the frequency and magnitude of flow reductions; 2) develop a flow reduction protocol that uses standard methods for assessment;
and, 3) collect data and identify possible mitigation measures in response to observed fish stranding impacts. The revised fish stranding protocol, “Canadian Lower Columbia River: Fish Stranding Risk Assessment and Response Strategy” (Golder, 2011), which updates and combines the lower Columbia (BC Hydro, 2003) and Kootenay protocols (BC Hydro, 2005), focuses on reducing incidences of fish stranding throughout the study area, by using the Fish Stranding Database to direct the fish salvage efforts. The continued accumulation of fish stranding and salvage information, as it relates to location, timing and magnitude of stranding, will assist in predicting the type of events and the locations that are more likely to have significant incidences of fish stranding. As the database continues to be populated with more data, the ability to accurately identify sites likely to strand fish during flow reductions will increase.

This report summarizes the information collected as a result of flow reductions from operations at Hugh L. Keenleyside Dam/Arrow Lakes Reservoir (HLK/ALH) on the Columbia River and Brilliant Dam/Expansion (BRD/X) on the Kootenay River. Stranding assessments were conducted for 19 of the 21 reduction events (REs) that occurred between 1 April 2010 and 1 April 2011. Five assessments were conducted in response to flow reductions from BRD/X and 14 assessments were in response to flow reductions from HLK/ALH. An estimated 20,320 isolated or stranded fish were observed during 15 of the REs with zero fish identified as stranded during the remaining 4 events. The majority (88%) of stranded fish were observed during 6 REs that occurred during a known high stranding risk period (1 June to 30 September). The total number of fish observed or captured for each RE ranged from 0 to 7,513. The majority of the isolated fish were identified from pools located at the Fort Shepherd Launch RUB (38.1%), Genelle Mainland LUB (20.0%), Kootenay River RUB (17.0%) and Kootenay River LUB sites (9.0%) (Table 3). The remaining 15.9% of the isolated fish were found at the Norn's Creek Fan RUB, Gyro Boat Launch RUB, Bear Creek RUB, Tin Cup Rapids RUB, Lions Head RUB, Casino Road Bridge LUB (downstream), CPR Island Mid, Millennium Park LUB, Beaver Creek RUB, Fort Shepherd Eddy LUB and the Zuckerberg Island LUB sites. Fish were not found stranded at the remainder of the sites visited during the monitoring period.

Over 90% of the stranded fish recorded at the Fort Shepherd Launch RUB site were young-of-the-year Smallmouth Bass observed during RE2010-12 and RE2010-13. Two adult Smallmouth Bass were also observed in isolated pools during these REs. A detailed memo summary was prepared for RE2010-12 as per the reporting requirements for a major stranding event (>5000 fish observed). Similarly, 92% of the stranded fish from the Kootenay River LUB site were observed during RE2010-11 (an assessment related to Kootenay load factoring) and a separate memo was provided. The majority (81%) of the fish stranded during RE2010-11 were larval cyprinids and catostomids. Subsamples (n=117) collected and preserved during this RE were identified as larval Sucker species, Longnose Dace, and Redside Shiner. The majority (90%) were Sucker species.

Over the 2010/2011 assessment period, 154 Umatilla Dace were stranded. Most of the Umatilla Dace were from the 2 sites on the Kootenay River (67%) and the Fort Shepherd Launch RUB site (29%). The remainder were from the Tin Cup Rapids RUB, Genelle Mainland LUB and Gyro Boat Launch RUB sites.

The 2010-11 fish stranding assessment annual report is the first year that information from the two systems has been combined into a single document.
This was done because fish stranding in this section of river is influenced by both systems and the same key variables that affect fish stranding and the management and methods are similar. Information that is distinct for each system has been identified and the BC Hydro Water Use Plan objectives and management questions have been evaluated.

b) Lower Columbia River Ramping Protocol

No ramping experiments were conducted during this last reporting period. The recommendations from the Lower Columbia River Fish Stranding Protocol Review suggest that there have been enough experiments done, between the Duncan and Lower Columbia, to provide adequate direction to BC Hydro.

c) No physical works, in the form of gravel bar re-contouring, occurred during the third year of the program. The locations and types of physical works that could be conducted to help reduce fish stranding were recommended through the Columbia and Kootenay River Fish Stranding Protocol Review: Literature Review and Fish Stranding Database Analysis report. Eight locations were recommended as having potential benefits from recontouring, and include: Lions Head in Robson; Norm’s Creek Fan; Kootenay Oxbow; Millenium Park in Castlegar; Genelle Mainland; Genelle Cobble Island; Gyro Boat Launch in Trail; and Fort Shephard launch near Waneta Dam. Budget dollars are available for this portion of the project between years 2013 and 2019.

4.2 CLBMON-43 Lower Columbia River Sculpin and Dace Life History Assessment

4.2.1 Management Questions

The key management questions addressed by this monitoring program are:

1) How do water level fluctuations (diel and seasonal) in the lower Columbia River affect the distribution and habitat use of sculpins and dace, especially the listed species?

2) What seasonal and diel habitat shifts do sculpins and dace (especially the listed species) make in response to water level fluctuations?

3) Do the operations of Hugh L. Keenleyside Dam alter these natural movements? Specifically, does this risk of stranding increase?

4) Which operations, and at what season, pose the highest risk of stranding or interference with the normal life cycles of sculpins and dace?

4.2.2 Overview

The primary objective of this monitoring program is to provide information on the life history and habitat use of six species of shallow-water dwelling fish (four sculpins and two dace with special emphasis on Columbia sculpin and Umatilla dace) in the lower Columbia River that may be affected by water level fluctuations resulting from daily and seasonal operations of HLK Dam. More specifically, information will be collected on the spawning habitats used by Umatilla dace and the timing of their
spawning period, the abundance of Columbia dace and the habitats used by this species, and the importance of flooded areas at the confluence of tributaries and the main river as nurseries for young-of-the-year sculpins and dace. These nursery areas are the key habitat component of the shorthead sculpin (C. confusus) that are likely to be affected by the operations of HLK Dam.

