Date: October 20, 2014

**TO:** Board Members – Vancouver Park Board

**FROM:** General Manager – Parks and Recreation

**SUBJECT:** Enhancement Plan for Beaver Lake

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**RECOMMENDATION**

*THAT the Final Concept for the enhancement of Beaver Lake (Appendix A) be adopted.*

**POLICY**

The Greenest City Action Plan sets out ten goals to make Vancouver the greenest city in the world by 2020. Goal 6, Access to Nature, addresses the need to allow people to experience nature in the city. This goal has spurred the development of a number of related strategies that build upon the access to nature vision, including the Biodiversity Strategy, Urban Forest Strategy, Vancouver Bird Strategy, Green Operations Environmental Framework, the Healthy City for All Action Plan and the Environmental Education and Stewardship Action Plan, all of which support the enhancement of Beaver Lake.

The Park Board Strategic Plan, which includes commitments to being a leader in greening with a focus on healthy ecosystems, green operations and engaging people, also supports enhancing valuable riparian and wetland resources.

The Stanley Park Forest Management Plan specifically identified riparian areas and wetlands as having a particularly high value to wildlife and that protection and enhancement activities for them are to be given a higher level of consideration than in other areas of the forest.

**BACKGROUND**

On January 17, 2011, the Park Board approved the Stanley Park Ecological Action Plan. This plan was a direct result of the release of the Stanley Park Ecology Society's State of the Park Report for the Ecological Integrity of Stanley Park in spring 2010 and provides direction towards preserving the ecological integrity of the park for future generations.

The rapid infilling of Beaver Lake, a much visited riparian and wetland feature unique to Stanley Park and in the City of Vancouver, was identified in the Action Plan as a top priority for short-term restoration and enhancement. Studies have shown that the lake appears to be undergoing rapid infilling and accelerated succession due to non-natural alterations to its watershed over the last century, such as logging, construction of roads, trails and the overflow weir, disruption to surrounding hydrology, and the introduction of invasive plant species, mainly Fragrant Water Lilies. Without intervention, the lake will soon disappear, possibly within a decade, and eventually be incorporated into the forest. Countering the anthropogenically (human) mediated changes of Beaver Lake is critical to preserving this important riparian and wetland habitat and is supported by the Park Board's current Strategic Plan, the Forest Management Plan and the conclusions and concerns raised in the State of the Park Report for the Ecological Integrity of Stanley Park.

The Park Board also recognizes that this area is of cultural and spiritual importance to the Musqueam, Squamish and Tsleil-Waututh. Consequently, the Board approved a consultancy to develop a vision and an implementation strategy to restore and enhance wildlife habitat in and around Beaver Lake consistent with Park Board values of maximizing biodiversity and respecting cultural integrity.

In September, Communities in Bloom judges awarded the City of Vancouver, which participated in the International Challenge Excellence category, a 5-Bloom rating and a special mention for the Beaver Lake Enhancement Plan.

**DISCUSSION**

Consultant Team

A request for proposals was developed by staff and the Stanley Park Ecology Society (SPES) with an advisory committee of academics who generously contributed their expertise. A team of consultants with a broad range of local and international expertise, led by AquaTerra Environmental Ltd. and including Northwest Hydraulic Consultants, Bianchini Biological Services, Dr. Valentin Schaefer, Thomas Biebighauser, Lees + Associates Landscape Architects and Planners, and Hemmera, was engaged in March 2013.

Methodology

The team began by reviewing all documentation that assessed the biophysical environment of Beaver Lake and initiating their own field studies and analyses where data gaps were identified. The consultant team visited Beaver Lake throughout the summer, 2013, investigated the vegetation mats, probed the sediments with a rod, collected sediment cores, examined culverts and vernal ponds, walked Beaver and North Creeks, and generally confirmed the current physical and biological state of the lake compared to what was previously reported. Additionally, the consultant team confirmed that the vegetation mats were floating and of varying thickness, limiting the lake function, resulting in adverse impacts to Beaver Creek and reducing biodiversity.

The consulting team also visited Deer Lake and Burnaby Lake on August 17, 2013 to review areas where dredging was used to deal with accumulated sediments and Fragrant Water Lily (Burnaby Lake) and where watershed management primarily in the form of constructed wetlands to trap nutrients and geotextile used to manage water lily were used instead of dredging (Deer Lake). Regular meetings were held on site with Park Board staff, the Stanley Park Ecology Society and representatives of the Musqueam, Squamish and Tsleil-Waututh First Nations to discuss their findings and initial directions.

Study Results

Some of the key findings from the consultant team included:

- thick floating mats of organic materials cover most of the lake and range from 40 to 50 cm thick, strong enough for a person to walk on (mat detatchment is anticipated to have been the result of on-going beaver damming of the Beaver Creek outlet, which resulted in rapid water level fluctuations affecting root adherence to the lake bottom);

- there was no evidence of water being diverted from Beaver Lake and the majority of runoff entering the watershed flows into the lake;
- there was very little evidence of animals controlling non-native invasive plants growing in the lake with the exception of the Beaver Creek outfall (beavers were also using water lilies in their dams);
- the number and variety of fish in the Beaver Lake watershed appear to be declining;
- Beaver Creek was experiencing significant localized erosion due to large discharges of water from Beaver Lake related to beaver activities (water levels increased about 40 cm when the outflow was dammed) following clearing of the Beaver Creek outlet by Park Board staff to avoid flooding;
- the consultants concluded that reports that 100,000 cubic metres of bottom sediments were dredged from the lake in 1928 was likely closer to 2,800 cubic metres (100,000 cubic feet); and
- limited mineral soils were being washed into the lake, assumed to be due to stormwater from the Causeway being diverted into the Lost Lagoon biofiltration pond.

Vision and Key Environmental Management Objectives for Beaver Lake

The overall vision for Beaver Lake is for it to be a diverse and healthy ecosystem that provides recreation opportunities for the public while requiring little maintenance.

Nine key environmental management objectives were identified by the project team intended to enhance existing and post-dredge environmental conditions at Beaver Lake. These management objectives, discussed in detail in the consultants' report (refer to Appendix A), are to:

- maximize biodiversity;
- encourage aquatic life;
- establish a habitat mosaic on the landscape;
- facilitate fish utilization;
- prevent the spread of invasive species;
- minimize maintenance requirements;
- utilize plants of ethnobotanical relevance;
- maintain site character; and
- reduce reliance on municipal water inputs.

Preliminary Concepts

Four preliminary concepts were developed by the consultant team to illustrate a range of approaches to enhancement of the lake to achieve this vision and respond to the environmental management objectives. The four concepts, illustrated on Information Boards 5, 6, 7, and 8 on the project web page under Documents and more fully described and evaluated in section 7.1 Preliminary Concepts in the consultants' report, were:

1. Islands and Viewing Platforms – Maximizes Habitat Creation and Biodiversity
2. Open Water and Floating Boardwalk – Increases Passive Recreation but Reduces Wildlife
3. Open Water and View Tower – Creates Less Habitat and Biodiversity but Represents the Lowest Capital Cost
4. Islands and View Tower – Balances Habitat Creation and Biodiversity with Cost Considerations

A series of other related considerations were also presented for comment, including bog maintenance, incorporation of plants of ethnobotanical relevance, reintroducing extirpated species, use of aerators and geotextile fabrics, expanding interpretive signage, and long-term beaver management.

Consultation and Engagement

Open houses were held on November 21, 2013 at the Coal Harbour Community Centre and on November 23, 2013 at the West End Community Centre. The information boards, which can be found on the Beaver Lake Enhancement Plan project web page under Documents, and the comment sheet were available on-line prior to the first open house. The four concepts were also on display at 2099 Beach Avenue from November 25, 2013 until January 2, 2014. People were asked to review the panels and fill out a comment sheet. The comment sheet was available on-line until December 31, 2013; 570 comment sheets had been received by January 10, 2014.

Beaver Lake is within the traditional territories of three First Nations. The project team initiated consultation with the Musqueam Indian Band, Squamish Nation and the Tsleil-Waututh First Nation in April 2013 prior to the onset of work. Engagement was based on an acknowledgment of and respect for the strong connection of these First Nations to Beaver Lake and the surrounding lands and waters. An information board developed in consultation with each of the First Nations was displayed during each of the public open houses.

