Columbia River Project Water Use Plan

Arrow Lakes Reservoir Operations Management Plan

Monitoring Program Terms of Reference

- **CLBMON-40 Arrow Lakes Reservoir: Arrow Lakes Reservoir Waterbird Monitoring Program**

Revision 1
August 2015

Monitoring Study No. CLBMON-40
Arrow Lakes Reservoir: Waterbird Monitoring

1.0 Monitoring Program Rationale

1.1 Background

Waterbirds include all wetland bird families, including wildfowl (divers, grebes, cormorants, swans, geese, ducks, coots and rails); shorebirds; gulls, terns and herons; and water-dependent birds of prey. Revelstoke Reach (Revelstoke Dam to Shelter Bay) is a relatively flat floodplain located at the higher elevations of the Arrow Lakes Reservoir that attracts considerable use by waterbirds (Bonar 1979; Jarvis & Woods 2001; Tremblay 1993). Revelstoke Reach provides important migratory stopover habitat and spring and summer breeding habitat. From 1991 to 2001, systematic waterbird surveys were conducted along a 12 km stretch of Revelstoke Reach to document seasonal use (Jarvis & Woods 2001). Sixty-five species of waterbirds were documented and both species diversity and abundance declined over the course of the study. In 1991 and 1992, over 20,000 individual waterbirds were observed from 58 species. By the late 1990s and 2000, the number of birds observed was approximately half (between 7,279 and 12,140) while the number of species had declined to 41 species. Waterbird abundance and species richness was lowest from December to February and highest between March and May, during spring migration. Eighteen species were suspected or confirmed to breed in the reach. The authors suggest that spring and summer flooding resulting from reservoir operations limit breeding opportunities (Jarvis & Woods 2001).

Over the course of the year, the water levels in Revelstoke Reach fluctuate between 15 to 20 m due to variations in precipitation, snow pack melt, water use requirements downstream at Hugh Keenleyside Dam and upstream at Mica and Revelstoke Dams. Water levels are usually low in winter and early spring, rise through late spring and early summer, and then drop through late summer and fall. However the water levels, and timing and duration of flooding are highly variable from year-to-year.

The reservoir is licensed to operate between 420.0 m and 440.1 m. At a water elevation of approximately 430 m, the floodplain starts to become inundated (Jarvis & Woods 2001). Habitat suitability maps developed using digital elevation modeling demonstrate that the amount of mudflat habitat for shorebirds, declines from about 1000 ha at a water elevation of 432 m to almost zero at 439 m (Axys Environmental Consulting 2002).

During the Columbia River Water Use Planning Process (WUP), the Consultative Committee (CC) recognized waterbirds as high management priorities in assessing the ecological impacts associated with the operations of the Arrow Lakes Reservoir. Specifically, concerns focused on the loss of available breeding and migratory habitat and the direct loss of nests due to flooding due to high water levels. Protecting and enhancing riparian areas, and maximizing the capacity of the Revelstoke Reach to provide habitat for both shorebirds and waterbirds emerged as key environmental objectives during the Columbia River Water Use Plan (WUP). To achieve these, and a multitude of other environmental and social objectives, the Columbia River Water Use Plan may consider a number of operating alternatives (“soft constraints”) that BC Hydro can implement within the Columbia River Treaty (CRT) and the BC Hydro

portion of the non-treaty storage. These "soft constraints" include the daily operational use of water (e.g., timing, magnitude, and rate), swapping water between Kinbasket and Arrow Reservoir, minimum and maximum reservoir levels with the constraints of the CRT, ramping rates, and incremental use of the BC Hydro portion of the Non-Treaty storage.

To evaluate operating alternatives and to monitor the impacts of reservoir operations on waterbirds and migratory shorebirds, the CC recommended that monitoring be conducted to 1) determine the abundance, distribution, and habitat use of waterbirds, particularly during their migrations; 2) monitor the productivity of waterbirds in Revelstoke Reach (waterfowl and raptors); 3) examine how variation in flow and reservoir water elevations influence seasonal and yearly abundance, distribution, and habitat use and productivity of waterbirds in Revelstoke Reach; and 4) assess whether physical works can be designed to mitigate any adverse impacts to waterbirds resulting from reservoir operations in Revelstoke Reach.

In the Arrow Lakes Reservoir Operations Monitoring Program proposed in the Columbia River Consultative Committee Report (CC Report), separate studies were recommended to monitor shorebirds and other waterbirds in Revelstoke Reach. As these two studies advanced toward implementation their similar natures and overlapping study areas prompted their combination under a single Term of Reference as CLBMON-40. This resulted in significant administrative, economic and logistical efficiencies as well as a more sound study design. Subsequently, study findings documented in the Five Year Interim Report 2008-2012 for CLBMON-40 (Cooper Beauchesne and Associates Ltd. 2013) showed shorebirds "are not very abundant, are patchily distributed, have highly ephemeral presence, and show relatively high plasticity in site selection." Because these factors made certain Management Questions as they applied to shorebirds less relevant than originally conceived, they have been revised in this Terms of Reference (TOR).

