Columbia River Project Water Use Plan
Kinbasket and Arrow Lakes Reservoir Revegetation Management Plan

Implementation Year 3

Reference: CLBMON-11B4

Monitoring Wetland and Riparian Habitat in Revelstoke Reach in Response t
Wildlife Physical Works

Study Period: 2012

Okanagan Nations Alliance, Westbank, BC
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Sidney, BC

March 2, 2013

EA3413

BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

CLBMON-11B4 Monitoring Wetland and Riparian Habitat in Revelstoke Reach in Response to Wildlife Physical Works




Annual Report - 2012

Prepared for

BC Hydro Generation
Water Licence Requirements
6911 Southpoint Drive
Burnaby, BC

BC Hydro Contract No. EC10-393872

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March 2, 2013

Suggested Citation:

Miller, M.T. and V.C. Hawkes. 2013. CLBMON-11B4 Monitoring Wetland and Riparian Habitat in Revelstoke Reach in Response to Wildlife Physical Works. Annual Report – 2012. LGL Report EA3413. Unpublished report by Okanagan Nation Alliance and LGL Limited environmental research associates, Sidney, BC, for BC Hydro Generation, Water Licence Requirements, Burnaby, BC. 52 pp.

Cover photos

From left to right: Cartier Bay, water-milfoil (*Myriophyllum* sp.) in Cartier Bay, Four-spotted Skimmer (*Libellula quadrimaculata*), Airport Marsh. Photos © Virgil C. Hawkes 2010.

EXECUTIVE SUMMARY

CLBMON-11B4 (*Monitoring Wetland and Riparian Habitat in Revelstoke Reach in Response to Wildlife Physical Works*) was commissioned by BC Hydro in 2010 under the Columbia Water Use Plan. The mandate of this 10 year project is to assess the effectiveness of wildlife physical works projects (CLBWORKS-30) at enhancing wetland and wildlife habitat in Revelstoke Reach, part of Arrow Lakes Reservoir in southern British Columbia. Here, we report results at the three-year mark of pre-implementation monitoring for the three wetland complexes within Revelstoke Reach being considered for physical works projects: Cartier Bay, Airport Marsh, and Montana Slough. In addition, this report provides a preliminary description of the wetland vegetation and macroinvertebrate communities at two new proposed study sites in Lower Arrow Lakes Reservoir: the Beaton Arm beaver ponds and Lower Inonoaklin Road.

Wetland vegetation and macroinvertebrates were sampled twice each year at Revelstoke Reach: once as the reservoir was rising in early summer (May/June) and again following reservoir inundation in late summer (August). Point data were collected on macrophyte frequency (calculated as the number of sample points in which a species occurred divided by the total number of sample points), abundance (measured for each species as volume x cover or VC), and biomass (dry weight of plant material collected per rake grab).

Macrophyte species exhibiting statistically significant inter-annual fluctuations included Small Pondweed (*Potamogeton pusillus)*, Floating-leaved Pondweed (*Potamogeton pusillus*) and Eurasian Water-milfoil (*Myriophyllum spicatum*). The frequency of Small Pondweed increased in Cartier Bay between 2011 and 2012, while the frequency of Floating-leaved Pondweed increased at Airport Marsh over the same time period. Local abundance (VC) varied significantly between the two years for both Eurasian Water-milfoil and Small Pondweed. Most of the significant inter-year variation was between the early season (June) rather than the late season (August) surveys. The methodology allowed us to detect differences ≥100 per cent over a one-year period at $\alpha = 0.05$ in the case of frequency and biomass, and differences >200 per cent for the abundance (VC) metric. Thus, an increase in sampling intensity and/or additional stratification may be needed to evaluate some of the performance measures at $\alpha = 0.05$. More time and data are needed to determine if the current methodology is sufficient to detect a change of 25 per cent at $\alpha = 0.20$ over 10 years, the proposed standard for statistical power on which the performance measures are based.

The two richest sites for macroinvertebrates were Airport Marsh and Beaton Arm, while the poorest site was Lower Inonoaklin Road. Species richness and diversity tended to decrease between June and August, particularly for those sites inundated by Arrow Lakes Reservoir (i.e., all sites except for the upper beaver ponds at Beaton Arm). Ephemeroptera (Mayflies), and Odonata (Dragonflies and Damselflies) appear to be suitable indicators of habitat change or productivity based on (1) their relative ease of identification; and (2) their propensity to spend several years as aquatic insects (Ephemeroptera), necessitating stable and suitable conditions to persist.

The following recommendations are made based on the 2012 study findings:

1. Continue to sample macrophytes and macroinvertebrates in 2013. However, rather than two annual samples, a single sample to characterize the aquatic flora

and fauna should suffice. We recommend that a single sampling session in late May or early June, prior to inundation, be conducted in 2013.

2. Continue to collect point samples of abiotic variables (water depth, temperature, pH, dissolved oxygen, etc.). We have deferred our investigation into the influence of abiotic variables on macrophyte and macroinvertebrate community composition and structure until the next implementation year, when the available data set will be larger and more amenable to principal coordinate analysis (PCA), multiple regression, and other statistical approaches.
3. For 2013 we recommend that sampling continue at Airport Marsh, Montana Slough, Cartier Bay, and Lower Inonoaklin Road. Beaton Arm should be dropped from the study because physical works are not proposed for this site.

The status of CLBMON-11B4 after Year 3 (2012) with respect to the management questions and management hypotheses is summarized in tabular form (below)

Management Question (MQ)	Management Hypotheses		Year 3 (2012) Status
i. Are the wildlife physical works projects effective at enhancing wildlife habitat in the drawdown zone?	HA2	HA2A	Wildlife physical works projects are still pending for wetlands in Revelstoke Reach. In each of 2010, 2011, and 2012, pre-impact, baseline data were collected on macrophyte and macroinvertebrate communities at Airport Marsh, Cartier Bay, and Montana Slough. Metrics of species abundance (frequency, cover, biomass) and distribution (diversity, evenness) have been computed. Baseline data were also collected on water depth, turbidity, temperature, and physicochemistry. Improvements with aerial photographs continue to lead to refinements in wetland community mapping. The management question will begin to be addressed in full once the physical works have been completed and post-impact effects can be assessed. The data being collected will permit testing of the management hypotheses.
ii. To what extent do the wildlife physical works projects increase the productivity of habitat in the drawdown zone for wildlife?	HA2D	HA3B	As above.
iii. Are some methods or techniques more effective than others at enhancing wildlife habitat in the drawdown zone?	HA3	HA3B	As above.

HA2A: Wildlife physical works projects do not change the area (m2) or increase the suitability of wildlife habitat in the drawdown zone.

HA2A: Wildlife physical works do not change wildlife use of the drawdown zone.

HA2D: Wildlife physical works projects do not change the abundance (e.g., biomass) and species diversity in the drawdown zone of invertebrates, which are prey for amphibians and reptiles, birds, and mammals.

HA3: The methods and techniques employed do not result in changes to wildlife habitats in the Arrow Lakes Reservoir drawdown zone.

HA3B: The methods used for wildlife physical works do not result in changes to wildlife habitat in the Arrow Lakes Reservoir drawdown zone as measured by indices of habitat suitability, site productivity (e.g., arthropod biomass), and forage production.

KEYWORDS: Arrow Lakes Reservoir, wildlife physical works, monitoring, drawdown zone, operating regime, wildlife, macrophyte, macroinvertebrate

ACKNOWLEDGEMENTS

The authors express their appreciation to the following individuals for their assistance in coordinating and conducting this study: Natasha Audy, Alexis Friesen, and James Pepper of the Okanagan Nation Alliance, Doug Adama, Jeremy Gatten, Krysia Tuttle, Janean Sharkey, and Robin Tamasi of LGL Limited, and Margo Dennis and Guy Martel with BC Hydro.

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1.0 INTRODUCTION

The Columbia River Water Use Plan (WUP) was developed as a result of a multi-stakeholder consultative process to determine how to best operate BC Hydro's Mica, Revelstoke and Keenleyside facilities to balance environmental values, recreation, power generation, cultural/heritage values, navigation and flood control. The WUP process followed the guidelines established by the Government of British Columbia (Government of British Columbia 1998; BC Hydro 2000) and involved a number of interest groups, First Nations, government agencies and other stakeholders, collectively referred to as the Consultative Committee (CC). Initiated in 2000, the WUP was completed in 2004 (BC Hydro 2005) and was approved by the Comptroller of Water Rights in January 2007 (Comptroller of Water Rights 2007).

During the WUP planning process, a number of reservoir operating alternatives were explored to balance environmental and social values in the Columbia system. While several of these alternatives included changes to the operating regime of the Arrow Lakes Reservoir (specifically maintaining lower, more stable reservoir levels during the spring, summer and fall), the CC recognized that physical works in lieu of operational changes may be a more cost-effective means of achieving environmental and social benefits given the value of the lost power generation associated with these alternatives. Consequently, the CC supported the implementation of physical works (revegetation and habitat enhancement) in the mid-Columbia River rather than changes to reservoir operations to help mitigate the impact of Arrow Lakes Reservoir operations on wildlife and wildlife habitat.

Coupled with habitat enhancements, the CC also recommended monitoring to assess the effectiveness of these physical works at enhancing habitat for wildlife. In particular, nest mortality and impacts to bird populations, along with impacts to reptile and amphibian species and their habitats, were identified as important wildlife concerns in Revelstoke Reach. As a result, 42 potential wildlife physical works projects were identified by the WUP wildlife technical subcommittee (BC Hydro 2005), and the feasibility of completing these wildlife physical works projects in the drawdown zone of Revelstoke Reach was investigated by Golder Associates (2009). Out of this assessment, five potential projects were prioritized and identified for development based on their engineering feasibility and ecological merit. Site plans for these five projects were developed (Golder Associates 2009), and incorporated environmental, engineering and archaeological considerations; three of these will be undertaken by BC Hydro over the period 2013-2019. This includes physical works at Cartier Bay and, potentially, Montana Slough that would increase shallow water habitat in the drawdown zone, as well as a third project at Airport Marsh which is designed to ensure that the wetland retains its current water levels.

Several of the wildlife physical works are intended to increase shallow wetland habitat. As such, there is an expectation that wetland productivity will increase in these areas over time. Nevertheless, multiple years of monitoring (both pre and post-impact) are needed to test the hypothesis that wetland productivity increases in response to physical works.

Several physical parameters and biological response variables may be considered when evaluating wetland productivity, including: (1) changes in the aquatic macrophyte community, (2) changes in aquatic plant biomass and volume, (3) changes in the areal extent of the target habitat type (i.e., shallow wetland habitat), (4) changes in the aquatic invertebrate assemblage associated with each shallow wetland, and (5) changes in the physical parameters (e.g., water depth, spatial extent, water temperature and chemistry) of affected wetlands. To properly assess the efficacy of a given wildlife physical works at enhancing wetland productivity, data related to these physical parameters and biological response variables should be collected before and after the implementation of the proposed physical works.

Here, we report results at the three-year mark of pre-implementation monitoring for the three wetland complexes within Revelstoke Reach being considered for physical works projects: Cartier Bay, Airport Marsh, and Montana Slough. During Year 1 (2010), a wetland monitoring protocol was developed and a pilot study conducted to evaluate the study design and sampling methodology. Reconnaissance-level sampling of biotic and abiotic conditions at each wetland was also undertaken (Hawkes et al. 2011).

Collection of baseline ecological and physical data continued in Year 2 (2011), enabling a description of the diversity and relative abundance/density of aquatic and emergent (and some terrestrial) plant communities at each of the three study sites, as well as the associated pelagic and benthic invertebrate communities (Fenneman and Hawkes 2012).

In Year 3 (2012), we continued the pre-implementation monitoring program for study sites in Revelstoke Reach, while expanding the scope of the study to include reconnaissance-level sampling of two additional, potential enhancement sites in mid and lower Arrow Lakes Reservoir: Beaton Arm Beaver Ponds and Lower Inonoaklin Road.

1.1 Rationale

The primary objective of CLBMON-11B4 is to use aquatic macrophytes and aquatic invertebrates as indicators of the effectiveness of physical works projects in restoring wetland areas in the drawdown zone of Revelstoke Reach and thus improving their suitability for wildlife. Data collection of physical parameters and biological response variables will help determine if the physical works implemented in Revelstoke Reach are successful at achieving the goals and objectives of the physical works, which have been established by the WUPCC and are intended to address concerns related to the impacts to bird, reptile, and amphibian habitats. As the physical works projects are completed, it is anticipated that ecological systems within the created or restored wetland habitats will change. These changes may be positive, in which the ecological function trends towards an established and healthy natural ecosystem, or they may be negative and trend towards a more disturbed environment with low diversity of native species, high abundance of exotic species, or other undesirable factors. The 2010, 2011, and 2012 surveys provide valuable baseline information on conditions at each of the proposed sites prior to the completion of any of the physical works projects, against which future conditions can be compared. Additionally, the 2012 surveys allowed for ongoing evaluation of the study design and sampling methodologies that had been described in 2010 (see Hawkes et al. 2011) to test their efficacy in detecting community-level changes in select biotic and abiotic variables.

2.0 MANAGEMENT QUESTIONS AND HYPOTHESES

2.1 Monitoring Program Objectives

The overall objectives of this study are to:

1. monitor the appropriate physical parameters and biological response variables to assess the effectiveness of the wildlife physical works programs at enhancing wildlife habitat in Revelstoke Reach;
2. assess the effectiveness of wildlife physical works projects at enhancing wetland and associated riparian habitat at both the site and landscape level; and
3. provide recommendations based on the results of the monitoring program to improve wetland enhancement techniques.

2.2 Management Questions

This monitoring program is designed to assess the effectiveness of revegetation programs and wildlife physical works at enhancing wildlife habitat in the drawdown zone of Arrow Lakes Reservoir. The monitoring program will assess the response of several wildlife taxa and habitat elements to wildlife habitat enhancements. The primary management questions to be addressed by the monitoring program are:

1. Are the wildlife physical works projects effective at enhancing wildlife habitat in the drawdown zone?

If so,

2. To what extent do the wildlife physical works projects increase the productivity of habitat in the drawdown zone for wildlife?
3. Are some methods or techniques more effective than others at enhancing wildlife habitat in the drawdown zone?

2.3 Management Hypotheses

The hypotheses to be tested under the proposed monitoring program relate to the effectiveness of the revegetation program and wildlife physical works projects at improving wildlife habitat within the reservoir drawdown zone. Specifically, these hypotheses test the quality and quantity of aquatic vegetation and aquatic macroinvertebrates that become established within the habitats created through the physical works projects. These parameters can then be used to assess the quality of the habitat for other wildlife.

The management hypotheses of CLBMON-11B that specifically relate to this project (CLBMON-11B4) are as follows:

HA$_{2:}$ Wildlife physical works do not change wildlife use of the drawdown zone.

HA$_{2A}$: Wildlife physical works projects do not change the area (m^2) or increase the suitability of wildlife habitat in the drawdown zone.

HA$_{2D}$: Wildlife physical works projects do not change the abundance (e.g., biomass) and species diversity in the drawdown zone of invertebrates, which are prey for amphibians and reptiles, birds, and mammals.

HA$_{3}$: The methods and techniques employed do not result in changes to wildlife habitats in the Arrow Lakes Reservoir drawdown zone.

HA$_{3B}$: The methods used for wildlife physical works do not result in changes to wildlife habitat in the Arrow Lakes Reservoir drawdown zone as measured by indices of habitat suitability, site productivity (e.g., arthropod biomass), and forage production.

2.4 Objectives and Performance Measures for Revelstoke Reach

The feasibility study for the physical works projects (Golder Associates 2009) identified the overall vegetation-specific objectives for the three sites (see Section 3.5 for a more detailed discussion of these sites):

1. For Site 6A (Airport Slough Outflow) and the adjacent Airport Marsh, the objective is to maintain the existing community. Thus, no significant changes in species diversity, distribution, or relative abundance should be detected over the 10 years of the monitoring program.
2. For Site 14 (Cartier Area), the objective is the eventual establishment of an ecological community similar to that growing in Cartier Bay within the current area of inundation. Existing conditions in Cartier Bay can thus act as a target condition for the newly inundated areas.
3. For Site 15A (Cartier Bay), the objective is to expand the existing wetland community by increasing the amount of flooded area (Golder Associates 2009) and subsequently establishing a community that is similar to that which currently exists in Cartier Bay.

A fourth site, Site 13 (Montana Slough), is also under consideration for habitat enhancement projects (Golder Associates 2009). No physical works are proposed for Montana Slough at this time. However, because this wetland provides important habitat for many types of wildlife, including turtles and waterfowl, the site will be monitored along with the other sites to obtain baseline data should physical works be implemented in the future. Use of this site as a control for other sites is not desirable given the unique physiochemical and biological conditions that are present at the site and which are very different from those present at the other monitoring sites.

2.4.1 Airport Slough Outflow (Site 6A) performance measures

The following performance measures for Airport Slough Outflow will be assessed solely with reference to possible impacts accruing from channel erosion. Where required for hypothesis testing, the accepted standard for statistical power will be 0.80 or greater.

1. No measurable change greater than 25 per cent from baseline conditions in the areal extent (hectares or square metres) of shallow wetland habitat over 10 years.

2. No change > 25 per cent in overall habitat conditions as measured by indicator habitat elements (e.g., water depth, pH, and turbidity) over 10 years.
3. No change > 25 per cent in cover, biomass, and diversity of aquatic macrophyte species over 10 years.
4. No change > 25 per cent in biomass and diversity of macroinvertebrates over 10 years.
5. No further erosion of Airport Marsh outflow following the completion of the physical works, and no indication that such erosion should be expected in the future. This is based on an assessment of the structural integrity of the physical works during the final year of monitoring to ensure that they are sound.