Consultation Results

There was a very clear consensus from the general public regarding directions for enhancement of the lake. Almost all (92%) respondents wrote a simple description of their ideal future for the lake which generally supported keeping the lake as a lake and making it as natural as possible. When asked which of the four concepts would they say most closely resembles their ideal future for the lake, noting the ultimate plan would likely be a hybrid design incorporating various features from all four, the majority (58%) preferred Concept I with islands and small viewing platforms. A large majority (77%) supported an option with a mixture of open water and islands (Concepts 1 and 4). There was very low support for Concepts 2 and 3 which had large structures and no islands. The majority of respondents supported:

- a balance of open water and islands (77%);
- controlling the worst of the invasive non-native plant species and embracing higher levels of diversity of habitat (66%);
- deepening the lake at greater initial cost to limit the spread of water lilies that now cover most of the lake (78%);
- deepening the lake to accommodate salmon moving through the lake (74%);
- temporarily relocating the resident beavers during lake enhancement and return them when complete with some design changes to limit the negative impacts of their activities (70%);
- having a few more viewing platforms around the shore of the lake (66%); and
- installing a toilet for greater convenience (50% - note: comments indicated support would have been higher if the plan showed the toilet further from the lake).

There was very little support for the idea of a floating boardwalk across the lake or for viewing towers near the lake.

There was clearly a large running and jogging contingent concerned their recreational use was not considered in the comment sheet. Many of them referred to a much valued 1 km loop around the lake that they wanted to see maintained.

Table 8 in the Ecological and Culturally Sensitive Enhancement Plan for Beaver Lake report (Appendix A) summarizes First Nations interests, issues and concerns. All three First Nations reviewed the options and Concept 1 is their preferred option for Beaver Lake. They are opposed to the inclusion of a toilet at the lake or a boardwalk feature crossing it.

Beaver Lake Bog

Three of the actions approved for Beaver Lake in the Stanley Park Ecological Action Plan were related to the bog located at the south-west end of the lake. Two of these actions were to update baseline information on the bog and monitor changes as a first step to prevent its disappearance, and to restore the bog's size and habitat values by removing encroaching trees and transplanting bog plants into damaged areas. Both of these actions have been completed by the Stanley Park Ecology Society, working with volunteers, and Park Board staff. Installation of a boardwalk and viewing platform with signage, to allow public access to the bog while reducing further damage from off-trail activities, was also approved but not yet funded.

The Beaver Lake comment form included a question about the bog to raise awareness of it as a special feature. Since it isn't yet accessible to the public, most respondents have never seen it. A majority (68%) supported keeping access to the bog restricted to protect its fragile vegetation from people and dogs. However, the Stanley Park Ecology Society supports building boardwalk into the bog to allow people to experience this unique habitat, in a controlled way, for its educational value and to have views over the bog to the lake. A boardwalk would have to be well-designed to control dogs and to prevent any other negative impacts on the bog.

A complete summary of comments received on the Beaver Lake Enhancement Plan can be found at on the project web page under Documents.

Recommended Design

Based on the results of the consultation and engagement, the recommended concept builds upon the preferred preliminary concept, Concept 1, which included islands and viewing platforms (illustrated and further elaborated in section 10 Finalized Conceptual Design of the consultants' report (Appendix A)). The recommended design with related enhancement features responds to the vision for restoration in that:

- biodiversity will be increased by creating a mosaic of habitat types in the Beaver Lake ecosystem consisting of restored open water, islands and riparian habitat;
- proposed passive recreation will be non-consumptive with little or no disturbance and includes walking, relaxation and nature appreciation; and
- self-perpetuating plant associations and communities will be established that are appropriate for the site.

The following key attributes were included:

- approximately 2.6 hectares of open water to depths that will allow fish passage and will slow the recolonization of invasive Fragrant Water Lily;
- constructed islands, which provide habitat for mammals, birds, amphibians, reptiles, fish and insects;
- vernal ponds (new and deepened existing ponds) around the perimeter trail which provide amphibian habitat and stormwater retention;
- improvements to the creeks to further enhance riparian habitat;
- a fish ladder and a 5 m deep channel through Beaver Lake, connecting Beaver Creek with North Creek to increase the potential for year-round salmonid utilization;
- a boardwalk and four additional viewing platforms to increase viewing and interpretive opportunities; and
- no changes which would impact the use of the perimeter path by runners or joggers.

Islands of various shapes and sizes could be formed within Beaver Lake from the sediment and some organic material removed to create open water. The islands would range in size from 6 to 40 metres in diameter, and be from 0.4 to 2 metres above the current elevation of water in the lake. The islands would increase animal and plant diversity, providing turtles with basking and nesting sites, birds with perches and nesting sites, and shade from trees on the islands would cool the open water in summer. A mosaic of open water, islands and wide range of plants provides excellent wildlife habitat and opportunities for viewing.

The consultants' report includes a detailed overview of the features of the finalized conceptual design including ecological features, recreation and interpretive features, infrastructure features, trail features, interpretative signage features, and aesthetic considerations.

Reducing Reliance on Potable Water

Municipal water is supplied to Beaver Lake to maintain lake levels and provide sufficient outflow to Beaver Creek. On January 17, 2011, the Board approved a recommendation to "continue to maintain water levels in the lake with municipal water until alternative sources can be found" because this water has been required to maintain optimal lake depth and flow in the watershed to sustain the bog and focal species, e.g. Cutthroat Trout, in North Creek. The consultant team was asked to suggest ways to increase flow into the lake, to increase rainwater retention in the Beaver Lake watershed and other ways to respond to the goal of reducing reliance on municipal water.

The consultants recommended a number of ways to reduce reliance on potable water:

- reinforce the dam controlling the water in Beaver Lake, which appears to have been built of permeable sandy loam soil;
- enlarge the small seasonal 'pocket' wetlands into vernal ponds along the Beaver Lake Trail (where soil was originally removed to build the dam and the trail around the lake) to capture runoff and allow it to slowly infiltrate into Beaver Lake under drought conditions;
- increase the capacity of the biofiltration area north of the overflow parking lot west of Pipeline Road into a larger stormwater storage/detention pond; and
- implement an improved and/or automated water supply management system so the source of potable water can be adjusted in response to water levels in Beaver Lake, i.e. install a sensor in the lake to continuously monitor water levels.

The project team dismissed diverting grey water to the lake due to the marginal anticipated volume, potential adverse environmental consequences (i.e. unknown water quality) and the anticipated high costs to collect and divert water to the lake. They considered the use of groundwater to supplement hydraulic inputs into the lake but were concerned about the costs and the potential for depleting or even inducing salination of the aquifer. If initial measures to reduce reliance on municipal water recommended by the consultants aren't completely successful, staff will further investigate the possibility and economic feasibility of groundwater as a potential supplementary water supply for the lake.

Next Steps

Upon approval of the recommended enhancement concept, consultants will be engaged to undertake an implementation plan including detailed design and construction documentation. The consultants will review technological approaches to the implementation with staff, SPES and any affected stakeholders in the park to evaluate their financial and environmental impacts and then develop a phasing plan with associated costs for the proposed enhancements. Funds are included in the 2015 – 2018 Capital Plan to begin implementation of the plan and to leverage funding from other levels of government.

A first phase to enhance the Beaver Lake watershed will be construction in 2015 of a Beaver Creek estuary step-pool and channel enhancement. This project, using funding secured by the Stanley Park Ecology Society, will allow upstream passage for salmonids from Burrard Inlet by eliminating existing barriers to their spawning migration.

**SUMMARY**

This report recommends adoption of the Final Concept for the enhancement of Beaver Lake (Appendix A, Ecological and Culturally Sensitive Enhancement Plan for Beaver Lake). The recommended concept will restore and maintain the lake in as natural a state as possible, reflecting the direction from the public consultation and the First Nations engagement. It also responds strongly to the Greenest City Action Plan's Access to Nature goal, which addresses the need to allow people to experience nature in the city, to related strategies and plans, and to the direction of the Stanley Park Forest Management Plan to give riparian areas and wetlands a higher level of consideration than in other areas of the forest due to their important habitat values.

General Manager's Office
Vancouver Board of Parks and Recreation
Vancouver, BC

Prepared by
Alan Duncan, Environmental Planner
/ad

# Ecological and Culturally Sensitive Enhancement Plan for Beaver Lake

Submitted to the Vancouver Board of Parks and Recreation
16 October 2014

Submitted to:

VANCOUVER BOARD OF PARKS AND RECREATION

CITY OF VANCOUVER

GREENEST CITY 2020

Submitted by:

AQUATERRA ENVIRONMENTAL LTD.

