Columbia River Project Water Use Plan

Kinbasket Reservoir Fish & Wildlife Information Plan

Revelstoke Reservoir Macrophyte Assessment

Implementation Year 2

Reference: CLBMON-55

Revelstoke Reservoir Macrophyte Assessment – Phase 2

Study Period: September 2014 to October 2014

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Revelstoke Reservoir
Macrophyte Assessment Program

Phase 2 (Year 5)

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EXECUTIVE SUMMARY

On behalf of the British Columbia Hydro and Power Authority (BC Hydro), G3 Consulting Ltd. (G3) was retained to complete a macrophyte monitoring program to evaluate potential incremental impacts of operating a fifth generating unit (REV5) at the Revelstoke Dam, located 5 km north of Revelstoke, BC. The overall program was comprised of two phases. Phase 1 was a baseline investigation, completed in 2009, prior to REV5 operation and Phase 2 (2014) involved follow-up field assessments (post REV5 start-up). High resolution SPOT satellite imagery and Normalized Difference Vegetation Index (NDVI) algorithms were used in conjunction with ground-truthing at ten long-term monitoring sites to map and compare (pre- and post) macrophyte community size, composition and spatial locations in Phase 1 and Phase 2.

In December 2010, REV5 became operational. Average monthly water elevation in Revelstoke Reservoir was 572.55 m prior to operation while average post REV5 operation levels were lower by 19 cm (572.36 m). In general, the observed macrophyte species in Revelstoke Reservoir were similar between Phase 1 and Phase 2. Reduced water elevations in the reservoir appear to have influenced relative abundance of those macrophytes more tolerant to lower water levels and those capable of improved growth under such conditions (e.g. *E. acicularis*). As such, the ability of macrophytes to adapt to changes in water level suggests that the overall macrophyte communities observed in Revelstoke Reservoir were not notably impacted by REV5 operation.

<table>
<tr><th colspan="4">Summary of Objectives and Results</th></tr>
<tr><th>Objectives</th><th>Management Hypotheses</th><th>Management Questions</th><th>Results</th></tr>
<tr><td rowspan="5">• assess the biodiversity of aquatic macrophytes at established long-term study sites;
• map the overall distribution of macrophyte communities.</td><td rowspan="5">H_0: Implementation of normal post-REV5 operations does not result in measurable impacts on aquatic macrophytes distributions and biodiversity in Revelstoke Reservoir.</td><td>1. What are the diversity and distribution of macrophytes in Revelstoke Reservoir?</td><td>1. All seven (7) species of aquatic macrophytes observed in Phase 1 were also observed in Phase 2: Potamogeton amplifolius, Potamogeton alpinus, Potamogeton foliosus, Eleocharis acicularis, Nitella sp., Myriophyllum spicatum, and Ranunculus aquatilis.
In Phase 1, Potamogeton amplifolius was found to be dominant at down reservoir sites (Sites 1 to 4), where it is generally deeper, and Nitella sp. was dominant at up reservoir sites (Sites 8 to 11), where it was generally shallower. In Phase 2 (2014) similar trends were noticed for Potamogeton amplifolius (dominant at Sites 1 and 2) and Nitella sp. (dominant species at Sites 8 and 9), and Eleocharis acicularis observed as dominant at Sites 10 and 11.
In Phase 2, P. amplifolius, a species that prefers deeper water, was observed to have moved to lower elevations at several down-reservoir sites (Sites 2 and 5 and potentially 3 and 4). Species that do well in shallow and disturbed areas such as E. acicularis were observed to have increased in relative abundance within many near-shore zones in Phase 2.</td></tr>
<tr><td>2. Did changes in reservoir drawdown and frequency, due to fifth-unit (REV5) operation at Revelstoke Dam, have any impact on aquatic macrophytes in Revelstoke Reservoir?</td><td>2. Average monthly water elevation in Revelstoke Reservoir (August 1984 to February 2010) was 572.55 m while post REV5 operation levels (December 2010 to December 2014) were lower (572.36 m). There was some evidence to suggest that reduced water elevations in the reservoir, post REV5, influenced relative abundance of certain species (e.g., E. acicularis).</td></tr>
<tr><td colspan="2">Should potential impacts be confirmed, other management questions also include:</td></tr>
<tr><td>3. Which species of aquatic macrophytes were most likely (if at all) affected by the operation of REV5?</td><td>3. In Phase 1, E. acicularis was observed at four (4) long-term study sites (Sites 5, 7, 10 and 11). These sites were potentially influenced by low drawdown and it was anticipated that low drawdown might increase distribution of this species where water regulation restricted other species growth (i.e., reducing inter-species competition). In Phase 2, E. acicularis was the most dominant species and observed at 2 additional sites (Site 1, 5, 7, 8, 10 and 11) suggesting that conditions were more favourable for E. acicularis post REV5, reflective of lower average water level elevations.</td></tr>
<tr><td>4. What are the best mitigating strategies to minimize any impact to aquatic macrophytes?</td><td>4. Overall, the same macrophyte species were observed in Revelstoke Reservoir between Phase 1 and Phase 2; however, some macrophyte species tend to be more tolerant to lower water levels and others showed improved growth under such conditions. The ability of macrophytes to adapt to changes in water level suggested that the overall macrophyte communities observed in Revelstoke Reservoir were not substantially impacted by REV5 operations.</td></tr>
</table>

1.0 INTRODUCTION

On behalf of the British Columbia Hydro and Power Authority (BC Hydro), G3 Consulting Ltd. (G3) was retained to complete a macrophyte monitoring program to evaluate potential incremental impacts of operating a fifth generating unit (REV5) at the Revelstoke Dam, located 5 km north of Revelstoke, BC. The overall program was comprised of two phases. Phase 1 was a baseline investigation, completed in 2009, the year prior to REV5 operation. Phase 2, presented in this report, involved follow-up field assessments conducted in September through October, 2014 (subsequent to REV5 commissioning).

The investigation outlined in this report was developed as part of a hypothesis-driven, Multiple Before-After, Control-Impact-Paired (MBACIP) statistical design, which accounted for confounding influences posed by the dynamic and heterogeneous nature of the reservoir and natural spatial and temporal variability posed by both natural phenomena and anthropogenic activities. This comparative investigation examined current and past conditions of the reservoir and associated macrophyte communities in an effort to map and compare surface area, composition and spatial location using high-resolution satellite imagery (Section 2.5.1) with ground-truthing to verify and attenuate a predictive algorithm (Section 2.5.5). Polygons generated from 2009 spectral data (baseline) were compared directly with those generated in 2014 to assess changes in size and distribution of macrophyte communities. Further, whole-reservoir modeled spectral data was compared between years to assess potential changes in community composition and vigour as outlined in the management questions and objectives posed for the project.

This report provides interpretive text and tables (Chapters 1 through 5), references and appendices. This chapter (Chapter 1) outlines study objectives for the Vegetation Monitoring Program and summarizes important information on Revelstoke Dam, general reservoir characteristics and ecology and the general study area. Chapter 2 provides an overview of the study design and methodology for field and laboratory work. Chapter 3 provides general study results and Chapter 4 a discussion of results. A summary and recommendations are provided in Chapter 5 with references and literature cited in Chapter 6.

Appendices provide figures (Appendix 1), photographs (Appendix 2), summary charts (Appendix 3), summary tables (Appendix 4), ecological characteristics of observed macrophytes (Appendix 5), the *Safety Management Plan* (Appendix 6) and a sample of field forms used (Appendix 7). Photographic meta data and excel spreadsheet of field data were provided as an Annex to this report.

1.1 Study Objectives

To meet the growing demand for clean power at a reasonable cost and to push BC closer to becoming self-sufficient for its power needs, BC Hydro installed of a fifth turbine unit (REV5) at the Revelstoke Dam. As part of the BC Hydro application to install the REV5 generating unit, a joint Environmental Impact Assessment (EIA; BC Hydro, 2006) and Columbia River Water Use Plan (WUP; BC Hydro, 2005) review was undertaken. These reviews resulted in amendments to the BC Comptroller of Water Rights (2007) order to implement the Columbia WUP, as specified in the Revelstoke Unit 5 Core Committee report (Core Committee, 2006) and WUP Addendum (BC Hydro, 2007). While these amendments did not include any operational constraints, they emphasized the need for addition physical works and monitoring programs, in lieu of operational changes. Due to a lack of information regarding potential impacts associated with REV5 operation on Revelstoke Reservoir macrophyte communities, as well as the general concern expressed during the consultative process, a pre- and post-project assessment of macrophytes was recommended, and subsequently approved, to verify predictions of low impact. This Phase 2 report provides post-project assessment results and discussion.

A number of objectives and management questions were established prior to commissioning the 2009 Macrophyte Assessment Program. Study design and field methodologies were specifically designed to achieve study-specific objectives and answer management questions. Objectives of the Revelstoke Reservoir macrophyte survey during Phase 2 were to:

- assess the biodiversity of aquatic macrophytes at previously established Phase 1 long term study sites; and,

- map the overall distribution of macrophyte communities.

Key management questions for both Phase 1 and Phase 2 included:

- what are the diversity and distribution of macrophytes in Revelstoke Reservoir prior to and subsequent to the fifth-unit (REV5) operation; and,
- did changes in reservoir drawdown and frequency, due to fifth-unit operation at Revelstoke Dam, have any impact on aquatic macrophytes in Revelstoke Reservoir?

Should potential impacts be confirmed, other management questions also included:

- which species of aquatic macrophytes were most likely (if at all) affected by the operation of REV5; and,
- what are the best mitigating strategies to minimize any impact to aquatic macrophytes?

1.2 Background & Project Rationale

Completed in 1984, Revelstoke Dam was originally designed as a six turbine unit facility, with units 1 to 4 currently in operation, providing the dam with a generating capacity of 1,980 MW. Revelstoke Reservoir was created in 1984 following completion of the Revelstoke Dam. The impounded area is a 129 km long section of Columbia River system, down reservoir of the Mica Dam and up reservoir of the Revelstoke Dam and Hydroelectric Generation Station. It is a narrow, deep, cold water body with generally low biological productivity (see Section 1.2.1 for further details).

The system generally flows north to south and is licensed to store 1.5 million acre feet (MAF). Revelstoke Reservoir has a surface area of approximately 11,530 ha and a corresponding volume of approximately 5,300 x 10^6 m^3 at a Maximum Normal Reservoir Level (MNRL) of 573.0 m (BC Hydro, 1999a; Hirst, 1991). In addition, the reservoir has a mean and maximum depth at forebay of 46 m and 125 m, respectively, and a mean water retention time of 75 days.

Revelstoke Reservoir is normally kept within 1.5 m of the maximum elevation (573.0 m) throughout the year by regulating output at the Mica Dam (into Revelstoke Reservoir) and Revelstoke Dam (BC Hydro, 1999b; RL&L, 1994). Although drawdown is rarely below an elevation of 571.5 m, weather-related emergencies (e.g., uncharacteristically dry summer) may occasionally result in water elevations as low as 568.8 m. Further, there is a maximum potential drawdown of 15.2 m (i.e., El. 557.8 m) following prolonged periods of basin drought or outage at the Mica Powerhouse (BC Hydro, 1998). Maximum drawdown tends to occur between May and the end of July (Axys and RL&L, 1995).

The addition of REV5 increased total capacity of the dam by 500 MW from 1,980 MW to 2,480 MW (BC Hydro, 2007). The operating range of Revelstoke Reservoir, after REV5 installation, was projected to be the same as pre-installation conditions, with reservoir fluctuations at the start of REV5 operations estimated to be less than 0.25 m, >90% of the time (BC Hydro, 2006). Based on a comparison of average daily elevations for the reservoir, the frequency of moderate drawdowns (i.e., drafting to approximately 572.5 m or by 0.5 m) was expected to be greater with five operating units than with four units; however, the frequency of low drawdowns (i.e., drafting to ≥571.5 m or by 1.5 m) was expected to be less frequent (BC Hydro, 2006).

In December 2010, the REV5 turbine became operational. Average monthly elevation levels in Revelstoke Reservoir from August 1984 to February 2010 were 572.55 m while post REV5 operation average monthly elevation levels from December 2010 to December 2014 were 572.36 m. Average daily Revelstoke Reservoir water elevation was 572.55 m during Phase 1 field work (September 28 to October 3, 2009) while average daily water elevation was 572.83 m during Phase 2 field work (September 30 to October 4, 2014). Daily and monthly Revelstoke Reservoir average water elevation, from January 1984 to December 2014, is provided in Chart 2-1 and Chart 2-2, Appendix 3.

1.2.1 Reservoir Characteristics

Reservoirs are typically described as occupying intermediate positions between rivers and natural lakes on a continuum of aquatic ecosystems (Kimmel and Groeger, 1984). River-flooded reservoirs, such as Revelstoke Reservoir undergo fluctuation of water levels associated with drawdown of water for hydroelectric power generation.

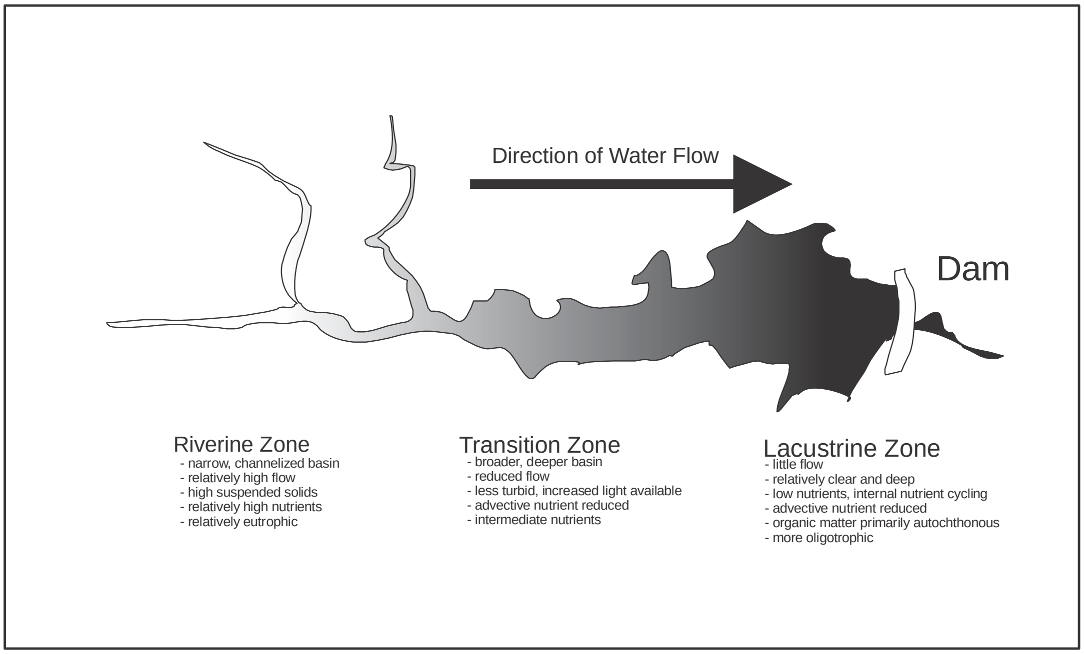
Compared with natural systems reservoirs are, in general, characterized by a large shore development ratio (SDR), dendritic shorelines (many-branched and convoluted), V-shapes bottom profiles, short retention times, large barren and unstable drawdown zones, high spatial and temporal heterogeneity, unidirectional flow and serial zonation, shorter lifespan and high allochthonous sediment loading due to high watershed-to-lake area ratio (Lind *et al.*, 1993; Straskraba *et al.*, 1993; Straškrábová *et al.*, 2005). The euphotic zone in reservoirs is usually only a few metres deep (Morris and Jiahua, 1998). Sediment inflow and re-suspension of bottom sediments by wave action can increase water turbidity, most notably up reservoir.

Reservoirs are influenced by climatological, hydrological and anthropogenic parameters, with the degree of response depending on the size and volume of reservoirs and varying proportionately to the magnitude of environmental parameters. The different uses of reservoirs and their watersheds may have an impact on water quality, and thus, on aquatic life.

Reservoirs can typically be divided into three regions (Figure 1-1):

- **Riverine Zone:** the region of a reservoir where the types of processes (e.g., bank erosion, water flow, sedimentation) occurring are more comparable to a river than a lake. This zone is characterized by narrow geometry, shallow waters, significant flow velocities and the transport of silts and clays (Morris and Jiahua, 1998). Allochthonous (i.e., external) organic material predominates in this zone; however, water remains well-oxygenated due to low depths. Water transparency can be reduced by high sediments loading from rivers or high primary productivity (e.g., algae blooms caused by high nutrient inputs from rivers). Many of the original riverine invertebrate and fish species persist. Excessive silting may influence bottom living invertebrates that rely on clean, sediment-free conditions;
- **Transition Zone:** headwaters are often dominated or influenced by the riverine inputs to the region. If inflows have a density greater than lacustrine zone surface waters, the inflows will tend to plunge beneath the lacustrine zone surface. Often a “trash line” of floating debris will indicate such a plunge point. If the inflow water is less dense, it will flow over the lacustrine zone surface. If inflow density is greater than the lacustrine zone surface, but less dense than that of the lacustrine zone bottom waters, these flows may extend into the lacustrine zone or perhaps throughout the lacustrine zone. Such interflows are common where plunging inflows attain depths similar to the penstock opening depth on the dam impounding the lacustrine zone. Substantial inflows (e.g., high flows from occasional precipitation events) can greatly influence the lacustrine zone thermal structure. For example, inflows with high (or low) temperatures have the potential to change the thermocline depth and, thus, may be a primary factor influencing the thermal structure of the lacustrine zone; and,
- **Lacustrine Zone:** the deepest region, typically downstream from the transition area, where strictly limnetic processes dominate. This zone extends to the dam and has characteristics similar to lakes (e.g., clearer water, lower sediments loading, stratified water column, organic matter mostly produced by reservoir plankton, primary production limited by nutrients loading rather than lack of light; Morris and Jiahua, 1998). True lacustrine phyto- and zooplankton develop in this zone. Floating vegetation, such as the water fern and the water hyacinth, may form extensive mats covering large areas of the reservoir. Lacustrine insects, such as lake flies (chironomids and chaoborids), also colonize this zone.

Figure 1-1: Reservoir Zonation (adapted from Thornton *et al.,* 1981)



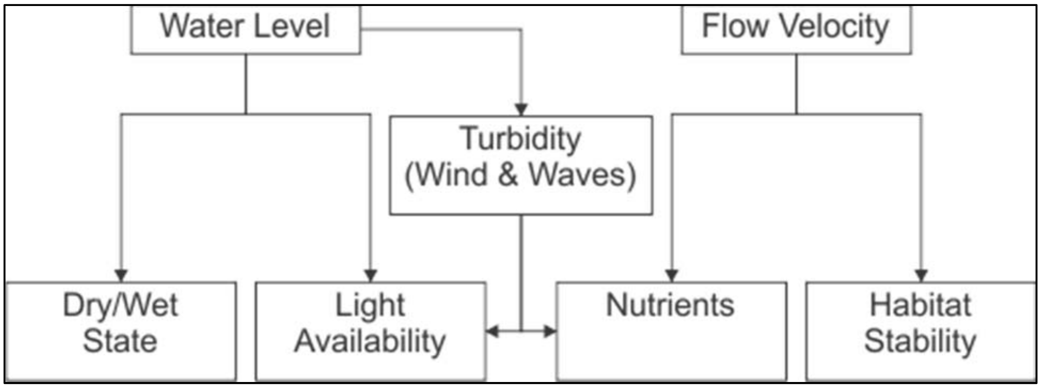
The region in which the lake gradually changes from riverine to limnetic dominance is aptly termed the transition area. This ecotone (i.e., ecological transition) is usually rich and diverse in biota, and dynamic and complex in hydrology. Mixing of riverine and lacustrine waters, when combined with reservoir drawdown cycles and seasonal influences (e.g., winds and related currents, winter freeze-up), result in complicated horizontal and vertical hydrological movements in the transition area. Changing seasonally, these forces produce differences in current and density between riverine and lacustrine waters.

The theoretical retention time of a reservoir is the ratio of reservoir volume to inflow rate. Short retention times prevent significant settling of suspended particles (Cooke *et al.*, 2005). Phytoplanktonic and macrophytic production depends greatly on reservoir retention time, specifically with regards to the settling of organic and inorganic suspended particles present in the water column. When retention time is low (e.g., a few days) and the reservoir is shallow, benthic algae dominate autotrophic production (Hargrave, 1969). In reservoirs with greater retention times, colonization by typical lake flora is favoured.

1.2.2 Reservoirs & Macrophyte Ecology

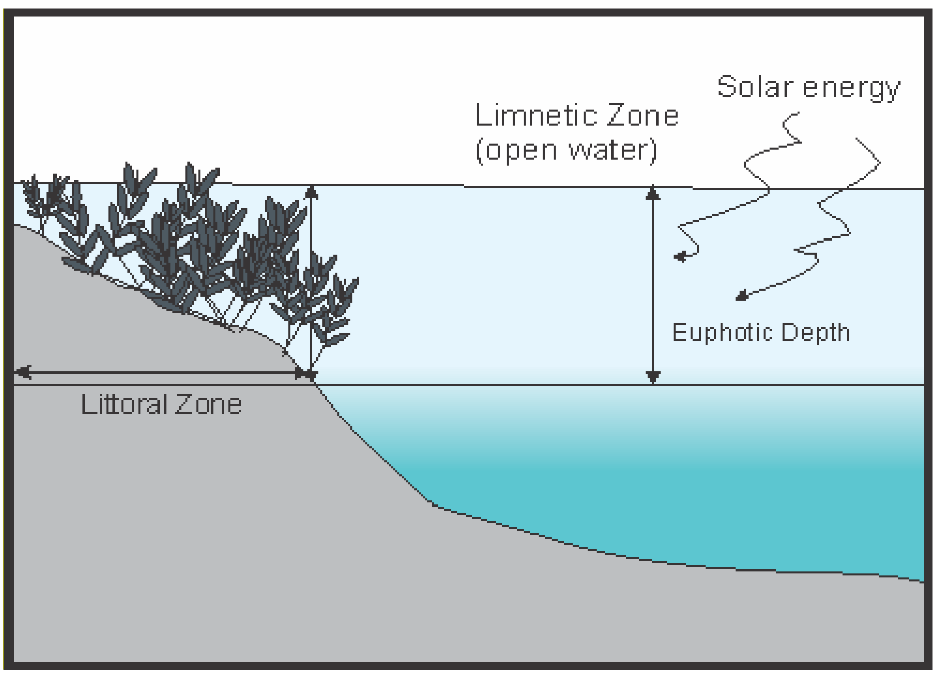
Macrophyte (i.e., emergent, submerged or floating-type plants) communities play an important role in fish and wildlife habitat. Macrophyte communities provide spawning, nesting, nursery and feeding habitat for a variety of organisms (i.e., fish, waterfowl, raptors, ungulates and other large herbivorous mammals, large carnivorous mammals, and small mammals, reptiles and amphibians). Upstream influx of nutrients can generate abundant levels of macrophyte growth which may cover fish habitat, causing decreased dissolved oxygen (DO) levels thereby reducing the quantity and quality of fish habitat (i.e., eutrophication). Macrophytes provide a number of ecosystem services (i.e., water purification, nutrient cycling, etc.) and are of critical importance to supporting fish, zooplankton and invertebrate populations (Cowx and Welcomme, 1998). Aquatic macrophytes are also a source of food for waterfowl, muskrats, beavers and moose (Mitchell and Prepas, 1990). Growth of macrophytes in reservoirs depends on several environmental parameters (e.g., light energy and nutrient availability, water temperature, water level fluctuations, water velocity; Figure 1-2):

Figure 1-2: Environmental Parameters Influencing Macrophyte Growth (Adapted from Stevenson et. al, 1996)



The type of substrate and reservoir slope can also have an impact (positive or negative) on macrophytes growth (Cooke *et al.*, 2005). Nearshore areas (i.e., littoral vs. limnetic, profundal and benthic) are characterized by better light availability and higher risk of desiccation (Figure 1-2) while deeper zones are characterized by lower light availability and higher flow velocity. The highest macrophyte biomass is typically observed in the littoral zone of reservoirs, especially during periods when water levels are constant (Wetzel, 2001).

Figure 1-2: Water Zonation within a Reservoir



Biophysical changes in the littoral zone of reservoirs associated with periodic drawdown and inundation typically have significant effects (positive or negative) on macrophyte development (Wetzel, 1983; Baxter, 1985; Kimmel and Groeger, 1986; Northcote and Atagi, 1997). Macrophyte mobility is very limited with their development depending on environmental parameters in both reservoir water and sediments. Macrophyte species are sensitive to physical and chemical changes in the surrounding environment and are, thus, good indicators of both current environmental conditions and long-term environmental changes.

Water level fluctuations within a reservoir constitute a periodic disturbance regime to the littoral environment. Studies in Canada (Hill *et al.,* 1998) and northern Europe (Rørslett, 1991; Hellsten, 2001) demonstrated that macrophyte diversity was, in general, lower in reservoirs than in non-regulated lakes.

The relationship between macrophyte diversity and disturbance is complex. The intermediate disturbance hypothesis states that species richness within an ecosystem is maximized at moderate levels of disturbance (Ward and Stanford, 1983; Hobbs and Huenneke, 1992). As an example, within a reservoir where disturbances are too rare, the competitively dominant macrophyte species will eliminate other species and reduce diversity. If disturbances are too frequent most species will go extinct due to intolerance of repeat disturbance. Intermediate disturbance may maximize diversity and allow disturbance-tolerant species and competitively dominant species to coexist. Murphy *et al.* (1990) suggested that a modest increase in disturbance had the potential to increase suitable habitats within a reservoir for European aquatic macrophytes. A survey of Scandinavian lakes (Rørslett, 1991) showed that macrophyte richness peaked with drawdown amplitudes of 1 m to 3 m. A similar phenomenon was reported for reservoirs regulated for hydropower in New Zealand where an increase in the range of monthly water level fluctuations appeared to increase biodiversity (Riis and Hawes, 2002). Inundated trees and brush seemed to enhance macrophyte colonization in water bodies with small level fluctuations (Judd and Taub, 1973; Nichols, 1974; Northcote and Atagi, 1997). Complex interactions between changes in water level, substrate, flow regimes and inundated terrestrial vegetation will ultimately determine the distribution and diversity of macrophyte communities within a reservoir. Changes in reservoirs cited above resulting from changes in water use may not be applicable to all reservoirs. Similarly, changes in Revelstoke Reservoir following changes in water use may be attributed to multiple factors within the reservoir.

1.3 Study Area

The Revelstoke Reservoir (Figure A-1, Appendix 1), is located 5 km upstream from the town of Revelstoke in southeastern British Columbia, approximately 641 km northeast of Vancouver and 415 km west of Calgary. Situated on the western edge of Mount Revelstoke National Park, much of the area’s vegetation is characteristic of the Interior Cedar-Hemlock (ICH) Biogeoclimatic Zone, containing a mixture of coniferous, deciduous and mixed forests. The Columbia River valley surrounds the Revelstoke Reservoir and is bounded by the Monashee Mountains (west) and the Selkirk Mountains (east). The steep-sided nature of the valley allows for little development of the littoral habitat. Many of the 41 main tributaries entering the Revelstoke Reservoir are steep, cold and glacial in origin (Triton, 1992). The reservoir is narrow, with average and maximum widths of less than 1 km and 1.2 km, respectively.

The study area for Phase 2 of the Macrophyte Assessment Program included ten previously identified long-term monitoring sites, determined during the Phase 1 study, which span the entire reservoir.

1.3.1 Watershed Land Use

Land use around the Revelstoke Reservoir includes forestry, hydroelectric power generation, recreation, transportation and municipal activities (BC Hydro, 1999b). These types of use represent confounding influences on aquatic vegetation communities and may cause changes in macrophyte distribution throughout the reservoir.

Mica and Revelstoke dams, two sources of hydroelectric power, can influence Revelstoke Reservoir’s flow, thermal and nutrient regimes (Schindler *et al.*, 2007); however, Mica Dam has the greater influence on thermal and nutrient regimes in the entire reservoir, while Revelstoke Dam’s influence is primarily limited to immediately up reservoir of the dam. Mica Dam can also increase dissolved gas levels (TGG, 2008).

Transportation infrastructure includes logging roads, an airstrip, private ferry landing sites, Highway 33 and various minor roads. Forestry activities and transportation corridors can have a negative effect on water quality (e.g., increased sediment inputs to tributary streams and the reservoir, run-off from pesticide applications, changes in nutrient input, effects of watershed nutrient export through log and needle removal and slash burning), as well as potentially altering discharge and thermal regimes. These forest-harvesting activities may also impact macrophyte communities (e.g., through loss of riparian habitat, increased shoreline erosion, reduced input of allochthonous material). Cumulative impacts of forestry and hydroelectric operations at Revelstoke include:

- effects of sediment from forestry roads and cutblocks on macrophyte communities;
- effects of changes in stream temperature due to forest canopy removal; and,
- effects of altered hydrologic regime in logged tributaries.

There are several point source discharges entering the Revelstoke Reservoir (e.g., discharge of secondary-treated sewage from Mica Dam into the tailrace, periodic overflow from the deactivated mine tailing ponds connected to Goldstream River, storm water run-off and culvert discharges) which could affect water quality and macrophyte communities. As the waters of Revelstoke Reservoir are nutrient poor (classified as ultra-oligotrophic), the input of additional nutrients from treated sewage may, in part, mitigate the loss of nutrients within the impoundment, which functions as a sediment and nutrient sink. The periodic overflow of deactivated mine tailing ponds to Goldstream River could also potentially increase metals entering Revelstoke Reservoir. Many aquatic plants are capable of assimilating heavy metals from water and soil, with some metals exercising a large role in growth and development (e.g., Fe, Mn, Zn, Cu, Mo, Ni). Certain plants can also accumulate metals which do not have high biological significance (e.g., Cd, Cr, Pb, Co, Se, Hg); however, excessive concentrations of heavy metals can be toxic to most plants (Peterson, 1983, 1993; Salt *et al.*, 1995; Lasat, 1996; Rascio, 1997).

1.3.2 Fisheries

The Revelstoke Reservoir supports a healthy fish community, including Kokanee (*Oncorhynchus nerka*), rainbow trout (*O. mykiss*), mountain whitefish (*Prosopium williamsoni*), burbot (*Lota lota*) and populations of Blue-Listed bull trout (*Salvelinus confluentus*). Reservoir limnology has not been very well documented since impoundment in 1984. Limited studies have been conducted through the Columbia Basin Fish and Wildlife Compensation Program (CBFWCP), a joint initiative between BC Hydro and the BC Ministry of Environment, which included assessments of reservoir productivity, fish enumeration and spawning surveys (CBFWCP, 2004).

Table 1-1: Revelstoke Reservoir Fisheries Resources

Common Name	Latin Name	Conservation Status
Sport Fish		
Kokanee	*Oncorhynchus nerka*	No Status
Rainbow Trout	*Oncorhynchus mykiss*	No Status
Bull Trout	*Salvelinus confluentus*	Provincial Blue Listed
Mountain Whitefish	*Prosopium williamsoni*	No Status
Burbot	*Lota lota*	No Status
Non-Sport Fish		
Northern Pikeminnow	*Ptychocheilus oregonensis*	No Status
Largescale Sucker	*Catostomus macrocheilus*	No Status
Peamouth Chub	*Mylocheilus caurinus*	No Status
Longnose Sucker	*Catostomus catostomus*	No Status
Sculpin	*Cottus sp.*	No Status
Redside Shiner	*Richardsonius balteatus*	No Status

1.4 Summary of Phase 1 (2009)

The 2006 Phase 1, baseline study was conducted by G3 Consulting Ltd. in 2009 (G3, 2010). Aerial reconnaissance, satellite imagery and Normalized Difference Vegetation Index (NDVI) and ground truthing were used to assess macrophyte distribution in the reservoir. Site assessments were conducted throughout the reservoir (September 28 to October 3, 2009). Eleven long-term study sites were originally selected spanning the reservoir from the southern portion near Revelstoke Dam to the northernmost up reservoir end, near Mica Dam. Site 6 was found to be unsuitable for further study, given its morphology, and the means by which this site was surveyed, which limited its utility in Phase 2. The mean surface water elevation of the reservoir had a range of 20 cm during the field survey (from 572.5 m [September 29, 2009] to 572.7 m [October 2, 2009]).

Macrophyte communities at the ten (10) long-term study sites (excluding Site 6) ranged in size from 0.23 ha (Site 10) to 5.91 ha (Site 8). Polygons detected by prior NDVI modeling at six of the eleven selected study sites were found to have comparable areas to those observed *in situ*. Post survey, the NDVI algorithm was attenuated to increase the predictive accuracy of the model.

Attenuating the NDVI model allowed for improve accuracy of predictions. By comparing NDVI pixel values at specific waypoints within the study sites with observed *in situ* communities at the same waypoints, it was possible to determine the NDVI digital number threshold where macrophyte communities were found to be present *in situ*. Similarly, waypoints where macrophyte communities ended or were not present were confirmed by visual observation and digital number values at these waypoints were used to define the boundaries of NDVI macrophyte community predictions.

The baseline study identified seven macrophyte species at the ten long-term study sites (i.e., *Eleocharis acicularis*, *Myriophyllum spicatum*, *Nitella sp*., *Potamogeton alpinus*, *Potamogeton amplifolius*, *Potamogeton foliosus*, *Ranunculus aquatilis*). Sites located in the southern half of the reservoir (down-reservoir) were dominated by *Potamogeton amplifolius* and *Nitella sp*. dominated sites located in the north half of the reservoir (up-reservoir). Two species (*Potamogeton foliosus* and *Ranunculus aquatilis*) were only observed at one site each. *Myriophyllum spicatum (*Eurasian milfoil) was observed sporadically (Sites 1 and 5) and likely introduced through public boat launches. *Equisetum palustre* was observed at Site 6 in Phase 1; however, the site was found to be unsuitable for further study in Phase 2, given its morphology.

Table 1-2: Phase 1 Macrophyte Taxa

Scientific Name	Common Name	Sites Identified
Potamogeton amplifolius	large-leaf pondweed	1, 2, 3, 4, 5, 7, 8
Potamogeton alpinus	northern pondweed	1, 2, 8, 9,10
Potamogeton foliosus	leafy pondweed	8
Eleocharis acicularis	needle spikerush	5, 7, 10, 11
Nitella sp.	nitella sp.	1, 2, 3, 5, 8, 9, 10, 11
Myriophyllum spicatum	Eurasian watermilfoil	1, 5
Ranunculus aquatilis	white water crowfoot	3

Sediments and water quality were comparable throughout the reservoir; however, sediments were disturbed nearest creek confluences. Water temperature decreased with increasing distance up reservoir from the Revelstoke Dam.

Recommendations for subsequent surveys (e.g. Phase 2) included finding ways to improve the accuracy of the image processing used during Phase 1. Higher spectral resolution satellite images were obtained for Phase 2 work to decrease the percent (%) error associated with the image analysis. Additionally, macrophyte boundaries and percent (%) cover estimates were conducted using visual assessments, sampling tools (i.e. macrophyte sampling rake and aquatiller) and a depth sounder where community boundaries were not visible from the surface of the water. To reduce error in areas where communities could not always be distinguished, a drop camera was recommended (and used) in Phase 2 to better delineate macrophyte community boundaries and estimate per cent (%) macrophyte cover.

2.0 STUDY DESIGN & METHODS

The Revelstoke Reservoir Macrophyte Assessment Program adopted a MBACIP (Multiple Before-After, Control-Impact-Paired) statistical design to assess potential spatial and temporal effects on reservoir macrophyte communities associated with the installation and operation of a fifth generating unit (REV5). The MBACIP design used multiple impact and control sites, assessed over time (Downes *et al.*, 2002). Phase 1 (2009) of this Macrophyte Assessment Program was the first component in which baseline data was established for comparison to Phase 2 (2014).

Pre-field tasks for Phase 2 work included summarizing existing information, developing a site-specific *Safety Management Plan*, scheduling (i.e., tasking) satellites and obtaining required imagery, then preparing base maps of each of the long-term study sites.

After several repeated attempts, the French satellite SPOT (Satellite Pour l'Observation de la Terre) successfully collected high-resolution, multiple bandwidth (colour spectrum) images of the Revelstoke Reservoir on September 11, 2014. Satellite data collected were subsequently used to generate NDVI (Normalized Difference Vegetation Index) and FCC (False Colour Composite) base maps.

A main objective of the Revelstoke Reservoir Macrophyte Assessment Program was pre- (Phase 1) and post-assessment (Phase 2) of macrophytes potentially affected by REV5 commissioning. Remote satellite sensing was used as a means to identify the size and presence of aquatic vegetation communities with time in the reservoir (i.e., compare satellite data collected at different times to track changes in macrophyte community size and presence over time). To this end, *In situ* vegetative community assessments and ground truthing were conducted from September 30 to October 4, 2014 to verify satellite map accuracy in Phase 2. Results of these assessments were then used to attenuate NDVI classification ranges in which macrophytes were found throughout the reservoir and produce a predictive macrophyte algorithm for the reservoir. Macrophyte communities observed on the Phase 1 (2009) and Phase 2 (2014) satellite maps were then compared and assessed for potential changes between Phases.

Methodologies employed during office and baseline assessments followed those developed by G3 on other environmental and macrophyte assessment programs, those specified in the original Request for Proposal (RFP) and those of the provincial Resource Inventory Committee (RIC, 1997).

2.1 Start-up Meeting & Communications

Prior to commencement of office and field activities, a project start-up meeting was convened by telephone (June, 2014). This meeting reviewed the scope of work (e.g., project objectives, budget, timing, methods/approach), discussed environmental and safety planning and introduced project participants and responsibilities.

2.2 Pre-Field

Pre-field assessments were completed to familiarize personnel with the subject area and to develop an *Operational Workplan* and a *Site Specific Safety Management Plan* required for Phase 2 assessments. Pre-field assessments included:

- summary of relevant existing information;
- review of current and historical satellite imagery, and site maps;
- acquiring high resolution satellite imagery (SPOT 6);
- development of classification algorithms and False Colour Composite (FCC) imagery (Section 2.2.2);
- development and approval by BC Hydro of the *Workplan*; and,
- development and acceptance by BC Hydro of a site-specific Revelstoke Reservoir *Site Specific Safety Management Plan* in accordance with criteria stipulated (i.e., *BC Hydro Water License Requirement Safety Requirements*).

2.2.1 Summary of Existing Information

Relevant available information on macrophytes in Revelstoke Reservoir, including Phase 1 (e.g., species list, relative abundance, contributing factors, distribution, etc.) was reviewed. Phase 2 field surveys, presented herein, were conducted in 2014 and conducted as a follow-up to the 2009 baseline assessment (Phase 1). Polygons generated from the Phase 1 (2009) spectral data (baseline) at both long-term study sites and for the entire reservoir were assessed and prepared for comparison to assess any potential changes in size, distribution and composition of macrophyte communities in Phase 2.

As part of the review process, historic reports on similar reservoirs in the area, such as the Arrow Lakes and Revelstoke reservoirs were reviewed. Information was obtained from grey and peer reviewed literature, queries to agencies (i.e., BC Hydro, BC Ministry of Environment) and consultant reports. Meta-analysis synthesized data from various sources and developed a historical background profile and current trend analysis.

2.3 Field Work

Field assessments of submerged and emergent aquatic vegetation at Revelstoke Reservoir were to be conducted in two phases:

Phase 1: Year 1 (2009) Baseline Assessment (G3, 2010); and,

Phase 2: Year 5 (2014) Final Vegetation Assessment (2014 study).

Year 1 (2009) field activities were conducted by G3 Consulting Ltd. between September 28 to October 3, 2009 and are described in detail in G3 (2010) and summarized in Section 1.4 of this report.

Year 5 (2014) field activities at Revelstoke Reservoir (this report) were conducted from September 30 to October 3, 2014 with detailed methodology described herein. Field activities were conducted in accordance with the *2014 Operational Workplan* provided to BC Hydro in advance of field work.

2.3.1 Research Vessel

A 6.7 m aluminum river boat with a 340 hp inboard jet drive engine (Photo 61, Appendix 2) was used to conduct field studies and was launched from various entry points along the eastern shoreline of the reservoir. The vessel was transported using a single axle EZ-load trailer, rated for highway transport and compliant with Transport Canada regulations. The boat was equipped with an emergency kit that included six life jackets, a survival kit, flashlights, a bail bucket, two oars, a rope, a life ring, flares and a VHF radio.

2.3.2 Revelstoke Reservoir Safety Management Plan

Prior to conducting assessments, G3 developed a project-specific *Safety Management Plan* in accordance with BC Hydro safety protocols. The *Safety Management Plan* (Appendix 6) included detailed protocols on:

- radio and communication;
- job hazards;
- field emergencies;
- Emergency Action Plans;
- water rescue;
- field mobility and activities (i.e., boat safety);
- field check-in procedures; and,

- emergency and program contacts (e.g., local fire, SAR, police, medical, BC Hydro, G3, etc.).

The *Safety Management Plan* was submitted to, and subsequently accepted by, BC Hydro prior to field crew deployment and followed BC Hydro Standard Operating Procedures (SOPs) and Occupational Safety and Health (OSH) guidelines.

2.3.3 Study Sites

Study sites were selected based on long-term study sites identified during Phase 1. In Phase 1 eleven study sites were selected and located throughout the reservoir (Figure A-1, Appendix 1). Ten of the eleven sites were chosen as long-term monitoring sites for continued assessment in Phase 2. Site 6 was removed prior to Phase 2 as it was found to be unsuitable for further study given its morphology (located in a highly convoluted and embayed area), and the means by which the site was surveyed (all three transects converged to a single point in Phase 1), which also limited its utility in Phase 2.

In Phase 1, long-term sites were chosen to be representative of various types of areas of the reservoir (e.g., undisturbed, located near creek confluences or exposed to anthropogenic activities). Given the recognized spatial zonation of the reservoir, and associated spatial distribution of macrophytes within these, a south-north, systematic gradient approach was used for site selection. In Phase 2, each of the long-term study sites were revisited and the macrophyte communities reassessed.

Reservoir elevation was higher in Phase 2 than in Phase 1 by 0.28 m and all sites were inundated to the high high water mark. Survey work was conducted from the research vessel at all sites in Phase 2. GPS coordinates, maps produced during Phase 1 and previously established site boundaries and transect markers were used to orient the field crew during Phase 2.

2.3.4 Site Layout

Site boundaries and transect points of commencement (POCs) were based on Phase 1 assessments and marked with flagging tape. Locations of all boundaries and markers were recorded using the Garmin GPS.

POCs were situated at the HHWM. The centre transect POC of each site was positioned equidistant from the northern and southern (or eastern and western) extents and measured using the Garmin GPS. Outer transect POCs were placed equidistant from the Centre POC and the corresponding site boundary (i.e., northern extent for north transect). Transects at each site were run parallel to each other (along established compass bearings) to prevent crossover and ensure comparability of communities obtained from quadrat sampling. Transect orientations are discussed in further detail in subsections below.

Three sample plots were established along each transect representing three separate ecological zones, associated with distance from the high-high water mark, visual observation of plant communities and depth. Ecological zones sampled at each study site were (Figure 2-1):

1. Near High-High-Water-Mark (HHWM; Zone A);
2. Mid-Distance from HHWM (Zone B); and,
3. Far from HHWM (Zone C).

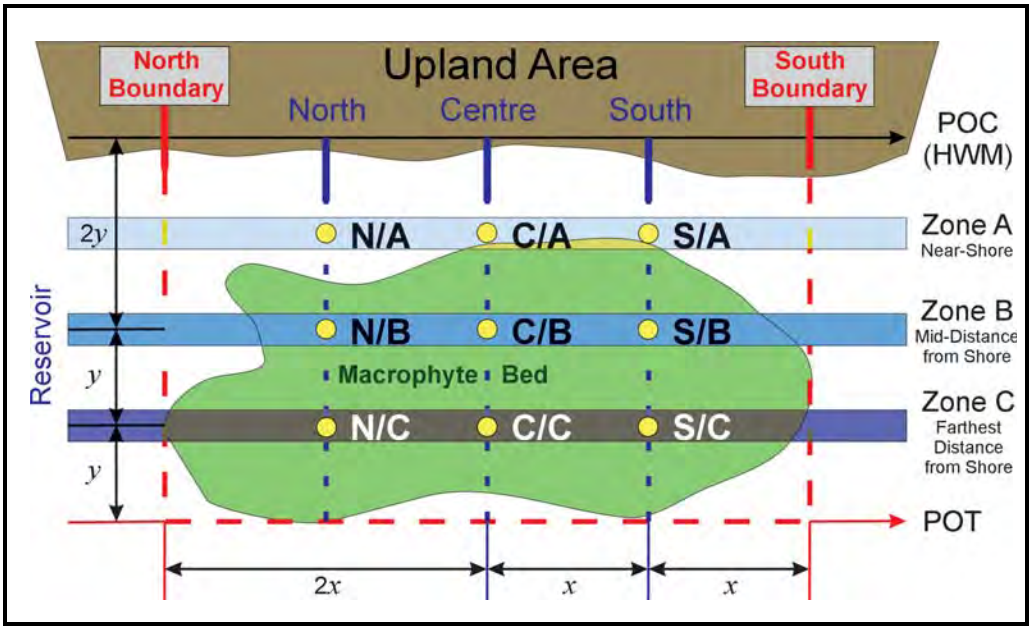
Sites were divided into quartiles as follows and illustrated in Figure 2-1. Zone B was established at the mid-point between the HHWM (i.e., POC) and the farthest point from shore where macrophytes were observed (i.e., Point of Termination [POT]. Zone A was set equidistant between B and the HHWM, and Zone C was equidistant between B and POT. Sites were comprised of nine 1 m^2 sample quadrats.

Table 2-1: Quadrat Distribution			
	North (or West)	**Centre**	**South (or East)**
Near HHWM (Zone A)	N(W)-Near	C-Near	S(E)-Near
Mid-Distance from HHWM (Zone B)	N(W)-Mid	C-Mid	S(E)-Mid
Far from HHWM (Zone C)	N(W)-Far	C-Far	S(E)-Far

HHWM – high high water mark

UTM coordinates for each sample plot were recorded using GPS and waypoint numbers recorded into field notes.

Figure 2-1: ***Example Layout Schematic for Macrophyte Site Surveys***



2.3.5 Drop Camera Macrophyte Boundary Assessments

At the end of Phase 1 it was recommended that a drop camera be used to reduce error in deeper and/or more turbid water where macrophyte communities could not always be distinguished visually from the surface. The drop camera helped provide a continuous view of the macrophyte bed and allowed for a more accurate assessment of macrophyte community boundaries and estimate per cent (%) macrophyte cover. Boundaries of the macrophyte communities were delineated using strategic underwater viewing with a drop camera, digital Lowrance LCX-15MT depth sounder and a Garmin GPSmap60Cx (Garmin GPS).

The drop camera was connected to a video monitor and lowered to the reservoir bottom for a real time video feed of substrate and any associated macrophyte communities. The research vessel then slowly traversed the study site in a grid formation. Several passes were made parallel to the shore (each pass progressively farther to shore than the last) until macrophytes were no longer detected and reservoir depth increased beyond suitable macrophyte growth range (depth in metres). Subsequent passes were made perpendicular to shore at several locations across the site. Location of all observed macrophyte communities and corresponding depth and distance to shore were recorded in project specific notebooks and macrophyte communities boundaries marked with a GPS device.

In Phase 1, visual estimates of macrophyte coverage was possible at most sample plots (only four sample plots couldn't be visually estimated due to depth and/ or poor visibility). A depth sounder was also used to help delineate macrophyte communities located in deeper areas which were present, though not visually observed from the boat or via satellite. As such, these differences in technology between Phase 1 and Phase 2 likely did not have notable bias on macrophyte coverage results.

2.3.6 Bathymetry

Simultaneous to drop camera surveys, a digital Lowrance LCX-15MT depth sounder, interfacing directly to an Omnistar differentially corrected DGPS receiver (measured in UTM coordinates, NAD83, Zone 11U), was used to record bathymetry of each site. The sounder was used to record depth, as well as help check for presence of submerged macrophytes and determine relative substrate condition and bottom slope. Information was stored in real-time and correlated with real-time collection of differentially-corrected GPS data. Bathymetric images of long-term monitoring sites were collected to enable comparative analysis between Phase 1 and Phase 2.

2.3.7 Collection of Biological & Physical Data

The main biophysical components assessed at each monitoring site were macrophyte communities (i.e., community distribution, diversity and abundance, delineation of community types, and estimated percent (%) cover). In addition *in situ* water quality (including: depth [m], temperature [°C], conductivity [uS/cm], pH, Oxidation Reduction Potential [mV] turbidity [FNU] and dissolved oxygen [mg/L]) and general sediment characteristics were taken where possible.

Distribution and size of macrophyte communities detected at the ten long-term monitoring sites were delineated using NDVI and FCC multispectral analysis on SPOT imagery. Predictions were assessed in comparison with Phase 1 *in situ* observations and used to aid in identifying macrophyte communities in Phase 2 field work. Each site was traversed by boat along transects running from shore to the site boundary from the northern most to southernmost extent of the site as mapped in Phase 1, and a drop camera was used to identify macrophyte communities. Where the community extended past the boundary of the Phase 1 site, observation continued until the end of the macrophyte community was observed. Community locations were recorded with GPS waypoints and used for post field comparison and NDVI calibration.

2.3.7.1 Macrophyte Collection

Physical collection of macrophytes from quadrats employed two different methods and was dependent on whether communities were submerged or emergent:

1. *Macrophyte Sampling Rake:* used in all submerged 1m^2 quadrats. The macrophyte sampling rake consisted of two standard 0.5 m wide metal garden rakes bolted back to back with tines facing outwards and weighted at the collection end (Photo 63, Appendix 2). Braided nylon rope was fastened to the handle for easy deployment and retrieval; and,

2. *Direct Observation and Removal:* used for very shallow quadrats, field personnel used trowels, and handheld garden rakes to remove macrophytes and root structures from quadrats for preservation and identification.

Over deeper sample plots, the drop camera was used as an initial check to determine if submerged macrophytes were present at that location. If observed and not be immediately identifiable, the primary collection method employed was the macrophyte sampling rake. The rake was lowered onto the sampling plot and dragged for one linear meter. This procedure was repeated three times within each quadrat regardless of whether macrophytes were collected.

Once successfully collected, macrophyte specimens were brought to the surface, removed from the sampling device and placed in pre-labeled sample containers (specific to transect point) for processing. A small amount of site water accompanied each sample to prevent desiccation of macrophytes. Preliminary identification was completed *in situ* to establish relative densities within each quadrat and to ensure that at least one specimen of each species was retained from each study site.

Representative plant specimens from each plot were labeled and placed in a project-specific plant press and dried. Specimens included stem, leaves and reproductive structures (when present). Specimens were labeled according to site, transect, quadrat, depth and date. Photos were taken of each new species collected at a site and of each specimen prior to pressing. Observations were recorded in G3-developed biophysical field forms, including site locations, quadrat depths, transect distances, dominant and subdominant substrate and vegetation and site layout. In Phase 1, a collection of voucher specimens was laminated, bound and submitted to BC Hydro. This baseline collection remains valid, with no new macrophyte species were observed during Phase 2 assessments.

2.3.7.2 Estimation of Percent (%) Macrophyte Cover

Estimates of per cent (%) macrophyte cover were made for each sample quadrat. Assessments were made through:

1. visual observation from the research vessel; and,
2. visual observations from the drop camera.

The drop camera was deployed at each sampling quadrat where macrophyte community percent cover could not be estimated from visual observations. Through use of each method above, assessments were made by estimating the extent of reservoir bottom covered by aquatic plants. Values were then averaged to yield the estimated per cent (%) coverage of a macrophyte community within a given quadrat. Macrophytes collected from each site were sorted to taxa. Relative percent (%) biomass of each taxa was used to estimate percent (%) composition of each quadrat. Estimates were recorded in field notebooks and on biophysical observation forms, photos were taken of each quadrat, where possible. Estimation methods were based on methods defined in Terry and Chilingar (1955).

2.3.7.3 In Situ Water Quality

A YSI EXO Sonde was used to assess *in situ* water quality. Readings were taken along the centre transects of select submerged quadrats. Water quality parameters assessed included, depth (m), temperature (°C), conductivity (uS/cm), pH, oxidation reduction potential (ORP; mV), turbidity (FNU) and dissolved oxygen (DO; mg/L). Measurements were saved directly to the YSI, backed up each night, then to the G3 server upon return from the field.

A Secchi disk was used to measure water clarity at the centre of each study site in cases where the bottom could not be visually observed; however, the Secchi disk was visible to the bottom at all sites even when macrophyte assessment couldn’t accurately be made from the surface.

2.3.7.4 Sediment

A stainless steel 15 cm Ponar was used to collect sediment samples from each study area (Photo 66, Appendix 2). Samples were collected within each zone of the centre transect and deposited on in a white bucket for visual assessment and photographic documentation.

Qualitative assessments of each sample were made *in situ* with descriptions documented according to criteria defined in sediment field forms developed by G3 specifically for this study (Appendix 7). In addition, qualitative nearshore evaluations were completed based on visual assessments. Gross sediment characteristics were assessed, based on the Environmental Effects Monitoring (EEM) Working Group (EWG) and USEPA National Benthic Workshop (PTI, 1993), included:

- overall sediment characteristics (i.e., texture, colour, consistency, odour, presence of debris, and presence of fauna);
- vertical profile characteristics (i.e., homogeneity, layering, oily sheen, varves); and,
- other distinguishing features.

2.3.8 Site Photos, Data & Observations

Photographs were taken of each study site (Appendix 2) using a Panasonic DMC-TS20 waterproof camera. Photos captured images from a number of monitoring site vantage points including cardinal directions and site specific vantage points.

Photographic documentation was maintained for each new macrophyte species, substrate sampled along the centre transect, emergent vegetation quadrats and methodologies employed. Photographs were catalogued in a database as described in Section 2.4.2.

2.4 Post Field

2.4.1 Taxonomy

Following field surveys, macrophyte samples were transported to the G3 taxonomic laboratory, then unpacked for subsequent taxonomic analysis. Samples were checked against field forms and identifications confirmed by examining corresponding site photographs. Pressed and dried samples were then individually identified through examination of morphological structures and comparison with diagnostic characterizations in appropriate published keys (See Section 6.0, Taxonomy References). Quality assurance procedures during the identification of macrophytes involved a comparison of specimens with other confirmed verified specimens.

2.4.2 Photographic Database

All G3 project photos were uploaded and entered into the 2014 Revelstoke Reservoir Vegetation Assessment Photo Database. *Photo Collector Professional* was used to create the database and chosen based on a number of beneficial traits including: ease of use; compatibility; and, functionality. Key information about each photograph was attached as a tag and can be searched using a query tool. The information attached to each photo includes, but is not limited to:

- site name;
- photo date and time;
- photographer;
- photo caption;
- file details (format, file size, resolution and colour);
- camera details (type, flash, zoom, focal length and aperture); and,
- additional notes.

Photographs and meta database were submitted to BC Hydro on included DVD-ROM media. All photographs were included in both their native resolution and as lower resolution 800 x 600 versions.

2.5 SPOT 6 Technology & Data Acquisition

2.5.1 Spot Technology

To assess the effectiveness of remote sensing in determining changes to macrophyte composition post drawdown, a high resolution optical imaging earth observation satellite known as SPOT 6 (Satellite Pour l'Observation de la Terre) was tasked to collect orthorectified, pan-sharpened multispectral satellite imagery of the Reservoir on September 11th, 2014 after four attempts. SPOT 6 imagery quality is superior to that of SPOT 5 in terms of resolution, bit depth and band wavelength, which aided in the detection of macrophyte communities in Phase 2.

The improved resolution of SPOT 6 relative to its predecessor SPOT 5 enabled the production of a more accurate NDVI (Normalized Difference Vegetation Index) calculation using the near infrared and red bands. The NDVI formula is described in detail in Section 2.5.2. Resolution for the SPOT 6 imagery was 6.0 m per pixel, compared with the 10 m resolution from SPOT 5 imagery. The smaller pixel size facilitated the process of determining the size and shape of polygon areas which contained NDVI threshold values indicating the presence of submerged aquatic vegetation.

Importantly, SPOT 6 imagery was provided in Blue, Green, Red, and Near-Infrared bands, allowing for generation of an accurate true color image. SPOT 5 does not have a native blue band, forcing users to simulate a blue band through band math. This results in less differentiation between colors representing potential macrophyte areas.

Additionally, the improved bit depth of SPOT 6 (12 bit vs 8 bit for SPOT 5) enabled greater differentiation between objects based on spectral response than SPOT 5, and resulted in better image quality in dark and bright areas. This allowed for improved detection of macrophyte communities through NDVI analysis and visual examination of the SPOT true color image.

The expanded wavelengths of SPOT 6 provided for increased spectral reflectance in all bands, allowing for an expanded range of NDVI values which aided in the detection of macrophyte communities. The wavelengths, resolutions and bit depths for SPOT 5 and SPOT 6 are presented in Table 2-2.

The accuracy of Phase 2 NDVI predictions were compared with *in situ* observations from both Phase 1 and 2 and with Phase 1 NDVI predictions. Differences between satellite image predictions and *in situ* observations were then compared for each phase of the assessment.

Improved Phase 2 resolution was used to draw macrophyte community polygons around pixels containing spectral reflectance signatures falling within specific digital number ranges.

Subsequently, satellite image resolution of Phase 2 imagery was downgraded to Phase 1 pixel size and a visual comparison of observed macrophyte communities for the entire reservoir was undertaken between imagery from both phases with the same pixel sizes. Polygon areas were calculated for both Phases and compared to assess changes to macrophyte community size and shape.

Table 2-2: Bands, Wavelengths & Resolutions of SPOT 5 & SPOT 6

Bands	SPOT 5 Wavelength (µm)	SPOT 5 Resolution (m)	SPOT 5 bit depth (bits)
SPOT 5			
Band 1 (Green)	0.50 - 0.59	10	8
Band 2 (Red)	0.61 - 0.68	10	8
Band 3 (Near Infrared)	0.78 - 0.89	10	8
Band 4 (Mid Infrared)	1.58 - 1.75	20	8
SPOT 6			
Band 1 (Blue)	0.455 - 0.525	6	12
Band 2 (Green)	0.53 - 0.59	6	12
Band 3 (Red)	0.625 - 0.695	6	12
Band 4 (Near Infrared)	0.76 – 0.89	6	12

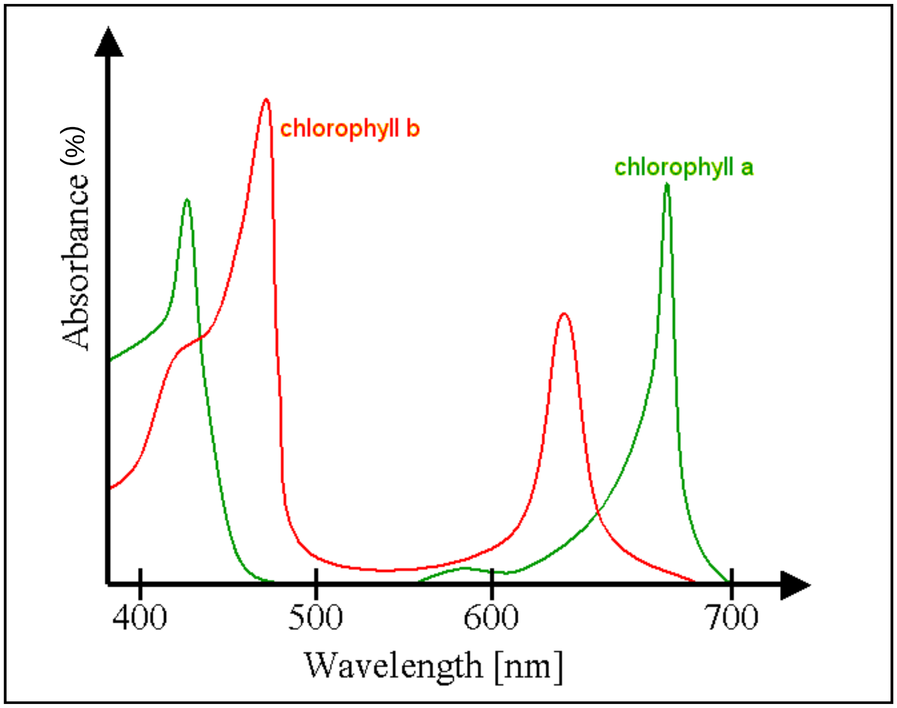
2.5.2 Vegetation Indices

While several indices were investigated, the most accepted method for determining presence and, to a lesser extent, health of vegetation, using satellite imagery was the Normalized Difference Vegetation Index (NDVI). The premise of this remote sensing technique lies with the reflective properties of vegetative species (Nelson *et al.*, 2006). Plant species that have chlorophyll as their primary mode of nutrient transfer absorb light well in the red spectrum (620 nm to 750 nm) and reflect light very well in the near infrared spectrum (>750 nm to ~10 µm). NDVI creates a number line index from the difference in reflectance between these two bandwidths (Dierssen *et al.*, 2006). Hall *et al.* (1992) noted that the difference between NDVI estimates and measurements from SPOT to be less than one per cent. SPOT data was then imported into ESRI ArcMap (version 10.1), enabling the use of ArcMap raster calculator tools to perform the image index generation. The algorithm formulas used in image index generation were:

$$\mathrm{NDVI} = \frac{(\mathrm{NIR} - \mathrm{RED})}{(\mathrm{NIR} + \mathrm{RED})}$$

where NDVI = Normalized Difference Vegetation Index, NIR = measured near infrared wavelength and RED = measured red wavelength.

Figure 2-2: Chlorophyll Absorption Spectra (adapted from Aushulz, 2008; GNU Commons)



By normalizing the difference between the NIR and red bands, the values can be scaled between a value of -1 to +1. This also reduces the influence of atmospheric absorption. These values from -1 to +1, known as digital numbers (DN's), are assigned to all pixels in the imagery. Imagery can then be classified on these threshold response values, highlighting areas of potential macrophyte coverage. Table 2-3 shows typical reflectance values in the red and infrared channels, and the NDVI for typical cover types. Water typically has an NDVI value less than 0, bare soils between 0 and 0.1 and vegetation over 0.1. In Phase 1 of the assessment, NDVI values from -0.33 to -0.39 were found to indicate macrophyte presence. However, this range required post field calibration relative to certain zones of the reservoir.

