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-13 Inventory of Mosquito Populations in the Revelstoke Area**

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-13
Inventory of Mosquito Populations in the Revelstoke Area

1.0 MONITORING PROGRAM RATIONALE

1.1 Background

Mosquitoes are common to the interior of BC and can cause considerable nuisance to humans and livestock. With the potential for West Nile virus (WNv) encroaching into BC, there is heightened public awareness of mosquitoes in general. There are about 50 species of mosquitoes in BC, only some of which show a preference for human blood meals and/or are potential carriers of West Nile virus[1]. The species of mosquito in BC that might be carriers of the virus have yet to be determined, although *Culex tarsalis* and *C. pipiens* are major vectors elsewhere in Canada. The role of potential bridge vectors (epizootic) such as *Aedes vexans* in the spread of the virus is uncertain but not believed to be significant in other Canadian provinces such as Ontario (Dr. Fiona Hunter, Brock University, pers. comm.)

A number of factors may influence mosquito production in any given area. Results of a recent mosquito study on the Duncan River system, for example, link snowmelt timing and natural runoff, water temperature, air temperature, rainfall, dam operations causing flooding at key times in susceptible habitats, and the presence of natural predators (Acroloxus Wetlands Consultancy 2002). Although most nuisance floodwater species pass through only one generation per year, eggs laid in previous years can remain dormant for many years until suitable conditions for hatching become available. The eggs of some species, such as *Aedes vexans*, may not hatch out simultaneously on the first flood and some will require two or three floods to be triggered into hatching. A recent study also suggests that drought years can often eliminate many natural mosquito predators and competitors, particularly in semi-permanent habitats, such as ephemeral pools (Acroloxus 2002). Because predators are often slow to re-establish whereas mosquitoes are rapid colonizers, larval mosquito populations are able to thrive in years subsequent to droughts until the predators return.

The Columbia Shuswap Regional District (CSRD) has identified in excess of 150 potential mosquito production sites around Revelstoke, with many additional potential hotspots in residential areas (birdbaths, tires, etc). In 2003, local residents complained that the level of nuisance from mosquitoes was high, particularly from June through August. The greatest nuisance appears to have come from small, highly aggressive mosquito species, most likely of the *Aedes* variety, but conditions caused by the extremely hot and dry summer might also have favored other species such as *Culex*, *Culiseta* and *Anopheles* in some locations. Although it was not possible to conclusively determine the factors contributing to high mosquito production in that year, it was speculated that this may have been due to ineffectiveness of the larvicide application, climatic variables and operation of Revelstoke Dam and Arrow Lakes Reservoir. It was noted that water levels in Arrow

[1] In 2003, the Interior Health Authority initiated a corvid (crow and raven) and mosquito surveillance program to test for West Nile virus (WNv) within their jurisdiction (Revelstoke/Electoral Area B Mosquito Control Program handout). Although the virus has yet to be detected in BC, it was detected in Alberta and Washington in 2005 and surveillance for the virus in BC continues.

Lakes Reservoir were kept artificially high during August to provide sufficient water to help with firefighting efforts near Burton. At high reservoir levels, water may have backed up in low-lying areas, such as the area surrounding the airport, and become trapped in depressions in vegetated areas as the reservoir levels receded (Serge Zoritch, BC Hydro, pers. comm.). Since 2003, mosquito abatement contractors have reported a high level of success in reducing mosquito nuisance during the spring and summer months in the Revelstoke area (Regan and Associates 2004, 2005).

Prior to impoundment of Arrow Lakes Reservoir, the area south of Revelstoke contained frequently inundated shallow sloughs during the mosquito breeding season. While it is suspected that operation of Revelstoke and Mica dams has reduced seasonal flooding of such habitats during freshet, Keenleyside Dam likely causes backwatering of portions of this area each year. Furthermore, fall rye planting of littoral areas of Arrow Lakes Reservoir is undertaken each April to prevent severe dust storms in Revelstoke and other areas are being actively re-vegetated. As reservoir water elevations recede, water pockets may form in these planted areas and in other vegetated spots, providing the potential for additional mosquito breeding habitat.