During the Columbia River WUP process, the CC noted that the lack of biological information precluded explicit consideration of shallow-water dwelling threatened and endangered fish species in the lower Columbia River. Specifically, data were too limited to assess the potential risks to threatened/endangered sculpins and dace species, as may be posed by the seasonal operations of Hugh L. Keenleyside (HLK) Dam. Consequently, the CC recommended a study to determine the relative abundance, distribution, life histories, and habitat use of sculpins and dace in the lower Columbia River between HLK Dam and the US border. The goal of the study is to provide a qualitative assessment of the risks that the operation of HLK Dam may pose for federally listed species of sculpin and dace.

**Monitoring Indicators:**

a) Program will monitor how water level fluctuations (diel and seasonal) in the lower Columbia River affect the distribution and habitat use of sculpins and dace, especially listed species.

b) Program will monitor what seasonal and diel habitat shifts sculpins and dace (especially listed species) make in response to water level fluctuations.

c) Program will monitor if the operations of HLK Dam alter the natural movements of these species and pose an increased risk of stranding.

d) Program will monitor which operations, and at what season, pose the highest risk of stranding or interference with the normal life cycles of sculpins and dace.

This monitoring program will use existing information on the life history and ecology of sculpins and dace as a basis for selecting monitoring sites in the Columbia River below HLK Dam. After the literature review is complete, the methodologies will be developed to resolve any data collection obstacles encountered in earlier studies. Passive sampling procedures such as snorkel surveys, view tubes, D-ring or drift net sampling, and nest or egg traps may be used. Electrofishing may be used as a means to collect adults of each species.

**4.2.3 Status**

This project began in December 2008 with the initiation of an extensive literature review on the 4 sculpin (prickly; shorthead; Columbia; torrent) and 2 dace (Umatilla; longnose) species identified in the Terms of Reference. We completed the draft literature review in 2009 and finalized it in 2010 releasing it with the 2010 data report. Field work began in February 2009 in several Okanagan drainages in order to collect life history information from non-regulated river systems. The life history knowledge and lessons learned from the Okanagan sampling were then used for the October 2009 initiation of the Columbia River sampling program. In July 2010, the Literature Review and Year 1 data report were released. Work continued on the Lower Columbia River between March and August, 2010 and the Year 2 data report was released in June 2011.
4.2.4 Interpretation of Data

The present summary discusses Year 2 results of this program, which was conducted in 2010 to assess life history timing and habitats of sculpin and dace species as well as the potential impacts due to dam operations. Observations collected at Lower Columbia River (LCR) index sites were restricted to the shallow shoreline areas and information may not necessarily represent what is occurring throughout the LCR since deeper habitats could not be sampled adequately. However, sampling shallow, wadeable habitats focused efforts in areas that are prone to water level changes during flow fluctuations. Therefore, our sample methodology was successful in compiling information for sculpins to use in future comparisons. Additional techniques will be used in Year 3 (2011) to try to sample deeper habitat areas to determine their extent of use by target species, where possible.

Preliminary observations in the LCR indicate that diel fish distribution may change in response to water level fluctuations since sculpins were observed to move away from areas threatened with dewatering; dace were not observed at this time. It cannot be concluded at this time whether the operations of HLK Dam specifically alter the natural movements of target species and increase the risk of stranding. However, information collected in the LCR and in the unregulated systems studied provides initial observations to start answering this management question. The period most critical to sculpins and dace life history seems to be the spawning, incubation, hatch and larval rearing period that occurs from late May to late August. Increased stranding risk during the winter period has also been observed and this is a time when sculpins are increasing their gonadal weight for spawning. Natural spawn timing for sculpins occurs along the \textit{descending} limb of the hydrograph and commences when water temperatures are approximately 8°C. Spawn timing for dace is not available at this time. In the LCR, the onset of spawning for sculpins occurred during the \textit{ascending} limb of the hydrograph when water temperatures were approximately 8°C in 2010. Although this observed shift from natural spawn timing may reduce the incidence of stranding, it has other negative implications for abundance and fitness. Male sculpins also guard their nests until eggs hatch and will stay on the nest even if it becomes dewatered as evidenced in Pass Creek (unregulated system). Egg survival is usually high in natural systems (~90-95%). In the LCR, sculpin nests observed at Genelle (mainstem area) had much lower egg survival (8-25%) compared to what is observed naturally. It was likely that these nests were not dewatered. However, these mainstem nests may have been in deeper, higher velocity areas and nest maintenance may be energetically more costly and decreased nest cleaning may result in decreased egg survival. Dace spawning was not directly observed, but the presence of young-of-the-year (YOY) dace throughout the summer suggests that the spawning period may occur in pulses. Therefore, flow changes in July causing newly flooded or other suitable spawning areas to dewater may interfere with the normal life cycle of dace. In the LCR, YOY dace were observed in quiet, warm, vegetated shoreline margins after emergence and throughout the summer; this is similar to what is observed in unregulated systems.
4.3 CLBMON-44 Lower Columbia Physical Habitat and Ecological Productivity Monitoring

4.3.1 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.

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 interannual 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?

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?

4.3.2 Overview

Over the past decade, BC Hydro has attempted to stabilize water releases from HLK Dam during the 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 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 viewed as a fundamental information requirement for supporting other monitoring programs associated with the lower Columbia River Fish Management Plan. The physical habitat and ecological productivity study complements parallel monitoring programs being implemented 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.

**Monitoring Indicators**

a) Program will monitor the changes in water electrochemistry and biologically active nutrients due to seasonal operations of HLK Dam.

b) Program will monitor the changes in composition, abundance and biomass of epilithic algae and benthic invertebrates due to seasonal operations of Hugh Keenleyside Dam.