Table 2-3: Typical NDVI values for various cover types; Holben, Brent (1986)

Cover Type	RED	NIR	NDVI
Dense vegetation	0.1	0.5	0.7
Dry bare soil	0.269	0.283	0.025
Clouds	0.227	0.228	0.002
Snow and ice	0.375	-	-
Water	0.022	0.013	-0.257

2.5.3 Acquisition of SPOT Imagery

To establish the validity of finer spatial resolution imagery, satellite imagery was collected through SPOT images for pre-fieldwork analysis and targeting. SPOT technology was chosen due to finer geometric resolutions (6 m) and broad spectral coverage in both the NIR and red bands.

Given that the value of satellite data is highly reliant on climatic parameters (e.g., cloud cover), four attempts at SPOT data acquisition were necessary to capture acceptable imagery. Table 2-3 provides the dates on which efforts were made to collect SPOT 6 imagery, as well as associated outcomes. A cloud cover of less than 5 percent was considered acceptable. Imagery was captured

September 11th with less than 1% cloud cover. Phase 1 images were collected on September 22, 2009.

Table 2-4: Acquisition Dates of SPOT 5 Imagery

Acquisition Date	Outcome
July 26, 2014	**Initial Acquisition Request Made**
July 28, 2014	**Unsuccessful** (Too early to compare with Phase 1)
August 23, 2014	**Unsuccessful** (~100% cloud cover)
August 29, 2014	**Unsuccessful** (~99.7 % cloud cover)
September 11, 2014	**Successful** (Data used to generate basemaps. Less than 1% cloud cover)

2.5.4 Image Processing & Basemap Creation

Identical NDVI algorithms were applied to each of the eight imagery tiles covering the ten (10) selected sites. This algorithm initially showed notable differences in processed digital numbers for areas where macrophytes were previously observed in Phase 1; however, NDVI ranges were consistent for sites in close proximity to one another. For Phase 1 pre-field mapping, NDVI ranged from -0.33 DN (digital numbers) to -0.39 DN and was used to predict macrophyte communities. In terrestrial environments, this range would indicate no vegetation or vegetation in poor health; however, given the effect of water on response values, these ranges were also included.

To compare NDVI predictions between Phase 2 and Phase 1 of the assessment, a comparison was done using NDVI response values and visual spot checking of the true color imagery. Clusters of NDVI pixels and shoreline discolorations in the true color imagery which were greater than 100 m^2 in size in Phase 2 were outlined for the entire reservoir. The total area of Phase 1 and 2 NDVI polygons was first compared for the entire reservoir, and then for areas where macrophytes were predicted in both phases of the assessment.

Images were also separated into four bands for each site and composited together as an RGB false color composite (i.e., red = NIR band, green = red band and blue = green band). False color imagery was then used to help detect macrophyte clusters visible in the water column and to aid in detection of the shoreline for each site.

2.5.5 Post-field Calibration

As macrophytes were observed in areas with NDVI values below -0.39 DN in certain areas, post-field adjustments were made to expand the NDVI response value indicating vegetation, with final values ranging from -0.33 DN to -0.55 DN across the reservoir. Nearby sites were found to have macrophytes located within similar NDVI ranges. Values below -0.55 DN did not indicate the presence of macrophytes across the reservoir. Values above 0 DN indicated terrestrial plants about the high water mark, and 0 DN to -0.33 DN indicated nearshore areas with few or sparse macrophyte coverage (generally).

Table 2-5 below summarizes the range of NDVI values where macrophytes were observed *in situ* in Phase 2 of the assessment.

Table 2-5: Range of NDVI Digital Numbers Across Assessment Sites

Assessment Site	Digital Number Range
1	**-0.33 to -0.525**
2	**-0.33 to -0.525**
3	**-0.33 to -0.37**
4	**-0.33 to -0.37**
5	**-0.33 to -0.45**
7	**-0.33 to -0.475**
8	**-0.33 to -0.475**
9	**-0.33 to -0.55**
10	**-0.33 to -0.55**
11	**-0.33 to -0.55**

Differences in NDVI ranges across sites observed in Phase 2 were attributed to differing spectral reflectance properties caused by water composition changes in different geographical areas of the reservoir. For example, in the middle of the reservoir, north of Downie Arm, the range of NDVI values was less than in the north and south ends. Macrophytes were observed in a small range from -0.33 to -0.37 at sites 3 and 4 located in this area, and from -0.33 to -0.45 at Site 5. Conversely, sites located at the north and south ends of the reservoir were found to contain macrophytes at areas with lower NDVI DN's (as low as -0.55 DN). Using the NDVI ranges at each site it was possible to develop an NDVI model for the entire reservoir by dividing the reservoir into different NDVI classification regions (Figure A-2, Appendix 1). A total of five (5) NDVI classification ranges over eight (8) regions of the Reservoir were used to develop the NDVI model for the entire reservoir.

NDVI classification ranges were then attenuated to physical field observations of macrophyte communities. GPS waypoints were recorded from the boat at macrophyte observation points observed by drop camera video. Waypoints were recorded both for areas where macrophytes were observed and where the communities ended or were not present. Sites were traversed along transects running perpendicular to the shore from the northernmost to southernmost extent of the sites, with waypoints recorded at 10 m intervals and where communities were observed to begin or stop. These waypoints were then overlaid on top of the NDVI pixels to determine the NDVI threshold for each site.

NDVI Polygons were subsequently drawn around NDVI spectral clustering from the northernmost to southernmost extent of each site and used to compare with *in situ* measurements and Phase 1 observations.

2.5.6 NDVI versus *In Situ* Polygons

Polygons predicted by NDVI and those observed *in situ* in Phase 2 and Phase 1 were compared as follows:

1. **Comparison of Phase 1 and 2 NDVI models:** Improvements in SPOT satellite technology used between Phase 1 and Phase 2 complicated comparisons and NDVI model development between Phases. To overcome differences in satellite technology a comparison of Phase 2 satellite images using similar resolution and bandwidths used in Phase 1 was completed to enable a more direct comparison. Subsequently, Phase 2

satellite true colour image quality was increased and colour spectrum bandwidths were attenuated to *in situ* ranges to assess what macrophyte communities would otherwise be visible using the new technology.

2. **Comparison of Phase 1 and Phase 2 NDVI Polygon-Estimated and *In situ* Polygons:** using basemap satellite polygons and data collected *in situ*, surface area of NDVI-predicted and *in situ* macrophyte communities were calculated using ArcGIS (version 10.1; see Appendix 4). Differences in surface area between NDVI polygons and those observed *in situ* were calculated for each site to evaluate accuracy of Phase 2 NDVI predictions and attenuate for entire reservoir predictions.

2.5.7 NDVI Classification

The total surface area was calculated for each NDVI class located within the *in situ* site boundary for each site. Data was then used to analyze the spectral composition of *in situ* communities at each site to determine in which NDVI range(s) macrophytes could be accurately predicted to be primarily located in locations throughout the reservoir.

2.6 Data Analysis for Macrophyte Community

Univariate parameters (i.e., relative abundance and species richness) were used to characterize the macrophyte community. As macrophyte diversity was very low in most samples, diversity indices (e.g., Shannon-Wiener Index, Pielou's index, Simpson's index, etc.) were not appropriate and, therefore not calculated.

Two-way ANOVA was used to assess differences in univariate parameters among sites and between years. A paired t-test was used to assess differences in relative abundance and species richness between Phase 1 and Phase 2 of the program at each site. Multivariate methods were then employed to analyze differences in macrophyte community structure, using the software PRIMER 6 (Plymouth Routines in Multivariate Ecological Research; Clarke and Gorley, 2006).

Similarities between macrophyte samples were calculated using the Bray–Curtis coefficient (Bray and Curtis, 1957):

$$S_{jk} = 100 * \left(1 - \frac{\sum_{i=1}^{p} \left| y_{ij} - y_{ik} \right|}{\sum_{i=1}^{p} \left(y_{ij} + y_{ik} \right)}\right)$$

where S_{jk} = similarity between *j*th and *k*th samples, y_{ij} = relative abundance for *i*th species in *j*th sample (*i* = 1,2,. . .,p; *j* = 1,2,. . .,n). The coefficient ranges between 0 and 100%. S = 100 means that species compositions in the two samples were identical, while S = 0 means no common species in the two samples. Abundance data were log(x+1) transformed before computing the coefficient, as relative abundance is in percentage.

Analysis of similarities (ANOSIM) was carried out to test the null hypothesis that there were no differences in community structure between sample groups. ANOSIM was measured using the global test (R) (Clarke and Warwick, 2001):

$$R = (r_B - r_W) / (M/2)$$

where r_B = the average of rank similarities from all pairs of replicates between different groups, r_W = the average of all rank similarities among replicates within groups, M = n*(n - 1)/2 and n = the total number of samples under consideration. R varies between 0 and 1, indicating some degree of discrimination between groups. R = 1 means all replicates within groups are more similar to each other than any replicates from different groups; R is approximately zero if similarities between and within groups are on average the same.

2.7 QA/QC & Data Management

A set of *Quality Assurance and Quality Control* (QA/QC) procedures and practices were implemented throughout this Phase 2 assessment to ensure program integrity at every level. QA/QC objectives were incorporated into workplans, established in the management strategy, and included protocols for handling and recording information (in the field and office) and criteria used to confirm accuracy and precision of that information. QA/QC objectives included established protocols for literature management to ensure accurate citations and relevance based on date and source of publication.

Sampling was undertaken using both replication (i.e., multiple samples in each quadrat) and duplication (i.e., multiple representative individuals of each species identified in the laboratory, multiple water quality readings) for measures taken in the field. Further, instrumentation was calibrated daily to ensure accurate performance.

Transcription or entry errors for raw data (e.g. macrophyte per cent coverage, GPS/ GIS coordinates, water quality and sediment characteristics) were checked through cross-referencing and review of original field notes and forms by alternate staff members on 20-25 % of entered data. When an error greater than five % was encountered the entire dataset was scrutinized. Macrophyte taxonomy QA involved comparison of specimens with verified specimens. No additional macrophyte species were observed during Phase 2.

In accordance with BC Hydro protocol, a quality assurance and safety field audit was conducted by a BC Hydro representative (October 2, 2014). The field audit evaluated a number of study elements which included, but were not limited to:

- project organization (e.g., schedule, field crew competency);
- study design (e.g., clearly stated objectives in project plan, field crew familiarity with study design and respective responsibilities);
- sampling methodology (e.g., sampling protocols consistent with regulatory standards, adherence to sampling protocols, appropriate field forms); and,
- data management (e.g., specific procedures for data entry and management, data storage compatible with BC Hydro).

Evaluation of study elements, safety and QA/QC procedures addressed BC Hydro requirements as defined by the program *Operational Work Plan* and *Safety Management Plan* defined in the original RFP.

3.0 RESULTS

The operating range of Revelstoke Reservoir, after REV5 installation, was projected to be the same as pre-installation conditions, with reservoir fluctuations at the start of REV5 operations estimated to be <0.25 m greater than 90% of the time (BC Hydro, 2006). With the increase from four to five operating units the frequency of moderate drawdowns (i.e., drafting to approximately 572.5 m or by 0.5 m) was predicted to be greater while the frequency of low drawdowns (i.e., drafting to ≥571.5 m or by 1.5 m) was predicted to be less frequent (BC Hydro, 2006). Impacts to aquatic macrophyte communities within Revelstoke Reservoir were predicted to be minimal based on the standard reservoir level daily variation of ≤0.25 m; however, little information was originally available regarding distribution and depth of macrophytes in Revelstoke Reservoir.

In December 2010 the REV5 turbine became operational. Average monthly elevation levels in Revelstoke Reservoir from August 1984 to February 2010 were 572.55 m while post REV5 operation levels (December 2010 to December 2014) were lower (572.36 m). Daily reservoir level variation post REV5 operation was ≤0.25 m 90.68% of the time (December 2010 to December 2014). Daily and monthly Revelstoke Reservoir average water elevation, January 1984 to December 2014, are provided in Chart 1 and Chart 2 (Appendix 3).

This study was designed to assess macrophyte communities before and after operation of the fifth unit to verify the null hypothesis that "selected biotic factors are the same for 'Before' vs. 'After' for the same location(s) throughout different habitat types, depths and reservoir longitudinal zones". The following section provides comparative results for Phase 1 (2009) and Phase 2 (2014) of the Revelstoke Reservoir Vegetation Monitoring Program using comparative multispectral image analysis and ground truthing.

A primary task of the Revelstoke Reservoir Macrophyte Assessment Program was to test and compare satellite map multispectral imaging using a Normalized Difference Vegetation Index (NDVI) produced in Phase 1 and Phase 2 to identify the size and presence of aquatic vegetation communities and track any changes in community size and presence over time. Basemaps were produced in both Phase 1 and Phase 2 that used identical NDVI algorithms and true colour satellite image spot check methodologies to compare estimated aquatic vegetation community size over time for the entire reservoir. Full reservoir basemap comparative results are discussed in Section 3.2.

To attenuate and verify NDVI algorithm accuracy, *in situ* vegetative community assessments and ground truthing were conducted in each phase. Each of the ten long-term baseline study sites were assessed prior to (Phase 1) and subsequent to (Phase 2) implementation and operation of a fifth generating unit (REV5) at Revelstoke Dam. Assessments included reservoir elevation, macrophyte distribution and extent (i.e., location, depth, relative abundance, biodiversity, etc.). Limited physical (i.e., water quality and sediment) and biological (i.e., macrophyte species identification and coverage) data were collected to aid in the understanding of macrophyte ecology within Revelstoke Reservoir. Both Phase 1 and Phase 2 data from each of the ten long-term sites was assessed and compared to identify any long term trends in the reservoir.

3.1 Basemap Comparison of Entire Reservoir (Phase 1 & Phase 2)

In situ vegetative community assessments and ground truthing were conducted to verify NDVI satellite map accuracy in both Phase 1 and Phase 2. Results of these assessments were used to attenuate the NDVI classification ranges in which macrophytes were found throughout the reservoir and produce a final more accurate macrophyte algorithm for the reservoir. Improvements in technology used between Phase 1 and Phase 2 complicated comparison of reservoir NDVI models between Phases. The improved resolution of SPOT 6 relative to its predecessor SPOT 5 enabled the production of more accurate NDVI calculations using the near infrared and red bands resulting in an increased ability to identify macrophyte communities in Phase 2. To minimize technology bias, comparisons were done using the same comparable NDVI response values and visual spot check techniques outlined for basemap development used in Phase 1. Maps were then developed in Phase 2 that used identical pixel size, NDVI algorithms and true colour satellite image spot check methodologies used in Phase 1 to compare aquatic vegetation community sizes over time for the entire reservoir. Adjustments to NDVI classes were made to narrow the range of NDVI response values indicating vegetation in the reservoir, with values ranging from -0.39 DN to -0.33 DN for Phase 1 and Phase 2. Potential macrophyte communities were delineated by using response range NDVI groupings inspected against true-colour composite imagery.

Table 3-1: Predicted Macrophyte Communities (Full Reservoir)

Phase	Area (sq km)	Number of Polygons
Phase 1 Polygon Area	1.26	56
Phase 2 Polygon Area	1.25	215
Phase 2 (Polygons overlapping with Phase 1)	0.94 (75%)	66

Note: while technology bias was minimized, reduced macrophyte coverage within polygons observed in the same area between Phase 1 and Phase 2 is also likely due in whole or in part to differences in reservoir elevation at the time of survey between Phase 1 and Phase 2 as well as increased resolution of the SPOT 6 technology

Macrophyte polygons in Phase 2 covered a similar polygon area to Phase 1 (1.26 sq km vs. 1.25 sq km, Table 3-1). This difference of macrophyte community area between Phases is likely spurious, however. Polygons were observed in the same areas as in Phase 1; however, many more individual polygons were also identified throughout the reservoir using the same methodology, due to improved SPOT 6 technology relative to its predecessor SPOT 5 (i.e., improved ability to discern individual polygon boundaries). Reduced macrophyte coverage within polygons observed in the same area between Phase 1 and Phase 2 is also likely due in whole or in part to differences in reservoir elevation at the time of survey between Phase 1 and Phase 2 as well as increased resolution of the SPOT 6 technology, providing more accurate NDVI and true colour images and not necessarily the result of changes in the reservoir operations affecting macrophyte communities.

3.2 Long-Term Study Site Macrophyte Observations

3.2.1 Study Sites

Sites chosen for long-term study in Phase 1 were divided into three general categories:

1. **Undisturbed** (not influenced by anthropogenic activities and/or creek inflows): Sites 8 and 9;
2. **Located Near Creek Confluences**: Sites 2 (La Forme Creek), 3 (Big Eddy Creek), 4 (Bourne Creek) and 7 (Kirbyville Creek); and,
3. **Exposed to Anthropogenic Activities**: Sites 1 (downstream of Martha Creek BC Provincial Park Campground), 3 (downstream of a private ferry landing and logging road), 5 (downstream of Downie Creek RV Resort), 10 (up reservoir of Mica Creek Village) and 11 (downstream of a bridge crossing and directly exposed to a run-off drainage channel).

Site 3 was classified as being located both near a creek confluence (Big Eddy Creek) and exposed to anthropogenic activities (downstream of a private ferry landing and logging road).

3.2.2 Macrophyte Community Size (Phase 1 & Phase 2)

NDVI Model

Comparing polygons generated using SPOT satellite data, and those derived from *in situ* observations, is an effective approach to evaluating the accuracy of NDVI predictions. Polygon surface areas generated using SPOT satellite data were compared to those derived from *in situ* observations to evaluating the accuracy of NDVI predictions. Communities observed in situ were found to overlap to a large degree with NDVI polygons. While configuration (size and shape) of the NDVI communities appeared influenced by other factors (e.g., suspended silt, metals, depth, scattered light, wave action, satellite orientation, etc.), sites located near to each other were found to have macrophytes located within similar NDVI ranges. Table 3-2 provides comparison between NDVI-derived polygons and *in situ* observations for the ten selected long-term sites.

In Phase 2 the attenuated NDVI model was able to predict and approximate macrophyte communities at each of the ten long-term monitoring sites more accurately than with the attenuated NDVI Phase 1 model (mean predicted polygon area differences were 84.0% [Phase 1] vs. 22.9% [Phase 2]).

Table 3-2: NDVI Predicted Polygons vs. *In Situ* Observations

	Phase 1			Phase 2		
Site	NDVI Polygon (m^2)	*In Situ* Polygon (m^2)	Difference (m^2)	NDVI Polygon (m^2)	*In Situ* Polygon (m^2)	Difference (m^2)
1	7,676	11,992	4,316 (56.2%)	8,725	10,563	1,838 (21.1%)
2	8,578	2,550	-6,028 (-70.3%)	2,031	1,683	-348 (-17.1%)
3	4,473	3,910	-563 (-12.6%)	2,610	2,976	366 (14.0%)
4	2,655	3,793 (no overlap with NDVI)	N/A	3,810	2,642	-1,168 (-30.7%)
5	14,728	17,898	3,170 (21.5%)	16,110	20,863	4,753 (29.5%)
7	12,404	1,306 (no overlap with NDVI)	N/A	2,694	2,074	-620 (-23.0%)
8	26,894	72,683	45,789 (170.3%)	44,625	36,592	-8,033 (-18.0%)
9	0	1,932	N/A	1,295	1,395	100 (7.7%)
10	39,195	2,323	-36,871 (-94.1%)	2,374	3,059	685 (28.9%)
11	12,404	32,660	20,256 (163.3%)	17,340	24,110	6,770 (39.0%)

In situ macrophyte community area measurements in Phase 2 were larger than the predicted NDVI area polygons at six of the ten long term monitoring sites (Site 1, 3, 5, 9, 10 and 11). The largest difference in NDVI mapping and *in situ* estimations of macrophyte surface areas was at Site 8; however, the overall percent (%) difference between *in situ* estimates and the NDVI polygon estimates was 18%, which was less than the mean percent difference (22.9%). Site 8 *in situ* observations were estimated to be 8,033 m^2 smaller than the NDVI model which predicted macrophytes in deeper water than actually observed. In Phase 1, Site 8 also had the largest difference between predicted NDVI model and *in situ* measurements (difference of 170.3%); however, the NDVI polygon predicted the area to be much smaller than *in situ* measurements demonstrated (26,894 m^2 vs. 72,683 m^2).

At Site 11, *in situ* area estimates were higher than the NDVI polygon by 6,770 m^2 with a high percent difference (39.0%). The NDVI model polygon at Site 11 was similar in shape to that observed *in situ*; however, shallow near-shore and far-shore fringe macrophyte communities were not identified with the NDVI model. The most similar *in situ* polygon area to predicted NDVI areas was at Site 9 in Phase 2 (difference of 100 m^2). In Phase 1 no Site 9 NDVI polygons were predicted.

At Site 7, *in situ* area estimates were similar to the NDVI predicted polygon area; however, the shape and location of the NDVI predicted polygon did not overlap well with *in situ* observations. Site 7 was located near Kirbyville Creek. Shallow sandbars were noted at the mouth of the creek and at Site 7 which likely affected NDVI predictions.

In some cases NDVI and field observations both identified macrophytes in a given area; however, NDVI did not fully estimate growth at all transect points where growth was verified *in situ.* Difference in reservoir elevation may account, in part, why field observations could not always confirm the presence of macrophyte communities in deeper areas (e.g., reduced water transparency). As well, differences in reservoir elevation at the time of SPOT satellite capture for Phase 1 and Phase 2 may explain differences in NDVI polygon areas between Phases. In Phase 2, satellite images were captured with a reservoir elevation of 572.162 m (September 11, 2014). In Phase 1, satellite images were captured with a lower reservoir elevation of 572.051 (September 22, 2009).

In Situ Community Size Comparison

Macrophyte community boundaries were measured *in situ* at each long-term site with the use of visual observations, macrophyte sampling equipment, depth sounder, and a drop camera (Phase 2). Based on macrophyte boundaries produced through *in situ* observations, three (3) macrophyte polygons increased in area between Phase 1 (2009) and Phase 2 (2014; Sites 5, 7 and10) and seven (7) macrophyte polygons decreased in area (Site 1, 2, 3, 4, 8, 9 and 11; Table 3-3, below).

Table 3-3: *In Situ* Area Observations (Phase 1 & Phase 2)

Site	Phase 1 (2009) *In Situ* Polygon Area (m^2)	Phase 2 (2014) *In Situ* Polygon Area (m^2)	Difference in Polygon Areas (m^2)
1	11,992	10,563	-1,429 (-11.9%)
2	2,550	1,683	-867 (-34.0 %)
3	3,910	2,976	-934 (-23.9%)
4	3,793	2,642	-1,151 (-30.4%)
5	17,898	20,863	2,965 (16.6%)
7	1,306	2,074	768 (58.9%)
8	72,683	36,592	-36,091 (-49.7%)
9	1,932	1,395	-537 (-27.8%)
10	2,323	3,059	736 (31.7%)
11	32,660	24,110	-8,550 (-26.2%)

Macrophyte communities at shallow, more gently sloping sites (e.g. Sites 1, 5 and 10) generally showed an increase or little change in overall polygon area. Sites with more abrupt elevation changes (e.g. Site 8, 9 and 11) tended to show a decrease in macrophyte community size where macrophytes were not observed as far from the high water mark as noted in Phase 1.

3.2.3 Macrophyte Coverage (Phase 1 & Phase 2)

Macrophytes were observed qualitatively and quantitatively (dominance ranking based on estimated per cent [%] cover) through visual observations. A list of the macrophyte species encountered in Revelstoke Reservoir during the Phase 1 and Phase 2 assessments is provided in Table 3-4. The estimated percent (%) coverage of taxa observed in Revelstoke Reservoir during Phase 1 and Phase 2 assessments is listed in Table 2 and 3, Appendix 4.

Seven macrophyte taxa were observed in Revelstoke Reservoir during the Phase 2 assessment: *Potamogeton amplifolius* (large-leaf pondweed), *Potamogeton alpinus* (northern pondweed), *Potamogeton foliosus* (leafy pondweed), *Eleocharis acicularis* (needle spikerush), Nitella sp., *Myriophyllum spicatum* (Eurasian watermilfoil), and *Ranunculus aquatilis* (white water crowfoot). All seven species were observed in Phase 1 and no new species were observed or absent between Phase 1 and Phase 2. Macrophyte distribution is discussed below, while the ecology of each species described in Appendix 5.

Table 3-4: Phase 1 & Phase 2 Macrophyte Taxa

Scientific Name	Common Name	Ecology	Conservation Status	
			Provincial Status[1]	BC List[2]
Potamogeton amplifolius	large-leaf pondweed	Commonly confused with Leafy Pondweed and found in similar habitats. Plants submersed with leaves below water surface and on water surface.	S4 (2001)	Yellow
Potamogeton alpinus	northern pondweed	Common aquatic perennial weed found in shallow cold water ponds and lakes. Plants submersed with narrow leaves below water surface and broader leaves found on water surface.	S4 (2001)	Yellow
Potamogeton foliosus	leafy pondweed	Common aquatic perennial weed found in a range of habitats including brackish waters. Plants are generally submersed with leaves below and on top of water surface. Generally found in 0.5 to 2.5 m of water.	S4 (2001)	Yellow
Eleocharis acicularis	needle spikerush	Annual or perennial spike sedge with long, grass-like stems to about 15 cm in height. Generally found in exposed moist organic soils and in shallow water up to 1 m in depth. Commonly occurs is marshes, vernal pools and bogs where it forms large, rooted mats.	S4 (2000)	Yellow
Nitella sp.	*Brittle/ stonewort*	Bright green algae commonly found in shallow to deep water of soft water to acidic lakes and bogs (conductivity <110). Often grows in deeper water than other flowering plants and frequently forms thick mats along the bottom.	SNA	Not Listed
Myriophyllum spicatum	Eurasian watermilfoil	Submersed aquatic perennial herb, where the whorled leaves are present near the surface and flowers are formed above the surface of the water body. A serious invasive aquatic weed found in a range of habitats throughout North America. Generally plants are found in water depths between 0.5 to 7 m.	SNA	Exotic
Ranunculus aquatilis	white water crowfoot	Annual/perennial aquatic plant generally found in bogs, ponds slow streams and marshes at shallow depths <1 m. Majority of plant is submerged with flowers at surface. Leaves are common when plant is only partially submerged in slow moving water, but may be absent in streams.	S5 (2000)	Yellow

(MOE, 2010; USDA, 2010).

[1] **Provincial Status:** Provincial Status applies to a species' or ecological community's conservation status in British Columbia. The number in parenthesis is the year the status rank was last reviewed. Status ranks have the following meaning: 3 = special concern, vulnerable to extirpation or extinction; 4 = apparently secure; NA = not applicable; 5 = demonstrably widespread, abundant, and secure.

[2] **BC List:** Species are assigned to provincial lists depending on their Provincial Conservation Status. The lists are as follows: **Yellow:** Includes species that are apparently secure and not at risk of extinction. Exotic: Species that have been moved beyond their natural range as a result of human activity.

In Phase 2, *Eleocharis acicularis* was the most abundant species observed overall. *E. acicularis* was observed at six sites (Sites 1, 5, 7, 8, 10 and 11) and was the only species observed at Site 7. *E. acicularis* was recorded in the highest number of quadrats (31 of 90 quadrats) and was dominant in 68% of them. Thirty-two per cent (32%) of the quadrats containing *Eleocharis acicularis* had >60% coverage by *Eleocharis acicularis*. In Phase 1, *Eleocharis acicularis* was dominant at four of the ten survey sites (Sites 5, 7, 10 and 11). *E. acicularis* was primarily dominant in nearest and mid-distance zones, though also dominant furthest from shore at Site 11. *E. acicularis* was sub-dominant nearest to shore at Sites 6 and 10 and furthest from shore at Site 11 in both Phase 1 and Phase 2. Coverage of *Eleocharis acicularis* was highest at Site 5 in both Phase 1 and Phase 2.

Nitella sp. was observed at both up-reservoir and down-reservoir sites; however, was more dominant at up-reservoir sites. *Nitella sp*. was observed at the most sites (7 out of 10 survey sites; Site 1, 2, 5, 8, 9, 10 and 11) in Phase 2 and was the most abundant species overall at two sites (Site 8 and 9). At other sites *Nitella sp*. was found in comparably lower amounts. In Phase 1, *Nitella sp.* was also most dominant in northern reaches of the reservoir (Sites 8 to 11). Per cent (%) coverage of *Nitella sp.* was especially high at up reservoir sites, with values as great as 100% (Sites 10 [S/A and C/A] and 11 [S/B, C/B and N/B]).

Table 3-5: Macrophyte Quadrat Occurrences & Percent Cover (Phase 1 & Phase 2)

Year	Parameter		Species						
			P. amplifolius	P. alpinus	P. foliosus	Nitella sp.	M. spicatum	R. aquatilis	E. acicularis
2009	Quadrat	Incidence	34	11	5	35	5	1	16
		Dominant	32	4	4	29	1	0	14
	Coverage (%)	>20%	30	4	4	23	1	0	13
		>40%	28	3	3	21	1	0	11
		>60%	22	1	2	15	0	0	7
		>80%	17	1	1	12	0	0	4
2014	Quadrat	Incidence	21	6	2	17	5	12	31
		Dominant	18	3	2	10	2	5	21
	Coverage (%)	>20%	17	3	1	7	0	4	19
		>40%	13	1	0	2	0	1	16
		>60%	7	0	0	1	0	1	10
		>80%	3	0	0	0	0	0	7

Ranunculus aquatilis was observed at six sites (Site 1, 5, 8, 9, 10 and 11) in Phase 2 while in Phase 1 was only observed at one site (Site 3) with <5% coverage. In Phase 2, *R. aquatilis* was observed at five sites where both *Eleocharis acicularis* and *Nitella sp.* were also observed (Site 1, 5, 8, 9, 10 and 11). *R. aquatilis* was not observed with high sample cover (60% cover at Site 3 N/C; <25% cover at all other quadrats); however, it was the dominant species in five of the twelve quadrats assessed.

In Phase 1, *Potamogeton amplifolius* was the most abundant species overall and was dominant in the southern portion of the reservoir (from Site 1 to Site 8). In Phase 2, *Potamogeton amplifolius* was also observed more commonly at down reservoir sites and at four sites overall (Site 1, 2, 5 and 8). *P. amplifolius* was more common at down-reservoir sites (Sites 1, 2 and 5) and at Sites 1 and 2, was the dominant species 86% of the time.

In Phase 1, *Myriophyllum spicatum* was only present in two long-term study sites (Site 1 and Site 5) and dominant furthest from shore at Site 5 and sub-dominant at the mid-distance and furthest from shore zones of Site 1 (Phase 1). In Phase 2, *Myriophyllum spicatum* was observed at three sites (Site 1, 5 and 8) with minimal per cent (%) cover. Site 1 (south transect near-shore [7% coverage] and south transect mid-distance [2%]), Site 5 (north transect far-shore [4%]) and centre transect far-shore [18%]) and Site 8 (north transect near-shore [15%]).

In Phase 1, *P. alpinus* was observed at Sites 1, 2, 9 and 10 and *P. foliosus* was observed at Site 8. *P. alpinus* was sub-dominant nearest to shore and mid-distance from shore at Site 9, and mid-distance from shore at Site 10 (i.e., northern portion of the reservoir). In Phase 2, *P. alpinus* was observed at three sites (Site 1, 5 and 9) and was dominant nearest to shore and mid-distance to shore at Site 1 and mid-distance to shore at Site 9. *P. foliosus* was observed at two sites (Site 3 and Site 10) with highest coverage at Site 3 (20%; centre transect, far-shore).

3.2.4 Macrophyte Bed Elevations (Phase 1 & Phase 2)

Average monthly water elevation in Revelstoke Reservoir has decreased from 572.55 m to 572.36 m since REV5 became operational (December 2010), potentially affecting shallow macrophyte communities. Although average elevation levels have dropped since operation of REV5, water elevation during Phase 2 assessments were higher (572.88 m) than the post REV5 operation daily average. In Phase 1, mean water elevation at Revelstoke Dam averaged 572.55 m and ranged between 572.41 m and 572.65 m from September 28 to October 3, 2009. In Phase 2, mean water elevation ranged between 572.78 m and 572.88 m. Daily and monthly Revelstoke Reservoir average water elevation, from January 1984 to December 2014, is provided in Chart 1 and Chart 2 (Appendix 3).

Over the course of a short period of time, rapid water level changes, due to climate influence (e.g., heavy rain) and/or dam operation, have the potential to influence macrophytes; however, water level fluctuations during the survey were not anticipated to have an effect (positive or negative) on macrophyte communities.

Table 3-6: *In situ* Macrophyte Community Elevations at Near-shore & Far-shore Edge

Site	Phase 1		Phase 2	
	Near-shore (m)	Far-shore (m)	Near-shore (m)	Far-shore (m)
1	571.2	566.5	572.3	568.8
2	572.5	570.9	571.8	568.9
3	571.6	566.8	572.5	565.8
4	570.8	563.4	571.6	566.0
5	572.4	569.7	572.4	568.1
7	571.9	570.9	572.6	567.6
8	572.4	563.1	572.6	568.2
9	571.3	562.8	572.4	567.4
10	572.5	571.7	572.7	571.1
11	572.5	565.6	572.7	568.0

Near-shore and far-shore edge macrophyte community elevations were compared for each site in Phase 1 and Phase 2. Macrophyte bed elevations were measured based on bathymetry data collected *in situ* in Phase 2 and reservoir elevation at the time of assessment. Near-shore and far-shore macrophyte community bed elevations were similar between phases with a few exceptions.

At Site 1, macrophytes boundaries were observed at higher elevations in Phase 2 than in Phase 1 (near-shore +1.1 m and far-shore +2.3 m). *Potamogeton amplifolius* was the dominant species observed in both Phase 1 and Phase 2; however, two shallow zone species (*Eleocharis acicularis* and *Ranunculus aquatilis*) were observed in Phase 2 and were not observed in Phase 1.

Table 3-7: Observed Dominance Species (Phase 1 & Phase 2)

Site	Dominant Species	
	Phase 1 (2009)	Phase 2 (2014)
1	*Potamogeton amplifolius*	*Potamogeton amplifolius*
2	*Potamogeton amplifolius*	*Potamogeton amplifolius*
3	*Potamogeton amplifolius*	*Potamogeton foliosus*
4	*Potamogeton amplifolius*	None Observed
5	*Eleocharis acicularis*	*Eleocharis acicularis*
7	*Eleocharis acicularis*	*Eleocharis acicularis*
8	*Nitella sp.*	*Nitella sp.*
9	*Nitella sp.*	*Nitella sp.*
10	*Nitella sp.*	*Eleocharis acicularis*
11	*Nitella sp.*	*Eleocharis acicularis*

Site 2, located in a shallow, gradually sloping bay, had macrophyte communities at lower elevations in Phase 2 than in Phase 1 (near-shore -0.7 m and far-shore -2 m). *Potamogeton amplifolius* was the dominant species in both Phase 1 (98.18% relative abundance) and Phase 2 (97.96% relative abundance). *P. amplifolius* is a species that prefers deeper water and observations indicate that the species has moved to a lower elevation to coincide with overall lower reservoir elevation since REV5 operation.

Site 3, located in an area with a steep drop-off at the far-shore edge of the macrophyte community, had macrophytes at lower elevations (far-shore) in Phase 2 compared to Phase 1 (-1.0 m). At the centre of the site macrophytes in Phase 2 were not observed as close to shore as in Phase 1 and *P. amplifolius* was not observed in any of the Phase 2 quadrats. In Phase 1, *P. amplifolius* was the dominant species.

Site 4, was located in a small bay with a steep drop-off with large cobble and boulder substrate. In Phase 1 *P. amplifolius* was the only species observed within quadrats while no species were observed within quadrats in Phase 2. Small patches of *P. foliosus* were observed with the drop camera in Phase 2. Macrophyte community end points indicate a shift to higher elevation for the plant community in Phase 2 over Phase 1; however observations were few in Phase 2 and far-shore site boundaries in Phase 1 were established using the depth sounder at Site 4.

Site 5 was a large shallow bay with gentle slopes. In both Phase 1 and Phase 2, *Eleocharis acicularis* was the dominant species observed. The near-shore macrophyte community boundary did not change between Phase 1 and Phase 2 while the far-shore macrophyte community boundary was noted to have extended to lower elevations.

Site 7, located at the mouth of Kirbyville Creek had gravel bars which made comparison between Phases difficult. Macrophytes were generally located in different areas and in both Phases 1 and 2 *Eleocharis acicularis* was the dominant species observed.

Site 8 was located within a large bay with a sudden drop off at the far-shore edge of the site. *Nitella sp.* was the dominant species in Phase 1 and Phase 2. While *Potamogeton amplifolius* was observed in both Phases, it was observed in near-shore and mid-distance zones in Phase 1 and mid-distance and far-shore zones in Phase 2. Two shallow species (*Eleocharis acicularis* and *Ranunculus aquatilis*) were observed with higher relative abundance in Phase 2 than in Phase 1. Elevation data indicates that both the near-shore macrophyte community edge elevation increased between Phases (near-shore +0.2 m, far-shore +5.1 m).

Site 9, located within a bay with a sudden drop off at the far-shore edge of the site had an overall increase in elevation between Phase 1 and Phase 2 (near-shore 1.1 m, far-shore 4.6 m). *Nitella sp.* was the dominant species in both Phase 1 and Phase 2.

Site 10 was located in a shallow area with a gently slope. Macrophyte Community elevations increased in at the near-shore edge of the community (+0.2 m) and decreased at the far-shore edge of the community (-0.6 m). In Phase 1, *Nitella sp.* was the dominant species while in Phase 2 *Eleocharis acicularis* was the dominant species.

Site 11, closest to Mica dam at the north end of the reservoir, consisted of a large shallow bay with a sudden drop-off at the far-shore edge of the site. Macrophyte communities increased in elevation between Phase 1 and Phase 2 (near-shore edge +0.2 m, far-shore edge +2.4 m). In Phase 1 *Nitella sp.* was the dominant macrophyte species while in Phase 2 *Eleocharis acicularis* was the dominant species.

3.2.5 Macrophyte Community Structure (Phase 1 & Phase 2)

Macrophyte Species Richness

In Phase 2, Sites 1 and 5 had the highest species richness (6 species). In Phase 1, the highest species richness was at Sites 1, 5, and 8 (each with 4 species). Lowest species richness in Phase 1 was at Sites 4 (no species within quadrats) and Site 4 in Phase 1 (1 species). In Phase 2, macrophytes were observed in one quadrat at Site 3 (*Potamogeton foliosus*). In Phase 1, three species were observed at Site 3 with *P. amplifolius* observed in all six mid-distance and far-shore sample quadrats. One species was observed at Site 7 in Phase 2 (*Eleocharis acicularis;* within five of six mid-distance and far-shore quadrats) while two species were observed in Phase 1 (*E. acicularis and P. amplifolius*). The number of species observed increased at six of the ten long-term study sites (Sites 1, 5, 8, 9, 10, 11) in Phase 2. At Site 4 no macrophytes were observed within quadrats in Phase 2; however, limited patches of macrophytes were noted at Site 4 using the drop camera.

Table 3-8: Macrophyte Quadrat Abundance

Year	Site	Macrophyte Quadrat Abundance (9 Quadrats per Site)							Species/ Site
		P. amplifolius	P. alpinus	P. foliosus	Nitella sp.	M. spicatum	R. aquatilis	E. acicularis	
2009	1	4	2	0	4	3	0	0	4
	2	6	1	0	1	0	0	0	3
	3	6	0	0	2	0	1	0	3
	4	6	0	0	0	0	0	0	1
	5	6	0	0	1	2	0	5	4
	7	2	0	0	0	0	0	3	2
	8	4	2	5	7	0	0	0	4
	9	0	5	0	9	0	0	0	2
	10	0	1	0	5	0	0	2	3
	11	0	0	0	6	0	0	6	2
	# Sites	7	5	1	8	2	1	4	7
2014	1	8	4	0	1	2	1	3	6
	2	5	0	0	1	0	0	0	2
	3	0	0	1	0	0	0	0	1
	4	0	0	0	0	0	0	0	0
	5	4	1	0	4	2	3	7	6
	7	0	0	0	0	0	0	5	1
	8	4	0	0	5	1	2	4	5
	9	0	1	0	4	0	2	0	3
	10	0	0	1	1	0	1	6	4
	11	0	0	0	1	0	3	6	3
	# Sites	4	3	2	7	3	6	6	7

As macrophyte species richness was very low and no macrophyte species were found in many samples, data were pooled into transect data for species richness. The highest mean value of species richness was 3.67 species per transect at Site 8 in 2009 and 4 species per transect at Site 5 in 2014, while the lowest mean values of species richness were at Site 4 in both years (Chart 1-2, Appendix 3). Highest total species richness was at Sites 1, 5 and 8 (4 species) in 2009, and 6 species at Sites 1 and 5 (2014). There were no significant differences in species richness between 2009 and 2014 at any site except Site 4 where no macrophytes were noted from transect assessments in 2014 (Chart 1-2, Appendix 3). There were significant differences in species richness among sites (two-way ANOVA on transect data). No significant difference was found in species richness between Phase 1 and Phase 2.

Sample data were also pooled by group for species richness, based on distance from shore (i.e. near-shore, mid-distance and far-shore zones) at each site. Species richness showed a general increase from near-shore distance to far-shore distance at some sites (Sites 2, 3, 5, 8, 10 and 11; Chart 1-4, Appendix 3); however, there were no significant differences in relative abundance and species richness among distance groups, as determined by 2-way ANOVA.

Macrophyte Relative Abundance

In total, seven macrophyte species were recorded during the two-phase survey. The highest mean macrophyte relative abundance (% coverage) was 97.78% per sample at Site 8 (2009) and 81.11% at Site 5 in 2014 (Chart 1-1, Appendix 3). The lowest mean macrophyte relative abundance was 33.89% per sample at Site 7 (2009), and no macrophytes at Site 4 (2014). Relative abundance of macrophyte communities decreased significantly ($p < 0.05$, paired t-test) at six sites (Site 2 [p=0.0192, Cohen’s d=0.89], Site 3 [p=0.0029, Cohen’s d=1.73], Site 4 [p=0.0068, Cohen’s d=1.63], Site 8 [p=0.0013, Cohen’s d=2.02], Site 9 [p=0.0011, Cohen’s d=3.99] and Site 11 [p=0.0308, Cohen’s d=0.90]) between 2009 and 2014, and showed no significant difference at remaining sites (Chart 1-1, Appendix 3). Relative abundance was significantly higher in Phase 1 than in Phase 2 among sites and between Phase 1 and Phase 2 ($p < 0.0001$), as determined by 2-way ANOVA.

Non-metric MDS plot displays spatial and temporal differences in community structure of transect samples at the 10 sites in 2009 and 2014 (Chart 1-5, Appendix 3). Overall, macrophytes were significantly different in community structure between 2009 and 2014 (two-way ANOSIM, $R = 0.373$, $p < 0.001$), and among sites ($R = 0.641$, $p < 0.001$). No clear pattern could be found among sample groups with distance from shore (Chart 1-6, Appendix 3), which was also confirmed by no significant difference among 3 distance groups (i.e., near-shore, mid-distance and far-shore zones).

There were significant differences in species richness among sites; however, no significant difference was found in species richness between Phase 1 and Phase 2 as determined by 2-way ANOVA.

Table 3-9: Overall Mean Macrophyte Abundance

Site	Phase 1 Mean Macrophyte Abundance (% Coverage per Quadrat)	Phase 2 Mean Macrophyte Abundance (% Coverage per Quadrat)
1	29.9	57.2
2	61.1	27.2
3	53.9	2.2
4	38.4	0.0
5	92.8	81.1
7	33.9	24.2
8	97.8	47.2
9	58.1	20.0
10	55.6	38.9
11	67.2	28.9

Sample data were also grouped for relative abundance and pooled by group for species richness, based on distance from shore (i.e., near-shore, mid-distance and far-shore zones), at each site. There was no clear pattern in relative abundance for sample groups with distance from shore (Chart 1-3, Appendix 3). Paired t-test analysis for each site showed no significant difference in total macrophyte distribution area between 2009 and 2014.

3.3 Biophysical Observations

Data provided below is from *in situ* profiling of selected points. Data may not be representative of general reservoir conditions.

3.3.1 Water Quality (Phase 1 & Phase 2)

Water quality profiles were conducted in September and October 2014 at Revelstoke Reservoir for temperature, conductivity, pH, redox (ORP), turbidity and dissolved oxygen (DO) and are discussed below. Mean water quality values are discussed below for four sites in Phase 2 (Sites 1, 5, 7 and 8) and compared to the same sites in Phase 1.

This study examines water quality at a single event only and results may not be representative of annual conditions. General trends between regions of the reservoir and among study year are discussed below.

Temperature

In the Revelstoke Reservoir, mean temperatures during the Phase 2 assessments generally decreased with increasing distance up reservoir from the Revelstoke Dam. This pattern was also observed during the Phase 1. Mean temperatures were generally higher at down reservoir sites compared to up reservoir (Site 1 [14.76 °C ± 0.05°C], Site 5 [13.00°C ± 0.00°C], Site 7 [10.09°C ± 0.53°C] and Site 8 [11.91°C ± 0.01°C]), tending to support better vegetation growth closer to Revelstoke Dam vs. sites further up reservoir. Temperatures at each site were comparable between Phase 1 and Phase 2.

Water temperature is an important variable that can affect the suitability of an ecosystem to support aquatic organisms. Factors which can influence water temperature include seasonal and daily changes in sunlight energy, shade, air temperature, stream flow, water depth, inflow of groundwater or surface water, and the colour and turbidity of the water. Optimal water temperatures for aquatic life (i.e., salmonids) are typically below 15°C (EPA, 1998). Water temperatures consistently outside of this range (i.e., 20+°C) may negative effect sensitive species. High water temperatures (up to an organism-specific limit) generally increase biological activity for many organisms (Fidler and Oliver, 2001; Haidekker, 2005). Temperature also affects biological activity by influencing water chemistry. Warm waters contain less dissolved oxygen (DO) than cooler waters, as solubility of oxygen in water is temperature-dependent (Mel'nichenko *et al.*, 2008). Such reduced DO levels may be insufficient to support development of macrophyte communities.

Sites located near anthropogenic activities (e.g., forestry, waste discharges, transportation rights-of-way and recreation sites) in the Revelstoke Reservoir (i.e., Sites 1, 5) did not have temperatures that differed from other sites, suggesting Revelstoke Reservoir waters temperatures were not influenced by anthropogenic inputs. Anthropogenic activities may cause thermal effects (i.e., degradation of water quality by any process that changes ambient water temperature). Discharge of heated water from industrial processes can increase the reservoir water temperature (Brown et al., 1983). Removal of shading vegetation along reservoir banks and increases in water turbidity due to anthropogenic activities can be other sources of thermal pollution (Henry and Heinke, 1996).

Dissolved Oxygen (DO)

Water at each of the available long-term study sites in Revelstoke Reservoir was well oxygenated, with DO levels ranging from 9.88 mg/L ± 0.00 mg/L (Site 5) to 10.58 mg/L ± 0.06 mg/L (Site 7). DO concentrations were similar to Phase 1 levels (ranging from 9.42 mg/L [Site 2] to 11.67 mg/L [Site 11]).

Dissolved oxygen (DO) analysis is a measure of the amount of gaseous oxygen (O_2) dissolved in an aqueous solution. Oxygen dissolves into water by diffusion from the surrounding air, by aeration (rapid movement) and as a by-product of photosynthesis (Poppe, 1987). Riverine waters are usually more oxygenated than lacustrine waters, given that water movement tends to introduce more oxygen into the water, which may explain why up reservoir sites were slightly more oxygenated than those down reservoir.

Conductivity

Conductivity measurements, both prior to the impoundment phase and in Phase 1 and Phase 2 of this assessment, were similar, suggesting changes in land use activities (e.g., logging, urbanization) throughout the Revelstoke Reservoir watershed between 1984 and 2009 did not appear to effect nutrient inputs at selected potential long-term sites; however, given that conductivity data were not available for macrophyte sampling sites between 1984 and 2009, this hypothesis could not be further affirmed.

Conductivity measurements collected during 2014 field surveys ranged from 74.93 µS/cm ± 7.10 µS/cm (Site 7) to 119.34 µS/cm ± 0.03 µS/cm (Site 8) which were comparable to Phase 1 observations (86 µS/cm [Site 7] to 148 µS/cm [Site 9]). Conductivity was generally higher at up reservoir sites compared with those assessed downstream, suggesting possible releases from upstream sources through the Mica Dam providing nutrient input to Revelstoke Reservoir. Conductivity measurements remained low throughout the reservoir during field surveys. As such, it is unlikely that a discernable difference in effect (positive or negative) was imparted by conductivity between macrophyte communities located at sites up reservoir and those down reservoir.

Conductivity provides an estimate of the amount of total dissolved ions in water. Many factors influence the conductivity of freshwater, including geology, watershed size, input from point and non-point sources of nutrients and minerals, atmospheric fallout, evaporation rates, precipitation and bacterial metabolism (McNeil and Cox, 2000).

Conductivity can have an influence on the distribution and health of macrophytes, with some species being more sensitive to excessively high or low values than others. For example, Holmes and Whitton (1975) reported that *Ranunculus aquatilis* was negatively correlated to conductivity (i.e., increases in conductivity lead to corresponding decreases in *R. aquatilis* coverage), while several species of *Potamogeton* can be positively correlated to conductivity; however, there were no notable correlations between species and specific environmental parameters.

pH

In Phase 2, pH values from available data files (Site 1, 5, 7 and 8) ranged from 7.81 ± 0.05 (Site 7) to 7.98 ± 0.05 (Site 1) and were similar to pH values observed in Phase 1 (7.57 [Site 7] to 7.94 [Site 2]). Values were slightly lower at up reservoir sites compared to those down reservoir.

If water becomes either too alkaline or acidic, it can be inhospitable to many species of macrophytes. The Canadian Council of Ministers of the Environment (CCME, 2012) states the optimum range of pH for the protection of aquatic life to be 6.5 to 9.0 pH units. Water profiles within the Revelstoke Reservoir were noted to be within this range.

pH is a measure of the hydrogen ion concentration (or acidity) in water. A pH of 7 is considered neutral. Values lower than 7 are considered acidic, while values higher than 7 are basic. Many important chemical and biological reactions are strongly affected by pH. In turn, chemical reactions and biological processes (e.g., photosynthesis, respiration) can influence pH (CCME, 1999).

Revelstoke Reservoir water was found to be slightly basic at all sites studied, suggesting that pH could prevent or cause certain species to grow, though it did not impart a decisive influence on macrophyte community presence or absence between study sites.

Redox (ORP)

During Phase 2 assessments, redox values ranged from 165.64 mV ± 6.31 mV (Site 7) to 185.71 mV ± 16.81 mV (Site 1), and did not exhibit any obvious trends with distance from the Revelstoke Dam. Data was slightly lower at each of the four sites when compared to Phase 1 which ranged from 181 mV (Site 7) to 203 mV (Site 5).

The decomposition of organic matter proceeds in a succession of redox reactions oxidizing an organic substance to yield carbon dioxide and water. Oxidation-reduction (i.e., redox) reactions are characterized by the flow of electrons between oxidized and reduced states toward equilibrium (Wetzel, 2001). When oxygen is dissolved in water, a redox potential (Eh) is generated. Dissolved organic compounds effectively lower redox potential in sediment and reduce the depth to the redox discontinuity (RPD) layer, a zone of rapid change from positive to negative Eh values (the transition between oxic, oxidizing and anoxic reducing layers; Sampou and Oviatt, 1991; Levington, 1995). High rates of organic matter loading eventually create anoxic sediments with Eh levels of less than 0 mV and surface RPD (Hargrave *et al.*, 1997). In freshwater, redox can range between +500 mV in the oxic zone to approximately -200 mV in the sulfidic- and methane-based zones (Mackie, 2004). The dimensions of these zones vary depending on the concentration of decomposed organic substances in sediment and turnover rates of those sediments. Redox values can often fluctuate in the range of ±50 mV (Schüring et al., 2000).

Redox values were representative of an oxic zone environment at each of the study sites. Redox values in freshwater ecosystems mostly depend on the type of rocks present in the watershed (Schüring et al., 2000), explaining why there are few differences between measurements at selected sites. Reductive agents (e.g., organic compounds) are a contributing factor in the decrease of oxygen in water. Reductive agents also decrease the redox potential, indicating the deterioration of water quality.

The lowest redox values measured among monitoring sites were reported at Site 7 (165.64 mV ± 6.31 mV); located at the confluence with Kirbyville Creek). There was no discernable trend in redox values with distance from the Revelstoke Dam and/or with land use activities.

Turbidity

In Phase 2, Revelstoke Reservoir turbidity ranged from 1.16 NTU ± 0.49 NTU (Site 1) to 3.67 NTU ± 0.17 NTU (Site 7) for the four sites assessed. Phase 2 turbidity values were comparable to Phase 1 values, with the exception two sites, which were higher in Phase 1. These sites include Site 1 (42.9 NTU [Phase 1] vs. 1.16 NTU [Phase 2]) and Site 8 (8.9 NTU [Phase 1] vs. 2.97 NTU [Phase 2]).

Turbidity is a measure of water clarity. Turbidity in water is caused by suspended matter (e.g., clay, silt, organic matter, plankton, other microscopic organisms) that interferes with the passage of light through water (APHA, 1998). Very clear water, however, is not necessarily a sign of good water quality, as suspended particles can be induced to fall (decreasing turbidity readings) by high acid or salt conditions. Turbidity of natural waters tends to increase during runoff events due to increased overland flow, stream flow and erosion. Increased turbidity reduces light penetration, thereby decreasing the growth of aquatic plants and organisms (Gradall and Swenson, 1982). Further, very turbid waters will reduce the diversity and coverage of macrophyte communities.

Turbidity typically ranges from 0 to 1,000 NTU in freshwater ecosystems (i.e., lakes and rivers), with values exceeding 10 NTU considered turbid (Gradall and Swenson, 1982). Turbidity did not exceed 10 NTU at the four sites assessed. During Phase 1 the waters were clear; however, slightly elevated turbidity readings were reported which may be attributed in part to sediment possibly stirred up during study boat operation in shallow areas. Lower turbidity values measured at other sites indicated no discernable correlation between anthropogenic activities and/or creek confluences and turbidity. Of note, Revelstoke Reservoir is usually more turbid in the spring when several glacial tributaries transport sediments (Downie Creek being one of the major contributors; Hirst, 1991).

Studies implemented in the Kinbasket Reservoir, upstream of Golden, measured turbidity levels less than 2 NTU, except in the vicinity of large rivers such as the Sullivan (NTU = 50.0; BC Hydro, 2009). Turbidity did not appear to influence macrophyte community composition and distribution between down reservoir and up reservoir sites in either Phase 1 or Phase 2.

Transparency

Water bodies with medium and dense macrophyte cover are characterized by a low concentration of suspended sediments and, thus, high water transparency. Such high water transparency enables light to penetrate deeper into the water column and decreases attenuation of photosynthetically active radiation (PAR) with depth, thereby facilitating colonization of macrophyte communities (usually adapted to low irradiances) in deeper areas (O'Sullivan and Reynolds, 2004). Conversely, water transparency decreases where coverage and density of aquatic macrophytes are reduced, such as in cases of eutrophication (Hargeby *et al*., 1994). In freshwater ecosystems, where macrophytes reappear after a period of absence, water transparency gradually improves with increasing vegetation cover.

Water transparency (clarity) was based on *in situ* visual observations and Secchi disk readings, and was high in the reservoir. Macrophyte communities present at most sites were small and restricted to waters immediately above bottom substrates (~20 cm). As such, visual detection of macrophytes was not always possible even at sites where bottom substrates were visible. The Secchi disk was used to measure water clarity at the centre of each study site in cases where the bottom could not be visually observed; however, the Secchi disk was visible to the bottom at all sites in Phase 2, even when macrophyte assessment couldn't accurately be made from the surface. In Phase 1 Secchi depths were measured at Sites 4 (2.5 m), 6 and 9 (2.9 m at both). Secchi readings confirmed turbidity measurements taken concurrently at study sites in October 2009 and suggested that climate conditions (e.g., wind, rain) may impart a greater effect on water transparency than land use or the given site location. The research of Shulman and Bryson (1961) further substantiates the influence of climate conditions on water transparency, with the depth of wind frictional influence observed to be between 2 and 3.5 m on a moderate-sized lake (Lake Mendota).

3.3.2 Substrate Characteristics (Phase 1 & Phase 2)

No trends between qualitative sediment observations and zonation within the reservoir were reliably identified in Phase 1 and Phase 2. Variation in sediment quality was more consistent within a site than within a given reservoir zone.

Colonization of submerged, rooted macrophyte species depends on sediment bed characteristics, given that they are a source of nutrients and means of plant anchorage (Clarke and Wharton, 2001). Consequently, some macrophyte species may be sensitive to both physical and chemical sediment characteristics. Qualitative substrate observations were made at the near-shore, mid-distance and farthest from shore zones of the Centre Transect (i.e., C/A, C/B, C/C) for each site and are tabulated in Appendix 4.

Hydrogen sulfide (H_2S) imparts sediments with a distinctive smell (i.e., odour reminiscent of rotten eggs), and usually indicates anoxic sediments (i.e., lack of oxygen). Anthropogenic activities are usually an important source of organic matter in reservoirs and can cause anoxic sediments. *In situ* observations found sediment to be odourless in most cases, while some samples exhibited a hydrogen sulphide (H_2S) odour especially at Sites 3, 4 and 8 in both Phase 1 and 2. No notable trend in hydrogen sulfide odour was evident at sites near anthropogenic activities (i.e., Sites 1, 3, 5 and 11): most sediments collected at Site 1 and Site 5 were odourless, while H_2S odours were more prevalent at Site 3 in both Phase 1 and 2. Site 4 was located near a creek confluence and Site 8 was considered to be undisturbed. Wood and macrophyte debris were observed in sediments collected along the reservoir, though no correlation was discernable between hydrogen sulphide odour and debris present in sediment.

Soil erosion, associated with precipitation, is a main source of sediment input into creeks and rivers, subsequently transporting and depositing these materials to reservoirs (Morris and Jiahua, 1998). Several studies have reported that tributary inflow does not readily mix with main stream flow, resulting in abrupt changes to sediment colour for some distance downstream from the confluence (Murthy, 1996; Cohen, 2003; Vanoni, 2006). Transect points located near creek confluences (i.e., Sites 2, 3, 4, 7) tended to have grey-brown sediment colour near-shore and were more gravelly with notable sand and cobbles near-shore, and being more thick, pudding-like and silky at mid-distances from shore. Substrate at transect points located near anthropogenic activities (i.e., sites 1, 3, 5, 10, 11) did not have any consistency in colour, texture or smell.

Flows in a reservoir tend to decrease with proximity to the dam. This decrease in flow results in a loss of transport capacity and subsequent deposition of sediments; however, smaller sediment particles travel farther into the reservoir before deposition (USACE, 1997). Deep reservoirs, such as Revelstoke Reservoir, do not fully mix and are more conducive to the formation of turbidity currents (i.e., where currents dominated by suspended solids plunge and travel along the sloping bottom as an underflow, or an interflow in a stratified system where the density of the underflow equals that of the water column).

3.4 Climate Characteristics

Climate characteristics (i.e., mean, maximum and minimum monthly temperatures, total annual precipitation, and mean monthly wind speed) in the Revelstoke Reservoir area (1984 to 2014) are reported in Charts 3-1 to 3-3, Appendix 3 (TuTiempo, 2014). Mean annual temperatures ranged from 5.0°C (1996) to 8.9°C (1998), with a mean value for years from 1984 to 2014 of 7.1°C. Mean temperature in 2014 (7.1°C) was similar to mean values observed in previous years and fell within the standard deviation (7.1°C ± 0.8°C). In 2009 (Phase 1) the mean temperature was 6.8°C.

Between 1984 and 2014, annual maximum and minimum temperatures ranged from 26.0°C (August 2011) to 38.0°C (July 2003) and -4.8°C (January 2010) to -29.5°C (January 1991), respectively. Between 1984 and 2014, the mean maximum and minimum temperatures were 33.7°C to -18.4°C, respectively. In 2014, the maximum temperature recorded was 29.1°C (July), and minimum temperature was -9.9°C (February). 2014 was a mild year and maximum and minimum temperatures were outside the 1984 to 2014 standard deviation (i.e., 33.7°C ± 3.1°C and -18.4°C ± 6.8°C, respectively). In 2009, the maximum temperature recorded was 34.7°C (July), and minimum temperature was -18.3°C (January). 2009 maximum and minimum temperatures were within the 1984 to 2009 standard deviation (i.e., 34.8 °C ± 1.8°C and -20.7°C ± 4.8°C, respectively).

Total annual precipitation ranged from 450.4 mm (1993) to 1,197.1 mm (1988), with a mean of 874.8 mm (1984 to 2014). Total precipitation in 2014 was 735.3 mm, which was within one standard deviation for the period of 1984 to 2014 (874.8 mm ± 204.9 mm). Total precipitation in 2009 was 790.14 mm.

Wind speed may affect macrophyte community growth and distribution through changes in water movement and wave energy that may ultimately increase sediment resuspension, reduce light penetration and alter substrate materials (Madsen *et al.*, 2001). Mean monthly wind speed ranged from 4.4 km/h (1988) to 7.6 km/h (1990) between 1984 and 2014, with an overall mean of 6.1 km/h. Mean wind speed was similar between Phase 1 (6.1 km/h) and Phase 2 (6.2 km/h).

4.0 DISCUSSION

The primary goal of this program is to provide baseline information on macrophytes in Revelstoke Reservoir before and after the start of operations of the fifth generating unit at Revelstoke Dam. Key management questions addressed by this program are:

1. what are the diversity and distribution of macrophytes in Revelstoke Reservoir?; and,
2. would the changes in drawdown amplitude and frequency due to five-unit operations at Revelstoke Dam have any impact on aquatic macrophytes in Revelstoke Reservoir based on a comparison of Phase 1 and Phase 2 studies?

Should potential impacts be confirmed, other management questions include:

3. which species of aquatic macrophytes are most likely to be affected by the operation of REV5? and;
4. what are the best mitigating strategies to minimize any impact to or from aquatic macrophytes?