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# 1 Introduction

Photo: Beaver Lake in Winter (1898) – Vancouver Archives

Beaver Lake, situated within Stanley Park in the City of Vancouver, British Columbia, was documented formally in 1865 by Captain Edward Stamp[1], being referenced simply as a 'pond'. In 1907, the observed presence of beavers in the lake inspired its current name. Currently, Beaver Lake has an approximate surface area of 3.95 hectares (ha) with a watershed size of approximately 112 ha, dominated by mature coniferous forest. Historically, Beaver Lake may have been as large as 6.7 ha in size as a result of anthropogenic changes (Steel, 1988; refer to Section 3.2 for additional details); however, based on project-related discussions with First Nations and historical photographs (see above – note island with mature conifer in centre lake of lake), it is anticipated that the lake traditionally functioned more as a wetland, consisting of areas of localized open water on a seasonal basis. Currently, hydraulic inputs to Beaver Lake include North Creek, Zoo Creek, several unnamed ephemeral drainages, road run-off, designated stormwater inputs, precipitation, and municipal water.

# 2 Project Overview

## 2.1 Project Rationale and Objectives

Beaver Lake is a popular natural feature in Stanley Park, located in close proximity to some of the most heavily developed parts of the City of Vancouver. The lake has experienced sediment infilling in recent decades coupled with watershed modifications relative to its original pre-contact condition, resulting in shifts in water quality and habitat conditions. The incursion of non-native plant and animal species has also contributed to shifts in biodiversity and ecosystem function.

The sediment infilling of Beaver Lake has been identified as a top priority for short-term restoration and enhancement by the City of Vancouver and the Vancouver Board of Parks and Recreation (Vancouver Park Board). The Stanley Park Forest Management Plan (Vancouver Park Board 2009) has specifically identified riparian areas and wetlands as having a particularly

[1] An English sailor and entrepreneur who contributed to the early economic development of BC, including the development of a mill in the 1860s. Those workers settled in the area where the City of Vancouver later developed.

high value to wildlife and that their protection and enhancement activities are to be given a higher level of consideration than in other areas of the forest. Consequently, the option of "doing nothing" and allowing the rapid infilling of Beaver Lake to continue is counter to the Vancouver Park Board's current Strategic Framework (Vancouver Park Board 2012), the Forest Management Plan and the conclusions and concerns raised in the State of the Park Report for the Ecological Integrity of Stanley Park (SPES, 2010). Vancouver Park Board also recognizes that this area is of cultural and spiritual importance to the Musqueam, Squamish and Tsleil-Waututh Nations. The goal is to restore and enhance wildlife habitat in and around Beaver Lake in keeping with Park Board values of maximizing biodiversity and respecting cultural integrity.

In an effort to meet these abovementioned commitments, the City of Vancouver has engaged a team of consultants, led by AquaTerra Environmental Ltd. (AquaTerra), to develop an Ecological and Culturally Sensitive Enhancement Plan for Beaver Lake. In undertaking this work, the consultant team worked closely with the Stanley Park Ecology Society (SPES). Existing available data was compiled and reviewed from a comprehensive library of previous studies and surveys, additional field data was collected where data-gaps were identified and to describe the physical and ecological systems, and First Nations were consulted regarding traditional use and traditional knowledge. The resulting collated information on Beaver Lake and the contributing watershed, including some potential historical inaccuracies, was carefully considered during the development of several enhancement options, which were presented during the public consultation process. This report represents a summary of the findings from the field studies and consultation, outlines the preliminary and preferred enhancement options, and outlines the next steps to advance the project.

## 2.2 Project Team

The project team consists of an international multidisciplinary group of consultants, comprised of independent biologists, researchers and academics who each applied his or her specialised skills and knowledge to the project. The team is led by AquaTerra Environmental Ltd., supported by Hemmera Envirochem (First Nations consultation), Northwest Hydraulics Consultants (hydrology and geology), Lees+Associates (landscape architecture and planning), Bianchini Biological Services (wildlife), Dr. Val Schaefer (lake restoration and invasive species management) and Mr. Tom Biebighauser (wetland restoration and invasive species management). Key project team personnel and roles are discussed below:

**Chris Lee** (AquaTerra) is a Registered Professional Biologist (RPBio), and Principal of AquaTerra Environmental Ltd. Chris has extensive experience in aquatic and terrestrial biology, environmental monitoring, dredging, Species-at-Risk, and erosion & sediment control.

**Jemma Scoble** (Hemmera) has diverse and extensive local experience working in the areas of First Nations engagement and consultation. Jemma has unparalleled experience leading consultation and engagement with First Nations on habitat compensation and restoration projects throughout the Lower Mainland.

**Derek Ray (P.Geo.) and Dr. André Zimmermann** (**P.Geo.**) (Northwest Hydraulics Consultants). Derek Ray is senior geomorphologist and a Principal with NHC with over 15 years of experience in watershed restoration, fish habitat assessment and restoration, and construction within sensitive aquatic ecosystems. Dr. Zimmermann is a senior geomorphologist and Associate with NHC. He specialises in hydrology, sediment dynamics, and watershed processes. He previously conducted an undergraduate research project at Beaver Lake that investigated the age and composition of sediments. As part of this previous work, he also developed a hydrology model of the watershed.

**Erik Lees, John Kirbyson and Katy Amon** (Lees+Associates Landscape Architects and Planners). John Kirbyson is a former employee of the City of Burnaby, who assisted in the coordination of the dredging of Burnaby Lake, which was completed in 2011. Lees+Associates personnel prepared the preliminary conceptual designs, coordinated public consultation events, and developed the finalized the preferred conceptual design for Beaver Lake.

**Claudio Bianchini** (Bianchini Biological Services) is a Registered Professional Biologist and former SPES member with over 25 years of experience relating to birds and Species-at-Risk. Having completed numerous projects within Stanley Park, Claudio possesses a unique insight pertaining to the subtleties and key issues of Stanley Park ecosystems.

**Dr. Valentin Schaefer** (University of Victoria) is the faculty coordinator of restoration of natural systems at the University of Victoria and is an Urban Lake Restoration Specialist. Dr. Schaefer has undertaken research relating to urban ecosystems and the function of modified (i.e., anthropogenically influenced) ecosystems.

**Thomas Biebighauser** (Independent Biologist and Author) is a wildlife biologist and wetland ecologist, and is author of ‘Wetland Restoration and Construction’, amongst other books. Based out of Kentucky USA, Tom is regularly retained by the provincial government and educational groups to give workshops and assist with design and construction of lakes, ponds and wetlands. To date, he has restored over 1,400 wetlands.

The team was supported by **Robyn Worcester and Brian Titaro** (SPES), who have both amassed a wealth of knowledge relating to the ecological function of Beaver Lake. Additionally, First Nations provided significant value relating to the traditional knowledge of the area, including but not limited to historical plant and animal species observations and historical habitat conditions.

## 2.3 Role of SPES

The Stanley Park Ecology Society provides experiential learning, educational outreach, and conservation and programs within Stanley Park. SPES entered into a Joint Operating Agreement with the Vancouver Park Board in 1997 and advises the Vancouver Park Board on conservation within the park with an emphasis on wildlife, habitat and Species-at-Risk. SPES’s

key goals applicable to the project include the undertaking of collaborative research to provide a basis for informed actions by SPES, its partners and the broader community, and to maintain and restore the ecological integrity of Stanley Park's ecosystems through independent initiatives and partnerships. SPES provided the project team with a variety of historical studies completed for Beaver Lake and Stanley Park as well as ongoing monitoring data and an inventory of the watershed undertaking by students of BCIT's Fish, Wildlife and Recreation program.