This monitoring program involves preparation of artificial substrates and associated rigging to allow for sampling under different velocity and depth scenarios, including desiccated conditions. Monitoring of water temperature and river stage will be conducted in each of the three reaches established for ecological productivity monitoring in a total of five index locations. Seasonal water quality sampling will be conducted at the beginning and the end of the sample collection for the ecological productivity study at each index location, primary tributaries and at three supplemental times throughout the year.

An electronic database will be developed and maintained to preserve the information collected during the Lower Columbia River Physical Habitat and Ecological Productivity program. The database will be compatible with a similar system being
developed for the mid Columbia River and must be able to facilitate the testing of hypotheses about physical habitat or ecological productivity changes.

4.3.3 Status

This monitoring program began in June 2008, and will continue through 12 years. We delivered the second year report in July 2010 and the third year report in July 2011. For 2011, the program monitors water quality only but will resume water quality and ecological productivity monitoring in 2012.

4.3.4 Interpretation of Data

This study focuses on benthic productivity and investigates how various environmental parameters influence periphyton and macroinvertebrate communities. The primary field work, conducted in 2010 from June to October, coincided with the summer growing season and measured the different physical, chemical, and biological parameters at different temporal intervals and at multiple locations.

In 2008, a multi-year study of physical habitat and ecological productivity was initiated on the Lower Columbia River in British Columbia, between the outflow of the Hugh L. Keenleyside Dam and the Birchbank gauging station. Data collection continued in this initial phase of study during the years of 2009 and 2010. The management questions and hypotheses aim to examine the influence that three different flow periods (mountain whitefish flows January 1–March 31, rainbow trout flows April 1–June 30, and fall flows September 1–October 31) have on select physical habitat and ecological productivity measures.

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River flows in the Lower Columbia River from 2008 to 2010 were comprised mainly of water from the Columbia River (55.5%) and secondly the Kootenay River (41.6%). Generally, the annual flow hydrograph from the Columbia River at Hugh L. Keenleyside Dam appears much more regulated than the hydrograph from the Kootenay River.

Water levels reflected the changes in river flow. During the mountain whitefish flow period, mean water levels decreased by 2.09 m. Most of the water level lost during the mountain whitefish flow period was regained during the rainbow trout flow period (2.01 m). Fall flow period water levels then generally decreased but were more variable than water levels during the other two flow periods. Regression modeling indicated that during the mountain whitefish and rainbow trout flow periods, river flows from both Hugh L. Keenleyside Dam and Brilliant Dam were important in regulating water level. Water level change also varied by water quality index station. During mountain whitefish flows a decrease in flow by 1 m$^3$/s at Hugh L. Keenleyside Dam or Brilliant Dam is predicted to decrease water level by approximately 2 cm or 0.5 cm, respectively. During rainbow trout flows an increase in flow by 1 m$^3$/s at Hugh L. Keenleyside Dam or Brilliant Dam is predicted to respectively increase water level by approximately 1.8 cm or 0.7 cm.

Based upon modeled and measured water levels, since the implementation of mountain whitefish protection flows, the difference between maximum flow during mountain whitefish spawning and minimum flow during mountain whitefish egg incubation has been reduced. The difference in water levels between this maximum and minimum flow was estimated to be 3.7 m during pre mountain whitefish
A water level index was developed to assess stability of water levels at Norns Creek Fan during rainbow trout spawning and egg incubation (April 1 to June 30). The water level index is the sum (in meters) of declining water levels during this time period. The modeled water level index indicated that prior to the implementation of rainbow trout protection flows (1984 to 1991), the index was 4.5. After rainbow trout protection flows were implemented (1992 to 2007) and during the current study period (2008 to 2010), the water level index decreased to 1.2 and 0.7, respectively. Given the decrease in the water level index, water levels appear to be more constant since the implementation of rainbow trout protection flows and presumably less detrimental in terms of redd dewatering and desiccation.

During mountain whitefish flows, water temperatures ranged from 2.9°C to 5.7°C. Water temperatures increased during rainbow trout flows, ranging from 7.5°C to 10.3°C. Water temperatures were warmest during fall flows, ranging from 13.2°C to 16.9°C, but began to decrease as winter approached. Variation in mean hourly diel temperatures was greatest during the rainbow trout flow period, with a difference between minimum and maximum temperatures of 1.9°C.

In terms of water quality guidelines, water temperatures during mountain whitefish spawning and incubation were all within the optimal range. During mountain whitefish rearing, water temperatures were both in and outside of the optimal range. Since the water temperature sensors were in relatively shallow water, rearing mountain whitefish that may experience thermal stress could likely move to presumably cooler, deeper water. During rainbow trout spawning and incubation, the water quality guidelines indicate that most water temperatures were below the optimal range. Lower than optimal water temperatures may slow growth in rainbow trout. A small number of water temperature measurements exceeded the optimal range for rainbow trout during late summer.

During the rainbow trout and fall flow periods, the effect of flow on water temperature was found to be very small in relation to other covariates. Water temperatures seem to be predicted much better by general climatic conditions as indicated by the strength of the previous day water temperature variable, which was also highly correlated with air temperature.

Field measurements for dissolved oxygen, pH, nitrate as N, turbidity, and total suspended solids all indicated high water quality in relation to water quality guidelines. Since most measures of water quality rarely if ever crossed a water quality guideline, statistical examination of most water quality measures and river flow was not carried out. Concentration levels of nitrate and phosphorus species were quite low, indicating an oligotrophic system, which has implications for ecological productivity, i.e., relatively low productivity. Lower method quantification limits are necessary to better understand how these parameters may affect measures of interest such as periphyton biomass. Related to this issue with left censored nutrient data, statistical relationships could not be developed between nutrient concentrations and river flows. Similarly, total suspended solid concentrations were typically below the method quantification limit. Total suspended solids likely represents the food supply to benthic filter feeding macroinvertebrates. Benthic filter feeders in the Lower Columbia River represent a major component of
the benthic macroinvertebrate assemblages in terms of both density and biomass. Relating total suspended solid load to benthic filter feeder densities and biomass could prove useful in understand a major portion of the benthic macroinvertebrate assemblages, which are also undoubtedly an important component of mountain whitefish and rainbow trout diets.