The project's null hypothesis is:

H_0: Implementation of normal post-REV5 operations does not result in measurable impacts on aquatic macrophytes distributions and biodiversity in Revelstoke Reservoir.

The hierarchy of questions contained within the project's null hypotheses is as follows:

A. Does the operation of the fifth unit exert an effect on the macrophyte community of Revelstoke Reservoir:

   a. Is the macrophyte community significantly different (confounding spatial and temporal influences addressed) between pre- (Baseline Year One) and post-unit installation (Year Five)?

      I. *Communities differ significantly in biodiversity, species richness, abundance, and/or abundance hierarchy between Year One and Year Five;*

      II. *Communities differ in extent and distribution between Year One and Year Two; and,*

      III. *Community structure (e.g., spatial heterogeneity, relative abundance, introduction of new species or elimination of old one(s)) has shifted between Year One and Year Five.*

These questions will be discussed in the following two sections. This section provides a discussion of the Phase 1 (2009) and Phase 2 (2014) results for the Revelstoke Reservoir Macrophyte Assessment Program. Discussion focuses on: use of NDVI as a model for macrophyte communities in Revelstoke reservoir; ecological descriptions of observed macrophyte communities; reservoir wide and individual test site macrophyte community comparisons between sites and between years; evaluation of environmental parameters influencing macrophyte distribution; and, assessment of potential influences to macrophyte communities from start-up of REV5 operations.

4.1 Influence of REV5 Operations (Overview)

The operating range of Revelstoke Reservoir, after REV5 installation, was projected to be the same as pre-installation conditions, with reservoir fluctuations at the start of REV5 operations estimated to be less than 0.25 m over 90% of the time (BC Hydro, 2006). With the increase from four to five operating units the frequency of moderate drawdowns (i.e., drafting to approximately 572.5 m or by 0.5 m) was predicted to be greater while the frequency of low drawdowns (i.e., drafting to ≥571.5 m or by 1.5 m) was predicted to be less frequent (BC Hydro, 2006). Impacts to aquatic macrophyte communities within Revelstoke Reservoir were predicted to be minimal based on the standard reservoir level daily variation of ≤0.25 m;

however, little information was originally available regarding distribution and depth of macrophytes in Revelstoke Reservoir.

In December 2010, the REV5 turbine became operational. Average monthly water elevation in Revelstoke Reservoir (August 1984 to February 2010) was 572.55 m while post REV5 operation levels (December 2010 to December 2014) were lower (572.36 m). Daily reservoir level variation, post REV5 operation was within the predicted fluctuation range (≤0.25 m 90.68% of the time; December 2010 to December 2014).

Eleocharis acicularis is a species well-adapted to fluctuating water levels, usually growing in marshes and shallow water of lakes, ponds and streams. Several studies have shown that *E. acicularis* is capable of rapid reproduction, rapid seed production and a flexible survival strategy (Nilsson, 1981; Rørslett, 1989; Renman, 1989; Hill et al., 1998). *E. acicularis* can spread rapidly when conditions are favourable. Goldsby and Sanders (1977) observed an increase in *E. acicularis* biomass at depths influenced by drawdown in a Louisiana lake, reflective of a shift in lake vegetation to an earlier successional stage (i.e., a stage where species with high fecundity, small body size, early maturity onset, short generation time and ability to disperse widely are dominant). Both terrestrial and aquatic forms of *E. acicularis* are genetically identical and freely interconvertible (Rothrock and Wagner, 1975).

In Phase 1, *E. acicularis* was observed at four long-term study sites (Sites 5, 7, 10 and 11) potentially influenced by low drawdown and it was anticipated that low drawdown might increase distribution of this species where water regulation restricted other species growth (i.e., reducing inter-species competition). In Phase 2, *E. acicularis* was the most dominant species and observed at six sites (Site 1, 5, 7, 8, 10 and 11) suggesting that conditions were more favourable for *E. acicularis* post REV5 and reflective of lower average water level elevations.

Overall, the same macrophyte species were observed in Revelstoke Reservoir between Phase 1 and Phase 2; however, some macrophyte species are more tolerant of lower water elevations, while others are capable of improved growth under such conditions. In the Chippewa Flowage of Wisconsin, a water body that has received repeated winter drawdowns for fifty years, Nichols (1975) identified five submersed species that either recovered or increased in coverage after repeated water fluctuations. In a separate study of several North American lakes, Davis and Brinson (1980) observed that *Potamogeton sp. affinity pusillus* moved 4 to 5 m closer to shore after re-flooding of a prairie pothole marsh. In addition, emergent species also had a tendency to germinate and invade the submersed zone during drought periods, such that biomass and species richness of the zone increased after re-flooding. These examples illustrate that although some submersed species may be severely affected by extreme water level fluctuations (especially species not rooted), others are able to adapt through a shift in zonation. Considering the community as a whole, Davis and Brinson (1980) noted that, irrespective of life form, water level fluctuation imparted little overall change to community production and diversity.

Reduced water elevations in the reservoir, post REV5, appear to have influenced relative abundance of certain species (i.e., *E. acicularis, R. aquatilis, Nitella sp,* and *P. amplifolius*); however, the ability of macrophytes to adapt to changes in water level suggests that the overall macrophyte communities observed in Revelstoke Reservoir were not notably impacted by REV5 operations.

4.2 NDVI Model

SPOT Satellite Imagery was tasked to capture high-resolution optical images of Revelstoke reservoir to help in answering the key management questions using a Normalized Difference Vegetation Index (NDVI). NDVI was used in an effort to map and compare surface area, composition and spatial location of macrophyte communities and to examine changes to the communities over time prior to and post operation of the fifth generating unit (REV5).

SPOT Satellite Imagery was captured within 2.5 weeks prior to field assessments in both Phase 1 (2009) and Phase 2 (2014) to ensure that macrophyte communities were at comparable stages of growth for satellite data acquisition and field survey. Improvements in SPOT satellite technology used between Phase 1 and Phase 2 complicated comparisons and NDVI model development between Phases. To overcome differences in satellite technology a comparison of Phase 2 satellite images using similar resolution and bandwidths used in Phase 1 was completed to enable a more direct comparison. Subsequently, Phase 2 satellite true colour image quality was increased and colour spectrum bandwidths were attenuated to *in situ* ranges to assess what macrophyte communities would otherwise be visible using the new technology.

Baseline comparison of Phase 1 and Phase 2 models with similar NDVI response values and spot check techniques was conducted to produce a more direct comparison of potential macrophyte communities between Phases. Using the baseline approach, macrophyte polygons were identified in the same or overlapping areas with Phase 1 polygons. In addition, potential macrophyte communities were identified on Phase 2 basemaps where no indication of macrophytes was observed on the Phase 1 basemaps. While the resolution and NDVI range of classes of SPOT images was adjusted to be the same in Phase 1 and Phase 2 the higher quality images produced by SPOT 6 allowed for more accurate potential macrophyte community observations to be made.

Ten long-term study sites were established in Phase 1. To attenuate and verify NDVI algorithm accuracy in each Phase, *in situ* vegetative community assessments and ground truthing were conducted. In Phase 2 the attenuated NDVI model was able to predict and approximate macrophyte communities at each of the ten long-term monitoring sites more accurately than in Phase 1 (mean predicted polygon area differences were 84.0% [Phase 1] vs. 22.9% [Phase 2]). Not all NDVI site predictions overlapped with study site ground truthing in Phase 1 (Site 4, 7 and 9) while all sites overlapped and compared well in Phase 2. The increased accuracy of the model made the comparison of changes to macrophyte communities complex between Phase 1 and Phase 2 over the entire reservoir.

NDVI classification ranges were attenuated to physical field observations of macrophyte communities. Using a single set of NDVI ranges across all long-term study sites in Phase 2 was assessed to be less meaningful due to differing reflectance properties caused by reservoir morphology, water elevation, water quality changes and other factors (e.g. silting, dissolved chemicals, surface reflectance, etc.). For example, in the middle of the reservoir north of Downie Arm, the range of NDVI values was less than in the north and south ends. Macrophytes were observed in a small range from -0.33 to -0.37 in this area (Sites 3 and 4), and from -0.33 to -0.45 at Site 5. Conversely, sites located at the north and south ends of the reservoir were found to contain macrophytes at areas with lower NDVI DN’s (as low as -0.55 DN).

Expanding the attenuated Phase 2 NDVI model to include estimates of macrophyte community coverage of the entire Revelstoke reservoir yielded approximate macrophyte coverage of 5.57 sq km for the entire reservoir.

4.3 Assessment of Macrophyte Communities at Long-term Study Sites

4.3.1 Macrophyte Assessment Methodology

Differences in macrophyte community extent and relative abundance may also be, in part, due to increases in method accuracy in Phase 2 over Phase 1. When assessing macrophytes, sampling procedures represent a critical component of plant community studies, particularly for deep-water submerged species that are not easily observed.

In Phase 1, a sampling rake was the primary method used to collect macrophytes. An Aqua-tiller® was used at deeper transect locations when no or minimal macrophytes were collected using the sampling rake and macrophytes were ‘seen’ using a sounder when poor visibility in the water prevented field personnel from determining conditions on the reservoir bottom. This device may have favoured sampling of larger macrophytes and appeared less effective in collecting smaller species. Capers (2000) found that small macrophyte species were particularly vulnerable to underestimation in boat surveys. The more frequent use of this device at down reservoir sites may have resulted in a bias by underestimating coverage of small species (e.g., *Nitella sp.*) at these sites.

Macrophyte per cent (%) coverage estimates were made at each sample plot where possible. In Phase 1 per cent (%) coverage at only four sample plots could not be made due to depth and/ or poor visibility. A depth sounder was also used to help delineate macrophyte communities located in deeper areas which were present, though not visually observed from the boat or via satellite.

A drop camera was employed during Phase 2 macrophyte assessments making it possible to visually observe macrophyte communities at all site locations and in deeper/ more turbid water. The drop camera enabled more effective estimates of per cent (%) cover, species presence, and macrophyte community boundaries in Phase 2. The potential increase in resolution in Phase 2 was considered in the analysis of macrophyte abundance between years; however, there were no significant differences in species richness between 2009 and 2014 at any site (except Site 4 where no macrophytes were noted).

4.3.2 Macrophyte Community Structure

Phase 1 and Phase 2 of the Revelstoke Reservoir Macrophyte Assessment Program provided information on the richness of macrophyte communities at the ten long-term study sites, as well as coverage of each species as documented at each transect point used to represent the long-term sites. Overall relative abundance of macrophyte communities significantly decreased ($p < 0.05$, paired t-test) at 6 sites (Site 2 [p=0.0192, Cohen's d=0.89], Site 3 [p=0.0029, Cohen's d=1.73], Site 4 [p=0.0068, Cohen's d=1.63], Site 8 [p=0.0013, Cohen's d=2.02], Site 9 [p=0.0011, Cohen's d=3.99] and Site 11 [p=0.0308, Cohen's d=0.90]) between 2009 and 2014, and showed no significant difference at remaining sites (Chart 1-1, Appendix 3).

No significant difference in species richness was found between Phase 1 and Phase 2 and there were no observable trends noted in macrophyte coverage and taxa richness between down-reservoir and up-reservoir sites or with distance from shore in either Phase 1 or Phase 2. The absence of such trends may be attributed to a number of factors, including:

- not all macrophyte species have the same morphology. For example, *Eleocharis acicularis* is small in size with no leaves, while *Potamogeton amplifolius* has large leaves and, as such, smaller numbers can still produce comparatively large spatial coverage;
- in shallow depths, water level fluctuations and wave erosion regularly and repeatedly create open patches in macrophyte communities where pioneer/opportunistic species can develop, thereby helping to maintain diversity near-shore. Therefore, changes in reservoir drawdown frequency post REV5 installation may alter/reduce the ability of some macrophyte species to occupy shallow areas; however, other pioneer/opportunistic species may begin to inhabit these areas; and,
- some extremely productive macrophytes have morphological adaptations that effectively reduce the opportunity (outcompete) for other aquatic plants to colonize a site. *Myriophyllum spicatum* has a high canopy-forming capability that often results in mono-specific communities. No notable trends were observed for *Myriophyllum spicatum* at long-term survey sites between Phase 1 and Phase 2.

A trend noted in the Phase 1 (2009) assessment described two obvious distributions of dominant species (i.e., *Potamogeton amplifolius*, *Nitella sp*.). *Potamogeton amplifolius* was found to be dominant at down reservoir sites (Sites 1 to 4), where it is generally deeper, while *Nitella sp*. was dominant at transect points of up reservoir sites (Sites 8 to 11), where it was generally shallower. In Phase 2 (2014) similar trends were noticed for *Potamogeton amplifolius* (dominant at Sites 1 and 2) and *Nitella sp.* (dominant species at Sites 8 and 9). Given that *Potamogeton amplifolius* was dominant in southern sections of the reservoir; this zonation suggests the species is competitive at locations where reservoir depths are high. The competitive nature of *P. amplifolius* may be attributed to its large leaves, which enable greater use of photosynthetically active radiation (PAR) and facilitate colonization of deeper waters. Conversely, the zonation also suggests *Nitella sp.*, a species having less surface area available for absorption of PAR, is more likely to colonize shallower areas, such as those in the northernmost section of the reservoir.

In shallow water, macrophyte production is limited by water volume and disturbance created by wave action and herbivory activities. Small taxa, such as *Nitella sp*., usually dominate in a mosaic of vegetated, disturbed shallow patches (Gilman *et al.*, 2008). Conversely, macrophyte communities in deep water are limited by light intensity. Species tolerant to low light and capable of rapid growth upward into improved light conditions tend to dominate. *Potamogeton amplifolius* is evergreen, with large leaves, thick stems and sturdy shoots that arise from underground rhizomes (see Appendix 5). These traits in part explain the long-term persistence of this species through reduced herbivory and rapid re-establishment of individual plants (Magnuson, 1990).

The most dominant species was *Potamogeton amplifolius* in 2009 (observed at Sites 1, 2, 3, 4, 5, 7 and 8) and *Eleocharis acicularis* in 2014. In 2009, *Eleocharis acicularis* was observed at four sites (5, 7, 10 and 11). In 2014, *Eleocharis acicularis* was dominant at Sites 5, 7, 10 and 11 and was also recorded at Sites 1 and 8 (no 2009 observations), possibly suggesting a slight shift to more favourable conditions for *Eleocharis acicularis. Potamogeton* species tend to be more sensitive to water level fluctuations, as they are less mobile and do not have terrestrial forms. *Eleocharis acicularis* can have both terrestrial and aquatic forms, suggesting that this species is not as vulnerable to water level fluctuations as other macrophyte species more sensitive to temporary exposure. *E. acicularis* usually colonizes areas with high organic content (Aiken *et al.*, 1999) and silt, thus explaining its presence at Site 7 (located at a creek confluence). Mats of *E. acicularis*, buried under silt, are capable of re-establishing themselves by internodal elongation and can produce new communities.

Several studies have shown that *Eleocharis acicularis* is capable of rapid reproduction, rapid seed production and a flexible survival strategy (Nilsson, 1981; *Rørslett*, 1989; Renman, 1989; Hill *et al*., 1998). *E. acicularis* can spread rapidly when conditions are favourable and is also resistant to erosion and bottom freezing (Hellsten, 2000). Goldsby and Sanders (1977) observed an increase in *E. acicularis* biomass at depths influenced by drawdown in a Louisiana lake, indicating a shift in lake vegetation to an earlier successional stage (i.e., a stage where species with high fecundity, small body size, early maturity onset, short generation time and ability to disperse widely are dominant). Increased distribution of this species may occur due to water regulations potentially restricting other species growth and reducing inter-species competition.

During Phase 1 assessments, Site 10 was noted to potentially be the most influenced by reservoir drawdown due to the shallow nature of the site. In Phase 2, *Eleocharis acicularis* was the dominant species at Site 10 and was most frequently observed. In Phase 1, *Nitella sp.* was the most dominant at Site 10, suggesting a possible influence from moderate reservoir drawdowns. *Nitella sp.* can move to deeper areas (through spore transport) where low drawdowns could potentially be detrimental. In 2014 *Nitella sp.* was only observed within a far-shore transect quadrat at Site 10.

Site 7 was also predicted to potentially be influenced by lowest reservoir drawdown. In Phase 1, *Eleocharis acicularis* and *Potamogeton amplifolius* were observed at Site 7 while in Phase 2, *Eleocharis acicularis* was the only species observed within sample plots.

Both macrophyte communities at Sites 7 and 10 may also be potentially influenced by confounding sources. Site 7 is at a confluence with Kirbyville Creek, which may lower the drawdown effect due to creek inflows. Creek inflows can change water quality and sediment characteristics at the confluence, thereby changing macrophyte habitat quality. Site 10 is located just up reservoir of Mica Creek Village and considered potentially influenced by the boating and fishing activities of residents and tourists residing there.

In Phase 1, *Ranunculus aquatilis* was considered a relatively "rare" species (i.e., found at only one long-term monitoring site). In Phase 2, *R. aquatilis* was observed at six sites (Sites 1, 5, 8, 9, 10 and 11). *R. aquatilis* usually colonizes shallow waters, less than 2.1 m (University of Wisconsin, 2010) can develop a terrestrial form and is able to tolerate a moderate amount of disturbance from desiccation and grazing (NCC, 1989), possibly suggesting that increased moderate drawdown may have favoured *R. aquatilis* growth in Revelstoke Reservoir.

In Phase 1 (2009) *Myriophyllum spicatum* (an invasive species) was observed sporadically (i.e., at Sites 1 and 5). In Phase 2, *M. spicatum* was again observed sparsely at Sites 1 and 5 and also within one sample plot at Site 8. Sites 1 and 5 were located in areas near anthropogenic activities (i.e., downstream from Martha Creek BC Provincial Park Campground and Downie Creek RV Resort, respectively) suggesting recreational boaters may have been the primary vector for introducing *M. spicatum* through use of public boat launches. Site 8 was an undisturbed site with no obvious indicator for introduction. *M. spicatum* was most likely introduced to Revelstoke Reservoir via boat motors, trailers, nets, boat propellers and fishing gear (Eiswerth *et al.*, 2000; Reed, 1977; Rothlisberger *et al.*, 2010). Concerted efforts to reduce and prevent spreading of *M. spicatum* appear to be working.

Water elevations in the reservoir showed an average decrease in elevation post REV5 turbine commissioning in December 2010. Average elevation levels prior to REV5 operation were 572.55 m (August 1984 to February 2010) while post REV5 operation levels were 572.36 m (December 2010 to December 2014), an average decrease of 19 cm.

In Phase 1 and Phase 2, maximum elevations at which macrophytes were observed were, in general, slightly lower at sites located in the southern half of the reservoir and attributed to shallower depths at north reservoir sites. These typically shallower sites were colonized by small species capable of growing in minimal water levels, but requiring large amounts of light to survive. Conversely, most macrophyte species colonizing the southern part of the reservoir required less light and were less sensitive to water depth. As a result, macrophyte communities at down reservoir sites tended to colonize deeper areas that were closer to shore (due to steeper slope).

In Phase 2, P. amplifolius, a species that prefers deeper water, was observed to have shifted to lower elevations at several down-reservoir sites (Sites 2 and 5 and potentially 3 and 4). Species that do well in shallow and disturbed areas such as E. acicularis were observed to have increased in relative abundance within many near-shore zones.

4.3.3 Macrophyte Community Extent

In situ measurements of macrophyte community size were made at each of the long-term sites in both Phase 1 (2009) and Phase 2 (2014) via visual observations, macrophyte sampling equipment, depth sounder, and drop camera (Phase 2 only).

No notable macrophyte community boundary trends were observed south and north reservoir sites. Macrophyte communities within shallow, more gently sloping sites (e.g. Sites 1, 5 and 10) generally showed some increase or little change in polygon area. Sites with more abrupt elevation changes (e.g. Site 8, 9 and 11) tended to show a decrease in macrophyte community size where macrophytes were not observed as far from the high water mark as noted in Phase 1. Decreases in community size at the far-shore edge of these sites are likely a result of increased ability to observe macrophyte communities (especially smaller macrophyte species) in deeper water at each site with the use of a drop camera.

Elevation can have an effect (positive or negative) on macrophyte communities, given that some species are more sensitive to elevation change than others (e.g., minimum water depth requirements, minimum light energy requirements). Researchers at the University of California (2001) identified different types of effects on macrophyte species depending on their tolerance to water drawdown, and noted that *Potamogeton amplifolius* growth was restricted by water drawdown levels (drafting from approximately 0.3-0.5 m to 1.2-1.5 m), while *Myriophyllum spp.* growth was found to be enhanced.

4.4 Environmental Parameters

Physical (i.e., sediment and water quality) data were collected to aid in the understanding of macrophyte ecology within Revelstoke Reservoir at the time of sampling both prior to and post REV5 installation and operation.

4.4.1 Substrate Characteristics

Colonization of submerged, rooted macrophyte species depends on sediment bed characteristics, given that they are a source of nutrients and means of plant anchorage (Clarke and Wharton, 2001). Consequently, some macrophyte species may be sensitive to both physical and chemical sediment characteristics. Further, there may be potential for interactions (e.g., competition, niche partitioning) among both individual plants and species related to sediment conditions. Macrophyte communities may also be influenced by the physical structure (e.g., particle size) and chemical nature (e.g., pH, nutrient load) of sediment. For example, coarse sediments are a good habitat for species with tough stems, roots and adventitious roots (e.g., *Myriophyllum spicatum*; Hynes, 1970); however, *M. spicatum* is a tolerant species that has also been observed in fine-textured, inorganic sediments (DCR, 2004). Finer sediments usually support fragile stoloniferous (i.e., capable of forming branches at their base that produce new plants) species and species with buried rhizomes such as some Potamogeton spp. (Hynes, 1970).

Sediment characteristics may have influenced reservoir macrophyte communities especially at sites located near creek confluences. Sediments from watershed soil erosion can be transported by creeks and deposited in the reservoir near creek confluences. Variation in substrate composition and sediment stability due to water flow at these creek confluences may favour colonization of opportunistic macrophyte species and/or prevent colonization by more sensitive species. Areas with many different substrates may be more likely to harbour opportunistic species than areas with homogenous substrate; however this trend was not observed in the either Phase 1 or Phase 2.

Anthropogenic activities may also influence sediment distribution and composition; however, no notable changes to macrophyte community structure (i.e., taxa richness and macrophyte distribution) were observed between monitoring sites located near anthropogenic activities and monitoring sites located farther from such activities (i.e., near creek confluences or in undisturbed areas).

4.4.2 Water Quality

Most aquatic life, including macrophytes, requires oxygen. Although high DO levels observed during both Phase 1 and Phase 2 assessments appeared favourable to macrophyte growth, a low productivity typical for many reservoirs was observed in this system. This low biological productivity was also reported in a previous study (Triton, 1992), based on low phosphorus and nitrogen concentrations (1978 to 1991). In the 1992 report, concentrations of phosphorus and nitrogen were sufficiently low to classify the Revelstoke Reservoir as an ultra-oligotrophic reservoir. Phosphorus levels varied significantly with depth, though not between seasons. Nitrogen concentrations did not vary significantly between seasons or with depth. In general, low nutrient levels (particularly phosphorus) were likely a limiting factor in the production of macrophytes in the reservoir. Low productivity reported in Phase 1 and Phase 2 may also be reflective of low nutrient content in Revelstoke Reservoir, rather than depletion in oxygen. Nutrients were not assessed in this program. There was no evidence of effects to dissolved oxygen concentrations due to REV5 operation.

Water temperature and conductivity are two water quality parameters that may have had an influence on macrophyte distribution in Revelstoke Reservoir. In winter, macrophytes usually stop growing. In October 2014, water temperatures had already begun to decrease, with macrophyte coverage also anticipated to decrease accordingly. Higher temperatures measured at down reservoir sites, which generally were of greater depth, were associated with the thermal retention properties of water and may have enabled some species, more sensitive to low temperatures (e.g., *Potamogeton amplifolius*), to grow in the reservoir for a longer period. This pattern was also observed in Phase 1.

Other water quality parameters (pH, redox, turbidity, transparency, dissolved oxygen) exhibited slight differences between sites; however, they were all favourable to macrophyte community growth in the reservoir and did not exhibit values that would otherwise appear to affect the growth and survival of sensitive species. No notable trends were observed between Phase 1 and Phase 2.

5.0 SUMMARY

The operating range of Revelstoke Reservoir, after REV5 turbine installation, was projected to be the same as pre-commissioning conditions, with reservoir fluctuations at the start of REV5 operations estimated to be less than 0.25 m over 90% of the time (BC Hydro, 2006). With the increase from four to five operating units the frequency of moderate drawdowns (i.e., drafting to approximately 572.5 m or by 0.5 m) was predicted to be greater while the frequency of low drawdowns (i.e., drafting to ≥571.5 m or by 1.5 m) was predicted to be less frequent (BC Hydro, 2006).

In December 2010, the REV5 turbine became operational. Average monthly elevation levels in Revelstoke Reservoir from August 1984 to February 2010 were 572.55 m while post REV5 operation average monthly elevation levels from December 2010 to December 2014 were lower (572.36 m). Daily reservoir level variation post REV5 operation was ≤0.25 m 90.68% of the time (December 2010 to December 2014).

5.1 Program Summary

Phase 1 and Phase 2 examined pre- and post-commissioning conditions of the reservoir and associated macrophyte communities in an effort to accurately map their size, composition and spatial location using high-resolution satellite imagery and ground-truthing. Site assessments were conducted throughout the reservoir, initiated in the southern portion near Revelstoke Dam and concluded at the northernmost up reservoir end, near Mica Dam. Sites 6, 8 and 9 were located in undisturbed areas (Figure A-3, Appendix 1), Sites 2, 3, 4 and 7 near creek confluences, and Sites 1, 3, 5, 10 and 11 near anthropogenic activities.

Maps generated from SPOT satellite imagery and a Normalized Difference Vegetation Index (NDVI) algorithm were effective tools to predict Revelstoke Reservoir macrophyte communities. *In situ* vegetative community assessments and ground truthing were conducted to verify NDVI satellite map accuracy in both Phase 1 and Phase 2. Results of these assessments were used to attenuate the NDVI classification ranges in which macrophytes were found throughout the reservoir and produce a final more accurate macrophyte algorithm for the reservoir. The increased accuracy of the model in Phase 2 over Phase 1 made the comparison of changes to macrophyte communities complex between Phase 1 and Phase 2 over the entire reservoir. Expanding the attenuated Phase 2 NDVI model to include estimates of macrophyte community coverage of the entire Revelstoke reservoir yielded approximate macrophyte coverage of 5.57 sq km for the entire reservoir.

All seven species observed in Phase 1 were also observed in Phase 2: *Potamogeton amplifolius* (large-leaf pondweed), *Potamogeton alpinus* (northern pondweed), *Potamogeton foliosus* (leafy pondweed), *Eleocharis acicularis* (needle spikerush), *Nitella* sp., *Myriophyllum spicatum* (Eurasian watermilfoil), and *Ranunculus aquatilis* (white water crowfoot). The most dominant species was *Potamogeton amplifolius* in 2009 (observed at Sites 1, 2, 3, 4, 5, 7 and 8) and *Eleocharis acicularis* in 2014. Relative abundance of macrophyte community significantly decreased at 6 sites (2, 3, 4, 8, 9 and 11) from 2009 to 2014, and showed no significant difference at the other four sites. Significant differences were found in relative abundance among sites and between 2009 and 2014, as well as in species richness spatially. No significant difference in species richness was found between Phase 1 and Phase 2. There were no significant differences in relative abundance and species richness among sample groups with different distance from shore.

In 2009, *Eleocharis acicularis* was observed at four sites (5, 7, 10 and 11). In 2014, the same species was dominant at Sites 5, 7, 10 and 11 and was also recorded at Sites 1 and 8 (no 2009 observations), possibly suggesting a slight shift to more favourable conditions for *Eleocharis acicularis.* A trend noted in the 2009 assessment described two obvious distributions of dominant species (i.e., *Potamogeton amplifolius*, *Nitella sp*.). *Potamogeton amplifolius* was found to be dominant at sites in the south half of the reservoir (Sites 1 to 4), where it was generally deeper, while *Nitella sp*. was dominant at sites in the north half of the reservoir (Sites 8 to 11), where it was generally shallower. In 2014 similar trends were noticed for *Potamogeton amplifolius* (dominant at Sites 1 and 2) and *Nitella sp.* (dominant species at Sites 8 and 9). Given that *Potamogeton amplifolius* was dominant in southern sections of the reservoir;

this zonation suggests the species is competitive at locations with deeper waters. In Phase 1, *Ranunculus aquatilis* was considered a relatively “rare” species (i.e., found at only one long-term monitoring site). In Phase 2, *R. aquatilis* was observed at six sites (Sites 1, 5, 8, 9, 10 and 11). *R. aquatilis* usually colonizes shallow waters, less than 2.1 m (University of Wisconsin, 2010) can develop a terrestrial form and is able to tolerate a moderate amount of disturbance from desiccation and grazing (NCC, 1989), possibly suggesting that increased moderate drawdown may have favoured *R. aquatilis* growth in Revelstoke Reservoir.

In Phase 1, Site 10 was noted to potentially be the most influenced by low reservoir drawdown due to the shallow nature of the site. In Phase 2, *Eleocharis acicularis* was the dominant species at Site 10 and most frequently observed. In Phase 1, *Nitella sp.* was the most dominant at Site 10, suggesting some influence from subtle changes to reservoir drawdown.

The colour and consistency/texture of site sediments at long-term monitoring stations varied between sites located near creek confluences and those that were undisturbed or near anthropogenic activities, potentially restricting the growth of species sensitive to substrate change in these areas. There were no observed anthropogenic influences on sediment quality during Phase 1 and Phase 2 assessments.

Low water temperatures and low conductivity were present throughout the reservoir, consistent with historic results, which may affect low productivity at down reservoir and up reservoir sites; however, anthropogenic activities and creek confluences did not appear to have a notable influence on water quality during field assessments.

Overall, the same macrophyte species were observed in Revelstoke Reservoir between Phase 1 and Phase 2. Reduced water elevations in the reservoir, post REV5, appear to have influenced relative abundance of certain species as some macrophyte species tend to be more tolerant to lower water levels, while others are capable of improved growth under such conditions. As such, the ability of macrophytes to adapt to changes in water level suggests that the overall macrophyte communities observed in Revelstoke Reservoir were not notably impacted by REV5 operations.

Table 5-1: Summary of Objectives and Results

Objectives	Management Hypotheses	Management Questions	Results
• assess the biodiversity of aquatic macrophytes at established long-term study sites; • map the overall distribution of macrophyte communities.	H_0: Implementation of normal post-REV5 operations does not result in measurable impacts on aquatic macrophytes distributions and biodiversity in Revelstoke Reservoir.	5. What are the diversity and distribution of macrophytes in Revelstoke Reservoir?	1. All seven (7) species of aquatic macrophytes observed in Phase 1 were also observed in Phase 2: *Potamogeton amplifolius*, *Potamogeton alpinus*, *Potamogeton foliosus*, *Eleocharis acicularis*, *Nitella* sp., *Myriophyllum spicatum*, and *Ranunculus aquatilis*. In Phase 1, *Potamogeton amplifolius* was found to be dominant at down reservoir sites (Sites 1 to 4), where it is generally deeper, and *Nitella sp.* was dominant at up reservoir sites (Sites 8 to 11), where it was generally shallower. In Phase 2 (2014) similar trends were noticed for *Potamogeton amplifolius* (dominant at Sites 1 and 2) and *Nitella sp.* (dominant species at Sites 8 and 9), and *Eleocharis acicularis* observed as dominant at Sites 10 and 11. In Phase 2, *P. amplifolius*, a species that prefers deeper water, was observed to have moved to lower elevations at several down-reservoir sites (Sites 2 and 5 and potentially 3 and 4). Species that do well in shallow and disturbed areas such as *E. acicularis* were observed to have increased in relative abundance within many near-shore zones in Phase 2.
		6. Did changes in reservoir drawdown and frequency, due to fifth-unit (REV5) operation at Revelstoke Dam, have any impact on aquatic macrophytes in Revelstoke Reservoir?	2. Average monthly water elevation in Revelstoke Reservoir (August 1984 to February 2010) was 572.55 m while post REV5 operation levels (December 2010 to December 2014) were lower (572.36 m). There was some evidence to suggest that reduced water elevations in the reservoir, post REV5, influenced relative abundance of certain species (e.g., *E. acicularis).*
		Should potential impacts be confirmed, other management questions also include:	
		7. Which species of aquatic macrophytes were most likely (if at all) affected by the operation of REV5?	3. In Phase 1, *E. acicularis* was observed at four (4) long-term study sites (Sites 5, 7, 10 and 11). These sites were potentially influenced by low drawdown and it was anticipated that low drawdown might increase distribution of this species where water regulation restricted other species growth (i.e., reducing inter-species competition). In Phase 2, *E. acicularis* was the most dominant species and observed at 2 additional sites (Site 1, 5, 7, 8, 10 and 11) suggesting that conditions were more favourable for *E. acicularis* post REV5, reflective of lower average water level elevations.
		8. What are the best mitigating strategies to minimize any impact to aquatic macrophytes?	4. Overall, the same macrophyte species were observed in Revelstoke Reservoir between Phase 1 and Phase 2; however, some macrophyte species tend to be more tolerant to lower water levels and others showed improved growth under such conditions. The ability of macrophytes to adapt to changes in water level suggested that the overall macrophyte communities observed in Revelstoke Reservoir were not substantially impacted by REV5 operations.

5.2 Recommendations

Future assessments of macrophytes in drawdown reservoirs would benefit from the following program modifications, based on work done in Phase 1 and Phase 2 of this program:

- Normalized Difference Vegetation Index (NDVI) modelling was conducted using SPOT 6 technology in Phase 2 and SPOT 5 technology in Phase 1. SPOT 6 provided a better spectral resolution that was able to predict macrophyte communities more accurately than SPOT 5. Satellite resolution should be similar between phases of work to allow for direct comparisons between years and if possible use a higher (more expensive) spectral resolution (hyperspectral) for all phases of work, where budget permits.
- Use of drop-camera or similar technologies on transects provides continuous observations of macrophytes *in situ* and the ability to accurately estimate macrophyte coverage in deeper water and when water visibility is poor; and,
- Increased substrate sampling and inclusion of nutrient testing to enable comparisons of vegetation types by substrate character.

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APPENDICES

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Figures C-1 to C10:	Site 1 to 11 – Bathymetry & Macrophyte Communities
Figures D-1 to D10:	Site 1 to 11 – False Colour Composite & Macrophyte Communities

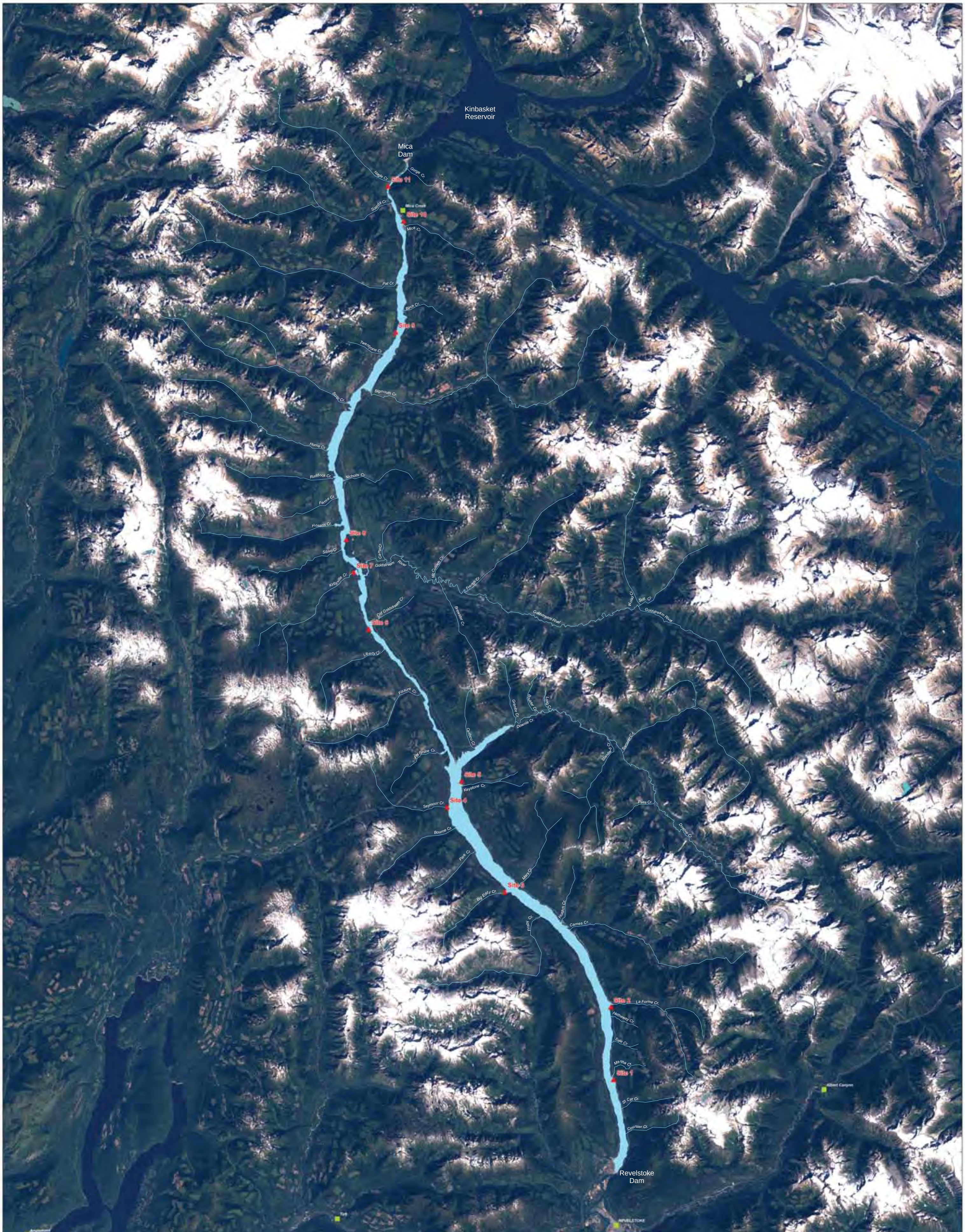

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Figure A-1: Macrophyte Assessment Program Selected Study Sites

Revelstoke Reservoir

Map Scale 1:125,000

Imagery: Landsat 7 ETM+
Date: August 23, 2002
Projection: UTM NAD83, Zone 11

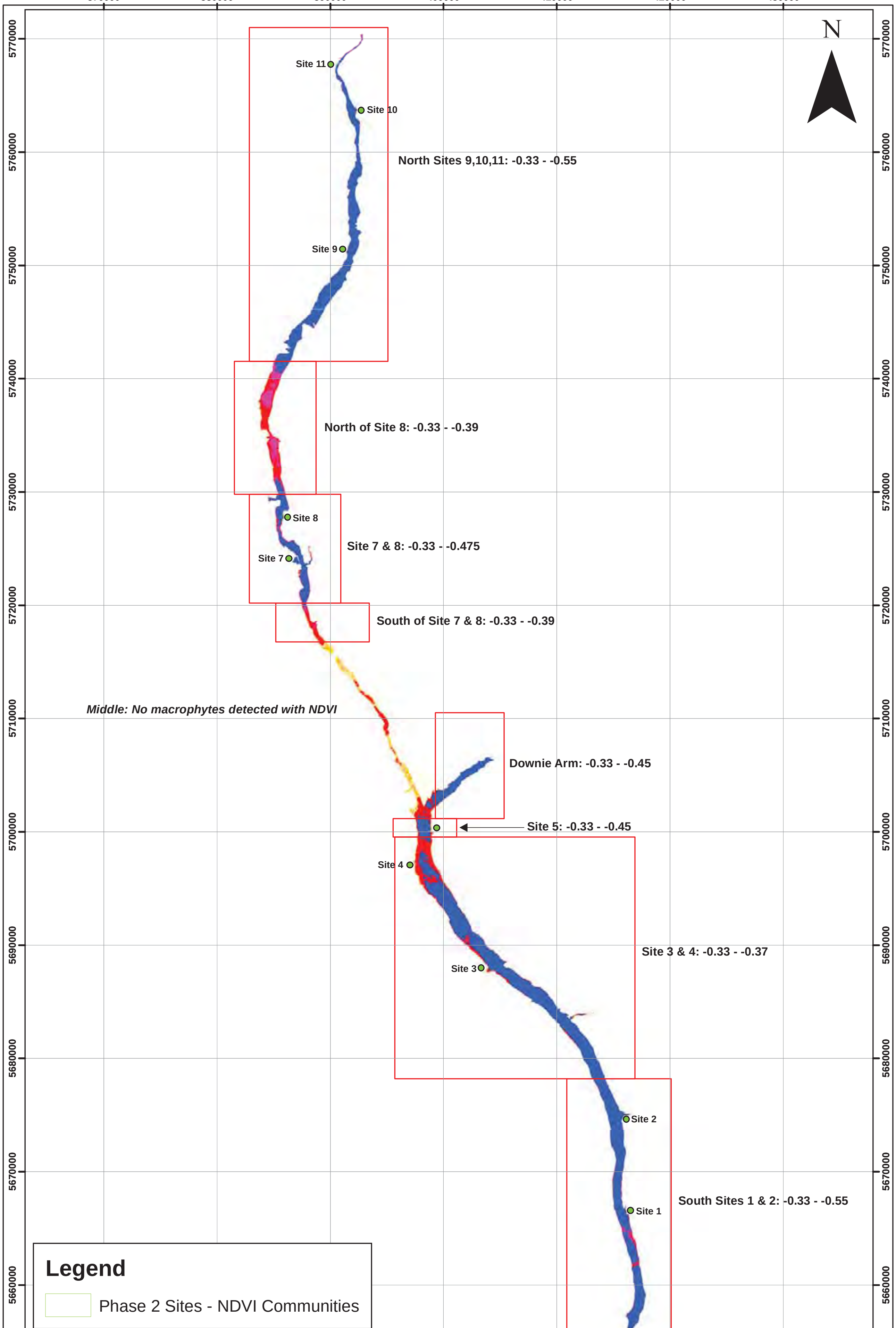

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Figure A-2: Revelstoke Reservoir Phase 2 NDVI Classification

0 2.5 5 10 15 20 25 30 35 40 45 50
Kilometers

Projection: NAD 83 UTM Zone 11
Data Source: Sept 29 - Oct 4 field work
Map Produced: Oct 31, 2014
Author: Chris Adamson

Map scale:
1:300,000

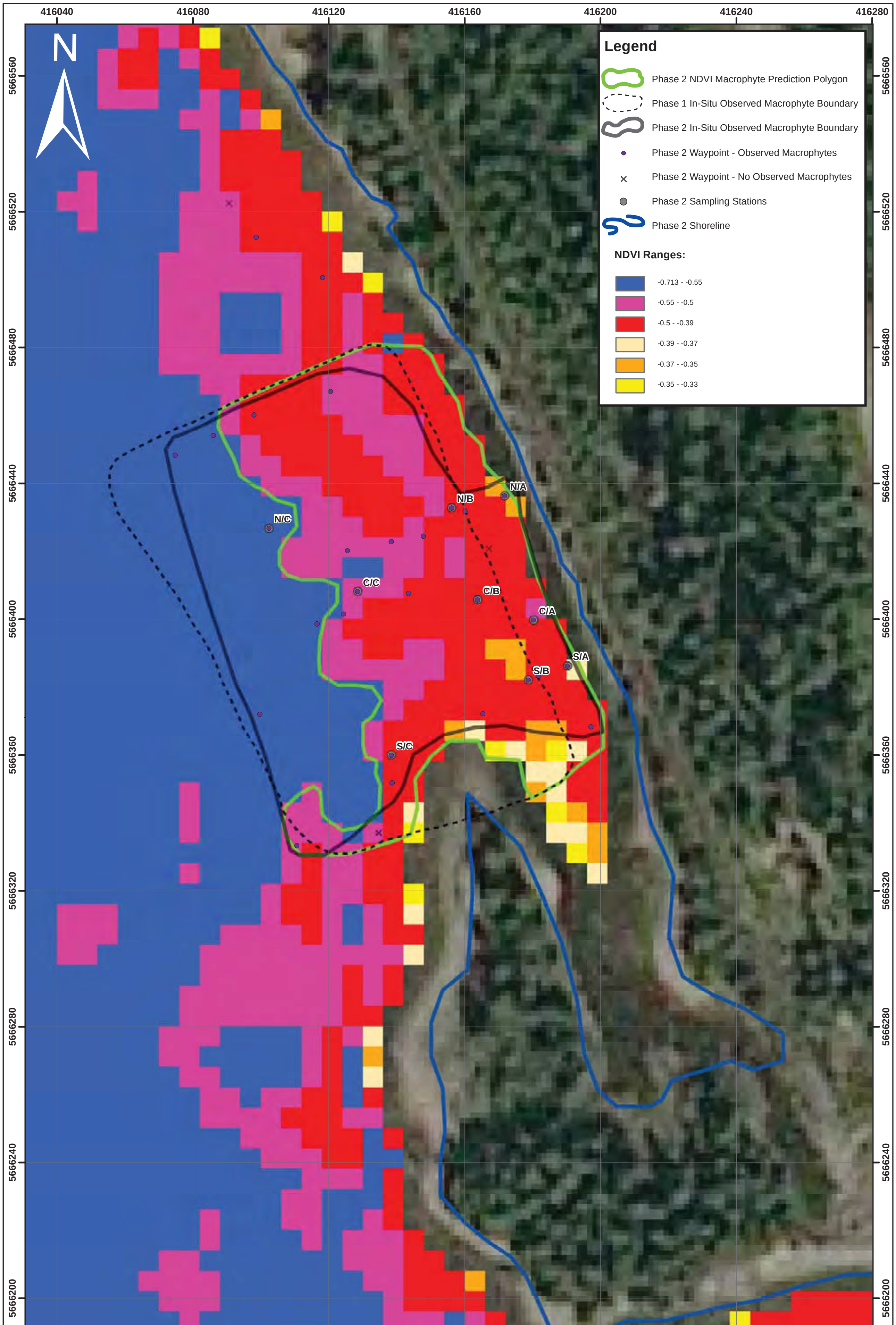

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Figure B-1: Revelstoke Reservoir
2014 Phase 2 NDVI Classifications - Site 1

0 5 10 20 30 40 50 60 70 80 90 100
Metres

Projection: NAD 83 UTM Zone 11
Data Source: Sept 29 - Oct 4 field work
Map Produced: Oct 31, 2014
Author: Chris Adamson

Map scale:
1:1,000

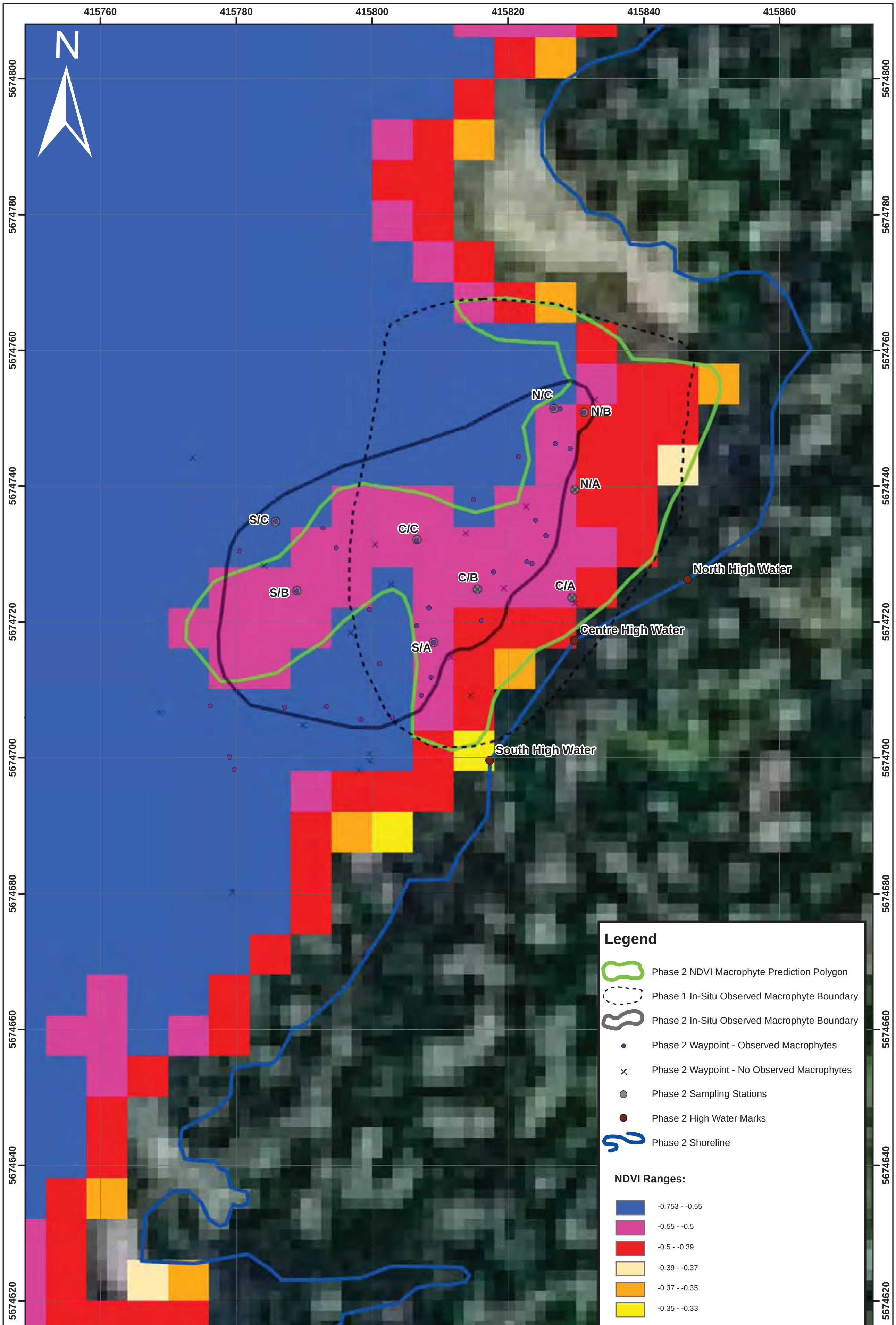

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Figure B-2: Revelstoke Reservoir 2014 Phase 2 NDVI Classifications - Site 2

Projection: NAD 83 UTM Zone 11
Data Source: Sept 29 - Oct 4 field work
Map Produced: Oct 31, 2014
Author: Chris Adamson

0 2.5 5 10 15 20 25 30 35 40 45 50
Metres

Map scale:
1:500

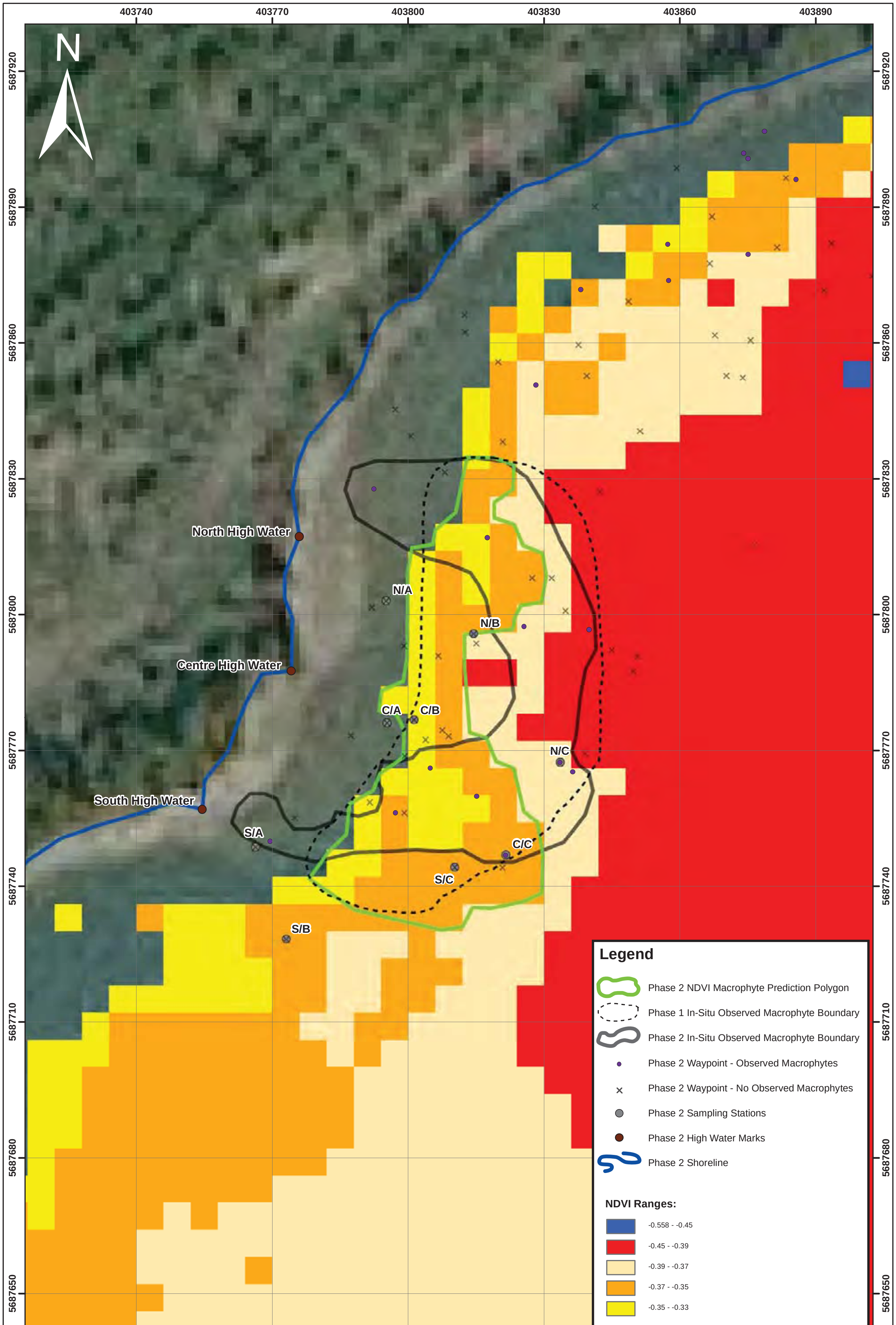

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Figure B-3: Revelstoke Reservoir
2014 Phase 2 NDVI Classifications - Site 3

0 5 10 20 30 40 50 60 70 80 90 100
Metres

Projection: NAD 83 UTM Zone 11
Data Source: Sept 29 - Oct 4 field work
Map Produced: Oct 31, 2014
Author: Chris Adamson

Map scale: 1:750

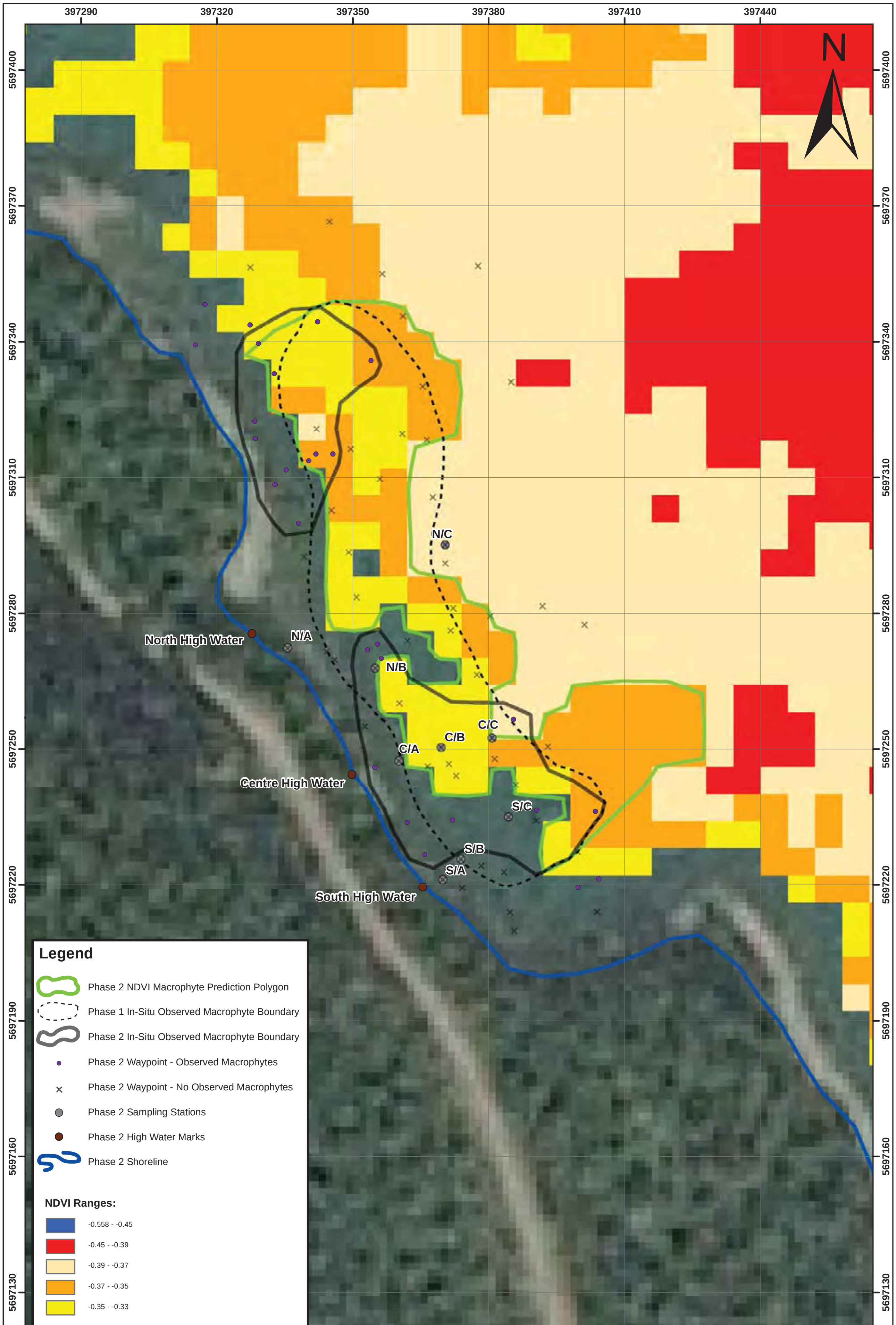

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Figure B-4: Revelstoke Reservoir
2014 Phase 2 NDVI Classifications - Site 4

0 5 10 20 30 40 50 60 70 80 90 100
Metres

Projection: NAD 83 UTM Zone 11
Data Source: Sept 29 - Oct 4 field work
Map Produced: Oct 31, 2014
Author: Chris Adamson

Map scale:
1:750

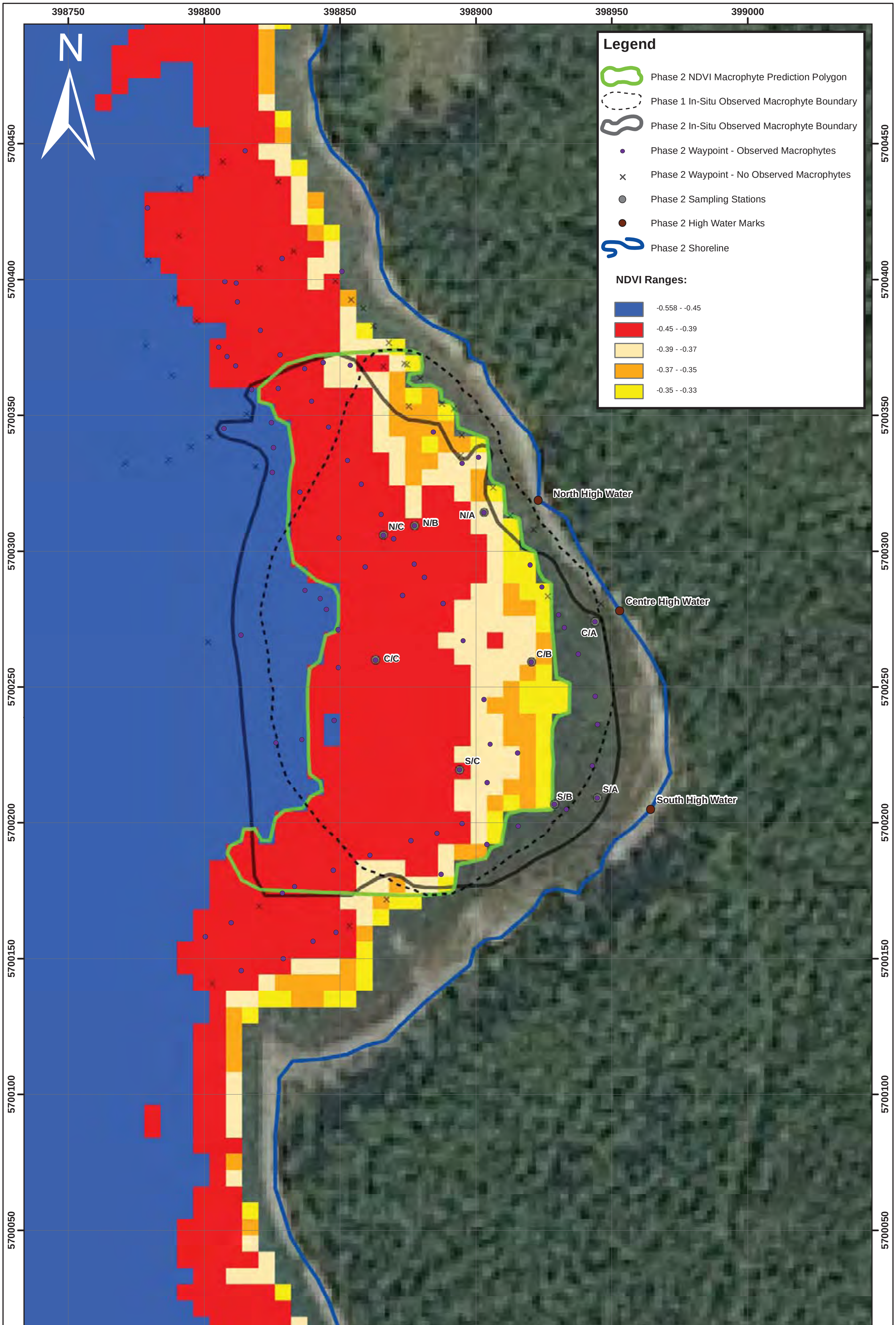

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Figure B-5: Revelstoke Reservoir
2014 Phase 2 NDVI Classifications - Site 5