1.2 Rationale and Summary of Key Revisions

The main proposed revisions to the TOR are as follows:

- As defined at the start of the Introduction, the technical term waterbird includes shorebirds. In the original TOR, shorebirds were a highlighted faunal group in addition to waterbirds. This may reflect the fact that at an earlier planning stage shorebirds were the subject of a separate monitoring study later combined with waterbirds in the current study, CLBMON-40. In spite of the logic of its origins this shared emphasis on waterbirds and one its subcomponents has been undermined by the low shorebird numbers encountered once the study commenced. The revised TOR uses the term waterbird inclusively and thus includes shorebirds, but the previous emphasis on the latter is now reduced.
- To implement this revised focus specific reference to shorebirds has been eliminated from MQ2, MQ3 and Management Hypothesis 1E (MH_{1E}), but as they remain defined within the category of waterbirds they continue to be a study component.
- In addition, shorebird studies have since the start of this study been limited to fall migration, prompting a more general text for revised Management Question (MQ) 1.

- MQ2 is deleted as it is redundant with MQ6.
- The term "productivity" was determined to be too general in most instances and was replaced by "index (or indices) of productivity." In this way the discussion will be defined by the specific metrics of productivity collected by the study team.
- Certain topics that were initially combined in Management Questions (e.g., waterbirds and shorebirds, revegetation and wildlife physical works) were separated for clarity because with the maturation of this project and multi-year data analysis, these originally conceived combinations did not share sufficient traits to be usefully analyzed together. This was the case with MQs 1-3, and MH_3.
- MH_1, MH_2, and MH_3 have been redrafted so that the objectives are stated as testable sub-hypotheses (MH_{1A}, MH_{1B}, MH_{1C}, and MH_{1D}; MH_{2A}, MH_{2B}, and MH_{2C}; and MH_{3A}, MH_{3B}, MH_{3C}, MH_{3D}, MH_{3E}, and MH_{3F}) rather than in their original combined and untestable format. As stated above, the original MH_{1E} was deleted.
- The term "diversity" has been replaced with "species richness." The latter refers to the number of species in a given sampling of biota and unlike diversity attributes no other properties to those numbers. Species richness is a more practical and appropriate metric for the purposes of this study.
- The term "population" has been replaced with either "abundance" or "numbers." Population implies occurrence information for areas well beyond the study area and thus beyond the geographic scope of this study.
- The focus of MQ_3 has been expanded from "habitats" to "habitats and wetland features" to reflect this study's original emphasis on wetlands as a rare habitat type in this part of the Columbia basin.
- The Approach and Methods sections have been edited consistent with and to provide updated background for the other revisions.
- In the case of shorebirds, the Approach section that summarized behavioural and habitat literature on this group was no longer as relevant in a study area with few shorebirds, and has been shortened.
- In the case of Methods, Task 2 has been substantially revised. The original title "Pre-stratification of Study Area" has been changed to the more accurate "Habitat Characterization and Site Selection." The habitat monitoring requirements of this task were altered because the vegetation sampling data became available from another project (CLBMON-11B-4), and the CLBMON-40 emphasis was directed to habitat mapping. The methods for the latter have been added to the text of this task.

1.3 Management Questions

The revised management questions to be addressed by this monitoring program are stated below. Where the text has been altered from the original, a rationale is provided, and the original is printed as a footnote:

1) What is the seasonal and annual variation in the abundance and spatial distribution of waterbirds within Revelstoke Reach during migration?[1]

   Reference to shorebirds has been deleted. As indicated in Section 1.2 shorebirds are defined within the waterbird category and do not require separate emphasis.

   The term "migration" is used instead of "spring and fall migration." The original terminology was not correct in that there were no systematic surveys of shorebirds in spring.

2) What implication does the year-to-year or within-year operations of Arrow Lakes Reservoir have on resident and migratory shorebird and waterbird populations?

   This question is deleted as it is redundant with Management Question 6.

3) Which habitats and wetland features within the drawdown zone in Revelstoke Reach are utilized by waterbirds and what are their characteristics (e.g., foraging substrate, vegetation, elevation and distance to water's edge)?[2]

   Wetland features was inserted into the Management Question to place emphasis on aquatic habitats that are rare in the Columbia basin. Their scarcity was a justification for this study.

4) What is the annual variation in summer productivity (reproduction) of waterbirds in Revelstoke Reach and do indices of waterbird productivity vary spatially (e.g., are there areas of higher waterbird productivity)?[3]

   Productivity has been qualified so that it is understood that with respect to data gathering only certain metrics of productivity are being sampled.

5) Which waterbird species have the greatest exposure to being highly impacted by reservoir operations?[4]

   Specific reference to shorebirds has been deleted. They are included in the definition of waterbird.

6) Do reservoir operations (e.g., daily and maximum monthly water levels) influence the distribution and abundance of waterbirds in Revelstoke Reach?[5]

   Specific reference to shorebirds has been deleted. They are included in the definition of waterbird.

[1] The original Management Question 1 was: "What is the seasonal and annual variation in the abundance and spatial distribution of waterbirds and shorebirds in Revelstoke Reach during spring and fall migration?"

[2] The original Management Question 3 was: "Which habitats within the drawdown zone in Revelstoke Reach are utilized by shorebirds and waterbirds and what are their characteristics (.e.g. foraging substrate, vegetation, elevation, and distance to the water's edge)?"

[3] The original Management Question 4 was: "What is the annual variation in summer productivity (reproduction) of waterbirds in Revelstoke Reach and does productivity vary spatially (e.g., are there areas of higher waterbird productivity)?"