Approximately 91% of periphyton substrates were recovered during sampling efforts from 2008 to 2010. Most algae in the periphyton were diatoms. Median diatom densities ranged from $2.0 \times 10^5$ cells/cm$^2$ to $7.4 \times 10^5$ cells/cm$^2$. For non-diatom algae within the periphyton, densities ranged from $3.8 \times 10^4$ NCU/cm$^2$ to $2.3 \times 10^5$ NCU/cm$^2$. Periphytic diatoms were largely comprised of *Achnanthidium sp.*, *Staurosira sp.*, and *Fragilaria sp*. The diatom assemblages varied during the period 2008 to 2010. The mechanisms controlling the variation in diatom assemblages have not been fully identified.

Annual median periphyton chlorophyll $a$ concentrations were relatively low and ranged from 0.48 µg/cm$^2$ to 4.26 µg/cm$^2$. Results of regression modeling indicate that periphyton biomass (chlorophyll $a$) accrual responded to changes in flow during each of the tested flow periods. Periphyton accrual responded most to flows during the mountain whitefish period, where an increase in flow by 1 m$^3$/s during this period is predicted to result in a 0.13% increase in accrual rate 25 weeks later. This suggests that during mountain whitefish flows when river flows are lower, a slight increase in flow may deliver more nutrients to periphyton, allowing for higher accrual rates later. Changes in flow during the rainbow trout and current/fall flow periods predicted less change in periphyton accrual.

At 87% for 2008 to 2010, the retrieval of rock baskets was less than the periphyton substrate retrieval rate. By abundance, benthic macroinvertebrates were mostly comprised of hydropsychids, with annual abundance ranging from 37% to 44%. Hydropsychids are filter feeders and therefore likely rely on fine particulate organic matter delivered from upstream sources. From summer to fall, abundance of these hydropsychids decreases presumably because of an emergence event. The macroinvertebrate assemblage varied not only by season but also by reach. Reach 1 had lower total abundance and total biomass than Reach 2 and Reach 3, but Reach 1 had a more even composition. By abundance, Reach 2 and Reach 3 were dominated (62% to 70%) by filter feeders such as the hydropsychids. By biomass, Reach 2 and Reach 3 were dominated by trichopterans (likely mostly comprised of hydropsychids) and gastropods. Annual median abundance ranged from 1,260/basket to 1,584/basket and annual median biomass ranged from 0.24 g dry weight/basket to 0.56 g dry weight/basket.

A canonical correspondence analysis of the macroinvertebrate assemblage and environmental variables indicated that river flow as represented by modeled water velocity was relatively an unimportant variable in explaining variation in the macroinvertebrate assemblage. The measured variables only accounted for 17.5% of all explainable variation in the macroinvertebrate assemblage. Year, incubation period, and water temperature explained the most variation. Modeled water velocity was one of the weakest variables in the canonical correspondence analysis. However, river flows are still suspected to be an important factor in shaping the macroinvertebrate assemblage. Filter feeding macroinvertebrates such as hydropsychids, dominated in both abundance and biomass. River flows likely play an important role in the delivery of food resources to these organisms.
Benthic macroinvertebrates collected from rock baskets and mountain whitefish and rainbow trout stomach contents represented 98% of the total biomass collected from rock baskets. Data from the same diet study indicate that 85% of organisms found in stomach contents were benthic macroinvertebrates. Zooplankton and terrestrial organisms comprised the remainder. Zooplankton may be important to early life stages depending on the amount of biomass contributed by these smaller organisms. Rock baskets should represent the benthic macroinvertebrate component of fish diets. However, more work is necessary to determine: 1) the relative importance of diet items in terms of biomass, 2) if fish diets change seasonally, and 3) if adding an additional sampling method such as drift sampling would represent fish diets more closely.

4.4 **CLBMON-45 Lower Columbia River Fish Population Indexing Surveys**

4.4.1 **Management Questions**

The key management questions addressed by this monitoring program are:

1) What is the abundance, growth rate, survival rate, body condition, age distribution, and spatial distribution of sub-adult and adult whitefish, rainbow trout and walleye in the lower Columbia River?

2) What is the effect of inter-annual variability in the whitefish and rainbow trout flow regimes on the abundance, growth rate, survival rate, body condition and spatial distribution of sub-adult and adult whitefish, rainbow trout and walleye in the lower Columbia River?

4.4.2 **Overview**

Since 1995, BC Hydro has attempted to ‘stabilize’ water releases from HLK Dam during the whitefish and rainbow trout spawning seasons (January through June) to minimize egg losses in the lower Columbia River. The stabilization for whitefish is intended to reduce flow during peak spawning periods to encourage spawning at lower water level elevations and protect eggs through emergence. For rainbow trout, the protection flows are aimed to minimize potential egg losses for mid-timed rainbow spawners (April and May) by providing stable or increasing discharge over this period. Provision of these flows is subject to annual negotiations with the U.S. to implement mutually beneficial changes to flows required under the Columbia River Treaty.

To address existing uncertainties around the effects of flows on whitefish and rainbow trout populations in the lower Columbia River, the WUP CC recommended the continuation of the existing Large River Fish Indexing Program to address data gaps about the effects of dam operations on fish populations in the lower Columbia River.

BC Hydro initiated the Large River Fish Indexing Program in 2001 with the objectives of collecting information on selected index species. Since its initiation, annual implementation of the program has led to the development of systematic monitoring tools to identify and assess the effects of whitefish and rainbow trout flows on downstream fish communities. The information gained from continued implementation of the Fish Indexing Program, in conjunction with monitoring data
from related monitoring studies in the lower Columbia River, will allow assessment of the current flow regime to determine its effectiveness at protecting whitefish and rainbow trout populations.

