Columbia River Project Water Use Plan

Monitoring Program Terms of Reference

Physical Works Terms of Reference

KINBASKET AND ARROW LAKES RESERVOIRS REVEGETATION MANAGEMENT PLAN

- **CLBMON-35 Arrow Lakes Reservoir Plant Response to Inundation**

25 January 2008

KINBASKET AND ARROW LAKES RESERVOIRS REVEGETATION MANAGEMENT PLAN TERMS OF REFERENCE

1.0 OVERVIEW

This document presents Terms of Reference for the physical works and effectiveness monitoring programs for the Kinbasket and Arrow Lakes Reservoirs Revegetation Management Plan (Table 1). These programs will involve implementation of revegetation physical works, monitoring of representative planting sites under various revegetation treatments, mapping and inventory of vegetation communities at different spatial scales, identification of riparian wildlife habitat and monitoring of wildlife utilization patterns in response to revegetation efforts in Kinbasket and Arrow Lakes reservoirs, and the mid Columbia River.

The Terms of Reference for CLBWORKS-1 Kinbasket Reservoir Revegetation Program Physical Works provide a detailed plan, scope and budge for the second implementation phase (Year 2-5). Leave to Commence for Year 1 (Phase 1) of this program has been received, as has Leave to Commence for Year 1 (Phase 1) of CLBWORKS-2 Mid Columbia River and Arrow Lakes Reservoir Revegetation Program. Leave to Commence has also been received for the monitoring programs CLBMON-10 Kinbasket Reservoir Inventory of Vegetation Resources and CLBMON-33 Mid Columbia and Arrow Lakes Reservoir Inventory of Vegetation Resources. Terms of Reference for CLBWORKS-2 Mid Columbia River and Arrow Lakes Reservoir Revegetation Program (Years 2 and 3) will be submitted by the revised ordered date of 26 February 2008.

An overview of the two physical works and seven effectiveness monitoring programs, which form part of this management plan, is provided below.

1.1 Physical Works

1) CLBWORKS-1 Kinbasket Reservoir Revegetation Program: a 5-year reservoir-wide revegetation program to enhance sustainable vegetation growth within the drawdown zone of Kinbasket Reservoir to benefit fish, wildlife, archaeological site protection, shoreline stabilization, aesthetics and recreation.

2) CLBWORKS-2 Mid Columbia River and Arrow Lakes Reservoir Revegetation Program: a 5-year reservoir-wide revegetation program to enhance sustainable vegetation growth within the drawdown zone of the mid Columbia River and the Arrow Lakes Reservoir to benefit fish, wildlife, archaeological site protection, shoreline stabilization, aesthetics, dust control and recreation.

Development of the final revegetation program for CLBWORKS-1 has incorporated feedback from public and First Nation consultation processes to ensure that:

a) the plan is not in conflict with other land uses (e.g., motorized and non-motorized recreation, beach areas);

b) revegetation prescriptions are compatible with First Nation archaeological site protection requirements; and,

c) revegetation prescriptions incorporate plant species traditionally valued by First Nations, where possible.

Monitoring Programs

1) CLBMON-9 Kinbasket Reservoir Monitoring of Revegetation Efforts and Vegetation Composition Analysis: a 10-year program to evaluate plant survival and monitor representative planting sites under the various revegetation treatments in Kinbasket Reservoir. This study will also assess changes in existing vegetation communities at the site (local) level in response to the operating regime of Kinbasket Resevoir.

2) CLBMON-10 Kinbasket Reservoir Inventory of Vegetation Resources: a 10-year program to assess and map spatial extent, structure and composition of existing vegetation communities at the landscape scale within Kinbasket Reservoir to determine inter-community changes over time in response to ongoing operation of Kinbasket Reservoir. This program also identified riparian wildlife habitat in Year 1.

3) CLBMON-11 Kinbasket and Arrow Lakes Reservoirs Effectiveness Monitoring of Revegetation and Wildlife Physical Works: an 11-year program to conduct effectiveness monitoring of wildlife habitat utilization in response to revegetation efforts in Kinbasket Reservoir, and revegetation efforts and wildlife physical works in the mid Columbia River and Arrow Lakes Reservoir.

4) CLBMON-12 Arrow Lakes Reservoir Monitoring of Revegetation Efforts and Vegetation Composition Analysis: a 10-year program to evaluate plant survival and monitor representative revegetation sites under the various revegetation treatments in the mid Columbia River and Arrow Lakes Reservoir. This study will also assess changes in existing vegetation communities at the site (local) level in response to the soft constraints operating regime of the Arrow Lakes Reservoir.

5) CLBMON-13 Monitoring of Mosquito Populations in the Revelstoke Area: a 2-year program to monitor the distribution and abundance of larval and adult mosquitoes in relation to physical environmental variables (elevation, temperature) and biotic variables (habitat) in the Revelstoke area.

6) CLBMON-33 Arrow Lakes Reservoir Inventory of Vegetation Resources: a 10-year program to assess and map vegetation distribution by elevation and identify riparian wildlife habitat in relation to inundation cycles and revegetation efforts in the mid Columbia River and Arrow Lakes Reservoir.