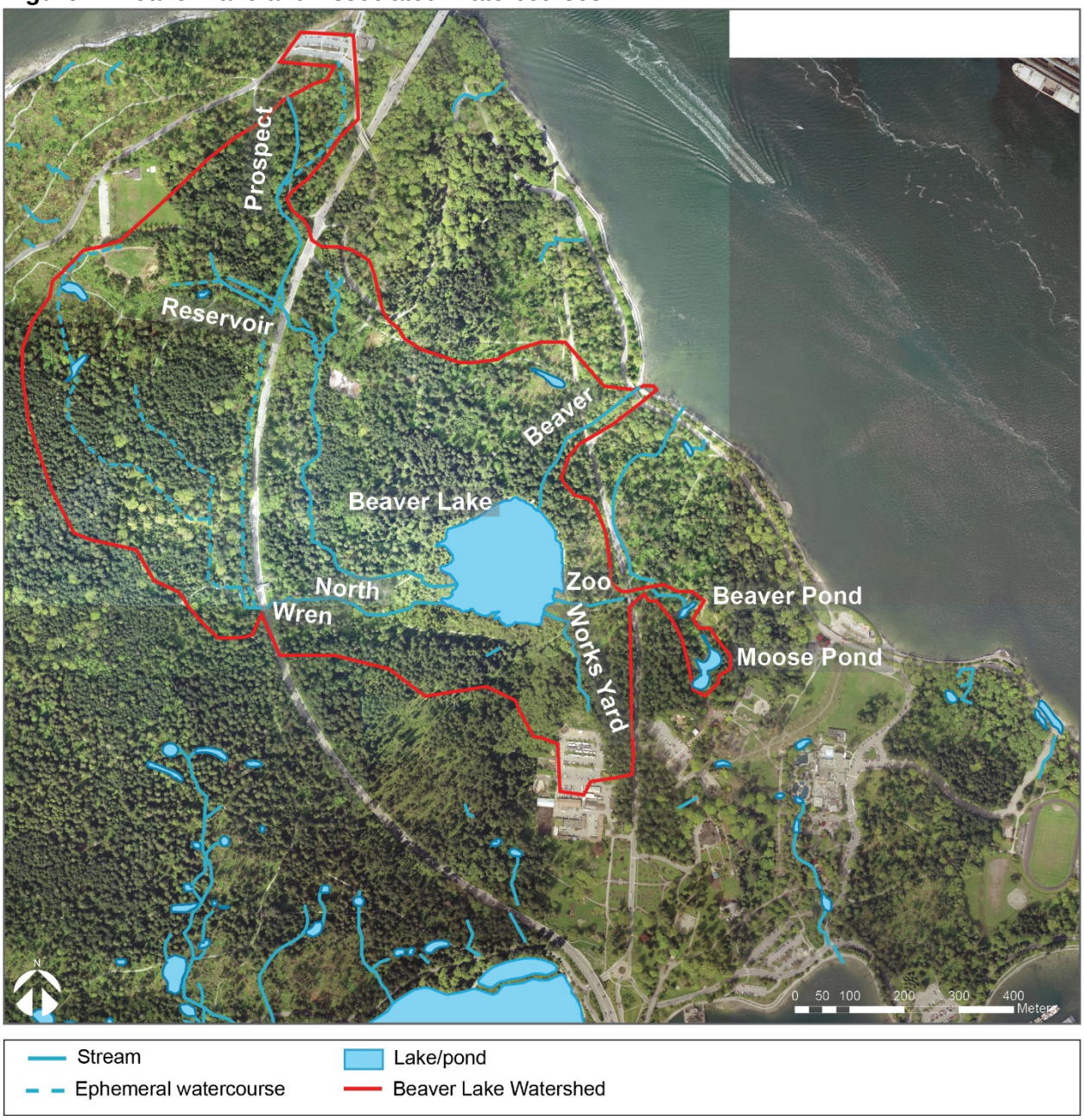
# 3 Site Description

## 3.1 Physical Setting

Beaver Lake is located in the east-central portion of Stanley Park, which is situated in close proximity to the densely populated West End neighbourhood of Vancouver, BC (**Figure** ). The lake covers an area of approximately 3.95 ha and drains a watershed area of 112 ha, divided into two main tributaries, Zoo Creek and North Creek. Outflow from Beaver Lake, which is controlled by an earth-filled dam and weir, drains into Burrard Inlet via Beaver Creek (**Figure 2**).

**Figure 1:** Beaver Lake, Stanley Park, and Neighbouring Core Vancouver Areas

**Figure 2:** Beaver Lake and Associated Watercourses




Underlying Stanley Park is Cretaceous-Tertiary Age sandstone (70 million years old and older) with Oligocene (30 million years old) basalt dikes at the north and south ends of the park (MineralsEd, 2012). An ice sheet retreated from Stanley Park following the recent Holocene glaciation, which ended approximately 9,000 years ago, and the area was inundated by the ocean during the post-glacial period (Clague, 1994). Following the emergence of Stanley Park as sea level dropped and the land rose, vegetation established to form a layer of organic soil at the surface. Much of the undeveloped portions of Stanley Park currently consist of coniferous coastal forest.

Beaver Lake is located in the wet coastal zone of British Columbia, which is typically dominated by low-pressure cyclonic weather systems in the fall and winter that track from the Pacific Ocean, bringing moist air that results in precipitation as the air mass rises over the adjacent mountains. In contrast, high-pressure anti-cyclonic systems, which tend to dominate during the summer months, result in clear skies and dry weather. Climate normals for the North Vancouver Wharves Station (#1105669) for the period 1981 to 2010 show that average precipitation in Vancouver is about 1,700 mm, much of which falls as rain, and over 80% of which falls between September and May.

In addition to typical rainfall events, precipitation extremes are also important to the hydrology of Beaver Lake. Intense rainfall systems that deliver over 20 mm of precipitation in a day are common in the fall and winter, and storms delivering up to 40 mm occur regularly, while extreme rainfall of over 100 mm within a 24-hour period has been recorded. Due to its position at just above sea level, snow in the watershed is rare but when it occurs, can contribute to increased run-off when melting occurs as part of a rain-on-snow event.

The strongly seasonal distribution of rainfall would typically result in very low, to no flow in small watersheds on the coast. Municipal water is supplied to North Creek, as required, to ensure constant flow within Beaver Creek and to maintain lake levels during dry periods year round.

## 3.2 Historical Conditions / Land Use

Stanley Park, which was incorporated in 1888, quickly became a popular gathering area for recreational activities including hiking, picnicking, fishing and ice skating. Soon thereafter, Beaver Lake became a recreational hub after a perimeter trail and outflow weir were constructed. In 1916, a fish hatchery was constructed and the lake was stocked with salmon and trout for the next 30 years. Notably, historical Park Board minutes indicate 100,000 trout and salmon were stocked in the lake in 1918 and a recreational fishing license was required to fish in the lake. To ensure sufficient water was available to maintain the stocked fish populations, flow into Beaver Lake was augmented with municipal water, which continues today.

Photo: Beaver Lake Fish Hatchery (1925) – Vancouver Archives

### 3.2.1 First Nations Use

Beaver Lake is within the traditional territories of the Musqueam, Squamish and Tsleil-Waututh First Nations. These Nations have been connected to the lands and waters of their territories since time immemorial and this is validated by their Oral Histories and genealogies. The project area is located in proximity to former village sites, cultural sites, and archaeological sites. Beaver Lake and Stanley Park are of known cultural and spiritual significance to the three Nations. As such, it was important to the project team, Vancouver Park Board and SPES that the area be understood in the context of traditional and current use.

Given the sacred nature of the project area, planning and design of preliminary and finalized enhancement concepts were undertaken in accordance with protocol and with respect. It is understood that future phases of design work as well as implementation and management of Beaver Lake will be undertaken with the same spirit.

### 3.2.2 Historical Dredging and Lake Levels

In 1918, trees and debris were reportedly removed from the perimeter of Beaver Lake followed by dredging of sediment from the lake bottom in 1928, which were undertaken by the Vancouver Park Board to slow the natural infilling of the lake, which had a maximum depth of only 1.2 m in 1911. Although the reported dredging volume was 105,505 $m^3$ (Steele 1988), a more likely dredge volume would have been 3,000 $m^3$ (105,505 $ft^3$). Comparatively, 105,505 $m^3$ would equate to dredging to a depth of 1 m below existing grade over an area of 10.6 hectares, which is significantly larger than the Beaver Lake surface area. No details or newspaper articles relating to the dredging were found in the Vancouver archives, further alluding to the presumably smaller scale of the dredging operation. Following weir and trail construction around Beaver Lake in 1911, it is estimated that the lake level consequently rose between 20-30 cm.

## 3.3 Priority Invasive Species

Beaver Lake and the adjacent riparian and forested habitats currently exist as a novel ecosystem[2], which has been significantly altered as a result of anthropogenic activities including the introduction of both invasive plant and animal species.

### 3.3.1 Invasive Plant Species

Since 2004, SPES has mapped numerous invasive species observations, as summarized in the 2012 SPES Invasive Plant Mapping Report (SPES 2012). Although SPES and its volunteers regularly remove invasives, limited resources and volunteer capacity issues serve to generally

[2] Defined as an ecosystem that has been altered in structure and function as a result of anthropogenic activities, but still maintains some habitat value.

reduce the rates of establishment, but not necessarily eradicate identified invasive plant species within the park boundaries.