[4] The original Management Question 5 was: "Which species of shorebirds and waterbirds are most likely to be affected by reservoir operations?"

[5] The original Management Question 6 was: "Do reservoir operations (e.g., daily and maximum monthly water levels) influence the distribution and abundance of waterbirds and shorebirds in Revelstoke Reach?"

7) To what extent do water levels in Arrow Lakes Reservoir influence indices of waterbird productivity in Revelstoke Reach?[6]

   The general term "productivity" has been replaced by the more specific "indices of productivity."

8) Can minor adjustments be made to reservoir operations to minimize the impact on migrating waterbirds or on indices of waterbird productivity?[7]

   Specific reference to shorebirds has been deleted. They are included in the definition of waterbird. The general term "productivity" has been replaced by the more specific "indices of productivity."

9) Can physical works be designed to mitigate any adverse impacts on migrating waterbirds or on indices of waterbird productivity resulting from reservoir operations?[8]

   Specific reference to shorebirds has been deleted. They are included in the definition of waterbird. The general term "productivity" has been replaced by the more specific "indices of productivity."

10) Does revegetating the drawdown zone affect the availability and use of habitat for waterbirds in Revelstoke Reach?[9]

    Specific reference to shorebirds has been deleted. They are included in the definition of waterbird.

11) Do physical works projects implemented during the course of this monitoring program increase waterbird abundance, or species richness, or indices of waterbird productivity?[10]

    Specific reference to shorebirds has been deleted. They are included in the definition of waterbird. Species richness is inserted in place of the less appropriate term diversity. The general term "productivity" has been replaced by the more specific "indices of productivity."

1.4 Management Hypothesis

The first grouping of management hypotheses to be tested by this monitoring program focusses on whether the annual and seasonal variation in water levels resulting from reservoir operations, the implementation of soft constraints, and the

[6] The original Management Question 7 was: "To what extent do water levels in Arrow Lakes Reservoir influence the productivity of waterbirds in Revelstoke Reach?"

[7] The original Management Question 8 was: "Can minor adjustments be made to reservoir operations to minimize the impact on migrating waterbirds and shorebirds or on waterbird productivity?"

[8] The original Management Question 9 was: "Can physical works be designed to mitigate any adverse impacts on migrating waterbirds and shorebirds or on waterbird productivity resulting from reservoir operations?"

[9] The original Management Question 10 was: "Does revegetating the drawdown zone affect the availability and use of habitat for shorebirds or waterbirds in Revelstoke Reach?"

[10] The original Management Question 11 was: "Do physical works projects implemented during the course of this monitoring program increase waterbird and shorebird abundance, or diversity, or waterbird productivity?"

potential impact from Rev 5, ("reservoir operations") result in a reduction of waterbird use.[11]

The original Management Hypothesis 1 (H_1) is deleted in favor of four testable sub-hypotheses (H_{1A}, H_{1B}, H_{1C}, and H_{1D}). H_1 included a confusing editing error, and in any case was not testable. The sub-hypotheses address the targeted issues.

H_{1A}: Reservoir operations do not result in decreased species richness in waterbirds utilizing the drawdown zone.[12]

Specific reference to shorebirds has been deleted. They are included in the definition of waterbird. Species richness is inserted in place of the less appropriate term diversity.

H_{1B}: Reservoir operations do not result in a decrease in the abundance of waterbirds utilizing the drawdown zone.[13]

Specific reference to shorebirds has been deleted. They are included in the definition of waterbird.

H_{1c}: Changes in the distribution of waterbird distribution in Revelstoke Reach are not attributable to reservoir operations.[14]

Specific reference to shorebirds has been deleted. They are included in the definition of waterbird.

H_{1d}: Reservoir operations do not result in a decrease in indices of productivity of waterbirds utilizing the drawdown zone.[15]

The general term "productivity" has been replaced by the more specific "indices of productivity."

$H_{1E:}$ Reservoir operations do not result in a decrease in shorebird foraging in the drawdown zone.

This management hypothesis has been deleted. Shorebird numbers are too low to address this question as a testable hypothesis.

If changes in species richness, abundance, distribution, or productivity are detected over time, the second grouping of hypotheses will be tested to determine whether

[11] The original Management Hypothesis 1 was: "The Annual and seasonal variation in water levels resulting from reservoir operations, the implementation of soft constraints, and the potential impact from Rev 5, ("reservoir operations"), do not result in a reduction of waterbird or shorebird use."

[12] The original Management Hypothesis H_{1A} was: "Reservoir operations do not result in decreased species diversity in waterbirds or migratory shorebirds utilizing the drawdown zone."

[13] The original Management Hypothesis H_{1B} was: "Reservoir operations do not result in a decrease in the abundance of waterbirds or migratory shorebirds utilizing the drawdown zone."

[14] The original Management Hypothesis H_{1C} was: "Changes in the distribution of waterbird or shorebird distribution in Revelstoke Reach are not attributable to reservoir operations."

[15] The original Management Hypothesis H_{1D} was: "Reservoir operations do not result in a decrease in the productivity of waterbirds utilizing the drawdown zone."

these changes can be attributed to changes in habitat quality or availability as a result of reservoir operations or due to revegetation efforts or physical works projects implemented during the course of this monitoring program.[16]

The original Management Hypothesis 2 (H_2) is deleted in favor of three testable sub-hypotheses (H_{2A}, H_{2B}, and H_{2C}). As drafted H_2 was not testable. The sub-hypotheses (below) generated from the original H_2 address the targeted issues.