0 10 20 40 60 80 100 120 140 160 180 200
Metres

Projection: NAD 83 UTM Zone 11
Data Source: Sept 29 - Oct 4 field work
Map Produced: Oct 31, 2014
Author: Chris Adamson

Map scale:
1:1,250

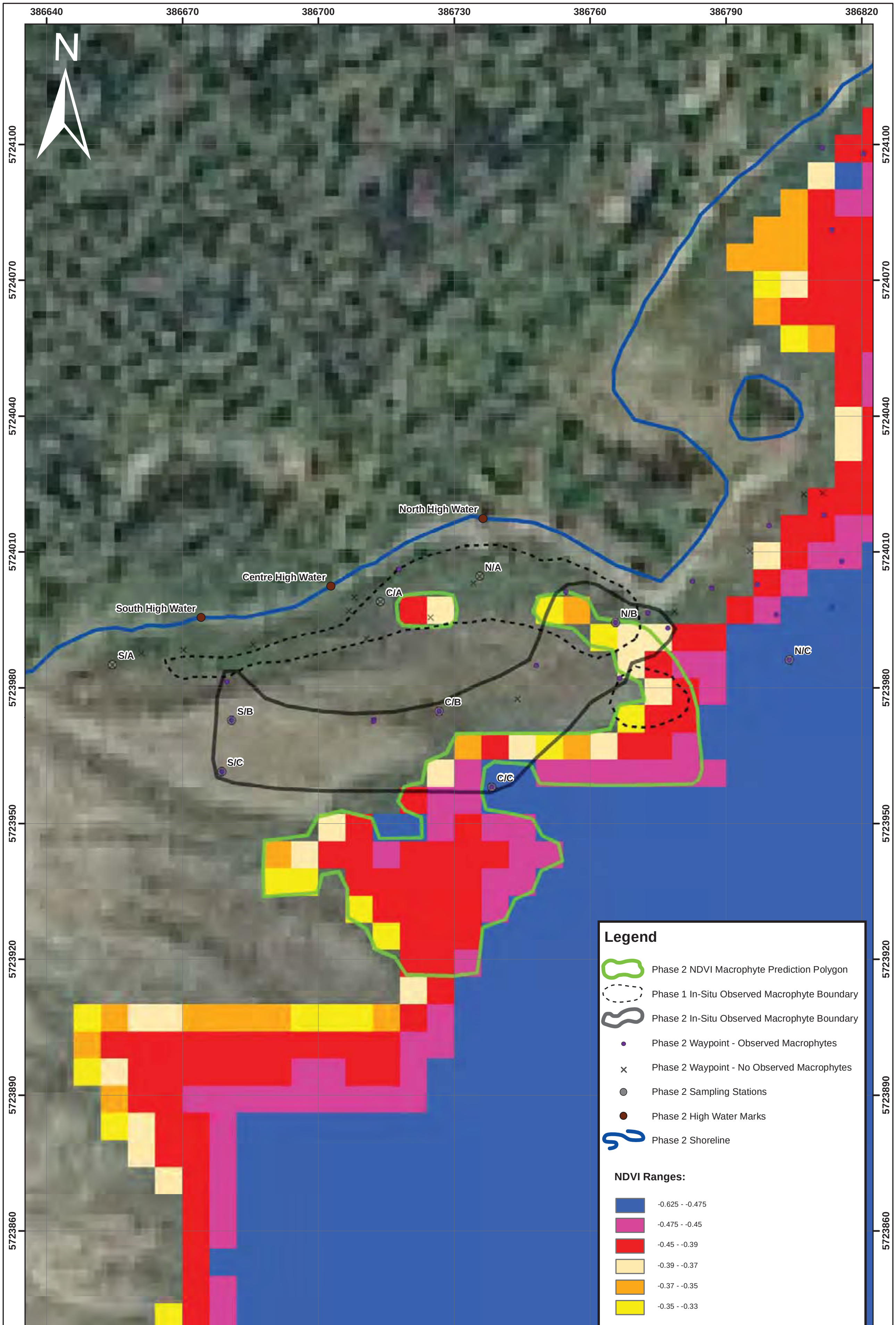

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Figure B-6: Revelstoke Reservoir
2014 Phase 2 NDVI Classifications - Site 7

0 5 10 20 30 40 50 60 70 80 90 100
Metres

Projection: NAD 83 UTM Zone 11
Data Source: Sept 29 - Oct 4 field work
Map Produced: Oct 31, 2014
Author: Chris Adamson

Map scale:
1:750

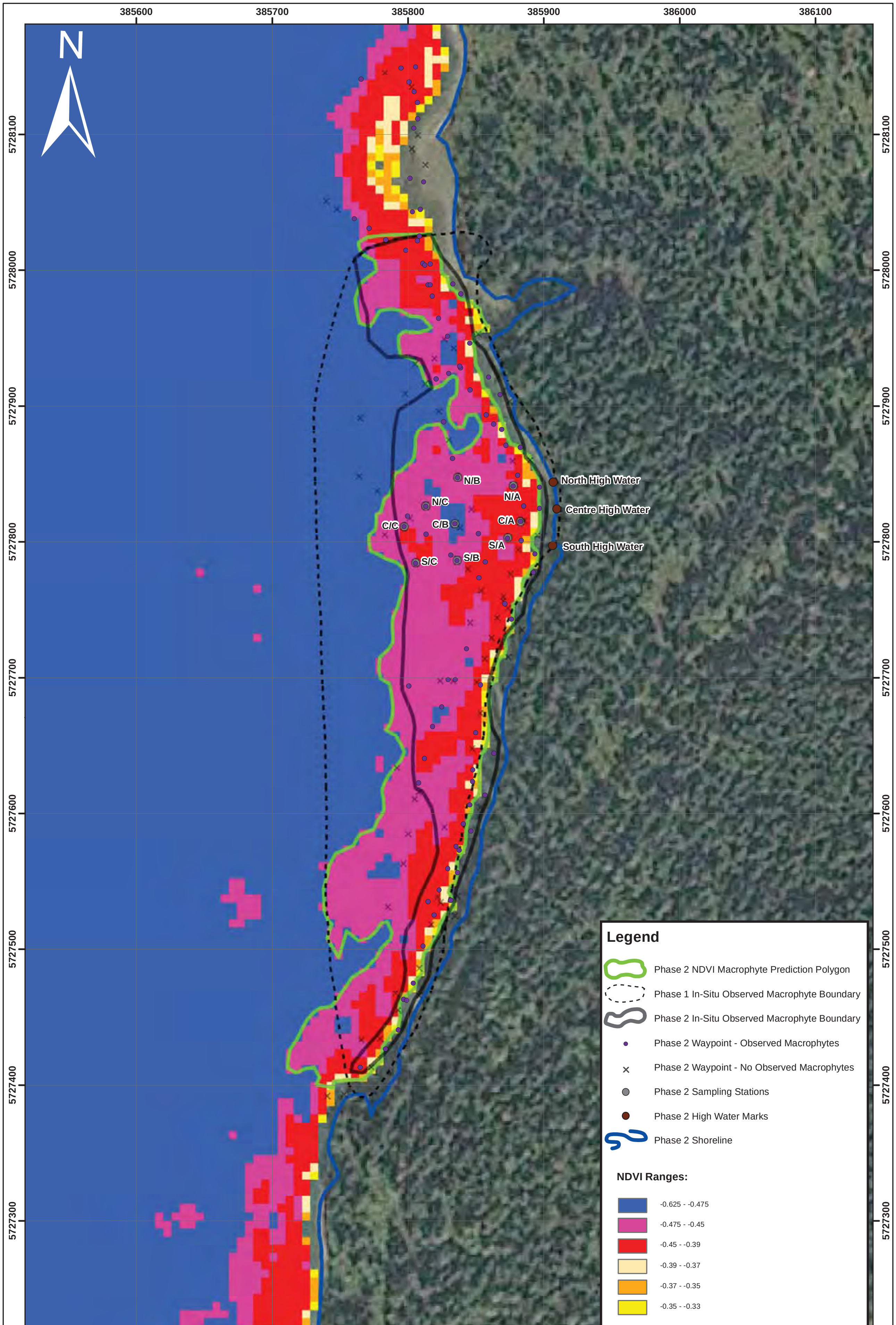

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Figure B-7: Revelstoke Reservoir
2014 Phase 2 NDVI Classifications - Site 8

0 20 40 80 120 160 200 240 280 320 360 400
Metres

Projection: NAD 83 UTM Zone 11
Data Source: Sept 29 - Oct 4 field work
Map Produced: Oct 31, 2014
Author: Chris Adamson

Map scale:
1:2,500

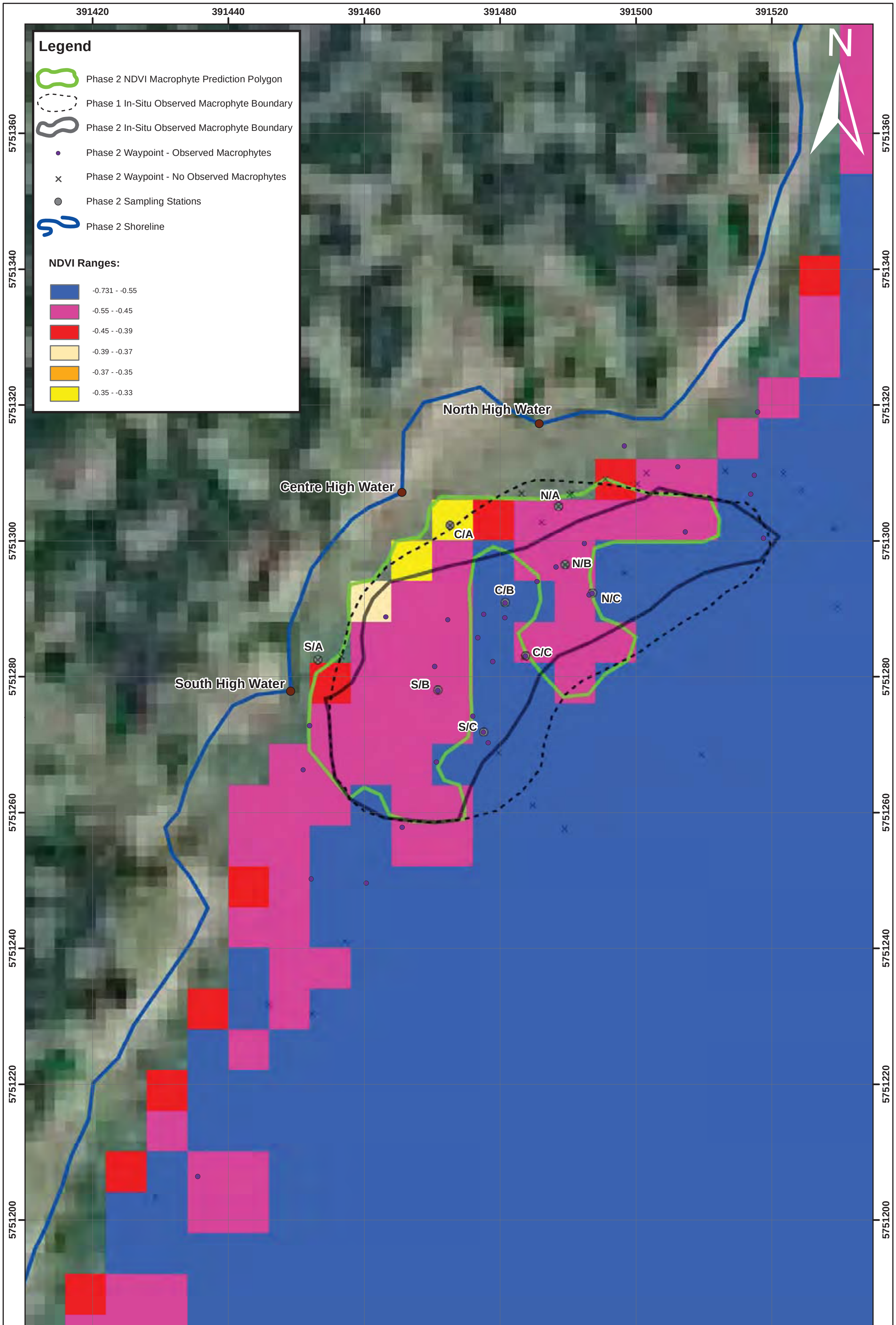

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Figure B-8: Revelstoke Reservoir
2014 Phase 2 NDVI Classifications - Site 9

0 2.5 5 10 15 20 25 30 35 40 45 50
Metres

Projection: NAD 83 UTM Zone 11
Data Source: Sept 29 - Oct 4 field work
Map Produced: Oct 31, 2014
Author: Chris Adamson

Map scale:
1:500

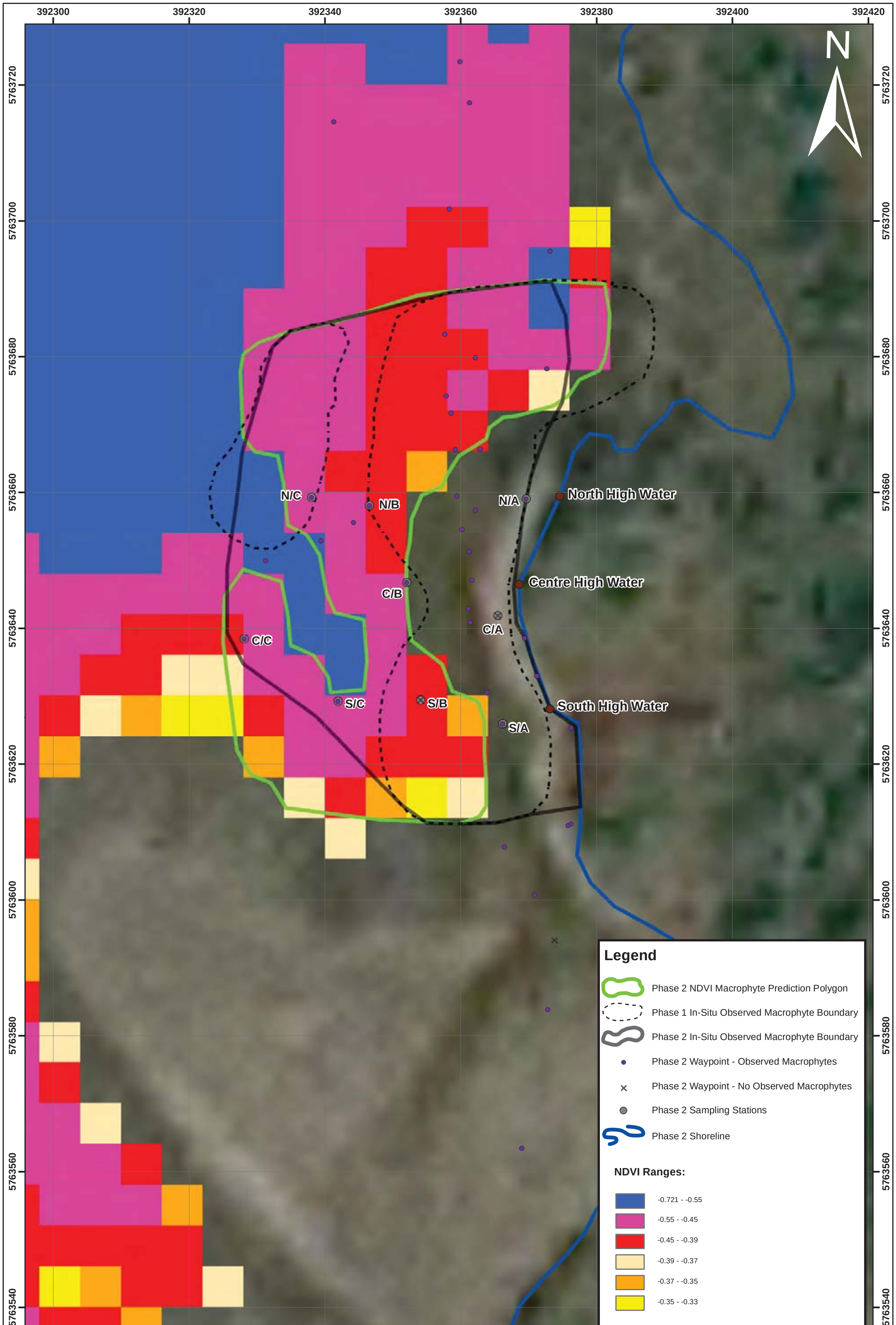

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Figure B-9: Revelstoke Reservoir
2014 Phase 2 NDVI Classifications - Site 10

0 2.5 5 10 15 20 25 30 35 40 45 50
Metres

Projection: NAD 83 UTM Zone 11
Data Source: Sept 29 - Oct 4 field work
Map Produced: Oct 31, 2014
Author: Chris Adamson

Map scale:
1:500

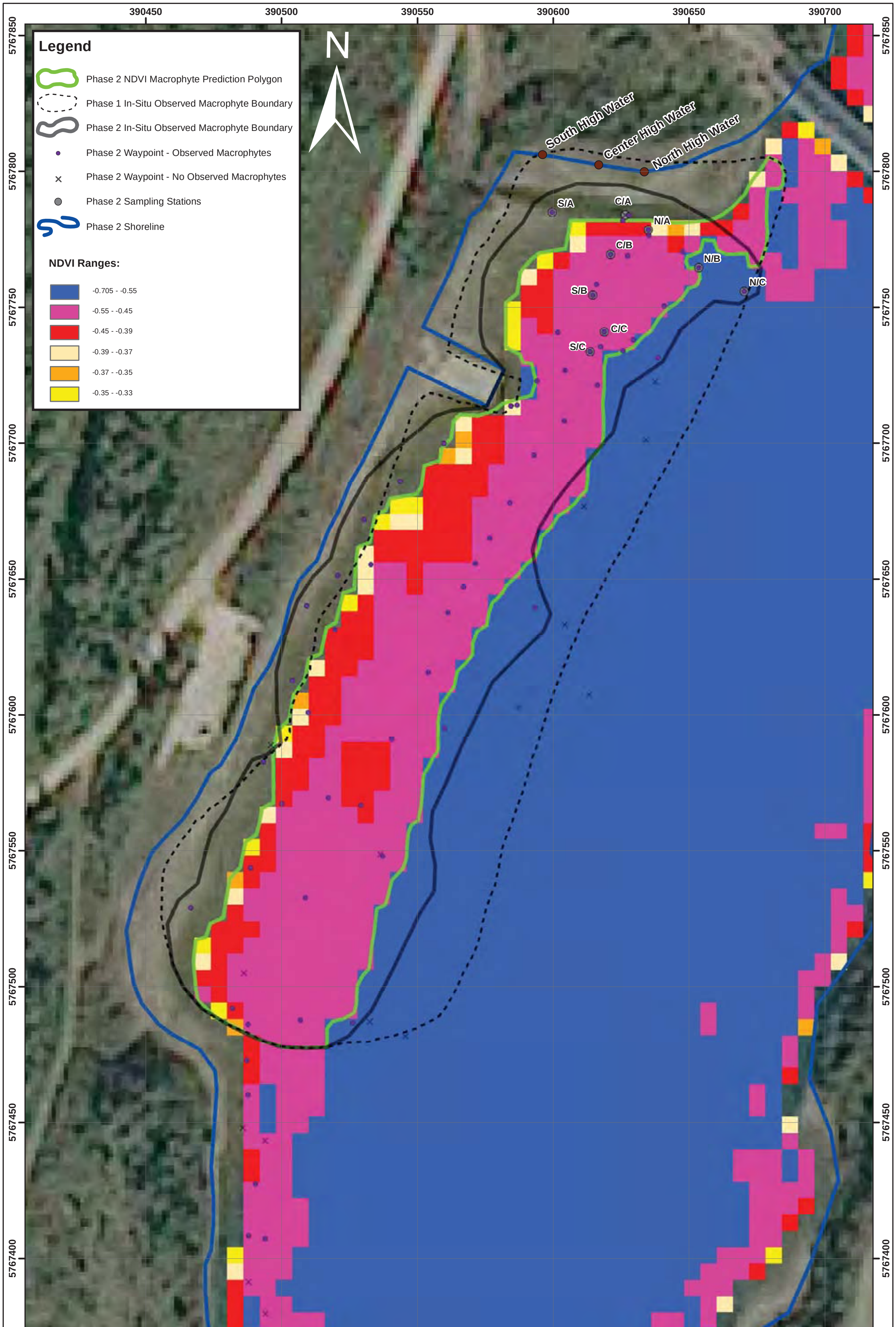

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Figure B-10: Revelstoke Reservoir 2014 Phase 2 NDVI Classifications - Site 11

0 10 20 40 60 80 100 120 140 160 180 200
Metres

Projection: NAD 83 UTM Zone 11
Data Source: Sept 29 - Oct 4 field work
Map Produced: Oct 31, 2014
Author: Chris Adamson

Map scale:
1:1,250

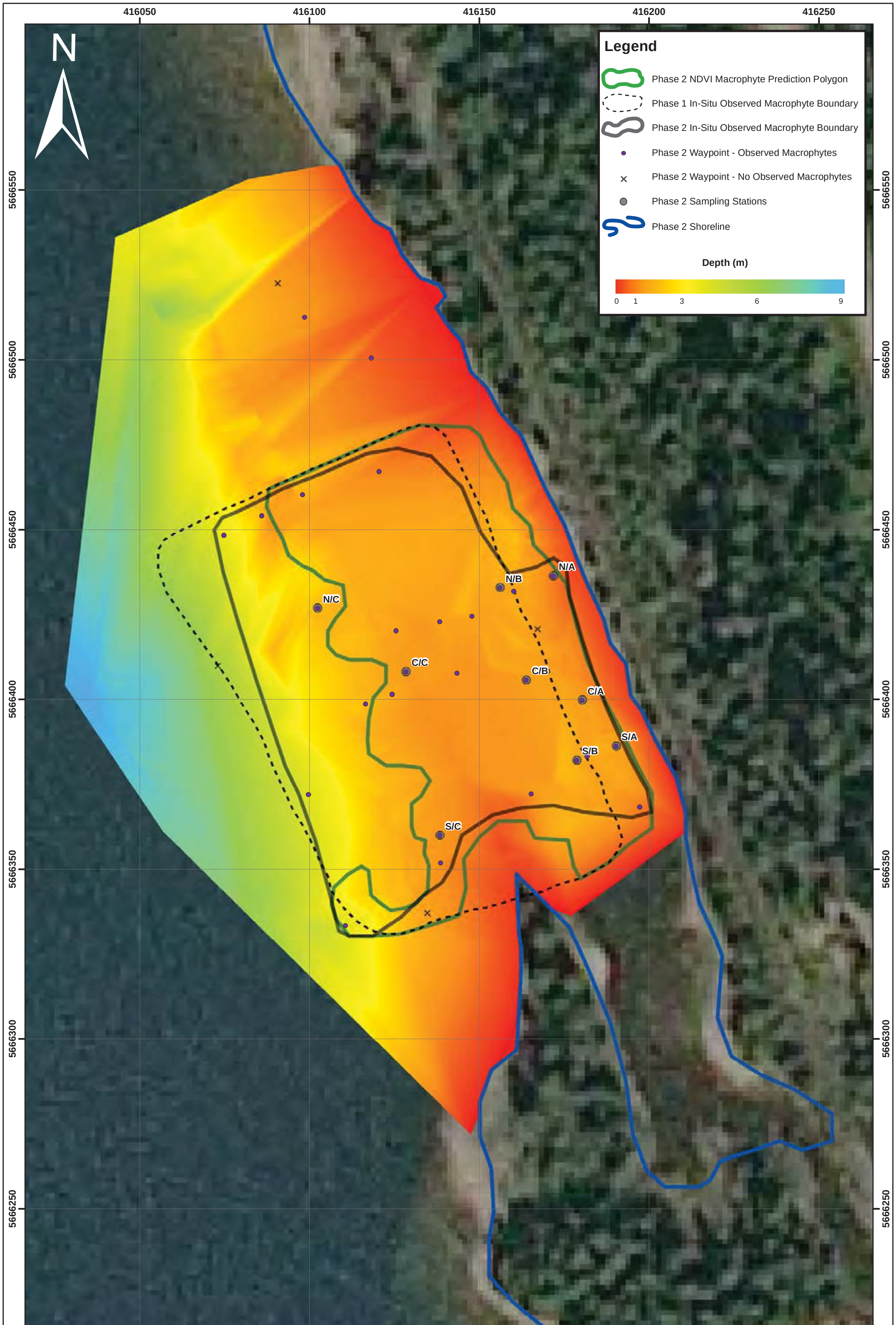

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Figure C-1: Revelstoke Reservoir
2014 Phase 2 Bathymetry & Macrophyte Communties - Site 1

0 5 10 20 30 40 50 60 70 80 90 100
Metres

Projection: NAD 83 UTM Zone 11
Data Source: Sept 29 - Oct 4 field work
Map Produced: Oct 31, 2014
Author: Chris Adamson

Map scale:
1:1,000

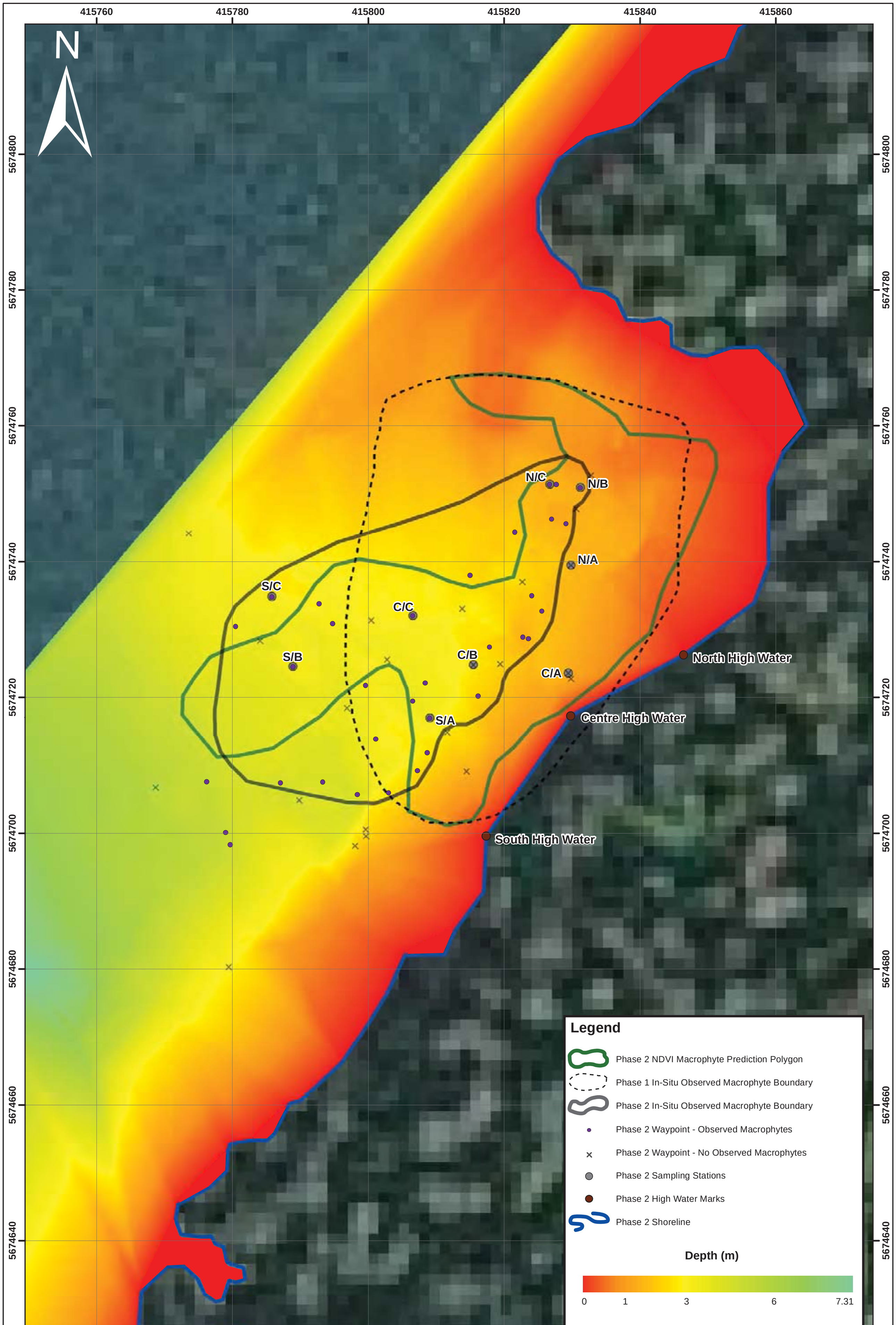

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Figure C-2: Revelstoke Reservoir
2014 Phase 2 Bathymetry & Macrophyte Communties - Site 2

0 2.5 5 10 15 20 25 30 35 40 45 50
Metres

Projection: NAD 83 UTM Zone 11
Data Source: Sept 29 - Oct 4 field work
Map Produced: Oct 31, 2014
Author: Chris Adamson

Map scale:
1:500

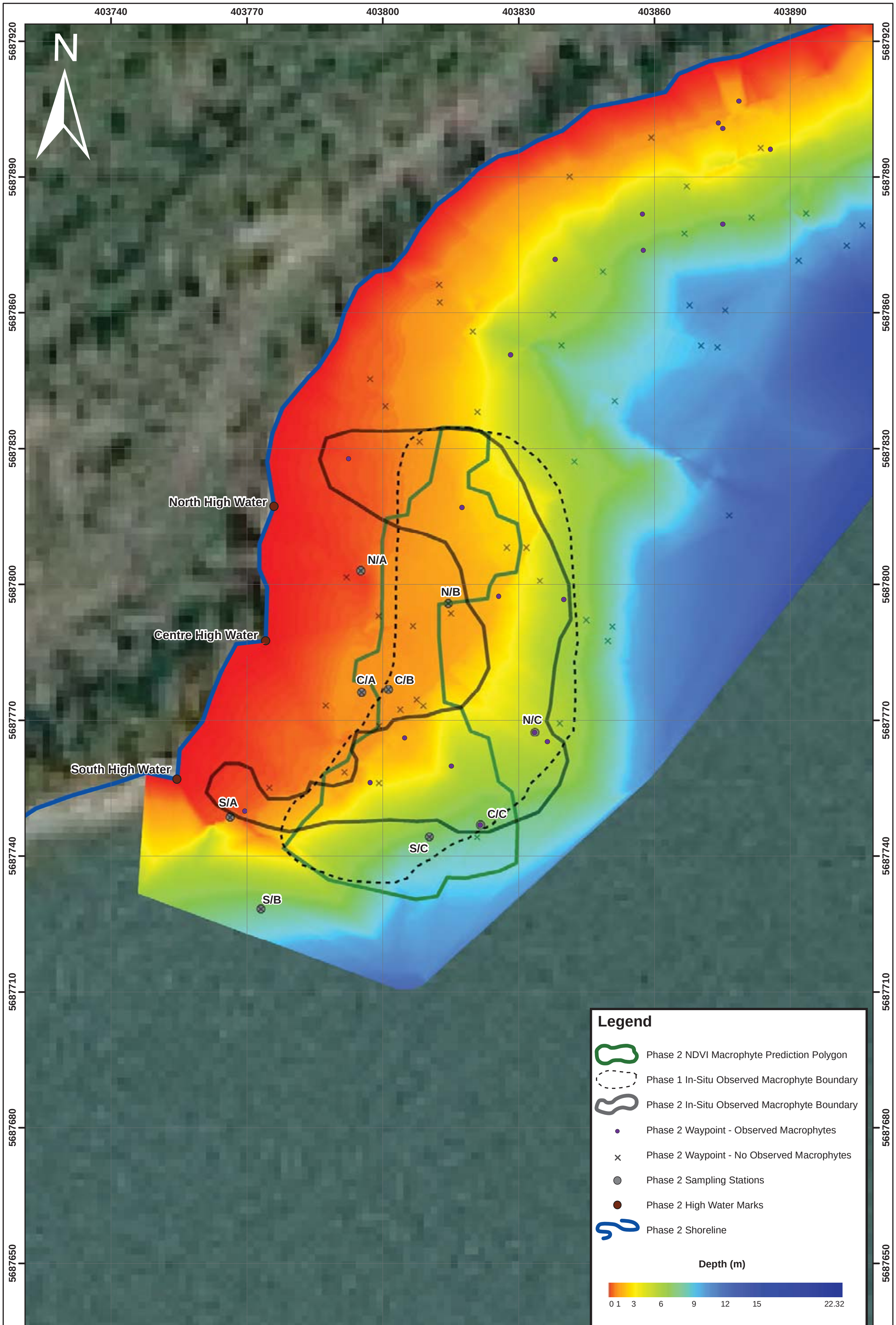

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Figure C-3: Revelstoke Reservoir
2014 Phase 2 Bathymetry & Macrophyte Communties - Site 3

0 5 10 20 30 40 50 60 70 80 90 100
Metres

Projection: NAD 83 UTM Zone 11
Data Source: Sept 29 - Oct 4 field work
Map Produced: Oct 31, 2014
Author: Chris Adamson

Map scale:
1:750

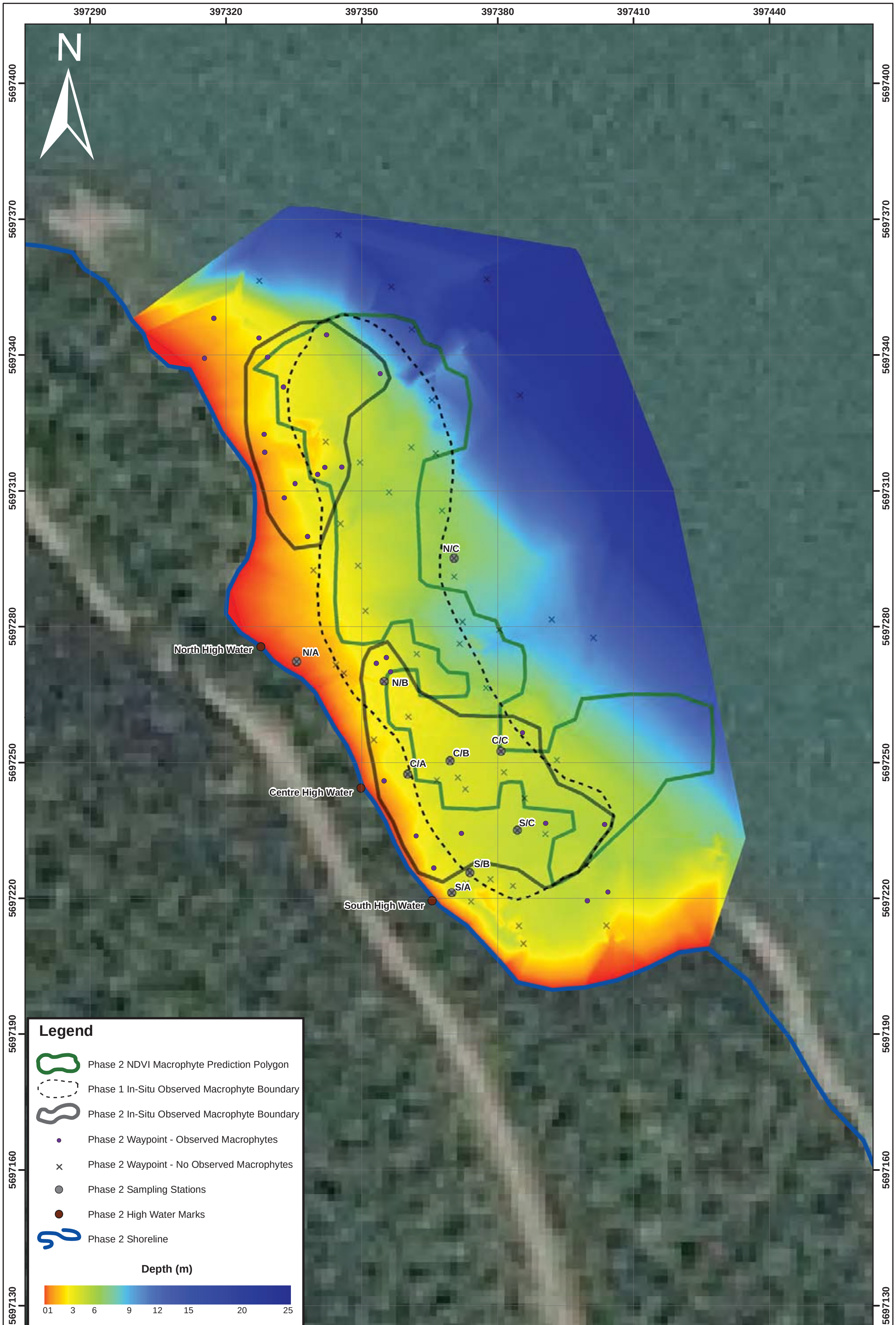

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Figure C-4: Revelstoke Reservoir
2014 Phase 2 Bathymetry & Macrophyte Communties - Site 4

0 5 10 20 30 40 50 60 70 80 90 100
Metres

Projection: NAD 83 UTM Zone 11
Data Source: Sept 29 - Oct 4 field work
Map Produced: Oct 31, 2014
Author: Chris Adamson

Map scale:
1:750

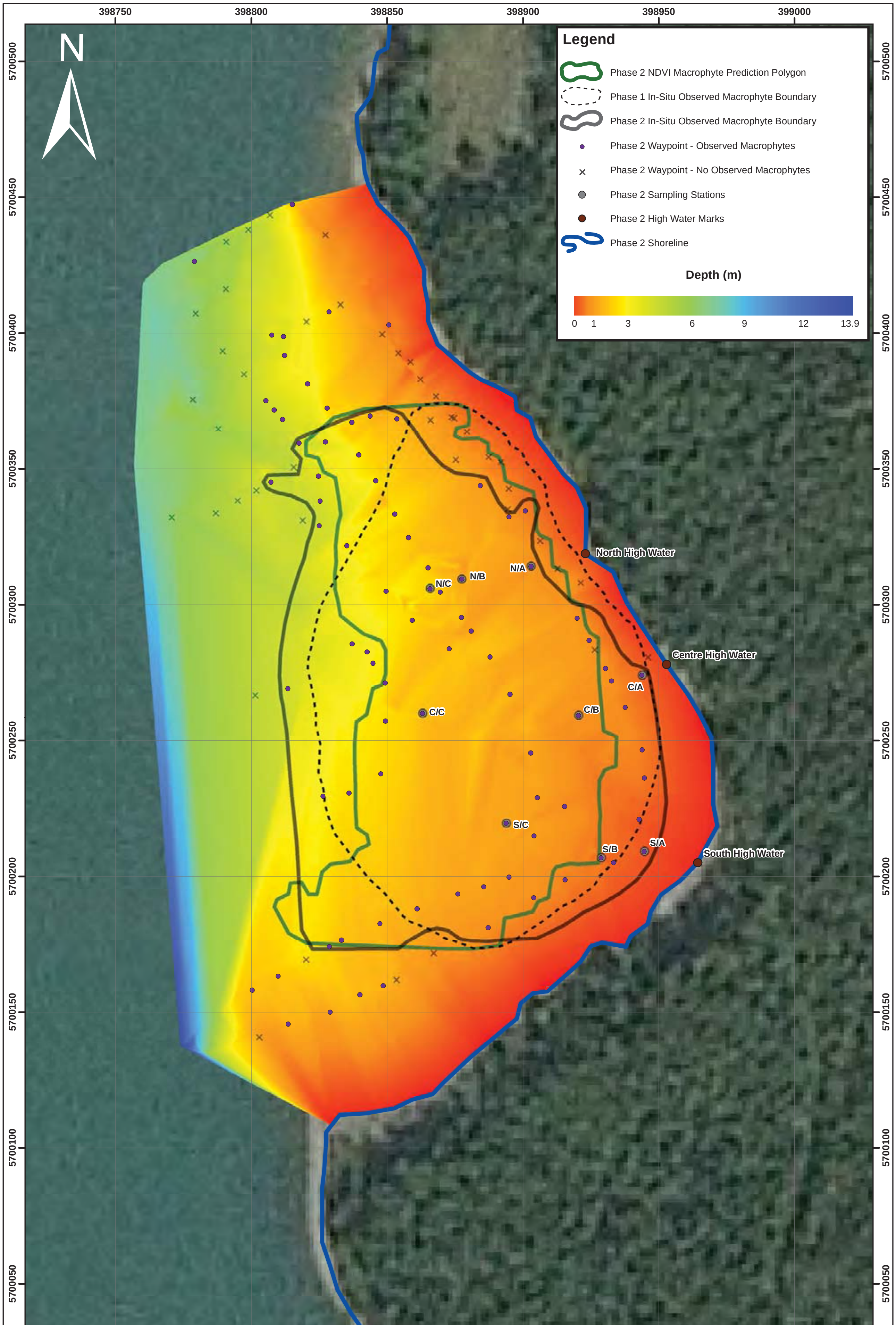

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Figure C-5: Revelstoke Reservoir
2014 Phase 2 Bathymetry & Macrophyte Communties - Site 5

0 10 20 40 60 80 100 120 140 160 180 200
Metres

Projection: NAD 83 UTM Zone 11
Data Source: Sept 29 - Oct 4 field work
Map Produced: Oct 31, 2014
Author: Chris Adamson

Map scale:
1:1,250

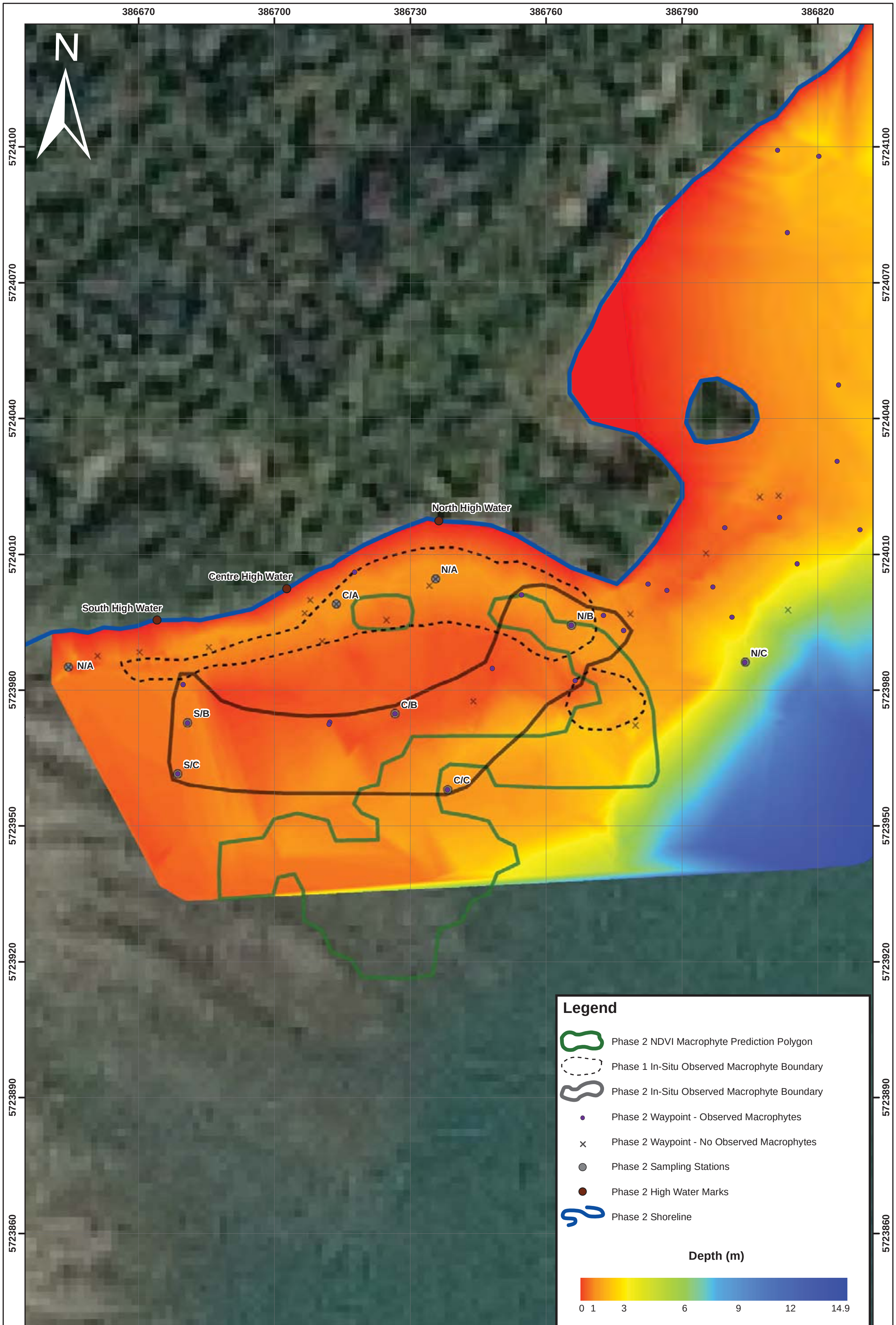

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Figure C-6: Revelstoke Reservoir
2014 Phase 2 Bathymetry & Macrophyte Communties - Site 7

0 5 10 20 30 40 50 60 70 80 90 100
Metres

Projection: NAD 83 UTM Zone 11
Data Source: Sept 29 - Oct 4 field work
Map Produced: Oct 31, 2014
Author: Chris Adamson

Map scale:
1:750

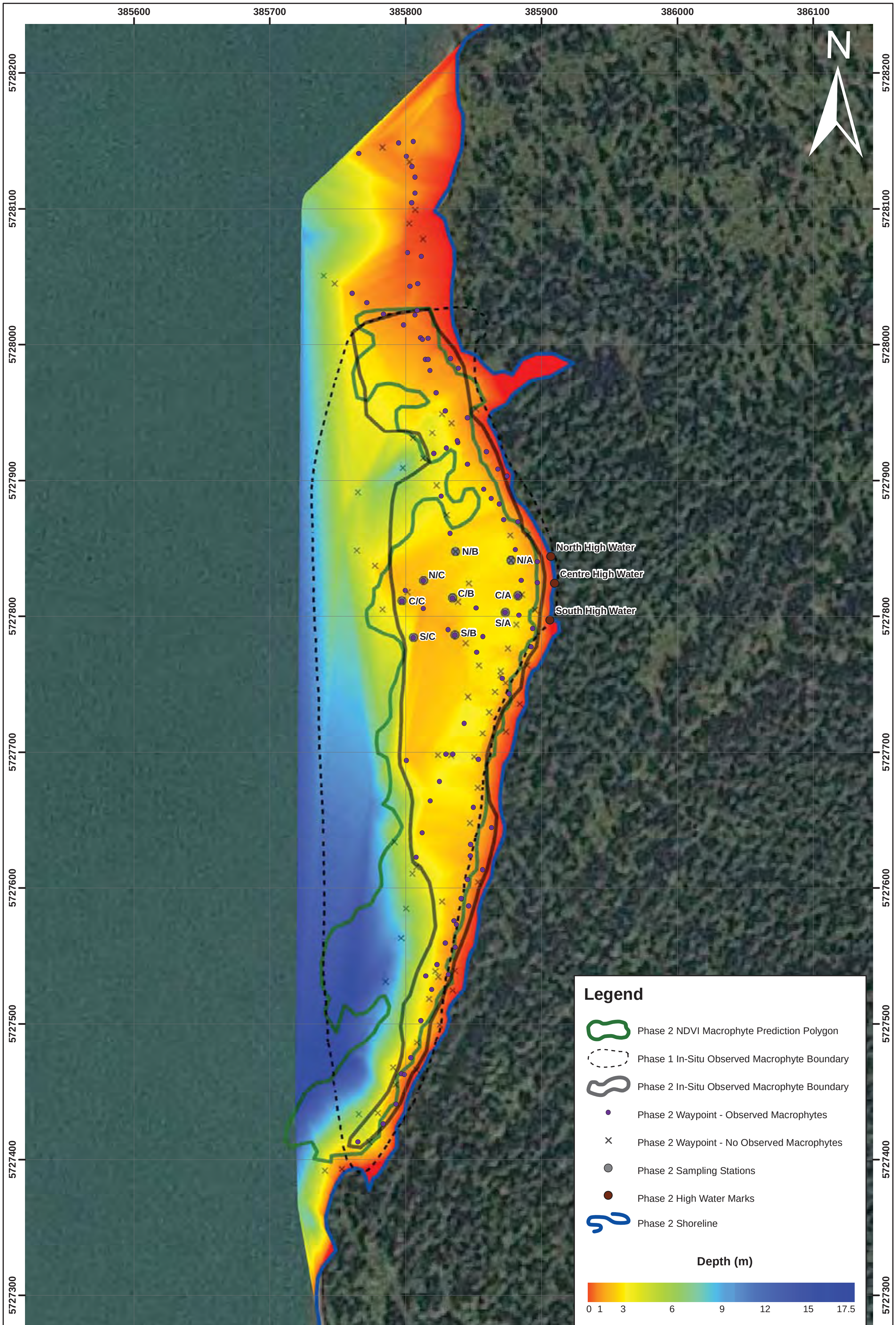

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Figure C-7: Revelstoke Reservoir
2014 Phase 2 Bathymetry & Macrophyte Communties - Site 8

0 20 40 80 120 160 200 240 280 320 360 400
Metres

Projection: NAD 83 UTM Zone 11
Data Source: Sept 29 - Oct 4 field work
Map Produced: Oct 31, 2014
Author: Chris Adamson

Map scale:
1:2,500

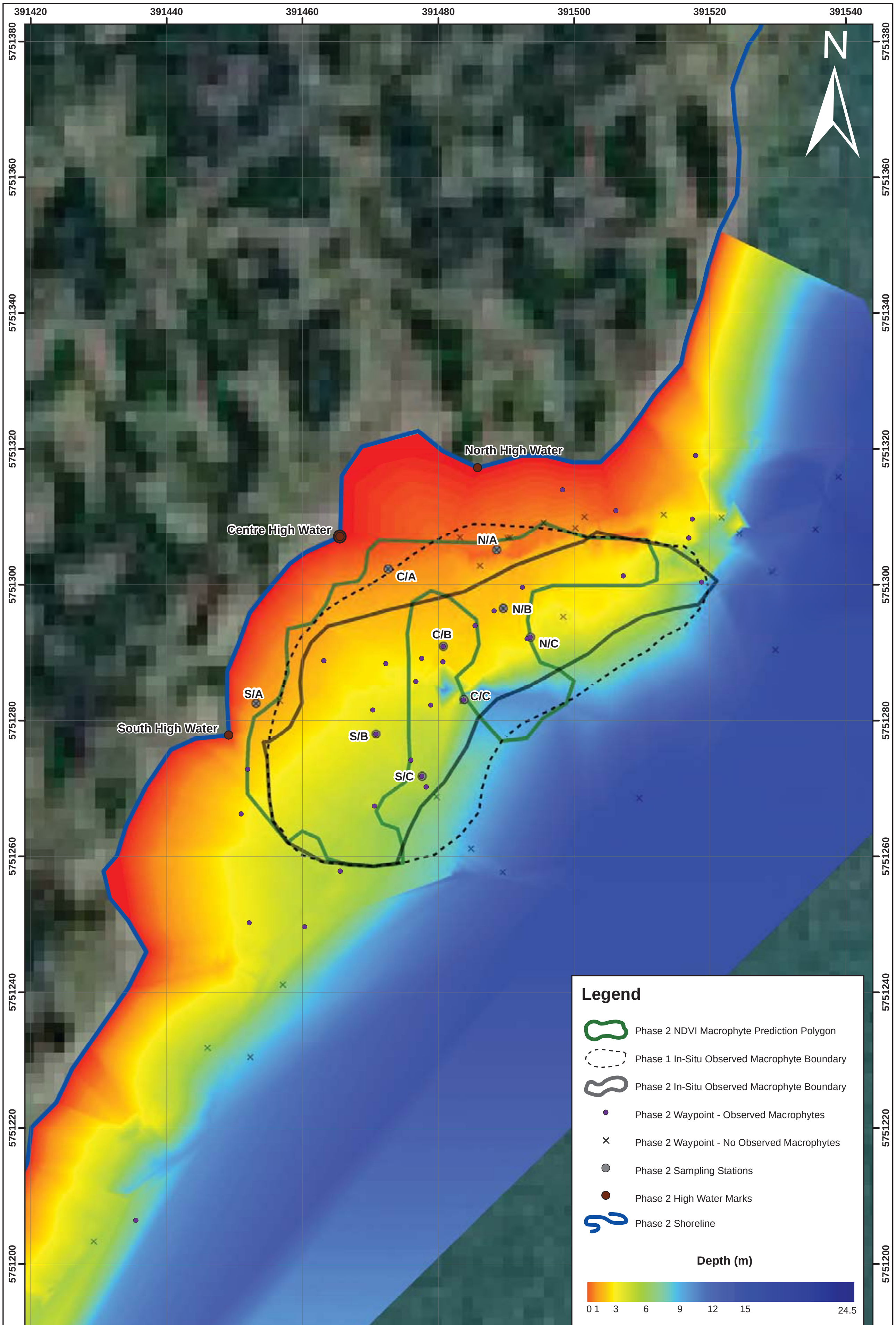

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Figure C-8: Revelstoke Reservoir
2014 Phase 2 Bathymetry & Macrophyte Communties - Site 9

0 2.5 5 10 15 20 25 30 35 40 45 50
Metres

Projection: NAD 83 UTM Zone 11
Data Source: Sept 29 - Oct 4 field work
Map Produced: Oct 31, 2014
Author: Chris Adamson

Map scale:
1:500

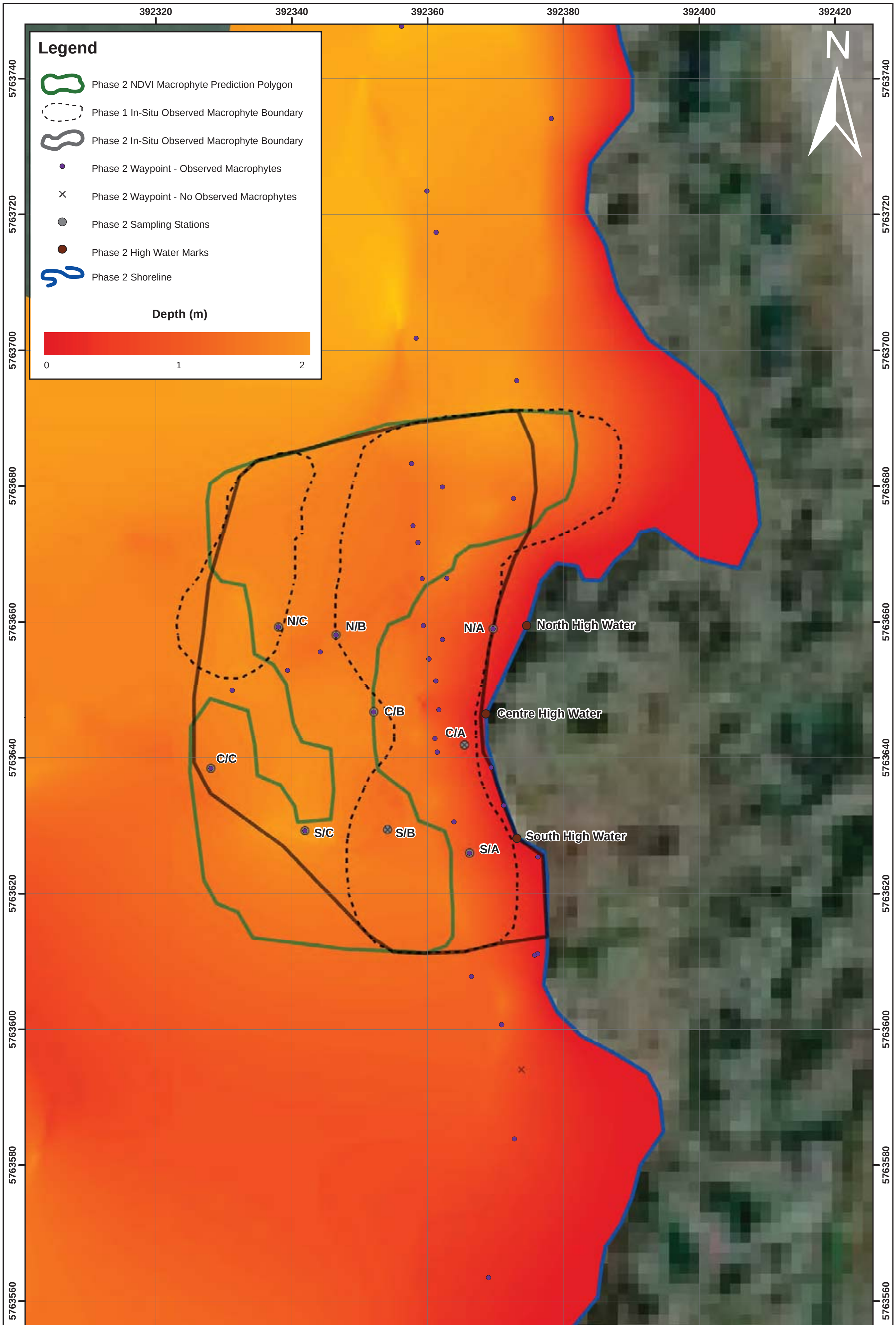

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Figure C-9: Revelstoke Reservoir
2014 Phase 2 Bathymetry & Macrophyte Communties - Site 10

0 2.5 5 10 15 20 25 30 35 40 45 50
Metres

Projection: NAD 83 UTM Zone 11
Data Source: Sept 29 - Oct 4 field work
Map Produced: Oct 31, 2014
Author: Chris Adamson

Map scale:
1:500

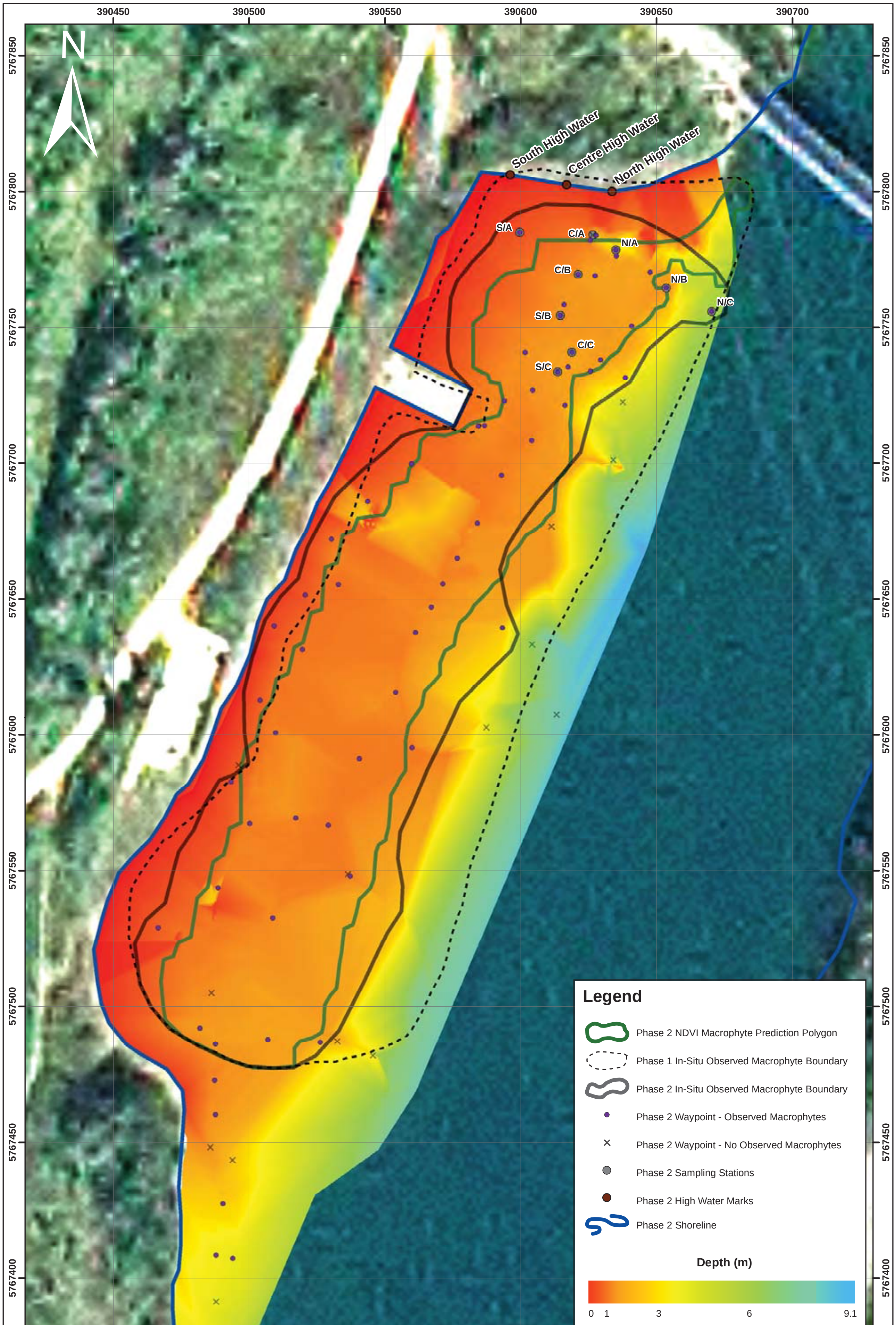

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Figure C-10: Revelstoke Reservoir
2014 Phase 2 Bathymetry & Macrophyte Communties - Site 11

0 10 20 40 60 80 100 120 140 160 180 200
Metres

Projection: NAD 83 UTM Zone 11
Data Source: Sept 29 - Oct 4 field work
Map Produced: Oct 31, 2014
Author: Chris Adamson

Map scale:
1:1,250

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Figure D-1: Revelstoke Reservoir
2014 Phase 2 False Colour Composite Image - Site 1

0 5 10 20 30 40 50 60 70 80 90 100
Metres

Projection: NAD 83 UTM Zone 11
Data Source: Sept 29 - Oct 4 field work
Map Produced: Oct 31, 2014
Author: Chris Adamson