Nine (9) high priority invasive plant species observed within or adjacent to Beaver Lake, with a high potential for modulating ecosystem function and limiting the success of restoration efforts (if inadequately managed), are as follows:

*Aquatic Invasive Plant Species*

1. Fragrant Water-lily (*Nymphaea odorata*) was introduced into Beaver Lake for the 40th Jubilee of Dutch Queen Wilhelmina in 1938. The lilies, which produce colourful flowers each summer, have accelerated the succession of Beaver Lake through an increase in decaying biomass and the establishment of floating mats (discussed in additional detail in Section 4.3). Shallow ponds and lakes are particularly susceptible to the rapid spread of this species, which can eventually cover the entire water's surface during summer months, limiting the mixing of oxygen and increasing water temperature. Water lilies are typically foraged on by beaver, muskrat and deer, which help to control their spread.

2. Purple Loosestrife (*Lythrum salicaria*) has been observed within Beaver Lake including areas within and adjacent to the floating mats, which are prevalent across much of the lake. The Purple Loosestrife density appeared higher within the eastern portion of the lake. If left unmanaged, Purple Loosestrife will rapidly propagate, resulting in dense monotypic stands that out-compete native wetland plants. Purple Loosestrife is typically not utilized as abundantly as native wetland species for cover, food or nesting.

3. Yellow Flag Iris (*Iris pseudacorus*) is prevalent along the perimeter of Beaver Lake, particularly along the northern boundary. Yellow Flag Iris spreads along shorelines, wetlands and lakes by seed or by slowly colonizing the shoreline via rhizomes, resulting in monocultures in water up to 0.3 m deep. It out-competes native riparian vegetation and is not typically used by native wildlife for food or habitat. Yellow Flag Iris can also alter habitat by trapping sediment, increasing the amount of decaying biomass, and compacting underlying substrate. In the spring, it is differentiated from surrounding vegetation by its large, showy flowers but can resemble native common cattail (*Typha latifolia*) during early emergence. Following flowering, seed pods develop. Managing the removal of seed pods is one of the methods for effective management.

*Riparian and Terrestrial Invasive Plant Species*

4. Japanese Knotweed (*Polygonum cuspidatum*) is a recent addition to the invasive species list in Stanley Park. It has been observed on the trails north of Beaver Lake and if left unmanaged, can quickly out-compete other vegetation, resulting in dense monostands. Often found near water and along stream corridors, this rhizomatous species forms a deep, dense mat, limiting the ability to effectively manage and control it.

In the fall and winter, Japanese Knotweed becomes dormant leaving banks exposed and susceptible to erosion.

5. Himalayan Blackberry (*Rubus armeniacus*) is prevalent throughout much of Stanley Park and is a species that was introduced in the late 1800s because of the large, sweet berries that it produces each summer. Unfortunately, Himalayan Blackberry has the common traits of an invasive species, including rapid growth, out-competition of native species, and decreasing habitat use by wildlife. The State of the Park report included a study on the effects of Himalayan Blackberry on biodiversity, noting that the diversity of bird species was almost twice as high in natural habitats relative to those dominated by Himalayan Blackberry (i.e., 91 bird species in natural habitats versus 48 bird species in blackberry-dominated habitats).

6. English Ivy (*Hedera helix*) suppresses and out-competes native vegetation to form a dense, monoculture groundcover with limited habitat function for wildlife. English Ivy can rapidly encircle shrubs and trees, growing vertically and weakening the tree by adding significant weight to the trunk and branches, increasing the potential for windthrow. There are on-going attempts by the Stanley Park Eco-Stewards (formerly 'Ivy Busters') in Stanley Park, which has removed hundreds of kilograms of material during removal efforts thus far.

7. Lesser Periwinkle (*Vinca minor*) is a trailing, evergreen garden escapee, which can form extensive mats along the forest floors and riparian areas that exclude native vegetation. Periwinkle is still commonly used as ornamental ground cover. During the 2013 field surveys, periwinkle was observed along the banks of Beaver Creek.

8. Yellow Lamium (*Lamiastrum galeobdolon*) is a trailing garden escapee often associated with hanging baskets. Lamium forms dense mats on the forest floor, limiting the growth of native herbaceous and shrub species. It is adapted to growing in both shaded and open areas and has a rapid growth rate. Seeds are often dispersed by insects, resulting in new colonies.

9. Reed Canarygrass (*Phalaris arundinacea*) is a perennial grass that begins to grow very early in the spring. Although native varieties of Reed Canarygrass are thought to exist across Canada, invasive varieties are thought to have originated in Eurasia. Hybridization between invasive and native varieties is thought to have occurred (Kaufman and Kaufman 2007). Reed Canarygrass can form dense colonies that exclude other plants and alter wildlife habitat. Moreover, Reed Canarygrass can alter the hydrology of an area as it serves to trap silt and detain water as a result of dense root mats. Nitrogen enrichment of wetlands increases the ability of Reed Canarygrass to suppress native species growth. As a result of its extensive underground root system,

Reed Canarygrass is difficult to control. Repeated cutting during the growing season can eliminate it. Prolonged inundation can also kill Reed Canarygrass.

### 3.3.2 Invasive Animal Species

The three (3) priority invasive animal species with the largest potential to adversely affect native species utilizing Beaver Lake consist of American Bullfrog (*Rana catesbeiana*), Green Frog (*Rana clamitans*), and Red-eared Slider (*Trachemys scripta elegans*).

American Bullfrog is not found naturally in BC and is surmised to have spread in the early twentieth century by people wanting to capitalize on the sale of frog's legs to receptive restaurants. American Bullfrog quickly began to spread and reproduce in a variety of aquatic habitats, which can include any waterbody that remains wet throughout the year. Unlike many native frog species, American Bullfrog tadpoles take two years to metamorphose into adults. Tadpoles are primarily herbivorous but they become predatory as adults, consuming a variety of insects, fish, birds, mammals and other amphibians, including native species, which are often out-competed by bullfrogs. In contrast, Green Frogs, which are native to eastern North America, are often able to coexist with native species. Because of their smaller size, they are often found alongside Northern Red-legged Frogs (*Rana aurora*); however, egg masses may contain upwards of 5,000 eggs. Despite being less aggressive than American Bullfrogs, the tadpoles and adults do compete with native amphibians for food and habitat resources, which can adversely affect some of the less adaptable native amphibian species.

Much like Green Frog, Red-eared Slider competes with native turtle populations for food and habitat (i.e., nesting, basking and refuge) resources. They are also known to be vectors for disease, which can be spread indiscriminately to other species (including humans) as well as native turtle populations, including the endangered Western Painted Turtle (*Chrysemys picta* population 4). The Red-eared Sliders at Beaver Lake are anticipated to have been released as unwanted pets by a member(s) of the public.

### 3.3.1 Invasive Species Ecosystem Effects

Invasive species can significantly alter the productivity of an ecosystem and the benefits, termed 'ecosystem services' that are provided by functional ecosystems. These services can include contributions to the human food supply, the provision of raw materials, air quality and climate regulation (carbon sequesterization), water regulation and purification, pollination and storm protection. Ecosystem effects can also be aesthetic, contribute to recreation/tourism, and include spiritual/cultural as well as educational and scientific values. In the United States alone, management of invasive species is projected to be in excess of $120 billion per year (Pejchar and Mooney 2009). The costs are largely the result of trying to maintain the ecosystem services that we rely upon and minimizing the impacts of invasive species, which can contribute to reduced flow in waterways, disrupted fire regimes, and the loss of biodiversity. Of note,

however, invasive species can also improve certain ecosystem services (Young 2012), such as improved nesting or cover for certain bird species. These altered, 'novel' ecosystems retain (positive or negative) ecological function and in the presence of continued environmental change and globalization, have resulted in the broadening of restoration and enhancement targets to ensure that goals relating to the maximization of biodiversity and maintenance of ecosystem services are not overly lofty or unrealistic by trying to fulfill unattainable traditional restoration goals.

The natural remnants of the altered ecosystem (termed 'ecological memory') often has implications for its ecological restoration and enhancement, being particularly true in urban situations, such as Beaver Lake, where repeated disturbance has masked the history of the site. The ecological memory remaining may be insufficient for a site to restore itself in the absence of intervention, and as a result, enhancement activities are required to direct the future of the site. Conversely, in light of climate change and other rapidly changing environments, the existing ecological memory may be poorly suited to the new conditions, resulting in the need to create new or increasingly novel ecosystems during restoration and enhancement efforts. The loss of ecological memory facilitates the establishment of foreign invasive species. These invasives may eventually create a new stable domain with its own ecological memory and degree of resilience.

Photo: April 2014 Fragrant Water-lily mats prior to becoming active. Float-plane fly-over.