To date, little scientific data have been collected on mosquito populations in the Revelstoke area and it remains unclear how BC Hydro operations influence mosquito production. The Water Use Plan Consultative Committee (WUP CC) recommended that further studies be undertaken to gain a better understanding of the species, life history and habitat requirements of mosquito species occupying habitats in the Revelstoke area, to determine any effect that dam discharge and reservoir management may have on mosquito levels in the area. The WUP CC recommended research studies specifically to address uncertainties related to:

- The species of mosquito that inhabit the Revelstoke town site, and which species are likely to be a nuisance to humans/livestock;
- Habitat and vegetation types occupied by mosquitoes in relation to the zone of influence of BC Hydro operations;
- Areas that constitute prime mosquito breeding grounds;
- Critical discharges and durations of flooding at which mosquito hatching occurs;
- Other environmental and biotic factors affecting egg hatching and larval survival (e.g., seasonal temperatures, precipitation, predators); and,
- Effects of vegetation management within the drawdown zone on mosquito production (species and abundance).

Given the interrelation of the proposed studies, they were combined into one study to ensure integration of study results and will be carried out in 2009. Because of the imminent threat of West Nile virus (WNv) arriving in BC, the WUP CC also recommended that the study scope include assessment of the risk of potential mosquito vectors in the Revelstoke area.

1.2 Management Questions

This study is designed to address the following management questions as they pertain to mosquito production in the Revelstoke area:

1) Does operation of Revelstoke Dam and Arrow Lakes Reservoir influence mosquito production through flooding/reflooding of habitats within the drawdown zone?

2) Are there opportunities to minimize nuisance and potential WNv vector mosquito populations through modifying operations of Revelstoke Dam or Arrow Lakes Reservoir?
3) Are there areas where revegetation (CLBWORKS-2) or wildlife physical work (CLBWORK 29/30) of the drawdown zone would exacerbate mosquito production?

1.3 Key Water Use Decision Affected

The key operating decision affected by this study is whether altering discharges from Revelstoke Dam and/or modifying the timing of rise and fall of Arrow Lakes Reservoir during the spring and summer months would minimize re-wetting previously flooded areas and alleviate hatching of mosquito larvae in the Revelstoke area. Results of this program are also expected to assist in prioritization of areas within the drawdown zone where revegetation efforts will be undertaken through the Arrow Lakes Reservoir Revegetation Program (CLBWORKS-2) and Wildlife Physical Works (CLBWORKS-30).

2.0 MONITORING PROGRAM PROPOSAL

2.1 Objective and Scope

The key objective of this study is to determine whether there are water management strategies and operating alternatives that could be implemented to minimize potential impacts on mosquito production in the Revelstoke area.

Study Area

The study area will include selected locations of the drawdown zone of Arrow Lakes Reservoir and surrounding low bench and littoral areas in and around the town of Revelstoke. Study sites within the drawdown zone will be confined to those with a flooding regime that allows shallow pool formation for a period of 7 to 10 days, such as in the Revelstoke Reach area. Sites will be identified by using classification of vegetation types as an indicator of distribution of different species of mosquito. Wetland vegetation classifications closely match flooding regimes, shade provision and water temperature, all of which are significant factors in the choice of egg-laying locations by the females of different mosquito species. An aerial photographic survey of the Revelstoke and Arrow Lakes area will be conducted as part of the Arrow Lake Vegetation Inventory Program (refer to CLMON-33). To avoid duplication, orthophoto analyses and a preliminary vegetation classification from this aerial survey will be used for the purpose of the mosquito inventory site selection. The wetland classification types in question are relatively easily defined and expected to be extensive enough that locating suitable sites will be relatively straightforward. Existing Digital Elevation Model (DEM) data of the Revelstoke area can also be used to help delineate these areas. Mosquito inventory sites selected through this preliminary process will be ground-truthed and then verified as the vegetation mapping progresses. The full extent of breeding grounds of different mosquito species in different vegetation types can be assessed from the vegetation classification maps once they are completed.

Study Duration and Timing of Surveys

This study will be carried out in a single year (2009). Field surveys will be carried out monthly from May through September, or at times to be specified that coincide with extreme water level changes between June and September. Each survey will be conducted over several days. Operations staff will be requested to provide advanced warning of upcoming events to ensure that the surveys are undertaken at key times when extensive flooding of low lying areas is most likely to occur.