Map scale:
1:1,000

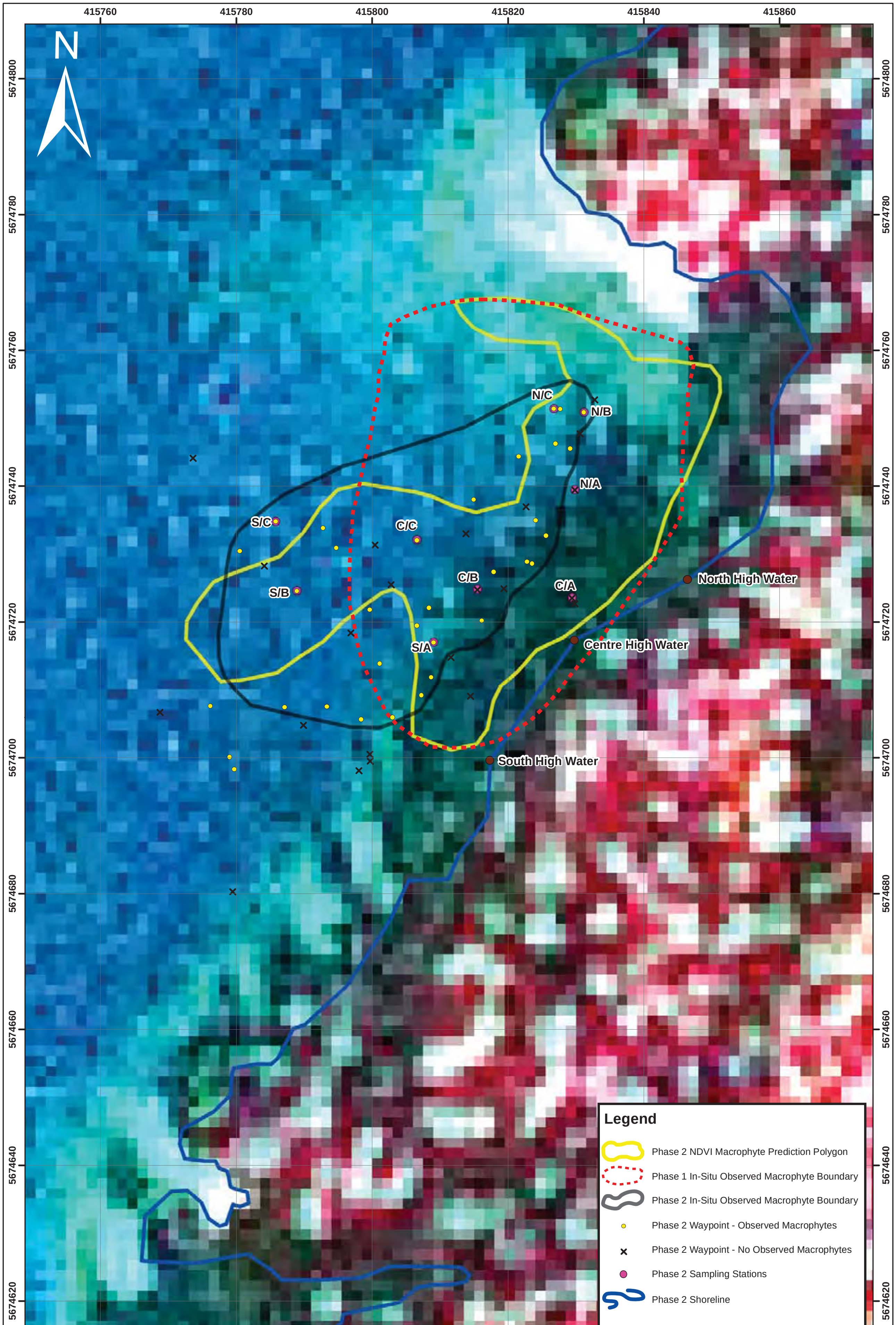

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Figure D-2: Revelstoke Reservoir
2014 Phase 2 False Colour Composite Image - Site 2

0 2.5 5 10 15 20 25 30 35 40 45 50
Metres

Projection: NAD 83 UTM Zone 11
Data Source: Sept 29 - Oct 4 field work
Map Produced: Oct 31, 2014
Author: Chris Adamson

Map scale:
1:500

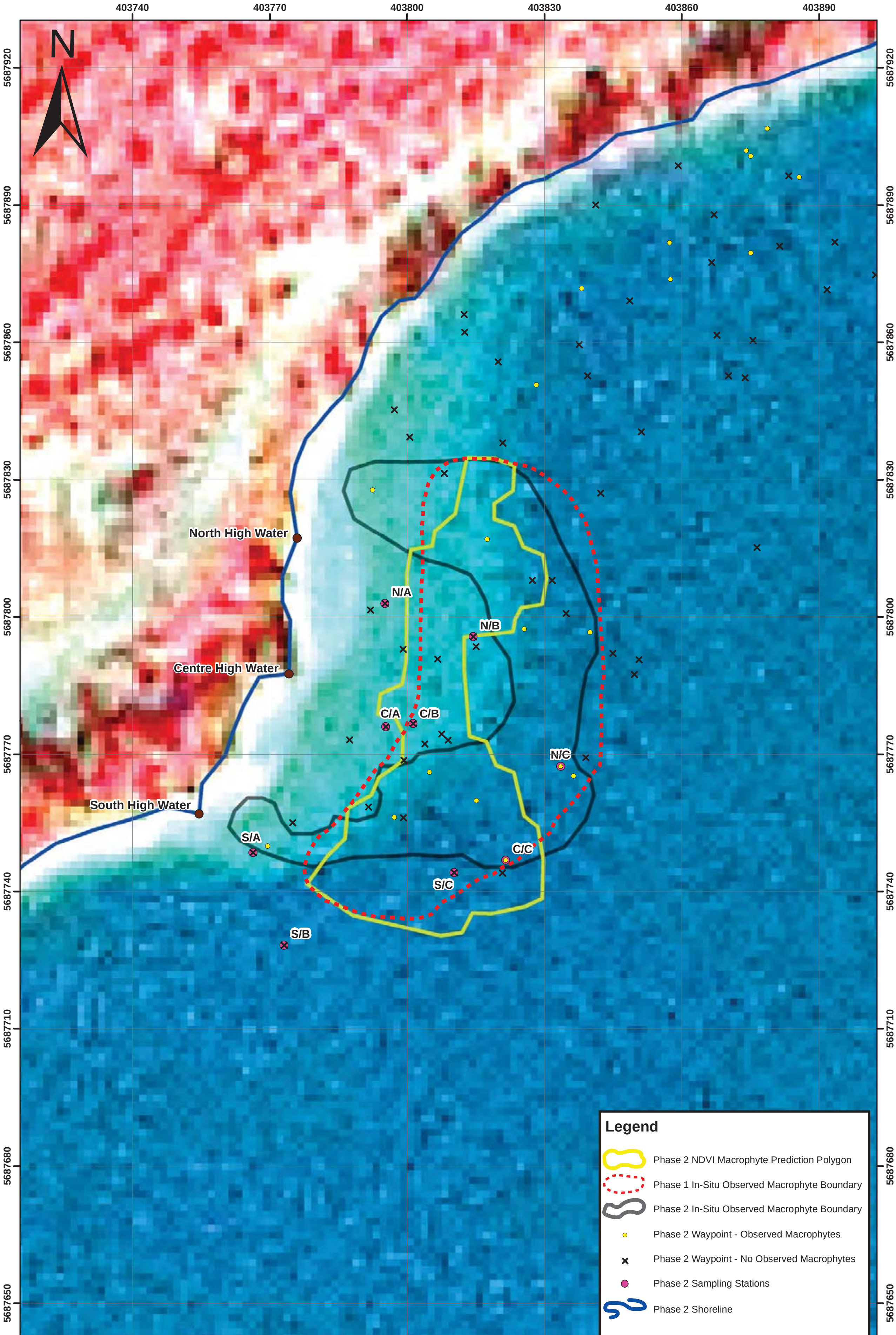

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Figure D-3: Revelstoke Reservoir
2014 Phase 2 False Colour Composite Image - Site 3

0 5 10 20 30 40 50 60 70 80 90 100
Metres

Projection: NAD 83 UTM Zone 11
Data Source: Sept 29 - Oct 4 field work
Map Produced: Oct 31, 2014
Author: Chris Adamson

Map scale:
1:750

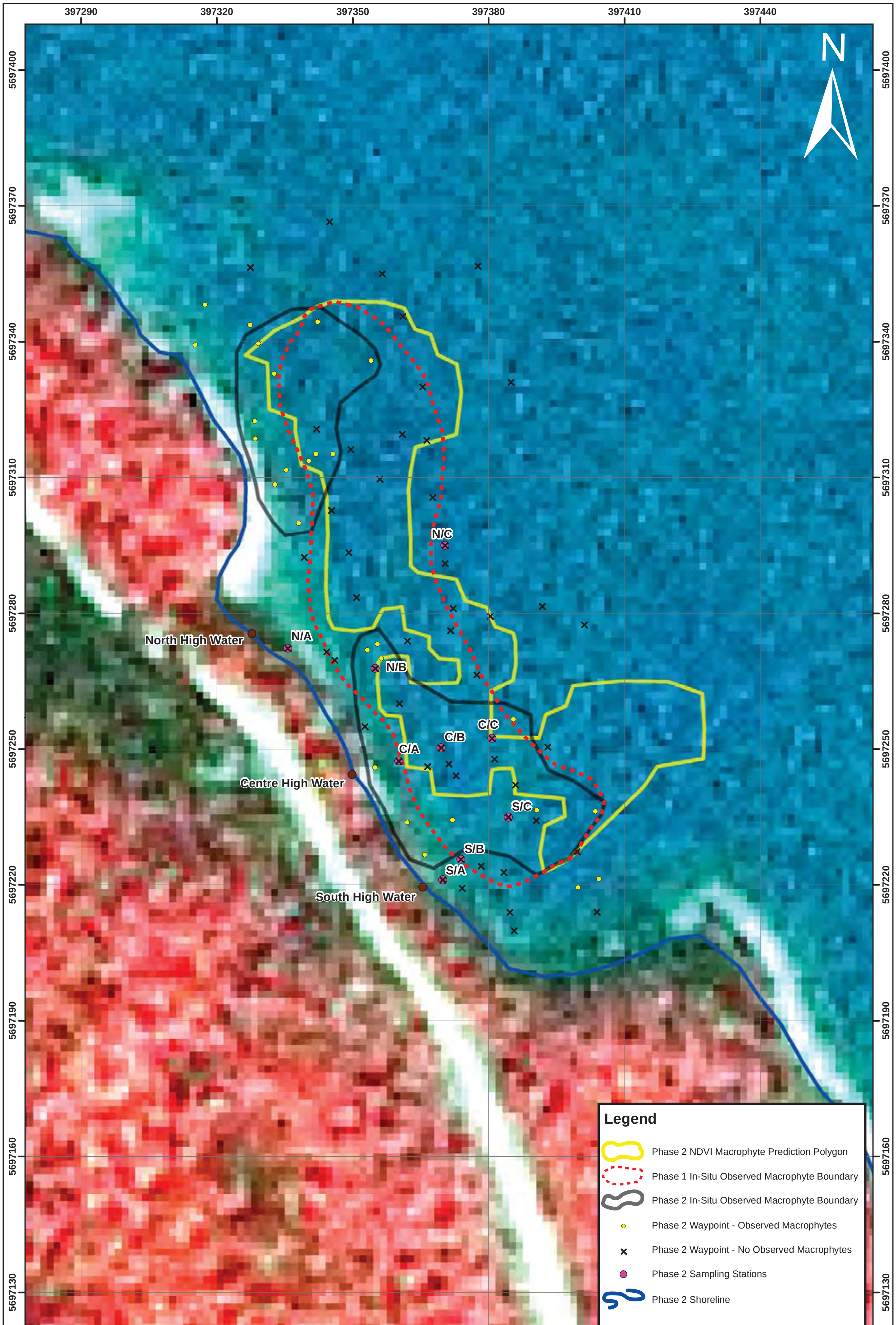

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Figure D-4: Revelstoke Reservoir
2014 Phase 2 False Colour Composite Image - Site 4

0 5 10 20 30 40 50 60 70 80 90 100
Metres

Projection: NAD 83 UTM Zone 11
Data Source: Sept 29 - Oct 4 field work
Map Produced: Oct 31, 2014
Author: Chris Adamson

Map scale:
1:750

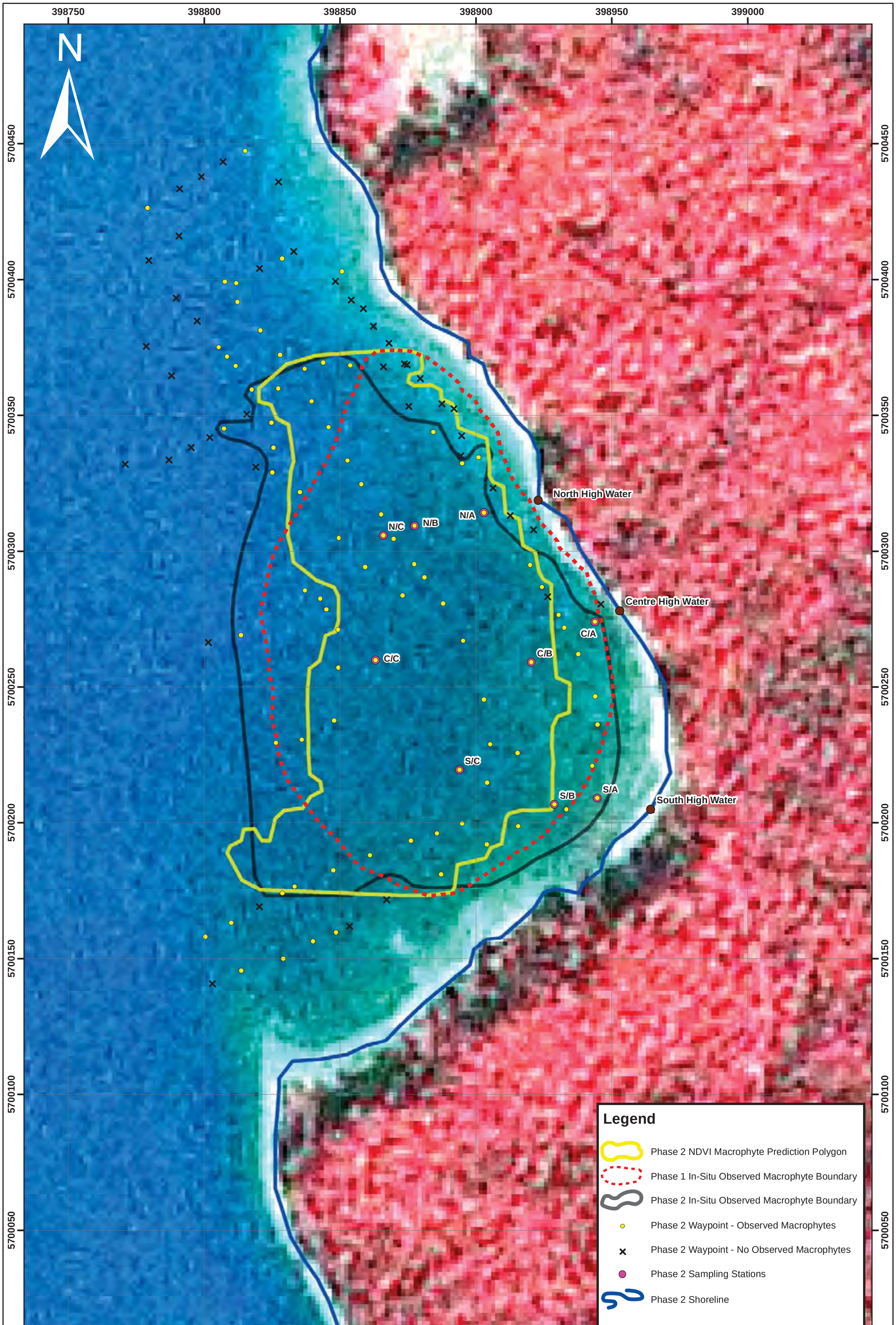

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Figure D-5: Revelstoke Reservoir
2014 Phase 2 False Colour Composite Image - Site 5

0 10 20 40 60 80 100 120 140 160 180 200
Metres

Projection: NAD 83 UTM Zone 11
Data Source: Sept 29 - Oct 4 field work
Map Produced: Oct 31, 2014
Author: Chris Adamson

Map scale:
1:1,250

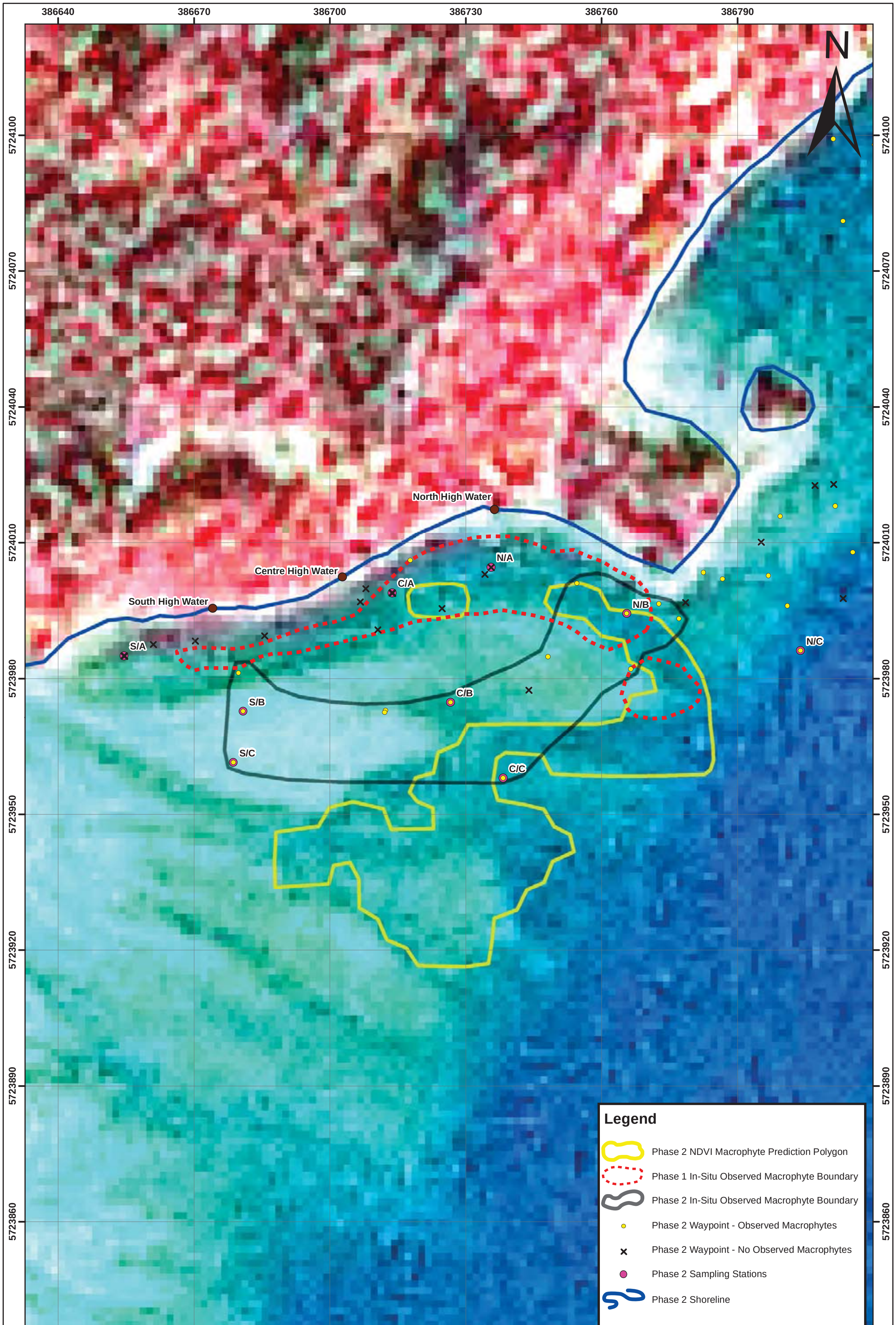

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Figure D-6: Revelstoke Reservoir
2014 Phase 2 False Colour Composite Image - Site 7

0 5 10 20 30 40 50 60 70 80 90 100
Metres

Projection: NAD 83 UTM Zone 11
Data Source: Sept 29 - Oct 4 field work
Map Produced: Oct 31, 2014
Author: Chris Adamson

Map scale:
1:750

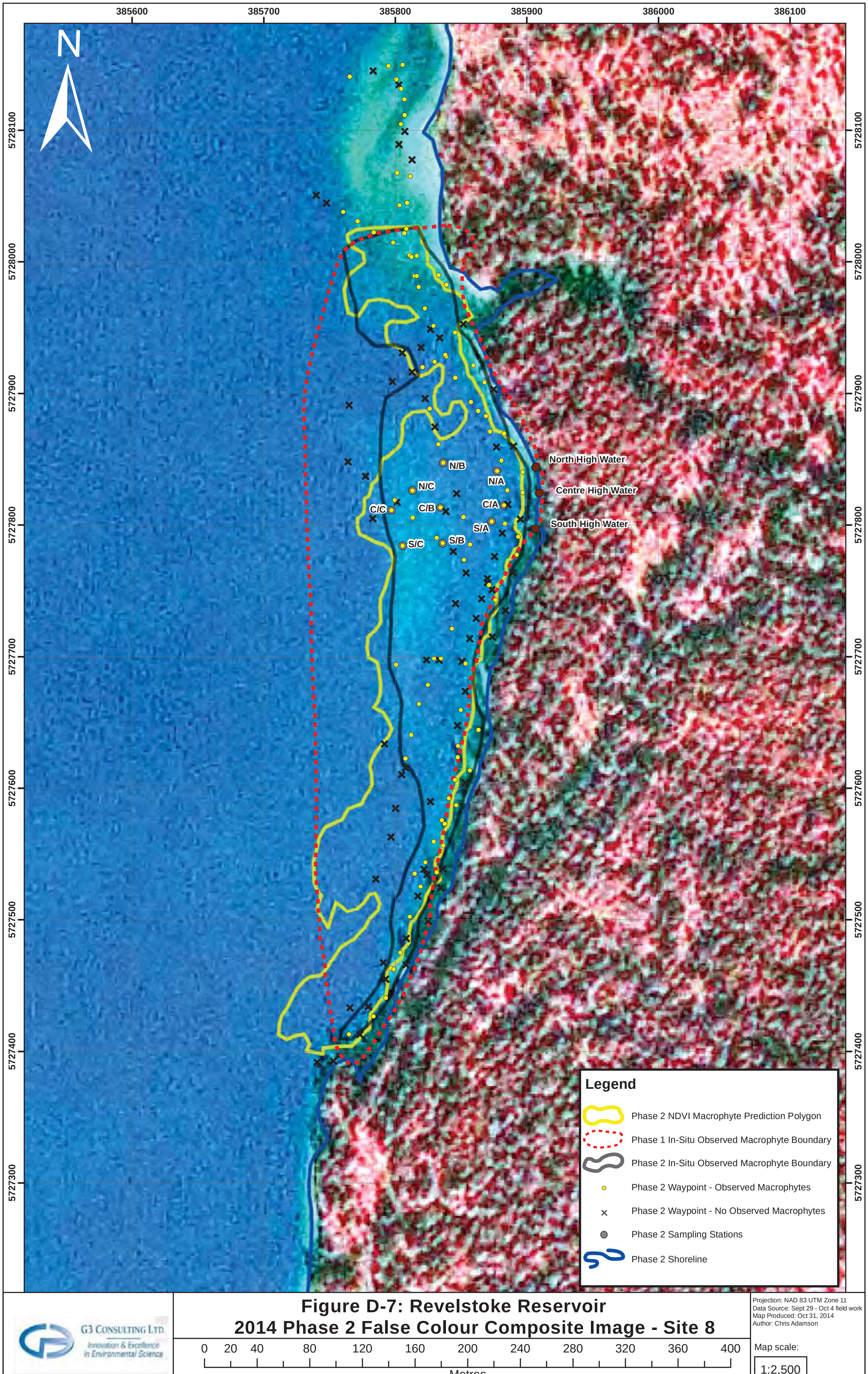

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Figure D-7: Revelstoke Reservoir
2014 Phase 2 False Colour Composite Image - Site 8

Projection: NAD 83 UTM Zone 11
Data Source: Sept 29 - Oct 4 field work
Map Produced: Oct 31, 2014
Author: Chris Adamson

Map scale:
1:2,500

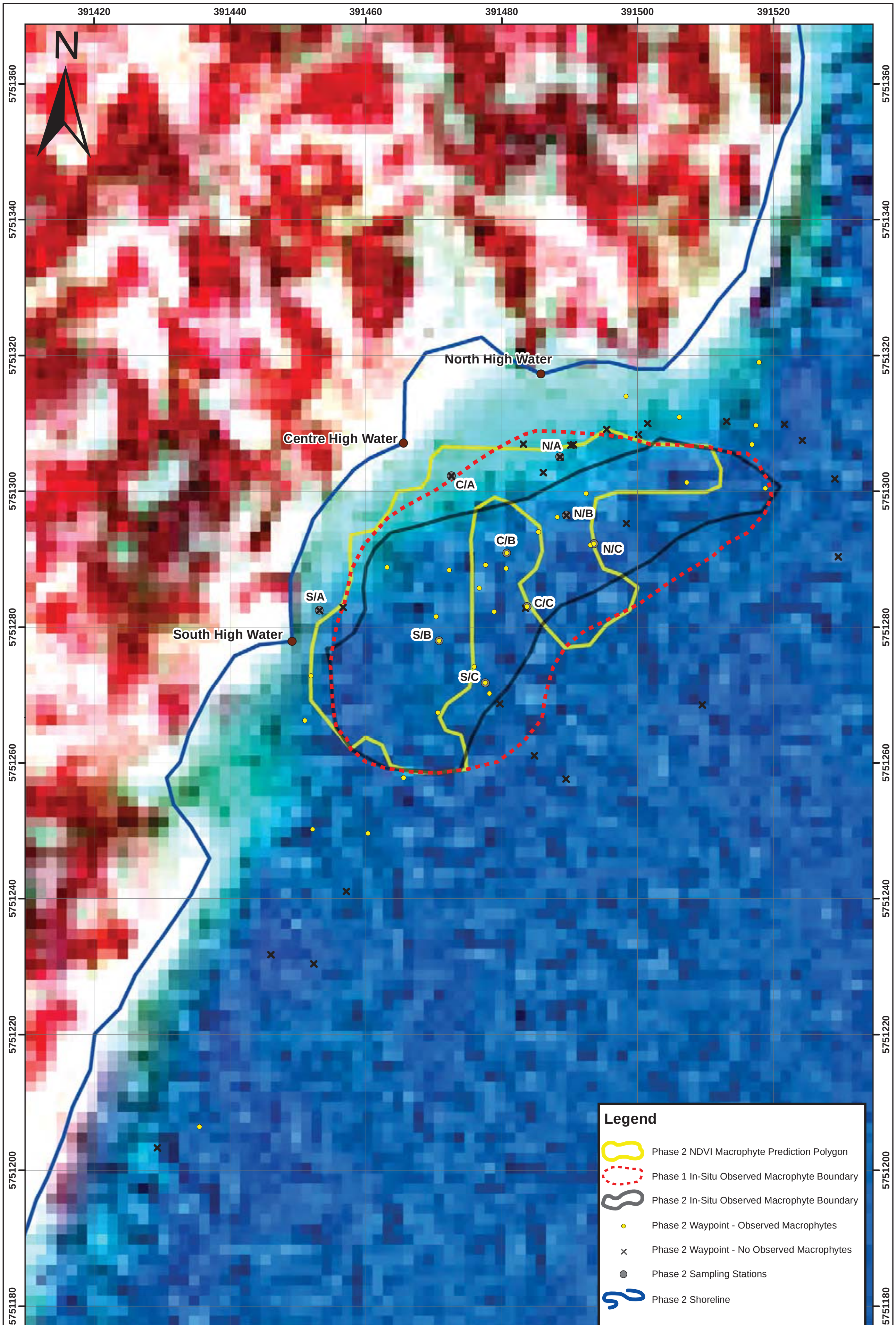

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Figure D-8: Revelstoke Reservoir
2014 Phase 2 False Colour Composite Image - Site 9

0 2.5 5 10 15 20 25 30 35 40 45 50
Metres

Projection: NAD 83 UTM Zone 11
Data Source: Sept 29 - Oct 4 field work
Map Produced: Oct 31, 2014
Author: Chris Adamson

Map scale:
1:500

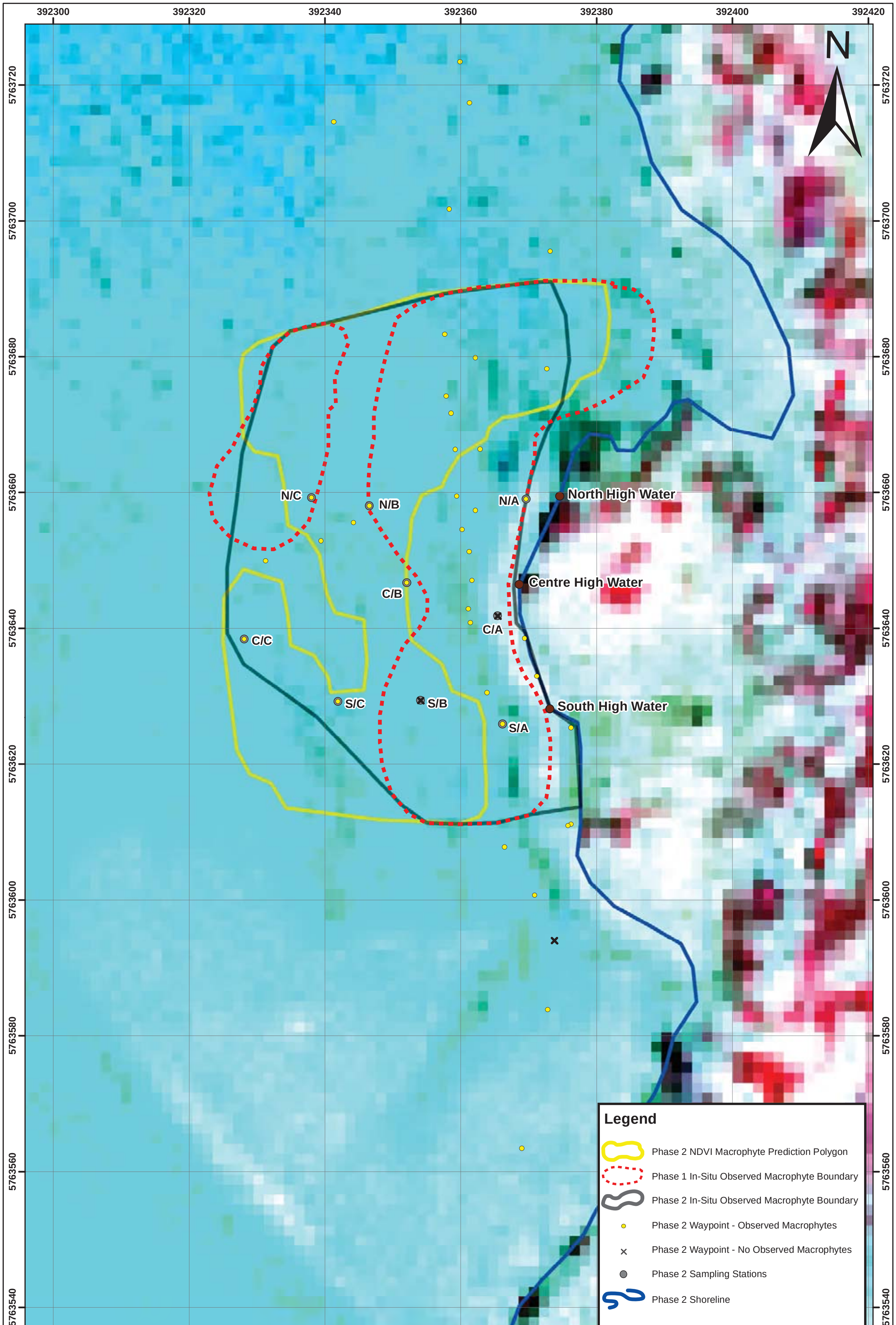

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Figure D-9: Revelstoke Reservoir
2014 Phase 2 False Colour Composite Image - Site 10

0 2.5 5 10 15 20 25 30 35 40 45 50
Metres

Projection: NAD 83 UTM Zone 11
Data Source: Sept 29 - Oct 4 field work
Map Produced: Oct 31, 2014
Author: Chris Adamson

Map scale:
1:500

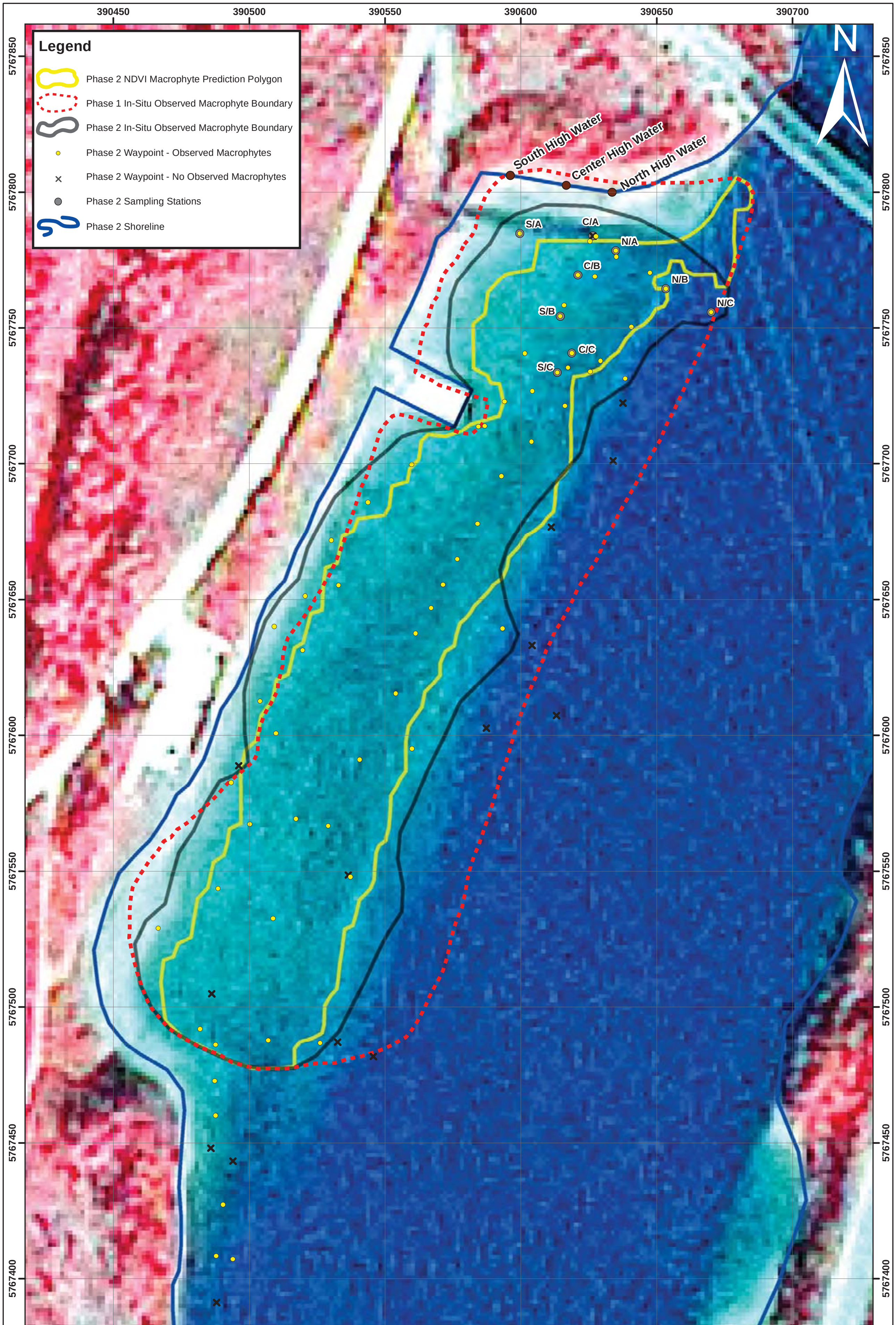

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Figure D-10: Revelstoke Reservoir
2014 Phase 2 False Colour Composite Image - Site 11

0 10 20 40 60 80 100 120 140 160 180 200
Metres

Projection: NAD 83 UTM Zone 11
Data Source: Sept 29 - Oct 4 field work
Map Produced: Oct 31, 2014
Author: Chris Adamson

Map scale:
1:1,250

APPENDIX 2

Photos

Photos 1 to 6:	Site 1
Photos 7 to 12:	Site 2
Photos 13 to 18:	Site 3
Photos 9 to 24:	Site 4
Photos 25 to 30:	Site 5
Photos 31 to 36:	Site 7
Photos 37 to 42:	Site 8
Photos 43 to 48:	Site 9
Photos 49 to 54:	Site 10
Photos 55 to 60:	Site 11
Photos 61 to 66:	Methodology

Appendix 2: Site 1 Description

Photo 1: Looking towards the south end of Site 1
(September 30, 2014)

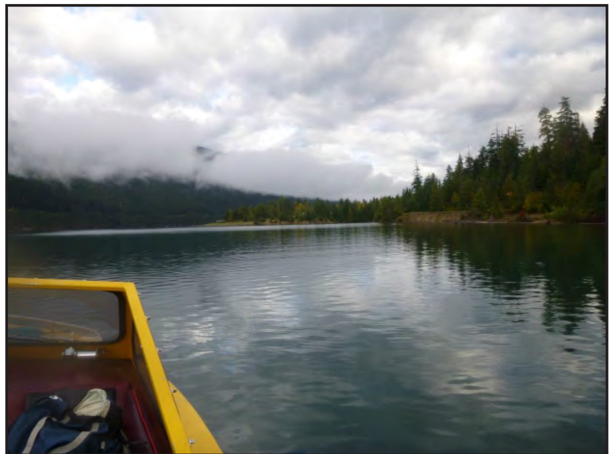


Photo 2: Looking towards the north end of Site 1
(September 30, 2014)

Photo 3: Shoreline looking east at Site 1
(September 30, 2014)

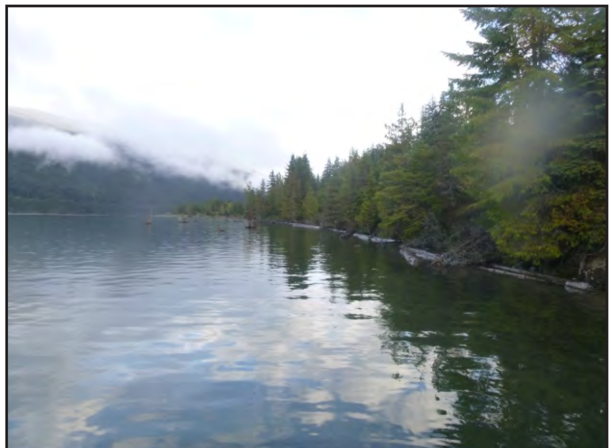


Photo 4: Looking toward the north end of Site 1
(September 30, 2014)

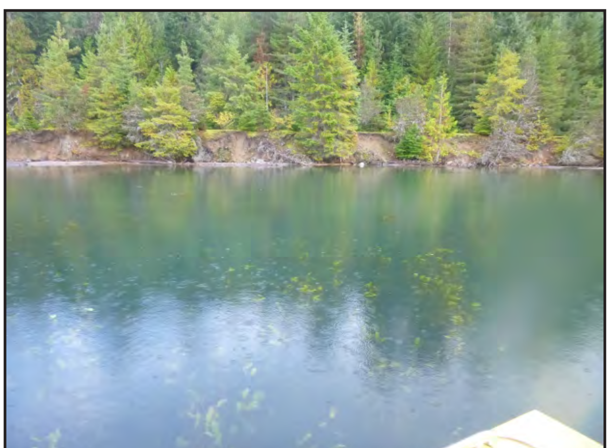


Photo 5: Macrophytes observed at Site 1
(September 30, 2014)

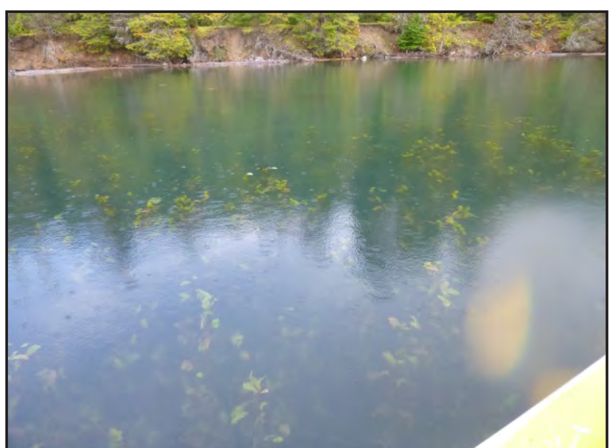


Photo 6: Macrophytes observed at Site 1
(September 30, 2014)

Appendix 2: Site 2 Description

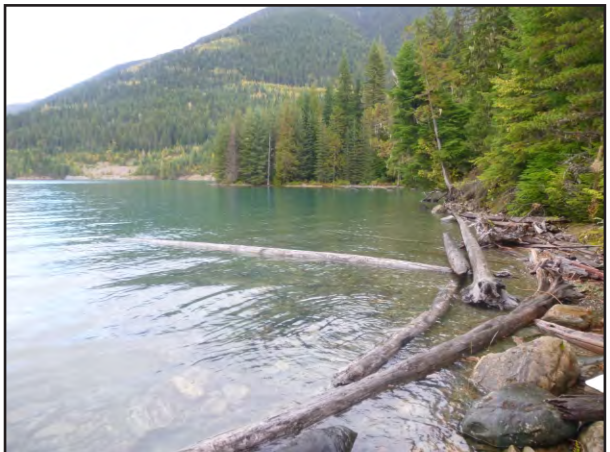


Photo 7: Looking towards the north end of Site 2 (September 30, 2014)

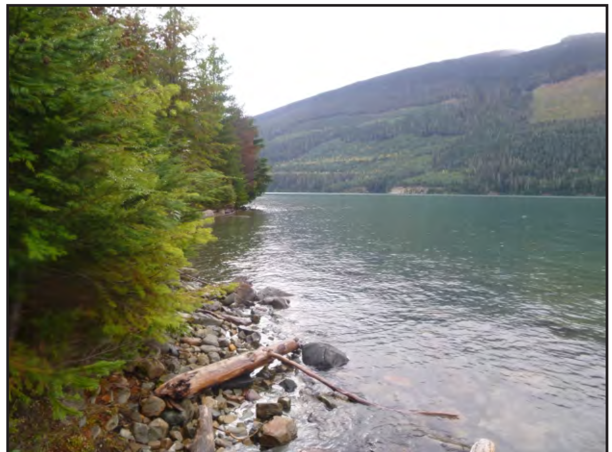


Photo 8: Looking towards the south end of Site 2 (September 30, 2014)

Photo 9: Looking west offshore from Site 2 (September 30, 2014)

Photo 10: Nearshore Substrate at Site 2 (September 30, 2014)

Photo 11: *P. alpinus* observed using drop camera at Site 2 (September 30, 2014)

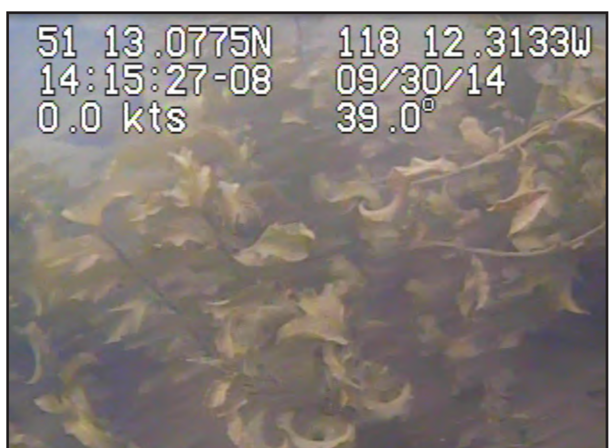


Photo 12: *P. amplifolius* observed using drop camera at Site 2 (September 30, 2014)

Appendix 2: Site 3 Description

Photo 13: Looking towards the south end of Site 3 (October 2, 2014)

Photo 14: Looking towards the north end of Site 3 (October 2, 2014)

Photo 15: Looking east offshore from Site 3 (October 2, 2014)

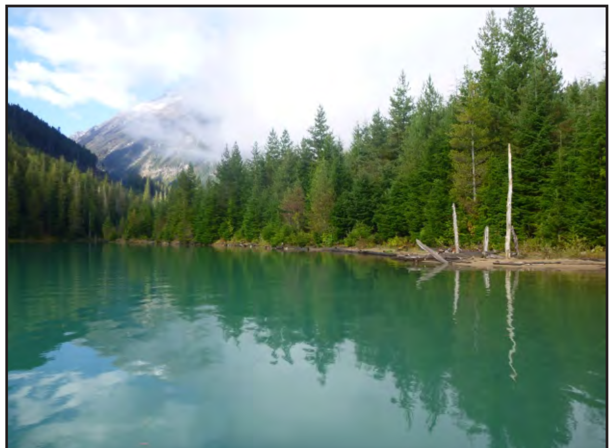


Photo 16: Looking towards the south end of Site 3 (October 2, 2014)

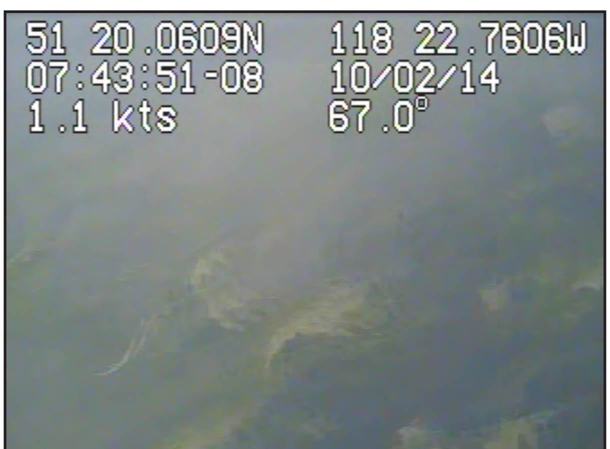


Photo 17: Macrophytes observed using drop camera at Site 3 (October 2, 2014)

Photo 18: Macrophytes observed using drop camera at Site 3 (October 2, 2014)

Appendix 2: Site 4 Description

Photo 19: Looking towards the north end of Site 4 (October 2, 2014)

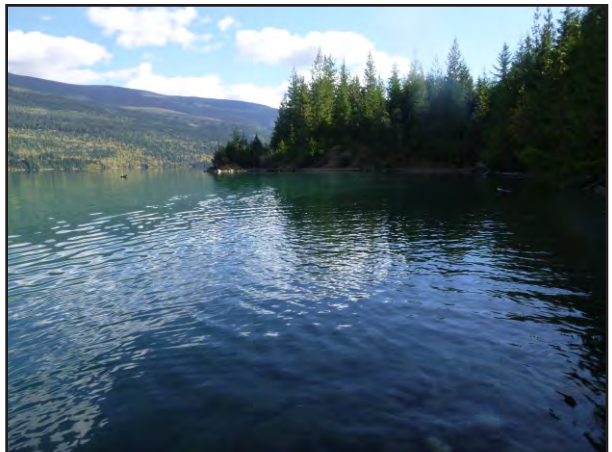


Photo 20: Looking towards the south end of Site 4 (October 2, 2014)

Photo 21: Looking north along the shoreline at Site 4 (October 2, 2014)

Photo 22: Looking northeast offshore from Site 4 (October 2, 2014)

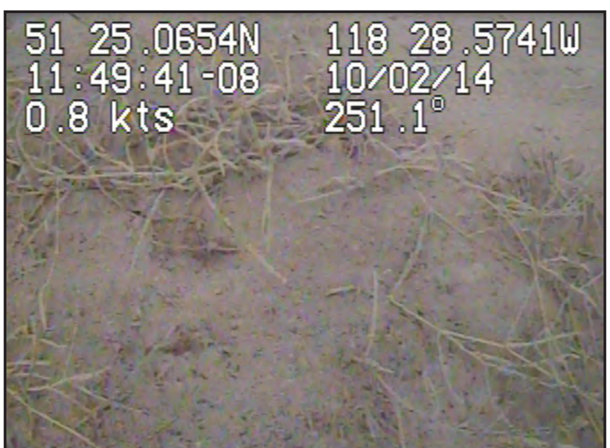


Photo 23: Macrophytes observed using drop camera at Site 4 (October 2, 2014)

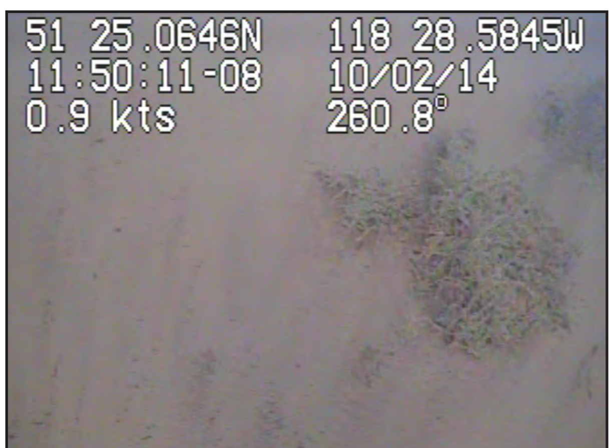


Photo 24: Macrophytes observed using drop camera at Site 4 (October 2, 2014)

Appendix 2: Site 5 Description

Photo 25: Looking towards the south end of Site 5 (October 4, 2014)

Photo 26: Looking towards the north end of Site 5 (October 4, 2014)

Photo 27: Looking north along the shoreline at Site 5 (October 4, 2014)

Photo 28: Looking west offshore at Site 5 (October 2, 2014)

Photo 29: *P. amplifolius* observed using drop camera at Site 5 (October 4, 2014)

Photo 30: Macrophytes observed at Site 5 (October 2, 2014)

Appendix 2: Site 7 Description

Photo 31: Looking towards the south end of Site 7 (October 1, 2014)

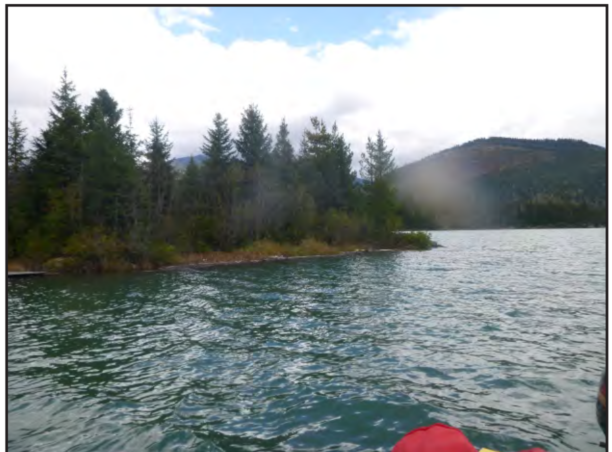


Photo 32: Looking towards the north end of Site 7 (October 1, 2014)

Photo 33: Looking east from a sand bank at south end of Site 7 (October 1, 2014)

Photo 34: Looking north near south end of Site 7. (October 1, 2014)

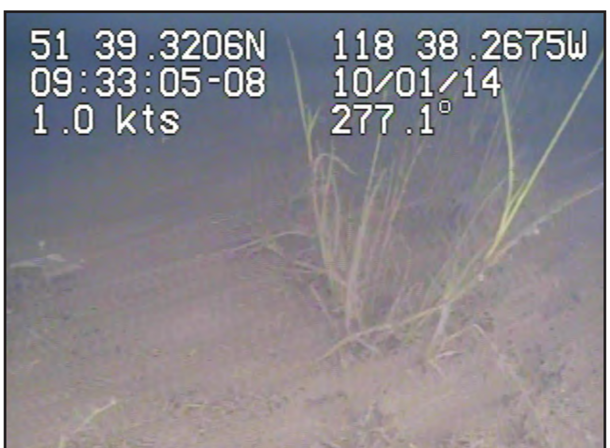


Photo 35: *E. acicularis* observed using drop camera at Site 7 (October 1, 2014)

Photo 36: Macrophytes observed at Site 7 (October 1, 2014)

Appendix 2: Site 8 Description

Photo 37: Looking towards the north end of Site 8 (October 1, 2014)

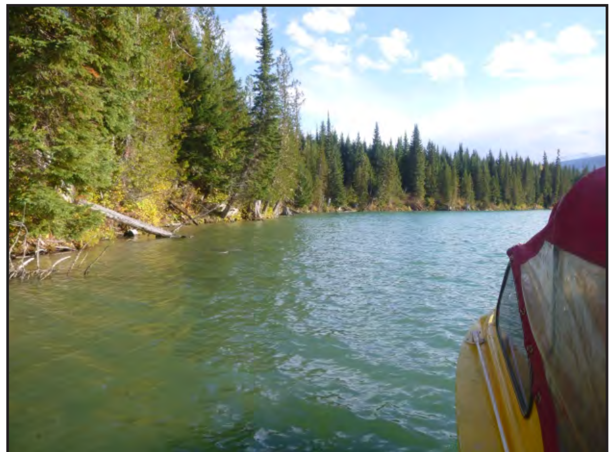


Photo 38: Looking towards the south end of Site 8 (October 1, 2014)

Photo 39: Shoreline looking east at Site 8 (October 1, 2014)

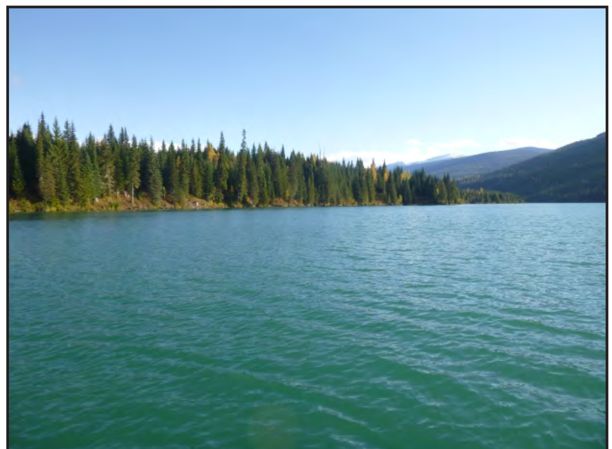


Photo 40: Looking towards the south end of Site 8 (October 1, 2014)

Photo 41: Macrophytes observed using drop camera at Site 8 (October 1, 2014)

Photo 42: Macrophytes observed using drop camera at Site 8 (October 1, 2014)

Appendix 2: Site 9 Description

Photo 43: Looking towards south end of Site 9 (October 3, 2014)

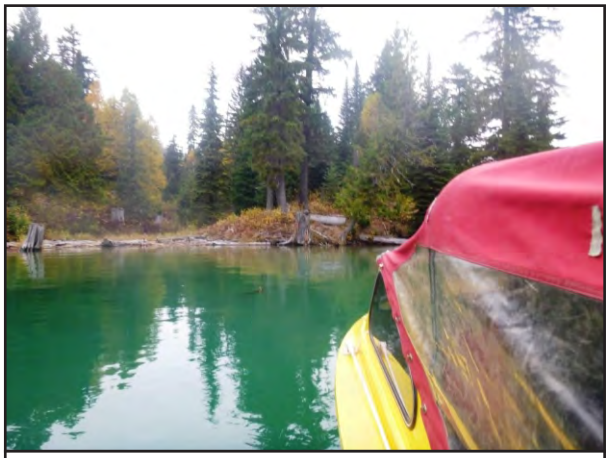


Photo 44: Looking towards the north end of Site 9 (October 3, 2014)

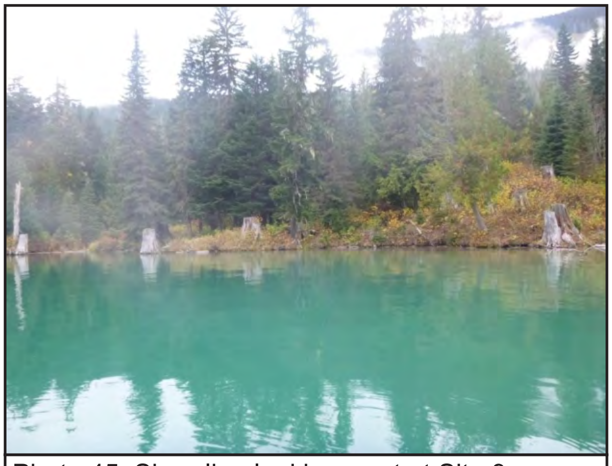


Photo 45: Shoreline looking west at Site 9 (October 3, 2014)

Photo 46: Looking towards the north end of Site 9 (October 3, 2014)

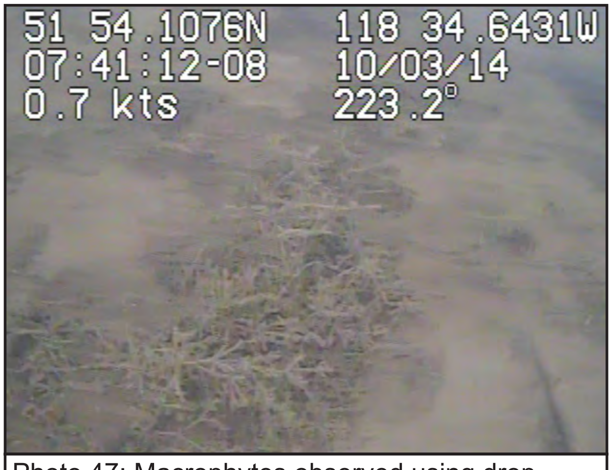


Photo 47: Macrophytes observed using drop camera at Site 9 (October 3, 2014)

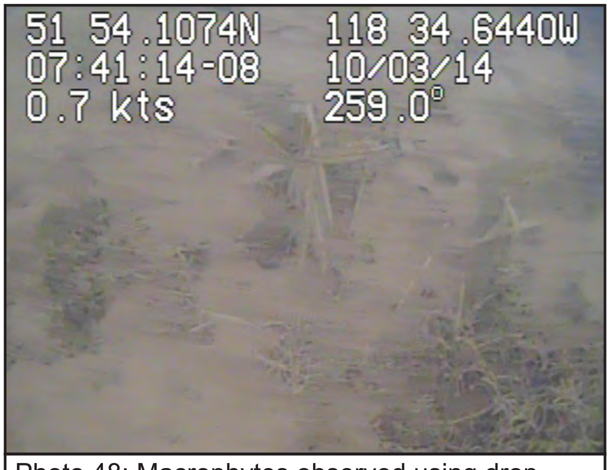


Photo 48: Macrophytes observed using drop camera at Site 9 (October 3, 2014)

Appendix 2: Site 10 Description

Photo 49: Looking towards the south end of Site 10 (October 3, 2014)

Photo 50: Looking towards north end of Site 10 (October 3, 2014)

Photo 51: Looking towards the south end of Site 10 (October 3, 2014)

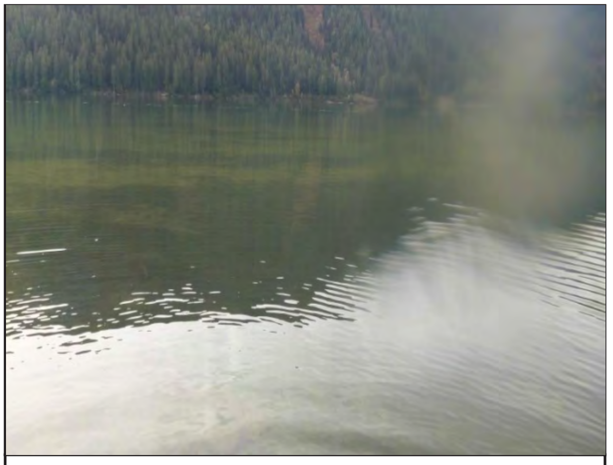


Photo 52: Looking east offshore at macrophyte beds at Site 10 (October 3, 2014)

Photo 53: Macrophytes observed at Site 10 (October 3, 2014)

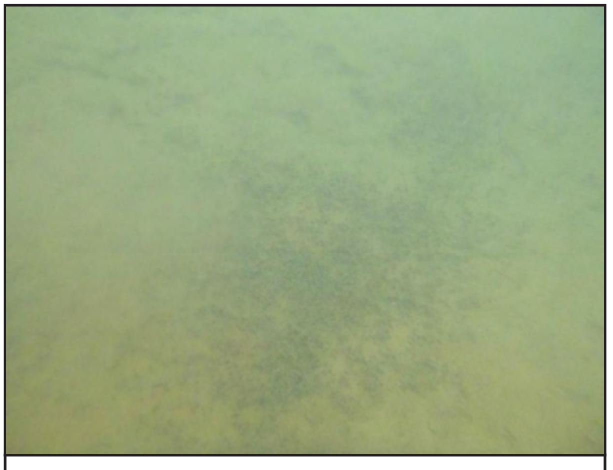


Photo 54: Macrophytes observed at Site 10 (October 3, 2014)

Appendix 2: Site 11 Description

Photo 55: Looking towards the north end of Site 11 (October 3, 2014)

Photo 56: Looking towards the south end of Site 11 (October 3, 2014)

Photo 57: Looking east away from Site 11 (October 3, 2014)

Photo 58: Looking southeast from the shore at Site 11 (October 3, 2014)

Photo 59: Macrophytes observed using drop camera at Site 11 (October 3, 2014)

Photo 60: Macrophytes observed using drop camera at Site 11 (October 3, 2014)

Appendix 2: Method Photos


Photo 61: Aluminum research jet boat (6.7 m)


Photo 62: Temporary markers used to identify transects


Photo 63: Macrophyte sampling rake


Photo 64: Sample of *P. amplifolius* collected using sampling rake.