Photo: July 2014 Fragrant Water-lily mats established. Float-plane fly-over.

## 3.4 Effects of Beaver Activity

Photo: Beaver Bafflers and Outlet Protection. Installed June 2014.

In early June 2014, SPES and the Vancouver Park Board collaborated to construct and install two beaver bafflers (based on the Clemson Pond leveler design) around the Beaver Lake outfall, which conveys flow into Beaver Creek. The primary purpose of the bafflers is to prevent the resident beavers from damming the outfall, which reduces creek flow resulting in fish stranding, localized erosion, and potential mortality. In the absence of intervention, flow to Beaver Creek would be cut-off and the lake would flood over the perimeter trail and into the surrounding forest. The beavers utilizing the lake would attempt to continue to maintain some open water; however, beaver activity alone would be insufficient to maintain the lake.

Prior to the construction of the bafflers, Park Board staff were tasked with regularly removing organic material (often comprised of sediment, branches, and roots) that had been pushed against the outfall by beavers in an effort to stop the discharge of water from the lake. As a result of the beaver activity, the area surrounding the Beaver Lake outfall consisted of open water, whereas surrounding areas were covered by floating Fragrant Water-lily mats. The water depth at the outfall was also significantly deeper than the rest of the lake, which may be the combined result of beaver activity and historical dredging.

Park staff collect a significant amount of material each year, which is temporarily stockpiled along Beaver Lake Trail. The removal of accumulated material results in a rapid release of Beaver Lake into Beaver Creek, which has the potential to result in localized erosion and adversely affect resident and released fish populations within the creek. As part of the project, Northwest Hydraulics installed a flow gauge within the creek beneath Pipeline Road, the results of which are discussed in detail in Section 5.3.3.


Photo: Accumulated material on Beaver Lake Trail.

The constant beaver damming efforts coupled with the periodic removal of accumulated material by park staff has resulted in minor, yet fairly rapid, fluctuations in the lake level. The project team surmises that these lake water level fluctuations are the primary factor contributing to the floating

organic mats. Specifically, the shallow rooting structure of the Fragrant Water-lilies and exerted buoyancy forces imposed on the lilies during water level fluctuations caused the lilies and associated root masses to become unsecured from the lake bottom. In some cases, the underlying organic substrate has accompanied the root masses, leaving an exposed substrate consisting of glaciomarine clay and sand.

Photo: Accumulated material at outfall prior to bafflers.

The vegetation mats contain numerous native species of emergent vegetation including American Bulrush (*Scirpus americanus*), Chamisso's Cotton-grass (*Eriophorum chamissonis*) and sedges (*Carex* sp.). Some of the mats are actively undergoing succession to dry land with Red Alder (*Alnus rubra*) over 2 m in height already growing in some areas.

# 4 Review of Available Background Information

## 4.1 Summary of Biophysical Studies

A total of forty-four (44) scientific reports/studies dating back to 1941 have been completed within Stanley Park, which has been compiled and maintained by SPES. As part of the background review portion of the project, available and pertinent background information was reviewed to identify focal survey areas, species of management concern, and to assess biological, ecological and biophysical changes over time. A summary of the reports/studies and the area(s) of interest are included in **Appendix A**.

## 4.2 Summary of Historical Studies

### 4.2.1 Stormwater Management Plan

In 1999, Kerr Wood Leidal (KWL) completed a study evaluating stormwater inputs and identifying stormwater management objectives for Stanley Park, including Beaver Lake and North Creek. The study concludes that run-off from road surface is a very small portion of the total water input into the hydrologic regime, and will not have a measurable impact on water levels or flow-through, necessitating flow augmentation (via municipal water inputs) to maintain current water levels.

The causeway run-off (which has since been diverted to a settlement pond) included a variety of contaminants including sand, grit, sediments, metals (partially associated with particulates and

partially in dissolved forms), low levels of oil, grease and fuels, and low levels of nutrients from organic matter.

### 4.2.2 A Study of the Beaver Creek Watershed: Historical Sedimentation, Contemporary Ecology and Hydrology with Predictive Monitoring

In 1999, a study was published which served to assess the lake bed sediments, hydrology and ecology. A number of sediment samples were collected. Inorganic samples comprised up to 60% of some samples, suggesting that the sedimentation rate was much slower than previous estimates. Sedimentation rates were estimated at 0.52 – 0.62 kg/m$^2$/year (average: 0.57 kg/m$^2$/year). Organic sediments were concluded to be almost completely derived from the die-off of aquatic plants. The inorganic sediments have greatly increased since the onset of industrialization and were concluded to be likely be coming from lake margin areas and stormwater inputs rather than air transport. Additionally, informal discussions with park staff indicated that trails crews had historically put between 4-5 m$^3$ of gravel on the trail per year to replace gravel that had eroded away (and presumably entered the lake). Other contributions were concluded to potentially include North Creek and Zoo Creek.

Predictive modelling, accounting for evaporation and stream discharge concluded that lake and creek water levels would drop drastically with the elimination of city water, but winter precipitation amounts would be sufficient to keep a substantial amount of water flowing through the lake and creek.

### 4.2.3 Sediment Characteristics of Beaver Lake and Implications for Remediation; A Pilot Project

In 2011, a study funded by the Faculty of Environment, Environmental Science Program at Simon Fraser University to undertake a study to evaluate concentrations of metals in the Beaver Lake sediment. Metals concentrations decreased with increasing sediment lake and it was concluded that there was no direct point source of metal into the lake. The elvated metals were concluded to be of atmospheric origin.

The report recommended the following:

1. Confirm the presence of high levels of metals, notably copper in Beaver Lake sediments prior to dredging.
2. Remove plant growth from the interior of the wetland to reduced autochthonous organic matter inputs.
3. Replace the gravel trail with a board walk, (at least partial), restricting the amounts of gravel entering into the wetland.

# 5 2013 Field Study Program

## 5.1 Fish Presence Survey Results


Photo: Captured Three-spined Stickleback

On 21 June 2013, AquaTerra personnel conducted a detailed assessment of fish presence within Beaver Lake and Beaver Creek using hand dip-nets in shallower portions of the lake and an electrofisher within Beaver Creek. Within Beaver Lake, captures were limited to Three-spined Stickleback (*Gasterosteus aculeatus*). The warm lake temperature, low dissolved oxygen concentration (refer to Section 5.4 for details) and shallow depth are anticipated to preclude the presence of salmonids. Within Beaver Creek, fish captures included Three-spined Stickleback, juvenile Coho Salmon (*Oncorhynchus kisutch*), and Prickly Sculpin (*Cottus asper*), located in the lower reach near the outflow. The juvenile Coho Salmon captured during the fish presence survey are reportedly released as part of elementary school programs (information source: SPES) and do not naturally occur within the system.


Photo: Electrofishing

The Hatfield (1984) study found that the maximum depth of Beaver Lake was 1.8 m. The fish found in the lake at the time were Three-spined Stickleback (*Gasterosteus aculeatus*), Carp (*Cyprinus carpio*), Prickly Sculpin (*Cottus asper*) and Cutthroat Trout (*Oncorhynchus clarkii clarkii*). The fish in Beaver Creek included Cutthroat Trout, Coho Salmon (*Oncorhynchus kitsch*) – likely released as a component of educational programs, Threespine Stickleback and Western Brook Lamprey (*Lampetra richardsoni*) – Carp and Western Brook Lamprey were incidental. In North Creek, fish captures were limited to Cutthroat Trout. No Cutthroat Trout captures were reported elsewhere in the lake. Cutthroat Trout are still present within the system; however, their distribution appears to be limited North Creek, which flows into Beaver Lake from the northwest. Periodic fish sampling, conducted by SPES, has not resulted in any captures of Cutthroat Trout in Beaver Lake since 2009.


Photo: Captured Coho fry.

## 5.2 Marsh Bird Survey Results

One of the few identified data-gaps during the review of available background data consisted of a formal inventory of marsh bird data. As a result, digital audio files of target species calls (American Bittern [*Botaurus lentiginosus*], Sora [*Porzana carolina*], Virginia Rail [*Rallus limicola*], and Green Heron [*Butorides virescens*]) were prepared. Calls files conformed to Resources Inventory Committee (RIC) standards for marsh birds[3] (RIC 1998). These call playbacks were played at each call playback station (**Figure 3**) on 21 and 28 June 2013 to assess for the presence/absence of target species. Survey timing coincided with the breeding season for targeted marsh bird species. Two different calls were used for Virginia Rail and Green Heron.