7) CLBMON-35 Arrow Lakes Reservoir Plant Response to Inundation: a 5-year program to evaluate responses of plants of different ages, seedlings to mature plants, and species to inundation cycles in the mid Columbia River and Arrow Lakes Reservoir.

Table 1 Kinbasket and Arrow Lakes Reservoir Revegetation Management Plan Physical Works and Monitoring Program Terms of Reference Submission Information

Name of Monitoring Program or Physical Works	Order Clause Fulfilled	Submitted with this Package	Previously Submitted To CWR	Submission Date	Leave to Commence
CLBWORKS-1 Kinbasket Reservoir Revegetation Program	Schedule A: 1.a	Yes	Yes	04 April 2007	Yes – Year 1 only
CLBWORKS-2 Mid Columbia River and Arrow Lakes Reservoir Revegetation Program	Schedule C: 1.a Schedule D: 1.a	No[1]	Yes	04 April 2007	Yes – Year 1 only
CLBMON-9 Kinbasket Reservoir Monitoring of Revegetation Efforts	Schedule A: 2.a	Yes	No	25 January 2008	No
CLBMON-10 Kinbasket Reservoir Inventory of Vegetation Resources	Schedule A: 2.b	No	Yes	04 April 2007	Yes
CLBMON-11A Wildlife Effectiveness Monitoring of Revegetation in Kinbasket Reservoir	Schedule A: 2.c	Yes	No	25 January 2008	No
CLBMON-11B Effectiveness Monitoring of Revegetation in the mid Columbia River and the Arrow Lakes Reservoir	Schedule C: 5.a Schedule D: 2.a	No	No		No
CLBMON-12 Mid Columbia River and Arrow Lakes Reservoir Monitoring of Revegetation Efforts and Vegetation Composition Analysis	Schedule C: 2.a Schedule D: 2.b Schedule D: 2.c	Yes	No	25 January 2008	No
CLBMON-13 Inventory of Mosquito Populations in the Revelstoke Area	Schedule C: 5.b	Yes	No	25 January 2008	No
CLBMON-33 Mid Columbia and Arrow Lakes Reservoir Inventory of Vegetation Resources	Schedule C: 2.b Schedule D: 2.c	No	Yes	04 April 2007	Yes
CLBMON-35 Arrow Lakes Reservoir Plant Response to Inundation	Schedule C: 2.c Schedule D: 2.d	Yes	No	25 January 2008	No

[1] Terms of Reference for the implementation phase (Years 2-3) of CLBWORKS-2 Arrow Lakes Reservoir Revegetation Program will be submitted by the revised ordered date of February 26, 2008.

2.0 PROGRAM RATIONALE

The Columbia River Water Use Plan Consultative Committee (WUP CC) recognized the value of riparian vegetation surrounding Kinbasket and Arrow Lakes reservoirs for enhancing littoral productivity, providing physical, structural and biological character for wildlife habitat, protecting cultural heritage sites, and providing aesthetic benefits (e.g., reduction of dust storms) within the drawdown zone. As a result, the protection and enhancement of high quality riparian vegetation emerged as a key environmental objective for Columbia River Water Use Plan, and operational, as well as non-operational alternatives to maximize vegetation diversity and wildlife habitat were a fundamental consideration throughout the water use planning process.

The WUP CC supported reservoir-wide revegetation programs for Kinbasket and Arrow Lakes reservoirs in lieu of maintaining lower elevations during the growing season than those provided under current operations, to maximize vegetation growth in the drawdown zones. The revegetation approach consists of multi-year programs with intervention over five years to facilitate long-term vegetative cover in those areas that have good potential to become self-sustaining. Key environmental and social objectives of the revegetation program are to:

- maximize vegetation growth[2] in the drawdown zones; and,
- provide benefits to littoral productivity, wildlife habitat, recreation, shoreline erosion and archaeological site protection.

Monitoring programs and physical works Terms of Reference presented herein collectively form the Kinbasket and Arrow Lakes Reservoirs Revegetation Management Plan (RMP).

Kinbasket Reservoir Revegetation Program

During the WUP process, the regulation of reservoir filling and changes to minimum annual elevations were explored by the WUP CC as a means of achieving a number of environmental and social benefits for Kinbasket Reservoir; however, modeling of these alternatives revealed that these incremental changes in operations would incur very high costs in foregone power generation (BC Hydro 2005). In addition, preliminary work on developing revegetation strategies for the drawdown zone of Kinbasket Reservoir (Moody and Carr 2003) indicated that the greatest limiting factor to vegetation establishment was not the operation of the reservoir (based on reservoir operation data between 1991 and 2001), but lack of initial vegetation establishment, which could likely be addressed through targeted planting. The WUP CC therefore agreed to reject further analysis of operating alternatives for the purpose of enhancing vegetation potential, and recommended instead a revegetation program for Kinbasket Reservoir, aimed at maximizing vegetation growth in the drawdown zone to meet the environmental and social objectives stated above. This program will be implemented through the revegetation physical works CLBWORKS-1 (Kinbasket Reservoir Revegetation Program).