2.4.2 Cartier Bay (Sites 14 and 15A) performance measures

The following performance measures for Cartier Bay (Sites 14 and 15A) will be assessed with reference to effects accruing from the physical works. Where required for hypothesis testing, the accepted standard for statistical power will be 0.80 or greater.

1. Site 14: creation of at least 1 ha of new wetland habitat within one year following the implementation of the physical works.
2. Site 15A: measurable increase of at least 10 per cent in areal extent (hectares or square metres) of existing shallow wetland habitat within one year following the implementation of the physical works.
3. Measurable increase in wetland productivity:
    a. Successful natural establishment of native macrophytes into newly created wetlands within ten years. “Successful establishment” is here defined as continuous species presence for at least five years.
    b. Increases of at least 25 per cent from baseline conditions in cover and diversity (species richness and evenness) of native macrophytes within 10 years. This includes species that occur in the wetlands and those that become successfully established.
    c. Successful natural establishment of native macroinvertebrates into newly created wetlands within ten years. “Successful establishment” is here defined as continuous species presence for at least five years.
    d. Measurable increases of at least 25 per cent from baseline conditions in biomass and diversity (species richness and evenness) of native macroinvertebrates within ten years. This includes species that occur in the wetlands and those that become successfully established.
4. No measurable increases greater than 25 per cent from baseline conditions in cover and diversity (species richness and evenness) of key undesirable macrophyte species over 10 years. Undesirable macrophytes include any introduced species, particularly those that are considered invasive. In the case of Revelstoke Reach, this term refers primarily to Eurasian Water-milfoil

(*Myriophyllum spicatum*), which is the dominant invasive plant of aquatic habitats within the drawdown zone.

5. No measurable increases greater than 25 per cent from baseline conditions in biomass and diversity (species richness and evenness) of key undesirable macroinvertebrate species over 10 years.
6. No erosion or other structural failure of the dikes following the completion of the physical works, and no indication that such events should be expected in the future. This is based on an assessment of the structural integrity of the physical works during the final year of monitoring to ensure that they are sound.

2.5 Key Water Use Decision

Results from this study will aid in more informed decision-making with respect to the need to balance the requirements of wildlife species dependent on wetland and riparian habitats with other values such as recreational opportunities, flood control and power generation. The key water use planning decision affected by the results of this monitoring program is whether revegetation and wildlife physical works are effective at enhancing wildlife habitat in lieu of operational changes to reservoir operations. Results from this study will also assist in refining the approaches and methods for enhancing wildlife habitat through adaptive management.

2.6 Program Linkages

CLBMON-11B4 is directly and indirectly linked to other programs being implemented in the Arrow Lakes Reservoir (Figure 2-1). The monitoring program developed for CLBMON-11B1 will provide an indication of the efficacy of the physical works implemented in Revelstoke Reach at enhancing wildlife habitat. In addition, data collected as part of that monitoring program are related to several long-term monitoring programs—specifically, CLBMON-37, -40 and -36. Although the protocol for monitoring physical works implemented in Revelstoke Reach is being developed, it could be applied to physical works proposed for mid- and lower Arrow Lakes where wetland enhancement or creation is the objective (i.e., CLBWORKS-29B).

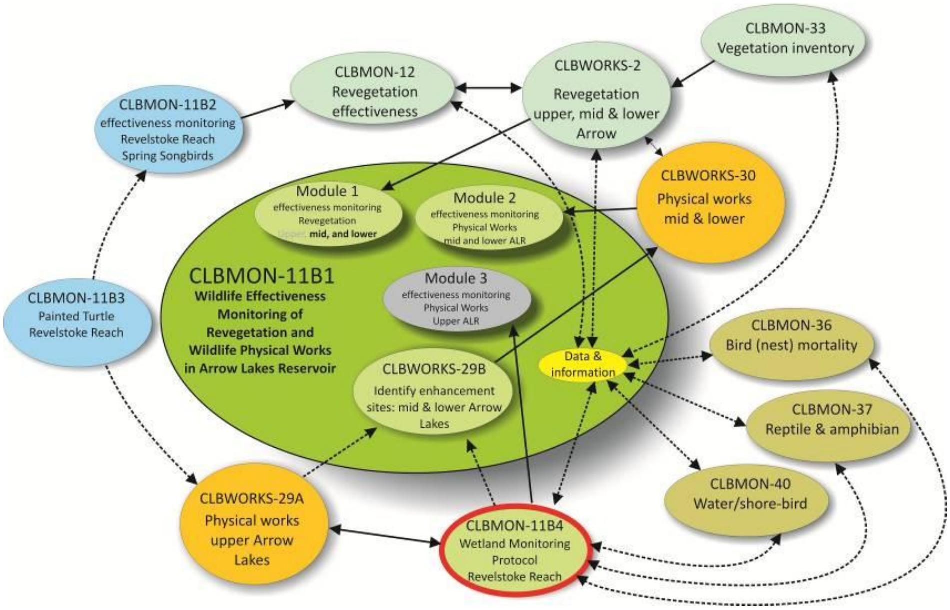

Figure 2-1: **The relationship of CLBMON-11B4 (outlined in red) to other physical works and wildlife monitoring projects in Arrow Lakes Reservoir.** Direct linkages between relevant projects are shown as solid lines; information flow (e.g., data sharing) is indicated by dashed lines. Module 3 of CLBMON-11B1 has yet to be implemented, and Module 1 of CLBMON-11B1 applies only to mid- and lower Arrow Lakes Reservoir

3.0 STUDY AREA

3.1 Physiography

The Columbia Basin in southeastern British Columbia is bordered by the Rocky, Selkirk, Columbia and Monashee mountains. The headwaters of the Columbia River are at Columbia Lake in the Rocky Mountain Trench, and the river flows northwest along the trench for ~250 km before emptying into Kinbasket Reservoir behind Mica Dam (BC Hydro 2007). From Mica Dam, the river continues southward for about 130 km to Revelstoke Dam. The river then flows almost immediately into Arrow Lakes Reservoir behind Hugh Keenleyside Dam. The entire drainage area upstream of Hugh Keenleyside Dam is approximately 36,500 km2. The Columbia Basin is characterized by steep valley side slopes and short tributary streams that flow into Columbia River from all directions.

The Columbia River valley floor elevation extends from approximately 800 m near Columbia Lake to 420 m near Castlegar. Approximately 40 per cent of the drainage area within the Columbia River Basin is above 2000 m elevation. Permanent snowfields and glaciers are widespread in the northern high mountain areas above 2500 m elevation, and about 10 per cent of the Columbia River drainage area above Mica Dam exceeds this elevation.

3.2 Climate

Precipitation in the Columbia Basin occurs from the flow of moist low pressure weather systems that move eastward through the region from the Pacific Ocean. More than two-thirds of the precipitation in the basin falls as winter snow. The persistence of below freezing temperatures, in combination with abundant precipitation, results in substantial snow accumulations at middle and upper elevations in the watersheds. Summer snowmelt is reinforced by rain from frontal storm systems and local convective storms.

Air temperatures across the basin tend to be more uniform than precipitation. With allowances for temperature lapse rates, station temperature records from the valley can be used to estimate temperatures at higher elevations. The summer climate is usually warm and dry, with the average daily maximum temperature for June and July ranging from 20° to 32°C. The average daily minimum temperature ranges from 7° to 10°C. The coldest month is January, when the average daily maximum temperature in the valleys is near 0°C and average daily minimum is near -5°C.

During the spring and summer months, the major source of water in the Columbia River is water stored in large snowpacks that developed during the previous winter months. Snowpacks often continue to accumulate above 2000 m elevation through May, and continue to contribute runoff long after the snowpack has become depleted at lower elevations. Runoff begins to increase in April or May and usually peaks in June to early July, when approximately 45 per cent of the runoff occurs. Severe summer rainstorms are not unusual in the Columbia Basin. Summer rainfall contributions to runoff generally occur as short-term peaks superimposed on high river levels caused by snowmelt. These rainstorms may contribute to annual flood peaks under the current Columbia River Treaty operations. The mean annual local inflows for the Mica, Revelstoke and Hugh Keenleyside projects are 577 m^3/s, 236 m^3/s, and 355 m^3/s, respectively.

3.3 Biogeoclimatic Zones

Two biogeoclimatic zones occur at the lower elevations surrounding Arrow Lakes Reservoir: the Interior Cedar Hemlock (ICH) and the Interior Douglas-fir (IDF). Most of the reservoir area occurs within the ICH, with three subzones and four variants represented (Table 3-1). The IDF is restricted to the southernmost portion of the area and consists of a single subzone (IDFun); this area is outside of the study area of this project. The subzones are a reflection of increasing precipitation from the dry southern slope of Deer Park to the wet forests near Revelstoke (Enns et al. 2008). The Arrow Lakes Reservoir study is situated primarily within the Arrow Boundary Forest District, but a small portion of its northerly area is in the Columbia Forest District.

Table 3-1: Biogeoclimatic zones, subzones and variants that occur in the Arrow Lakes Reservoir study area

Zone Code	Zone Name	Subzone/Variant Description	Forest Region & District
ICHdw1	Interior Cedar – Hemlock	West Kootenay Dry Warm	Nelson Forest Region (Arrow Forest District)
ICHmw2	Interior Cedar – Hemlock	Columbia-Shuswap Moist Warm	Nelson Forest Region (Columbia Forest District)
ICHmw3	Interior Cedar – Hemlock	Thompson Moist Warm	Nelson Forest Region (Columbia Forest District)
ICHwk1	Interior Cedar – Hemlock	Wells Gray Wet Cool	Nelson Forest Region (Arrow Forest District)
IDFun	Interior Douglas-fir	Undefined	Nelson Forest Region (Arrow Forest District)

Most of the Columbia Basin watershed remains in its original forested state. Dense forest vegetation thins above 1500 m elevation and tree line occurs at ~2,000 m elevation. The forested lands around Arrow Lakes Reservoir have been and continue to be logged, with active logging (2007/2008) occurring on both the east and west sides of the reservoir.

3.4 Arrow Lakes Reservoir

Arrow Lakes Reservoir is a ~230 km long section of the Columbia River drainage between Revelstoke and Castlegar, B.C. It has a north-south orientation and is set in the valley between the Monashee Mountains to the west and the Selkirk Range to the east. The Hugh Keenleyside Dam, located 8 km west of Castlegar, spans the Columbia River and impounds Arrow Lakes Reservoir. Arrow Lakes Reservoir has a licensed storage volume of 7.1 million acre-feet (MAF) (BC Hydro 2007), and the normal operating range of the reservoir is between 440.1 m and 418.64 m ASL.

The study area for CLBMON-11B4 is restricted to Revelstoke Reach at the north end of Arrow Lakes Reservoir (Figure 3-1), from Airport Marsh southeast to Cartier Bay, with all work focused on the east side of the reach. The area hosts several large wetland complexes, large open sedge/grass habitats and several willow-shrub complexes. The combination of elevation, limited topographical relief, and undulating terrain has contributed to the development of important bird, reptile and amphibian habitats within the seasonally inundated drawdown zone of Arrow Lakes Reservoir.

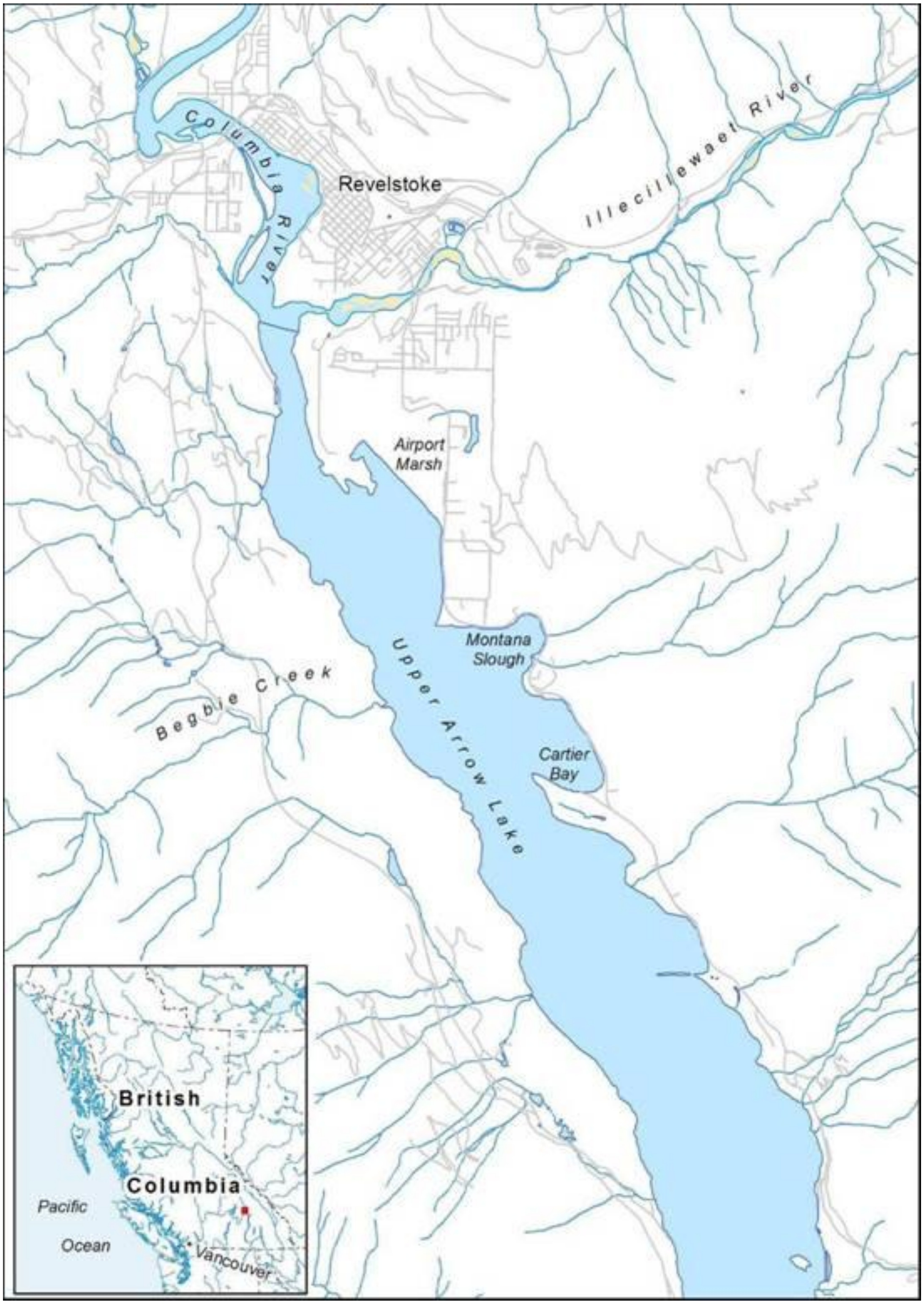

Figure 3-1: Location of Airport Marsh, Montana Slough and Cartier Bay in Revelstoke Reach, Arrow Lakes Reservoir

3.5 Proposed Physical Works – Project Descriptions

The following project descriptions were extracted from Golder Associates (2009). Because physical works are proposed for most of these sites (with the exception of Montana Slough), it is important to obtain baseline data against which further data can be compared. This will ensure the proper implementation of a BACI[1]-style study design and that any comparisons made between data sets are valid.

3.5.1 Site 14: Cartier Bay

Site 14 is located 8 km south of Revelstoke on the east side of the reservoir and immediately north of Cartier Bay. It is approximately 1.3 km south of Site 13 and 300 m north of Site 15A. At Site 14, there is a deep gap in the rail grade that allows for uninhibited drainage of water when the floodplain is not inundated by the reservoir. The proposed project design for Site 14 is a dike with swale to close the gap in the rail grade to retain water and flood low lying ground upstream of the proposed dike. Ancillary habitat works include the placement of coarse woody debris/large woody debris within flooded shallow basins.

3.5.2 Site 15A: Cartier Bay

Site 15A in Cartier Bay consists of an existing pond/wetland complex that historically may have been an oxbow of the Columbia River. The wetland consists of two compartments separated by a gap in an old road bed that bisects a large 24.3 ha pond. The outflow of this pond/wetland complex is through a gap in the rail grade where a collapsed wooden box culvert exists. The persistence of water in this pond/wetland complex is a result of the plugged box culvert creating a rudimentary dike. The proposed design for this project is to replace the ad hoc dike and box culvert with an engineered dike to prevent potential further compression and/or failure of the existing structure, which could be catastrophic to existing habitat values. We also propose to increase the invert elevation of the swale of the constructed dike by 1 m to increase water storage in Cartier Bay and increase the extent of shallow open water habitat behind the new dike. Ancillary habitat work includes placement of loafing logs for turtles and large woody debris/coarse woody debris along the southern shoreline, as well as nest boxes in trees on adjacent high ground for cavity nesting waterfowl.

3.5.3 Site 6A: Airport Slough outflow

Site 6A is a small erosion channel immediately northwest of Machete Island (at the western end of Airport Marsh). The channel begins at the northwest edge of Machete Island and runs northeast towards the old Arrowhead Highway Road bed before splitting into an east and west arm. The west arm is eroding into the surrounding floodplain, whereas the east arm is eroding towards the old Arrowhead Highway Road bed. Site 6A is on BC Hydro land but must be accessed via a road that follows the Illecillewaet River, and includes gated access through a privately operated gravel pit. The physical works proposed for Site 6A include the reinforcing of the erosion channel to ensure that it does not continue to erode and, eventually, fail. In such a scenario, Airport Marsh would

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[1] BACI: Before-After Control-Impact

be expected to drain almost completely of water, severely impacting the wetland community that is established there.