H_{2A}: Annual variation in reservoir water levels or reservoir operations do not result in a reduction or degradation of waterbird habitats.

H_{2B}: The implementation of soft constraints does not result in a reduction or degradation of waterbird habitats.

H_{2C}: Rev 5 does not result in a reduction or degradation of waterbird habitat.

The third grouping of hypotheses will be tested to determine if revegetation and/or wildlife physical works positively affect the species richness, abundance, and indices of productivity of waterbirds in the drawdown zone.[17]

The original Management Hypothesis 3 (H_3) is deleted in favor of six testable sub-hypotheses (H_{3A}, H_{3B}, H_{3C}, H_{3D}, H_{3E}, and H_{3F}). As drafted H_3 was not testable, in part because revegetation and wildlife physical works represent different habitat enhancements that do not share sufficient attributes to be combined in this manner. The sub-hypotheses (below, and identified by mistake in the original TOR as sub-hypotheses of H_2) generated from the original H_3 separate revegetation and wildlife physical works and address the targeted issues. In addition the original H_{3B} and H_{3C} are virtually identical in language and are assumed to have been restatements of the same hypothesis. In summary, to separate revegetation and wildlife physical works hypotheses the original H_{3A} has become H_{3A} and H_{3B}, the original H_{3B} and H_{3C} (virtually identical) have become H_{3C} and H_{3D}, and H_{3D} has become H_{3E} and H_{3F}.

H_{3A}: Revegetation does not result in an increase in the species richness or abundance of waterbirds utilizing the drawdown zone.[18]

Wildlife physical works have been deleted from this MH, as discussed above, and are addressed separately by the next sub-hypothesis. Species richness has been inserted in place of the less appropriate diversity.

H_{3B}: Wildlife physical works do not result in an increase in the species richness or abundance of waterbirds utilizing the drawdown zone.[19]

[16] The original Management Hypothesis H_2 was: “Annual variation in reservoir water levels reservoir operations, the implementation of soft constraints, and the potential impacts from Rev 5, do not result in a reduction or degradation of waterbird or shorebird habitats.”

[17] The original Management Hypothesis H_3 was: “Revegetation and wildlife physical works do not increase the utilization of habitats by birds in the drawdown zone.”

[18] The original Management Hypothesis H_{3A} was: “Revegetation and wildlife physical works do not increase the species diversity or abundance of shorebird or waterbirds utilizing the drawdown.”

[19] The original Management Hypothesis H_{3B} was: “Revegetation and wildlife physical works do not result in an increase in the productivity of waterbirds utilizing the drawdown zone.”

This sub-hypothesis is a restatement of the original H_{3A} addressing in this case wildlife physical works only. Species richness has been inserted for diversity.

H_{3C}: Revegetation does not increase indices of productivity of waterbirds utilizing the drawdown zone.[20]

Wildlife physical works have been deleted from this MH, as discussed above, and are addressed separately by the next sub-hypothesis. The general term "productivity" has been replaced by the more specific "indices of productivity."

$H_{3D:}$ Wildlife physical works do not increase indices of productivity of waterbirds utilizing the drawdown zone.[21]

This sub-hypothesis is a restatement of the original H_{3B} and H_{3C} addressing in this case wildlife physical works only. The general term "productivity" has been replaced by the more specific "indices of productivity."

H_{3E}: Revegetation does not increase the amount of waterbird habitat in the drawdown zone.

Wildlife physical works have been deleted from this MH, as discussed above, and are addressed separately by the next sub-hypothesis. Specific reference to shorebirds has been deleted. They are included in the definition of waterbird.

H_{3F}: Wildlife physical works do not increase the amount of waterbird habitat in the drawdown zone.

This sub-hypothesis is a restatement of the original H_{3D} addressing in this case wildlife physical works only. Specific reference to shorebirds has been deleted. They are included in the definition of waterbird.

1.5 Key Water Use Decision Affected

The key water use plan decision influenced by the results of this monitoring program is the selection of an operating regime for Arrow Lakes Reservoir that balances power generation, recreational, fish, and flood control interests with requirements for local wildlife. In evaluating operating alternatives of the Arrow Lakes Reservoir during the Columbia WUP, it was assumed that waterbirds would benefit by: (1) maintaining lower reservoir water levels in the spring, and (2) quickly drafting the reservoir after attaining full pool to ensure lower water levels in the late summer/early fall period. Spring and fall operational constraints were recommended by the CC to maintaining current levels of vegetation in the drawdown zone at and above elevation 434 m for breeding birds and fall migrants.

Results of this monitoring program will help determine how reservoir operations affect the species richness, abundance, and distribution of waterbirds, and indices of waterbird productivity in Revelstoke Reach, and provide recommendations with

[20] The original Management Hypothesis H_{3C} was: "Revegetation and wildlife physical works do not result increase the productivity of waterbirds utilizing the drawdown zone."

[21] The original Management Hypothesis H_{3D} was: "Revegetation and wildlife physical works does not increase the amount of shorebird or waterbird habitat in the drawdown zone."

respect to reservoir operations and physical works projects. This monitoring program will also help to evaluate the effectiveness of physical works and revegetation efforts on waterbird populations.