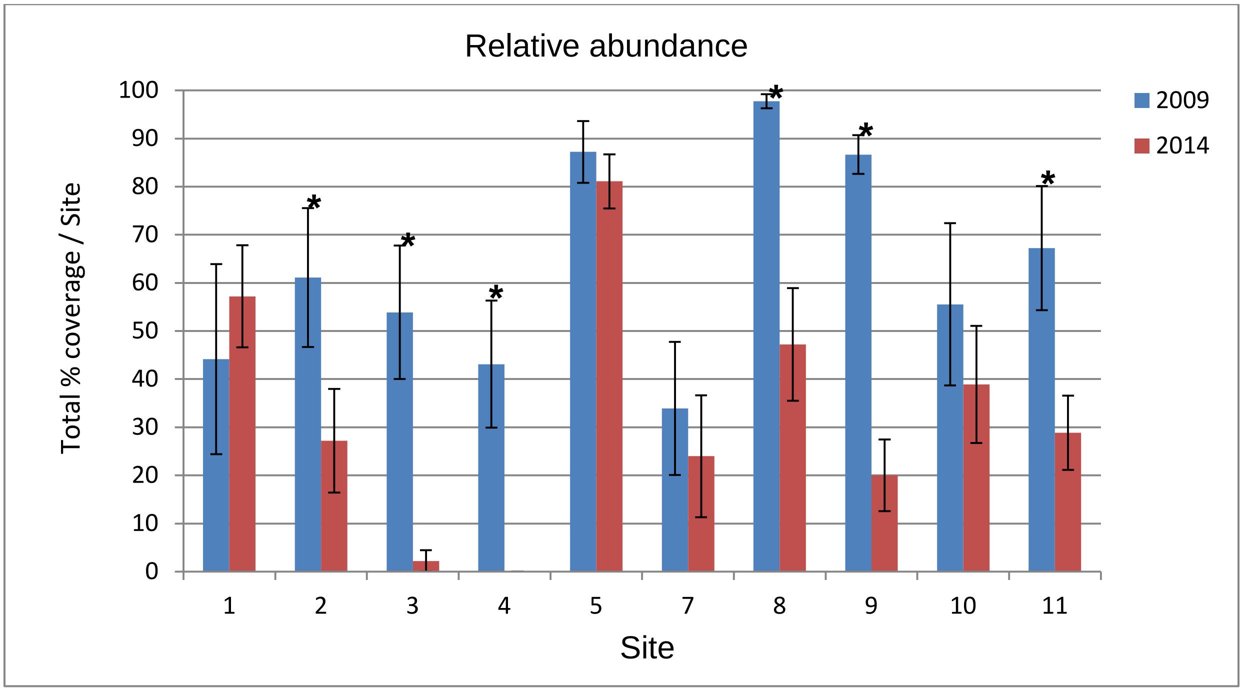

Photo 65: Quadrat used to assess macrophytes in shallow waters

Photo 66: Stainless steel Ponar used for collecting sediment

APPENDIX 3

Charts

Chart 1-1: Relative abundance (mean ± SE) of macrophyte communities (Phase 1 & Phase 2; Revelstoke Reservoir, 2014).



Star mark (*) denotes significant differences ($p < 0.05$) between 2009 and 2014.

Chart 1-2: Species richness (mean ± SE) of macrophyte communities (Phase 1 & Phase 2; Revelstoke Reservoir, 2014).

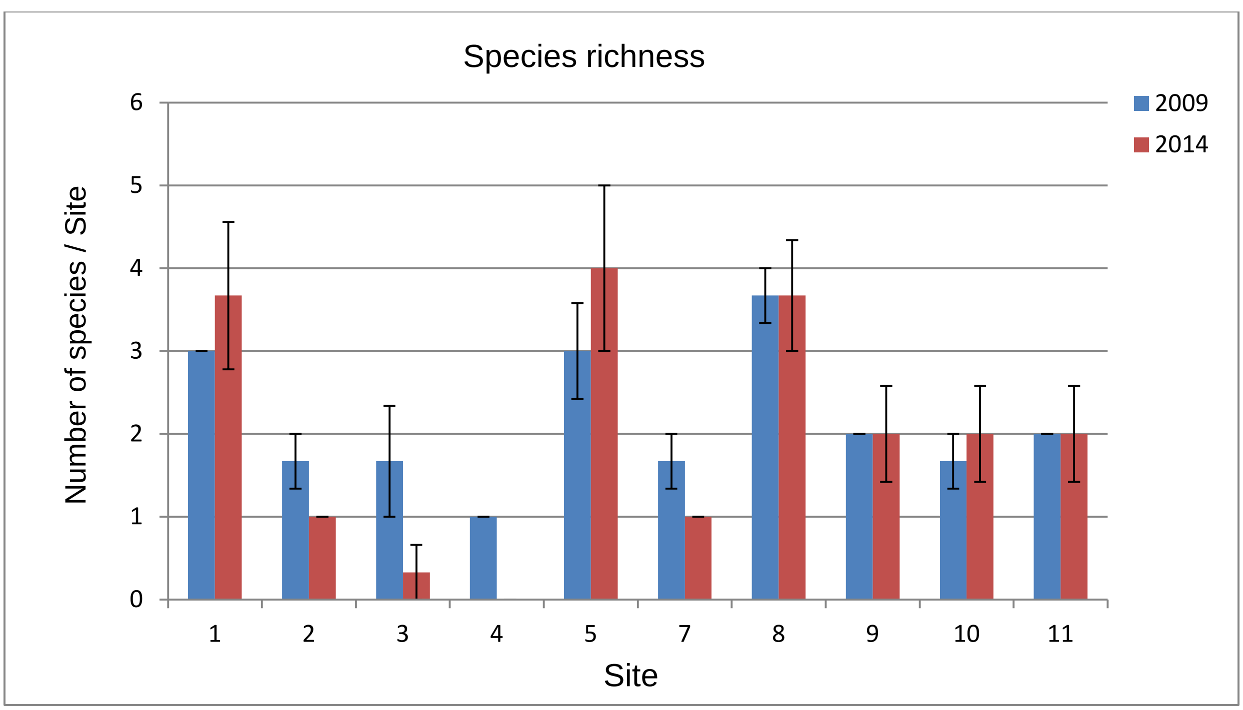


Chart 1-3: Relative abundance (mean ± SE) of macrophyte community at near-shore mid distance and far-shore sampling locations (Phase 1 & Phase 2; Revelstoke Reservoir, 2014).

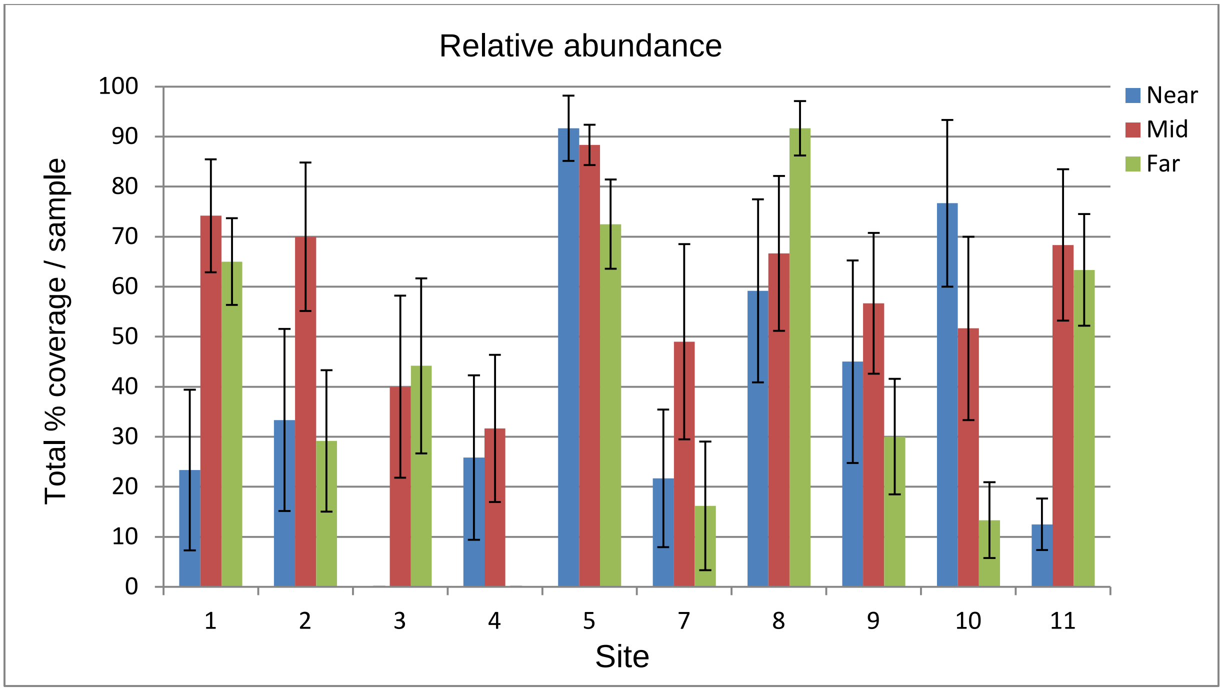


Chart 1-4: Species richness of macrophyte communities at near-shore mid distance and far-shore sampling locations (Phase 1 & Phase 2; Revelstoke Reservoir, 2014).

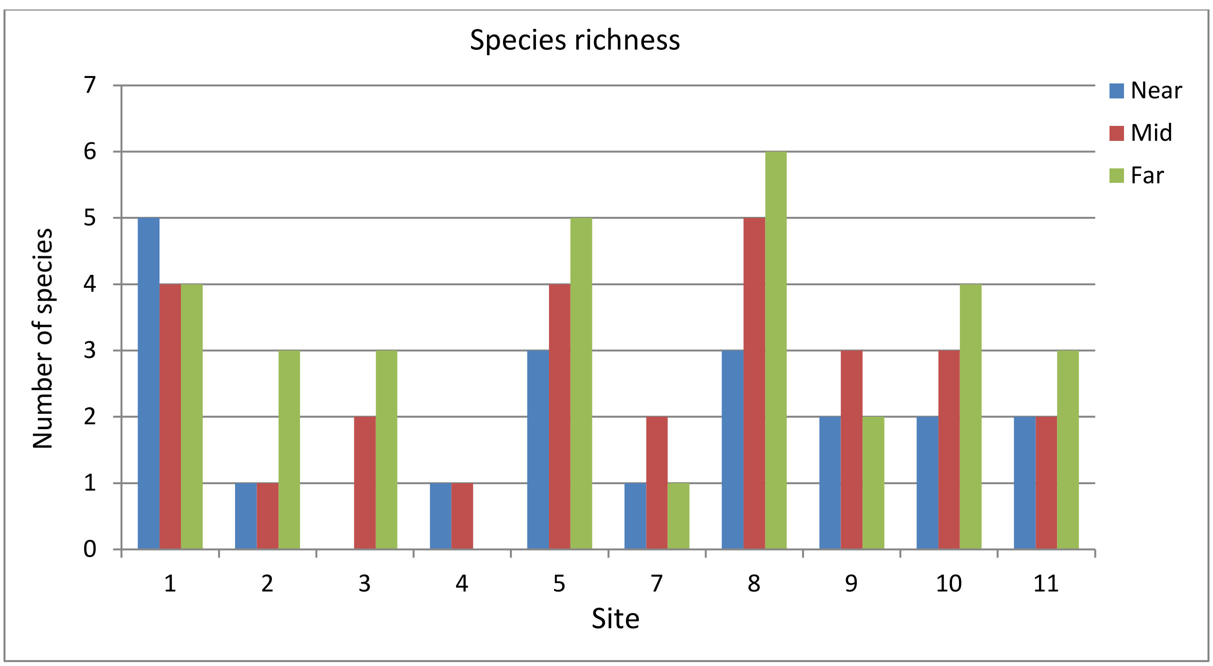


Chart 1-5: MDS plot of transect samples, macrophyte communities (Phase 1 & Phase 2; Revelstoke Reservoir, 2014).

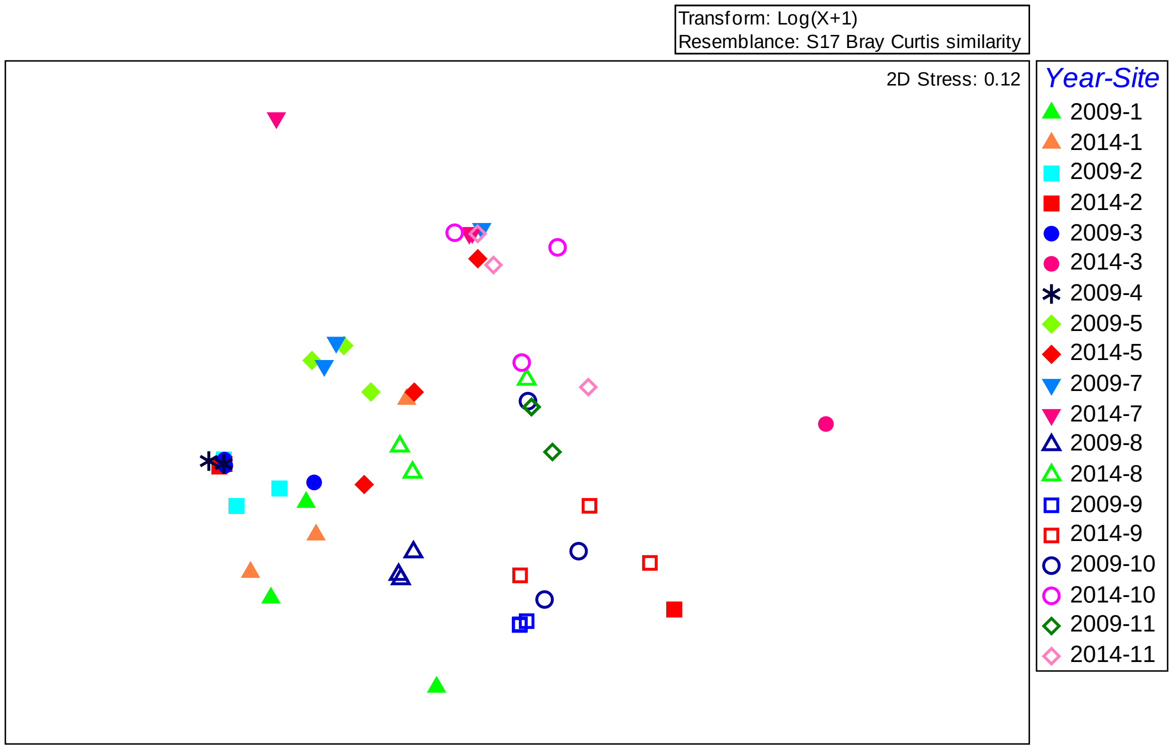


Chart 1-6: MDS plot of macrophyte samples in 3 groups at near-shore mid distance and far-shore sampling locations (Phase 1 & Phase 2; Revelstoke Reservoir, 2014).

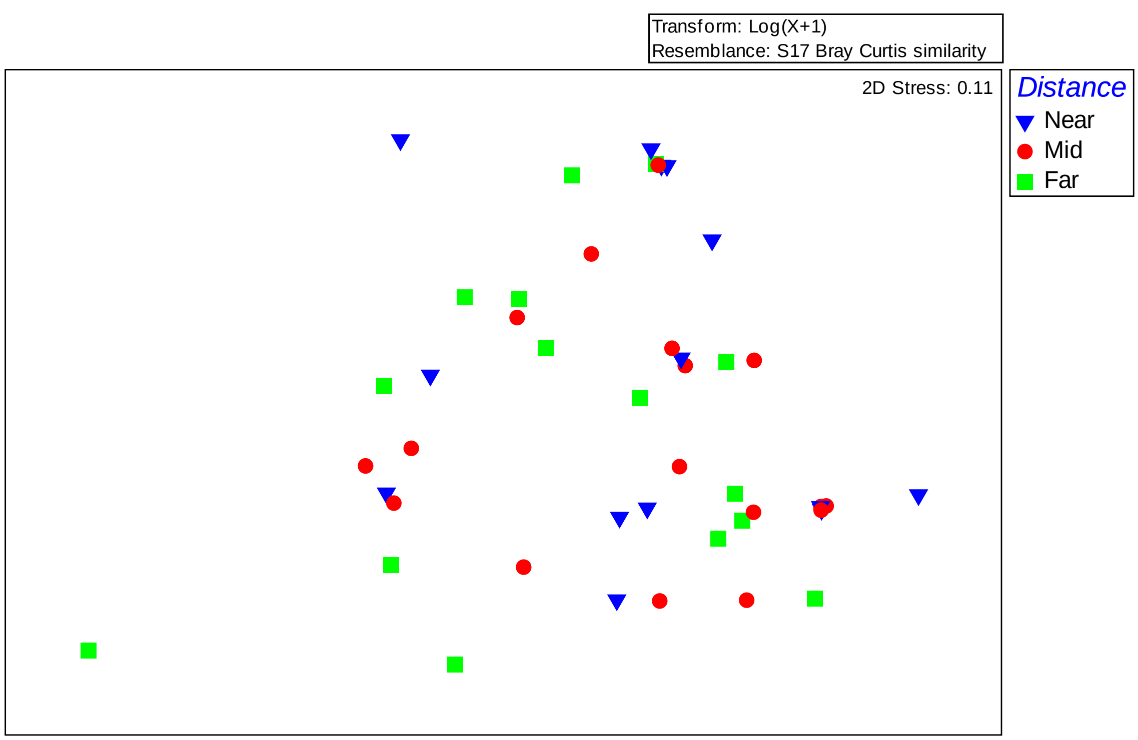


Chart 2-1: Daily Revelstoke Reservoir Elevation & Turbine Flow (January 2009 to December 2014)

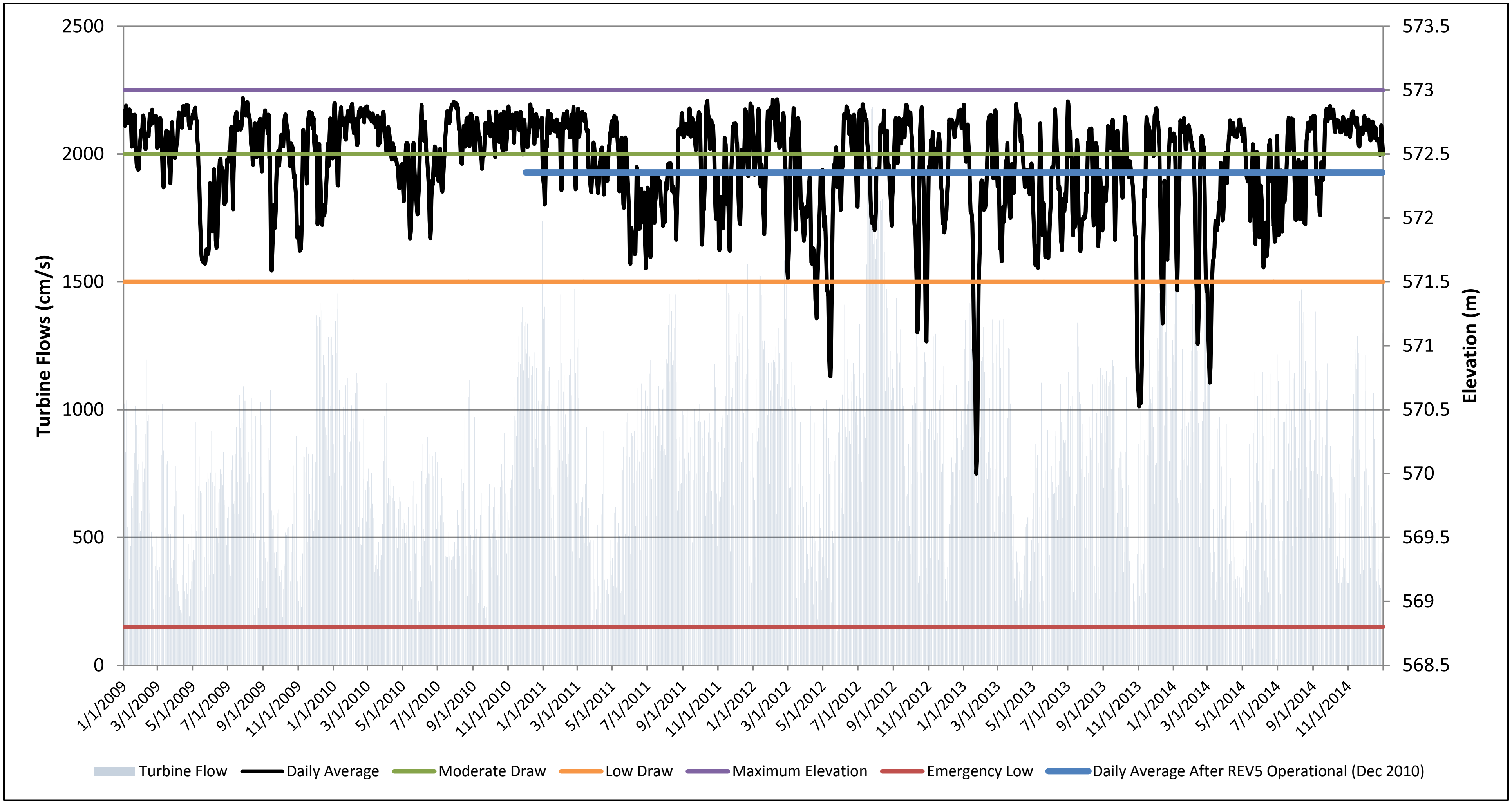


Chart 2-2: Historic Revelstoke Reservoir Average Monthly Elevation (January 1984 -December 2014)

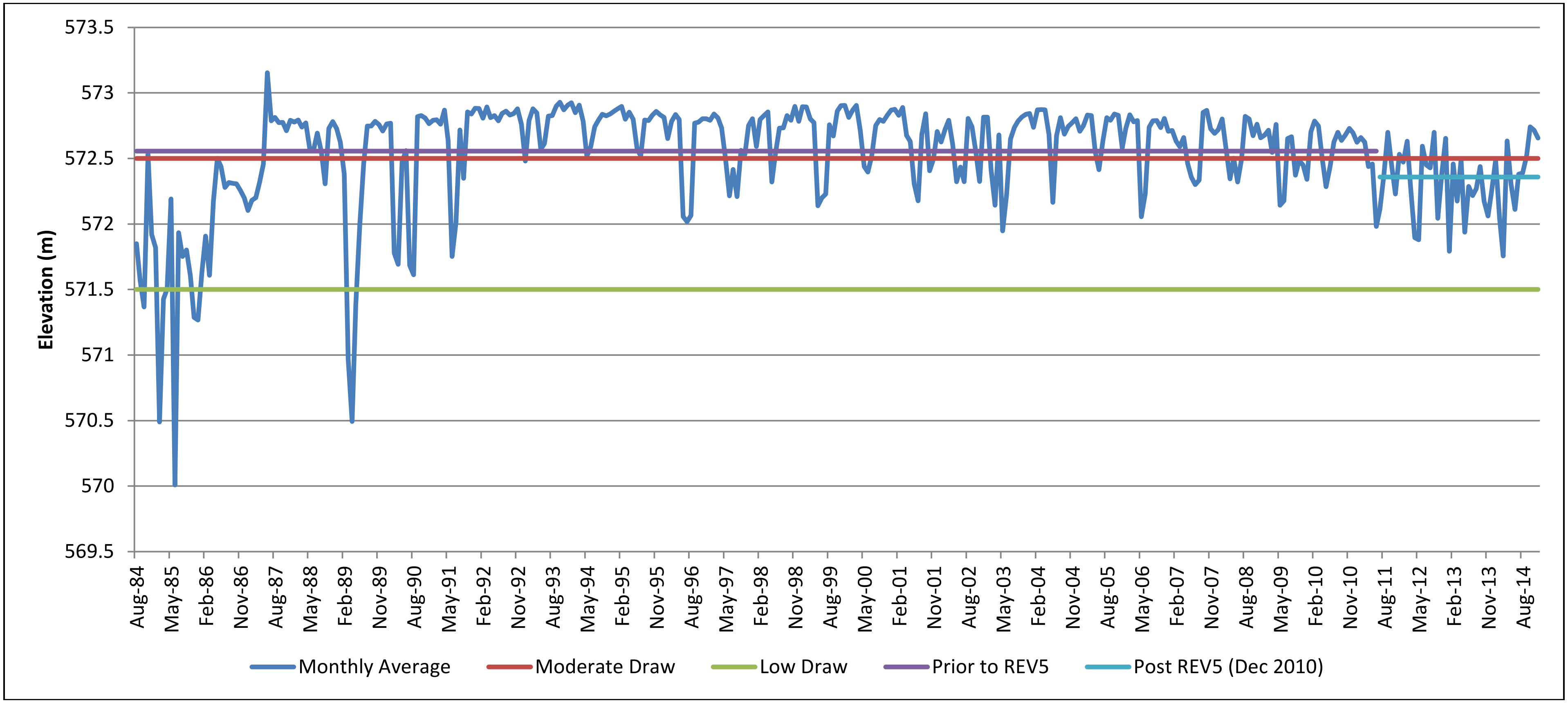


Chart 3-1: Annual Mean, Maximum & Minimum Temperature (Revelstoke, 1984 – 2014)

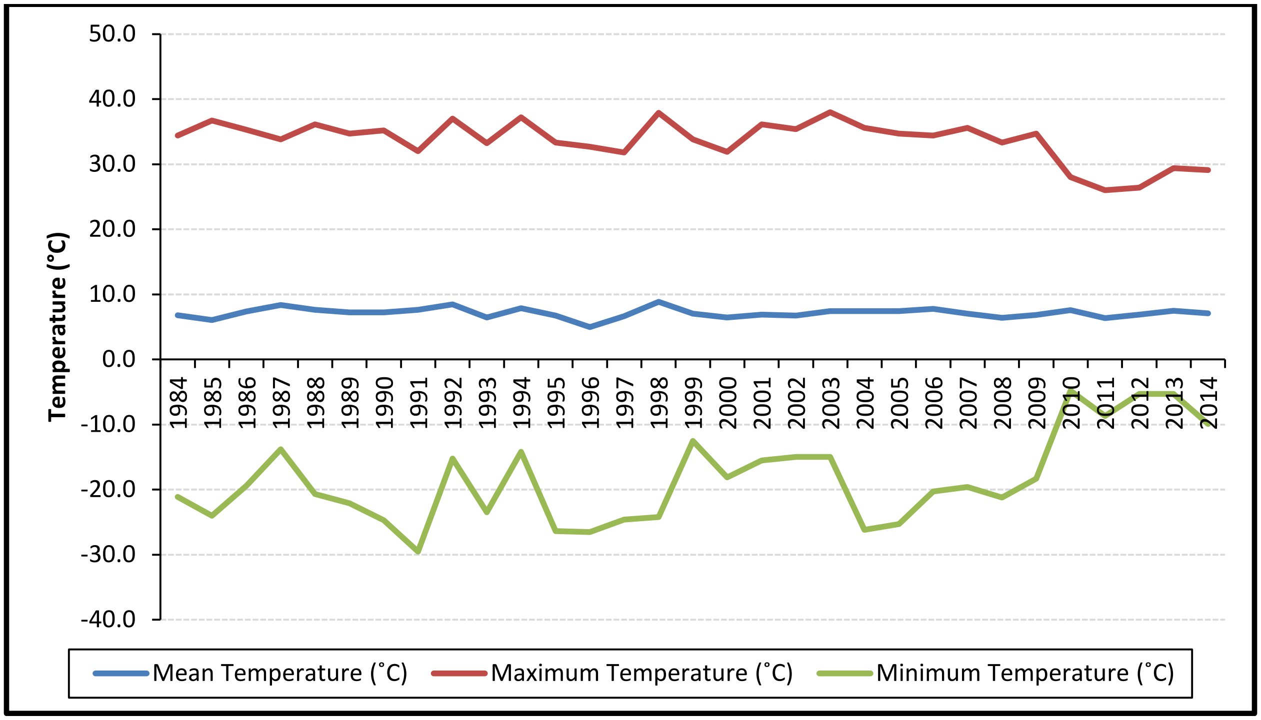


Chart 3-2: Annual Total Precipitation (Revelstoke, 1984 – 2014)

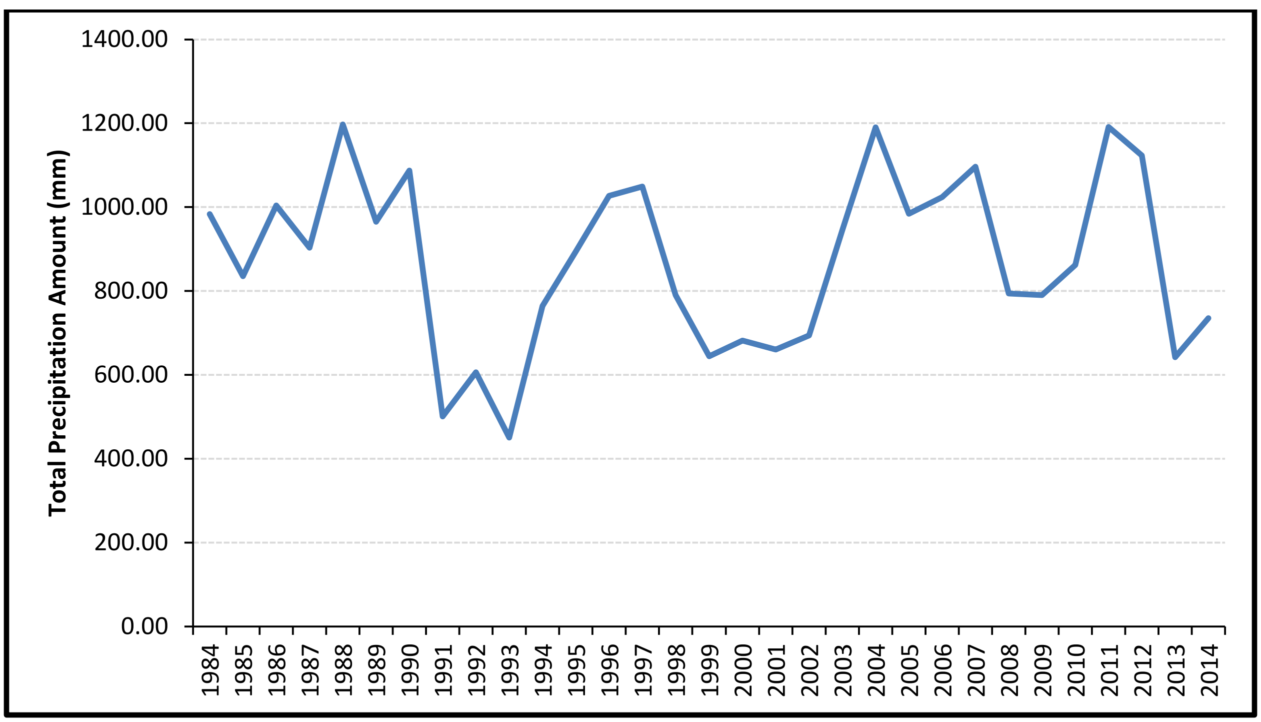
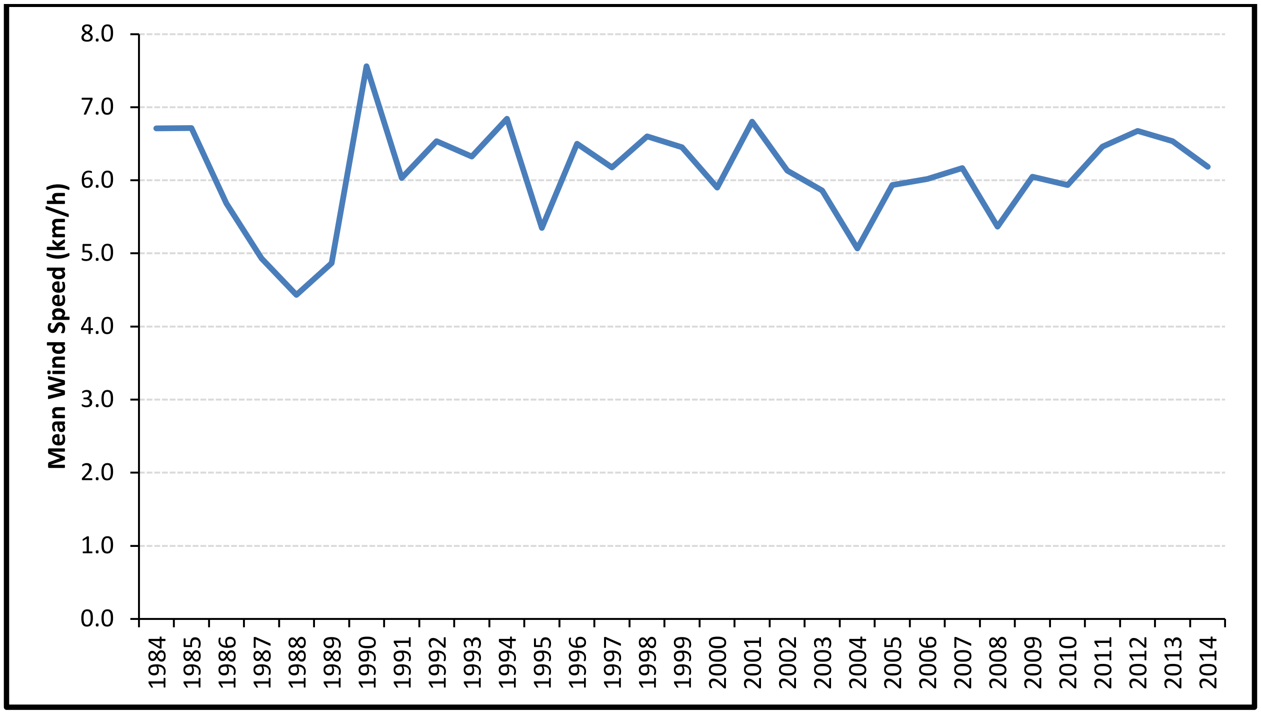


Chart 3-3: Annual Mean Wind Speed (Revelstoke, 1984 – 2014)



APPENDIX 4
Tables

Table 1: Macrophyte Distribution (Phase 1 & Phase 2)

Year	Site	Zone	Transect	Depth	Total % Cover	Potamogeton amplifolius	Potamogeton alpinus	Potamogeton foliosus	Nitella sp.	Myriophyllum spicatum	Ranunculus aquatilis	Eleocharis acicularis
2009	1	A	N	0.3	0							
2009	1	A	C	0.3	0							
2009	1	A	S	0.3	0							
2014	1	A	N	1.7	100	50	50					
2014	1	A	C	1.5	30	12			12			6
2014	1	A	S	1.6	10	2.9				7		0.1
2009	1	B	N	1.8	90.0		80		5	5		
2009	1	B	C	1.8	90.0	80			5	5		
2009	1	B	S	1.8	85.0	40	40			5		
2014	1	B	N	1.7	30	9	21					
2014	1	B	C	1.9	50	50						
2014	1	B	S	1.7	100	90	8			2		
2009	1	C	N	4.6	ind				ind			
2009	1	C	C	4.6	ind	ind			ind			
2009	1	C	S	3.0	ind	ind						
2014	1	C	N	3.3	50	50						
2014	1	C	C	1.7	65						19.5	45.5
2014	1	C	S	2.1	80	72	8					
2009	2	A	N	1.7	0							
2009	2	A	C	1.9	90	90						
2009	2	A	S	2.1	90	90						
2014	2	A	N	2	0							
2014	2	A	C	1.6	0							
2014	2	A	S	2	20	20						
2009	2	B	N	2.0	90	90						
2009	2	B	C	2.0	90	90						
2009	2	B	S	2.1	90	90						
2014	2	B	N	3.1	90	90						
2014	2	B	C	3.2	0							
2014	2	B	S	3.4	60	60						
2009	2	C	N	1.5	90	90						
2009	2	C	C	2.2	5				<5			
2009	2	C	S	2.3	5		<5					
2014	2	C	N	4	50	50						
2014	2	C	C	4	5				5			
2014	2	C	S	4	20	20						
2009	3	A	N	0.3	0							
2009	3	A	C	0.3	0							
2009	3	A	S	0.2	0							
2014	3	A	N	1	0							
2014	3	A	C	0.8	0							
2014	3	A	S	0.8	0							
2009	3	B	N	1.3	90	85			<5			
2009	3	B	C	1.1	65	65						
2009	3	B	S	1.8	85	85						
2014	3	B	N	1.5	0							
2014	3	B	C	1.4	0							
2014	3	B	S	7.6	0							
2009	3	C	N	1.3	95	85			<5			
2009	3	C	C	1.8	65	65						
2009	3	C	S	3.4	85	85						
2014	3	C	N	4.6	0							
2014	3	C	C	6.5	20			20				
2014	3	C	S	9.2	0							
2009	4	A	N	1.2	0							
2009	4	A	C	2.5	85	85						
2009	4	A	S	2.3	70	70						
2014	4	A	N	2	0							
2014	4	A	C	4.2	0							
2014	4	A	S	3.3	0							
2009	4	B	N	3.2	50	50						
2009	4	B	C	3.0	60	60						
2009	4	B	S	3.8	80	80						
2014	4	B	N	4.6	0							
2014	4	B	C	4	0							
2014	4	B	S	4.5	0							
2009	4	C	N	3.4	ind	ind						
2009	4	C	C	4.1	0							
2009	4	C	S	4.3	0							
2014	4	C	N	7.7	0							
2014	4	C	C	5	0							
2014	4	C	S	4.9	0							
2009	5	A	N	0.7	60	10						50
2009	5	A	C	0.7	100							100
2009	5	A	S	0.4	100							100
2014	5	A	N	1.9	100	80			10			10
2014	5	A	C	1	90							90
2014	5	A	S	0.8	100							100
2009	5	B	N	1.0	90	90						
2009	5	B	C	0.5	100							100
2009	5	B	S	0.7	100	20			<10			70
2014	5	B	N	1.7	80	64	8		7.2			
2014	5	B	C	1.2	80						4	76
2014	5	B	S	0.8	80							80
2009	5	C	N	1.9	50	50				50		
2009	5	C	C	1.5	85	85						
2009	5	C	S	1.3	100	90				10		
2014	5	C	N	2.2	50	45			0.5	4		0.5
2014	5	C	C	2	90	45			18	18	9	
2014	5	C	S	1.6	60						6	54

Legend
80-100
60-79
40-59
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0-19

Con'd...

Table 1: Macrophyte Distribution (Phase 1 & Phase 2) Con'd

Year	Site	Zone	Transect	Depth	Total % Cover	Potamogeton amplifolius	Potamogeton alpinus	Potamogeton foliosus	Nitella sp.	Myriophyllum spicatum	Ranunculus aquatilis	Eleocharis acicularis
2009	7	A	N	0.4	70							70
2009	7	A	C	0.4	0							
2009	7	A	S	0.4	60							60
2014	7	A	N	1.4	0							
2014	7	A	C	1.4	0							
2014	7	A	S	1	0							
2009	7	B	N	0.8	75	75						
2009	7	B	C	0.6	100	50						50
2009	7	B	S	0.6	0							
2014	7	B	N	1.4	20							20
2014	7	B	C	0.3	100							100
2014	7	B	S	0.4	10							
2009	7	C	N	0.4	0							
2009	7	C	C	0.5	0							
2009	7	C	S	0.0	0							
2014	7	C	N	4	80							80
2014	7	C	C	0.2	25							16.5
2014	7	C	S	0.2	5							1
2009	8	A	N	0.6	100.0	50			50			
2009	8	A	C	0.6	100	100						
2009	8	A	S	1.0	100	50			50			
2014	8	A	N	3	15					15		
2014	8	A	C	2.7	20	20						
2014	8	A	S	2	20				20			
2009	8	B	N	2.3	90	30		30	30			
2009	8	B	C	2.0	100			50	50			
2009	8	B	S	2.1	90			90				
2014	8	B	N	2.1	80	68			12			
2014	8	B	C	2.2	35	31.5						3.5
2014	8	B	S	2.3	5						5	
2009	8	C	N	1.6	100		50		50			
2009	8	C	C	1.2	100		20	10	70			
2009	8	C	S	0.9	100			70	30			
2014	8	C	N	2	100	10			20		60	10
2014	8	C	C	2.2	80				72			8
2014	8	C	S	1.8	70				14			56
2009	9	A	N	0.9	95		5		90			
2009	9	A	C	1.3	80.0				80			
2009	9	A	S	1.1	95		5		90			
2014	9	A	N	1	0							
2014	9	A	C	1	0							
2014	9	A	S	2.5	0							
2009	9	B	N	1.8	90		10		80			
2009	9	B	C	2.9	90		10		80			
2009	9	B	S	3.4	70		10		60			
2014	9	B	N	2	0							
2014	9	B	C	2.5	40		28				12	
2014	9	B	S	3.5	50				50			
2009	9	C	N	3.2	ind				ind			
2009	9	C	C	4.1	ind				ind			
2009	9	C	S	5.0	ind				ind			
2014	9	C	N	4.7	10				10			
2014	9	C	C	3.2	30				30			
2014	9	C	S	5.5	50				25		25	
2009	10	A	N	0.4	100				90			10
2009	10	A	C	0.4	100				100			
2009	10	A	S	1.0	100				100			
2014	10	A	N	0.7	100							100
2014	10	A	C	0.4	0							
2014	10	A	S	0.8	60							60
2009	10	B	N	0.5	90							90
2009	10	B	C	1.6	0							
2009	10	B	S	1.0	100		5		95			
2014	10	B	N	0.6	80							80
2014	10	B	C	0.8	40							40
2014	10	B	S	0.6	0							
2009	10	C	N	0.8	10				10			
2009	10	C	C	0.8	0							
2009	10	C	S	0.9	0							
2014	10	C	N	0.9	10							10
2014	10	C	C	0.6	10			10				
2014	10	C	S	1.1	50				20		10	20
2009	11	A	N	0.1	5.0							5
2009	11	A	C	0.2	20.0							20
2009	11	A	S	0.1	30.0							30
2014	11	A	N	0.5	20						16	4
2014	11	A	C	0.8	0							
2014	11	A	S	1	80							
2009	11	B	N	1.6	100.0				100			
2009	11	B	C	1.2	100.0				100			
2009	11	B	S	1.4	100.0				100			
2014	11	B	N	1.5	20				12			8
2014	11	B	C	1.1	60							60
2014	11	B	S	1.2	30							30
2009	11	C	N	0.3	70.0				60			10
2009	11	C	C	0.3	100.0				50			50
2009	11	C	S	0.3	80.0				40			40
2014	11	C	N	4.7	20						20	
2014	11	C	C	1.3	60						12	48
2014	11	C	S	1.2	50							50

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20-39
0-19

Table 2-1: Macrophyte Community General Characteristics (Site 1)

Site 1		2009						2014					
Descriptor	Transect	Near-shore (A)		Mid-distance (B)		Furthest from Shore (C)		Near-shore (A)		Mid-distance (B)		Furthest from Shore (C)	
		Species	Cover	Species	Cover	Species	Cover	Species	Cover	Species	Cover	Species	Cover
Coverage (%)	South (S)	0	0	*P. alpinus* *P. amplifolius* *M. spicatum*	40% 40% 5%	*P. alpinus* *M. spicatum*	N/A	*M. spicatum* *P. amplifolius* *E. acicularis*	7% 2.9% 0.1%	*P. amplifolius* *P. alpinus* *M. spicatum*	90% 8% 2%	*P. amplifolius* *P. alpinus*	72% 8%
	Centre (C)	0	0	*P. amplifolius* *M. spicatum* *Nitella sp.*	80% 5% 5%	*Nitella sp.* *P. amplifolius*	N/A	*P. amplifolius* *Nitella sp.* *E. acicularis*	12% 12% 6%	*P. amplifolius*	50%	*E. acicularis* *R. aquatilis*	45.5% 19.5%
	North (N)	0	0	*P. alpinus* *M. spicatum* *Nitella sp.*	80% 5% 5%	*Nitella sp.*	N/A	*P. amplifolius* *P. alpinus*	50% 50%	*P. alpinus* *P. amplifolius*	21% 9%	*P. amplifolius*	50%
Taxa Richness	South (S)	0		3		2		3		3		2	
	Centre (C)	0		3		2		3		1		2	
	North (N)	0		3		2		2		2		1	
Transect Total Taxa Richness		0		4		2		5		3		4	
Total Taxa Richness		4						6					

N/A: no data

Table 2-2: Macrophyte Community General Characteristics (Site 2)

Site 2		2009						2014					
Descriptor	Transect	Near-shore (A)		Mid-distance (B)		Furthest from Shore (C)		Near-shore (A)		Mid-distance (B)		Furthest from Shore (C)	
		Species	Cover	Species	Cover	Species	Cover	Species	Cover	Species	Cover	Species	Cover
Coverage (%)	South (S)	*P. amplifolius*	90%	*P. amplifolius*	80%	*P. alpinus*	<5%	*P. amplifolius*	20%	*P. amplifolius*	60%	*P. amplifolius*	20%
	Centre (C)	*P. amplifolius*	90%	*P. amplifolius*	90%	*Nitella sp.*	<5%	0	0	0	0	*Nitella sp.*	5%
	North (N)	0	0	*P. amplifolius*	90%	*P. amplifolius*	90%	0	0	*P. amplifolius*	90%	*P. amplifolius*	50%
Taxa Richness	South (S)	1		1		1		1		1		1	
	Centre (C)	1		1		1		0		0		1	
	North (N)	0		1		1		0		1		1	
Transect Total Taxa Richness		1		1		1		1		1		2	
Total Taxa Richness		3						2					

Table 2-3: Macrophyte Community General Characteristics (Site 3)													
Site 3		2009						2014					
Descriptor	Transect	Near-shore (A)		Mid-distance (B)		Furthest from Shore (C)		Near-shore (A)		Mid-distance (B)		Furthest from Shore (C)	
		Species	Cover	Species	Cover	Species	Cover	Species	Cover	Species	Cover	Species	Cover
Coverage (%)	South (S)	0	0	*P. amplifolius*	85%	*P. amplifolius*	85%	0	0	0	0	0	0
	Centre (C)	0	0	*P. amplifolius*	65%	*P. amplifolius*	65%	0	0	0	0	*P. foliosus*	20%
	North (N)	0	0	*P. amplifolius* *Nitella sp.*	85% <5%	*P. amplifolius* *Nitella sp.* *R. aquatilis*	85% <5% <5%	0	0	0	0	0	0
Taxa Richness	South (S)	0		1		1		0		0		0	
	Centre (C)	0		1		1		0		0		1	
	North (N)	0		2		3		0		0		0	
Transect Total Taxa Richness		0		2		3		0		0		0	
Total Taxa Richness		3						1					

Table 2-4: Macrophyte Community General Characteristics (Site 4)													
Site 4		2009						2014					
Descriptor	Transect	Near-shore (A)		Mid-distance (B)		Furthest from Shore (C)		Near-shore (A)		Mid-distance (B)		Furthest from Shore (C)	
		Species	Cover	Species	Cover	Species	Cover	Species	Cover	Species	Cover	Species	Cover
Coverage (%)	South (S)	*P. amplifolius*	70%	*P. amplifolius*	80%	0	0	0	0	0	0	0	0
	Centre (C)	*P. amplifolius*	85%	*P. amplifolius*	60%	0	0	0	0	0	0	0	0
	North (N)	0	0	*P. amplifolius*	50%	*P. amplifolius*	N/A	0	0	0	0	0	0
Taxa Richness	South (S)	1		1		0		0		0		0	
	Centre (C)	1		1		0		0		0		0	
	North (N)	0		1		1		0		0		0	
Transect Total Taxa Richness		1		1		1		0		0		0	
Total Taxa Richness		1						0					

N/A: no data

Table 2-5: Macrophyte Community General Characteristics (Site 5)

Site 5		2009						2014					
Descriptor	Transect	Near-shore (A)		Mid-distance (B)		Furthest from Shore (C)		Near-shore (A)		Mid-distance (B)		Furthest from Shore (C)	
		Species	Cover	Species	Cover	Species	Cover	Species	Cover	Species	Cover	Species	Cover
Coverage (%)	South (S)	*E. acicularis*	100%	*E. acicularis* *P. amplifolius* *Nitella sp.*	70% 20% <10%	*P. amplifolius* *M. spicatum*	90% 10%	*E. acicularis*	100%	*E. acicularis*	80%	*E. acicularis* *R. aquatilis*	54% 6%
	Centre (C)	*E. acicularis*	100%	*E. acicularis*	100%	*P. amplifolius*	85%	*E. acicularis*	90%	*E. acicularis* *R. aquatilis*	76% 4%	*P. amplifolius* *M. spicatum* *Nitella sp.* *R. aquatilis*	45% 18% 18% 9%
	North (N)	*E. acicularis* *P. amplifolius*	50% 10%	*P. amplifolius*	90%	*P. amplifolius* *M. spicatum*	50% 50%	*P. amplifolius* *Nitella sp.* *E. acicularis*	80% 10% 10%	*P. amplifolius* *P. alpinus* *Nitella sp.*	64% 8% 8%	*P. amplifolius* *M. spicatum* *Nitella sp.* *E. acicularis*	45% 4% 0.5% 0.5%
Taxa Richness	South (S)	1		3		2		1		1		2	
	Centre (C)	1		1		1		1		2		4	
	North (N)	2		1		2		3		3		4	
Transect Total Taxa Richness		2		3		2		3		5		5	
Total Taxa Richness		4						6					

Table 2-6: Macrophyte Community General Characteristics (Site 7)

Site 7		2009						2014					
Descriptor	Transect	Near-shore (A)		Mid-distance (B)		Furthest from Shore (C)		Near-shore (A)		Mid-distance (B)		Furthest from Shore (C)	
		Species	Cover	Species	Cover	Species	Cover	Species	Cover	Species	Cover	Species	Cover
Coverage (%)	South (S)	*E. acicularis*	60%	0		0	0	0	0	0	0	*E. acicularis*	1%
	Centre (C)	0	0	*P. amplifolius* *E. acicularis*	50% 50%	0	0	0	0	*E. acicularis*	20%	*E. acicularis*	16.5%
	North (N)	*E. acicularis*	70%	*P. amplifolius*	75%	0	0	0	0	*E. acicularis*	100%	*E. acicularis*	80%
Taxa Richness	South (S)	1		0		0				0		1	
	Centre (C)	0		2		0				1		1	
	North (N)	1		1		0				1		1	
Transect Total Taxa Richness		1		2		0				1		1	
Total Taxa Richness		2						1					

Table 2-7: Macrophyte Community General Characteristics (Site 8)

Site 8		2009						2014					
Descriptor	Transect	Near-shore (A)		Mid-distance (B)		Furthest from Shore (C)		Near-shore (A)		Mid-distance (B)		Furthest from Shore (C)	
		Species	Cover	Species	Cover	Species	Cover	Species	Cover	Species	Cover	Species	Cover
Coverage (%)	South (S)	*Nitella sp.* *P. amplifolius*	50% 50%	*P. foliosus*	90%	*P. foliosus* *Nitella sp.*	70% 30%	*Nitella sp.*	20%	*R. aquatilis*	5%	*E. acicularis* *Nitella sp.*	56% 14%
	Centre (C)	*P. amplifolius*	100%	*P. foliosus* *Nitella sp.*	50% 50%	*Nitella sp.* *P. alpinus* *P.foliosus*	70% 20% 10%	*P. amplifolius*	20%	*P. amplifolius* *E. acicularis*	31.5% 3.5%	*Nitella sp.* *E. acicularis*	72% 8%
	North (N)	*Nitella sp.* *P. amplifolius*	50% 50%	*P. amplifolius* *Nitella sp.* *P. foliosus*	30% 30% 30%	*Nitella sp.* *P. alpinus*	50% 50%	*M. spicatum*	15	*P. amplifolius* *Nitella sp.*	68% 12%	*R. aquatilis* *Nitella sp.* *P. amplifolius* *E. acicularis*	60% 20% 10% 10%
Taxa Richness	South (S)	2		1		2		1		1		2	
	Centre (C)	1		2		3		1		2		2	
	North (N)	2		3		2		1		2		4	
Transect Total Taxa Richness		2		3		3		3		4		4	
Total Taxa Richness		4						5					

Table 2-8: Macrophyte Community General Characteristics (Site 9)

Site 9		2009						2014					
Descriptor	Transect	Near-shore (A)		Mid-distance (B)		Furthest from Shore (C)		Near-shore (A)		Mid-distance (B)		Furthest from Shore (C)	
		Species	Cover	Species	Cover	Species	Cover	Species	Cover	Species	Cover	Species	Cover
Coverage (%)	South (S)	*Nitella sp.* *P. alpinus*	90% 5%	*Nitella sp.* *P. alpinus*	60% 10%	*Nitella sp.*	N/A	0	0	*Nitella sp.*	50%	*Nitella sp.* *R. aquatilis*	25% 25%
	Centre (C)	*Nitella sp.*	80%	*Nitella sp.* *P. aplinus*	80% 10%	*Nitella sp.*	N/A	0	0	*P. alpinus* *R. aquatilis*	28% 12%	*Nitella sp.*	30%
	North (N)	*Nitella sp.* *P. alpinus*	90% 5%	*Nitella sp.* *P. aplinus*	80% 10%	*Nitella sp.*	N/A	0	0	0	0	*Nitella sp.*	10%
Taxa Richness	South (S)	2		2		1		0		1		2	
	Centre (C)	1		2		1		0		2		1	
	North (N)	2		2		1		0		0		1	
Transect Total Taxa Richness		2		2		1		0		3		2	
Total Taxa Richness		2						3					

N/A: no data

Table 2-9: Macrophyte Community General Characteristics (Site 10)													
Site 10		2009						2014					
Descriptor	Transect	Near-shore (A)		Mid-distance (B)		Furthest from Shore (C)		Near-shore (A)		Mid-distance (B)		Furthest from Shore (C)	
		Species	Cover	Species	Cover	Species	Cover	Species	Cover	Species	Cover	Species	Cover
Coverage (%)	South (S)	*Nitella sp.*	100%	*Nitella sp.* *P. alpinus*	95% 5%	0	0	*E. acicularis*	60%	0	0	*E. acicularis* *Nitella sp.* *R. aquatilis*	20% 20% 10%
	Centre (C)	*Nitella sp.*	100%	0		0	0	0	0	*E. acicularis*	40%	*P. foliosus*	10%
	North (N)	*Nitella sp.* *E. acicularis*	90% 10%	*E. acicularis*	90%	*Nitella sp.*	10%	*E. acicularis*	100%	*E. acicularis*	80%	*E. acicularis*	10%
Taxa Richness	South (S)	1		2		0		1		0		3	
	Centre (C)	1		0		0		0		1		1	
	North (N)	2		1		1		1		1		1	
Transect Total Taxa Richness		2		3		1		1		1		4	
Total Taxa Richness		3						4					

Table 2-10: Macrophyte Community General Characteristics (Site 11)													
Site 11		2009						2014					
Descriptor	Transect	Near-shore (A)		Mid-distance (B)		Furthest from Shore (C)		Near-shore (A)		Mid-distance (B)		Furthest from Shore (C)	
		Species	Cover	Species	Cover	Species	Cover	Species	Cover	Species	Cover	Species	Cover
Coverage (%)	South (S)	*E. acicularis*	30%	*Nitella sp.*	100%	*Nitella sp.* *E. acicularis*	40% 40%	0	0	*E. acicularis*	30%	*E. acicularis*	50%
	Centre (C)	*E. acicularis*	20%	*Nitella sp.*	100%	*Nitella sp.* *E. acicularis*	50% 50%	0	0	*E. acicularis*	60%	*E. acicularis* *R. aquatilis*	48% 12%
	North (N)	*E. acicularis*	5%	*Nitella sp.*	100%	*Nitella sp.* *E. acicularis*	60% 10%	*R. aquatilis* *E. acicularis*	16% 4%	*Nitella sp.* *E. acicularis*	12% 8%	*R. aquatilis*	20%
Taxa Richness	South (S)	1		1		2		0		1		1	
	Centre (C)	1		1		2		0		1		2	
	North (N)	1		1		2		2		2		1	
Transect Total Taxa Richness		1		1		2		2		2		2	
Total Taxa Richness		2						3					

Table 3-1: Phase 2 NDVI Predicted Polygons vs. *In Situ* Observations (2014)			
Site	**NDVI Polygon Area (m^2)**	***In Situ* Polygon Area**	**Difference in Polygon Areas**
1	2,031	10,563	1,838
2	2,610	1,683	-348
3	3,810	2,976	366
4	16,110	2,642	-1,168
5	2,694	20,863	4,753
7	44,625	2,074	-620
8	1,295	36,592	-8,033
9	2,374	1,395	100
10	17,340	3,059	685
11	2,031	24,110	6,770

Table 3-2: *In Situ* Area Observations (Phase 1 & Phase 2)			
Site	**Phase 1 (2009) Recalculated *In Situ* Polygon Area (m^2)**	**Phase 2 (2014) *In Situ* Polygon Area (m^2)**	**Difference in Polygon Areas (m^2)**
1	11,992	10,563	-1,429
2	2,550	1,683	-867
3	3,910	2,976	-934
4	3,793	2,642	-1,151
5	17,898	20,863	2,965
7	1,306	2,074	768
8	72,683	36,592	-36,091
9	1,932	1,395	-537
10	2,323	3,059	736
11	32,660	24,110	-8,550
		Overall Difference	-45,090

Table 4: Phase 1 & Phase 2 Sediment Characteristics (Revelstoke Reservoir, 2014)						
Site	**Phase**	**Zone**	**Colour**	**Consistency & Texture**	**Odour**	**Other Features**
1	1	A	Grey-Brown	Gravelly (with sand and cobbles)	Odourless	N/A
	2	A	Dark brown, brown-green	Watery; silky	Creosote, soil	Organic debris, macrophytes
	1	B	Black	Gritty; watery; mixture of sand and gravel	Odourless	Abundant small organic debris (sticks, bark pieces); heterogeneous
	2	B	Dark brown	Watery; gritty	Odourless	Small wood fragments
	1	C	Dark Brown	Unconsolidated; silky; gritty	Odourless	Abundant organic debris; homogenous throughout
	2	C	Red brown	Falls apart into fluffy pellets, sand; gritty	Odourless	Macrophyte
2	1	A	Grey-Brown	Gravelly (with cobbles and sand)	Odourless	N/A
	2	A	N/A	Gritty, gravelly	N/A	N/A
	1	B	Black-Grey	Thick like pudding; silky, gritty, watery	Light H_2S odour	No woody debris, many macrophyte roots; homogenous throughout
	2	B	Dark brown	Thick like pudding; silky	Odourless	Small bit of woody debris
	1	C	Dark Brown	Unconsolidated; watery; mixture of gravels, sand and clay	Odourless	Some small twigs; homogenous throughout
	2	C	Dark brown	Thick like pudding; silky	Odourless	Small woody debris, dead leaves
3	1	A	Dark Brown-Grey	Thick like pudding; silky; gritty	H_2S odour	N/A
	2	A	Dark brown, brown-green	Thick like pudding; gritty	Odourless	No organic material
	1	B	Dark Brown-Grey	Thick like pudding; silky; gritty	H_2S odour	Abundant macrophyte roots; small woody debris; flakes of mica/silica; homogenous throughout
	2	B	Dark brown	Thick like pudding; gritty	Slight H_2S odour	Uniform, no organic material
	1	C	Dull Grey	Unconsolidated; gritty, gravelly	H_2S odour	Very little debris; few macrophyte roots; heterogeneous
	2	C	Brown-green, light brown	Loose; silky	H_2S odour	Organic debris
4	1	A	Brown-Grey	Gritty; Gravelly (with sand and cobbles)	Odourless	N/A
	2	A	N/A	N/A; gritty, gravelly	N/A	N/A
	1	B	Dull Grey	Thick like pudding; silky	H_2S odour	Abundant macrophyte roots, small woody debris and macrophyte pieces; homogenous throughout
	2	B	Dark brown	Loose; silky	H_2S odour	Organic material
	1	C	Dull Grey	Unconsolidated; watery; silky (with gravels and cobbles)	H_2S odour	Abundant small debris (macrophyte roots, wood flakes); heterogeneous (silty layer on top of gravels/cobbles)
	2	C	Brown-green	Gel-like; silky	Odourless	No debris
5	1	A	Brown	Gritty; sandy (with some gravel)	Odourless	N/A
	2	A	Light brown	Thick like pudding; gritty, gravelly	Odourless	Gravel, grit, organics
	1	B	Dull Grey	Unconsolidated; gritty; gravelly	Odourless	Homogenous throughout (top layer of grass with fine sands underneath)
	2	B	Brown-green	Thick like pudding; gritty, slightly gravelly	Odourless	Organic material throughout surface, *macrophytes* on surface, piece of wood in grab
	1	C	Black	Thick like pudding; silky	H_2S odour	Abundant macrophyte roots, dead macrophytes and woody debris; homogeneous throughout
	2	C	Brown-green	Loose; silky	Odourless	Organic debris on top