**Monitoring Indicators:**

a) Program will monitor for changes in the abundance, growth rate, survival rate, body condition, age distribution and spatial distribution of sub-adult and adult whitefish, rainbow trout and walleye in the lower Columbia River.

b) Program will monitor for the effect of inter-annual variability in the whitefish and rainbow trout flow regimes on the abundance, growth rate, survival rate, body condition and spatial distribution of sub-adult and adult whitefish, rainbow trout and walleye in the lower Columbia River.

The methods used in this monitoring program are based on intensive boat electrofishing in the fall over pre-selected index sites. The data are then subject to statistical analysis and used for population estimation, catch-at-age analysis, population modeling, quantitative assessment of temporal patterns in population abundance, mean size-at-age, survival and distribution for each key species to evaluate long-term trends in these parameters. Given the uncertainty about factors that control fish populations, a weight of evidence approach will be applied to interpret fish population index information. Inferences about the patterns and/or trends in fish abundance, growth and survival in relation to the continued implementation of whitefish and rainbow flow will be interpreted in conjunction with other measurements/monitoring provided by physical habitat and ecological productivity monitoring, as well as spawning assessments and habitat use programs.

**4.4.3 Status**

This monitoring program began in September 2007, and will continue annually over 13 years. The third program report was delivered in July 2010 and the fourth program report was delivered in August 2011.

**4.4.4 Interpretation of Data**

The study area for CLBMON-45 includes the portion of the Columbia River between HLK and the Canada-U.S. border (approximately 56.5 km of river habitat) and the Kootenay River downstream of Brilliant Dam (BRD).

Field work was conducted in the fall of 2010, which corresponded approximately to the timing of data collected during earlier study years (i.e., 2007 to 2009) and to data collected between 2001 and 2006 as part of the Lower Columbia River Large River Fish Indexing Program. Fish were sampled by boat electroshocking at night within nearshore habitats. All captured mountain whitefish, rainbow trout, and walleye were measured for fork length, weighed, and implanted with a Passive Integrated Transponder (PIT) tag. Temporal and spatial variations in species abundance, spatial distribution, and body condition were estimated using hierarchical Bayesian Analyses (HBA).

Outputs from the HBAs were precise enough to show temporal and spatial trends/patterns in abundance, spatial distribution, and body condition for subadult
and adult mountain whitefish and rainbow trout and adult walleye. The effect of inter-
annual variability in the whitefish and rainbow trout flow regimes on the above
metrics could not determined.

Based on HBA outputs for Mountain Whitefish, the population remained relatively
stable between 2004 and 2010. However, for unknown reasons, abundance of
subadult Whitefish decreased during that time. HBA outputs indicate a slight
decrease in the number of adult Rainbow Trout and a slight increase in the number
of adult Walleye. Catch and length data suggest a strong 2009 brood year for
Walleye. Past strong age-classes of Walleye were correlated with declining densities
of Mountain Whitefish and Rainbow Trout, probably due to predation.

Recommendation include modifying the HBA analyses to: 1) allow the calculation of
annual growth rates based on mark-recapture and length-frequency data (in 2011);
2) allow the calculation of annual survival using a Cormack-Jolly-Seber (CJS) mark-
recapture model (in 2012); 3) allow the input of water temperature, discharge, and
cover type as explanatory variables in the abundance analysis; and, 4) allow the
input of water temperature and abundance as explanatory variables in the body
condition analysis. Additional recommendations include discontinuing the use of
Program MARK to generate population abundance estimates and investigating the
feasibility of sampling additional portions of the study area.

4.5  CLBMON-46 Lower Columbia River Rainbow Trout Spawning and Habitat
Assessment

4.5.1  Management Questions

The key management questions addressed by this monitoring program are:

1)  Does the implementation of rainbow trout spawning protection flows over the
course of the monitoring period lead to an increase the relative abundance of
rainbow trout spawning in the lower Columbia River downstream of Hugh L.
Keenleyside Dam?

2)  Does the implementation of rainbow trout spawning protection flows over the
course of the monitoring period lead to an increase in the spatial distribution of
locations (and associated habitat area) that rainbow trout use for spawning in
the lower Columbia River downstream of Hugh L. Keenleyside Dam?

3)  Does the implementation of rainbow trout spawning protection flows over the
course of the monitoring period protect the majority of rainbow trout redds (as
estimated from spawning timing) from being dewatered in the lower Columbia
River downstream of Hugh Keenleyside Dam?

4.5.2  Overview

The primary objective of this monitoring program is to continue the collection of
annual rainbow trout data to qualitatively and quantitatively assess changes in the
relative abundance, distribution and spawn timing of rainbow trout in the lower
Columbia River. Secondary objectives include: 1) determining whether an earlier
transitioning from mountain whitefish flows to rainbow trout spawning protection flows
reduces the number of early spawning rainbow trout redds that dewater, and 2) to identify whether spawning habitat in the lower Columbia River is fully utilized.

Since 1993, BC Hydro has successfully negotiated Non-Power Use Agreements with the U.S. with the aim of providing more stable flow regimes for rainbow trout spawning below HLK Dam than would normally occur under Columbia River Treaty operations. In the past, BC Hydro has secured these flow changes by storing an additional 1 MAF in Arrow Lakes Reservoir for release from July to August for U.S. salmon flow augmentation.

The Columbia River WUP CC recommended that BC Hydro continue to pursue the rainbow trout protection flows through negotiations with the U.S. (BC Hydro 2005a, 2005b), and continue annual discussions with regulatory agencies as to timing of transition from whitefish flows to rainbow trout protection flows (typically April 1).

The CC also recommended that annual monitoring be undertaken to monitor the status of the rainbow trout population in the lower Columbia River in response to the continued implementation of the protection flows to better understand the link between the flow management strategy during the spring spawning period and population abundance.

**Monitoring Indicators:**

a) Program will monitor the relative abundance of rainbow trout observed each year.

b) Program will monitor the relative abundance of rainbow trout redds observed each year.

c) Program will compare rainbow trout population trend data from the Lower Columbia River Indexing program to the relative abundance of rainbow trout and trout redds over the same time period.