2.0 Monitoring Program Proposal

2.1 Objectives and Scope

The key objectives of this monitoring program are to:

- Determine the extent of use of Revelstoke Reach by waterbirds by determining their abundance, species richness, distribution, productivity, and patterns of habitat use.
- Inform BC Hydro on how reservoir operations affect waterbirds by monitoring their abundance, species richness, distribution, productivity, and patterns of habitat use over time.
- Determine whether minor adjustments can be made to reservoir operations to minimize the impact on waterbirds or whether mitigation strategies are required to reduce the risks to these populations from reservoir operations.
- Provide the data necessary to inform how physical works projects may enhance waterbird habitat in Revelstoke Reach.
- Provide the data necessary to evaluate whether physical works projects or revegetation initiatives enhance waterbird habitat in Revelstoke Reach.

The collection of long-term data will be necessary to inform on potential changes in abundance, species richness, distribution, productivity, and seasonal patterns of habitat use in response to reservoir operations. Different survey components will be conducted throughout the year. The duration of this project specified in WUP is 10 years. Progress reports will be prepared annually, and comprehensive reports will be provided at Years 5 and 10. The interim report at Year 5 will inform how physical works projects may enhance waterbird habitat.

2.2 Approach

The approaches proposed entail monitoring the abundance, species richness, distribution, and seasonal patterns of habitat use of all species of waterbirds during spring migration (wildfowl) and fall migration (wildfowl and shorebirds), and monitoring the productivity of two waterbird guilds: wildfowl and raptors (Osprey, Bald Eagle, Northern Harrier, and Short-eared Owl[22]).

Due to the sheer number of waterbird species (62 species including wildfowl, raptors, shorebirds, heron, terns, gulls, and kingfisher) and their differing life histories, monitoring the productivity of all waterbird species is not practical. Survey methods

[22] Although Short Eared-Owls are an open prairie/tundra species that often breed in open wetland meadows, they are not typically considered waterbirds. However, they are included here as Performance Measures were set for this species by the Consultative Committee with respect to operating alternatives for Arrow Lakes Reservoir.

will include aerial surveys[23], nest surveys (raptors only), and ground-based observational surveys from permanent observation stations (including wildfowl brood surveys). Results of these surveys provide the indices of productivity referenced above in MQs 4, 7, 8 and 9.

To address seasonal patterns of habitat use, habitat data will be collected to identify important waterbird habitat (e.g., nesting habitat for Short-Eared Owls, Northern Harrier, and wildfowl) and where feasible to model and monitor habitat use in relation to reservoir operations. This approach utilizes habitat data and mapping products from other WLR studies, particularly CLBMON-11B-4. This latter project produces detailed habitat data within these wetlands. CLBMON-40 collects detailed mapping data on use by waterfowl. By combining data from these studies, the most detailed analysis of habitat use can be conducted. As part of this, GIS mapping (e.g., vegetation community mapping, Digital Elevation Models, bathymetry models etc.) will be used extensively to address topics regarding habitat selection.

Detection Probabilities

In drawing inferences from wildlife surveys, incorporating detection probabilities is imperative when the probability of detecting wildlife obscures actual trends in population size and habitat occupancy (Boulinier et al. 1998; Mackenzie et al. 2002; Royle & Nichols 2003). Factors such as weather, habitat type, time of day, species of interest, and observer experience can influence waterbird detectability (Fletcher & Hutto 2006). Surveys for waterbirds will include “double survey”, “double observer”, and/or “distance sampling” approaches, where appropriate, to account for imperfect detection probabilities ($p<1$).

2.3 Methods

Task 1: Project Coordination

Project coordination involves the general administration and technical oversight of the program, which will include, but may not be limited to: 1) budget management, 2) program team management, 3) logistics coordination, 4) technical oversight in field and analysis components, 5) facilitation of data transfer among other investigations associated with the Arrow Reservoir Operations Management Plan, 6) permit applications, and 7) liaison with regulatory agencies, as required.

A safety plan must be developed and submitted to BC Hydro for all aspects of the study involving field work, in accordance with BC Hydro procedures and guidelines. Specific safety training may be required (e.g., first aid, small boat operation).

Task 2: Habitat Characterization and Site Selection

Study design for CLBMON-40 captures habitat-use at three scales: 1) habitat use within sites (major wetlands), 2) habitat use at and among sites over time, and 3), habitat use throughout the study area. In the former case, analysis at the fine scale requires detailed habitat data to be collected within wetlands. The second among-site scale has more to do with time series analysis, where usage is documented at and among the major wetlands as a function of time and conditions. At the scale of the

[23] In Year 1, the use of aerial surveys will be evaluated closely since a portion of the survey area passes through the community of Revelstoke. Although less efficient and in some respects disadvantageous, boat based surveys may be considered an alternative method for surveying waterbirds.

study area two types of data are required: a simple polygon map for aerial surveys to document the distribution of waterfowl during census counts, and a habitat map in order allow polygon characteristics to be compared.