This document provides detailed Terms of Reference for the implementation phase (Years 2-5) of CLBWORKS-1, based on results obtained during Year 1 of this program[3] (Keefer 2007). Incorporated into the final revegetation program are feedback from public and First

[2] Vegetation growth can be defined as the increase in area of self-sustaining vegetation cover.

[3] Phase 1 work included field verification of revegetation potential and prioritization of revegetation sites, collection of seed and initiation of nursery stock.

Nation consultation processes to ensure that the planned approach does not conflict with other land uses (e.g., motorized and non-motorized recreation, beach areas), and that revegetation prescriptions are compatible with First Nation archaeological site protection requirements and incorporate traditional use species, where possible.

In association with the revegetation physical works, the WUP CC recommended inventory and effectiveness monitoring programs to ensure that the Kinbasket Reservoir revegetation efforts are providing the intended environmental and social benefits over the long term. The monitoring programs include the following Terms of Reference:

- Kinbasket Reservoir Monitoring of Revegetation Efforts and Vegetation Composition Analysis (CLBMON-9)
- Kinbasket Reservoir Inventory of Vegetation Resources (CLBMON-10)

Mid Columbia River and Arrow Lakes Reservoir Revegetation Program

Riparian vegetation in Arrow Lakes Reservoir, and in particular in Revelstoke Reach (mid Columbia), presently extends over an elevation range of about 10 m (430 m to 440 m). Expansion of vegetation into the lower elevations has been largely the result of a fall rye seeding program that began in the early 1990s, which has facilitated the spread of natural vegetation (sedge and grass). A series of low water years during the 1990-1999 period also allowed the establishment of natural vegetation by providing seedlings sufficient growing time to develop into mature plants that are capable of tolerating subsequent extended inundation. These factors have worked in concert over the past decade to allow the establishment and persistence of extensive areas of natural vegetation, which now dominate the drawdown zone of Revelstoke Reach and smaller areas in the main body of Arrow Lakes Reservoir (Moody 2005).

Recognizing the importance of this vegetation as a means of achieving a number of environmental and social benefits for Arrow Lakes Reservoir, the WUP CC explored several operating alternatives, designed to maintain existing vegetation in the mid Columbia (Revelstoke Reach) and Arrow Lakes Reservoir, by imposing lower reservoir elevations for longer periods during the early part of the growing season (late spring and early summer). Modeling of these alternatives showed that stricter elevation constraints would provide varying levels of protection to vegetation, but could incur very high costs in lost power generation in some years. There was also concern around the high level of uncertainty in many of the assumptions used to develop elevation constraints, particularly around the relative importance of timing, frequency, duration and depth of inundation on the distribution, biomass and diversity of vegetation.

To address these concerns, the WUP CC recommended a multi-year revegetation program between elevations 434 m and 440 m in those areas that have a good potential to become self-sustaining after five years of treatment as a more cost-effective means of maximizing vegetation growth in the drawdown zone of Arrow Lakes Reservoir. The goal of the program is to provide benefits to littoral productivity, large river habitat, wildlife habitat, shoreline erosion and archaeological site protection. The program will be implemented through the Mid Columbia and Arrow Lakes Reservoir Revegetation Program Physical Works (CLBWORKS-2). The WUP CC agreed that annual monitoring of the revegetation program would be critical to evaluate the effectiveness of planting efforts, and confirm the effectiveness of techniques for vegetation and wildlife habitat enhancement. The monitoring program includes the following Terms of Reference:

- Arrow Lakes Reservoir Monitoring of Revegetation Efforts and Vegetation Composition Analysis (CLBMON-12)

- Arrow Lakes Reservoir Inventory of Vegetation Resources (CLBMON-33)
- Arrow Lakes Reservoir Plant Response to Inundation (CLBMON-35)

2.1 Additional Monitoring Programs

Two additional programs are included in the Kinbasket and Arrow Lakes Reservoir Revegetation Management Plan (RMP), specifically:

- Kinbasket and Arrow Lakes Reservoirs Effectiveness Monitoring of Revegetation and Wildlife Physical Works (CLBMON-11)
- Monitoring of Mosquito Populations in the Revelstoke Area (CLBMON-13)

CLBMON-11 will monitor the effectiveness of wildlife habitat utilization in the Kinbasket and Arrow Lakes reservoir drawdown zones, with the goal of assessing the benefits of revegetation efforts and physical works (mid Columbia and Arrow Lakes only) to wildlife.

The goal of CLBMON-13 is to gain a better understanding of the species, life history and habitat requirements of mosquito species occupying habitats in the Revelstoke area, to determine the effect that dam discharge and reservoir management have on mosquito levels in the area. Because water pockets that form in revegetated areas and in other vegetated spots when reservoir levels recede may provide additional mosquito breeding habitat, this program will also examine potential effects of revegetation efforts in the drawdown zone on mosquito production (species and abundance).