2.2 Approach

The general approach of this study will be to collect data on mosquito populations in the Revelstoke townsite area to resolve current gaps in the understanding of how dam and reservoir operations affect the distribution, abundance and productivity of these mosquito populations. This will be accomplished by:

1) Studying the most recent orthophotographs, existing vegetation mapping and DEM elevation data of the Revelstoke Reach area to establish broad vegetation classifications that relate to different flooding regimes. Establishing locations of mosquito study sites according to vegetation classification.
2) Conducting surveys of low bench and littoral areas in the Revelstoke area to determine the extent and production of mosquito breeding grounds (where females lay eggs, larvae and pupae develop and adults emerge), particularly those of *Aedes vexans* and *A. sticticus* and potential high competence WNv vectors. Monitor water levels and temperatures at survey sites.
3) Conducting surveys of larval and adult mosquito populations to determine species composition in the Revelstoke area and the level of nuisance at different times of year.
4) Correlating changes in water levels at sampling sites with dam discharges and reservoir level variations throughout the monitoring program.
5) Plotting the distribution of breeding grounds of different mosquito species in the Revelstoke floodplain in relation to natural vegetation classifications and ‘planted’ areas.
6) Compiling historical climate data to determine the effects of dam discharges and natural runoff on nuisance mosquito production at various reservoir levels and climatic conditions.
7) Identifying the locations of potential WNv vectorspots and, in consultation with CSRD and Interior Health Authority, prepare an integrated pest management plan to address potential WNv risk. This latter task will only be considered if high competency WNv vectors such as *Culex tarsalis* and *C. pipiens* are found during the surveys.

2.3 Methods

2.3.1 Task 1: Project Coordination

A project coordinator will be responsible for overseeing the program, including all administration of field staff, data collation, mapping, scheduling of site visits, data analysis and compilation of project reports.

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 BCH procedures and guidelines. Specific safety training may be required.

2.3.2 Task 2: Field Surveys

a) Site Selection

Site selection will be undertaken prior to field work commencing. Sites will be selected on the basis of wetland types with characteristic flooding regimes and plant assemblages, as set out in standard wetland classification texts and from studies in other areas such as the Lower Duncan floodplain (Acroloxus Wetlands Consultancy 2002). Site selection will use existing data from closely related studies, including the study of Potential Areas for Vegetation Establishment in the Arrow Lakes Reservoir (Moody 2005), and Columbia-Shuswap Regional District Mosquito Control Program Summary Reports (2001-2005), as well as existing digital elevation model (DEM) and satellite imagery of Revelstoke Reach. It will also use aerial survey data obtained from the Arrow Lakes Vegetation Inventory Program.

b) Low Bench Surveys

The low bench surveys will be undertaken on the ground by a team of freshwater entomologists with extensive experience of mosquito ecology, monitoring and surveillance, in particular of known vectors of West Nile virus. The team will also include an experienced wetland botanist and field personnel familiar with the use of GPS technology and mosquito sampling protocols. The data will be collated into a GIS database.

Larval Mosquito Sampling Techniques

Sampling sites will be chosen within each wetland type to allow a statistically robust analysis of the results. Larval sampling will be initiated once the floodplain is inundated by spring freshet (varies from year to year), and will continue once per month for four months.

Larval and pupal mosquitoes will be sampled at each surface water site with a standard 500 ml long handled dip sampler (Service 1976), following the standard larval sampling procedure described in the Municipal Mosquito Control Guidelines (Ellis 2004).

Data recorded on GPS handheld units at each surface water site will include habitat type, temperature, water level, water clarity, presence of fish and vegetation cover. All pupae and instars of larval mosquitoes collected will be saved. Specimens will be counted and categorized as either ‘early’ (1st or 2nd) or ‘late’ (3rd or 4th) instars. Late instars will be preserved (Belton 1983).

Where large numbers of larvae are found, sub-samples may be taken and earlier instars will be kept in large containers and reared to later instars that can be subsequently identified. Pupae will be similarly kept in containers and reared to adults. Wherever possible, larvae will be identified to species or at least to genus.