This monitoring program involves the use of aerial and boat surveys to track the abundance, distribution and spawn timing of rainbow trout in the lower Columbia River. During these surveys, the number of redds and trout in different sections of the river are documented. In addition, redds that are identified in shallow water are measured for their depth in the water column to estimate the number of redds that are at risk of dewatering under different spawning flows scenarios (e.g., variation in timing of implementation).

### 4.5.3 Status

This monitoring program began under WUP in 2008, and will end in 2017. The second year report was completed in January 2010 and the third year was completed in January 2011.

### 4.5.4 Interpretation of Data

Each spring, large numbers of rainbow trout spawn in the lower Columbia River (LCR) below Hugh L. Keenleyside Dam (HLK) as well as in the lower Kootenay River (LKR) below Brilliant Dam (BRD). Prior to 1992, the spring discharge below HLK typically involved decreasing flows during the March to May period which resulted in substantial numbers of rainbow trout redds being dewatered. In order to minimize the
number of rainbow trout redds dewatered, BC Hydro has since 1992 stabilized the spring flow releases from HLK. However, these Rainbow Trout Spawning Protection Flows (RTSPF) are achieved by storing an additional 1 million acre feet (MAF) of water in Arrow Lakes Reservoir which has negative consequences for riparian vegetation, littoral productivity and wildlife habitat (BC Hydro 2007). Consequently, the current monitoring program, which commenced in 2008, was implemented to better understand the links between the spring flow regime and the abundance of the rainbow trout population (BC Hydro 2007).

The number of rainbow trout spawners and redds has increased since 1999. The peak count of 2,200 redds in 2010 was the highest red count on record while the adult spawner peak count of 1,895 fish was the third highest. RTSPF may be responsible for the increase by protecting the majority of redds and eggs from dewatering. Since 1999 on average less than 1% of the total egg deposition has been dewatered. RTSPFs were initiated in 1992, however the percentage of dewatered redds have only been recorded since 1999.

The number of locations at which spawning occurs (habitat area) as well as the spatial distribution of spawning have increased since 1996. This may be related to an increase in the number of rainbow trout spawners that now utilize sites outside of the traditional prime spawning locations.

4.6 CLBMON-47 Lower Columbia River Whitefish Spawning Ground Topographic Survey

4.6.1 Management Questions

The key management questions for this monitoring program are associated with uncertainties related to how changes in dam releases influence the area of wetted channel area at key whitefish spawning locations. These questions are:

1) What are the topographic characteristics of the key spawning locations for mountain whitefish in the lower Columbia and Kootenay rivers?

2) What is the hydraulic response of the river to discharge fluctuations at these key spawning locations? How do changes in river discharge influence river stage, and how does river stage relate to wetted channel area at these key spawning locations?

3) How do daily flow changes contribute to cumulative channel dewatering in key spawning areas over the whitefish reproductive period?

4.6.2 Overview

The Columbia River WUP CC supported the implementation of an adaptive management program for evaluating the effectiveness of the whitefish flow management (WFM) to conserve mountain whitefish populations of the lower Columbia River. An objective of the adaptive management program was to collect better information on the topographic characteristics of whitefish spawning locations, and utilize that information to achieve better understanding of how regulated flow changes create potential risks for egg dewatering in the lower Columbia and Kootenay rivers.
Monitoring has confirmed that whitefish eggs are dewatered by flow changes in the lower Columbia River. However, egg losses estimates derived from field data were not precise enough to support trade-off decision making processes related to WFM implementation. In 2003, a process-based whitefish egg loss model (ELM) 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 whitefish ELM is now the primary analytical tool for quantifying egg losses that occur as a consequence of changing flow patterns. The model utilizes daily flow data and river cross-section information 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. The model provides a transparent quantitative framework for evaluating egg loss risk. However, the WUP CC expressed concern about the reliability of the ELM for quantifying the egg loss resulting from regulated flow changes during the adaptive management program.

A key data gap identified by the WUP CC was the low quality and quantity of topographic data to describe characteristics of whitefish spawning locations. Limited availability of relevant topographic data resulted in the use of as few as one channel cross-section through a representative whitefish spawning area to predict flow dependent changes in river stage and areas of channel dewatering. Limited topographic information at spawning areas contributed to reduced confidence in the degree to which existing data represented the habitats of concern, and overall reliability of egg loss estimates. To reduce this uncertainty, the WUP CC recommended implementing a monitoring program to: a) document topographic characteristics of representative whitefish spawning locations; and b) update the existing whitefish ELM to include new topographic and biological data collected in the whitefish adaptive management program (via CLBMON-48 Lower Columbia River Whitefish Life History and Egg Mat Monitoring, and CLBMON-44 Lower Columbia River Physical Habitat and Ecological Productivity Monitoring).

Monitoring Indicators:

a) Program will monitor for the topographic characteristics at the key spawning locations for mountain whitefish in the lower Columbia and Kootenay rivers.

b) Program will monitor the hydraulic response of the river to discharge fluctuations at these key spawning location (i.e., how will changes in river discharge influence river stage, and how does river stage relate to wetted channel area at these key spawning locations?)

c) Program will monitor how daily flow changes contribute to cumulative channel dewatering in key spawning areas over the whitefish reproductive period.

There are two primary components to the work: 1) field surveys to document topographic characteristics of whitefish spawning habitats, and 2) the updating of the physical and biological assumptions of the ELM.

4.6.3 Status

This monitoring program began in November 2010 and will be carried out over three years. Detailed surveys of Lower Columbia River flows were not carried out until
August 2011 due to the high flows from the Kootenay River system this Spring and Summer. A final report is expected in December 2011 due to this delay in sampling.

4.6.4 Interpretation of Data

At this time, there are no data to interpret for this monitoring program.

4.7 CLBMON-48 Lower Columbia River Whitefish Egg Monitoring and Life History Study

4.7.1 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?