3.0 REFERENCES

BC Hydro. 2005. Consultative Committee report: Columbia River Water Use Plan, Volumes 1 and 2. Report prepared for the Columbia River Water Use Plan Consultative Committee by BC Hydro, Burnaby, BC. 924 pp.

Carr, W.W. and A.I. Moody. 2003. Mica - Revelstoke - Keenleyside Water Use Plan: Potential areas for vegetation establishment in the Kinbasket Reservoir. Report prepared for BC Hydro. 40 pp.

Keefer, M.E., T. Ross and K. Kettenring. 2007 Kinbasket Reservoir Revegetation Program Physical Works (Phase 1) Site Verification and Seed Collection. Report prepared for BC Hydro. 34 p. plus appendices.

Moody, A.I. 2005. Mica-Revelstoke-Keenleyside Water Use Plan: potential areas for vegetation establishment in the Arrow Lakes Reservoir. Prepared for BC Hydro. 49 pp.

Monitoring Study No. CLBMON-35
Arrow Lakes Reservoir
Plant Response to Timing and Duration of Inundation

1.0 MONITORING PROGRAM RATIONALE

1.1 Background

From 1991 to 1993, wetland trials were conducted in the Revelstoke Reach portion of Arrow Lakes Reservoir to examine the feasibility of establishing a perennial cover of native wetland species for dust control in the drawdown zone (Carr 1992; Carr and Moody 1992; Carr et al. 1993; Moody 1998; Moody 2002b). Long-term monitoring of the survival of these species and monitoring of permanent plots yielded valuable information regarding individual species tolerances to water level fluctuations as a result of the reservoir operating regime. However, these plots did not span the full range of elevations now occupied by natural vegetation within the drawdown zone (approximately 440 m to 430 m).

There has been no subsequent testing of the absolute limits of plant endurance or which aspects of the reservoir operating regime (i.e. inundation timing, frequency, depth or duration) are the most significant for plant survival. This lack of specific information hindered the Water Use Plan (WUP) Consultative Committee's ability to assess the performance of operating alternatives for Arrow Lakes Reservoir on existing vegetation communities. Numerous assumptions were built into the vegetation performance measures, which the WUP Consultative Committee (WUP CC) acknowledged needed to be tested to improve future decision making regarding reservoir management. A key assumption used in deriving the vegetation performance measure scores was that plant condition and survival is constrained by the opportunity for spring growth. This assumption led to the Committee's prediction that if flooding occurred one week earlier in the spring, a decrease in duration of flooding of at least two weeks would be required to maintain plant condition and survival in vegetation existing communities. It was also assumed that the current distribution of vegetation within Revelstoke Reach has evolved in response to recent historic water levels (1990-1999), and that a change in average conditions should therefore determine trends in vegetation change over time.

In accepting soft constraints operating regime for Arrow Lakes Reservoir, the WUP CC recognized the uncertainty associated with the response of existing vegetation communities to flexible operations on a yearly basis, and consequently recommended a monitoring program comprised of a series of interlinked studies at different spatial scales to investigate the effects of the operating regime on riparian and wetland vegetation communities. These Terms of Reference address monitoring at the scale of the individual organism (plant) spatial scale to document the responses of individual plants to the stresses imposed by the soft constraints operating regime. The monitoring program will address existing uncertainties regarding the relative contribution and importance of timing, frequency, depth and duration of inundation on plant survival at different sizes and ages, and the effect of multi-year stresses on trends in plant viability.

1.2 Management Questions

The fundamental management questions to be addressed by this monitoring program are:

- How are individual riparian and wetland plant species affected by the soft constraints operating regime with respect to timing, frequency, duration and depth of inundation?
- How different are the responses of the different plant species to the operating regime?
- How do the responses of plant species to the operating regime interact with other factors (e.g. substrate, climate, presence of other plant species)?
- Are there potential opportunities to modify operations to better maintain the existing condition of riparian and wetland plant species plants at the scale of the organism?
- What recommendations can be made to more effectively maintain existing vegetation at the site level in the future?

To resolve key uncertainties regarding the influence of operating conditions of Arrow Lakes Reservoir on vegetation status, results from this monitoring program will be integrated with findings from two other vegetation monitoring programs, CLBMON-33 Arrow Lakes Reservoir Inventory of Vegetation Resource and CLBMON-12 Arrow Lakes Reservoir Monitoring of Revegetation Efforts and Vegetation Composition analysis. A full synthesis of study results across the three monitoring program and integration of results will be carried out by BC Hydro in Years 5 and 10 of program implementation.

1.3 Management Hypotheses

The management hypothesis and the sub-hypotheses that will be tested directly with this monitoring program are:

H_0: Implementation of the soft operational constraints maintains survival of individual plants of specific riparian and wetland species in the drawdown zone of Arrow Lakes Reservoir.

H_{0A}: Timing of inundation (week of first flooding) is a primary determinant of plant survival.

H_{0B}: Frequency of inundation is a primary determinant of plant survival.