Table 4: Phase 1 & Phase 2 Sediment Characteristics (Revelstoke Reservoir, 2014) Con'd						
Site	**Phase**	**Zone**	**Colour**	**Consistency & Texture**	**Odour**	**Other Features**
7	1	A	Grey-Brown	Gritty; gravelly (with sand and cobbles)	Odourless	N/A
	2	A	Blue-gray	Falls apart into fluffy pellets, sand, gritty	Odourless	Silt and sand
	1	B	Dull Grey-Green	Thick like pudding; silky	Odourless	Few small macrophyte roots; homogenous throughout
	2	B	Dark brown	Thick like pudding; silky	Odourless	Held together by macrophytes
	1	C	Dull Grey	Unconsolidated; gritty	Odourless	Small layer of debris (e.g., grass roots) on top of silt and clay; heterogeneous
	2	C	Dark brown	Thick like pudding; gritty	Odourless	Sand and silt with organic debris
8	1	A	Brown	Gritty (with sand)	Odourless	N/A
	2	A	Brown-green	Thick like pudding; silky	H_2S odour	Organic debris, roots
	1	B	Black & Rusty Brown	Gel-like; very silky	H_2S odour & Odourless	Very little debris; heterogeneous; black layer (H_2S odour) on top of rusty brown layer (odourless)
	2	B	Brown-green	Thick like pudding; silky	H_2S odour	Organic material, heterogeneous
	1	C	Black	Thick like pudding; very silky	H_2S odour	Abundant macrophyte roots and pieces; homogenous throughout
	2	C	Dark brown	Thick like pudding; gritty	H_2S odour	Held together by macrophytes, 2 rocks
9	1	A	Brown	Gritty (with sand)	Odourless	N/A
	2	A	Brown-green, gray-green	Thick like pudding; gritty	Odourless	
	1	B	Black	Thick like pudding; silky	Odourless	Little debris and some macrophyte roots; homogenous throughout
	2	B	Gray-green, light brown	Loose; silky	Odourless	Much debris on tops and caught in grab
	1	C	Black	Thick like pudding; silky	Odourless	Abundant woody debris and *Nitella sp*. at the surface; homogenous throughout
	2	C	Black, gray-green	Gel-like; silky	Odourless	N/A
10	1	A	Grey	Cobbles (with gravels, sand and boulders)	Odourless	N/A
	2	A	N/A	N/A; gritty, gravelly	N/A	N/A
	1	B	Black & Dull Grey	Unconsolidated; thick like pudding; silky; gritty (with sand and mica/silica)	Odourless	Small woody debris and macrophyte roots; heterogeneous; black layer (thick like pudding) on top of dull grey layer (gritty with sand and mica/silica)
	2	B	Dark brown	Falls apart into fluffy pellets; gritty	Odourless	none
	1	C	Dull Grey	Unconsolidated; gritty	Odourless	Some woody debris and lots of mica/silica; homogenous throughout
	2	C	Dark brown	Falls apart into fluffy pellets, sandy	Odourless	none
11	1	A	Brown	Silky (little sand, gravels and cobbles)	H_2S odour	N/A
	2	A	N/A	Gritty, gravelly	N/A	N/A
	1	B	Black	Thick like pudding; silky	H_2S odour	Some macrophyte roots; homogenous throughout
	2	B	Dull gray, light brown	Thick like pudding; silky	Odourless	*macrophytes* on surface
	1	C	Light Brown	Gel-like; silky	Odourless	Some macrophyte roots; heterogeneous; grey streaks observed
	2	C	Gray-green	Thick like pudding; silky	Odourless	*macrophytes*

Table 5-1: Site 1 *In Situ* Water Quality Profile (North Transect)						
Adjusted Depth (m)	**Temperature (°C)**	**Specific Conductivity (uS/cm)**	**pH**	**ORP (mV)**	**Turbidity (FNU)**	**Dissolved Oxygen (mg/L)**
0.007	14.75	92.35	8.05	172.36	0.88	9.84
0.016	14.74	92.36	8.05	172.41	0.90	9.85
0.024	14.74	92.36	8.05	172.28	0.90	9.85
0.032	14.74	92.37	8.05	172.33	0.90	9.86
0.040	14.74	92.36	8.05	172.45	0.91	9.87
0.050	14.73	92.35	8.04	172.58	0.92	9.87
0.061	14.73	92.35	8.04	172.71	0.93	9.88
0.073	14.73	92.35	8.04	172.83	0.91	9.89
0.089	14.73	92.35	8.04	172.97	0.90	9.89
0.111	14.73	92.35	8.03	173.09	0.90	9.90
0.131	14.73	92.35	8.03	173.21	0.90	9.90
0.151	14.73	92.35	8.03	173.33	0.91	9.91
0.171	14.73	92.34	8.03	173.44	0.92	9.91
0.195	14.73	92.33	8.03	173.54	0.91	9.91
0.215	14.72	92.32	8.02	173.65	0.91	9.92
0.230	14.72	92.32	8.02	173.75	0.91	9.92
0.243	14.72	92.31	8.02	173.85	0.90	9.92
0.255	14.72	92.30	8.02	173.94	0.91	9.93
0.269	14.72	92.31	8.02	174.04	0.89	9.93
0.282	14.72	92.31	8.02	174.14	0.88	9.93
0.294	14.72	92.31	8.02	174.25	0.87	9.93
0.304	14.72	92.31	8.02	174.37	0.89	9.94
0.311	14.72	92.31	8.01	174.47	0.88	9.94

Table 5-2. Site 1 *In Situ* Water Quality Profile (South Transect)						
Adjusted Depth (m)	**Temperature (°C)**	**Specific Conductivity (uS/cm)**	**pH**	**ORP (mV)**	**Turbidity (FNU)**	**Dissolved Oxygen (mg/L)**
1.059	14.84	92.13	8.02	211.32	1.83	10.12
1.045	14.83	92.13	8.02	211.23	1.96	10.11
0.942	14.81	92.16	8.02	211.15	2.03	10.10
0.832	14.79	92.18	8.01	211.06	2.12	10.09
0.740	14.78	92.20	8.01	210.98	2.18	10.09
0.673	14.77	92.22	8.01	210.89	2.35	10.08
0.598	14.76	92.23	8.01	210.82	2.38	10.08
0.551	14.76	92.24	8.00	210.75	2.43	10.08
0.512	14.76	92.24	8.00	210.69	2.42	10.08
0.486	14.76	92.25	8.00	210.63	2.15	10.07
0.465	14.77	92.25	7.99	210.58	2.01	10.07
0.451	14.78	92.26	7.99	210.51	1.94	10.08
0.440	14.79	92.26	7.99	210.46	1.78	10.08
0.430	14.81	92.25	7.99	210.41	1.63	10.08
0.421	14.82	92.24	7.99	210.37	1.50	10.08
0.414	14.84	92.22	7.98	210.31	1.35	10.09
0.409	14.86	92.21	7.98	210.24	1.28	10.09
0.404	14.87	92.18	7.98	210.17	1.18	10.09
0.399	14.88	92.17	7.98	210.08	1.11	10.09
0.394	14.89	92.16	7.98	210.00	1.07	10.09
0.391	14.90	92.15	7.98	209.92	0.96	10.09
0.387	14.90	92.14	7.98	209.83	0.90	10.09

Table 5-3. Site 1 *In Situ* Water Quality Profile (Centre Transect)						
Adjusted Depth (m)	**Temperature (°C)**	**Specific Conductivity (uS/cm)**	**pH**	**ORP (mV)**	**Turbidity (FNU)**	**Dissolved Oxygen (mg/L)**
0.004	14.74	92.56	7.91	176.01	0.86	9.85
0.019	14.74	92.56	7.91	175.96	0.86	9.85
0.040	14.74	92.56	7.92	175.93	0.86	9.85
0.058	14.74	92.56	7.92	175.90	0.87	9.85
0.078	14.73	92.56	7.92	175.87	0.87	9.86
0.103	14.73	92.56	7.92	175.84	0.89	9.86
0.126	14.73	92.55	7.92	175.81	0.88	9.86
0.148	14.73	92.55	7.92	175.78	0.89	9.86
0.166	14.73	92.53	7.92	175.73	0.90	9.86
0.182	14.73	92.52	7.92	175.71	0.90	9.86
0.195	14.73	92.51	7.92	175.67	0.90	9.86
0.201	14.73	92.50	7.92	175.66	0.91	9.86
0.208	14.73	92.49	7.92	175.67	0.90	9.86
0.214	14.73	92.49	7.92	175.66	0.90	9.86
0.219	14.73	92.49	7.92	175.65	0.89	9.86
0.224	14.73	92.48	7.92	175.64	0.89	9.86
0.227	14.73	92.48	7.92	175.63	0.89	9.86
0.230	14.73	92.48	7.92	175.60	0.89	9.86
0.232	14.74	92.49	7.92	175.57	0.88	9.86
0.234	14.74	92.49	7.92	175.55	0.89	9.86
0.237	14.74	92.50	7.92	175.49	0.87	9.86
0.240	14.74	92.52	7.92	175.48	0.88	9.86
0.242	14.74	92.53	7.92	175.38	0.86	9.87
0.246	14.74	92.55	7.92	175.36	0.86	9.86
0.249	14.74	92.55	7.92	175.28	0.86	9.86
0.252	14.74	92.56	7.92	175.16	0.85	9.86

Table 5-4. Site 5 *In Situ* Water Quality Profile (North Transect)

Adjusted Depth (m)	Temperature (°C)	Specific Conductivity (uS/cm)	pH	ORP (mV)	Turbidity (FNU)	Dissolved Oxygen (mg/L)
0.151	13.00	98.46	7.93	182.99	1.65	9.88
0.167	12.99	98.46	7.93	183.04	1.65	9.88
0.181	12.99	98.46	7.93	183.09	1.64	9.88
0.194	13.00	98.48	7.93	183.14	1.66	9.88
0.212	13.00	98.49	7.93	183.19	1.68	9.88
0.229	13.00	98.51	7.93	183.24	1.68	9.88
0.979	13.00	98.52	7.93	183.27	1.69	9.88
1.044	13.00	98.53	7.93	183.31	1.71	9.88
1.269	13.00	98.53	7.93	183.36	1.72	9.88
1.346	13.00	98.53	7.93	183.43	1.71	9.88
1.439	13.00	98.53	7.93	183.48	1.72	9.88
1.519	13.00	98.53	7.93	183.57	1.71	9.88
1.604	13.00	98.53	7.92	183.63	1.72	9.88
1.662	13.00	98.51	7.92	183.67	1.73	9.88
1.708	13.00	98.50	7.92	183.70	1.71	9.88
1.761	13.00	98.48	7.92	183.71	1.76	9.88
1.818	13.00	98.44	7.92	183.72	2.29	9.88
1.880	13.00	98.40	7.92	183.71	4.33	9.88

Table 5-6. Site 7 *In Situ* Water Quality Profile (North Transect)

Adjusted Depth (m)	Temperature (°C)	Specific Conductivity (uS/cm)	pH	ORP (mV)	Turbidity (FNU)	Dissolved Oxygen (mg/L)
0.004	10.70	83.34	7.76	173.07	3.53	10.48
0.010	10.70	83.29	7.75	173.09	3.46	10.49
0.015	10.70	83.26	7.75	173.11	3.46	10.50
0.020	10.70	83.28	7.75	173.12	3.48	10.51
0.025	10.71	83.35	7.75	173.13	3.46	10.52
0.031	10.74	83.49	7.75	173.15	3.44	10.53

Table 5-7. Site 7 *In Situ* Water Quality Profile (South Transect)

Adjusted Depth (m)	Temperature (°C)	Specific Conductivity (uS/cm)	pH	ORP (mV)	Turbidity (FNU)	Dissolved Oxygen (mg/L)
0.000	9.69	69.56	7.86	160.47	3.87	10.61
0.004	9.68	69.47	7.86	160.52	3.83	10.62
0.005	9.68	69.40	7.85	160.58	3.83	10.62
0.009	9.67	69.32	7.85	160.64	3.86	10.62
0.011	9.67	69.27	7.85	160.68	3.80	10.63
0.015	9.66	69.25	7.85	160.72	3.79	10.63
0.016	9.66	69.23	7.84	160.75	3.73	10.63
0.020	9.66	69.23	7.84	160.79	3.74	10.63
0.022	9.66	69.22	7.84	160.81	3.75	10.63

Table 5-8. Site 8 *In Situ* Water Quality Profile (North Transect)						
Adjusted Depth (m)	Temperature (°C)	Specific Conductivity (uS/cm)	pH	ORP (mV)	Turbidity (FNU)	Dissolved Oxygen (mg/L)
0.010	11.93	119.39	7.91	181.50	4.47	9.98
0.015	11.93	119.39	7.91	181.53	4.32	9.99
0.023	11.93	119.38	7.91	181.56	3.94	10.00
0.029	11.93	119.38	7.91	181.66	2.16	10.00
0.037	11.93	119.36	7.91	181.73	2.17	10.02
0.047	11.92	119.35	7.90	181.80	2.19	10.04
0.054	11.92	119.35	7.90	181.85	2.20	10.05
0.062	11.92	119.35	7.90	181.88	2.22	10.07
0.071	11.92	119.34	7.90	181.94	2.26	10.09
0.082	11.91	119.33	7.90	181.96	2.31	10.10
0.092	11.91	119.32	7.90	181.99	2.34	10.11
0.106	11.91	119.31	7.90	182.04	2.34	10.12
0.126	11.91	119.31	7.90	182.15	2.38	10.13
0.998	11.90	119.31	7.90	182.18	2.42	10.14
1.290	11.90	119.31	7.90	182.27	2.44	10.15
1.510	11.90	119.31	7.90	182.30	2.53	10.16
1.628	11.90	119.32	7.90	182.38	2.55	10.17
1.693	11.90	119.33	7.90	182.41	2.59	10.18
1.812	11.90	119.34	7.89	182.45	2.61	10.18
1.874	11.90	119.34	7.89	182.51	3.71	10.19
1.919	11.90	119.33	7.89	182.52	4.67	10.19
1.928	11.90	119.32	7.90	182.55	6.49	10.20

Table 5-9. Site 8 *In Situ* Water Quality Profile (South Transect)						
Adjusted Depth (m)	Temperature (°C)	Specific Conductivity (uS/cm)	pH	ORP (mV)	Turbidity (FNU)	Dissolved Oxygen (mg/L)
0.168	11.99	118.78	7.91	182.09	2.63	10.31
0.198	11.99	118.78	7.91	181.93	2.63	10.31
1.291	11.99	118.78	7.91	181.80	2.63	10.31
1.462	11.99	118.79	7.91	181.79	2.63	10.31
1.495	11.99	118.80	7.91	181.85	2.64	10.31
1.606	11.99	118.81	7.91	181.93	2.61	10.31
1.747	11.99	118.83	7.91	182.01	2.59	10.31
1.748	11.99	118.84	7.91	182.09	2.61	10.31

Table 5-10. Mean Water Quality Values (Phase 1 & Phase 2)						
Site	Temperature (°C)	Specific Conductivity (uS/cm)	pH	ORP (mV)	Turbidity (FNU)	Dissolved Oxygen (mg/L)
Phase 2						
1	14.76 ± 0.05	92.36 ± 0.14	7.98 ± 0.05	185.71 ± 16.81	1.16 ± 0.49	9.94 ± 0.10
5	13.00 ± 0.00	98.49 ± 0.04	7.93 ± 0.00	183.40 ± 0.25	1.88 ± 0.63	9.88 ± 0.00
7	10.09 ± 0.53	74.93 ± 7.10	7.81 ± 0.05	165.64 ± 6.31	3.67 ± 0.17	10.58 ± 0.06
8	11.91 ± 0.01	119.34 ± 0.03	7.90 ± 0.01	182.05 ± 0.34	2.97 ± 1.14	10.10 ± 0.07
Phase 1						
1	12.55 ± 1.44	98 ± 0.38	7.93 ± 0.07	187 ± 2.1	42.9 ± 1.6	9.67 ± 0.40
2	14.46 ± 0.87	96 ± 0.59	7.94 ± 0.25	201 ± 5.94	1.9 ± 5.2	9.42 ± 0.16
3	13.33 ± 0.82	96 ± 1.62	7.92 ± 0.11	182 ± 3.10	0.6 ± 0.07	10.32 ± 0.23
4	13.39 ± 0.81	100 ± 0.43	7.9 ± 0.2	201 ± 6.5	7.4 ± 11.3	10.26 ± 0.25
5	12.92 ± 1.37	102 ± 0	7.79 ± 0.37	203 ± 44	2.2 ± 4.3	10.52 ± 0.65
7	10.07 ± 089	86 ± 2.5	7.57 ± 0.62	181 ± 37.3	3.9 ± 14.3	11.05 ± 0.34
8	11.7 ± 0.68	102 ± 0	7.78 ± 0.33	196 ± 1.99	8.9 ± 9.7	10.6 ± 0.09
9	7.88 ± 0.30	148 ± 0	7.88 ± 0.10	189 ± 3.31	3.7 ± 10.4	11.1 ± 0.2
10	7.38 ± 0.13	129 ± 0.81	7.83 ± 0.25	228 ± 26.26	1.2 ± 1.78	11.64 ± 0.08
11	7.65 ± 0.84	131 ± 1.39	7.88 ± 0.29	230 ± 1.49	25.6 ± 22.8	11.67 ± 0.30

APPENDIX 5

Macrophyte Ecology

MACROPHYTE DESCRIPTOR DEFINITIONS (USDA, 2010)

Morphology

Active Growth Period: seasonal period when the plant has their most active growth (i.e., spring; spring & fall; spring & summer; spring, summer & fall; summer; summer & fall; fall; fall, winter & spring; year-round).

Growth Rate: growth rate after successful establishment relative to other species with the same growth habit.

Growth Form: growth form that most enhances plant ability to stabilize soil (i.e., bunch, colonizing, multiple stems, rhizomatous, single crown, single stem, stoloniferous, thicket forming).

C:N Ratio: percentage (%) of organic carbon divided by the percentage (%) of total nitrogen in organic material (low: <23; medium: 23 – 59; high: >59).

Nitrogen Fixation: amount of nitrogen fixed by the plant in monoculture (None: 0 lb N/acre/year; 0<Low<85; Medium: 85-160; High: >160).

Foliage Texture: general texture of the plant's foliage relative to other species with the same growth habit (i.e., fine, medium, coarse).

Foliage Porosity Summer: how porous the foliage is during the summer months (i.e., porous, moderate, dense).

Foliage Porosity Winter: how porous the foliage is during the summer months (i.e., porous, moderate, dense).

Toxicity: toxicity of the plant to either humans or livestock (i.e., none, slight, moderate, severe).

Shape & Orientation: growth form or predominant shape of an individual plant.

Fall Conspicuous: leaves or fruits are conspicuous during autumn.

Known Allelopath: plant species has been shown to be allelopathic to at least one other species.

Growth Requirements

Adaptated to Coarse Textured Soils: coarse textured surface layers include sand and loamy sand.

Adaptated to Fine Textured Soils: fine textured surface layers include sandy clay, silty clay and clay.

Adaptated to Med Textured Soils: medium textured surface layers include silt, sandy clay loam, sandy loam, silty clay loam, silt loam, clay loam and loam.

Anaerobic Tolerance: relative tolerance to anaerobic environments (i.e., none, low, medium, high).

Cold Stratification Required: the seed germination percentage of this plant increases significantly with cold stratification.

Fertility Requirement: relative level of nutrition (N, P, K) required for plant normal growth and development (i.e., low, medium, high).

Shade Tolerance: relative tolerance to shade conditions (i.e., intolerant, intermediate, tolerant).

Temperature, Minimum: lowest air temperature (°F) recorded in the plant's historical range.

Precipitation, Minimum: minimum tolerable rainfall (in inches), expressed as the average annual minimum precipitation that occurs 20% of the time (i.e., the probability of it being this dry in any given year is 20%) at the driest climate station within the known geographical range of the plant.

Precipitation, Maximum: maximum tolerable rainfall (in inches), expressed as the annual average precipitation of the wettest climate station within the known geographical range of the plant.

Reproduction

Bloom Period: seasonal period when the plant blooms the most (i.e., spring, early spring, mid spring, late spring, summer, early summer, mid-summer, late summer, fall, winter, late winter, indeterminate).

Fruit/Seed Abundance: amount of seed produced by the plant compared to other species with the same growth habit (i.e., none, low, medium, high).

Fruit/Seed Period: season in which the earliest fruit or seed of the fruit/seed period is visually obvious (i.e., spring, summer, fall, winter, year-round).

Seed Spread Rate: rate the plant can spread compared to other species with the same growth habit (i.e., none, slow, moderate, rapid).

Seedling Vigor: expected seedling survival percentage of the plant compared to other species with the same growth habit (i.e., low, medium, high).

Vegetative Spread Rate: rate can this plant can spread compared to other species with the same growth habit (i.e., none, slow, moderate, rapid).

Potamogeton amplifolius, Tuck. — Largeleaf Pondweed

General Description

Classification

Kingdom *Plantae* – Plants
Subkingdom *Tracheobionta* – Vascular plants
Superdivision *Spermatophyta* – Seed plants
Division *Magnoliophyta* – Flowering plants
Class *Liliopsida* – Monocotyledons
Subclass *Alismatidae* Order *Najadales*
Family *Potamogetonaceae* – Pondweed family
Genus *Potamogeton* L. – pondweed

Native Status

United States, Canada

Duration

Perennial

Threatened & Endangered Information

Maryland	Endangered, Extirpated
Tennessee	Threatened

Habitat

Lakes and ponds. Will grow in clear water as deep as 6 m.

Growth Habit

Forb/herb (i.e., vascular plant without significant woody tissue above or at the ground)

Morphology/ Physiology

Active Growth Period
Summer & Fall

Growth Rate
Rapid

Growth Form
Rhizomatous

Shape and Orientation
Prostrate

C:N Ratio
Medium

Nitrogen Fixation
None

Flower Color
Green

Flower Conspicuous
No

Foliage Texture
Fine

Foliage Color
Green

Foliage Porosity Summer
Porous

Foliage Porosity Winter
Porous

Fruit/Seed Color
Orange

Fruit/Seed Conspicuous
No

Toxicity
None

Fall Conspicuous
No

Known Allelopath
No

Growth Requirements

Adapted to Coarse Textured Soils
No

Adapted to Fine Textured Soils
No

Adapted to Medium Textured Soils
No

Anaerobic Tolerance
High

Cold Stratification Required
No

pH, Min-Max
5.5->7.0

Fertility Requirement
Medium

Shade Tolerance
Intolerant

Temperature, Minimum (°F)
-33

Precipitation, Min-Max
12-55

Reproduction

Bloom Period
Mid Summer

Fruit/Seed Abundance
Medium

Fruit/Seed Period
Summer-Fall

Fruit/Seed Persistence
No

Propagated by Bare Root
Yes

Propagated by Sprigs
Yes

Propagated by Seed
Yes

Propagated by Tubers
No

Seed Spread Rate
Slow

Seedling Vigor
Medium

Vegetative Spread Rate
Rapid

Potamogeton alpinus, Balbis — Alpine Pondweed

General Description

Classification

Kingdom *Plantae* – Plants
Subkingdom *Tracheobionta* – Vascular plants
Superdivision *Spermatophyta* – Seed plants
Division *Magnoliophyta* – Flowering plants
Class *Liliopsida* – Monocotyledons
Subclass *Alismatidae* Order *Najadales*
Family *Potamogetonaceae* – Pondweed family
Genus *Potamogeton* L. – pondweed

Native Status

United States, Alaska, Canada, Greenland

Duration

Perennial

Threatened & Endangered Information

New Hampshire & New York	Endangered
New Jersey & Pennsylvania	Threatened

Habitat

Ponds, lakes, and slow-moving streams; 400-2500 m.

Growth Habit

Forb/herb (i.e., vascular plant without significant woody tissue above or at the ground)

Morphology/ Physiology

Active Growth Period
Summer & Fall

Growth Rate
Not available

Growth Form
Rhizomatous

Shape and Orientation
Prostrate

C:N Ratio
Medium

Nitrogen Fixation
None

Flower Color
Green

Flower Conspicuous
No

Foliage Texture
Fine

Foliage Color
Green

Foliage Porosity Summer
Porous

Foliage Porosity Winter
Porous

Fruit/Seed Color
Orange

Fruit/Seed Conspicuous
No

Toxicity
None

Fall Conspicuous
No

Known Allelopath
No

Growth Requirements

Adapted to Coarse Textured Soils
No

Adapted to Fine Textured Soils
Yes

Adapted to Medium Textured Soils
Yes

Anaerobic Tolerance
High

Cold Stratification Required
No

pH, Min-Max
6.5-7.4

Fertility Requirement
Medium

Shade Tolerance
Intolerant

Temperature, Minimum (°F)
Not available

Precipitation, Min-Max
Not available

Reproduction

Bloom Period
Not available

Fruit/Seed Abundance
Not available

Fruit/Seed Period
Summer-Fall

Fruit/Seed Persistence
No

Propagated by Creeping Rhizomes
Yes

Propagated by Sprigs
No

Propagated by Seed
Yes

Propagated by Tubers
Yes

Seed Spread Rate
Not available

Seedling Vigor
Medium

Vegetative Spread Rate
Not available

Potamogeton foliosus, Raf. — Leafy Pondweed

General Description

Classification

Kingdom *Plantae* – Plants
Subkingdom *Tracheobionta* – Vascular plants
Superdivision *Spermatophyta* – Seed plants
Division *Magnoliophyta* – Flowering plants
Class *Liliopsida* – Monocotyledons
Subclass *Alismatidae* Order *Najadales*
Family *Potamogetonaceae* – Pondweed family
Genus *Potamogeton* L. – pondweed

Native Status

United States, Alaska, Canada, Hawaii, Puerto Rico

Duration

Perennial

Threatened & Endangered Information

Maryland	Endangered
New Hampshire	Endangered

Habitat

Shallow to >4' deep water; in soft sediment

Growth Habit

Forb/herb (i.e., vascular plant without significant woody tissue above or at the ground)

Morphology/ Physiology

Active Growth Period
Spring & Summer

Growth Rate
Moderate

Growth Form
Single Crown

Shape and Orientation
Prostrate

C:N Ratio
Medium

Nitrogen Fixation
None

Flower Color
Green

Flower Conspicuous
No

Foliage Texture
Fine

Foliage Color
Green

Foliage Porosity Summer
Porous

Foliage Porosity Winter
Porous

Fruit/Seed Color
Brown

Fruit/Seed Conspicuous
No

Toxicity
None

Fall conspicuous
No

Known Allelopath
No

Growth Requirements

Adapted to Coarse Textured Soils
No

Adapted to Fine Textured Soils
No

Adapted to Medium Textured Soils
No

Anaerobic Tolerance
High

Cold Stratification Required
No

pH, Min-Max
5.5-7.0

Fertility Requirement
Medium

Shade Tolerance
Intolerant

Temperature, Minimum (°F)
-38

Precipitation, Min-Max
12-55

Reproduction

Bloom Period
Late Spring

Fruit/Seed Abundance
Medium

Fruit/Seed Period
Summer

Fruit/Seed Persistence
No

Propagated by Bare Roots
Yes

Propagated by Sprigs
Yes

Propagated by Seed
Yes

Propagated by Tubers
No

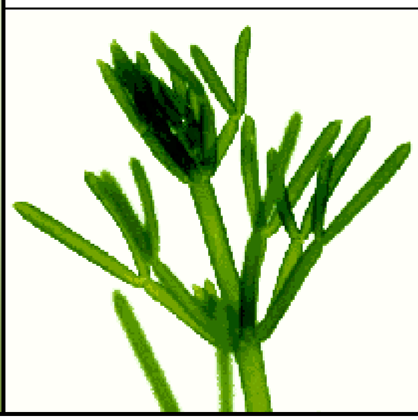
Seed Spread Rate
Moderate

Seedling Vigor
Medium

Vegetative Spread Rate
Slow

Nitella sp. Brittlewort

General Description



Classification

Kingdom *Plantae* – Plants
Division *Chlorophyta* – Green algae
Class *Chlorophyceae* – Green algae
Order *Charales* – Green algae
Family *Characeae* – Green algae
Genus *Potamogeton* L. – pondweed

Native Status
Worldwide

Duration
Not available

Threatened & Endangered Information
Not available

Habitat
Shallow to deep waters of soft water or acid lakes and bogs. They often grow in deeper water than flowering.

Growth Habit
Not available

Morphology/ Physiology

Active Growth Period
Not available

Fall Conspicuous
No

Growth Form
Not available

Coppice Potential
Not available

C:N Ratio
Not available

Nitrogen Fixation
Not available

Growth Rate
Not available

Flower Color
No flower

Flower Conspicuous
No

Foliage Texture
No true leaves

Foliage Color
Green

Foliage Porosity
No true leaves

Foliage Porosity Winter
No true leaves

Leaf Retention
No

Lifespan
Not available

Fruit/Seed Conspicuous
No fruit

Fruit/Seed Color
No fruit

Toxicity
None

Shape and Orientation
Prostrate

Known Allelopath
No

Growth Requirements

Adapted to Coarse Textured Soils
Not available

Adapted to Fine Textured Soils
Not available

Adapted to Medium Textured Soils
Not available

Anaerobic Tolerance
Not available

$CaCO_3$ Tolerance
Not available

Cold Stratification Required
Not available

Drought Tolerance
None

Fertility Requirement
Not available

Root Depth, Minimum (cm)
Not available

Shade Tolerance
Tolerant

pH, Min-Max
> 6

Temperature, Minimum (°F)
Not available

Precipitation, Min-Max
Not available

Reproduction

Bloom Period
Not available

Fruit/Seed Abundance
No fruit

Fruit/Seed Period
No fruit

Fruit/Seed Persistence
No fruit

Propagated by Creeping Rhizomes
Not available

Propagated by Sprigs
Not available

Propagated by Seed
Not available

Propagated by Tubers
Not available

Seed Spread Rate
Not available

Seedling Vigor
Not available

Small Grain
No

Vegetative Spread Rate
Not available

Eleocharis acicularis (L.) Roem. & Schult. — Needle Spikerush

General Description

Classification

Kingdom *Plantae* – Plants
Subkingdom *Tracheobionta* – Vascular plants
Superdivision *Spermatophyta* – Seed plants
Division *Magnoliophyta* – Flowering plants
Class *Liliopsida* – Monocotyledons
Subclass *Commelinidae* Order *Cyperales*
Family *Cyperaceae* – Sedge family
Genus *Eleocharis* R. Br. – spikerush

Native Status
United States, Alaska, Canada, Greenland, St. Pierre and Miquelon

Duration
Annual, Perennial

Threatened & Endangered Information
Not endangered or threatened in North America

Habitat
Adapted to fluctuating water levels. Marshes, shallow water of lakes, ponds, and stream beds.

Growth Habit
Graminoid

Morphology/ Physiology

Active Growth Period
Spring, Summer, Fall
Growth Rate
Moderate
Growth Form
Rhizomatous
Shape and Orientation
Erect
C:N Ratio
Medium
Nitrogen Fixation
None

Flower Color
White
Flower Conspicuous
No
Foliage Texture
Fine
Foliage Color
Green
Foliage Porosity Summer
Porous
Foliage Porosity Winter
Porous

Fruit/Seed Color
Brown
Fruit/Seed Conspicuous
No
Toxicity
None
Fall Conspicuous
No
Known Allelopath
No

Growth Requirements

Adapted to Coarse Textured Soils
No
Adapted to Fine Textured Soils
Yes
Adapted to Medium Textured Soils
Yes
Anaerobic Tolerance
Medium

Cold Stratification Required
Yes
pH, Min-Max
4.5-7.0
Fertility Requirement
Medium
Shade Tolerance
Intolerant

Temperature, Minimum (°F)
-23
Precipitation, Min-Max
14-50

Reproduction

Bloom Period
Mid Summer
Fruit/Seed Abundance
Low
Fruit/Seed Period
Summer-Fall
Fruit/Seed Persistence
No

Propagated by Bare Root
Yes
Propagated by Sprigs
Yes
Propagated by Seed
Yes
Propagated by Tubers
No

Seed Spread Rate
Slow
Seedling Vigor
Low
Vegetative Spread Rate
Rapid

Myriophyllum spicatum, L. — Eurasian Watermilfoil

General Description

Classification

Kingdom *Plantae* – Plants
Subkingdom *Tracheobionta* – Vascular plants
Superdivision *Spermatophyta* – Seed plants
Division *Magnoliophyta* – Flowering plants
Class *Magnoliopsida* – Dicotyledons
Subclass *Rosidae* Order *Haloragales*
Family *Haloragaceae* – Water Milfoil family
Genus *Myriophyllum* L. – watermilfoil

Native Status

United States, Alaska, Canada

Duration

Perennial

Threatened & Endangered Information

Not endangered or threatened in North America

Habitat

Lakes, ponds, sloughs, irrigation ditches and other water bodies

Growth Habit

Forb/herb (i.e., vascular plant without significant woody tissue above or at the ground)

Morphology/ Physiology

Active Growth Period
Spring & Summer

Growth Rate
Rapid

Growth Form
Rhizomatous

Shape and Orientation
Prostrate

C:N Ratio
Medium

Nitrogen Fixation
Yes

Flower Color
Pink

Flower Conspicuous
No

Foliage Texture
Fine

Foliage Color
Green

Foliage Porosity Summer
Porous

Foliage Porosity Winter
Porous

Fruit/Seed Color
Orange-red

Fruit/Seed Conspicuous
No

Toxicity
None

Fall Conspicuous
No

Known Allelopath
No

Growth Requirements

Adapted to Coarse Textured Soils
Yes

Adapted to Fine Textured Soils
Yes

Adapted to Medium Textured Soils
Yes

Anaerobic Tolerance
High

Cold Stratification Required
No

pH, Min-Max
5.4-11.0

Fertility Requirement
Medium

Shade Tolerance
Intolerant

Temperature, Minimum (°F)
Not available

Precipitation, Min-Max
Not available

Reproduction

Bloom Period
Not available

Fruit/Seed Abundance
Not available

Fruit/Seed Period
Not available

Fruit/Seed Persistence
No

Propagated by Creeping Rhizomes
Yes

Propagated by Sprigs
No

Propagated by Seed
Yes

Propagated by Tubers
No

Seed Spread Rate
Rapid

Seedling Vigor
Not available

Vegetative Spread Rate
Rapid

Ranunculus aquatilis, L. — White Water Crowfoot

General Description

Classification

Kingdom *Plantae* – Plants
Subkingdom *Tracheobionta* – Vascular plants
Superdivision *Spermatophyta* – Seed plants
Division *Magnoliophyta* – Flowering plants
Class *Magnoliopsida* – Dicotyledons
Subclass *Magnoliidae* Order *Ranunculales*
Family *Ranunculaceae* – Buttercup family
Genus *Ranunculus* L. – buttercup

Native Status

United States, Alaska, Canada

Duration

Perennial

Threatened & Endangered Information

NA

Habitat

Ponds, slugging streams, sloughs, water-filled ditches

Growth Habit

Forb/herb (i.e., vascular plant without significant woody tissue above or at the ground)

Morphology/ Physiology

Active Growth Period
Not available

Growth Rate
Not available

Growth Form
Not available

Shape and Orientation
Not available

C:N Ratio
Medium

Nitrogen Fixation
Not available

Flower Color
White

Flower Conspicuous
Not available

Foliage Texture
Not available

Foliage Color
Green

Foliage Porosity Summer
Porous

Foliage Porosity Winter
Not available

Fruit/Seed Color
Not available

Fruit/Seed Conspicuous
Not available

Toxicity
None

Fall Conspicuous
Not available

Known Allelopath
Not available

Growth Requirements

Adapted to Coarse Textured Soils
No

Adapted to Fine Textured Soils
Yes

Adapted to Medium Textured Soils
Yes

Anaerobic Tolerance
Not available

Cold Stratification Required
Not available

pH, Min-Max
5.5-8.0

Fertility Requirement
Medium

Shade Tolerance
Intolerant

Temperature, Minimum (°F)
Not available

Precipitation, Min-Max
Not available

Reproduction

Bloom Period
Not available

Fruit/Seed Abundance
Not available

Fruit/Seed Period
Not available

Fruit/Seed Persistence
Not available

Propagated by Creeping Rhizomes
Yes

Propagated by Sprigs
Not available

Propagated by Seed
Yes

Propagated by Tubers
Not available

Seed Spread Rate
Not available

Seedling Vigor
Not available

Vegetative Spread Rate
Rapid

Equisetum palustre, L. — Marsh Horsetail

General Description

Classification

Kingdom *Plantae* – Plants
Subkingdom *Tracheobionta* – Vascular plants
Division *Equisetophyta* – Horsetails
Class *Equisetopsida*
Order *Equisetales*
Family *Equisetaceae* – Horsetail family
Genus *Equisetum* L. – horsetail

Native Status

United States, Alaska, Canada

Duration

Perennial

Threatened & Endangered Information

Connecticut	Special Concern
New Hampshire, New York, Vermont	Threatened

Habitat

Shallow water of marshes and swamps, stream banks and forests

Growth Habit

Forb/herb (i.e., vascular plant without significant woody tissue above or at the ground)

Morphology/Physiology

Active Growth Period Spring & Summer	**Flower Color** Green	**Fruit/Seed Color** Brown
Growth Rate Rapid	**Flower Conspicuous** No	**Fruit/Seed Conspicuous** No
Growth Form Rhizomatous	**Foliage Texture** Fine	**Toxicity** None
Shape and Orientation Erect	**Foliage Color** Green	**Fall Conspicuous** No
C:N Ratio High	**Foliage Porosity Summer** Porous	**Known Allelopath** No
Nitrogen Fixation None	**Foliage Porosity Winter** Porous	

Growth Requirements

Adapted to Coarse Textured Soils Yes	**Cold Stratification Required** No	**Temperature, Minimum (°F)** -33
Adapted to Fine Textured Soils Yes	**pH, Min-Max** 4.5-6.0	**Precipitation, Min-Max** 30-55
Adapted to Medium Textured Soils Yes	**Fertility Requirement** Medium	
Anaerobic Tolerance High	**Shade Tolerance** Intolerant	

Reproduction

Bloom Period Late Spring	**Propagated by Bar Roots** No	**Seed Spread Rate** None
Fruit/Seed Abundance None	**Propagated by Sprigs** Yes	**Seedling Vigor** Not available
Fruit/Seed Period Summer	**Propagated by Seed** No	**Vegetative Spread Rate** Rapid
Fruit/Seed Persistence No	**Propagated by Tubers** No	

APPENDIX 6

OHS & Site Specific Safety Plan

Occupational Health & Safety Plan

Site Specific Safety Plan

Site Specific Safety Management Plan

Field Operations
(2014/2015 Field Season)

REVELSTOKE MACROPHYTE ASSESSMENTS

BC hydro

G3 Consulting Ltd.
Innovation & Excellence in
Environmental Science

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1.0 OVERVIEW OF PROJECT INFORMATION

As part of the CLBMON-55 Revelstoke Reservoir Macrophyte Study G3 will be conducting a field component during mid September. G3 will notify BC Hydro the week before the field study takes place so that they may notify other interested personnel in the Revelstoke area. The field study will take place over an approximate five (5) day period and include the following tasks:

Using an aluminum 7m jet boat G3 will collect representative macrophyte species from up to 12 sites along the entire length of reservoir. Water and sediment sampling will also occur at each site. Prior to each days field sampling, G3 will notify BC Hydro of area it will be working in; and, traverse the 12 study sites using the study boat mapping each using a GPS Sonar.

2.0 SAFETY RESPONSIBILITIES

In accordance with G3 Field Protocol, a Safety Officer will be assigned for the duration of the field program. The Safety Officer will make final decisions on issues regarding individuals or group safety as related to work tasks. In addition the Safety Officer will be responsible for the spill management and ensuring any and all Best Management Practices (BMPS) are followed when conducting field activities. Activities will be abandoned if deemed, by the Safety Officer, as too great a risk. The Safety Officer will possess a fist aid and, transportation (if required) certificate valid for the number of personnel under their supervision.

The field portion of this program will require the use of boats and four-wheel drive vehicles. Work will involve sampling and observations on or about water, and may include: water quality measurements; water column sampling; macrophyte sampling; and/or, sediment sampling. Work may be conducted on or around flowing water or reservoirs and has the potential for wildlife encounters. Appropriate personal gear (i.e. footwear, waders, life vest, rainwear and appropriate clothing, etc.) is the responsibility of each individual crew member. Personnel will not be permitted to participate in field activities if the Safety Officer deems personal equipment to be inadequate.

2.1 Roles & Responsibilities

It is the Safety Officers responsibility to ensure each that crew member has reviewed this SMP prior to conducting fieldwork, and to ensure the team is equipped with the following supplies:

- WCB Level I First Aid Kit and associated supplies. (Each G3 crew member will have completed at least the WCB level one first aid course and selected crew members would have the transportation endorsement, if required);
- Hand Held Radio (appropriate map/code)/Cell Phone & Charger;
- Survival Gear;
- Rescue gear (as required);
- Bear Knowledge, Bear Spray, and Bear Deterrents (if deemed necessary);
- Firearms training, and Firearm (only if required for a given project);
- Signaling Devices; and,
- **THIS EMERGENCY ACTION PLAN**

Any concerns regarding safety should be addressed directly to the Safety Officer.

Role	Name	Phone #	Email
Person In Charge of Project	Greg Thomas	604-598-8501	gthomas@g3consulting.com
Person In Charge of Project on Site	Alex Caldicott	604-598-8501	acaldicott@g3consulting.com
Person Responsible for Safety on the Project	Alex Caldicott	604-598-8501	acaldicott@g3consulting.com

See Appendix 1 for copies of safety forms and safety records

2.1.1 Responsibility of Supervisors

All supervisors shall be responsible for the safe execution of all work in their area of responsibility, including:

- Assigning qualified workers to all jobs;
- Ensuring the safety of the workers and contractors under their supervision and the general public in connection with the work;

- Assigning tools and equipment adequate for the work, supervising the manner in which they are used, and removing defective tools and equipment from the workplace;
- Investigating verbal or written reports of alleged hazardous conditions and correcting such conditions;
- Promptly investigating and reporting all incidents; and,
- Enforcing this Safety Management Plan.

2.1.2 Responsibility of workers

A worker shall not carry out or cause to be carried out any work process, or operate or cause to be operated any tool, appliance, or equipment, if that person has reasonable cause to believe that to do so would create an undue hazard to the health and safety of any person (refer to WorkSafeBC OHS Regulation, Part 3.12).

Documented tailboards will be held for all hazardous work involving one or more workers:

- before work commences; and,
- and/or whenever there is a significant change in the work plan.

When workers are working alone in a hazardous situation or traveling in a remote area where they might not be able to secure assistance, a worker check procedure shall be implemented, as described in OSH standard 801.

2.2 Training

Field crew members will have a valid occupational first aid certificate. Any field crew member who performs a work task while on a boat, (e.g. electro-fishing) and, or, have any duties assisting the operator in the operation of any small vessel, will possess MED A3 (Marine Emergency Duties) training.

A portfolio of field crew training records, licenses and certificates, as required for personnel to perform the work will be available for review on site.

Worker Name	Training	Expiry
Alex Caldicott	Occupational First Aid Level I	August 2017
	MED A3	N/A
Adrian MacKay	Occupational First Aid Level I	August 2017
	MED A3	N/A
Heather Stewart	Occupational First Aid Level I	May 2017
	MED A3	N/A
Colm O’Connell	Occupational First Aid Level I	August 2017
Chris Adamson	Occupational First Aid Level I	August 2017

3.0 HAZARD IDENTIFICATION & RISK ASSESSMENT

There are several risks associated with the nature of certain field portions of any program. For this reason it is imperative that field members use their best judgment and remain vigilant in their application of safety protocols. If a question or uncertainty related to field safety arises, it is the responsibility of each crew member to consult the Safety Officer or this SAFETY PLAN document.

Certain risks associated with field work can be limited through application of common sense and judgment. Remember where you are and think about the risk involved in the work task and the potential outcome in the event of an emergency. Emergency resources may be limited, requiring absolute caution during all aspects of field work.

A WSBC First Aid Assessment has been completed for this work and is provided in Appendix 1.

Potential hazards identified by BC Hydro are listed below:

Hazard Type	Hazard Description	Best Management Practices
Travel to work-site	Road conditions, traffic, ferries and wildlife are all concerns for workers travelling to/ from the Site and between sites.	Drive with caution. Consult http://www.drivebc.ca/ for up to date road condition information.
Working From Boats	Boaters are cautioned that, bars, rocks or debris, including stumps, may lie just below the surface. Boaters should also be aware of strong winds that occur suddenly, causing high waves and strong currents.	Boaters should always be alert for floating debris, submerged debris and shoals at different reservoir levels.
Slips/Trips/Falls	Site work areas may be located on natural ground settings. As such, ground surfaces may be uneven, contain wood debris, pokes, cobbles, and boulders. Some works areas may be in close proximity to steep slopes with lose ground.	Workers should always be aware of ground surfaces in their proximity and ensure proper footholds and grip when working. Proximity to other potential hazards such as steep slopes should be made note of before entering an area.
Forest Fire	Fire hazards in the region vary but exist during spring & summer months – local authorities may limit work activities during extreme conditions.	Precautions must be taken with any work activities or equipment that may create sparks as well as workers smoking on site. Workers must ensure they follow all requirements of the Wildfire Act and Regulations.
Communications Issues	Cellular communications are unavailable. Satellite communication may be limited. Radio communication may be effective through resource road management	Keep note of where satellite communication is available near the area of work. It is essential to keep in close communication with the office at the beginning and end of each day to inform others where work is being completed and that everyone is safe.
Emergency/ Rescue	Emergency Helicopter Evacuation for an injured worker is recommended if travel to nearest medical facility will be greater than 1 hour.	Nearest medical facility Address: Queen Victoria Hospital 1200 Newlands Road Revelstoke, BC V0E 2S0 Phone: 250-837-2131 Emergency Services operates 24 hours/day; 7 days/week
Wildlife and insects	Wildlife and insect risks include attacks from large animals such as bears and cougars, and bites and stings from snakes and insects, etc.	Appropriate precautions must be used. Bear spray, and bear deterrents must be easily accessible at all times
Flammable/Explosive Materials or Emissions	Fire, explosion caused by inappropriate storage/use of fuel and/or other flammable liquids.	Inspect equipment and fuel daily for proper storage. Ensure field crew is aware of field vessel fire extinguisher location
Weather	Weather is subject to quick changes that can affect workers in different way : Weather changes may create hazards by the conditions of the wind, thunderstorm, rain, snow etc. High and low temperature affect workers and need to be considered	Local weather shall be considered prior commencing a new task. Appropriate gear is required to work in poor conditions

Hazard Type	Hazard Description	Mitigation
Heat & Cold Stress	Hypothermia, frostbite may develop due to exposure to cold temperatures, the effects of wind chill, dehydration, exhaustion, and/or wearing inadequate clothing, .	It is the responsibility of the Safety Officer to ensure that all workers have the appropriate gear at the beginning of each work day
Sun Exposure	Dehydration, Heat stroke caused by warm temperature and poor hydration.	Ensure workers are properly hydrated and adequately protected from the sun
Health Risk	Diseases and infections caused by contact with contaminated water or soils containing parasites, viruses and bacteria	Ensure drinking water is brought in to the site and any cuts are properly cleaned and dressed before proceeding with work
Public Interaction	The public and public activities like hunting, outdoor sports, etc. can be an hazard for workers	contractor may consider the presence of public near work zone and take appropriate measures to maintain a good climate with public next to the work zone and make sure that public don't interfere in works

Additional potential hazards may include:

Hazard Type	Hazard Description	Mitigation
Generators & Motors	Fueling motors and generators may cause fires or spills if done incorrectly	**Never refuel a running motor.** Be sure that the appropriate fuel type is used when refueling. Alert other crew members when starting a generator, particularly when using power tools or related electrical appliances.
Working Over/ Near Water	Working adjacent to rivers and rushing water can limit the hearing of wildlife and increase the chance or startling animals if approached from downwind. Drowning and cold water immersion hypothermia, which may be caused by falling into water while sampling, attempting dangerous stream crossings, when working from boats, when water is a greater depth than anticipated	Sample collections from shore are to be conducted by experienced field members equipped with appropriate safety gear. All crew members must have a personal flotation device if sampling near swift water, wading belt (if using chest waders), and appropriate footwear. There must be throw lines stationed nearby for all in water activities. Swims (if required) are to be conducted by experienced field members equipped with appropriate dry suits and floatation devices. Crew members are not to conduct swims alone unless accompanied by a drift raft equipped with appropriate rescue equipment and experienced personnel.

4.0 SAFE WORK PRACTICES & PROCEDURES

4.1 Tailboard Meetings

Tailboard meeting forms are available in Appendix 1 and are required to be filled out during each tailboard meeting. Tailboard meetings would be held each morning before commencement of field work. Tailboard meeting and orientation records must be maintained and be made readily available.

Tailboard meetings are an important aspect of field work. They are used to review safety procedures, project objectives and timelines, focus and discuss daily activities and benchmarks and a means by which to discuss and review project progress and any issues, complications or findings.

Each day's work plan would be discussed and crew obligations, hazards specific to the scope and location of the work being performed, QA/QC criteria, and specific expectations outlined. The safety officer would provide input as to any specific safety issues or concerns and overview any procedures needed for the day (e.g., boat protocol, aircraft procedures, etc.). Each field personnel will be provided a waterproof field book in which daily activities will be noted and specific instructions listed.

Additional evening tailboard meetings would be held to review and compare daily objectives with those identified in the morning and to identify any follow-up or action items for the next day (e.g. safety concerns, purchase of supplies, re-testing, shipment of samples, etc.). Tailboard discussions would be recorded by the field coordinator for reference.

Tailboard discussions shall include the following topic areas:

- The scope and task sequence of the planned work, including any applicable procedures;
- A review of any relevant preliminary or pre-job documentation;
- The location and boundaries of the work and the placement of signage/demarcation of safety zones to establish safety zones as required;
- Environmental conditions which could impact the work;
- Communication requirements and systems;
- Rules and regulations applicable to the work being performed;
- All the known hazards and the required barriers;
- Required personal protective equipment;
- Safety management plans and environmental management plans, including requirements for emergency response, rescue plans and first aid;
- Other work that could affect the work are; and,
- Worker experience and knowledge of the job at hand.

4.2 Check-In Procedures

During the field work all crew members will remain together and in close contact with each other. Everyone will leave the launch point, and return to it, together at the end of each day. To ensure management is aware that each day was successful and that each personnel is accounted for, the crew leader will report to the office manager at the end of each day by 7pm, or once all crew members have returned to the hotel. Status reports and data uploads will also be given to the office manager with crew check-ins.

In the event that a check-in is not completed, all attempts will be made to contact the field crew via cell phones and hotel staff. If no contact can be established by 10pm, G3 will contact emergency authorities and report them missing with their last know location and the location of all the study sites.

4.3 Inspections

4.3.1 General Equipment Inspections

Prior to the start of each field day, equipment and tools will be inspected by field crew and the Safety Officer to ensure tools and equipment adequate for the work and that each person is trained to use the equipment properly and in a safe manner. It is the responsibility of the Safety Officer to ensure that all field crew have appropriate personal gear to prevent personal injury during the field day.

Inspection forms are available in Appendix 1.

4.3.2 Vessel Inspections

Prior to each trip, an inspection will be completed to check load, bilges, fuel, oil, emergency equipment and boat general condition.

Automatically inflatable life jackets must be inspected as per the original equipment manufacturer's requirements.

Inspection forms are available in Appendix 1.

4.4 BCH Applicable Life Saving Rules

- Maintain you Limits of Approach;
- Protect yourself from falling when working at height;
- Maintain a safe atmosphere in a confined space and ensure you can be rescued;
- Don't work while under the influence of alcohol or drugs; and,
- Adjust your driving to the weather and road conditions.

4.5 Operations of Vehicles

Workers requiring transportation by vehicle must follow all applicable requirements of the WorkSafe BC Regulation (Part 17 [Worker Transportation]), the Motor Vehicle Act, and BC Hydro's OSH Standard 401 'Motor Vehicle Safety'.

All aspects of safety of the vehicle including condition, maintenance, operation, and use are the responsibility of the Safety Officer and field crew operating the vehicle.

4.6 Operation of Boats

Any field crew member who performs a work task while on a boat, (e.g. water sampling, electro-fishing) and, or, have any duties assisting the operator in the operation of any small vessel within BC Hydro, must possess MED A3 (Marine Emergency Duties) training.

4.6.1 General Boating Safety Guidelines

The following general boating safety guidelines must be followed:

- Carry proper equipment and know how to use it;
- Maintain the boat and equipment in good condition; keep bilges clean;
- Know and obey the Rules of the Sea/Water;
- Operate with care, courtesy and common sense;
- Always keep the boat under complete control;
- Watch posted speeds; slowdown in anchorages;
- Never overload the boat;
- Ensure that life-saving equipment is accessible;
- Check local weather reports before departure;
- Guard against leakage of engine fuel and cooking fuel;
- Have fire extinguishers ready;
- All boats carrying passengers will have two-way radio communication capable of contacting persons that can effect emergency operations if required;
- When transporting passengers, the operator will notify the contact person before departure and on arrival;

- The boat must be appropriate to the type of operation and water conditions to which it will be exposed;
- Transport Canada approved PFDs (Personal Floatation Device) or life jackets must be worn at all times while on a BC Hydro boat. When "Personal Floatation Devices" are chosen to be worn, one Transport Canada approved "Lifejacket" must still be onboard the vessel and available to every person onboard any vessel;
- Any boat that uses gasoline or other flammable products with an enclosed pilot house or bilge must have a vapour detector installed;
- Each boat operated by BC Hydro must be equipped with a first aid kit suitable for the number of persons on board;
- The Canada Shipping Act specifies minimum requirements of portable safety equipment, according to the length of the boat;
- Boat and fire drills shall be conducted and recorded on an annual basis; and,
- BC Hydro boats shall follow lighting requires as per regulation.

4.6.2 Required Boating Safety Equipment

The following safety equipment must be carried onboard the field vessel:

- One approved life jacket available for each person on board
- One of the following throwing devices:
- Buoyant heaving line at least 15m long, with rescue quoit, or
- Approved life buoy with a diameter of 610mm or 762mm that is attached to a buoyant line of at least 15m
- Two oars or rowlocks, two paddles or one anchor with at least 15m of cable, rope or chain, or any combination of cable,
- rope or chain
- One bailer or manual pump
- Six approved pyrotechnic distress signals of which three must be type A, B or C
- One ANSUL red line 20 lb. multi-purpose fire extinguisher (BC Hydro Stock #151-0018) for boats with inboard engines or
- One ANSUL red line 5 lb. multi-purpose fire extinguisher (BC Hydro Stock #151-0016) for outboard engine
- A watertight flashlight
- Six approved pyrotechnic distress signals of which at least are type A,B or C
- A BC Hydro 11 unit first aid kit
- A sound signalling device, or a sound signalling appliance

4.7 Incident Reporting & Investigation

As per BCH Safety Practice Regulations:

All incidents shall be reported to the supervisor promptly.

The following types of incidents shall be reported on the Intranet using the BC Hydro Incident Management System:

- Those requiring first aid treatment or medical attention;
- Lost time incidents requiring medical treatment;
- Those in which there is no treatment but there is a possibility of future disability;
- Motor vehicle incidents; and,
- "Near-miss" incidents in which there is no injury, but potential for injury was high and/or there are lessons that could prevent future incidents.

Motor vehicle incidents must be reported to the appropriate external authorities, if required by the Motor Vehicle Act.

The workers' first responsibility is to make the scene of the incident safe for both workers and the public.

If the scene of an incident is critical to an investigation, workers shall retain as found the scene of the incident and any equipment connected with the incident. If the conditions surrounding the scene of the incident are likely to change, photographs should be made promptly to illustrate the circumstances of the incident.

An incident investigation report form is available in Appendix 1.

4.8 Personal Protective Equipment (PPE)

- All PPE shall meet the requirements of WorkSafeBC regulations and specifications;
- All personal protective equipment and tools shall be inspected before each use;
- All workers shall wear clothing and footwear that protects them from the hazards associated with their type of work;
- When workers are over or adjacent to water where there is a hazard of drowning, they shall wear approved buoyancy equipment (life jackets, vests, etc.); and,
- Workers shall select buoyancy equipment that is rated for the extra weight of any attached tools and equipment.

4.9 Spill Management Procedures

Field work may involve the re-fueling of equipment (boat, generators etc.) in addition to managing this equipment over a sensitive waterbody. The procedures below are to be followed to prevent and manage a spill should one occur.

4.9.1 Preventing Spills in the Field

- The refueling of boats and or equipment while on the water is prohibited. Any and all refueling will take at an appropriate fueling station or at a distance >100 m from the shoreline.
- Any portable fuel containers used in the field must be <20 L and be CSA (or equivalent) approved.
- Fuel containers will not be left unattended at any time while on the water.
- An appropriately sized spill kit will be kept with the boat during the course of the field work.

4.9.2 Dealing with a Spill

If a spill does occur while in the field the following procedures will be implemented by the Safety Officer to ensure proper containment and clean-up:

- **Assess safety** – Ensure the spill does not pose a health safety risk to crew members.
- **Contain and Clean the Spill** – Locate the spill kit and contain the spill using spill booms (if in water), ditches and spill rags. All of the contaminated soil and rags should be put into buckets.
- **Report the Spill** – If the spill is on land and greater then 10 L, report the spill to the Provincial Emergency Program (PEP). Notify BC Hydro and G3 Head office of any spill that occurs on site. All spills into a waterbody are to be reported to the PEP and BC Hydro.
- Prevent Future Spills – Assess how and why the spill occurred and rectify the problem so that it does not occur in the future.

5.0 FIRST-AID

The workers' first responsibility is to make the scene of the incident safe for both workers and the public.

Immediate first aid treatment shall be obtained by workers for each injury, however minor it may appear. When planning any job, workers shall meet all requirements for ensuring quick and efficient first aid treatment and/or Emergency Medical Services (EMS) Response. All workers shall have access to, and be instructed in, approved rescue procedures for the type of work in which they are engaged.

First Aid Patient Assessment and First Aid Record Forms are available in Appendix 1 and are required to be filled out. Records must be maintained and be made readily available.

5.1 Basic requirements (WSBC)

- The employer must provide for each workplace such equipment, supplies, facilities, first aid attendants and services as are adequate and appropriate for:
  - promptly rendering first aid to workers if they suffer an injury at work, and
  - transporting injured workers to medical treatment.
- For the purpose of complying with subsection (1), the employer must conduct an assessment of the circumstances of the workplace, including
  - the number of workers who may require first aid at any time,
  - the nature and extent of the risks and hazards in the workplace, including whether or not the workplace as a whole creates a low, moderate or high risk of injury,
  - the types of injuries likely to occur,
  - any barriers to first aid being provided to an injured worker, and
  - the time that may be required to obtain transportation and to transport an injured worker to medical treatment.
- The employer must review the assessment under subsection (2)
  - within 12 months after the previous assessment or review, and
  - whenever a significant change affecting the assessment occurs in the employer's operations

5.2 First Aid Procedures (WSBC)

- The employer must keep up-to-date written procedures for providing first aid at the worksite including
  - the equipment, supplies, facilities, first aid attendants and services available,
  - the location of, and how to call for, first aid
  - how the first aid attendant is to respond to a call for first aid,
  - the authority of the first aid attendant over the treatment of injured workers and the responsibility of the employer to report injuries to the Board,
  - who is to call for transportation for the injured worker, and the method of transportation and calling, and
  - prearranged routes in and out of the workplace and to medical treatment.
- The employer must post the procedures conspicuously in suitable locations throughout the workplace or, if posting is not practicable, the employer must adopt other measures to ensure that the information is effectively communicated to workers.
- The first aid attendant and all other persons authorized to call for transportation for injured workers must be trained in the procedures.

5.3 Minor Emergency Care

- Coordinate crew consolidation, return to predetermined established safety point (i.e. the vehicle or launch point);
- Crew size will never be below two (2) persons;
- If necessary a first aid attendant will accompany the injured worker to the nearest first aid post or hospital;

- Complete applicable WCB and field notes pertaining to the events; and,
- Report incident to the G3 Head Office as soon as possible.

During evacuation or in the event of a rescue time delay (where safety permits):

- All G3 crew will be advised of the situation immediately and offer assistance;
- Inform G3 Head office of all details and action taken or needed; and,
- Maintain communication with the G3 office.

6.0 EMERGENCY RESPONSE & RESCUE RESPONSE

In the event of an emergency, the Safety Plan is to be followed according to criteria described below. A first aid/rescue post is to be established at a readily accessible site (e.g., vehicle, launch site, etc.). It is the Safety Officers responsibility to ensure that this post is appropriately stocked and supplies are maintained in good condition.

The closest hospital from the study area is:

Queen Victoria Hospital
1200 Newlands Road, Revelstoke, BC, V0E2S0.
Phone: **250-837-2131**
Emergency Services operates 24 hours/day, 7 days/ week.

If an ambulance is not required or immediate transport is required for transportation, G3 would use the field vehicle equipped with spine board and blankets, to transport any injured personnel.

The nature of the field work requires the use of boats and may require use of 4x4 vehicles. In the event of an emergency be sure to identify the following points to the response team:

- situation involves stranded/injured field member(s) (in the river, up a road) requiring a search and rescue; and/or,
- situation involves injured field member(s) requiring assistance from the first aid/rescue post (e.g., field camp, truck, etc.).

Contents of the first aid/rescue post include:

- Level 1 first aid kit and spine board;
- survival gear;
- VHF and/or satellite phone (optional);
- swift water rescue equipment (where applicable); and,
- rescue/extraction equipment (e.g., ax, winch, etc.).

This post is to serve as the emergency gathering point in the event of crew separation at the work site. A log will be maintained at this site to leave and receive messages in the event that communication by radio/phone is not established. A copy of this Plan is to remain at the post at all times.

At all time you must know:

- WHERE YOU ARE;
- WHERE YOU ARE IN RELATION TO THE POST;
- NEAREST BOAT/TRUCK ACCESS; and,
- LOCATION OF NEAREST FIRST AID/RESCUE EQUIPMENT.

In the event of an emergency:

Describe the nature of the accident in sufficient detail to assist in appropriate response. Keep details to the essential points. Speak slowly and clearly to avoid confusion. Be decisive in your actions and requests and have your request repeated back to you for confirmation. Provide the following information to the response team:

1. Nature of emergency (Medical, Accident, Storm/Weather, etc.);
2. Number of persons involved;
3. Type of assistance required (Paramedic, SAR Team, Heli/Air evacuation, Emergency towing, etc.);
4. Field location; and,

5. Site Description (as viewed from the air, water, road, etc.).

Remember to use logic. If the field team is known to be at a specific location, assistance and searches should focus on that area first.

6.1 Life Threatening Work Place Emergency

In the event of a LIFE THREATENING work place emergency.

- Cease work action;
- Identify danger;
- Assess situation;
- Make area safe to administer or offer help;
- Begin life saving first aid;
- Stabilize victim; and,
- Radio crew members and contact **Emergency Services (911)** or other available station for assistance / evacuation.

Tell Them:

- LOCATION;
- DETAILS OF INJURY; and,
- ASSISTANCE REQUIRED.

6.2 Extreme Danger, Life Threatening Injuries:

Circumstances will determine the appropriate action.

6.2.1 Helicopter Available for Evacuation

DO NOT MOVE FROM REPORTED LOCATION.

- Remain Calm;
- At First Aid Attendants discretion of patients stability, transport patient to:
- Nearest First Aid Post; or,
- Nearest Hospital.

6.2.2 Helicopter Not Available for Evacuation

DO NOT MOVE FROM REPORTED LOCATION UNLESS UNSAFE.

- Remain Calm;
- Stabilize victim. You may be there for several minutes to several hours. In all cases prepare mentally and physically for several hours or overnight; and,
- Relay Radio to nearest radio station, to send transportation and first aid attendant.