4.7.2 Overview

The Columbia River 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. A goal of this adaptive management program is 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.

The purpose 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 HLK Dam to improve the annual estimate of egg mortality. Specifically, the key objectives are 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 being undertaken through CLBMON-47, Lower Columbia River Mountain Whitefish Spawning Ground Topographic Survey.

**Monitoring Indicators:**

a) Program will monitor the spatial and timing distribution of whitefish spawning activities in the lower Columbia and lower Kootenay Rivers to see if there is there inter-annual variation in spawning habitat use or if the spatial distribution of spawning locations is associated with flow management.

b) Program will monitor the physical and hydraulic characteristics of whitefish spawning and egg incubation habitats, the patterns of egg dispersal and the pre and post-spawning seasonal movements of whitefish.

c) Program will monitor juvenile whitefish use of the lower Columbia and Kootenay Rivers.

The first year of monitoring includes: (1) a radio/acoustic tagging program to track mountain whitefish movements to spawning locations; and, (2) a field sampling program to evaluate the biology, habitat use, relative abundance, and distribution of pre-adult mountain whitefish life stages. This portion of the program will be repeated for a period of five years to identify key spawning periods and spawning locations and to assess other life history characteristics.

Results from the first year of monitoring will be used to begin assessing egg dispersal patterns at key spawning locations. Sampling protocols will be assessed after Year 1 and then those protocols used to sample dispersal patterns for the remainder of the study. In the final year, the results from all five years will be assembled and synthesized, and a final report will be prepared.

**4.7.3 Status**

This monitoring program was initiated in August 2008, and will be carried out over a 5-year period. The first program report was completed in April 2009. Monitoring in Year 2 of the program focused on the spawning locations to observe activity and delineate egg distribution at five key locations.
4.7.4 Interpretation of Data

Mountain whitefish (*Prosopium williamsoni*) are the most abundant sportfish in the lower Columbia River (defined as the Columbia River from Hugh L. Keenleyside Dam [HLK] to the Canada-US Border) and use this area for all life history functions. Although mountain whitefish do not support a recreational fishery in the lower Columbia River, they do represent an important indicator species in the Columbia River ecosystem. Results of previous studies conducted by BC Hydro raised concerns by regulatory agencies about the effects of river regulation on mountain whitefish reproductive success in the lower Columbia River. These concerns led to the development and initiation of BC Hydro’s Whitefish Flow Management (WFM) program in the winter of 1994 - 95 and a series of subsequent intensive studies on mountain whitefish life history characteristics between 1995 and 1999.

In 2008, BC Hydro initiated Year 1 of a proposed five year CLBMON-48 study program to update information on juvenile mountain whitefish abundance and distribution and adult mountain whitefish spawning activity in the lower Columbia River. This information is needed to inform management actions related to the effects of flow regulation on mountain whitefish recruitment success. This data report describes the study components conducted, the methods used, and a brief description of the results obtained during Year 3. Selected data from past studies on mountain whitefish in the study area are incorporated where warranted to highlight similarities or differences between years, but the possible reasons for these differences are not discussed. Detailed analysis of the data, statistical comparisons, and in-depth discussions of study results and how these have addressed the management questions will be provided in the Year 5 summary report.

In Year 3, the onset and peak of mountain whitefish spawning in the Columbia River at the CPR Island area occurred over temporal and temperature ranges similar to those recorded in previous study years. At the Kootenay River spawning area, both the onset of spawning and peak spawning during the present study occurred at temperatures approximately 3.0°C warmer than in previous study years. A bi-modal peak spawning pattern in the Kootenay River area continues to support the hypothesized presence of two spawning runs. Egg deposition in the CPR Island and lower Kootenay River areas occurred in essentially the same locations and within the same habitat parameters of depth, substrate composition, and surface velocity as documented during previous studies in these areas. The patterns of egg deposition recorded during the present study and previous studies indicate a high use of the shallow habitats in these areas for spawning. Eggs deposited within shallow areas are at risk of stranding during periods of reduced flow in the Columbia or Kootenay rivers over the course of the egg incubation period.

Boat electroshocking surveys focussed in the upper reach of the Columbia River at sites where high densities of juvenile mountain whitefish were recorded in Years 1 and 2. Overall, substantially fewer juveniles and lower overall CPUEs (fish/km/hr) were recorded in Year 3. In Year 3, recaptures of marked juveniles were too low to develop population estimates for the combined area within the upper section. Similar to previous studies, age-0 and age-1 mountain whitefish were encountered.

The juvenile tagging survivability study showed moderate survival using the V5 tag with very poor survival for PIT tags and V5 & PIT implantation. Stress during the holding period may have resulted in the high mortality rate.
Results from this monitoring program will help develop management prescriptions for mountain whitefish in the lower Columbia River. A data gap analysis involving both BC Hydro and Golder will occur after the submission of this report, which will provide formal recommendations and direction for the Year 4 sampling program.

4.8 CLBMON-49 Lower Columbia River Effects of Whitefish Flows on Great Blue Heron and Winter Use of Waldie Island by Great Blue Heron

4.8.1 Management Questions

This monitoring program is designed to address the following management questions as they pertain to a small wintering refuge area (Waldie Island) for GBH in the lower Columbia River and to the breeding colony of GBH near Revelstoke, BC.

1) Do GBH use Waldie Island as an overwintering area or as a short-term stopover migrating elsewhere?

2) Does the current early winter flow regime in the lower Columbia River affect the quality and quantity of overwintering habitat (e.g. foraging, roosting) for GBH and influence foraging ecology of GBH on Waldie Island?

3) Are there operational changes that could provide for protection of overwintering habitat to ensure that it can support dependent winter GBH aggregations?

4) Are there ‘physical works’ alternatives in lieu of operational changes that would benefit GBH overwintering at Waldie Island?

5) Do GBH nesting at the Revelstoke colony use Waldie Island as a winter refuge site or as a stopover site during migration?

6) What is the regional importance of Waldie Island as a winter refuge area for GBH that nest at the Revelstoke colony?