H_{0C}: Duration of inundation (number of wetted weeks) is a primary determinant of plant survival.

H_{0C}: Depth of inundation is a primary determinant of plant survival.

H_{0D}: Plants of different ages (seedling vs. mature plant) have different survival patterns under the inundation regime.

H_{0E}: Different plant species have different survival patterns under the inundation regime.

The sub-hypotheses are structured from the “bottom-up” to determine 1) the overall effects of the operating regime on plant survival; 2) whether effects on survival, if they occur, are different among different growth stages of plants (i.e. are some plants at different stages more or less likely to be adversely affected by the operating regime?), and 3) what component of the operating regime (timing, frequency, depth or duration) has the most pronounced effect on plant survival. Taken together, the patterns of survival that will be characterized under these hypotheses will provide information to evaluate the long-term effects of the current operating regime, and to

develop *a priori* predictions about the potential effects of future alterations of the regime to plant distributions in the drawdown zone.

1.4 Key Water Use Decision Affected

The key operating decision affected by this monitoring program is the maintenance of the soft constraints operating regime for Arrow Lakes Reservoir. The decision of the WUP CC to implement a revegetation program in lieu of operational changes in Arrow Lakes Reservoir was based on the assumption that such a program could be successful under the soft constraints operations. A key objective of the soft constraints is maintaining (or enhancing) existing vegetation communities and associated ecosystems in the drawdown zone through maintaining lower water levels during the growing season. However, it should be noted that it may not be possible for BC Hydro to implement the soft constraints for the Arrow Lakes Reservoir across all water years during the monitoring period due to obligations under the Columbia River Treaty, weather variability in the Columbia basin and load requirements.

Findings from this study, in conjunction with results from CLBMON-33 Arrow Lakes Reservoir Inventory of Vegetation Resources and CLBMON-12 Arrow Lakes Reservoir Monitoring of Revegetation Efforts and Vegetation Composition Analysis will be used during the 5-year review to determine whether vegetation objectives, as set out by the WUP CC, are being achieved and/or whether there is a need to review Arrow Reservoir operations. If a new operating alternative is considered at the 5-year review, continued monitoring of sites under this program will help to predict the likely long-term benefits of the new operating regime on plant survival at the organism level.

2.0 MONITORING PROGRAM PROPOSAL

2.1 Objective and Scope

The overall objectives of the monitoring program are to: 1) evaluate the responses of plants of different species and ages to timing, frequency, duration and depth of inundation, and 2) provide organism-level information required to link the effects of reservoir operations to larger-scale trends in vegetation composition, structure and spatial extent. The program will improve understanding of the impacts of inundation on existing perennial vegetation species within the drawdown zone to assist in on-going and future decision-making regarding the management of Arrow Lakes Reservoir.

The monitoring program will be conducted for five consecutive years over the implementation of the Columbia River Water Use Plan.

2.2 Approach

The monitoring study will require an experimental approach, involving both reciprocal field transplants and greenhouse culture, to determine the relative importance of timing, frequency, duration and depth of inundation to survival of plants of different species and ages (seedlings and mature plants).

While *in situ* observations can yield valuable information about the response of plants to hydrologic conditions of the reservoir, controlled environment greenhouse studies will provide a better understanding of other environmental variables that may be important covariates affecting the field experiments.

A five year field program will established to investigate the effects of variable water levels encountered during these years under the soft constraints operating regime. Greenhouse experiments will be implemented for four successive years to allow for controlled experimental testing of a range of inundation conditions imposed by the operating regime and/or to test alternate species.

2.3 Methods

2.3.1 Task 1: Project Coordination

Project coordination will involve the general administrative and technical oversight of the program, which will include, but not be limited to: 1) budget management, 2) study team management, 3) logistic coordination, 4) technical oversight in field and analysis components, 5) participation in planning processes for other programs under the Kinbasket and Arrow Lakes Reservoirs Revegetation Management Plan, and 6) maintenance of data records and facilitation of data transfer among other investigations associated with the Kinbasket and Arrow Lakes Reservoir Revegetation Management Plan.

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

2.3.2 Task 2: Statistical Design

Due to the complexity of the physical habitats of the reservoir drawdown zone, the involvement of a biostatistician will be required to ensure that the field and greenhouse experiments and subsequent data analysis utilize statistically valid approaches for testing the management hypotheses and drawing causal inferences to support the management questions.

The proposal must clearly demonstrate how the study design will allow for quantitative, statistically robust testing of the management hypotheses. Furthermore, the proposal shall describe why the proposed statistical method is suitable for this monitoring program and outline potential advantages and shortcomings of the method(s) proposed.