Adult Mosquito Sampling Techniques

Adult mosquitoes will be sampled using one of three methods: light traps, gravid traps or emergent traps. Choice of trap will depend on a number of factors, including site characteristics, accessibility, cost, staffing and availability of materials. Traps will be placed at sampling locations determined by field investigations and specific factors related to the nature of the breeding grounds and the behaviour of particular mosquito species. Adult trapping should begin from late May to early June and

continue at monthly intervals or at specific times and places, as required throughout the season, at least until September to monitor high competence WNv species. Different species of mosquitoes have different life cycle patterns; for example, most *Aedes* species overwinter as eggs and have single generations, whereas *Culex* species overwinter as adults and go through many generations each year. Adult sampling techniques and timing will depend on the species that are found in the study area, and will be prescribed accordingly once the earlier phases of the program are complete.

It is anticipated that the following procedures will be followed::

Light Traps: CDC light traps baited with dry ice (CO2), set between 6:00 pm and 8:00 pm, and collected the next morning between 7:00 am and 9:00 am.

Gravid Traps: CDC Gravid traps will be set using hay infusions prepared 7 days in advance, set between 6:00 pm and 8:00 pm and collected the next morning between 8:00 am and 10:00 am.

Emergence Traps: Emergence traps set for periods of between 1 and 2 weeks, depending on the availability of field crews to check the catches.

In all cases, adults will be frozen after collection and identified to species and sex. It is customary to set more than one style of trap at each sampling location and to use pairs of traps at each site.

Water levels will be monitored at each site throughout the study. Temperature loggers will also be installed at one or two locations within each group of sampling sites of each vegetation type.

c) Adult Mosquito Survey of the Revelstoke Townsite Area

As adult nuisance mosquitoes are known to fly up to 15 km from their breeding grounds after emergence, surveys will be carried in and around the town of Revelstoke to measure the abundance of adult mosquitoes dispersing to residential areas. The timing of this survey will be coordinated in tandem with the Low Bench survey. Methods similar to those used to monitor adult mosquitoes in the drawdown zone (Task 2) will ensure data compatibility (see Task 5 below).

2.3.3 Task 3: Integrated Mosquito Management for WNv

Larvae of the *Culex* mosquitoes are most likely to be vectors of WNv and are commonly prevalent in man-made environments. The virus is maintained in bird reservoirs and mosquitoes that bite both birds and humans are required for transmission. Certain people are more prone to contracting the disease, such as elderly people with compromised immune systems. The virus is most commonly detected in humans late in the mosquito season, as adult *Culex* mosquitoes seek indoor overwintering sites between August and October.

An integrated mosquito management strategy is required for evaluating the risk posed to visitors and local residents of Revelstoke, and addressing areas of greatest West Nile virus concern. Breeding or development sites will be rated according to perceived levels of risk so that appropriate control measures can be applied with minimal damage to the environment. Development of such a management plan will require:

- Evaluation – identification of vectorspots (breeding grounds for known West Nile virus vector mosquito species using data collected from Task 2); and
- Strategic Planning – detailed surveillance and assessment of health risks at vectorspots and formulation of an Integrated Mosquito Management Plan.

Accurate mapping of WNv vector mosquito breeding habitats enables a targeted control program that fully addresses public concerns. The information collected should be designed to form a baseline dataset for future monitoring studies.

BC Hydro will work cooperatively with the CSRD and Interior Health Authority to develop a strategy and an adaptive management plan to monitor the success of control measures in areas where BC Hydro operations have been found to contribute to mosquito breeding and to the potential spread of WNv. If no significant populations of potential WNv vectors are found, this component of the study may not be considered necessary.

2.3.4 Task 4: Information gathering

a) Compilation of Historical Climate Data and Evidence of Mosquito Nuisance

Historical climate data will be collated from BC Hydro, Environment Canada and other available local sources such as the Revelstoke Airport. Information will be collected from nuisance abatement records from 2001, and local operations staff and others will be consulted for anecdotal evidence of 'good' and 'bad' mosquito nuisance year.

b) Arrow Lakes Reservoir Level and Revelstoke Dam Discharge

Data on reservoir water level, river flow, and dam discharge will be obtained from BC Hydro Operations staff to calculate mean levels and flows for different time periods, as required.