Although the proposed physical works will not alter the existing conditions at Airport Marsh, monitoring of this site is necessary. This is largely due to the importance of the marsh locally for Painted Turtles (Chrysemys picta), many species of waterfowl, and wetland-associated songbirds. Monitoring across time will determine whether the integrity of the marsh is unaffected by the proposed physical works. Furthermore, as the best-established wetland community of all of the study sites, Airport Marsh represents the "Control" wetland for the CLBMON-11B4 study (see Section 4.1, below).

3.5.4 Montana Slough

No physical works are proposed for Montana Slough at this time. However, because Montana Slough provides important habitat for many species, including Painted Turtles (see Hawkes and Tuttle 2010) and waterfowl, it is necessary to obtain baseline data in the event that physical works are planned and subsequently implemented.

4.0 METHODS

Hawkes et al. (2011) provide a detailed discussion of the rationale for this project, as well as a summary of reconnaissance-level sampling that was conducted during 2010. The results from the 2010 sampling season helped develop the methodology that was applied in both 2011 and 2012.

4.1 Study Design

The study design for CLBMON-11B4 follows a modified BACI-style design (Before-After Control-Impact), the aim of which is to evaluate whether or not a stress has changed the environment, to determine which components are adversely affected, and to estimate the magnitude of the effects (Hawkes et al. 2011). In the case of CLBMON-11B4, the "stress" that is being investigated is the effects of the physical works projects on wetland habitats in the drawdown zone of Revelstoke Reach, whether they be designed to retain water at its existing level in the wetlands of interest or rather to flood new areas and create additional wetland habitat that did not exist prior to the physical works (Hawkes et al. 2011). Because the physical works projects affect the entire study area, the study lacks a statistical control in the traditional sense; instead, we must rely on adjacent wetlands to serve as ecological reference sites (hence "modified" BACI design).

The study uses ecological data on aquatic macrophytes, aquatic invertebrates, and wetland physicochemistry collected before the implementation of the physical works projects (the "Before" component) and uses this information as a baseline against which to compare the conditions of these same parameters in the years following completion of the physical works projects (the "After" component). Airport Marsh, which is situated high in the drawdown zone, receives relatively minimal annual inundation from the reservoir, and has a much more complex and well-developed wetland community, will serve as a reference wetland against which to compare the ecological conditions that are detected at the "impact" wetlands (Cartier Bay, Montana Slough). Wetlands that occur above the drawdown zone, and are thus not impacted by reservoir activities at any time of year, are considered less desirable to use as reference sites as the conditions that exist at these sites could never be replicated within the drawdown zone.

Sampling in 2012, which represented the third year of the "Before" component of the study, was completed during two separate field sessions: early June and late August. This schedule was implemented for two reasons. First, sampling pre- and post-inundation enabled a time-sensitive comparison of the methodology's ability to detect changes occurring at different times during the growing season. Second, sampling early and late in the growing season presumably allows for the detection of a higher diversity of species due to differing species phenologies (i.e., some species are more easily detectable early in the season but not later, and vice versa).

4.2 Selection of Sampling Sites

Site selection was based on the sites identified for physical works by Golder Associates (2009) and the potential to use sites like Airport Marsh as a reference site. All monitoring locations were in Revelstoke Reach; two were in the drawdown zone of Arrow Lakes Reservoir. Hawkes et al. (2011) recommended that each site be stratified based on broad categories of habitat (e.g., emergent vegetation, open water, submergent vegetation), and that a power analysis be used to determine the minimum number of samples required to achieve statistical power of 0.80 assuming a measureable effect size of 0.25 (i.e., 25 per cent change in shallow wetland area or a 25 per cent change in the indices being measures). Using these criteria, we determined that 30 sampling locations should be sampled in Cartier Bay, 20 in Montana Slough, and 40 in Airport Marsh. Site selection was random and accomplished by overlaying a 25 m X 25 m grid on each study site, identifying which cells were completely within the confines of each wetland, and randomly selecting 30, 20, or 40 sites. All grid work and site selection was done using ArcMap 9.3.1 and 10. This process was repeated for all three study sites, and a list of UTM coordinates representing the centre of each randomly selected grid cell was generated. An example of this process is provided in Figure 4-1.

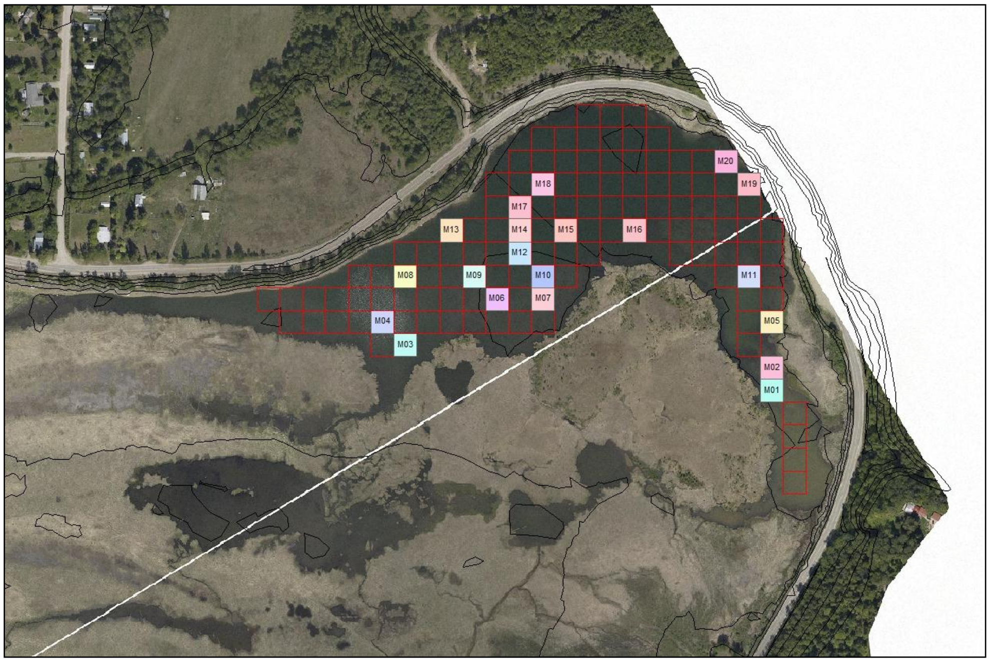

Figure 4-1: **Example of the site selection process used for Montana Slough.** Grid cells entirely within Montana Slough are shown in red. Coloured cells with alphanumeric labels indicate cells that were randomly selected through GIS

4.3 Aquatic Macrophyte Sampling

Submergent vegetation was sampled using a double-headed rake, as detailed in Alberta Environment (2006), G3 Consulting Ltd. (2010) and Hawkes et al. (2011). Sampling effort was standardized at each location by dropping the rake to the bottom of the water column and dragging it approximately 1 m. A cluster sampling approach was used in which two samples were taken at each location. See Hawkes et al. (2011) for a justification of the use of cluster sampling in this study. Once collected, the volume of the entire sample was estimated (Table 4-1), as was the relative cover of each macrophyte species in the sample (Table 4-2).

Floating vegetation was sampled using a buoyant 1 m x 1 m quadrat frame constructed from PVC pipe (Figure 4-2). Using this frame, one short (2 m x 1 m) belt transect was placed on each side of the boat (total 4 m x 1 m). The per cent cover of the water surface occupied by each floating species was recorded for each of the four quadrats. For analysis, the per cent cover value of each species was averaged among the four quadrats.

Figure 4-2: **Buoyant, 1 m x 1 m PVC quadrat frame used for sampling floating aquatic vegetation**

In addition to determining the relative abundance of plant species at the study sites, the vegetation samples that were collected within the submergent and floating communities were retained for biomass calculations. Biomass samples (which constituted the entire vegetation sample at a given sampling location) were collected at the first sample point at each site, and at every second sampling point thereafter. The samples were stored in Ziploc bags in the field, and the bags were labelled with the date of collection, study site and sampling point. The samples were shipped to the laboratory, where they were weighed ("wet weight") and then dried in an oven until all moisture had been removed and the sample mass remained constant ("dry weight").

Table 4-1: **Volume classes for vegetation samples**

Volume Class	Sample Volume	Definition
1	Trace	Sample is restricted to one or very few strands of vegetation
2	Small	Sample fills less than half of the tines of the sampling rake
3	Large	Sample fills half or more of the tines of the sampling rake

Table 4-2: **Cover classes for vegetation samples**

Cover Class	Definition
T	Species is present but contributes negligibly (< 1 per cent) to the sample volume
1	Species contributes less than 10 per cent of the sample volume
2	Species contributes 11–20 per cent of the sample volume
3	Species contributes 21–50 per cent of the sample volume
4	Species contributes 51–75 per cent of the sample volume
5	Species contributes 76–100 per cent of the sample volume

4.4 Emergent and Terrestrial Vegetation Sampling

Emergent and terrestrial plant communities within or adjacent to the physical works sites were sampled using a belt transect approach. Each belt transect consisted of four contiguous 1 m x 1 m (1 m^2) quadrats (Figure 4-3). When sampling was done from a boat, the belt transect was divided into two shorter transects each consisting of two 1 m^2 quadrats, with one transect placed on each side of the boat (as for floating macrophyte beds, above). The per cent cover of each vascular plant was recorded within each of the four quadrats at each sampling location. For analysis, the per cent cover value of each species was averaged among the four quadrats.

4.5 Aquatic Invertebrate Sampling

Two different collection methods were used to sample invertebrates at the three sampling sites: epipelagic sampling using a dip net, and benthic sampling using a hand-held Ponar grab (2.4 L). By using these methods, the two primary species groups (epipelagic, benthic) were sampled. Hawkes et al. (2011) provide a more detailed discussion of these and other sampling techniques that were considered for this project.

For epipelagic species of invertebrates, two sweeps of 1 m were completed (one on each side of the boat) at a depth of 20–30 cm using a fine-meshed, 17 cm x 25 cm aquarium dip net. These samples were then transferred to a WhirlPac with ethanol (70 per cent concentration) for preservation. For benthic species, the Ponar grab (Figure 4-4) was lowered to the sediment using a rope and then was tripped, thereby capturing a ~2.4 L sample of the upper layers of sediment. Note that, under certain conditions, such as on harder substrates, the grab was unable to sample the full 2.4 L; however, because the 2011 sampling for assessing presence/absence of various invertebrate taxa in the benthic samples rather than actual abundance (see below), recording the volume of each entire sample was not necessary. Once removed from the water, the sediment sample was strained using a fine-meshed (0.4 mm) dip net as a sieve. A 500 ml subsample was then collected and transferred to a WhirlPac® sample bag with an ethanol preservative. Both the epipelagic and benthic samples were stored in refrigerated conditions until they could be analyzed following completion of the field sessions.

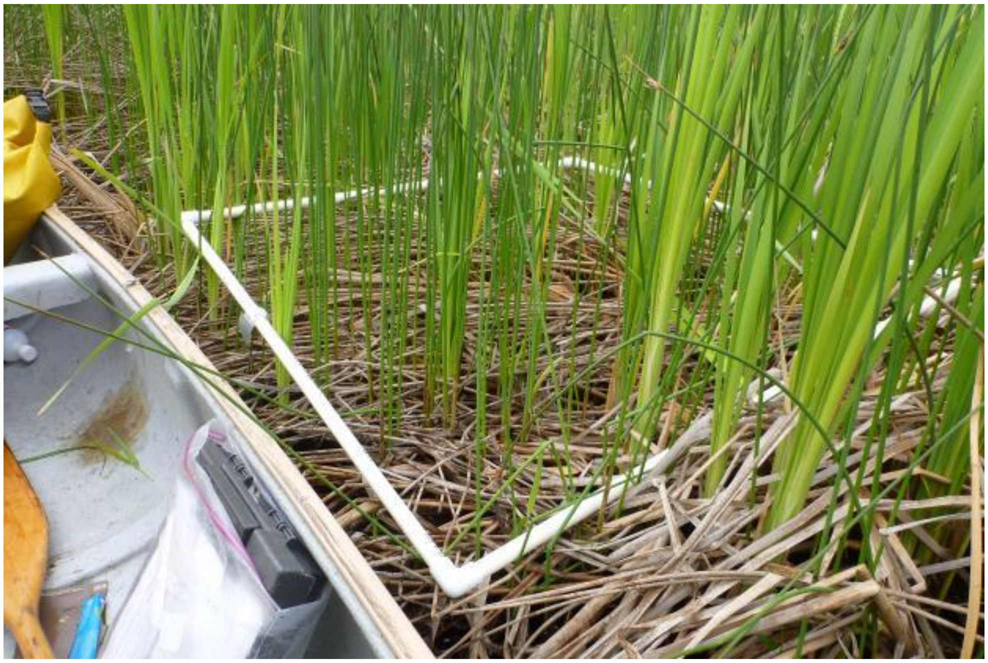

Figure 4-3: **1 x 1 m quadrat frame used to sample emergent wetland vegetation**

4.5.1 Aquatic Macroinvertebrate Laboratory Methods

All samples were kept cold and sorted as shortly after collection as possible to reduce the chance of specimen deterioration. The samples were removed from the Whirl-Pac® sample bags and strained through a piece of fine 400 μm mesh to remove preservatives and debris. Debris (e.g., sticks, leaves, vegetation) and mesh were thoroughly washed with water and inspected under a VanGuard Model 1200-ZDPC-2 dissecting microscope for remaining invertebrates. A standardized portion of each sample was placed in a Petri dish under the microscope and individuals were counted as they were removed. In some instances the number of invertebrates was estimated due to large numbers in the sample. Damaged individuals were counted only if identification to taxonomic group was certain. To avoid double counting, only individuals with heads attached were included in the tally unless the taxon was unique to the sample. The entire sample of each Whirl-Pac® sample bag was assessed for invertebrates. The relative abundance of each taxa documented was calculated by dividing the number of taxa counted by the total samples taken from a given wetland. This returned the number of taxa per sample, which could be compared between wetlands.

Figure 4-4: **ONA researcher deploying the Ponar benthic sampler at Airport Marsh**

Invertebrates were sorted to the lowest practical taxonomic group (Order, Family) and life stage was recorded. Digital and hard copy taxonomic guides were used to sort taxa (see below).

Aquatic Invertebrates of Alberta. Hugh F. Clifford. http://sunsite.ualberta.ca/Projects/Aquatic_Invertebrates/index.php

Cavanagh, N., R.N. Nordin, L.W. Pommen, and L.G. Swain. 1998a. Guidelines for designing and implementing a water quality monitoring program in British Columbia. BC Ministry of Environment, Lands and Parks. Resources Information Benthic Invertebrate Sampling Guidelines Ministry of Environment 22 Standards Committee, Victoria BC. 80p. http://srmwww.gov.bc.ca/risc/pubs/aquatic/design/index.htm

Digital Key to Aquatic Insects of North Dakota. Valley State University Macro-Invertebrate Lab. http://www.waterbugkey.vcsu.edu/orderlist.htm

Flash Cards of Common Freshwater Invertebrates of North America. The McDonald & Woodward Publishing Company, Granville, Ohio

Key to Macroinvertebrates. Copyright © 2013 New York State Department of Environmental Conservation. http://www.dec.ny.gov/animals/35772.html

Merritt, R.W and K.W. Cummins.1996 An Introduction to the Aquatic Insects of North America.3rd ed. Kendall Hunt. Dubuque, Iowa

Picture Guide to the Common Aquatic “Bugs” of Saskatchewan. Prepared by Dale Parker, AquaTax Consulting, 2012. http://www.aquatax.ca/BugGuide.html

Benthic samples were obtained in 2012 and treated in the same manner as the pelagic samples. In most cases a standardized amount of benthos was extracted (~1 tsp) and examined for invertebrates using a microscope. If no invertebrates were observed a second, and sometimes a third sub-sample was evaluated. The majority of all samples did not have any observable macroinvertebrates. As such, only the results of associated with the pelagic data are presented.

4.6 Assessment of Abiotic Conditions

In addition to aquatic macrophyte and invertebrate samples, the abiotic conditions at each sampling location were noted:

- Water depth (cm)
- Substrate: documented using the Ponar grab, or for shallow/clear water, by visual means. Substrate type was categorized as one (or more) of the following classes: F = fines (clay/silt); S = sand; SM = small gravel; LG = large gravel; C = cobble; B = boulders; BR = bedrock; M = muck (fine organic material); CD = coarse organic detritus; W = wood
- Turbidity: the relative clarity of the water was assessed as clear or cloudy to give an indication of relative turbidity
- Dissolved oxygen (mg/L): measured using a YSI-85 meter within 30 cm of the surface
- Conductivity (µS): measured using a YSI-85 meter within 30 cm of the surface
- Water temperature (°C), within 30 cm of the surface
- pH: measured using a pH meter at the surface

4.7 Data Analyses

Macrophyte frequency (defined as the proportion of sample plots in which a species or group of species was detected) was compared across sites and time periods using 2 x 2 tables (Madsen 1999, Hawkes et al. 2011).

The analysis of aquatic macrophyte data also entailed derivation of a metric that considered both the relative cover and sample volume of each species as estimated by rake grabs at each sample point. To derive this value we multiplied the volume and the relative cover estimated for each species at each location to produce a single numeric value representing the overall abundance of the species at each sampling point. Possible volume classes ranged from 1 through 3, and possible relative abundance classes ranged from 0.1 (for trace) to 1 through 5 (Table 4-1, Table 4-2). For each sample point, the values were averaged across two rake grabs. Thus, the minimum possible volume value was 0.5 and the minimum possible relative cover value was 0.05. The minimum possible (non-zero) value for the volume x cover metric was then 0.5 x 0.05 = 0.025, and the maximum possible value for the volume x cover metric was 3 x 5 = 15.