Prior to data collection a study design was created to monitor usage within and among wetland sites, and to monitor waterfowl usage throughout the study area. Monitoring usage within and among sites required defining fixed stations to monitor migratory wildfowl and shorebirds at wetland habitats within the study area (e.g., Downie Marsh, Airport Marsh, Montana Slough and Cartier Bay). Fixed observation stations were also chosen specifically to monitor the effectiveness of Wildlife Physical Works projects that may be implemented during the course of the study. For the aerial waterfowl surveys, the study area was to be subdivided into practical size and shaped polygons for aerial census counts between Shelter Bay and Revelstoke Dam. Aerial census polygons were defined based on natural habitat configuration, taking into account aspects such as elevation, topography, and habitat type.

Initially it was anticipated that CLBMON-40 habitat use analyses would require the project to gather detailed habitat data in the field, and that it could benefit from habitat mapping layers provided by other WLR projects in the Arrow Lakes Reservoir. However, after the project was underway, it was realized that the opposite was true: detailed habitat data were available but mapping was lacking. Detailed data collected within the major wetlands became available under the CLBMON-11B-4 WLR project, initiated shortly after CLBMON-40 was underway. This related study mapped the bathymetry of the wetlands, used random sampling to document the distribution and abundance of aquatic macrophytes and invertebrates within and among the wetlands, and additionally monitored physiochemical properties of the wetlands. As a result, a focus of CLBMON-40 habitat monitoring shifted away from habitat sampling towards habitat mapping.

A top down mapping approach was taken, where the map was first drafted, followed by validation in the field, with options to make adjustments as necessary. The mapping was informed by various data sources including a 5 m pixel digital elevation model, orthophoto imagery [1:5000 colour photos (2007), 1:10,000 black-and-white photos (2007) and 1:5000 colour photos (2010)], and a large library of photos taken during aerial waterfowl surveys. The mapping was completed in the drawdown zone from the Trans-Canada Highway bridge to the south end of Revelstoke Reach. Polygons of habitat with consistent habitat structure and topographical characteristics (elevation/slope) were delineated at a scale appropriate for most wildlife applications. Polygons were initially defined based on an objective classification of mutually exclusive habitat strata (e.g., ‘grassland’), and subdivided into fine categories of habitat (e.g., ‘reed canarygrass’ vs. ‘mixed grass’). Mapping validation occurred with ground truthing at 78 randomly selected polygons (~9.6 % of all polygons) which were classified in the field by a biologist familiar with the map, but blind to the classification of the sites. This process identified means for improvement to the map, and scored 70% correct classification at the fine scale classification.

Task 3: Waterbirds Surveys

During the spring (April and May) and fall (September and October) migration periods[24], weekly aerial surveys and ground-based observations from fixed stations

[24] The exact scheduling of these studies may require some adjustment to account for variations in the timing of migration between species.

will be conducted to monitor waterbird abundance, species richness, and distribution. These surveys will focus on wildfowl, gulls, terns and herons; and water-dependent birds of prey.

Aerial Wildfowl Surveys

During migrations, aerial wildfowl surveys will be used to conduct a complete census of the study area using a helicopter. Two surveyors will observe and record species occurrences (counts) and characteristics such as age class, sex, group size. All observed wildfowl will be assigned within mapped polygons produced during the pre-stratification phase. Procedures for conducting aerial surveys are outlined in Resources Inventory Committee (1999b). Logistical considerations for conducting aerial surveys such as the choice of aircraft, equipment, navigation procedures, safety, and considerations for pilots and personnel are discussed in greater detail in Resources Inventory Committee (2002). The ideal conditions for conducting aerial surveys is at midday, on a bright day but overcast day (Bibble et al. 2002). Surveys will not be conducted during periods of rain, high winds, fog, or under any other conditions that reduces visibility.

Land-based Wildfowl Surveys

Between April and May and between September and October[25], land-based surveys will be conducted from permanent observational stations established in Task 2. Using binoculars and telescopes surveyors will record and map species occurrence (counts) and characteristics including age class, sex, group size and behaviour for all waterbird species. Habitat characteristics (water levels, extent of emergent vegetation, etc.) and environmental conditions (temperature, wind, precipitation, cloud cover, etc.) will also be documented. Procedures for conducting land-based observational surveys are outlined by the Resources Inventory Committee (1999b). Surveys will not be conducted during periods of rain, high winds, fog, or under any other conditions that reduce visibility.

Task 4: Weekly Fall Shorebird Surveys

During the fall shorebird migration period (mid-July to the end of October[26]), weekly ground-based transect surveys, and boat-based surveys (six per season) will be conducted to monitor shorebird abundance, diversity, and distribution.

Land-Based Shorebird Surveys

Weekly counts of migratory shorebirds at suitable shorebird habitats will be conducted from the beginning of July until the end of October. Counts will be conducted using a standardized protocol (ground counts - Resources Inventory Committee 1997; Skagen et al. 2006). Shorebirds will be mapped, enumerated and classified by species, age class (juvenile or adult), sex at fixed observation stations. Observers will conduct surveys in pairs alternating between primary and secondary observers. Environmental data, habitat data, and the presence or sign of other wildlife species will be collected along each transect.

[25] The exact scheduling of these studies may require some adjustment to account for variations in the timing of migration between species.

[26] The exact timing of these studies may require some adjustment to account for variations in the timing of migration between species.

Boat-based Shorebird Surveys

Six boat-based surveys will be conducted during each fall migration in order to access hard to get to sites. Boat surveys will follow standardized procedures (Resources Inventory Committee 1997) to survey pre-stratified shoreline transects. Data collected will include shorebird species, location (UTM coordinates), count data, age class (juvenile or adult), sex, environmental conditions and habitat data.