For the greenhouse trials, it is expected that traditional approaches to formulating statistical tests (e.g. factorial or block-treatment repeated measures analysis of variance) can offer good models for analyzing the effects observed under various types of treatments. These methods may also be applicable to the field portions of the study, provided that sufficient replication[4] is carried out, and careful plot selection controls for covariates and/or confounded variables. Unless plot selection is carefully controlled, inferences based on the analysis of plant survival at different elevational strata will be influenced by covariates unrelated to operations (e.g., climatic or site conditions). The effect of such potential covariates will need to be explicitly addressed in the study design, to ensure that any confounded factors are appropriately identified, controlled or accounted for in the analysis. Therefore, a detailed study design, which will form part of the contract deliverables, must describe environmental variables to be measured, identify potential covariates, and demonstrate how the proposed statistical model will account for covariation attributed to environmental variables. Analysis methods selected should aim to differentiate any

[4] Required replication must consider sample size and the associated power of the statistical tests.

relationship between operations and the observed trends from covariates. It should be noted that the field component of this study cannot utilize designed manipulation of reservoir levels, since these are dictated by hydrology and power generation demands[5]. Lack of control over reservoir levels will also prevent establishment of control sites in non-inundated areas[6]. Consequently, classical paired sampling designs (e.g. before-after-control-impact (BACI) cannot be used for this component of this study.This limitation presents a challenge for comparing the field and greenhouse results, and involvement of a biostatistician at the preliminary design stage of the program and subsequent to the data gathering is critical to ensure that statistical design will permit the strongest possible inferences to address the management questions and hypotheses.

2.3.3 Task 3: Experimental studies

Experimental studies should use reciprocal field transplants and greenhouse cultures to measure the response of individual plants of different species and ages to a simulated range of inundation conditions imposed by the soft constraints operating regime. Development of parallel design elements (i.e. sampling stratification and ranges of environmental variables) between the field and greenhouse studies is essential to provide a consistent and comparable approach.

The proposal shall demonstrate which information will be collected during the experimental studies to quantitatively test the response of individual plants to timing, frequency, duration and depth of inundation. Recommended response variables include, but are not limited to: plant vigour ratings for each plant, based on a standardized rating scheme (e.g. "Field manual for describing terrestrial ecosystems[7]" (1998)), survival rate statistics, and plant size (biomass) under each experimental treatment. All observations will be supported by photo-documentation.

In Situ Study

The controlled greenhouse studies should use a minimum of three key plant species that occur within the natural wetlands of Revelstoke Reach. The recommended species are lenticular sedge (*Carex lenticularis)*, reed canarygrass (*Phalaris arundinacea)* and Columbia sedge (*Carex aperta*), which represent the most common species in Revelstoke Reach. Two ages (seedlings and fully developed plants) of each plant species should be used in the experiments, which will have been cultivated to appropriate ages in the greenhouse prior to the onset of the experiment. Because a standard nursery soil mix may not representative of substrate conditions in Revelstoke Reach, the in situ study should use soil obtained from sites within the Reach. Protocols for cultivation of these transplants will be developed and provided to BC Hydro for review and acceptance prior to implementation. Extra seedlings and plants will be produced in addition to those required for the greenhouse program for inclusion with the field transplant program. Seeds (sufficient to ensure adequate germination rates) must be obtained from the Arrow Lakes Reservoir one season prior to commencing cultivation and must be stratified over the

[5] For a given plot and elevation, all individual plants will experience the “treatment” applied through the soft constraints operating regime, which will vary intra- and inter-annually, depending on weather conditions and constraints under the Columbia River Treaty. Similarly, temporal replication of inundation conditions between years is unlikely, since reservoir operating conditions are highly variable between years.

[6] Establishing controls at sites that will not be inundated, but will experience all other conditions equally, is not considered feasible, as it would likely require physical exclusion of rising water levels.

[7] http://www.for.gov.bc.ca/hfd/pubs/docs/Lmh/Lmh25.htm

winter. Note that seed for lenticular sedge, and potentially other species, may be available through the Arrow Lakes Reservoir Revegetation Program Physical Works (CLBWORKS-2). Efficiencies in seed collection must be realized for the two programs to avoid duplication of effort.

Experimental treatments in the greenhouse setting will involve exposing plants to inundation regimes that are representative in timing and duration to those encountered in Revelstoke Reach. Careful consideration must be given to how to replicate these reservoir conditions in a greenhouse. For example, flooding a plant for certain period may information on inundation survival, but to compare these results with reservoir conditions, light levels must also be manipulated. It is recommended that three timing and three duration treatments, plus associated controls, be undertaken with a minimum of three replicates each (i.e. a minimum of 48 combinations and replicates). Timing of these experiments should parallel the field program to expose plants to similar natural light intensities and temperatures. Efforts should be made to keep greenhouse conditions as close as possible to actual field conditions in Arrow Lakes Reservoir, including similar temperature and precipitation regimes. Details on how these conditions will be achieved (including recording of environmental conditions at the reservoir and transmission of this information to the greenhouse) will be detailed in a greenhouse protocol, to be submitted to BC Hydro for review and acceptance prior to initiating the experiments. Given that greenhouses typically have large diurnal temperature fluctuations and Arrow Reservoir waters are cool to cold, the protocols should outline how this, and other potential challenges in duplicating environmental conditions, may be addressed.