Differences in the volume x cover metric (VC) were summarized through box plots (Massart et al. 2005). Box plots display the differences between groups of data without making any assumptions about their underlying statistical distributions and show their dispersion and skewness (Massart et al. 2005). Boxes represent between 25 per cent and 75 per cent of the ranked data. The horizontal line inside the box is the median. The length of the boxes is their interquartile range (Sokal and Rohlf 1995). A small box indicates that most data are found around the median (small dispersion of the data). The opposite is true for a long box: the data are dispersed and not concentrated around the median. Whiskers are drawn from the top of the box to the largest observation within 1.5 interquartile range of the top, and from the bottom of the box to the smallest observation within 1.5 interquantile range of the bottom of the box.

Because the VC data were highly skewed and contained many zeros, non-parametric Wilcoxon Rank Sum tests (Zar 1999) were used to test for significance in abundance differences between 2011 and 2012 (for both May/June and August sampling sessions).

Seasonal differences (spring and summer) in macroinvertebrate species richness (q), diversity (H) and evenness (J) were assessed for each wetland sampled. Species richness was defined as the number of species collected in each wetland.

Diversity was computed as Shannon's entropy and corresponded to a measure of species composition, combining both the number of species and their relative abundances (Legendre and Legendre 1998). For each transect, diversity was computed as:

$$H = -\Sigma\ (pi \log pi)$$

where pi is the relative proportion of species i.

A value of 0 means that the sampling unit contains only one species; H then increases along with the number of species recorded in the sampling unit. A high value of H means that many species were recorded. Shannon's entropy index (H) does not indicate how evenly individuals are distributed among species/taxa across the sample points.. To determine how even the community is, Pielou's evenness was computed (Pielou 1966):

$$J = H/Hmax = (-\Sigma\ (pi \log pi))/\log q$$

where q is species richness.

The more J tends towards 1, the more even the community; conversely, a value close to zero means that one or more species are dominating the community (i.e., the distribution of individuals among species is uneven).

We have deferred our investigation into the influence of abiotic variables (water depth, temperature, pH, etc.) on macrophyte and macroinvertebrate community composition and structure until the next implementation year, when the data set will be larger and more amenable to analysis.

5.0 RESULTS

Aquatic macrophytes and macroinvertebrates were sampled during June and August 2012 (June 9 to 13 and August 23 to 29). Reservoir elevations at the time of sampling ranged from 435.09 m to 435.92 m ASL in June; 436.96 m to 438.03 m ASL in August. Sampling in June occurred just as Arrow Lakes Reservoir levels were impounding the open water habitats at Montana Slough, Cartier Bay, and Lower Inonoaklin Road. The Beaton Arm beaver pond complex is situated outside of the drawdown zone.

5.1 Macrophytes

Airport Marsh, with 16 species recorded in 2011 and 12 species in 2012, supported the highest number of aquatic macrophytes of all three sites (Table 5-1). Lower Inonoaklin Road was the least diverse, with just two species observed in 2012. More aquatic macrophytes were recorded in Cartier Bay than at Montana Slough in both 2011 and 2012. Other species were present in some of these wetlands but, because of local rarity, were not captured in the random samples.

Per cent frequency, defined as the proportion of samples in which a species was encountered (Hawkes et al 2011), ranged from nil (for several species) to a high of 92 per cent (for Small Pondweed at Airport Marsh in 2012) (Table 5-1). Eurasian Water-milfoil and Common Hornwort were the most commonly observed species overall; each was recorded at all three physical works areas in every sampling session in 2011 and 2012, except for Montana Slough in late summer of 2012, when Eurasian Water-milfoil was not observed.

Table 5-1: Per cent frequency of aquatic macrophyte species detected in random samples (rake grabs) of the three physical works areas of Revelstoke Reach (Airport Marsh, Montana Slough, Cartier Bay) during the 2011 and 2012 surveys. Species presence (but not frequency) is also indicated for two other sites in Arrow Lakes Reservoir that were surveyed for the first time in 2012 (Beaton Arm Beaver Ponds and Lower Inonoaklin Road). Not all macrophytes listed are strictly aquatic as defined in Warrington (2001); for completeness, also included in this table are any emergent wetland species that were found rooted underwater at the time of sampling. These are indicated with a *. Values in the upper (bolded) cells correspond to the early summer sampling session, those in the lower cells to the late summer sampling session

Species	**Airport Marsh (Site 6A)**		**Montana Slough (Site 13)**		**Cartier Bay (Site 15A)**		**Beaton Arm Beaver Ponds**	**Lower Inonoaklin Road**
	2011	**2012**	**2011**	**2012**	**2011**	**2012**	**2012**	**2012**
Eurasian Water-milfoil (*Myriophyllum spicatum*)	**35** 35	**59** 70	**13** 38	**08** -	**68** 05	**54** 25		
Common Hornwort (*Ceratophyllum demersum*)	**15** 20	**34** 41	**13** 19	**25** 8	**74** 33	**69** 44		
Richardson's Pondweed (*Potamogeton richardsonii*)	**5** 5	**10** 22	**-** -	**-** -	**-** 14	**15** 6	√	
Small Pondweed (*Potamogeton pusillus*)	**10** 40	**28** 37	**-** 6	**-** 8	**47** 52	**92** 6	√ √	
Eel-grass Pondweed (*Potamogeton zosteriformis*)	**5** -	**3** 7	**-** -	**-** -	**16** 14	**-** 6		
Floating-leaved Pondweed (*Potamogeton natans*)	**5** 15	**38** 33	**13** 13	**17** 8	**-** -	**8** -	√ √	 √
Water Smartweed (*Persicaria amphibia*)	**45** 30	**10** 7	**-** -	**-** -	**-** -	**23** -	√ √	
Greater Bladderwort (*Utricularia macrorhiza*)	**5** 30	**14** 4	**-** -	**-** -	**-** 5	**-** -		
Bladderwort (*Utricularia*	**-**	**-**	**-**	**-**	**-**	**-**	√	

Species	Airport Marsh (Site 6A)		Montana Slough (Site 13)		Cartier Bay (Site 15A)		Beaton Arm Beaver Ponds	Lower Inonoaklin Road
	2011	**2012**	**2011**	**2012**	**2011**	**2012**	**2012**	**2012**
sp.)								
Yellow Pond-lily (*Nuphar polysepela*)	**-** -	**-** -	**-** -	**-** -	**-** -	**-** -	√ √	
Reed Canarygrass (*Phalaris arundinacea*)*	**50** 25	**21** 4	**-** -	**-** -	**-** -	**-** -	√ √	
Common Mare's-tail (*Hippuris vulgaris*)	**5** 10	**3** 4	**-** -	**-** -	**-** -	**-** -		
Common Spike-rush (*Eleocharis palustris*)*	**-** -	**3** -	**-** -	**-** -	**-** -	**-** -		
Soft-stemmed Bulrush (*Schoenoplectus tabernaemontani*)*	**-** -	**7** -	**-** -	**-** -	**-** -	**-** -		
Small-flowered Bullrush (*Scirpus microcarpus*)*	**5** 15	**3** -	**-** -	**-** -	**-** -	**-** -	√ √	
Narrow-leaved Bur-reed (*Sparganium angustifolium*)	**5** 5	**3** -	**-** -	**-** -	**-** -	**-** -		
Bur-reed (*Sparganium* sp.)	**-** -	**-** -	**-** -	**-** -	**-** -	**-** -	√	
Common Cattail (*Typha latifolia*)*	**10** 5	**7** -	**-** -	**-** -	**-** -	**-** -	√ √	
Marsh Cinquefoil (*Comarum palustre*)*	**5** -	**7** -	**-** -	**-** -	**-** -	**-** -		
Water Sedge (*Carex aquatilis*)*	**-** 15	**-** -	**-** -	**-** -	**-** -	**-** -	√	
Hemlock Water-parsnip (*Sium suave*)	**5** -	**-** -	**-** -	**-** -	**-** -	**-** -		
Tufted Loosestrife (*Lysimachia thyrsifolia*)	**5** -	**-** -	**-** -	**-** -	**-** -	**-** -		
Swamp Horsetail (*Equisetum fluviatile*)	**20** 10	**7** 4	**-** -	**-** -	**-** -	**-** -	√ √	
Marsh Horsetail (*Equisetum palustre*)	**5** -	**-** -	**-** -	**-** -	**-** -	**-** -		
European forget-me-not (*Myosotis scorpiodes*)	**-** -	**-** -	**-** -	**-** -	**-** -	**-** -		
Small-flowered Forget-me-not (*Myosotis laxa*)	**5** -	**-** -	**-** -	**-** -	**-** -	**-** -		
Moss sp.*	**10** -	**3** -	**-** -	**-** -	**8** -	**-** -		
Stonewort (*Chara* sp.)	**20** 40	**38** 41	**-** 8	**8** -	**58** 19	**54** 38	√ √	**n/a** √

5.1.1 Cartier Bay

Thirteen randomly distributed points in Cartier Bay were sampled on June 10, 2012 after the bay had already been partially inundated (Figure 5-1). A bathymetric map produced for Cartier Bay shows the distribution of shallow and deep areas (Figure 5-2). This map is based on data collected in 2011 and on preliminary bathymetric data from 2010. Water depths of the June 2012 sample points ranged from <1 m to 3.0 m. Another sixteen sampling locations were visited between Aug. 24-27 (five of the same points sampled during the June session, plus 11 additional points) when the reservoir had been fully inundated. Water depths at the August 2012 sample points ranged from 3.3 m to ~6 m.

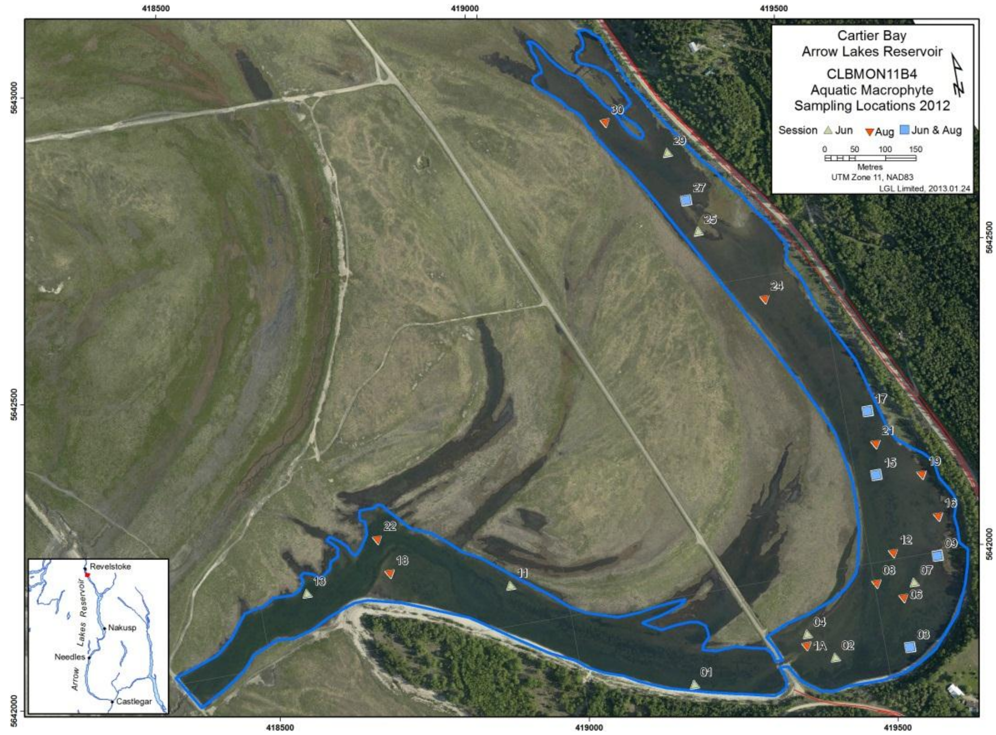

Figure 5-1: **Distribution of samples in Cartier Bay in 2012, May and August sessions.**

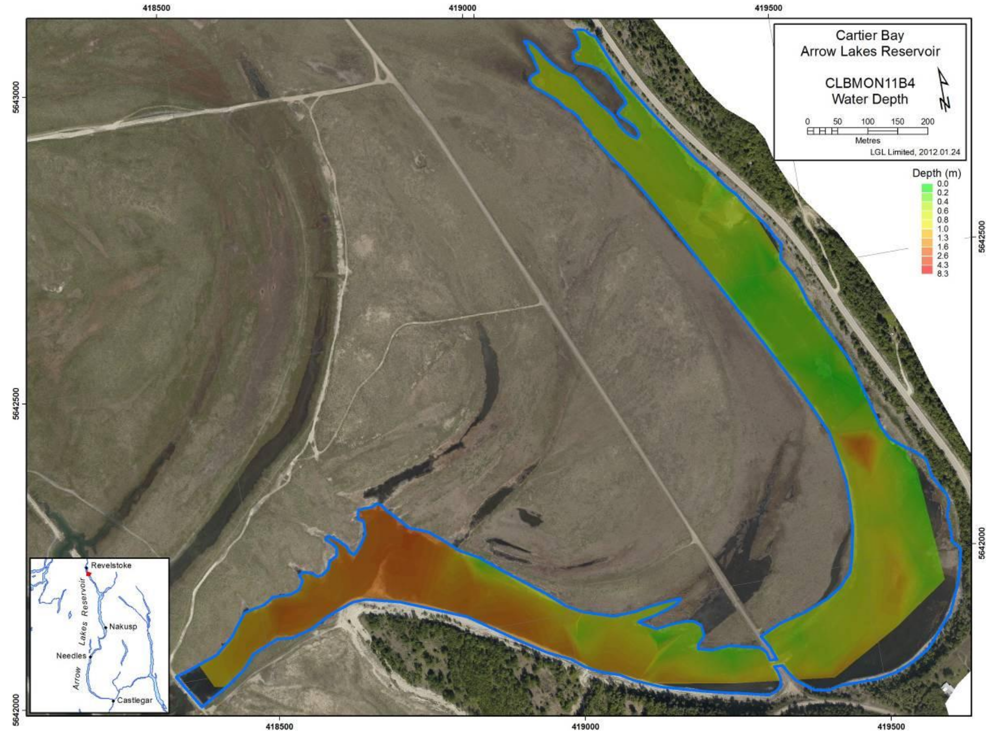

Figure 5-2: Bathymetric map of Cartier Bay, based on water depths collected in 2011 and augmented with depths collected in 2010. Only pre-inundation (May) water depths were used from the 2011 data

5.1.1.1 Macrophyte Frequency, Abundance, and Biomass

Aquatic macrophytes were detected in all points sampled in the June 2012 field session and in 75 per cent of points in the August 2012 field session, a pattern of seasonal reduction similar to that observed in 2011 (Fenneman and Hawkes 2012). However, the difference in macrophyte frequency between seasons was not statistically significant (Fisher's exact test, p = 0.107). There was also no statistical difference in overall macrophyte frequency between 2011 and 2012 (result consistent for both the early and late summer sampling periods). With respect to individual species frequencies, the only aquatic macrophyte to undergo a significant change in frequency between years was Small Pondweed (Fisher's exact test, p = 0.011). This species' occurrence increased from 47 per cent of sample points in 2011 to 92 per cent of sample points in 2012 (early season census; Table 5-1).

Local abundance of dominant species, as represented by the volume X cover (VC) metric (Section 4.7), varied from point to point in the wetland as indicated by the dispersion of data around the median VC values (Figure 5-3). For many species, the maximum VC value for a species was much greater than its median value, probably reflecting patchy local distributions (Figure 5-3). Only Small Pondweed (POTAPUS) varied significantly between years (May/June: p = 0.056; August: p = 0.001, Wilcoxon Rank Sum test).

Dry weight of biomass samples from Cartier Bay averaged 16.1 g in June 2012 (SD = 26.5, n = 12) and 5.2 g in August (SD = 9.4, n = 8). By comparison, the corresponding early and late summer dry weight averages for 2011 (Fenneman and Hawkes 2012) were 36.6 g (SD = 19.6, *n* = 6) and 3.25 g (SD = 4.8, *n* = 8), respectively. As sample sizes for biomass were small and data were non-normally distributed, a Wilcoxon Rank Sum Test was used to evaluate intra- and inter-annual differences in this variable (Zar 1999). For the two 2012 sample sessions, the seasonal difference was non-significant (*p* = 0.363). There was a significant drop in early summer biomass between 2011 and 2012 (*p* = 0.036), but no significant annual difference in late summer biomass was detected (*p* = 0.834). Early summer biomass was significantly greater at Cartier Bay than at Montana Slough (*p* = 0.014), but significantly less than at Airport Marsh (*p* = 0.025).