Task 5: Wildfowl Productivity

Between mid-June and July 31[27], bi-weekly ground-based observational surveys (as described in Task 3) will be conducted to record wildfowl brood counts. During these surveys, the number of ducklings and age class of each brood are to be documented using the aging scheme described by Gollop and Marshall (1954).

Task 6: Raptor Productivity

During the spring and summer, the productivity of Bald Eagles, Osprey, Northern Harrier, and Short-Eared Owls will be monitored. Aerial surveys will be employed for the arboreal nesting raptors (Bald Eagles and Osprey) and ground-based observational surveys, transect surveys, and nest searches will be conducted for the ground nesting raptors (Short-Eared Owl and Northern Harrier).

Bald Eagle and Osprey

Aerial nest surveys for Bald Eagles and Osprey will be done in conjunction (either before or after) with the aerial surveys described in Task 3 to locate and monitor nests. Procedures for conducting aerial nest surveys for raptors are described by the Resources Inventory Committee (2001). Visual ground-based surveys may be required to confirm brood numbers and additional surveys may be required to monitor osprey nests as Ospreys fledge considerably later than Bald Eagles (Marc-Andre Beaucher, pers. comm.). Surveys for eagles should occur by the first week of July, whereas those for ospreys should occur in later July.

Northern Harrier and Short-Eared Owl

From mid-April to the end of May[28], ground-based observational surveys (Tasks 3 and 4), and nest searches will be conducted for Short-Eared Owl and Northern Harrier. Ground-based nest searches will be conducted for Northern Harrier and Short-Eared Owls in spring and summer, when these species' nesting success and reproductive output are determined. Procedures for conducting foot surveys and nest searches are described by the Resources Inventory Committee (2001).

Detailed habitat information will be collected where nests are located. Habitat data will include vegetation data (plant community, species lists, structural stages, and percent cover), substrate, ground cover (woody debris, boulders, etc.), size of habitat polygon, and distance to water (e.g., Luttmerding et al. 1998; MacKenzie & Moran 2004).

[27] The exact timing of these studies may require some adjustment to account for variations in the timing of migration between species.

[28] The exact timing of these studies may require some adjustment to account for variations in the timing of migration between species.

Task 7: Data Analysis

A brief summary of the data collected during each year will be provided in an annual progress report. This will include a summary of sampling effort expended and an overview of the data. The intent of the data summary is to provide a synopsis of the sampling effort and results and to ensure data are checked on an annual basis. Comprehensive analysis of the data will be ongoing.

A range of analysis and statistical methods are expected to be required. The choice of statistical methods must be clearly stated and justified. It is expected that nest survivorship models will be implemented to make inferences about nesting success (Mayfield 1961, Shaffer 2004). Basically, statistical approaches will be chosen to suit the data that the study has produced rather than conform to prescriptive approaches that over time may become inappropriate.

Task 8: Reporting

Annual reports will provide three types of information: (1) a brief account of the annual progress including any changes or adjustments to methods since the last annual report, (2) a review of the progress in the multi-year dataset, and (3) an account of updated analyses.

The annual progress summary will be brief and include the locations of field work, sampling effort, a high level account of what was observed and monitored (e.g., numbers and types of nests located and monitored, a review of nest outcomes), and a record of the conditions encountered (e.g., weather, reservoir operations, notable relevant observations unique to the year).

The annual progress reports will include a review of multi-year progress, will review the status of the multi-year dataset, and will highlight targets for the following year. The analysis section will showcase progress being made towards addressing the management questions, for example, by testing the management hypotheses. Such analyses may be draft results, or final results, depending on the circumstances (e.g., need for additional data, or additional analysis). Annual reports will contain a detailed Executive Summary, followed by a brief Introduction, Methods, Results, Discussion, References, and Appendices.

Also in each year of the study, sampling protocols will be developed/updated describing the location of study plots in the Revelstoke Reach.

Manuscripts prepared for peer-review publication will be submitted along-side annual reports, and referenced as a separate document.

Digital deliverables to BC Hydro will include

- A database of nest observations

The final report:

A technical report will be prepared following the completion of Year 10. This report will include:

- an executive summary;
- an introduction;
- a detailed description of the project methods used;

- a detailed overview of how each management question and hypothesis has been addressed and remaining data gaps or other sources of uncertainty. This section will refer to peer-reviewed reports, or similar stand-alone documents (e.g., manuscripts in draft form), or to new analyses, each presented in detail in their own appendix;
- a discussion of the final results, and identification of remaining knowledge gaps;
- recommendations for (i) modifying the operating parameters of the Upper Arrow Reservoir to reduce negative effects on waterbirds and/or (ii) management efforts (revegetation or physical works) that would mitigate any negative effects of operating regimes currently in use.
- A final digital appendix with data from all years including:
    i. A database and/or Shapefiles of survey transects and observation sites;
    ii. A database and Shapefiles of the habitat maps created during this study;
    iii. A database of nest observations;

Reports will follow the standard format for WUP monitoring projects. 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. The locations and associated data for significant species such as species at risk will be provided to the Ministry of Environment following the Wildlife Species Inventory (WSI) standards (http://www.env.gov.bc.ca/wildlife/wsi/formats.htm).