7) Does operation of Arrow Lakes Reservoir affect foraging opportunity and success for GBH breeding at the Revelstoke colony?

4.8.2 Overview

From late October until late February, Great Blue Heron (GBH) are known to aggregate in the vicinity of Waldie Island, near Castlegar, BC downstream of HLK Dam. Data collected over a 3-year period suggests high river flows and water elevations during the early winter period limits the availability of suitable shallow-water foraging habitat downstream of HLK Dam. From late November to mid December, outflows from Arrow Lakes Reservoir are increased to provide stable flows during the late December to late January period in order to protect spawning whitefish and egg incubation. As there are few other ice-free shoreline areas downstream of HLK Dam, protracted periods of higher flow releases may be negatively affecting GBH by reducing available foraging habitat, which in turn is increasing GBH dependency on Waldie Island and increasing localized competition for food and resting sites. The island is relatively well protected from predators, weather and disturbance, and provides suitable roost trees and access to nearby shallow water foraging habitat. Based on observations, Machmer (2003)
recommended that BC Hydro modify the flow regime of HLK Dam in years of high flows to ensure that some parts of CPR Island and Waldie Island foreshore remain exposed and usable by GBH during the early winter period. A maximum elevation of 421 m was recommended for the period of 15 November to 21 December.

During the Columbia River WUP, the CC sought to address concerns related to the impacts that the flow regime of HLK Dam has on the availability of shallow-water foraging habitat downstream of the dam, and whether GBH that breed in the Revelstoke Colony overwinter on Waldie Island. Two related studies were recommended to (1) confirm the importance of Waldie Island as a winter refuge area; (2) address uncertainty related to the potential impact of high early winter flows on survival of overwintering GBH at Waldie Island; (3) determine whether modifications to the current flow regime should be considered to minimize flow-related impacts on this winter GBH aggregation, (4) determine whether GBH that breed in the Revelstoke Colony overwinter on Waldie Island, and (5) assess whether the operation of Arrow Lakes Reservoir affects the foraging opportunities of GBH breeding at the Revelstoke colony.

**Monitoring Indicators:**

a) Program will monitor the response of winter GBH populations on Waldie Island to potential impacts of high flows/river stage during the winter period on foraging habitat.

b) Program will address whether GBH from the Revelstoke nesting colony are the same individuals as those observed at Waldie Island.

c) Program will monitor whether the foraging ecology of these birds is being negatively affected by operation of Arrow Lakes Reservoir during the breeding season.

This monitoring program will employ the use of GPS telemetry data loggers to obtain a sufficient number of data points to determine habitat selection of GBH and assess the effects of river flow and stage on habitat use (e.g., foraging). The GPS data loggers will be fitted to GBH captured during the fall as they begin to arrive at Waldie Island. Observational data will also be gathered to determine the timing of the arrival and departure of GBH from Waldie Island over the course of the winter. Data loggers will be affixed to animals every fall and retrieved the following summer. In addition, it will be important to monitor the attendance and foraging activity of GBH at Waldie Island (and area) over the course of the winter to detect changes in use patterns in relation to changing river flows and environmental conditions.

In addition to the Waldie Island surveys, there will be monitoring of habitat use during the breeding season in the Revelstoke Reach area of the upper Columbia River. Surveys will be conducted weekly to obtain information on use and location of important feeding areas by GBH at the Revelstoke colony. The surveys should be conducted throughout the nesting season (April to June) until the majority of adults have dispersed from the colony.

**4.8.3 Status**

The Terms of Reference for this monitoring program will be resubmitted.
4.8.4 Interpretation of Data

At this time there are no data to interpret for this monitoring program.

5 Lower Columbia River Fish Management Plan- Monitoring Program Costs

The following table summarizes the approved costs of the monitoring programs and physical works under the Lower Columbia River Fish Management Plan of the Columbia River WUP, as well as the Actual Costs to July 31, 2011.
### Table 5-1: Columbia River Monitoring Programs and Physical Works Costs

<table>
<thead>
<tr>
<th>Monitoring Programs</th>
<th>Activity</th>
<th>Costs approved by CWR</th>
<th>Total Forecast (Life to Date Actuals and Forecast)</th>
<th>Variance Total to Approved</th>
<th>Explanation</th>
<th>Corrective Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower Columbia River Management Plan Annual Report</td>
<td></td>
<td>$8,978</td>
<td>$8,977.61</td>
<td>$0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CLBMON#42 LOW COL FISH STRANDING ASSESSMENT AND RAMPING PROTOCOL</td>
<td>Direct Management</td>
<td>$1,515,971</td>
<td>$1,515,971</td>
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<tr>
<td></td>
<td>Implementation</td>
<td>$1,268,061</td>
<td>$1,268,061</td>
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<td></td>
</tr>
<tr>
<td>CLBMON#43 LOW COL SCULPIN &amp; DACE LIFE HISTORY ASSESSMENT</td>
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<tr>
<td></td>
<td>Implementation</td>
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</tr>
<tr>
<td>CLBMON#44 LOW COL PHYSICAL HABITAT &amp; ECOLOGICAL PRODUCTIVITY</td>
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</tr>
<tr>
<td></td>
<td>Implementation</td>
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<tr>
<td>CLBMON#45 LOW COL FISH POPULATION INDEXING</td>
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<td>$2,744,109</td>
<td>$2,588,109</td>
<td>$156,000</td>
<td>There is a 156K variance due to 2007 costs being charged to ESI in error.</td>
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<td>$156,000</td>
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<td></td>
<td>Implementation</td>
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<tr>
<td>CLBMON#47 LOW COL WHITEFISH SPAWNING GROUND TOPOGRAPHIC SURVEY</td>
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<tr>
<td>CLBMON#48 LOW COL WHITEFISH EGG MONITORING &amp; LIFE HISTORY STUDY</td>
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<td>Implementation</td>
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<td>Implementation</td>
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* Red values in parentheses denote overage.