After onset of the treatment at the beginning of the growing season, each greenhouse experiment is expected to last for approximately four months. The greenhouse experiments have been budgeted for four successive years to allow for testing of a range of inundation conditions imposed by the soft constraints operating regime and/or to test alternate or additional species.

Field study

The field component of this monitoring program will involve establishing vegetation transplants in Revelstoke Reach over a range of elevations (strata) that provide similar inundation regimes to treatments used in the greenhouse study (i.e., timing, frequency, depth and duration of inundation). Species should be tested at a series of decreasing elevations in the reservoir drawdown zone to a lower elevation of 430 m. Revelstoke Reach is the recommended planting location due to its range of inundation elevations and established complement of vegetation, ease of access, and prior studies as a source of background information.

Good randomization and replication of field plots at each elevation zone (stratum) will be required. It should be noted, however, that maintaining adequate sample sizes (as dictated by the choice of analysis methods) throughout the time period of the study will be a potential challenge. Some plots may be lost, and others become inaccessible through changes in the reservoir's physical conditions or access. To compensate, more sites should be selected at the outset than are needed for year-on-year sampling, and these sites should be used to replace lost sites. Location of field plots must take into account other programs running concurrently in the same area, including CLBWORKS-2 (Arrow Lakes Reservoir Revegetation Program), CLBMON-11B (Wildlife Effectiveness Monitoring of Revegetation in the Arrow Lakes

Reservoir), CLBMON-12 (Arrow Lakes Reservoir Monitoring of Revegetation Efforts and Vegetation Composition Analysis) and CLBMON-33 (Arrow Lakes Reservoir Inventory of Vegetation Resources). Coordination of sampling locations with these other programs is the responsibility of the consultant, with assistance from BC Hydro.

Reciprocal transplants of three species (*Carex lenticularis, Phalaris arundinacea and Carex aperta*) will be undertaken at the start of the growing season (late April/early May). Transplants should be monitored at least once prior to inundation to assess transplant shock. Greenhouse grown seedlings and mature plants[8] will be planted along with the reciprocal transplants to provide additional information regarding survival of greenhouse grown plant stock in comparison to the transplants. These plants will be monitored in successive years to determine responses to timing, frequency, depth and duration of inundation. It is not intended that the transplants be replicated each year unless unanticipated catastrophic events cause losses to transplanted plots, and replacement transplants are required. To capture the impacts across a range of water levels, and because plants may take time to respond to environmental stresses, the monitoring program will run for five consecutive years to provide an assessment of the long term plant responses to these conditions.

In Year 5, monitoring will include harvesting a sub-set of the transplants to evaluate biomass and nutrient levels in above- and below-ground components, according to standardized procedures[9]. Harvesting will require clipping of aboveground components, excavation and washing of belowground components and preparation of samples for laboratory analyses. A comprehensive evaluation of plant size and expansion of the remaining transplants should also be undertaken at this time.

Establishment of permanent photo-monitoring points within the field plots will be undertaken to provide a photographic record of site-specific conditions on an annual basis. As in the case of biomass sampling, the photography will occur within a set timeframe each year to optimize between-year comparisons and incorporate a devise for scale, as well as location signage. Locations of photo-monitoring points will be well documented with GPS positions and compass bearings, and a permanent database will be created for this data. Permanent marking of the photo-monitoring points is essential for repeat documentation. The location in the drawdown zone poses unique challenges for permanent marking of locations. Marking of these sites must not pose a hazard for other users of the reservoir but must be sufficiently permanent to be re-locatable. These sites may be subject to floating debris, boat activity or ATV damage among others. GPS locations should be recorded for all sample plots, biomass plots and permanent photo-monitoring points.

Protection of Archaeological Sites

Several archaeological sites have been identified in the drawdown zone of Revelstoke Reach. Locations of these sites will be provided upon contract award. Because of the risk of impacting known and unknown sites, the standard procedure of digging soil pits to identify the mineral soil horizons cannot be carried out. Instead, soil profiles should be identified from cut-banks or restricted to assessment of surficial material only, where sites are known to be present In areas where no sites

[8] To produce mature plants, 1 gallon size plants should be initiated in Year 1 for use along side of transplants in Year 2.

[9] (e.g. Vegetation Resource Inventory Change Measurement Procedures, MoF 2000, available at http://www.for.gov.bc.ca/hts/inventory/reports/gymonitor/growthyield/changemonitoring/vrichangemeas.pdf)

have been identified, soil characteristics may be assessed with soil cores of up to 60 cm in depth.

Should sites be encountered accidentally during field work associated with this project, BC Hydro's Field Guide for Archaeological and Heritage Resources (Appendix I) will apply.

2.3.4 Task 4: Data Analysis

The proposal shall clearly demonstrate how the data analysis will address the management questions and associated hypotheses, while accounting for inherent limitations in the study (e.g. replication of environmental conditions in greenhouse, lack of experimental manipulation for field portion). It is expected that standard hypothesis testing will be possible for the greenhouse component of the study, and the proposed study design and associated data analysis methods shall reflect this.