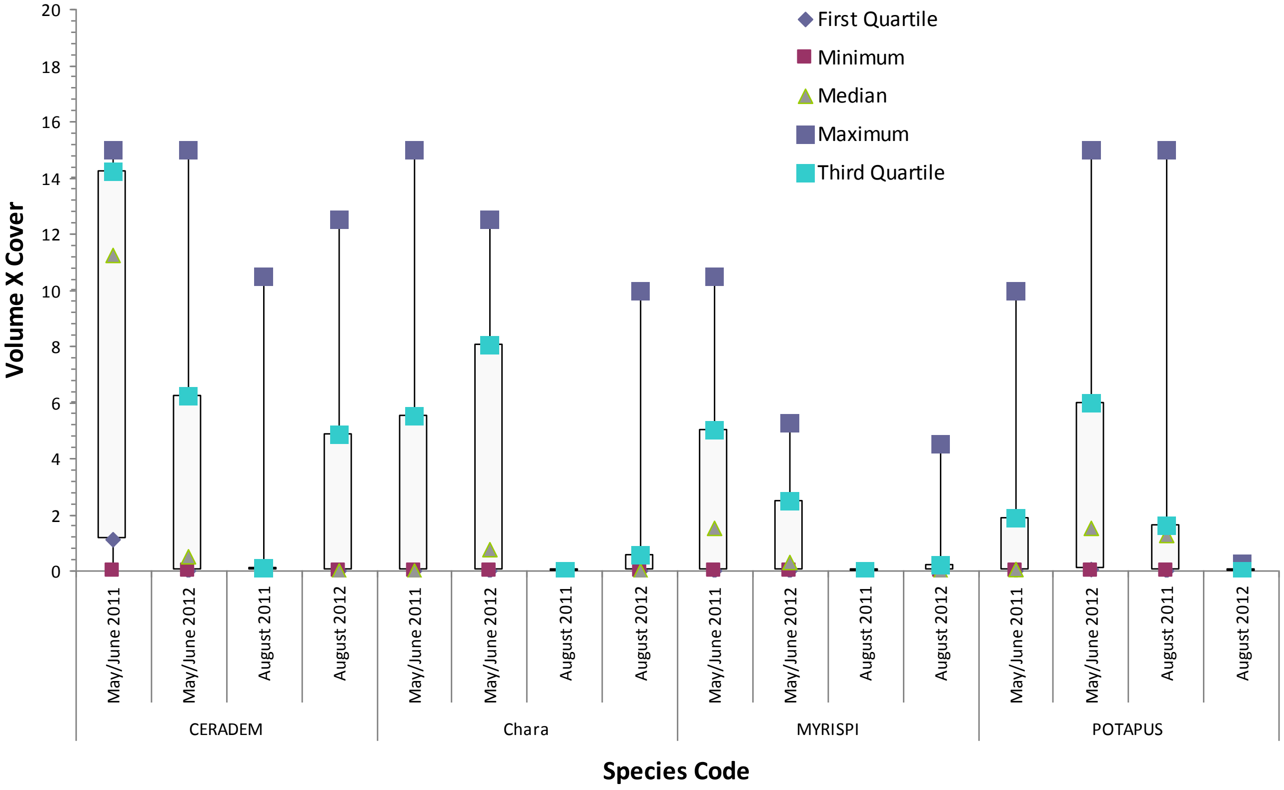

Figure 5-3: **Abundances of dominant aquatic macrophytes at Cartier Bay 2011 and 2012.** Abundances during both May/June and August sampling sessions are shown. See Section 4.7 for an explanation of the Volume x Cover metric that is used to represent abundance. See Table 5-1 for species codes

5.1.2 Montana Slough

Twelve randomly-distributed points in Montana Slough were sampled on June 9, 2012, before the bay had been inundated (Figure 5-4). A bathymetric map produced for Montana Slough shows the distribution of shallow and deep areas (Figure 5-5). Water depths at the June 2012 sample points ranged from < 1.0 m to 5.0 m. Another 12 sampling locations were visited on Aug. 27 (nine of the same points sampled during the June session, plus three additional points), when the reservoir had been fully inundated. Water depths at the August 2012 sample points ranged from 1.6 m to 9.5 m.

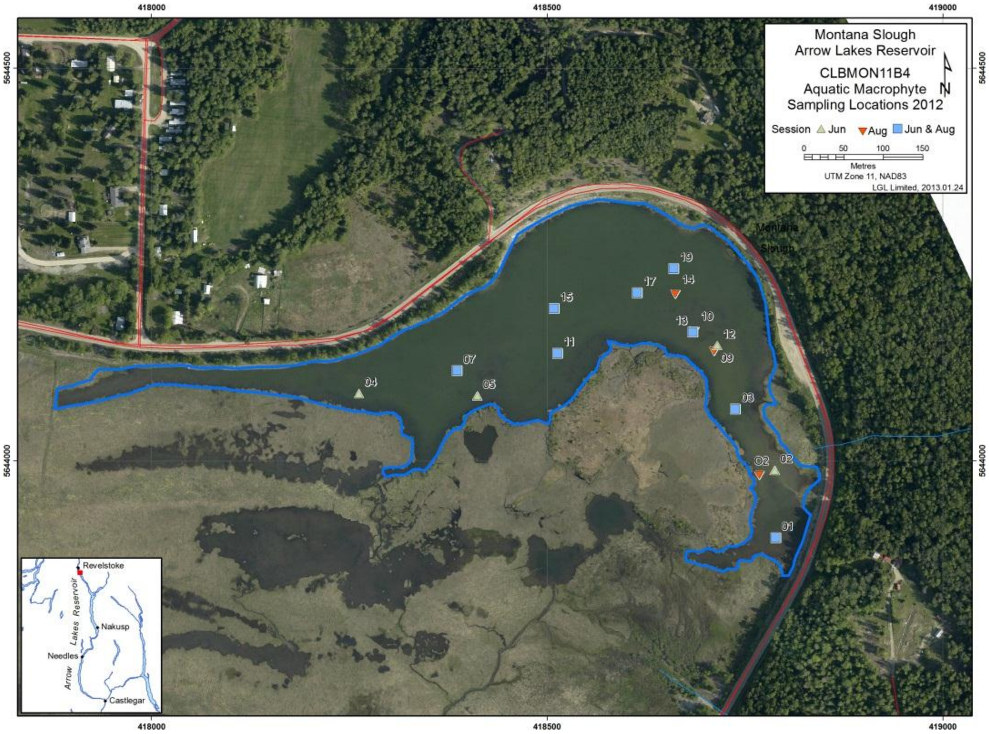

Figure 5-4: **Distribution of sampling locations at Montana Slough in 2011, including both the May and August sessions**

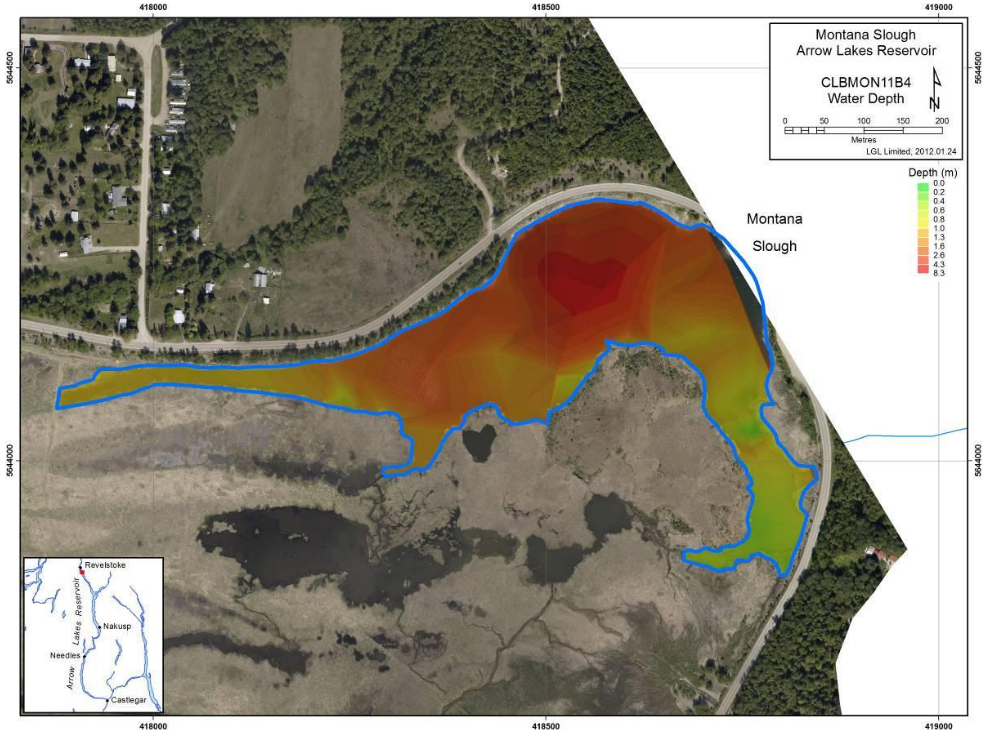

Figure 5-5: **Bathymetric map of Montana Slough, based on water depths collected in 2011 and augmented with depths collected in 2010.** Only pre-inundation (May) water depths were used from the 2011 data

5.1.2.1 Macrophyte Frequency, Abundance, and Biomass

Only five species of aquatic macrophytes were documented in Montana Slough during the 2012 sampling, and most occurred with low frequency (Table 5-1). Common Hornwort was the most common species, occurring at 25 per cent of sample points. Localized patches of Stonewort, Eurasian Water-milfoil, and Floating-leaved Pondweed occurred at depths <2.5 m. Yellow Pond-lily also occurred around the perimeter of the wetland, but no patches of this species were captured by the randomly selected sampling points. Overall, macrophytes were detected at 25 per cent of points sampled in the June 2012 field session, and in 17 per cent of the August samples; this slight seasonal difference was not statistically significant. There was also no statistical difference in overall macrophyte detection rates between 2011 and 2012 (either for early or late summer sampling periods). Individual species' frequencies also did not change significantly between years.

Local abundance of dominant species, as represented by the volume X cover (VC) metric (Section 4.7), varied from point to point as indicated by the dispersion of data around the median VC values (Figure 5-6). Abundances were generally low. For many species, the maximum VC value for a species was much greater than its median value (usually zero), probably reflecting patchy local distributions (Figure 5-6). Only Eurasian Water-milfoil (MYRISPI) varied significantly between years, and only for the August time period (Wilcoxon Rank Sum test, $p = 0.021$).

Dry weight of biomass samples from Montana Slough averaged 0.5 g in June 2012 (SD = 1.2, $n = 8$) and 5.2 g in August (SD = 12.8, $n = 6$). However, as in 2011 (Fenneman and Hawkes 2012) most samples in both periods contained no vegetation or just a trace of vegetation, and the seasonal difference was not statistically significant (Wilcoxon Rank Sum Test, $p = 0.855$). There was a significant drop in early summer biomass between 2011 and 2012 at the $\alpha = 0.1$ level ($p = 0.076$), but no significant annual difference in late summer biomass ($p = 0.402$). Early summer 2012 biomass was significantly less than at both Cartier Bay (Section 5.1.1) and Airport Marsh ($p = 0.080$).

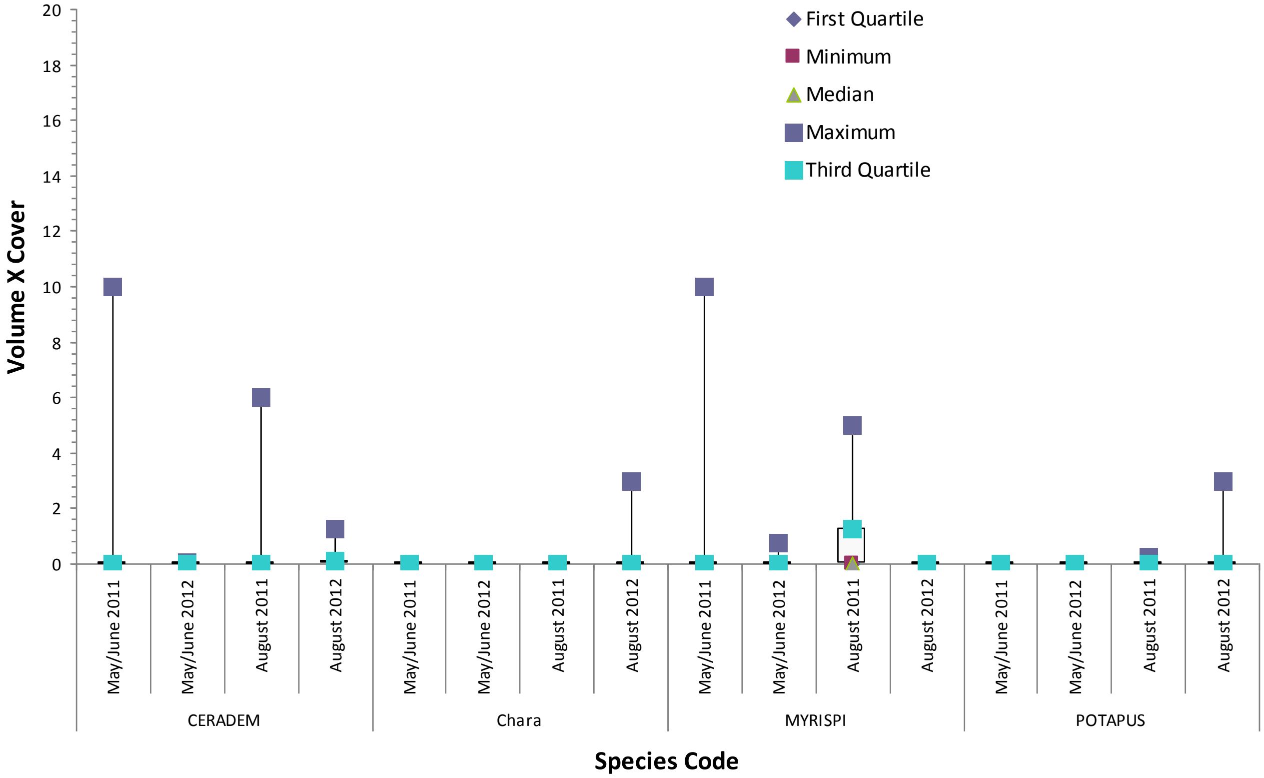

Figure 5-6: **Changes in the abundance of aquatic macrophytes at Montana Slough between May and August 2011.** The sample size available for analysis was very low at this site due to the scarcity of vegetation. See Section 4.7 for an explanation of the Volume x Cover metric that is used to represent abundance. See Table 5-1 for species codes

5.1.3 Airport Marsh

Twenty-nine randomly-distributed points in Airport Marsh were sampled between June 11 and 14, 2012. Twenty-two of these points, plus seven additional points, were visited on August 25 and 26 during the second field session (Figure 5-7). Of the 29 sites sampled in June, five were located in semi-terrestrial habitats adjacent to the open water of Airport Marsh. Water depths at the June 2012 sample points (excluding terrestrial plots) ranged from 0.15 m to 3.10 m during the June session and from 0.49 m to 2.6 m during the August session. Because extensive beds of emergent vegetation masked the true perimeter of the wetland, making it difficult to accurately delineate the water-land boundary from aerial photos (Figure 5-7), a bathymetry map for Airport Marsh was not produced.

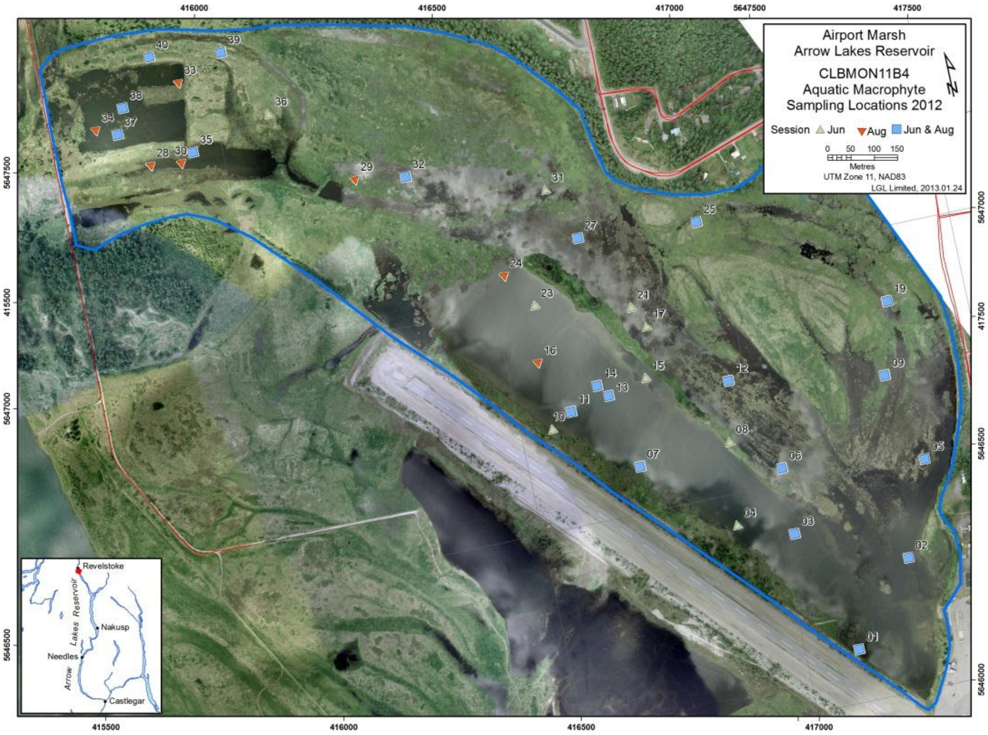

Figure 5-7: Distribution of sampling locations at Airport Marsh in 2011, including both the June and August sessions. The blue boundary represents the broadly defined boundary of Airport Marsh (at the highest water levels), but the water level rarely reaches this boundary except during reservoir inundation

5.1.3.1 Macrophyte Frequency, Cover, and Biomass

Submergent and/or floating species were detected at 93 per cent of points sampled in the June 2012 field session and at 96 per cent of points in the August 2012 field session, a pattern of slight seasonal increase consistent with that observed in 2011 (Fenneman and Hawkes 2012). However, the difference in macrophyte frequency between seasons was not statistically significant (Fisher's exact test, $p = 1.000$). There was also no statistical difference in overall macrophyte frequency between 2011 and 2012 (result consistent for both the early and late summer sampling periods). The only aquatic macrophyte to undergo a significant change in frequency between years was Floating-leaved Pondweed (Fisher's exact test, $p = 0.016$). This species' occurrence rate increased from 5 per cent of sample points in 2011 to 38 per cent of sample points in 2012 (early season census; Table 5-1).