**Figure 3:** Marsh Bird Call Playback Locations


[3] American Bittern: three series of 20 seconds of calls followed by 30 seconds of silence. The last call series is followed by 1 minute of silence. Sora: three series of 20 seconds of calls followed by 30 seconds of silence. The last call series is followed by 1 minute of silence. Virginia Rail: Call 1: three series of 20 seconds of call 1 followed by 30 seconds of silence; Call 2: three series of 20 seconds of call 2 followed by 1 minute of silence. Green Heron: Call 1: three series of 20 seconds of call 1 followed by 30 seconds of silence. Call 2: three series of 20 seconds of call 2 followed by 2 minutes of silence.

Call playbacks were 10 minutes in duration and were broadcast using an Apple iPod Nano™ and a Fanon™ (10 watt) megaphone. In addition to responses by target species, the following data were recorded at each call playback station: survey number, station number, start time, end time, cloud cover, wind, precipitation and temperature (**Table 1**).

**Table 1:** Marsh Bird Surveys - Weather Conditions and Station Information

| Date | June 21, 2013 | June 28, 2013 |
|---|---|---|
| Cloud (%) | 100 | 50 |
| Wind (Beaufort) | 0 | 0 |
| Precipitation | Nil | Nil |
| Temperature (°C) | 15 | 16 |
| Sunrise | 05:06 | 5:10 |
| Station 1 UTM | 10 U 490012 5461265 | 10 U 490012 5461265 |
| Station 2 UTM | 10 U 489893 5461396 | 10 U 489893 5461396 |
| Station 1 Start Time | 06:10 | 06:15 |
| Station 2 Start Time | 06:34 | 06:42 |

At each plot, notes were also taken on the response of target species. Particulars noted included: which species call elicited a response, when responses occurred, and pattern of response vocalizations (e.g., one call). In addition, incidental wildlife observations were also recorded. There were no responses by the target species to any of the calls during the two surveys. Bird species observed incidentally during the marsh bird surveys were also recorded. Results are summarized in **Table 2**.

**Table 2:** Incidental Wildlife Species Detected During Call Playback Surveys

| Species | Scientific Name | June 21, 2013 | June 28, 2013 |
|---|---|---|---|
| ***Birds*** | | | |
| American Robin[1] | *Turdus migratorius* | **X** | **X** |
| Black-capped Chickadee[1] | *Poecile atricapillus* | | **X** |
| Black-throated Gray Warbler[1] | *Dendroica nigrescens* | | **X** |
| Brown-headed Cowbird[1] | *Molothrus ater* | **X** | |
| Brown Creeper[1] | *Certhia americana* | **X** | |
| Chestnut-backed Chickadee[1] | *Poecile rufescens* | **X** | **X** |
| Common Yellowthroat[2] | *Geothlypis trichas* | **X** | **X** |
| Great Blue Heron[2] | *Ardea herodias fannini* | **X** | **X** |
| Golden-crowned Kinglet[1] | *Regulus satrapa* | **X** | **X** |
| Mallard[3] | *Anas platyrhynchos* | **X** | **X** |
| Marsh Wren[2] | *Cistothorus palustris* | **X** | **X** |
| Northwestern Crow[4] | *Corvus caurinus* | **X** | **X** |
| Purple Finch[1] | *Carpodacus purpureus* | **X** | |
| Red-breasted Sapsucker[1] | *Sphyrapicus ruber* | **X** | |

**Table 2:** Con't.

| Species | Scientific Name | June 21, 2013 | June 28, 2013 |
|---|---|---|---|
| ***Birds*** | | | |
| Red-winged Blackbird[2] | *Agelaius phoeniceus* | **X** | **X** |
| Rufous Hummingbird[5] | *Selasphorus rufus* | **X** | **X** |
| Song Sparrow[5] | *Melospiza melodia* | **X** | **X** |
| Spotted Towhee[5] | *Pipilo maculatus* | **X** | **X** |
| Swainson's Thrush[1] | *Catharus ustulatus* | **X** | **X** |
| Townsend's Warbler[1] | *Dendroica townsendi* | **X** | **X** |
| Warbling Vireo[1] | *Vireo gilvus* | **X** | **X** |
| Western Tanager[1] | *Piranga ludoviciana* | **X** | |
| Wood Duck[3] | *Aix sponsa* | **X** | **X** |
| ***Mammals*** | | | |
| Beaver[2,3] | *Castor canadensis* | **X** | **X** |

[1] Forested Habitat [2]Pond Vegetation [3]Open Water [4]Overflight [5]Peripheral Shrubs

## 5.3 Biophysical and Bathymetric Field Survey Results

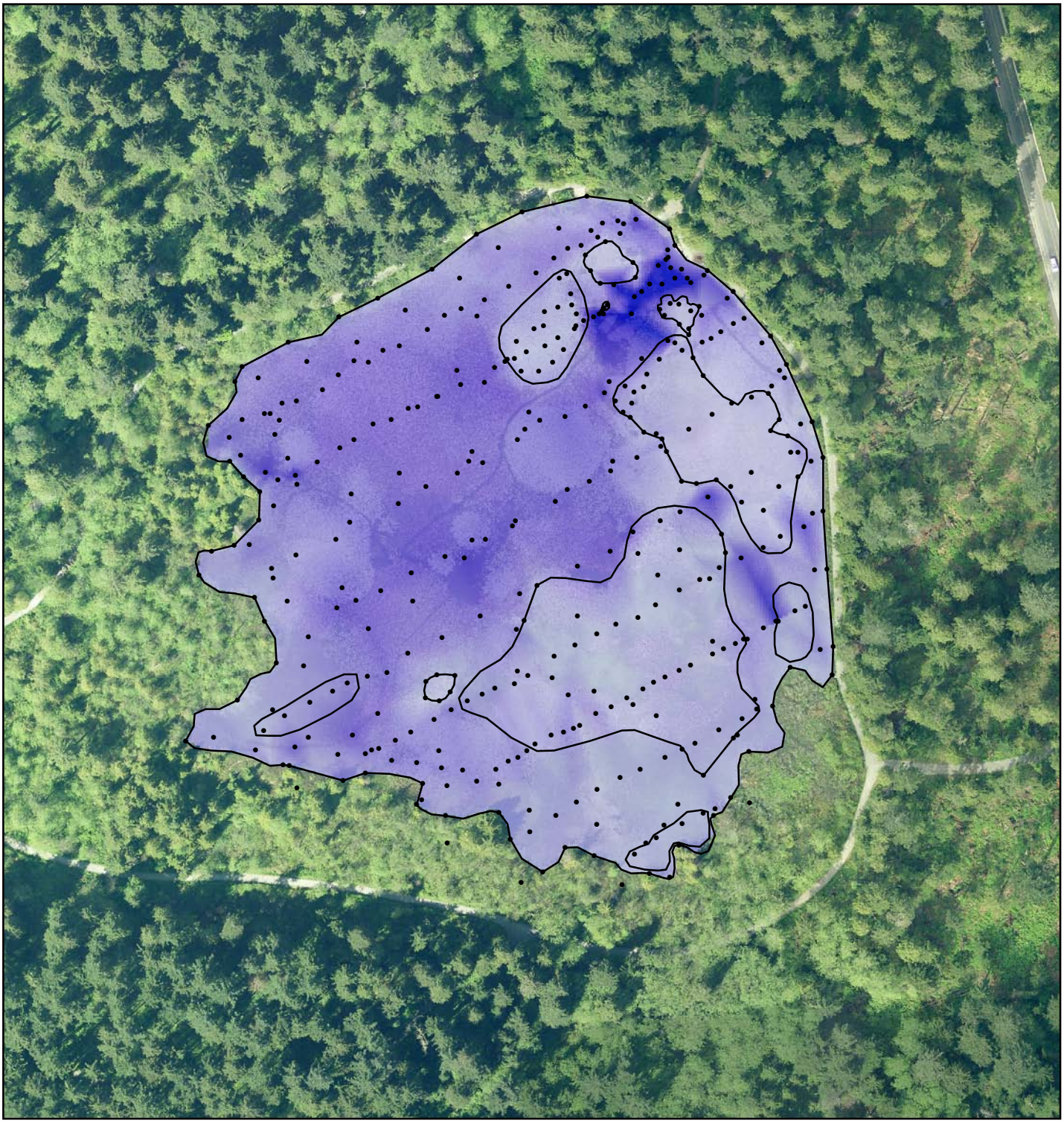
### 5.3.1 Hydraulic and Sediment Inputs

A bathymetric survey was conducted between 02-10 May 2013 using a real-time kinetic (RTK) GPS instrument that provides centimeter-level accuracy in both the vertical and horizontal planes. Survey data was collected through a combination of wading and paddling using a canoe. As anticipated, the lake is generally shallow except for the area immediately in front of the outlet weir. Maximum depths in front of the weir are 1.7 m (depths relative to typical water surface elevation of 9.434 m GSC). **Figure 4** illustrates the survey points and the depth contours of the lake based on the survey.