For the field portion of the program, the proposal shall indicate how lack of experimental manipulation and confounded factors may affect analysis results, and how hypotheses testing may be accomplished in light of these challenges. It is anticipated that inferences from field data analysis can be strengthened by correlating data for the controlled greenhouse experiments with data for transplants survival in the natural environment. The proposal shall outline how this may be accomplished, given potential challenges in replicating environmental conditions in the laboratory. It is expected that the analysis approach will involve general linear modeling of factor effects, with the possible use of regression methods in some tests. A detailed description of the data analysis, including limitations and benefits of the selected method(s) and a discussion of statistical power/sample size, will be provided in the study design submission (part of contract deliverables), which will be submitted to BC Hydro for review and comment prior to project implementation.

The observed patterns of vegetation survival at individual elevation strata should be interpreted with the assistance of the digital elevation model (DEM) developed for CLBMON-33 (Arrow Lakes Inventory of Vegetation Resources) and water level records (available from BC Hydro) to determine relationships between plant survival and inundation timing, frequency, depth and duration resulting from the soft constraints operating regime.

2.3.5 Task 5: Reporting

A brief technical report will be prepared for each year of the monitoring program in Years 1 to 4 to summarize the sampling and statistical analysis methods employed during the program, preliminary data analyses and study findings. A comprehensive report will be prepared at the conclusion of Year 5 of the study, which will include:

- an executive summary;
- a description of sampling and analysis methods;
- a summary of data collected;
- analysis results and a comparison of results among years in relation to the observed operating regime and other explanatory variables observed in each year;
- a detailed summary of the findings as they relate to the ecological hypotheses and the management questions; and
- any recommendations for operational changes as a result of observed trends in species survival as a result of the inundation regime.

Reports will follow the standard format that has been developed for WUP monitoring programs. All reports will be provided in hard-copy and as Microsoft Word and Adobe Acrobat (*.pdf) format, and all maps and figures will be provided either as embedded objects in the Word file or as separate files. All map data, including meta data, will also be provided electronically in ARC GIS compatible format. Data (including photographic time-series) will be maintained in a relational database with a full description of the contents of each attribute.

2.4 Interpretation of Monitoring Program Results

The monitoring data will be used to assess the response of different plant species at the individual plant scale to the timing, frequency, duration and depth of inundation, and to provide quantitative response information that can be used in conjunction with results from other monitoring studies (CLBMON-12 and 33) to identify linkages between the soft constraints operating regime and maintenance of riparian vegetation in the drawdown zone of Arrow Lakes Reservoir. Analysis of these relationships will provide a better understanding of the effects of reservoir operation on survival and distribution of existing vegetation communities.

Data collected during the monitoring program will be used to assess the degree to which management objectives can be met by implementation of soft constraints operating regime. This information will be critical for guiding decision making during the 5-year review of Arrow Lakes Reservoir operations, and informing the full review of the Water Use Plan after 13 years.

2.5 Schedule

The field study component of this monitoring program will be carried out in five consecutive years over the implementation period of the Columbia River Water Use Plan, while the greenhouse component will run for four years. Field studies and greenhouse work will run in parallel after Year 1 and should be initiated in late April/early May of each year. Monitoring of field transplants will occur until water levels rise (usually in mid to late June, depending on the water year). Greenhouse experiments will be ongoing for approximately 4 months in each of the four consecutive years.

2.6 Budget

The average annual cost of the monitoring program is estimated at an average annual $44,016 (including inflation and contingency, which exceeds the WUP CC estimate of $30,000 (in 2004 dollars). The additional expenses are incurred through the inclusion of a biostatistician during the study design and data analysis, as well as inclusion of a travel budget. Table CLBMON-35-1 provides annual budget estimates assuming a 2% rate of inflation and a 5% contingency for the duration of the program.

3.0 REFERENCES

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Appendix I
BC Hydro Field Guide for Archaeological and Heritage Resources

BC Hydro FIELD GUIDELINES

Archaeological and Heritage Resources

If you come upon evidence of past human occupation, such as:

- human bones
- stone tools
- shell deposits (middens)
- pithouses
- rock paintings
- culturally modified trees

You should:

STOP WORK IMMEDIATELY, and notify your manager, as soon as possible. AVOID disturbing the site.

Why?

You may have discovered unrecorded archaeological resources which are protected under the Heritage Conservation Act. Under this Act, all BC Hydro employees and contractors are responsible for protecting archaeological resources uncovered during the course of our work.

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If you come upon suspected human remains, you should:

STOP WORKING IMMEDIATELY and notify the RCMP, and your manager, as soon as possible. AVOID disturbing the site.

Why?

1. You may have discovered a crime scene. Any disturbance may hamper the police investigation.
2. You may have uncovered an archaeological site. The burial remains and any related artifacts are protected by the Heritage Conservation Act.
3. It shows respect for the human remains.

Who To Call

Environment & Sustainability, Engineering	604 528-1770
Aboriginal Relations	604 528-2805
Regional Enviro. Coordinator -	_____
RCMP/Police -	_____

BC hydro