The most frequently recorded species at Airport Marsh was Eurasian Water-milfoil, which occurred at 59 per cent and 70 per cent of points in the early and late season samples, respectively (Table 5-1). As in 2011, Common Hornwort and Stonewort were also relatively common, occurring with over 30 per cent frequency in 2012 (Table 5-1).

Local abundance of dominant species, as represented by the volume X cover (VC) metric (Section 4.7), varied widely from point to point in the wetland as indicated by the wide dispersion of data around the median VC values (Figure

5-6). For many species, the maximum VC value for a species was much greater than its median value (often zero), probably reflecting patchy local distributions (Figure 5-8). Both Eurasian Water-milfoil (MYRISPI) and Small Pondweed (POTAPUS) abundance varied significantly between years in the May/June period (MYRISPI: *p* = 0.009; POTOPUS: *p* = 0.041, Wilcoxon Rank Sum test). Abundance did not vary significantly for any species between the two August time periods.

Dry weight of biomass samples from Airport Marsh averaged 98.3 g in June (SD = 144.9, *n* = 14) and 46.0 g in August (SD = 43.5, *n* = 13). By comparison, the corresponding early and late summer dry weight averages for 2011 were 12.3 g (SD = 13.8, *n* = 7) and 7.3 g (SD = 8.1, *n* = 7; Fenneman and Hawkes 2012), respectively. As sample sizes for biomass were small and data were not normally distributed, a Wilcoxon Signed Rank Test was used to evaluate intra- and inter-annual differences in this variable (Zar 1999). For the two 2012 sample sessions, the seasonal difference was non-significant (*p* = 0.576). The difference in early season biomass between 2011 and 2012 was also non-significant (*p* = 0.780); however, the difference in late summer biomass between the two years was significant (*p* = 0.023). Early summer biomass in 2012 was significantly greater at Airport Marsh than at either Cartier Bay or Montana Slough (Sections 5.1.1 and 5.2.1).

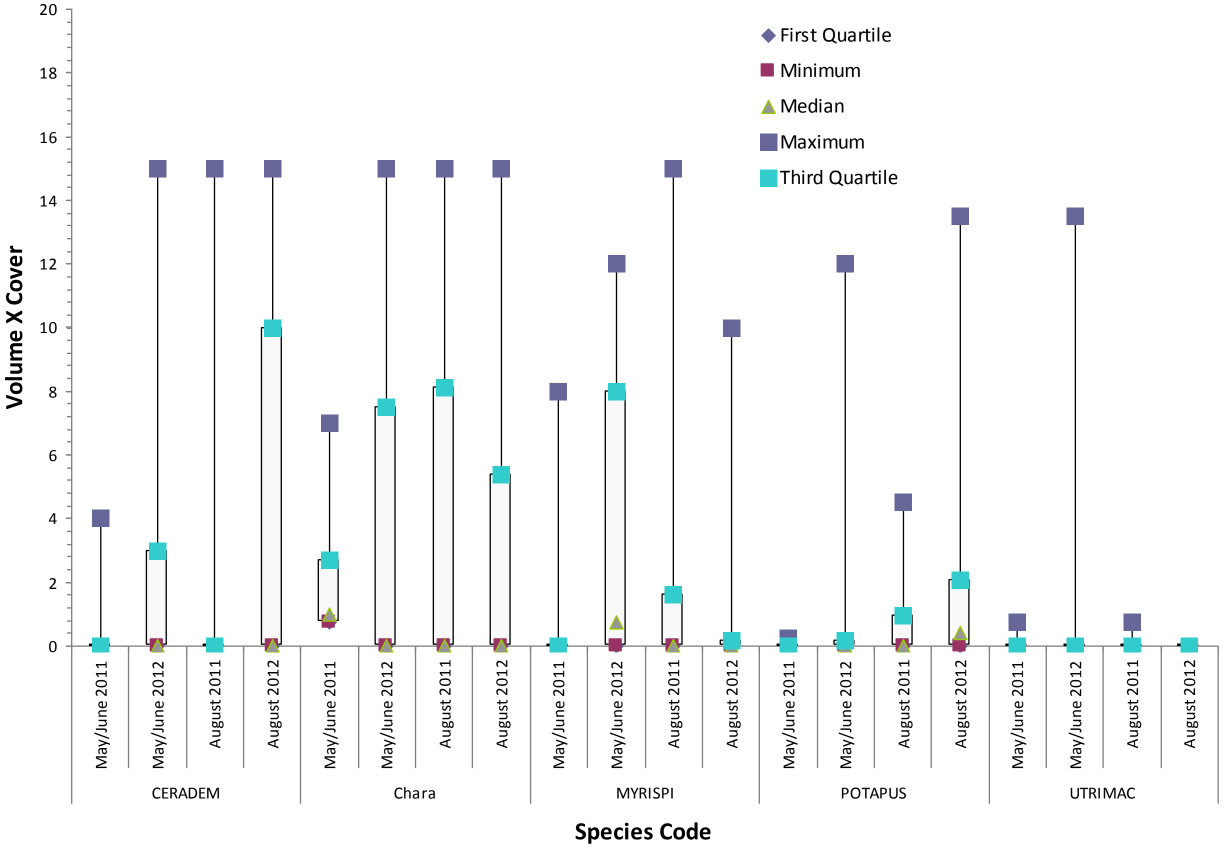

Figure 5-8: **Changes in the abundance of aquatic macrophytes at Airport Marsh between May and August 2011.** The sample size available for analysis was very low at this site due to the scarcity of vegetation. See Section 4.7 for an explanation of the Volume x Cover metric that is used to represent abundance. See Table 5-1 for the species codes.

5.1.3.2 Floating and Emergent Vegetation

Vegetation communities that occurred in standing water but were characterized by non-submergent vascular plants, i.e., floating beds and emergent stands, were present in all three of the Revelstoke Reach sites, but only at Airport Marsh were they common enough to be recorded by random sampling. These community types were sampled using the belt transect/quadrat method (Sections 4.3 and 4.4). Thirteen points at Airport Marsh were sampled this way during the 2012 June field session and 11 during the August field session (Table 5-2). Water depth at points ranged from 15 to 160 cm. In contrast to Cartier Bay, cover of floating species increased between the first and second field sessions. Presumably, this was because there was minimal reservoir inundation in this higher elevation wetland community, which allowed the established vegetation communities to grow and develop naturally and without the dramatic inundation that characterized the two lower elevation study sites.

Species recorded included truly emergent species such as Water Sedge and Common Cattail, typical surface-floating species such Water Smartweed and Floating-leaved Pondweed, and various aquatic macrophytes (such as Eurasian Milfoil) that can appear as either submergent or floating depending on developmental stage and the time of year (Table 5-2). As in 2011 (Fenneman and Hawkes 2012), some transects contained only emergents, others only floating beds, while some had submergent and/or floating-leaved species beneath a canopy of emergents. Floating-leaved Pondweed was the most frequently recorded species during the June sampling session. By August, however, Eurasian Water-milfoil was just as ubiquitous, occurring in most of the transects sampled. Water Smartweed and other pondweed species (Richardson’s Pondweed, Small Pondweed) also became more frequent on the water’s surface later in the season (Table 5-2).

The per cent cover of floating and emergent species varied between 2011 and 2012 and also between seasons within years (Figure 5-9). Sample sizes were too small to assess the statistical significance of cover differences; only summary data are shown. The cover of individual species generally averaged <10 per cent, although Eurasian Water-milfoil had >14 per cent cover in 2012. Certain apparent differences (e.g., in cover of the larger emergents such as Water Sedge, Soft-stemmed Bulrush, and Common Cattail) probably reflect sampling variation rather than any actual community change: Airport Marsh extends over a large area and some emergent communities were, through chance, not sampled equally in all sampling periods. Nevertheless, there was a notable difference between years in the recorded surface cover of some aquatic macrophytes such as Eurasian Water-milfoil and Floating-leaved Pondweed, both of which appeared to be more extensive in 2012 compared to 2011, whereas Water Smartweed appeared to have higher cover in 2011 compared to 2012 (Figure 5-9).

Table 5-2 **Per cent Cover of floating and emergent vegetation in Airport Marsh, 2012.** Total number of species and cover values for individual species represent the average of four quadrats

Sample Point	Total No. Species	Dominant Species (>10 per cent cover)		Minor Species (<10 per cent cover)	
		Species	Per Cent Cover	Species	Per Cent Cover
First Session (June 11–14)					
A5	1	Floating-leaved Pondweed	17.5	–	–
A6	1	Floating-leaved Pondweed	11.7	–	–
A9	8	–	–	Marsh Cinquefoil Reed Canarygrass Water Sedge Water Smartweed Swamp Horsetail Common Mare's-tail Small-fruited Bullrush Greater Bladderwort	7.5 2.0 2.5 0.3 0.1 0.1 7.0 0.1
A10	1	Reed Canarygrass	20.0	–	–
A12	1	–	–	Floating-leaved Pondweed	7.5
A17	1	–	–	Floating-leaved Pondweed	4.3
A19	1	Common Cattail	27.5	Common Spike-rush Soft-stemmed Bulrush	0.1 7.5
A21	1	Floating-leaved Pondweed	11.5	–	–
A27	3	–	–	Bur-weed sp. Water Smartweed Floating-leaved Pondweed	1.8 0.6 2.5
A31	1	Floating-leaved Pondweed	15.0	–	–
A35	1	–	–	Floating-leaved Pondweed	1.3
A37	1	–	–	Floating-leaved Pondweed	5.5
A38	1	–	–	Floating-leaved Pondweed	0.5
Second Session (August 25-26)					
A1	2	–	–	Floating-leaved Pondweed Eurasian Water-milfoil	2.5 0.5
A5	2	Floating-leaved Pondweed	10.5	Eurasian Water-milfoil	5.5
A7	2	Floating-leaved Pondweed Eurasian Water-milfoil	15.0 10.5	–	–
A9	3	Floating-leaved Pondweed	10.0	Eurasian Water-milfoil Small Pondweed	1.0 0.1
A12	3	Eurasian Water-milfoil Floating-leaved Pondweed	35.0 10.5	Eel-grass Pondweed	2.5
A14	5	Floating-leaved Pondweed Greater Bladderwort Common Mare's-tail	25.1 25.5 15.0	Eurasian Water-milfoil Richardson's Pondweed	7.5 1.0
A19	3	Eurasian Water-milfoil	30.0	Floating-leaved Pondweed Richardson's Pondweed	1.5 0.5
A27		–	–	Floating-leaved Pondweed Small Pondweed Eurasian Water-milfoil	7.5 4.0 3.0
A28	1	Water Smartweed	32.5	–	–
A37	3	–	–	Water Smartweed Small Pondweed Eurasian Water-milfoil	7.0 0.1 2.3
A38	2	Eurasian Water-milfoil	62.5	Floating-leaved Pondweed	4.0

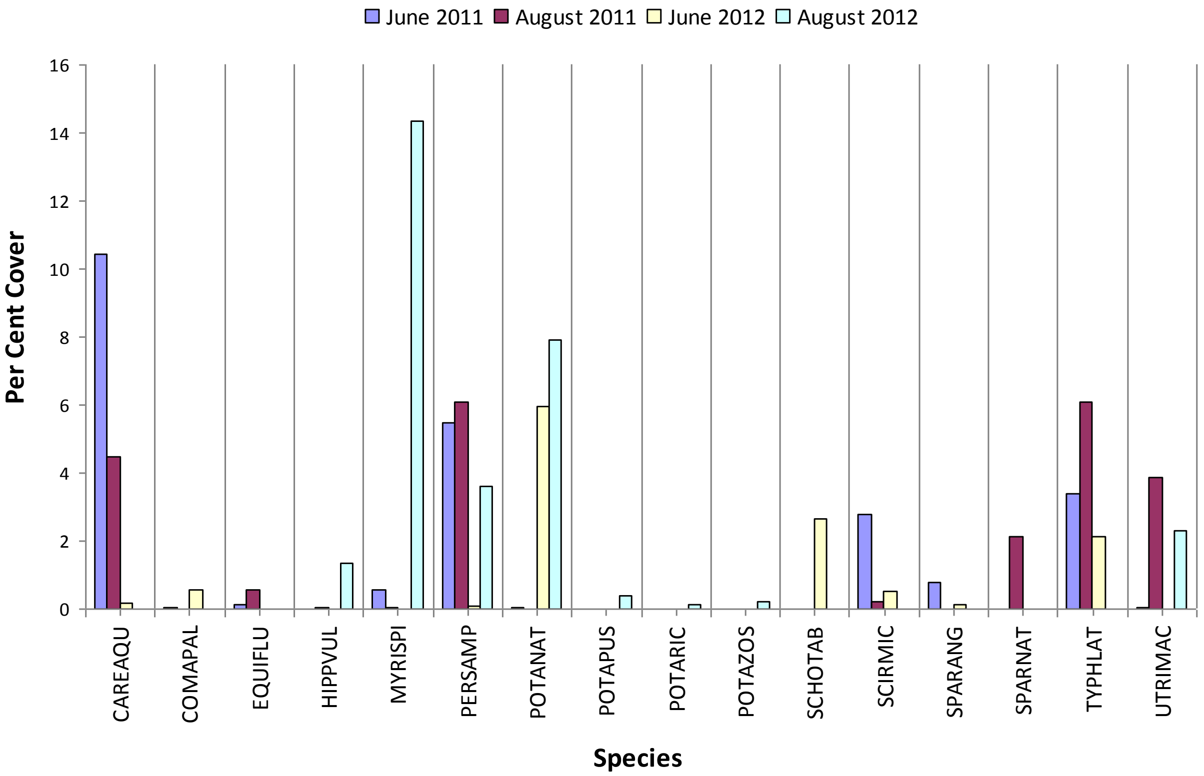

Figure 5-9: Average per cent cover of floating and emergent species recorded within randomly located 4 m x 1 m belt transects at Airport Marsh in 2012. Some very infrequent species appearing in Table 5- are not shown. For June 2011, n = 8 transects; for August 2011, n = 7 transects; for June 2012, n = 13 transects; and for August 2012, n = 11 transects. Refer to Table 5-1 for species codes.

5.1.4 Beaton Arm Beaver Ponds

The Beaton Arm site is a complex of beaver ponds extending in stepwise fashion from the forest edge above the drawdown zone into the drawdown zone itself (Figure 5-10). Ponds range in size from about 0.5 ha to about 20 m x 20 m. The largest ponds occur outside the drawdown zone, with pond size decreasing with descent into the drawdown zone. As boat access was difficult and the pond substrates were too soft for wading, surveys were completed from the shore. A 4 m x 1 m belt transect was sampled at a representative location at the edge of each pond to obtain preliminary floating and emergent cover estimates, and a rake grab was used to sample submergent macrophytes. Four representative ponds were surveyed in June, and again in August (when a fifth pond was also sampled). The macrophyte community in the majority of the ponds is strongly dominated by floating beds of Yellow Pond-lily (*Nuphar polysepala*), which cover >50 per cent of the water surface in places. Floating-leaved Pondweed is also abundant. Associated macrophytes include other Pondweeds (Small Pondweed, Richardson's Pondweed), Bladderwort (*Utricularia* sp.), Bur-reed (*Sparganium* sp.), Water Smartweed, and Stonewort. Water Sedge, Swamp Horsetail, Common Cattail, and Reed Canarygrass occur in shallower waters along the shoreline (Table 5-3).

Pond 1 is situated at the top of the drawdown zone and is ~30 m x 30 m in size. Yellow Pond-lily is the dominant floating vegetation, which together with Floating-leaved Pondweed covered ~50 per cent of the water surface in June (Figure 5-11). Rake grabs yielded submergent Small Pondweed and Bladderwort. Riparian vegetation includes Canary Reedgrass, Awl-fruited Sedge (*Carex stipata*), Water Sedge, and Small-fruited Bullrush. Cover within the belt transect sample was dominated by Yellow Pond-lily in association with Floating-leaved Pondweed, Swamp Horsetail, Canary Reedgrass, and Water Smartweed (Table 5-3).