2.4 Interpretation of Monitoring Program Results

A key result of this monitoring program will be information on waterbirds abundance, species richness, distribution, productivity, and patterns of habitat use in Revelstoke Reach. Information on the timing of waterbird migration and the abundance, species richness, distribution of waterbirds, and indices of waterbird productivity will facilitate an evaluation of how reservoir operations impact these populations. An assessment of how variation in operating parameters of Arrow Lakes Reservoir, including the implementation of soft constraints and the addition of Revelstoke Unit 5, influence waterbirds habitat will enable a detailed assessment of the level of risk imposed by different operating regimes. Detailed data on changes in habitat use over time will facilitate an assessment of how revegetation and physical works influence waterbirds.

2.5 Study Design Limitations

Monitoring changes in wildlife abundance and habitats can be complicated by numerous factors, and limitations such as a poor study design or sampling strategy. Despite efforts to reduce these limitations, we acknowledge that this monitoring program has several constraints. First, this monitoring program does not include controls to account for the influence of external factors on waterbird abundance. Second, reservoir operations (water levels, filling and drafting rates) may have limited variability among years, which may reduce the ability to correlate specific reservoir conditions to waterbird abundance. This may be further complicated by the implementation of soft constraints over the course of the monitoring program. Third, while efforts have been made to account for imperfect detection probabilities, ensuring that the assumptions implicit in these models are not violated may be challenging.

As conditions on the Arrow Reservoir are unpredictable, the sampling program may be altered, interrupted, or curtailed in any given year. Components of the sampling program will be scheduled as required to provide the safest and most efficient delivery.

2.6 Schedule

This project will be implemented over a 10-year period from 2008 to 2017. The anticipated annual schedule for each key task associated with the proposed work is presented below in Table 40-1.

2.7 Budget

The total estimated cost is $2,700.938

Table 40-1. Annual schedule of Tasks

Tasks	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb
1) Project Coordination	√	√	√	√	√	√	√	√	√	√	√	√
2) Habitat Characterization & Site Selection	√											
3) Waterbird Migration		√	√				√	√				
4) Shorebird Migration					√	√	√					
5) Wildfowl Productivity				√	√							
6) Raptor Productivity		√	√	√	√	√						
7) Data Analysis									√	√		
8) Reporting										√	√	√

Table 40-3: CLBMON-40 Key Changes and Rationale for Revised TOR

CLBMON-40 TOR		
Section	**Change From Original TOR to the Current Revised TOR**	**Rationale**
Overall	Intermittent editing	Edited to improve clarity and consistency, and in most instances replace “diversity” with the more accurate "species richness,” and delete specific reference to shorebirds for two reasons: low numbers encountered after study initiation, and shorebirds were already included within the broad term “waterbird.”
Background	Minor changes to wording	Edited to update information on shorebird abundance
Management Questions	All - minor changes to wording	Edited to improve clarity and reflect information from Years 1-7
Management Questions	Delete Question 2.	Question 2 is redundant with Question 6.
Management Questions	Reference to shorebirds deleted from Question 3.	Shorebirds included in the term waterbird.
Management Questions		
Management Questions	In Question 4, 7, 8, and 9 the general term ”productivity” has been modified to “index (or indices) of productivity.”	The term productivity is too general; only a few specific metrics in this study relate to productivity.
Management Hypotheses	Deleted H1, H2, and H3 in favour of addressing their components within testable sub-hypotheses (MH_{1A}, MH_{1B}, MH_{1C}, MH_{1D}; MH_{2A}, MH_{2B}, MH_{2C}; MH_{3A}, MH_{3B}, MH_{3C}, MH_{3D}, MH_{3E}, MH_{3F}).	Reworded to improve clarity and testability of sub-hypotheses.
Management Hypotheses	MH_{1E} has been deleted.	Low shorebird abundance has made this MH untestable.
Management Hypotheses	Reworded MH3 (including sub-hypotheses) to be consistent with revised MQs, and in two instances to separate revegetation and wildlife physical works.	In practice the process and effects of revegetation and wildlife physical works are sufficiently different that to combine them confounds interpretation.
Management Hypotheses	Added MH_{3E} and MH_{3F}.	These are added as part of separating revegetation and wildlife physical works.
Objectives and Scope	All - minor changes to wording	Edited to improve clarity and consistency
Approach	All – moderate changes to wording specifically as it responds to current information on waterbird numbers, and to describing adjustments in approach to habitat monitoring.	Modified and clarified to reflect current stage of the project with respect to shorebirds, and a revised approach to habitat monitoring (See Methods below).
Methods ALL	All – moderate changes to wording	Edited to improve clarity and reflect information from Years 1 – 7, especially Task 2 where title has changed to the more accurate Habitat Characterization and Site Selection, how project CLBMON-11B-4 has allowed reduced habitat data collection in favour of habitat mapping, and a description of methods to fulfill the latter.
Data Analysis	All – minor changes to wording	Simplified to allow statistical approaches to be chosen, with justification, to suit the data that the study has produced rather than prescribing statistical approaches that may not suit the data.
Interpretation of results	All – minor changes to wording	Edited to improve clarity and reflect information from Years 1 - 7
Study design limitations	All – minor changes to wording	Edited to improve clarity

3.0 References

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