6.2.3 If No Evacuation Is Available

- Remain Calm;
- Stabilize victim;
- MAKE ALL EFFORTS TO CONTACT OR ARRANGE EVACUATION;
- DO NOT MOVE FROM REPORTED LOCATION UNLESS UNSAFE;
- Maintain scheduled radio reports every 15 minutes with the other group or nearest radio. Keep help informed of situation. Keep radio use to minimum safe level to save battery and aid rescue attempts; and,
- Use Survival Gear to await help, prepare a signal device to attract attention from passing; boats or aircrafts.

6.2.4 If No Radio Contact Is Established

- Stabilize Victim;
- Remain Calm;
- MAKE ALL EFFORTS TO CONTACT OR ARRANGE EVACUATION;
- DO NOT MOVE FROM LOCATION UNLESS UNSAFE TO REMAIN;
- Use Survival Gear to await help, prepare a signal device to attract attention from passing, boats or aircrafts; and,
- The Safety Plan will be implemented and a search will begin within the designated time. If you are not heard from an emergency will be assumed and assistance will be sent.

After evacuation to medical center you must:

- Inform remaining crew and rescuers of evacuation completion;
- Inform G3 Head Office of all details and action taken or needed;
- Complete applicable WCB and field notes pertaining to the events; and,
- Report Incident to BC Hydro Project Contact

6.3 Water Rescue

In the event of a water rescue the Safety Officer will coordinate the rescue team until the point at which a professional SAR Tech. of higher qualification arrives on site.

To reduce the chance of requiring swift water rescue, personal floatation devices (PFDs) are to be worn by ALL crew members when working near any fast moving water. Throw bags will be situated at each sample site as required. PFDs must be worn by all crew members while in the boat at all times. At least one crew member should be trained in swift water rescue for all work in or near flowing water.

6.3.1 Rescue Equipment (As Required)

In the event that strong currents are observed at a sample site, equipment designed specifically for swift water rescue will be located at either the on shore the first aid/rescue post (where applicable) or on the sampling boat.

Rescue Equipment includes:

- Throw bag;
- assorted 1" rescue webbing;
- 1 Rescue life jacket;
- assorted prussic slings;
- assorted locking carabiners; and,
- Level 1 first aid kit.

THIS EQUIPMENT IS TO BE USED FOR RESCUE PURPOSES ONLY.

6.3.2 Rescue Procedures

Swift water rescue requires special training and skills. In-stream rescues are to be conducted by appropriately trained field members only (i.e., Swift Water Rescue Technician 1). Rescue procedures are to be conducted in accordance to Swift Water Rescue procedures described in the Swift Water Rescue Training (SRT) course. Refer to SRT literature for appropriate procedures.

REMEMBER:

THROW	Throw bag first;
ROW	Assist with a boat or raft; and,
GO	Properly equipped swimming rescue as final resort.

7.0 RADIO & TELEPHONE PROCEDURES

Ensure all crew members are familiar with radio operation and know where the radio is located. Establish the following:

- an appropriate relay station (i.e., nearest party);
- approximate range of radio signal; and,
- barriers to radio use (i.e., valleys, mountains, etc.).

Revelstoke RCMP City	139.50000
Revelstoke RCMP Rural East	139.56000
Revelstoke RCMP Rural West	139.41000
Revelstoke RCMP Sicamous	139.44000
Revelstoke Fire Department	155.49000
Revelstoke EMS Repeater	149.68000

7.1 Emergency Phone and Radio Procedures

7.1.2 Emergency Radio Call Procedure

1. Radio Callsign of the station you are calling;
2. “This is” <Give Radio Callsign>;
3. “Do you Copy”;
4. “Over.”

Speak slowly and clearly to avoid confusion. Talking across the face of the microphone may make communications more understandable. If the emergency **requires** interruption of non-emergency communication radio protocol “Break Break” requests the channel be cleared for your priority message.

Once communication has been established with emergency services, provide the following information:

- Nature of emergency (Medical, Accident, Storm/Weather, etc.);
- Number of persons involved;
- Type of assistance required (Paramedic, SAR Team, Heli/Air evacuation, Emergency towing, etc.);
- Field location; and,
- Site Description (as viewed from the air, water, road, etc.).

Remember to use logic. If the field team is known to be at a specific location, assistance and searches should focus on that area first.

7.2 Emergency Telephone Numbers

G3 Consulting Ltd.	604-598-8501	
G3 Field Cellular	604-308-6702	
Emergency Services	911	
Nearest Hospital	Queen Victoria Hospital 1200 Newlands Rd, Revelstoke, BC	1-250-837-2131
Advanced Care Hospital	Kelowna General Hospital 2268 Pandosy St, Kelowna, BC	1-250-862-4000
Regional RCMP	Revelstoke RCMP	1-250-837-5255
Regional Search & Rescue	Arrow Lakes Search and Rescue	1-250-265-4370
Regional Fire	Nakusp Fire Department	1-250-837-2884
Forest Fire	1-800-663-5555	*5555
Spill Reporting (PEP)	1-800-663-3456	

Accommodation
(G3 Field Crew)

Employee	Hotel (room)	Telephone	Cellular

Remember: Safety First

APPENDIX 1

Forms

First Aid Assessment Worksheet

1. Name of workplace: Revelstoke Reservoir

Conduct a separate assessment for each identified workplace (see flow chart Step 1)

2(a) Hazard rating on Assigned Hazard Rating List L ___ M ✓ H ___

2(b) Job functions, work processes and tools

Using an aluminum 7m jet boat G3 will collect representative macrophyte species from up to 12 sites along the entire length of reservoir. Water and sediment sampling will also occur at each site. Tools include: petit ponar for sediment, water meter, GPS Sonar to map each site, macrophyte sampling device, quadrats, underwater camera.

Typical of industry? Yes ✓ No ___

2(c) Types of injuries that can potentially occur

working from boats, slips/trips/falls, forest fire, wildlife encounters, extreme weather, heat and cold stress, fast flowing water

Typical of industry? Yes ✓ No ___

2(d) Rating adjustment: if hazard rating is adjusted, provide documentation.

Overall workplace hazard rating L ___ M ✓ H ___

3(a) Surface travel time to hospital

✓ greater than 20 minutes

___ 20 minutes or less

4(b) Total number of workers per shift 4 (include dispatched workers and workers in lodgings)

5(f) Barriers to reaching medical treatment

Satellite communication may be limited, remote work area, potentially no road access

ASSESSMENT RESULTS

(different shifts may require different first aid services)

5(a) Supplies/equipment/facilities required WCB level 1 First Aid Kit, spine board, satellite phone

5(c) Number and level of first aid attendants 4 - occupational first aid level 1

5(e) Transportation needs 4x4 vehicle, 7 m jet boat

Date: 2014-08-06 Change in Business Operations: ___

Consulted (health and safety committee, worker representative, others):
BC Hydro

Name: Alex Caldicott Signature: [signature]

OCCUPATIONAL FIRST AID
PATIENT ASSESSMENT

DATE AND TIME OF ILLNESS / INJURY AM / PM	DATE AND TIME REPORTED TO FIRST AID AM / PM
TIME OF ARRIVAL AT FIRST AID (WALK IN) AM / PM	TIME ON SCENE (IF APPLICABLE) AM / PM

EMPLOYEE NAME DATE OF BIRTH D M Y	EMPLOYER NAME EMPLOYER PHONE NUMBER
EMPLOYEE'S DOCTOR	CONTACT PERSON

GLASGOW COMA SCALE	EYE OPENING RESPONSE	BEST VERBAL RESPONSE	BEST MOTOR RESPONSE
	4 SPONTANEOUSLY 3 SPEECH 2 TO PAIN 1 NO RESPONSE	5 ORIENTED 4 CONFUSED 3 INAPPROPRIATE WORDS 2 INCOMPREHENSIBLE SOUNDS 1 NO RESPONSE	6 OBEYS COMMANDS 5 LOCALIZES PAIN 4 WITHDRAWS FROM PAIN 3 FLEX TO PAIN (DECORTICATE) 2 EXTENDS TO PAIN (DECEREBRATE) 1 NO RESPONSE

PATIENTS CHIEF COMPLAINT

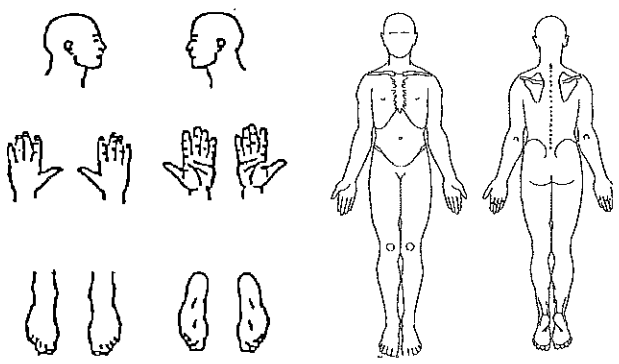
MECHANISM OF INJURY / HISTORY OF ILLNESS

PHYSICAL FINDINGS

VITAL SIGNS	TIME	TIME	TIME	TIME
RESPIRATIONS				
PULSE				
LOC / GCS	E TOTAL V M	E TOTAL V M	E TOTAL V M	E TOTAL V M
PUPIL SIZE & REACTION + / -	L R	L R	L R	L R
SKIN				

ALLERGIES

PLEASE MARK INJURED OR EXPOSED AREA



MEDICATIONS

INTERVENTIONS (PLEASE CHECK)

☐ AIRWAY CLEARED ☐ MAINTAINED ☐ OROPHARYNGEAL AIRWAY

☐ VENTILATED ☐ PKT. MASK ☐ BVM

☐ CONTROLLED BLEEDING ☐ OXYGEN ADMINISTERED LPM________

DEFINITIVE TREATMENTS (PLEASE CHECK)

☐ TRACTION ☐ SPLINTED ☐ IMMOBILIZED

☐ SPINAL IMMOBILIZATION ☐ ADDITIONAL TREATMENTS (PLEASE EXPLAIN)

RECOMMENDATIONS

☐ RETURN TO WORK ☐ FIRST AID FOLLOW UP ☐ MEDICAL AID

TRANSPORTED BY (PLEASE CHECK)

☐ ETV ☐ INDUSTRIAL AMBULANCE ☐ B.C. AMBULANCE SERVICE

☐ AIR EVACUATION ☐ OTHER (PLEASE EXPLAIN)

CHANGES IN PATIENTS CONDITION (PLEASE EXPLAIN)

F.A.A. NAME (PLEASE PRINT)	F.A.A. SIGNATURE	OFA CERTIFICATE #	OFA LEVEL
			☐ 1 ☐ TE ☐ 2 ☐ 3

NAME OF WITNESSES (PLEASE PRINT)	EMPLOYER MAILING ADDRESS STREET / AVENUE
EMPLOYEE SIGNATURE	CITY / TOWN POSTAL CODE

55M60 (R01/06)

WORK SAFE BC

FIRST AID RECORD

This record must be kept by the employer for three (3) years. This form must be kept at the employer's workplace. Do **NOT** submit to WorkSafeBC.

Sequence number

Name	Occupation
Date of injury or illness *(yyyy-mm-dd)*	Time of injury or illness *(hh:mm)* a.m. ☐ p.m. ☐
Initial reporting date and time *(yyyy-mm-dd) (hh:mm)* a.m. ☐ p.m. ☐	Follow-up report date and time *(yyyy-mm-dd) (hh:mm)* a.m. ☐ p.m. ☐
Initial report sequence number	Subsequent report sequence number(s)

Description of how the injury, exposure, or illness occurred ***(What happened?)***

Description of the nature of the injury, exposure, or illness ***(What you see — signs and symptoms)***

Description of the treatment given ***(What did you do?)***

Name of witnesses

1.	2.

Arrangements made relating to the worker ***(return to work/medical aid/ambulance/follow-up)***

Provided worker handout Yes ☐ No ☐ Alternate duty options were discussed Yes ☐ No ☐	A form to assist in return to work and follow-up was sent with the worker to medical aid Yes ☐ No ☐
First aid attendant's name *(please print)*	First aid attendant's signature
Patient's signature	

WorkSafeBC

FIRST AID RECORD

This record must be kept by the employer for three (3) years. This form must be kept at the employer's workplace. Do **NOT** submit to WorkSafeBC.

Sequence number

Name	Occupation
Date of injury or illness *(yyyy-mm-dd)*	Time of injury or illness *(hh:mm)* a.m. ☐ p.m. ☐
Initial reporting date and time *(yyyy-mm-dd) (hh:mm)* a.m. ☐ p.m. ☐	Follow-up report date and time *(yyyy-mm-dd) (hh:mm)* a.m. ☐ p.m. ☐
Initial report sequence number	Subsequent report sequence number(s)

Description of how the injury, exposure, or illness occurred ***(What happened?)***

Description of the nature of the injury, exposure, or illness ***(What you see — signs and symptoms)***

Description of the treatment given ***(What did you do?)***

Name of witnesses

1.	2.

Arrangements made relating to the worker ***(return to work/medical aid/ambulance/follow-up)***

Provided worker handout Yes ☐ No ☐ Alternate duty options were discussed Yes ☐ No ☐	A form to assist in return to work and follow-up was sent with the worker to medical aid Yes ☐ No ☐
First aid attendant's name *(please print)*	First aid attendant's signature
Patient's signature	

WORKSAFE BC
WORKING TO MAKE A DIFFERENCE

INCIDENT INVESTIGATION REPORT

Worker and Employer Services Division

This form is provided to employers for the purpose of documenting the employer's investigation into a workplace incident. Please attach a separate sheet if necessary.

Employer name	Employer number
Employer head office address	

Incident occurred *ref: s. 3.4(a) Occupational Health and Safety Regulation (OHS Regulation)*

Address where incident occurred *(including nearest city)*	
Date yyyy-mm-dd	Time a.m. ☐ p.m. ☐

Injured person(s) *ref: s. 3.4(b) OHS Regulation*

Last name	First name	Job title	Age	Length of experience with this employer	Length of experience at this task/job
1)					
2)					

Nature of injury/injuries

1)
2)

Witnesses *ref: s. 174(4) WCA and s. 3.4(c) OHS Regulation*

Last name	First name	Address	Telephone
1)			( )
2)			( )
3)			( )

Incident description *ref: s. 3.4(d)–(e) OHS Regulation*

Briefly describe what happened, including the sequence of events preceding the incident.

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Statement of causes *ref: s. 174(2)(a)–(b) WCA and s. 3.4(f) OHS Regulation*

List any unsafe conditions, acts, or procedures that in any manner contributed to the incident.

Recommendations *ref: s. 174(2)(c) WCA and s. 3.4(g) OHS Regulation*

Identify any corrective actions that have been taken and any recommended actions to prevent similar incidents.

Recommended corrective action	Action by whom	Action by date
1)		
2)		
3)		
4)		

Persons conducting investigation *ref: s. 3.4(h) OHS Regulation*

Name	Signature	Type of representative			Date
		Employer ❐	Worker ❐	Other ❐	
		Employer ❐	Worker ❐	Other ❐	
		Employer ❐	Worker ❐	Other ❐	

For additional information on WorkSafeBC (Workers' Compensation Board of B.C.) and on the requirements for incident investigations, please refer to WorkSafeBC's web site: WorkSafeBC.com

Mailing address WorkSafeBC
PO Box 5350 Stn Terminal
Vancouver BC V6B 5L5

Fax number: 604 276-3247

Telephone information

Call centre: 604 276-3100 or toll free within B.C. 1 888 621-SAFE (7233)

After hours health and safety emergency: 604 273-7711 or toll free 1 866 922-4357 (WCB-HELP)

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WorkSafe Incident Reporting

Use this guide in conjunction with the requirements of the *Workers Compensation Act* (*WCA*), Part 3 Division 10, and the Occupational Health and Safety Regulation (OHS Regulation), section 3.4.

When is an investigation required?
Employers are required to immediately undertake an investigation into any accident or other incident that:
• Is required to be reported under section 172 of the *Workers Compensation Act*, or
• Resulted in injury requiring medical treatment, or
• Did not involve injury to a worker or involve a minor injury that did not require medical treatment but had the
potential for causing serious injury, or
• Was an incident required by regulation to be investigated.

Who should conduct the investigation?
• Incidents must be investigated by people knowledgeable about the type of work involved at the time of
the incident.
• If reasonably available, investigations must be carried out with the participation of one employer representative and one worker representative.

What is the purpose of an investigation?
The purpose of an investigation is to determine the cause or causes of the incident, to identify any unsafe conditions, acts, or procedures that contributed to the incident, and to recommend corrective action to prevent similar incidents.

Who receives copies of the report?
Incident investigation reports required by the *WCA* must be provided to the joint health and safety committee or worker representative as applicable, and to WorkSafe BC.

What follow-up action is required after an incident investigation?
After an investigation, the employer must without undue delay undertake any corrective action required to prevent recurrence of similar incidents and must prepare a report of the action taken. The report must be provided to the joint health and safety committee or worker representative as applicable. The follow-up report does not have to be provided to WorkSafe BC unless requested by a WorkSafe BC officer.

What information should be included in the investigation report?
An incident investigation report should answer the WHO, WHERE, WHEN, WHAT, WHY, and HOW questions with regard to the incident.
WHO Employer, injured person(s), other person(s) involved in the incident, witnesses, and persons carrying out the investigation
WHERE Place, location where incident occurred
WHEN Date and time of the incident
WHAT A brief description of the incident, including the sequence of events that preceded the incident
Before the incident occurred:
• What were the events that led up to the incident?
• What process(es) was/were occurring immediately prior to the incident?
• What was/were the worker(s) doing immediately prior to the incident?

• What was the last event before the incident occurred?
At the time of the incident:
• What happened at the time of the incident?
• What process(es) was/were occurring at the time of the incident?
• What was/were the worker(s) doing at the time of the incident?
• What hazard(s) was/were the worker(s) exposed to?
• What hazards may have contributed to the incident occurring?
• What hazards did the worker(s) encounter?
• What personal factors may have contributed to the incident occurring?
Other information:
• Other observations
• Other related information

WHY From the answers to “what,” identify any unsafe conditions, acts, or procedures that in any manner contributed to the incident. Why did the unsafe conditions, acts, or procedures occur? Why were the personal factors not identified and/or addressed before the incident occurred?

HOW An investigation report should recommend corrective actions to prevent similar incidents from occurring. Once it is known why an incident occurred, determine how to prevent recurrence.

For example:
• Improve workplace inspection and maintenance programs
• Repair or replace equipment/building
• Install safeguards
• Establish or revise safe work procedures
• Train/retrain person(s)
• Improve supervision

Additional information for determining why an incident happened To determine the most probable cause(s) of an incident, consider all details of the investigation, including witness statements and, where possible, the injured worker’s statement. Determine if the incident was due to an unsafe act, an unsafe condition, unsafe or inadequate procedures, or a combination of these. Consider whether the accepted/current procedures adequately address safety concerns associated with the activity that was taking place when the incident happened. Consider training, supervision, equipment controls, safeguards, and lock-out.

Unsafe acts — An unsafe act is a specific action or lack of action by an individual that is under the individual’s control. Examples of unsafe acts include: knowingly not following established rules, knowingly not following established procedures, knowingly disregarding a hazard, wilful misconduct, abusing equipment, knowingly using equipment incorrectly, choosing not to use personal protective equipment, and not locking out when required. Generally, violating a safety rule, not following a safe work procedure, or disregarding a hazard are considered unsafe acts.

Unsafe conditions — Examples include poor housekeeping, congested areas, deficient equipment, equipment lacking safeguarding or having ineffective safeguarding, lack of personal protective equipment, poor visibility, poor weather conditions, and lack of or inadequate training. Inadequate training should be considered an unsafe condition as opposed to a deficiency in skill or ability (personal factors). Inadequate procedures — Indications that procedures are inadequate include:

- Procedures are not available in written form
- Procedures do not identify inherent hazards
- Procedures do not identify hazard control methods
- Procedures do not identify safeguards that must be in place
- Procedures do not address pre-operation inspection requirements
- Procedures do not address lock-out requirements
- Procedures direct improper use of equipment or tools

Personal factors — A personal factor is a deficiency in skill or ability, a physical condition, or a mental attitude.

It is a factor inherent in an individual at the time of the incident. Examples include work fatigue due to manual exertion, distress due to emotional problems, the influence of alcohol or drugs, or illness. A condition causing an allergic reaction in some but not most workers should be considered a personal factor, not an unsafe condition.

TAILBOARD SAFETY MEETING FORM

To be competed by supervisor prior to beginning of new job, when changes in work procedures occur, or when additional hazards are present. Reference Job Hazard Analysis and ensure this form is maintained for the record.

Project Number:	
Date:	
Location:	
Meeting Held By:	

Crew Members Attending		Crew Members Absent
Name	**Signature**	**Name**

Topics Discussed:

Topic	Yes	No	Comments
Scope and task sequence of planned work			
Review of preliminary documentation			
Environmental conditions that could impact the work			
Communication requirements			
Rules and regulations applicable to work			
Known hazards			
Required personal protective equipment			
Safety management plan			
Emergency Response and Rescue			
First Aid			
Check-in Procedures			
Inspections			
Operation of equipment			
Worker experience and knowledge of the job at hand			

New Topics for Discussion:

SAFETY MANAGEMENT INSPECTION FORM

Inspector:	Date:

Subject	Yes	No	Comment
Training			
Does initial training include a thorough review of hazards and accidents associated with the job?			
Is adequate instruction in the use of personal protective equipment provided?			
Is training for the use of emergency equipment provided?			
Are workers knowledgeable in the "Right to Refuse" procedures?			
Environment			
Are resources available to deal with very hot or very cold conditions (drinking water, lined gloves, insulated boots)?			
Is the rain/cold weather gear that is provided comfortable, and light enough so as not to constitute a hazard?			
Are work surfaces and grip surfaces safe when wet?			
Do workers know the symptoms of heat cramps/heatstroke, or frost bite/hypothermia?			
Medical and First Aid			
Is the first aid kit accessible and clearly labelled?			
Do all employees know how to get first aid assistance when needed?			
Do the first-aiders know when and to which hospital or clinic an injured person should be taken?			
Do workers know where to find MSDSs for chemical products?			
Are there employees trained as first-aid practitioners on each shift worked?			
Are first-aid kits provided as per first-aid regulations?			
Are first-aid supplies replenished as they are used?			
Personal Protective Equipment (PPE)			
Is required equipment provided, maintained and used?			
Does equipment meet requirements?			
Is it reliable?			

EQUIPMENT MANAGEMENT INSPECTION FORM

Inspector:	Date:

Subject	Yes	No	Comment
Boat			
Check load			
Check bilges			
Check fuel			
Check oil			
Ensure boat general condition is good			
Ensure safety equipment is adequate (Section 4.6.2 of SMP)			
Ensure an appropriately sized spill kit is kept with the boat during the course of the field work			
Other Equipment			
Equipment is in good condition			
Workers have appropriate gear to prevent personal injury			
Batteries are charged and backups are available			
Current inventory list of all equipment and supplies exists			
Equipment is tested as specified by the manufacturer			
Pilferage and theft have been considered			
All PPE meets the requirements of WorkSafeBC regulations and specifications			

Workplace Inspection Report

Use this report to record the results of your regular workplace inspections.

Company name: ____________________

Date: ____________________

Inspectors' names: ____________________

Precise location	Description of hazard	Recommended corrective action	Person responsible for corrective action	Due date	Completed	
					Yes	No

G3 Consulting Ltd.

OHS: Occupational Health & Safety Program

WORKSAFE BC

WORKING TO MAKE A DIFFERENCE

worksafebc.com

Policy Statement for OHS Program

G3 Consulting Ltd. (G3) wants its workplace to be a healthy and safe environment. To achieve this, our company has established and maintains an occupational health and safety program designed to prevent injuries and disease. We, as the employer are responsible for providing workers with adequate instruction in health and safety and for addressing unsafe situations in a timely, effective manner. All workers and service contractors are required to work safely and to know and follow our company guidelines for safe work procedures.

G3's responsibilities include:

- Establishing the health and safety program
- Conducting an annual review in December of each year
- Training supervisors
- Providing a safe and healthy work environment

Supervisors' responsibilities include:

- Providing a health and safety orientation to new workers
- Providing ongoing training to workers
- Taking part in inspections and investigations
- Reporting any safety or health hazards
- Correcting unsafe acts and conditions

Workers' responsibilities include:

- Learning and following safe work procedures
- Correcting hazards or reporting them to supervisors
- Participating in inspections and investigations where appropriate
- Using personal protective equipment where required
- Helping to create a safe workplace by recommending ways to improve the health and safety program

WorkSafe BC Prevention Information Line

G3 Consulting has implemented this Occupational health and Safety Program to be consistent and compliant with regulations set forth in the BC WorkSafe and Prevention Program. Should you require any additional information or need answers to your questions about work- place health and safety, worker and employer responsibilities, and reporting a workplace accident or incident please ask your supervisor, the Project Manager or contact WorkSafe directly at:

Phone 604 276-3100 in the Lower Mainland, or call 1 888 621-7233 (621-SAFE) toll-free in British Columbia.

To report after-hours and weekend accidents and emergencies, call 604 273-7711 in the Lower Mainland, or call 1 866 922-4357 (WCB-HELP) toll-free in British Columbia.

CONTENTS

APPENDICES

1.0 INTRODUCTION

This booklet is for G3 Consulting Ltd. Employees to help identify and maintain an effective occupational health and safety (OHS) program.

The purpose of this OHS program is to prevent injuries and occupational diseases and to deal effectively with any accidents or incidents that occur.

This program:

- Identify hazards in the workplace;
- Eliminate or minimize the potential for injuries, disease, or loss of life;
- Limit financial losses resulting from injuries and disease; and,
- monitors to ensure this OHS Plan meets its goals and WorkSafe BC requirements

This booklet will help you comply with WorkSafe BC requirements but does not replace the *Workers Compensation Act* and the Occupational Health and Safety Regulation.

1.1 Employer's responsibilities

G3 has both a general and specific responsibility related to hazard control and worker health and safety. In carrying out these duties, management must and will demonstrate a commitment to health and safety in the workplace.

- Ensure the health and safety of employees and other workers present at the workplace.
- Establish occupational health and safety policies (this OHS program).
- Provide general direction to management, supervisors, and workers about their responsibilities and roles in providing a safe and healthy workplace.
- Provide specific direction and delegate authority to those responsible for health and safety.
- Consult and cooperate with individuals carrying out occupational health and safety duties (including joint committee members, worker health and safety representatives, and WorkSafe BC prevention officers).
- Provide workers with the information, instruction, training, and supervision necessary to protect their health and safety.
- Provide supervisors with the support and training necessary to carry out their health and safety responsibilities.
- Provide and maintain protective equipment, devices, and clothing, and ensure that they are used.
- Make a copy of the Workers Compensation Act and the Occupational Health and Safety Regulation readily available for review by workers.

Hazard control responsibilities

- Identify potential hazards through regular inspections and either eliminate or control the hazards without delay.
- Remedy any workplace conditions that are hazardous to worker health or safety.
- Develop written safe work procedures.
- G3 encourage ALL workers and sub trades to express concerns and suggest improvements on health and safety issues, for example, through safety talks, meetings, or consultation with worker representatives.

Supervisor's responsibilities

Supervisors MUST give health and safety the same priority as productivity and quality control. They must know and comply with occupational health and safety requirements.

A supervisor is defined in the Occupational Health and Safety Regulation as "a person who instructs, directs and controls workers in the performance of their duties." Any worker (management or staff) who meets this definition of supervisor has the responsibilities of a supervisor for the workers under their control.

General responsibilities

- Ensure the health and safety of all workers under their direct supervision.
- Know the WorkSafe BC requirements that apply to the work being supervised and ensure that they are followed.
- Ensure that workers under their supervision are made aware of all known or reasonably foreseeable health and safety hazards where they work.
- Consult and cooperate with worker(s) and cooperate with others carrying out occupational health and safety duties (including WorkSafe BC prevention officers).
- Ensure that the appropriate personal protective equipment and clothing are available, properly worn when required, and properly inspected and maintained.
- Investigate unsafe conditions reported to them and ensure that corrective action is taken without delay.

1.2 Workers' Responsibilities

Workers have general responsibilities for their own health and safety and that of other workers. In addition, they have the responsibility to refuse unsafe work; discriminatory action cannot be taken against them for refusing to do unsafe work.

General responsibilities

- Cooperate with the worker health and safety representative, WorkSafe BC prevention officers, and any other person carrying out occupational health and safety duties.
- Learn and follow safe work procedures.
- Be alert to hazards, and report hazards or problems to the supervisor or employer.
- Use the protective clothing, devices, and equipment provided.
- Perform work in a safe manner. Do not engage in horseplay or work while impaired by alcohol, drugs, or other causes. Responsibility to refuse unsafe work
- Refuse to do work that they have reasonable cause to believe would create an undue hazard to the health and safety of any person.
- Immediately report an unsafe situation to their supervisor or employer.

1.3 Owner's responsibilities

The owner of a worksite has responsibilities for a safe and healthy workplace. These are in addition to any other responsibilities the owner may have as the employer or prime contractor.

General responsibilities

- Maintain the land and premises used as a workplace in a manner that ensures the health and safety of persons at or near the workplace.
- Give the employer or prime contractor at the workplace any information known to the owner that is necessary to identify and eliminate or control hazards.
- Comply with occupational health and safety requirements and orders.

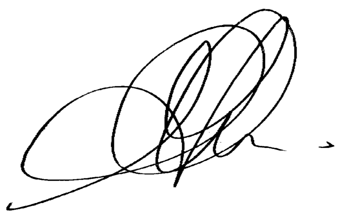
1.4 Responsibilities of Others

Suppliers of tools and equipment and directors and officers of a corporation also have responsibilities for health and safety under the Workers Compensation Act. If a person has two or more functions (for example, as employer and owner), the person must meet the obligations of each function.

As G3 has less than 20 employees the OHS program is less formal than perhaps others. That said, G3's level of commitment to the health and safety of its workers is no less great.

2.0 OHS POLICY

- G3 commits to the ongoing development, implementation, training and inspection of the terms and contents of this OHS Plan;
- G3 commits to protect the health and safety of its workers;
- G3 has an ongoing responsibility to its supervisors and workers.



Dr. Gregory P Thomas
President

August 2014

3.0 INSPECTION(s)

G3 will, on a regular basis, conduct regular inspections of the workplace. These inspections are intended to:

- Identify conditions and unsafe acts with the potential to cause injury or disease;
- Determine necessary corrective measures; and,
- Prevent unsafe work conditions from developing.

Three different kinds of inspections will occur:

- Regular: planned workplace inspections: Inspect buildings, structures, grounds, excavations, tools, equipment, machinery, and work methods and practices for hazards that might cause injury or disease.

- Scheduled: inspections at appropriate intervals to prevent unsafe conditions developing. Depending on the workplace and the type of hazards that might develop, inspections may be scheduled daily, weekly, or monthly.
- Equipment inspections: Workers must be trained to inspect and operate their machinery, tools, and equipment regularly, following the manufacturer's recommendations.

Inspections will be undertaken by both a worker and a management representative. The team will be familiar with the work process. A worksite inspection checklist (see Appendix) will be sued to assist these inspections. This form can be modified as necessary to ensure all aspects of the inspection are covered. Any unsafe or harmful conditions found during a regular inspection should be reported immediately to a G3 supervisor to remedy this issue(s) without delay.

Record and communicate all significant findings. All communications should be in the form of E-mail or written correspondence and printed and submitted to the front desk (Wendy) for appropriate filing). A copy of this correspondence will also be made available to the worker as well as on G3's OHS bulletin board (in the copier room).

4.0 WRITTEN INSTRUCTION(S)

Health and safety, productivity, and quality control all benefit from written procedures. Written procedures will be supplied in most circumstance, to prevent worker injury and to maximize benefits from communications. This will include the development of an Operational Work Plan and Emergency Action Plan tailored to each project. Works must review and sign these plans prior to work on a given project. Failure to do so may result in disciplinary action.

A written safe work procedures included in the Emergency Action Plan list the steps in doing a task safe. An example of this plan is provided in the Appendix. This OHS Plan and WorkSafe BC Health and Safety Regulation requires written work procedures for:

- Lockout
- Confined space entry
- Fall protection
- Personal protective equipment
- Violence in the workplace
- Emergency evacuation
- Chemical spills clean-up
- Asbestos removal
- Working alone or in isolation

For some tasks, safety issues will be addressed verbally in crew talks or during training. In deciding whether or not written procedures are required, consider the following:

- The requirements of the Occupational Health and Safety Regulation
- The level of hazard
- The number of workers doing the work
- The experience of the workers
- How frequently the work is being done
- The severity of injuries that might result if correct procedures are not followed
- Recommendations for written procedures as a result of an inspection or investigation

Written safe work procedures MUST and WILL be developed in consultation with those required to perform the work and based on past experience and projects. Workers will be provided with copies of these procedures. These procedures (EAP) is to be reviewed with every new project or when new personal or equipment are introduced. Work procedures may need to be adjusted as the result of recommendations from an inspection or from an investigation into an incident. Where the client has specific project or procedure specific training for site access, these will superseded and general procedures.

5.0 MEETINGS

Management meetings will be held as part of G3's administrative meeting process or as necessary to review health and safety activities and any reported incidents. These meetings would be used to:

- Review existing policies and procedures
- Review feedback from workers
- Consider reports and other information
- Address questions or concerns brought forward to management
- Review reports and other information about health and safety in workplaces performing similar work, as well as general information about workplace injury and disease prevention, to improve the existing OHS program

Recommendations for action from employees or supervisors would be considered and acted upon by:

- Developing an action plan for implementing the recommendation, or
- Suggesting an acceptable alternative Management decisions.

6.0 INVESTIGATIONS

G3 believes strongly in follow-up on any incident (major or minor) to ensure that everything possible is done to prevent reoccurrence and potential to cause an injury or disease. The purpose of these investigations is to identify the cause or causes and to recommend steps to prevent similar unsafe conditions.

6.1 What is an incident?

The Worksafe Occupational Health and Safety Regulations define an "incident" as "an accident or other occurrence which resulted in or had the potential for causing an injury or occupational disease." Incidents include the following:

- Accidents in which a worker is injured or killed
- Accidents in which no one is hurt but equipment or property is damaged
- Near misses (no visible injury or damage but the incident could have resulted in a serious injury, death, or property damage)

Serious incidents MUST be report to both G3 Management AND WorkSafe BC
Employers must immediately notify WorkSafe BC of any serious incidents
that:

- Resulted in serious injury to a worker or the death of a worker
- Involved a major structural failure or collapse of a building, bridge, tower, crane, hoist, temporary construction support system, or excavation
- Involved the major release of a hazardous substance

To report a serious incident, call 604 276-3100 in the Lower Mainland or 1 888 621-SAFE (7233) toll-free in B.C. To report an incident after normal business hours, call 604 273-7711 or toll-free 1 866 922-4357 (WCB-HELP).

In the event of a serious incident, the scene must be secured and left undisturbed until a WorkSafe BC officer releases it (except for attending to injured workers and preventing further injuries).

Incidents the employer must investigate
G3 will investigate the above serious incidents as well as any incidents that:

- Resulted in injury to a worker requiring medical treatment
- Did not involve injury to a worker, or involved only minor injury not requiring medical treatment, but had a potential for causing serious injury to a worker. Incident investigations will be carried out by personnel knowledgeable about the type of work being done. Where possible, investigations should involve both worker and employer representatives

An ***Incident Investigation Report*** (see Appendix 2) must completed and include:

- The place, date, and time of the incident
- The names and job titles of persons injured in the incident
- The names of witnesses
- A brief description of the incident

- A statement of the sequence of events that led up to the incident
- Identification of any unsafe conditions, acts, or procedures that contributed to the incident
- Recommended corrective actions to prevent similar incidents
- The names of persons who investigated the incident

G3 Management Duties

1. If one or more workers were injured, fill out forms 7 and 7A and send copies to WorkSafe BC or submit online:

- Form 7: Employer's Report of Injury or Occupational Disease
- Form 7A: First Aid Report

2. Determine who will investigate the incident.

3. Investigate the incident:

- Determine the cause or causes of the incident.
- Identify any unsafe conditions, acts, or procedures that contributed to the incident.
- Recommend corrective action to prevent similar incidents.

4. Prepare incident investigation report.

5. Provide copy of report to joint committee (and WorkSafe BC if required).

6. Take corrective action required to prevent reoccurrence of similar incidents.

7. Prepare follow-up report on corrective action taken.

8. Provide copy of follow-up report to management AND post on the OHS bulletin board (in the copier room).

7.0 RECORD KEEPING

Under the objectives and aims of this Plan, G3 will record the following information:

- Inspection reports and records of corrective actions taken
- Incident investigation reports and records of corrective actions taken
- Worker orientation records
- Records of worker and supervisor training showing the date, names of attendees, and topics covered (for example, lockout and WHMIS training)
- Records of meetings and crew talks at which safety issues were discussed
- Supervisors' notes and logs of safety contacts
- Records showing use of progressive discipline to enforce safety rules and written safe work procedures
- Meeting minutes showing steps taken to address health and safety issues
- Subcontractor pre-qualification documents
- Equipment logbooks and maintenance records
- First aid records, medical certificates, etc.
- Forms and checklists (e.g., permits, safe work procedures)
- Sampling and monitoring records for work around harmful substances
- Emergency response plan, record of drills, and any resulting Improvements

8.0. WORKER INSTRUCTION & SUPERVISION

Every worker must undergo office and field orientation in accordance with their specific role, job title and responsibilities. This orientation is done through a process of both formal training and courses as well as mentoring and project/equipment specific training by other staff or supervisors (see Appendix 3).
Education generally refers to formal classroom instruction that may include lectures, discussions, and videos. Training generally refers to hands-on, job-specific instruction provided individually or in small groups to workers.

Training often includes demonstrations and active participation by workers so that supervisors can confirm that workers understand safe work procedures.

An education and training record is maintained by G3 Management as part of the employee's record and covers and date of education or training. Education and training records are reviewed periodically to ensure that training requirements have been met and that certifications do not expire (electrofishing, First Aid, Swift Water Rescue, Bear Aware etc.).
Supervisors must supervise their workers to ensure that they follow safe work procedures. Adequate supervision WILL and MUST include (at all times):

- Ensuring proper training of workers
- Observing workers after training to ensure that they continue to follow safe work procedures
- Making informal inspections on a daily basis to ensure safe work procedures are being followed, including the proper use of protective equipment, devices, and clothing provided
- Enforcing safety rules and safe work procedures
- Conducting informal discussions (crew talks) with workers to discuss specific safety issues as they arise

Education and training topics include (but are not limited to the following).

Topic	Content
New Worker Orientation	• Location of first aid equipment and services • Reporting accidents, injuries, and unsafe conditions • Safe work procedures • Right to refuse unsafe work • Location of fire exits, routes, and safe gathering areas • Emergency procedures
WHMIS	Reading and understanding labels • Understanding information on MSDSs • Location of MSDSs • Hazards of products being used • Controls measures and appropriate personal protective equipment (PPE)
Personal Protective Equipment (PPE)	• When, why, where, and how to use specific PPE • Limitations of protection • Regular inspection and maintenance
Chemical hazards (such as lead, asbestos) • Biological hazards (such as HIV, hepatitis) • Physical hazards (such as noise, vibration, heat, cold, radiation)	• Potential health effects of exposure • Common routes of exposure • Ways to prevent exposure • Proper use of controls • How to recognize signs and symptoms of exposure
Project Specific Training	As identified by task or client needs
Electrofishing, transportation endorsement, First Aid, O2 Administration, Swift Water Rescue, MedA3 training, Sediment Erosion, Hazardous Materials	As identified for the specific individual and project responsibilities.

9.0 COMPLAINTS

As part of worker orientation and periodic reviews, workers WILL and ARE instructed that complaints concerning health and safety MUST be directed to their supervisor. However, if the situation is not handled to the worker's satisfaction, an alternate manager or administrative person MUST be contacted as soon as possible.

The admin person or supervisor will then work to resolve the complaint. It is important that that communications remain paramount and both the worker and supervisor will keep the worker informed of the disposition of the matter.

APPENDICES

Appendix 1.0

Workplace Inspection Checklist & Report

G3 Workplace Inspection Checklist

- Checklist for regular safety inspections as necessary.

Floors and walkways	Yes	No
Are aisles clear of materials or equipment?		
Are main aisles at least 1 m (36 in) wide?		
Are doorways clear of materials or equipment?		
Are carpets or tiles in good condition, free of loose or lifting carpeting or tile?		
Are floors clean and free of oil or grease?		
Are floors kept dry?		
If supplies or materials are stored on the floor, are they away from doors and aisles and stacked no more than three boxes high?		

Fire safety and security	Yes	No
Are fire extinguishers clearly marked?		
Are fire extinguishers properly installed?		
Have fire extinguishers been inspected within the last year?		
Are workers trained to use fire extinguishers?		
Are flammable liquids properly stored?		
Will space heaters shut off automatically when tipped over?		
Are emergency phone numbers close to phones?		
Are smoke, fire, and burglar alarms in place?		

Stairs, ladders, and platforms	Yes	No
Are ladders safe and in good condition?		
Are stair handrails fastened to the wall securely?		
Are stairwells clear of materials and equipment?		
Are stairs and handrails in good condition?		
Are ladders and stairs provided with anti-slip treads?		

Walls	Yes	No
Are signs and fixtures securely fastened to the wall?		

Lighting	Yes	No
Are lighting levels in work areas adequate?		
Are work areas free of glare or excessive lighting contrast?		
Is task lighting provided in areas of low light or high glare?		
Are windows covered with blinds, drapes, or other means of controlling light?		
Does emergency lighting work?		

Storage	Yes	No
Are supplies and materials stored properly on shelves?		
Does your storage layout minimize lifting problems?		
Are trolleys or dollies available to move heavy items?		
Are floors around shelves clear of rubbish?		
Are racks and shelves in good condition?		

Electrical	Yes	No
Are electrical cords in good repair?		
Is there clear access to electrical panels and switch gear?		
Are electrical cords secured?		
Are proper plugs used?		
Are plugs, sockets, and switches in good condition?		
Are ground fault circuit interrupters available, if required?		
Are portable power tools in good condition?		

Computers	Yes	No
Are display screens free of dust?		
Are display screens bright enough with sufficient contrast?		
Are display screens positioned at a comfortable viewing level?		

Equipment and machinery	Yes	No
Is equipment and machinery kept clean?		
Is the equipment regularly maintained?		
Are operators properly trained?		
Are start/stop switches clearly marked and in easy reach?		
Is machinery adequately guarded?		
Is there enough work space?		
Are noise levels controlled?		
Are fumes and exhaust controlled?		
Do you have a lockout procedure in place?		

Entrances and exits	Yes	No
Is there safe access for workers and customers?		
Are emergency exits clear of materials or equipment?		
Are emergency exit signs working?		
Are emergency lighting units provided? Are they working?		

First aid	Yes	No
Is the first aid kit accessible and clearly labelled?		
Is the first aid kit adequate and complete?		
Is the first aid kit clean and dry?		
Are emergency numbers displayed?		

Chairs	Yes	No
Are chairs in good condition?		
Are chairs properly adjusted?		

Garbage	Yes	No
Are bins located at suitable points?		
Are bins emptied regularly?		

Hazardous materials	Yes	No
Are Material Safety Data Sheets provided for all hazardous materials?		
Are containers clearly labelled?		
Are hazardous materials properly stored?		
Are hazardous materials disposed of properly?		

Environment	Yes	No
Is air quality good?		
Are workers protected from cool drafts or excessive heat?		
Are workers protected from excessive or irritating noise?		

Parking	Yes	No
Are parking spots and walkways appropriately lighted?		
Are parking spots safe? (Names should not be painted on spots.)		
Are workers encouraged to use a buddy or escort?		
Is a speed limit posted on the parking lot?		

General worker questions	Yes	No
Do workers know where to go and who to call for first aid assistance?		
Do workers know where to find MSDSs for chemical products?		
Do workers know where to find personal protective equipment (for example, disposable gloves, eye protection)?		
Do workers know how to use personal protective equipment?		
Do workers know the procedures for working alone?		
Do new/young workers receive orientation specific to their workplace?		
Do workers receive adequate training in safe work procedures?		

Workplace Inspection Report

Use this report to record the results of your regular workplace inspections.

Company name: ______________________________

Date: ______________________________

Inspectors' names: ______________________________

Precise location	Description of hazard	Recommended corrective action	Person responsible for corrective action	Due date	Completed	
					Yes	No

APPENDIX 2.0

WorkSafe Incident Report & Procedures

WORK SAFE BC
WORKING TO MAKE A DIFFERENCE

INCIDENT INVESTIGATION REPORT

Worker and Employer Services Division

This form is provided to employers for the purpose of documenting the employer's investigation into a workplace incident. Please attach a separate sheet if necessary.

Employer name	Employer number
Employer head office address	

Incident occurred *ref: s. 3.4(a) Occupational Health and Safety Regulation (OHS Regulation)*

Address where incident occurred *(including nearest city)*	
Date yyyy-mm-dd	Time a.m. ☐ p.m. ☐

Injured person(s) *ref: s. 3.4(b) OHS Regulation*

Last name	First name	Job title	Age	Length of experience with this employer	Length of experience at this task/job
1)					
2)					

Nature of injury/injuries

1)
2)

Witnesses *ref: s. 174(4) WCA and s. 3.4(c) OHS Regulation*

Last name	First name	Address	Telephone
1)			( )
2)			( )
3)			( )

Incident description *ref: s. 3.4(d)–(e) OHS Regulation*

Briefly describe what happened, including the sequence of events preceding the incident.

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Statement of causes *ref: s. 174(2)(a)–(b) WCA and s. 3.4(f) OHS Regulation*

List any unsafe conditions, acts, or procedures that in any manner contributed to the incident.

Recommendations *ref: s. 174(2)(c) WCA and s. 3.4(g) OHS Regulation*

Identify any corrective actions that have been taken and any recommended actions to prevent similar incidents.

Recommended corrective action	Action by whom	Action by date
1)		
2)		
3)		
4)		

Persons conducting investigation *ref: s. 3.4(h) OHS Regulation*

Name	Signature	Type of representative			Date
		Employer ❒	Worker ❒	Other ❒	
		Employer ❒	Worker ❒	Other ❒	
		Employer ❒	Worker ❒	Other ❒	

For additional information on WorkSafeBC (Workers' Compensation Board of B.C.) and on the requirements for incident investigations, please refer to WorkSafeBC's web site: WorkSafeBC.com

Mailing address WorkSafeBC
PO Box 5350 Stn Terminal
Vancouver BC V6B 5L5

Fax number: 604 276-3247

Telephone information

Call centre: 604 276-3100 or toll free within B.C. 1 888 621-SAFE (7233)

After hours health and safety emergency: 604 273-7711 or toll free 1 866 922-4357 (WCB-HELP)

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WorkSafe Incident Reporting

Use this guide in conjunction with the requirements of the *Workers Compensation Act* (*WCA*), Part 3 Division 10, and the Occupational Health and Safety Regulation (OHS Regulation), section 3.4.

When is an investigation required?
Employers are required to immediately undertake an investigation into any accident or other incident that:
• Is required to be reported under section 172 of the *Workers Compensation Act*, or
• Resulted in injury requiring medical treatment, or
• Did not involve injury to a worker or involve a minor injury that did not require medical treatment but had the
potential for causing serious injury, or
• Was an incident required by regulation to be investigated.

Who should conduct the investigation?
• Incidents must be investigated by people knowledgeable about the type of work involved at the time of
the incident.
• If reasonably available, investigations must be carried out with the participation of one employer representative and one worker representative.

What is the purpose of an investigation?
The purpose of an investigation is to determine the cause or causes of the incident, to identify any unsafe conditions, acts, or procedures that contributed to the incident, and to recommend corrective action to prevent similar incidents.

Who receives copies of the report?
Incident investigation reports required by the *WCA* must be provided to the joint health and safety committee or worker representative as applicable, and to WorkSafe BC.

What follow-up action is required after an incident investigation?
After an investigation, the employer must without undue delay undertake any corrective action required to prevent recurrence of similar incidents and must prepare a report of the action taken. The report must be provided to the joint health and safety committee or worker representative as applicable. The follow-up report does not have to be provided to WorkSafe BC unless requested by a WorkSafe BC officer.

What information should be included in the investigation report?
An incident investigation report should answer the WHO, WHERE, WHEN, WHAT, WHY, and HOW questions with regard to the incident.
WHO Employer, injured person(s), other person(s) involved in the incident, witnesses, and persons carrying out the investigation
WHERE Place, location where incident occurred
WHEN Date and time of the incident
WHAT A brief description of the incident, including the sequence of events that preceded the incident
Before the incident occurred:
• What were the events that led up to the incident?
• What process(es) was/were occurring immediately prior to the incident?
• What was/were the worker(s) doing immediately prior to the incident?

• What was the last event before the incident occurred?
At the time of the incident:
• What happened at the time of the incident?
• What process(es) was/were occurring at the time of the incident?
• What was/were the worker(s) doing at the time of the incident?
• What hazard(s) was/were the worker(s) exposed to?
• What hazards may have contributed to the incident occurring?
• What hazards did the worker(s) encounter?
• What personal factors may have contributed to the incident occurring?
Other information:
• Other observations
• Other related information

WHY From the answers to “what,” identify any unsafe conditions, acts, or procedures that in any manner contributed to the incident. Why did the unsafe conditions, acts, or procedures occur? Why were the personal factors not identified and/or addressed before the incident occurred?

HOW An investigation report should recommend corrective actions to prevent similar incidents from occurring. Once it is known why an incident occurred, determine how to prevent recurrence.

For example:
• Improve workplace inspection and maintenance programs
• Repair or replace equipment/building
• Install safeguards
• Establish or revise safe work procedures
• Train/retrain person(s)
• Improve supervision

Additional information for determining why an incident happened To determine the most probable cause(s) of an incident, consider all details of the investigation, including witness statements and, where possible, the injured worker’s statement. Determine if the incident was due to an unsafe act, an unsafe condition, unsafe or inadequate procedures, or a combination of these. Consider whether the accepted/current procedures adequately address safety concerns associated with the activity that was taking place when the incident happened. Consider training, supervision, equipment controls, safeguards, and lock-out.

Unsafe acts — An unsafe act is a specific action or lack of action by an individual that is under the individual’s control. Examples of unsafe acts include: knowingly not following established rules, knowingly not following established procedures, knowingly disregarding a hazard, wilful misconduct, abusing equipment, knowingly using equipment incorrectly, choosing not to use personal protective equipment, and not locking out when required. Generally, violating a safety rule, not following a safe work procedure, or disregarding a hazard are considered unsafe acts.

Unsafe conditions — Examples include poor housekeeping, congested areas, deficient equipment, equipment lacking safeguarding or having ineffective safeguarding, lack of personal protective equipment, poor visibility, poor weather conditions, and lack of or inadequate training. Inadequate training should be considered an unsafe condition as opposed to a deficiency in skill or ability (personal factors). Inadequate procedures — Indications that procedures are inadequate include:

- Procedures are not available in written form
- Procedures do not identify inherent hazards
- Procedures do not identify hazard control methods
- Procedures do not identify safeguards that must be in place
- Procedures do not address pre-operation inspection requirements
- Procedures do not address lock-out requirements
- Procedures direct improper use of equipment or tools

Personal factors — A personal factor is a deficiency in skill or ability, a physical condition, or a mental attitude.

It is a factor inherent in an individual at the time of the incident. Examples include work fatigue due to manual exertion, distress due to emotional problems, the influence of alcohol or drugs, or illness. A condition causing an allergic reaction in some but not most workers should be considered a personal factor, not an unsafe condition.

APPENDIX 3.0

Worker and Supervisor Orientation Checklist

Worker Orientation Checklist

Use this checklist when training new workers on health and safety in your workplace (see pages 18–19).

Employee name: ______________________

Position (tasks): ______________________

Date hired: ______________ Date of orientation: ______________

Person providing orientation (name and position): ______________________

Company name: ______________________

Topic	Initials (trainer)	Initials (worker)	Comments
1. Supervisor name: ________ Telephone number: ________			
2. Rights and responsibilities a) General duties of employers, workers, and supervisors			
b) Worker right to refuse unsafe work and procedure for doing so			
c) Worker responsibility to report hazards and procedure for doing so			
3. Workplace health and safety rules a) ________ b) ________ c) ________ d) ________			
4. Known hazards and how to deal with them a) ________ b) ________ c) ________ d) ________			
5. Safe work procedures for carrying out tasks a) ________ b) ________ c) ________ d) ________			
6. Procedures for working alone or in isolation			

Topic	Initials (trainer)	Initials (worker)	Comments
7. Measures to reduce the risk of violence in the workplace and procedures for dealing with violent situations			
8. Personal protective equipment (PPE) — what to use, when to use it, where to find it, and how to care for it a) ____ b) ____ c) ____ d) ____			
9. First aid a) First aid attendant name and contact information			
b) Locations of first aid kits and eyewash facilities			
c) How to report an illness, injury, or other accident (including near misses)			
10. Emergency procedures a) Locations of emergency exits and meeting points			
b) Locations of fire extinguishers and fire alarms			
c) How to use fire extinguishers			
d) What to do in an emergency situation			
11. Where applicable, basic contents of the occupational health and safety program			
12. Hazardous materials and WHMIS a) Hazardous materials (controlled products) in the workplace			
b) Hazards of the controlled products used by the worker			
c) Purpose and significance of hazard information on product labels			
d) Location, purpose, and significance of material safety data sheets (MSDSs)			
e) How to handle, use, store, and dispose of hazardous materials safely			

Topic	Initials (trainer)	Initials (worker)	Comments
f) Procedures for an emergency involving hazardous materials, including clean-up of spills			
13. Where applicable, contact information for the occupational health and safety committee or the worker health and safety representative			

The following are is a list of items (not inclusive) to be discussed with the worker (as applicable) upon orientation or as required or identified

Topic	Things to discuss	Resources
Worker rights and responsibilities	• Responsibility to follow the Regulation and other health and safety rules • Responsibility to use PPE when required • Right to refuse unsafe work	• Regulation: Part 3, Rights and Responsibilities • Regulation: Sections 115–117 (*Workers Compensation Act*)
Falls from elevation (including ladder safety)	• Fall protection system being used • Fall protection procedures • Proper use of fall protection equipment • Ladder safety • Inspection and maintenance of ladders and fall protection equipment	• Regulation: Part 11, Fall Protection • *An Introduction to Personal Fall Protection Equipment*
Slips, trips, and falls	• Keeping work areas free of clutter • Removing tripping hazards (such as loose cords) • Cleaning up and disposing of spills promptly	• Regulation: Sections 4.39–4.41 • *Health and Safety for Hospitality Small Business*, page 6 • *Health and Safety for New Retail Workers*, page 11
Lockout (for machinery and power tools)	• Define lockout • Types of lockout • When to lock out • Review procedures for specific equipment	• Regulation: Part 10, De-energization and Lockout • *Lockout*
Lifting and moving objects or people (strains and sprains)	• Demonstrate safe lifting technique • Use of specialized equipment for lifting or moving materials or people • Storage priorities (heavier items at lower heights and lighter items higher up)	• Regulation: Sections 4.46–4.53 • *Handle With Care: Patient Handling and the Application of Ergonomics (MSI) Requirements* • *Understanding the Risks of Musculoskeletal Injury (MSI)* • *Preventing Musculoskeletal Injury (MSI)*
Guarding (for machinery and power tools)	• Types and purposes of guards • Inspection and use of guards • Requirement to leave guards in place	• Regulation: Sections 12.1–12.6 • *Safeguarding Machinery and Equipment* • *Safeguarding in Manufacturing*
Electrical safety	• Procedures for de-energization and lockout • When and how to use PPE • Maintaining safe distances from exposed power lines or cables	• Regulation: Part 19, Electrical Safety • *Working Safely Around Electricity*

Topic	Things to discuss	Resources
Forklifts and other mobile equipment	• Maintaining eye contact with equipment operator • Speed limits and locations of travel lanes • Equipment inspection and maintenance • Load limits and procedures for safe operation • Operators must demonstrate competency in using equipment	• Regulation: Part 16, Mobile Equipment • *Safe Operation of Lift Trucks*
Confined spaces (for example, working in tanks, silos, vats, rail cars, hoppers, or sewers)	• Location of any confined spaces in the workplace, and the hazards they pose • Who may or may not enter a confined space • Procedures workers must follow if they are required to enter a confined space	• Regulation: Part 9, Confined Spaces • *Hazards of Confined Spaces* • *Confined Space Entry Program: A Reference Manual*
Personal protective equipment (PPE)	• When and how to use specific PPE • Where to find PPE • Limitations of protection • Storage, maintenance, and inspection	• Regulation: Part 8, Personal Protective Clothing and Equipment
Chemical, biological, and physical hazards	• Potential health effects of exposure • Common roots of exposure • Ways to prevent exposure • How to recognize signs and symptoms of exposure	• Regulation: Part 5, Chemical and Biological Substances • Regulation: Part 6, Substance Specific Requirements
WHMIS	• Reading and understanding labels • Reading and understanding MSDSs • Location of MSDSs • Hazards of products being used • Control measures and appropriate PPE	• Regulation: Sections 5.3–5.19 • OHS Guidelines: G5.3-1–G5.15 • *WHMIS at Work*
First aid and emergency procedures	• Names and locations of first aid attendants • Locations of first aid kits • Locations of fire exits • Locations of fire extinguishers and how to use them	• Regulation: Sections 3.14–3.21 • Online First Aid Assessment Tool www2.worksafebc.com/calculator/firstaid

Topic	Things to discuss	Resources
Violence	• Procedures for identifying and dealing with aggressive customers, clients, or patients • Procedures for preventing and dealing with shoplifting and robbery incidents • Procedures for handling money • Procedures for opening and closing	• Regulation: Sections 4.27–4.31 • *Preventing Violence, Robbery, and Theft* • *Preventing Violence in Health Care* • *Home and Community Health Worker Handbook* • *Take Care*
Working alone	• Procedures for person checks • Work activities that may place workers at risk of injury, and which should not be performed when working alone • Procedures for late-night (10:00 p.m. to 6:00 a.m.) work • Procedures described under "Violence" (see previous topic)	• Regulation: Sections 4.20.1–4.23 • OHS Guidelines: G4.20.1–G4.22.2 • *Handbook for Employers — Working Alone, Late Night Retail, and Prepayment of Fuel*

Supervisor Training/Orientation Checklist

Use this checklist when training supervisors in their health and safety responsibilities.

Supervisor name: ______________________________

Date of training: ______________________________

Person providing orientation (name and position): ______________________________

Annual review date: ______________________________

Topic	Initials (trainer)	Initials (supervisor)	Comments
1. Supervisor health and safety responsibilities (see section 117 of the *Workers Compensation Act*)			
2. Company health and safety rules			
3. Unsafe conditions — how to report them and to whom			
4. Right of workers to refuse unsafe work (section 3.12 of the Regulation)			
5. Personal protective equipment — making sure it is available to and used by workers; and that it is properly cleaned, inspected, maintained, and stored (section 8.8 of the Regulation)			
6. How to supervise new, young, and regular workers in the safe performance of their jobs			
7. How to take corrective action when workers do not follow safe work procedures			
8. Workplace inspections — how and when to conduct them			
9. Hazard identification and risk assessment			
10. First aid — name of first aid attendant and locations of first aid kits and eyewash facilities			

Topic	Initials (trainer)	Initials (supervisor)	Comments
11. Reporting injuries — how to report them and how to respond to a report from a worker			
12. Incident investigations — how and when to conduct them			
13. Safe work procedures — how and when to develop them			
14. Worker instruction and training — when and how to conduct the following: a) Orientation b) Instruction and training c) Crew talks			
15. Records — how to document worker instruction, training, and supervision			
16. Emergency procedures reviewed (be specific): a) b) c)			
17. Review of written safe work procedures used by workers being supervised (be specific): a) b) c)			
18. Other topics covered (be specific): a) b) c)			

APPENDIX 4

Sample Emergency Action Plan (to be adapted to each project)

APPENDIX 7

Sample Field Forms

Biophysical Observation Form

***In Situ* Sediment Data Form**

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Biophysical Observation Form

Date (yy/mm/dd)	Proj. No.	Site Location	UTMs	Recorder

Biophysical Observations

Zone	Transect	Depth (m)	Transect Distance (m)	Substrate		Vegetation			
				Dominant	Sub Dominant	Dominant		Sub Dominant	
						Type	%	Type	%
A	1								
	2								
	3								
B	1								
	2								
	3								
C	1								
	2								
	3								

Zone

Type	Symbol
Nearest to Shore	A
Mid-distance from Shore	B
Furthest from Shore	C

Bottom Substrate

Type	Symbol
Rocky Shore-Bedrock	R-b
Rocky Shore-Rubble	R-r
Unconsolidated Shore-Cobble Gravel	UG

Bed Material

Class	Symbol	Size	Description
Fines	F	<2 mm	Smaller than a ladybug
Gravels	G	2-64 mm	Ladybug to tennis ball
Cobbles	C	64-256 mm	Tennis ball to basketball
Boulders	B	>256 mm	Larger than a basketball
Rock	R	>4000 mm	Includes boulders and blocks >4 m and bedrock
Anthropogenic	A		Riprap or other structures

Site Location:	Date:	UTMs:	Sketch Artist:

Sketch:

Comments:

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IN SITU SEDIMENT DATA FORM

GROSS SEDIMENT CHARACTERISTICS

Colour (check):
black ☐ dark brown ☐ brown-green ☐ gray-green ☐ blue-gray ☐ dull gray ☐ other:

Consistency (describe & check):
gel-like ☐ loose ☐ watery ☐ thick like pudding ☐ falls apart into fluffy pellets ☐ other:

Texture (check): silky ☐ talcomy ☐ gritty ☐ gravelly ☐ other:

Smell (check): odourless ☐ rotten egg ☐ acrid ☐ chlorine ☐ oil ☐ creosote ☐ other:

Description of Debris Present:	**Other Comments:**

GROSS CHARACTERISTICS OF VERTICAL PROFILE

Penetration Depth of Grab (cm):

Homogeneous throughout? Yes ☐ No ☐

If not, describe (include any horizontal streaks of brown or black; presence of varves or other obvious vertical layers; presence of thin oxidized layer on surface):

Other Comments:

ATTENTION

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