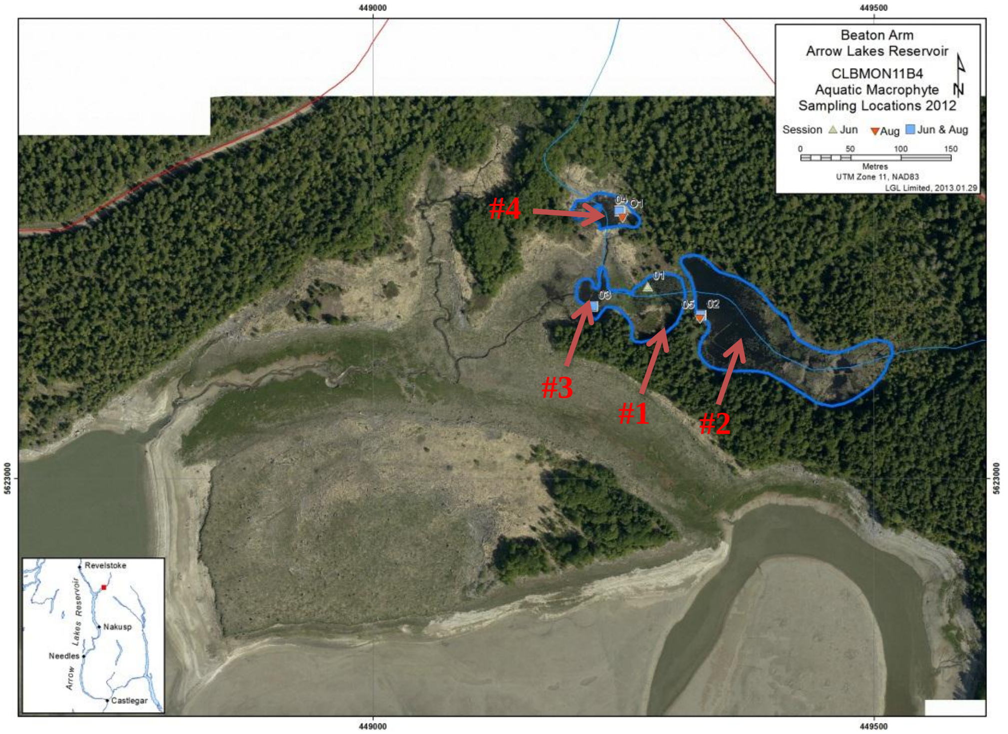

Figure 5-10: Distribution of sampling in Beaton Arm in June and August 2012

Pond 2 is situated above the normal operating maximum of the reservoir and thus generally unaffected by reservoir operations. Covering approx. 0.5 ha, this is the largest pond and also supports the most intact ecosystem. Beds of Yellow Pond-lily and Floating-leaved Pondweed covered ~10 per cent of the water surface in June. Small Pondweed is characteristic of the submergent layer. Cover within the June belt transect sample was low and was represented by Floating-leaved Pondweed and Bur-weed (Table 5-3).

Pond 3 is situated within the drawdown zone and is regularly inundated. There is relatively little floating plant cover compared to the higher-elevation ponds, although Yellow Pond-lily, Floating-leaved Pondweed, and Water Smartweed do occur in small patches. Reed Canarygrass occurs along the shoreline, along with Swamp Horsetail and Water Sedge (Table 5-3). When this pond was revisited in August the water was observed to be brown and turbid, presumably a consequence of reservoir flooding and subsequent drawdown. Nevertheless, in contrast to the June transect, the August transect contained a relatively high (42 per cent) cover of Yellow Pond-weed, suggesting that short-term inundation may not be detrimental for this species (Table 5-3).

Figure 5-11: Beaton Arm beaver pond (Pond 1), photographed June 13 2012

Pond 4 is a small 20 m x 20 m pond near the upper limit of the drawdown zone. In June, ~10 per cent of the pond was covered by floating vegetation beds (Yellow Pond-lily); several emergent species were also established including Water Sedge and Swamp Horsetail. However, the pond is quite shallow and there was no submergent layer evident. Patches of decaying Reed Canarygrass at the centre of the pond suggest that this site may dry out periodically. As at Pond 3, cover of Yellow Pond-lily was higher in the August transect than in the June transect (Table 5-3).

Table 5-3: Cover data for floating and emergent vegetation plots at Beaton Arm beaver ponds in June and August, 2012. Cover values for individual species represent the average of the three to four quadrats that comprised each sample point

Sample Point	Position in Drawdown Zone	Dominant Species (>10 per cent cover)		Minor Species (<10 per cent cover)	
		Species	Per Cent Cover	Species	Per Cent Cover
First Session (June 13)					
Pond 1	Upper DDZ	Yellow Pond-lily	50.0	Floating-leaved Pondweed Swamp Horsetail Reed Canarygrass Water Smartweed	3.0 0.1 0.1 0.1
Pond 2	Above DDZ	–	–	Floating-leaved Pondweed Bur-weed sp.	5.0 0.1
Pond 3	Mid DDZ	–	–	Water Smartweed Reed Canarygrass Floating-leaved Pondweed Water Sedge Yellow Pond-lily Swamp Horsetail	0.3 3.3 0.1 3.3 0.1 0.1
Pond 4	Upper margin of DDZ	–	–	Reed Canarygrass Swamp Horsetail Yellow Pond-lily Water Sedge Water Smartweed	8.3 0.7 2 1.1 0.1

Second Session (August 25-26)					
Pond 1	Upper DDZ	Yellow Pond-lily	75.0	Floating-leaved Pondweed Water Smartweed	2.8 0.1
Pond 2	Above DDZ	–	–	Floating-leaved Pondweed Yellow Pond-lily	7.8 0.3
Pond 3	Mid DDZ	Yellow Pond-lily	42.5	Floating-leaved Pondweed Reed Canarygrass	0.5 0.3
Pond 4	Upper margin of DDZ	Yellow Pond-lily	11.3	Floating-leaved Pondweed Swamp Horsetail Reed Canarygrass	2.5 0.3 2.8
Pond 5	Mid DDZ	Water Smartweed	10.75	Reed Canarygrass	0.25

5.1.5 Lower Inonoaklin Road

This site is at the outlet of Lower Inonoaklin Road, where two seepages feed into a backwater slough of Lower Arrow Lake Reservoir (Figure 5-12). The southern seepage flows down an open slope above the riparian zone and supports a vigorous community of Yellow Monkey-flower, mosses, Toad Rush, and Kellog's Sedge. The northern seepage exits from a culvert above the riparian zone and feeds into a vigorous stand of Marsh Horsetail, Kellog's Sedge, Reed Canarygrass, and Columbia Sedge. The riparian perimeter of the slough has well established herbaceous communities including a sedge/graminoid (Kellog's Sedge [*Carex lenticularis*], Columbia Sedge [*C. aperta]*, Reed canarygrass) association and a low herb – Annual Hairgrass (*Deschampsia danthonoides*) – Shortawn Foxtail (*Alopecurus aequalis*) – Kellog's Sedge association (Figure 5-13). There is also a restoration treatment of planted Small-fruited Bullrush plugs at the northwest end of the site. These plugs are generally healthy and well established.

Preliminary surveys of the slough were conducted in June and again in August. The June survey was conducted from shore; for the latter survey an inflatable boat was employed (Figure 5-12). In June, the water body was shallow and no macrophytes were evident. Rake grabs made from the shore also failed to capture any submergents. This is not surprising, since the slough had already begun to be inundated at this point and the submerged foreshore was likely just flooded terrestrial habitat supporting a continuation of the dwarf herb flats visible above the water line. The per cent cover of riparian species was assessed within four 3 m x 1 m belt transects laid out along the shoreline. The highest cover values were for Kellog's Sedge, Scouler's Popcornflower, Marsh Horsetail, European Forget-me-not, unidentified seedlings, and mosses (Table 5-4).

In late August, following full inundation of the slough, a few floating macrophyte beds consisting entirely of Floating-leaved Pondweed had established at the north end of the slough above recently submerged and decaying beds of Reed Canarygrass. Cover of Floating-leaved Pondweed in these beds averaged ~27 per cent (Table 5-4). Rake grabs conducted from a boat at seven additional locations around the slough yielded only trace amounts of Stonewort and moss (Table 5-4).

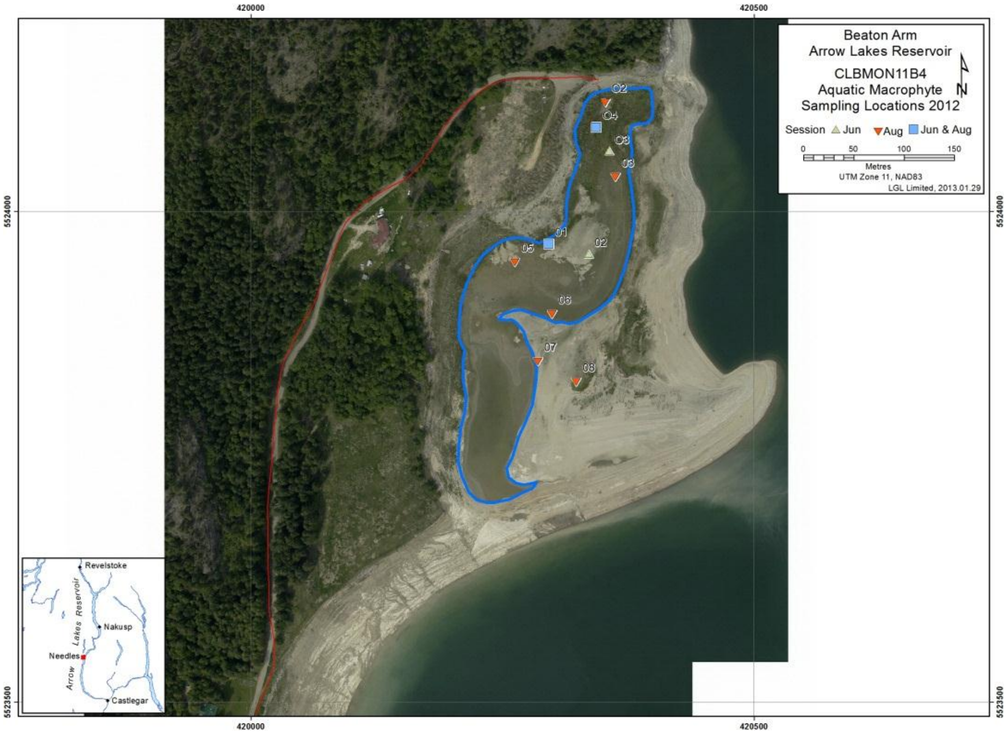

Figure 5-12: Distribution of sampling in Lower Inonoaklin Road in June and August 2012

Figure 5-13: Lower Inonoaklin Rd. site, photographed June 12 2012

Table 5-4: Per cent cover of terrestrial vegetation transects and floating plots at Lower Inonoaklin Road in June and August, 2012. Cover values for individual species represent the average of the three 1 m x 1 m quadrats that comprised each terrestrial sample point (average of two quadrats or two rake grabs in the case of boat samples)

Sample Point	Vegetation Type (Sampling Method)	Dominant Species (>10 per cent cover)		Minor Species (<10 per cent cover)	
		Species	Per Cent Cover	Species	Per Cent Cover
First Session (June 12)					
1	Terrestrial (belt transect)	Kellog's Sedge seedlings mosses	36.7 23.3 13.3	Scouler's Popcornflower Yellow Monkey-flower European Forget-me-not Toad Rush Common Horsetail Norwegian Cinquefoil Shortawn Foxtail Reed Canarygrass Common Spike-rush Purslane Speedwell	0.7 3.7 5.7 1.7 0.1 0.1 0.1 3.3 0.1 1.7
2	Terrestrial (belt transect)	Scouler's Popcornflower	53.3	Shortawn Foxtail Pineapple Weed Red Sand-spurry	0.7 0.4 3.0
3	Terrestrial (belt transect)	Scouler's Popcornflower mosses	56.7 16.7	Small-fruited Bullrush Shortawn Foxtail Norwegian Cinquefoil Common Horsetail Kellog's Sedge Reed Canarygrass Purslane Speedwell Scouler's Popcornflower Toad Rush	5.0 7.3 0.3 0.1 6.7 1.7 0.7 0.1 0.1
4	Terrestrial (belt transect)	Marsh Horsetail European Forget-me-not	50.0 76.7	Shortawn Foxtail Kellog's Sedge mosses Reed Canarygrass Toad Rush Yellow Monkey-flower Marsh Yellow Cress seedlings Pineapple Weed	0.3 6.7 3.3 1.3 0.3 0.1 0.1 8.3 0.1
Second Session (August 28)					
LI01	Floating macrophyte (belt transect)	Floating-leaved Pondweed	27.5	–	–
LI02	Submergent macrophyte (rake)	–	–	–	–
LI03	Submergent macrophyte (rake)	–	–	moss	n/a
LI04	Submergent macrophyte (rake)	–	–	Stonewort	n/a
LI05	Submergent macrophyte (rake)	–	–	–	–
LI06	Submergent macrophyte (rake)	–	–	Stonewort	n/a
LI07	Submergent macrophyte (rake)	–	–	–	–
LI08	Submergent macrophyte (rake)	–	–	–	–

5.2 Aquatic Macroinvertebrates – Pelagic

One hundred and two plots were sampled in five locations (35 in June; 67 in August; Table 5-5). Figure 5-1, Figure 5-4, Figure 5-7, Figure 5-10, and Figure 5-12show the distribution of sampling in each site and month.

Table 5-5: Distribution of aquatic macroinvertebrate sampling locations by reach relative to the drawdown zone (i.e., outside or inside)

Month	Site	Plots
June	Montana Slough	3
	Cartier Bay	13
	Airport Marsh	14
	Lower Inonoaklin	1
	Beaton Arm	4
August	Montana Slough	12
	Cartier Bay	16
	Airport Marsh	26
	Lower Inonoaklin	8
	Beaton Arm	5

Sixteen taxa were documented from all sampling locations in 2012 with 15 of those taxa documented in June and 10 in August (Table 5-6). The distribution and occurrence of each taxon relative to sampling location and month is shown in Table 5-6. The number of taxa per sampling area ranged from three to 15 in June and two to seven in August. Airport Marsh and Beaton Arm were the most speciose, with equal numbers of species recorded in June and slightly more at Beaton Arm than at Airport Marsh in August. Both of these wetland complexes do not typically get inundated by Arrow Lakes Reservoir; however, Airport Marsh was flooded in 2012 (Figure 5-14).

Cladocerans (water fleas) and Copepoda (freshwater crustaceans) were the most ubiquitous and generally the most abundant macroinvertebrates, occurring in four or five of the study areas in June and August. Ephemeroptera (Mayflies) were documented from four of five locations in June and one location (Beaton Arm) in August. Oligochaeta (aquatic and terrestrial worms) were documented in three sites in both June and August. These four groups tend to be common and locally abundant when present and their dominance of the data set is not surprising.

Table 5-6: **Distribution of aquatic macroinvertebrate taxa by site and month. Shaded cells indicates presence**

Taxon	June 2012						August 2012					
	Montana Slough	**Cartier Bay**	**Airport Marsh**	**Lower Inonoaklin**	**Beaton Arm**	**Total Sites**	**Montana Slough**	**Cartier Bay**	**Airport Marsh**	**Lower Inonoaklin**	**Beaton Arm**	**Total Sites**
Acari		■	■		■	3.0		■	■	■		3.0
Amphipoda			■			1.0						
Annelida											■	1.0
Cladocera	■	■	■		■	4.0	■		■	■	■	4.0
Cnidaria			■		■	2.0			■			1.0
Coleoptera			■		■	2.0	■					1.0
Collembolla			■		■	2.0						
Conchostraca					■	1.0						
Copepoda		■	■	■	■	4.0	■	■	■	■	■	5.0
Ephemeroptera	■		■	■	■	4.0					■	1.0
Hemiptera			■		■	2.0					■	1.0
Mollusca			■		■	2.0						
Odonata			■		■	2.0						
Ostracoda	■		■		■	3.0			■		■	2.0
Trichoptera			■		■	2.0						
Oligochaeta		■	■		■	3.0			■	■	■	3.0
Taxa per Site	**3**	**4**	**14**	**2**	**14**	**15**	**3**	**2**	**6**	**4**	**7**	**10**

Figure 5-14: Photo of Airport Marsh taken on July 19, 2012 showing the level of inundation. The chainlink fence is approximately 1.8 m in height. Reservoir elevation on day of photo was 440.41 m ASL, 30 cm higher than the normal maximum reservoir elevation for Arrow Lakes Reservoir

Species richness (the number of species, q), diversity (H') and evenness (J) varied by month and study site (Table 5-7). Species richness was lower for all sites sampled in August than June with the exception of Lower Inonoaklin Road; however, this could be related to an increase in sample size from one plot in June to eight in August. Despite the increase in sampling effort, species richness only doubled from two to four taxa. Patterns of change in species diversity mirrored that of species richness with decreases at all sites except for Lower Inonoaklin Road. Patterns of evenness were more variable and consistent with patterns of taxonomic dominance observed for each site. For example, the relative abundance of taxa at Airport Marsh and Beaton Arm (Table 5-8) was dominated by three of four taxa, which is reflected in the relatively low evenness scores. Conversely, although the relative abundance of aquatic macroinvertebrates was low at Montana Slough, Cartier Bay, and Lower Inonoaklin Road, the relative abundance of these taxa were similar, hence the higher evenness score. Evenness in Cartier Bay was low in June, which may be a result of the relative abundance of Cladocerans, which while still low relative to other sites, was five to 15 times higher than all other taxa (Table 5-8).