2.3.5 Task 5: Mapping the Distribution of Breeding Grounds of Different Mosquito Species

Based on the results of the mosquito surveys (Tasks 2), the projected distributions of different mosquito species will be mapped according to vegetation types in which they were found. GIS-based maps showing the distribution of mosquito breeding grounds will be developed using the inventory generated through the Arrow Lakes Vegetation Inventory Program.

2.3.6 Task 6: Data Analysis

Information on mosquito distribution and abundance will provide a baseline for future monitoring by establishing standard methodology for site selection, sampling protocols, and identification and calculation of relative abundance of different mosquito species.

At a minimum, the results will include:

1) A spatial analysis of mosquito breeding sites showing larval and adult densities of different species of mosquito in different wetland types at different stages of the breeding season.

2) For each wetland type, mean larval and adult numbers per sample for different mosquito species will be presented by season. The null hypothesis

that there is no difference in species composition and abundance between the different vegetation types will be tested.

3) Daily mean water temperatures based on hourly measurements for each vegetation type, with water depth, larval and adult species composition and abundance for each location.

4) A risk analysis of potential threat posed by the arrival of West Nile virus if suitable WNv vectors are identified in the study area (Revelstoke and the drawdown zone). This analysis will identify priority locations or vectorspots where pre-emptive controls may be required. An integrated mosquito management plan will be developed that considers short- and long-term options for mitigating threats from vectorspots through the most cost-effective and least environmentally harmful approach.

5) High and low 'mosquito nuisance years' will be related to daily or weekly reservoir levels, dam discharges, water flows, precipitation, snow melt and air temperature.

6) Maps will be produced showing the extent of potential breeding grounds (where females lay eggs, larvae and pupae develop and adults emerge) for each of the species in relation to wetland vegetation types and flooding regimes.

2.3.7 Task 7: Reporting

A final report will be prepared that will describe the methods employed, present a detailed analysis of the results, and provide a thorough discussion of the results with recommendations.

At a minimum the final report will:

i. Describe the factors affecting mosquito distribution and production in the Revelstoke Area
ii. Identify where high nuisance areas and population sources exist
iii. Assess the impacts of management activities such as physical work (CLBWORK-29/30), revegetation (CLBWORKS-2), fertilization, and control of water levels and flows on mosquito production,
iv. Provide recommendations on how reservoir operations could be adjusted to reduce potential mosquito nuisance, if warranted
v. Suggest remedial management strategies to reduce potential high-risk vectors of West Nile virus, if warranted.

Reports will follow the standard format developed for WUP monitoring programs. All reports will be provided in hard-copy and as Microsoft Word and Adobe Acrobat (pdf) format. All map data, including meta data, will also be provided electronically in ARC GIS compatible format. Observations of rare species will be reported to the BC Conservation Data Centre following the appropriate data submission format (See: http://www.elp.gov.bc.ca/rib/wis/cdc/).

Reports will include:

i. An Executive Summary;
ii. A Description of the Methods
iii. Results;
iv. Discussion with Recommendations:

v. A digital appendix with:
   - MS Excel spreadsheet of UTM coordinates for survey sites.
   - A database in MS Excel or MS Access of all data collected

2.4 Schedule

This study will be conducted in 2009. A schedule of task is presented in Table CLBMON-13-1.

Table CLBMON-13-1. Schedule of tasks for Monitoring of Mosquito Populations in the Revelstoke Area

Tasks	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
1) Project Coordination	√	√	√	√	√	√	√	√	√
2a) Site Selection	√	√							
2b) Low Bench Surveys			√	√	√	√			
2c) Revelstoke Surveys			√	√	√	√			
3) Wnx Management							√	√	√
4a) Climate and Mosquito data	√	√							
4b) Discharge and Reservoir levels							√	√	
5 &6) Mapping and Data Analysis							√	√	
7) Reporting								√	√

2.5 Budget

The total cost of the study is estimated at $80,656 (including 2% inflation). This cost is higher than the total cost estimated by the WUP CC for the three studies ($55,000 in 2004 dollars). Table CLBMON-13-2 provides a detailed budget breakdown by task and year (assuming a 2% rate of inflation and a 5% contingency) over the duration of the project.

3.0 REFERENCES

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