Table 5-7: **Species richness (q), diversity (H') and evenness for each wetland sampled in and adjacent to the drawdown zone of Arrow Lakes Reservoir in June and August 2012.** Sample size (N) is the number of plots per wetland

	June				August			
Study Area	**N**	**q**	**H'**	**J**	**N**	**q**	**H'**	**J**
Montana Slough	3	9	0.84	0.88	12	3	0.44	0.92
Cartier Bay	13	4	0.32	0.53	16	2	0.22	0.72
Airport Marsh	14	14	0.72	0.63	26	6	0.36	0.46
Lower Inonoaklin	1	2	0.28	0.92	8	4	0.48	0.79
Beaton Arm	4	14	0.61	0.53	5	7	0.51	0.60

Table 5-8: **Relative abundance of aquatic macroinvertebrates sampled per sampling location in 2012**

	June					August				
Taxon	Montana Slough	Cartier Bay	Airport Marsh	Lower Inonoaklin	Beaton Arm	Montana Slough	Cartier Bay	Airport Marsh	Lower Inonoaklin	Beaton Arm
Acari	0.0	0.1	2.4	0.0	1.3	0.0	0.1	0.0	0.1	0.0
Amphipoda	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Annelida	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
Cladocera	0.7	1.5	12.4	0.0	14.8	0.5	0.0	8.9	2.8	5.0
Cnidaria	0.0	0.0	0.2	0.0	1.3	0.0	0.0	0.0	0.0	0.0
Coleoptera	0.0	0.0	0.1	0.0	0.5	0.3	0.0	0.0	0.0	0.0
Collembolla	0.0	0.0	0.1	0.0	1.0	0.0	0.0	0.0	0.0	0.0
Conchostraca	0.0	0.0	0.0	0.0	1.3	0.0	0.0	0.0	0.0	0.0
Copepoda	0.0	0.3	8.7	2.0	23.3	0.8	0.3	5.7	4.4	6.0
Ephemeroptera	0.3	0.0	0.6	1.0	3.0	0.0	0.0	0.0	0.0	0.6
Hemiptera	0.0	0.0	0.2	0.0	1.0	0.0	0.0	0.0	0.0	0.4
Mollusca	0.0	0.0	2.9	0.0	1.3	0.0	0.0	0.0	0.0	0.0
Odonata	0.0	0.0	0.4	0.0	0.5	0.0	0.0	0.0	0.0	0.0
Ostracoda	0.3	0.0	0.7	0.0	33.0	0.0	0.0	0.1	0.0	0.2
Trichoptera	0.0	0.0	0.1	0.0	0.5	0.0	0.0	0.0	0.0	0.0
Oligochaeta	0.0	0.1	0.1	0.0	102.8	0.0	0.0	0.3	1.9	0.2

Beaton Arm and Airport Marsh supported the largest populations of aquatic invertebrates (Table 5-8). The relative abundances of Cladocerans, Copepoda were highest at sites least influenced by reservoir operations. The number of worms (Oligochaeta) was very high at Beaton Arm in June, but the relative abundance of this taxon decreased to relatively low levels in August at all sites. The relative abundance of taxa in Cartier Bay ad Montana Slough was low, with less than one individual per plot for all taxa documented. The relative abundance of aquatic macroinvertebrates was also low at Lower Inonoaklin Road.

The ecology of these sites is influenced by reservoir inundation on an annual basis and the combination of low species richness and relative abundance compared to more stable wetland complexes (i.e., Airport Marsh and Beaton Arm) suggests that reservoir operations are having a negative impact on the secondary productivity of wetlands situated in the drawdown zone of Arrow Lakes Reservoir.

Of the 16 taxa documented, three (Amphipoda, Ephemeroptera, and Trichoptera) are known to be sensitive or moderately sensitive to habitat changes[2], including changes in dissolved oxygen and turbidity, both of which are likely to result from the implementation of physical works in Revelstoke Reach. Because the proposed physical works are designed to increase the amount of shallow wetland habitat in Revelstoke Reach, these changes in habitat quality (area and productivity) are expected to have a net positive impact on aquatic macroinvertebrates. These three taxa were either rare (i.e., had low relative abundance) in the 2012 sample or were not present at all sites sampled. The sensitivity of these taxa to habitat change (i.e., varying conditions) may make one or more of them a suitable indicator regarding the efficacy of the physical works implemented in Revelstoke Reach to improve secondary productivity.

Of all taxa documented in 2012, Odonata and Ephemeroptera may be suitable indicators of habitat change or productivity. This is based on their (1) relative ease of identification (e.g., Odonata vs. Amphipoda, which can be difficult to distinguish at the family level); and (2) their propensity to spend several years as aquatic life history stages (Ephemeroptera), necessitating stable and suitable conditions for populations to persist.

6.0 DISCUSSION

6.1 Macrophytes

Previous surveys of the aquatic macrophyte, emergent, and terrestrial vegetation communities at Cartier Bay, Montana Slough, and Airport Marsh showed that these three sites differ strongly with respect to species composition and community structure (Hawkes et al. 2011, Fenneman and Hawkes 2012). The 2011 survey also revealed within-year seasonal differences in species richness and abundance that appeared to be related to mid-summer flooding by the Arrow Lakes Reservoir, especially at Cartier Bay (Fenneman and Hawkes 2012). However, it was unclear to what extent the observed differences were due to flooding effects as opposed to sampling error, since it is more difficult to observe or sample submergent vegetation reliably in the deeper waters of late summer than in the shallower waters of early summer (Fenneman and Hawkes 2012).

One of the objectives of the 2012 surveys was to test the ability of the sampling approach to detect community-level changes on an inter-annual basis, in anticipation of eventually detecting ecological changes stemming from the installation of the physical works. We were able to detect statistically significant differences in species frequency and abundance between 2011 and 2012 for some aquatic macrophytes (Small Pondweed, Floating-leaved Pondweed, and Eurasian Water-milfoil) but not others, a result that appears consistent with

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[2] Taxonomic sensitivity from http://lakes.chebucto.org/ZOOBENTH/BENTHOS/tolerance.html

wetland systems undergoing a moderate level of inter-annual environmental variation (Greet et al. 2011). The methodology allowed us to detect differences ≥100 per cent over a one-year period at $\alpha = 0.05$ in the case of frequency and biomass, and differences >200 per cent difference for the abundance (VC) metric (although detection thresholds varied from species to species). This suggests that an increase in sampling intensity and/or stratification may be needed to evaluate some of the performance measures at $\alpha = 0.05$. More time and data are needed to determine if the current methodology is sufficient to detect a change of 25 per cent at $\alpha = 0.20$ over 10 years—the proposed standard for statistical power on which the performance measures are predicated. Nevertheless, our success at detecting some statistically significant (if not necessarily biologically significant) differences under normal operating regimes gives us confidence that more dramatic changes accruing over several years from physical works projects, that directly impact the target wetlands, will also be detectable.

It is worth noting that most statistically significant differences in frequency and cover tended to be between the early season (June) not the late season (August) surveys. By August many macrophyte species have been deeply submerged by the flooding reservoir and have likely begun to senesce, reducing their overall detectability (along with our ability to detect meaningful changes in abundance). The growing season for macrophytes at Airport Marsh, which typically escapes inundation, appears to be longer than at either Cartier Bay or Montana Slough, which could account for the fact that there was a significant difference in biomass detected between the two August survey periods at Airport Marsh, but not at Cartier Bay or Montana Slough. The apparent lower variability between late summer periods could also reflect the greater difficulty in obtaining consistent macrophyte samples in deep waters (i.e., at post-inundation depths) versus shallow waters using the rake grab method. Whether the relatively low variability observed for late summer periods is due to naturally low variation at this time of year or to the inherent limitations of the sampling method, our results suggest that early season (June) surveys will be more effective at detecting short-term changes associated with physical works projects and should thus be emphasized over the late summer surveys.

The three macrophyte species in Revelstoke Reach exhibiting the highest inter-annual variability in frequency and/or VC (volume x cover) were, as noted, Small Pondweed, Floating-leaved Pondweed, and Eurasian Water-milfoil. The two pondweed species increased between 2011 and 2012 at Cartier Bay and Airport Marsh; Eurasian Water-milfoil increased at Airport Marsh but decreased at Montana Slough. The abundance of Eurasian Water-milfoil has previously been reported to fluctuate over time at Cartier Bay as well (Fenneman and Hawkes 2012). The natural variability of these three species, two of which are native and one of which is introduced, could limit their potential usefulness as indicator taxa (i.e., response variables) in a BACI-design study of the impacts to aquatic vegetation of physical works in Revelstoke Reach. The focus should perhaps rather be on less variable taxa, since it may be easier to attribute variation to specific factors (including those stemming from the proposed habitat improvements) in these taxa. However, given the relatively low macrophyte diversity in the three wetland systems, and our lack of knowledge about how each will respond to the physical works, no species should be eliminated from consideration as a potential ecological indicator at this stage of the study.

6.2 Macroinvertebrates

Anthropogenic control over the flow of running water, usually by means of dams and reservoirs, has influenced nearly all of the world's major river systems and the building of dams imposes a lentic habitat within a lotic system (Mackie 1998). The aquatic communities must suddenly adjust to the changes in physical, chemical and biological attributes of riverine systems to those of lacustrine systems. Some species are adapted to a lotic existence and perish when a lentic system is imposed upon them. Others, mostly highly tolerant forms like chironomids and tubificid worms, exploit the new habitat and explode in biomass. In several cases, it was found that, following the formation of an impoundment, Mayflies, Caddisflies and Stoneflies disappeared almost immediately but were replaced by high densities of midges. (Williams and Feltmate, 1992). Higher levels of sedimentation can affect aquatic insects by altering biochemical conditions, food resources, respiratory diffusion gradients, and habitat space (Williams and Feltmate, 1992).

The implementation of physical works in Revelstoke Reach is expected to have a net positive effect on the aquatic macroinvertebrate fauna of Montana Slough, Cartier Bay, and Lower Inonoaklin Road. This is because the proposed changes to existing shallow wetland habitat include (1) an increase in the spatial extent of these habitats, and (2) a stabilization of these habitats because they will not be influenced by reservoir operations to the extent they are currently. With changes to the physical characteristics of shallow wetland habitat in Revelstoke Reach is an expected change in the aquatic macroinvertebrate fauna. The current fauna has likely been impacted from reservoir creation and operations, over the last 45 years changing from one dominated by shredders and lotic filter feeders, grazers and predators to herbivores and lentic filter feeders and predators (as per Rosenburg 1998). However, there are likely to be measurable changes in the presence, abundance, and distribution of the current aquatic macroinvertebrate fauna that will be influenced by the implementation of physical works and overtime, it is expected that the macroinvertebrate fauna of Cartier Bay, Montana Slough, and Lower Inonoaklin Road will begin to resemble that of Airport Marsh, and to a lesser extent, the Beaton Arm beaver pond complex. The expected changes in the structure of the aquatic macroinvertebrate fauna emphasizes the need to continue monitoring this group prior to and following the implementation of physical work in Revelstoke Reach or mid- and lower Arrow Lakes Reservoir (as per Hawkes and Howard 2012).

Both species richness and diversity tended to decrease between June and August, particularly for those sites inundated by Arrow Lakes Reservoir (i.e., all sites except for the upper beaver ponds at Beaton Arm; Table 5-7). The magnitude of the changes in species richness and diversity was consistent across sites with species richness two to three times higher in June and species diversity around 1.3 times higher in June. This may be indicative of a seasonal change in the aquatic macroinvertebrate fauna that occurs at a regional scale. However, those sites not typically affected by reservoir operations (Beaton Arm and Airport Marsh) had one to seven times as many taxa in June and between 1 and 3.5 times more taxa in August as wetlands inundated by Arrow Lakes Reservoir (i.e., Montana Slough and Cartier Bay). This suggests that the aquatic macroinvertebrate fauna of wetlands inundated by Arrow Lakes Reservoir is limited in terms of species richness.

An alternate explanation is that filling Arrow Lakes Reservoir beyond full pool in 2012 affected even those sites not typically affected by reservoir operations in a manner consistent with those sites in the drawdown zone. The effect of this operation may have resulted in lower species richness and diversity at sites like Airport Marsh and Beaton Arm. Although 2012 was the first year of sampling for Beaton Arm, data from Airport Marsh in 2011 show an opposite trend where more taxa were documented in August than June. Reservoir operations in 2011 reached a maximum of 439.52 m ASL suggesting that exceeding full pool affects the ability to detect aquatic macroinvertebrates either because they have been dispersed by the full pool event (an indirect effect) or some taxa have been eliminated (a direct effect).

Aquatic macroinvertebrates are commonly utilized as indicators of environmental change. There are many advantages to using macroinvertebrates to monitor the status or change of ecosystems. Aquatic macroinvertebrates are generally ubiquitous in freshwater ecosystems, can be long-lived (i.e., live 3 to 5 years), encompass a broad range of niches and provide a primary food source for other animals such as fish. The popularity of using macroinvertebrates to monitor water quality trends over time is due to the understanding that this method surpasses traditional water chemical tests and capabilities (Gaufin 1973). The change in the abundance, presence and even morphology of sensitive organisms combined with the presence and abundance of tolerant organisms may be indicative of habitat change

Of the aquatic macroinvertebrate taxa sampled in the wetlands and ponds in and adjacent to the drawdown zone of Kinbasket Reservoir, three appear to be suitable candidates as indicator species: Trichoptera (Caddisflies), Ephemeroptera (Mayflies), and Odonata (Dragonflies and Damselflies). Of these, Odonata and Ephemeroptera may be suitable indicators of habitat change or productivity. This is based on their (1) relative ease of identification (e.g., Odonata vs. Amphipoda, which can be difficult to distinguish at the family level) or (2) their propensity to spend several years as aquatic insects (Ephemeroptera), necessitating stable and suitable conditions to persist.

The following sections provide a brief overview of each taxa and the rationale for considering the taxa as a possible indicator of wetland productivity.

Trichoptera (Caddisflies)

These holometabolous insects are closely related to and resemble moths. Adults have “hairy wings”(trichoptera=hairy wing) instead of the scales that moths posses. Almost all larvae are aquatic, have a single pair of hooks on a single pair of prolegs at the end of the body, produce silk and build cases armoured with found materials instead of cocoons. Larvae of this diverse family are common on substrate in all types of streams and rivers but some species are associated with cold flowing rivers and streams and are restricted to these habitats, such as members of the family Rhyacophilidae (Mandaville 2002). This family is a cornerstone importance to biomonitoring programs as certain species are susceptible to environmental disturbances and intolerant of high levels of pollution and low oxygen (Basaguren and Orive, 1990). Caddisflies were documented from one drawdown zone location in 2012 (Table 5-6). Additional sampling of the drawdown zone is required before selecting the Trichoptera as a focal taxon with which to assess habitat changes associated with increases in the area of shallow wetland habitat in Cartier Bay. Given the known sensitivity of this group, changes to water temperature, dissolved oxygen, flow rates, and sedimentation could combine to generate negative effects.

Ephemeroptera (Mayflies)

Adult Mayflies are ephemeral; they do not possess functional mouth parts and may live for less than a day. Adults exhibit synchronized emergence, reproduce, then die. Mayfly larvae are hemimetabolous and may spend several years as aquatic insects. They are distinguished from similar looking stonefly or dragonfly larvae by abdominal gills which can be covered by flaps or a carapace. They also have a single claw on the end of their hind leg while stoneflies have two (Marshall 2006). Larvae are typically grouped by behaviour e.g. burrowing, creeping, swimming or flattened, feeding method e.g., collecting-gather, scraping, shredding and some habitat needs (Needham 1996). Their prolonged aquatic phase suggests that this group could be monitored for several years. Changes in the presence or abundance of Mayflies, if correlated with changes in the physical or chemical attributes of the wetlands sampled resulting from the physical works, may be indicative of an adverse impact on wetland productivity.

Odonata (Dragonflies and Damselflies)

The Odonata are split into two sub-orders Anisoptera (Dragonflies) and Zygoptera (Damselflies), although it is not uncommon to refer to the whole order as dragonflies. All life stages are predaceous and the order is named after the nymphs' unique jaw structure (Odona=toothed jaws). They have a hemimetabolous lifecycle where most of their lifecycle is spent under water as a nymph with only a portion as an adult. Adult dragonflies are unique when compared to other orders in that they can migrate and may live several years as adults. One of the ways that the two families differ as nymphs (larvae) is that damselflies are generally narrow with three gill lamellae off the tip of the abdomen while anisopterans are bulky and retain the gills internally and need to expand and contract their abdomen to push water over the gills (Marshall 2006). They are sensitive and easily observed indicators of water quality (Marshall, 2006). Most spend at least a year in the nymphal stage before emerging. High species richness has been correlated with low turbidity (100 to 120 NTU), moderate conductivity (700 to 900 mS/cm) and high dissolved oxygen levels (7 to 8 mg/L) (Domsic, n.d.) and high vegetation species richness (Hornung and Rice, 2003).

7.0 Recommendations

The following recommendations are based on the first three years of study results:

1. Continue sampling macrophytes and macroinvertebrates in 2013. However, rather than two annual samples, a single sample to characterize the aquatic flora and fauna should suffice. This is justified because although we are observing what we believe to be reservoir effects on macrophytes and macroinvertebrates, we are not doing an effects assessment. Our goal is to characterize the aquatic vegetation and macroinvertebrate fauna of all sites that are likely to be affected by the implementation of physical works. We recommend a single sampling session in late May or early June, prior to inundation, be conducted in 2013.

2. Continue to collect point samples of abiotic variables (water depth, temperature, pH, dissolved oxygen (DO), etc.). We have deferred our investigation into the influence of abiotic variables on macrophyte and macroinvertebrate community composition and structure until the next implementation year, when the available data set will be larger and more amenable to principal coordinate analysis (PCA), multiple regressions, and other statistical approaches.
3. Sampling should only be continued at those sites that will be potentially affected by the implementation of physical works. For 2013 we recommend that sampling continue at Airport Marsh, Montana Slough, Cartier Bay, and Lower Inonoaklin Road. Beaton Arm should be dropped from the study because physical works are not proposed for this site.
4. Continue with mapping of the areal extent of macrophyte communities within each of the study sites so that their growth or reduction can be monitored following the completion of the physical works projects.
5. Obtain additional depth data to improve the bathymetric maps produced for Montana Slough and Cartier Bay. The collection of bathymetric data will continue to be a component of the study, and it is expected that the bathymetric maps for these sites will continue to improve as additional data are collected. Understanding the bathymetry of the wetlands will help to better define the boundaries of vegetation communities as well as allow for a more complete understanding of the physiological parameters of the wetlands.
6. Put greater effort into mapping the boundaries of Airport Marsh and developing a bathymetric map for this wetland. The complexity and size of this wetland have presented challenges in developing an accurate bathymetric map and precisely delineating the wetted perimeter of the wetland. During future survey sessions, more effort should be put into these two components of the study.

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