### 5.3.2 Lake Sedimentation

Characterising the sediments that comprise the lake bed was key to developing an enhancement plan because the physical characteristics of the materials that would need to be excavated to deepen the lake are a main determinant of the dredging cost and approach. Understanding the nature and rate of lake infilling provides a basis for predicting the project lifespan.

The working hypothesis of the development of lake bed sediments is based on a previous study undertaken by Hatfield Consultants Ltd. (Hatfield Consultants Limited, 1984) which used a narrow steel rod to provide an assessment of unconsolidated sediment deposits in the basin. Their results demonstrated that the depth to hardpan was as much as 4.3 m. As a result, it was inferred that the material above the hardpan was organic material that could be dredged.



• Survey DEM points

Approximate lake and island boundaries

Lake depth (m)

High : 1.71

Low : 0.00

Elevations and breaklines from NHC May 2013 survey and 2011 orthophoto
Depths based on water surface elevation of 9.434 m

2011 orthophotos from City of Vancouver

**CITY OF VANCOUVER**

# Beaver Lake Enhancement Plan
# Lake Depths

Scale - 1:2,000

0 20 40 60 80 100 120 Metres

| | | |
|---|---|---|
| coord. syst.: UTM Zone 10 | horz. datum: NAD 83 | horz. units: metres |
| Northwest Hydraulic Consultants | project no. 300209 | 17-May-2013 |

MSN, \\192.168.100.12\projects\300209 Beaver Lake\GIS\300209_MSN_Fig_Depth1.mxd

Figure 4

In 1999, Zimmermann et al. (1999) took a few deeper cores with a Hiller Corer and observed a soft glacial marine clay one meter below the top of the organics. However, the 1999 sampling was limited in extent and did not assess the prevalence of the glacial marine clay. Based on these above-mentioned studies, NHC concluded that the lake is underlain by a layer of dense glaciomarine clay, overlain in some areas by peat. Both layers would have developed prior to recent human settlement. Overlying these layers is a mixed layer of contemporary organic and mineral sediments that has developed since the lake was dredged in 1928.

Lake coring was undertaken using a Hiller peat corer that is capable of penetrating through the dense mats of vegetation and roots to hit a target depth and then retrieve the sample material for analysis. Eighteen cores were collected on 02 and 03 May 2013 around the perimeter of the lake as shown in **Figure 5**.

The initial coring interpretation provided results that contradict the general understanding of the amount of organics that are in the lake. In particular, on the north and east sides of the lake, the organic layer was thinner than expected. The glacial marine clay is also closer to the surface than previously estimated. **Figure 6** illustrates the elevation of the top of the glacial marine clay. Around the outfall and near the beaver lodge, the top of the clay is about 1 m (+/- 0.3) below the water surface and organics are typically less than 0.35 m thick. Along the south and west side of the lake, the clay is on the order of 2 m (+/- 0.3 m) below the water's surface. Additional information relating to the depth to clay interface is discussed in the sediment analysis section (Section 5.5).

The most surprising result from the coring is that the vegetated mats are not rooted to the lake sediments, but are generally free floating. These mats exist along the north, east and south sides of the lake and are actually organic material consisting of Fragrant Water-lily roots that have floated off the bottom (vegetated mat extents are mapped in **Figure 7**). During coring, it was found that as one pushes through them, there is a layer of clear water beneath. The floating mats are approximately 25 cm to 40 cm thick and are supporting forbs and trees in some areas. Around the beaver lodge and lake outlet, the organic layer is not present, possibly because the beavers have removed it, and the glaciomarine clay forms the lake bottom. The project team hypothesises that the relatively recent re-introduction of beaver to the lake has resulted in a greater fluctuation in the elevation of the water surface, which has contributed to the formation of the floating mats (refer to Section 3.4 for additional details).

Typical core material from the northwest portion of the lake, with the organic material overlying the glaciomarine clay (note the organic material has compressed from approximately 0.6 m thick to 0.28 m during the coring process).The core top is to the right in the photo.


NHC Core Location
*Collected May 2013*

2.05

Distance (m) from water surface to Glacial Marine Clay interface

2011 orthophotos from City of Vancouver
Reference map from Esri and NRCan

## Reference Map


**CITY OF VANCOUVER**

# Beaver Lake Enhancement Plan Core Locations

Scale - 1:2,000

0 20 40 60 80 100 120 Metres

| | | |
|---|---|---|
| coord. syst.: UTM Zone 10 | horz. datum: NAD 83 | horz. units: metres |
| Northwest Hydraulic Consultants | project no. P312088 | 09-May-2013 |

MSN, \\192.168.100.12\projects\P312088 Beaver Lake\GIS\P312088_MSN_Fig_NHCcores1.mxd

Figure 5

**Figure 6:** Elevation (m geodetic) of clay-organic interface at Beaver Lake.

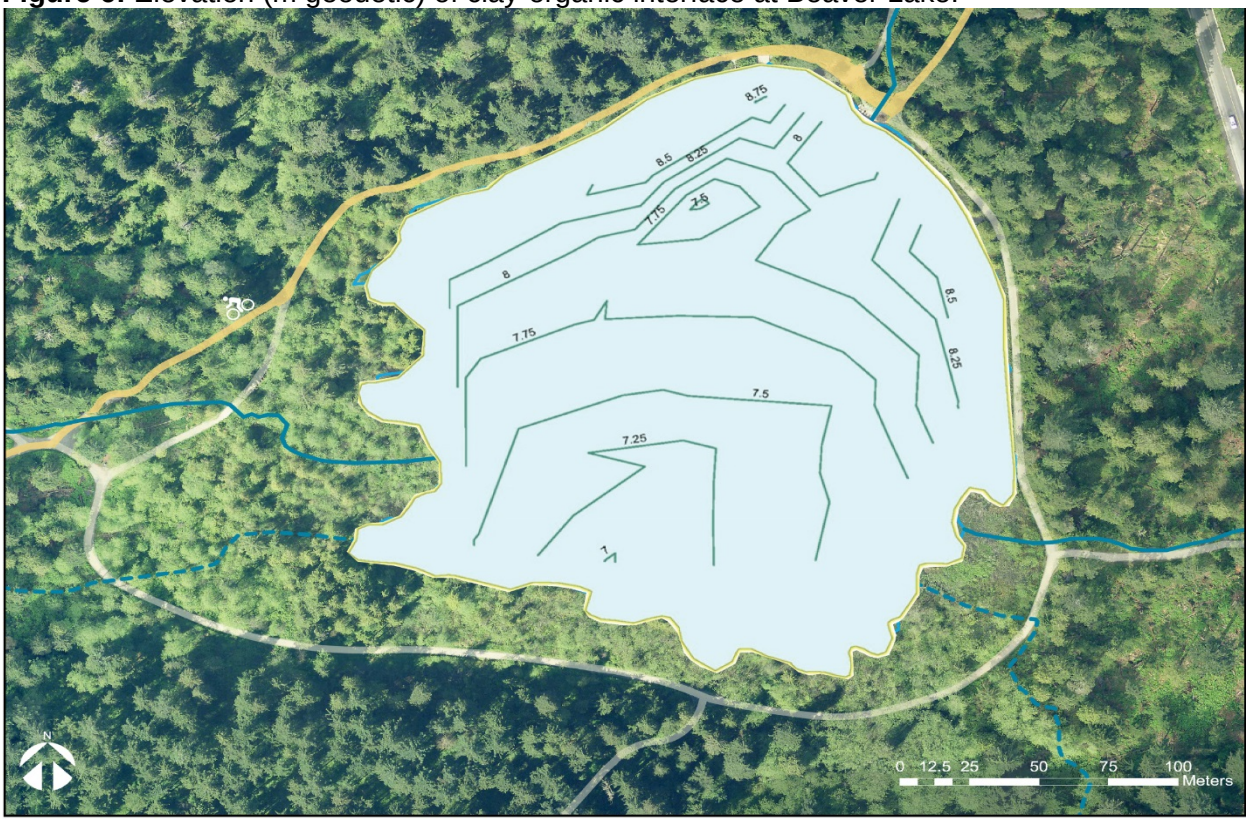
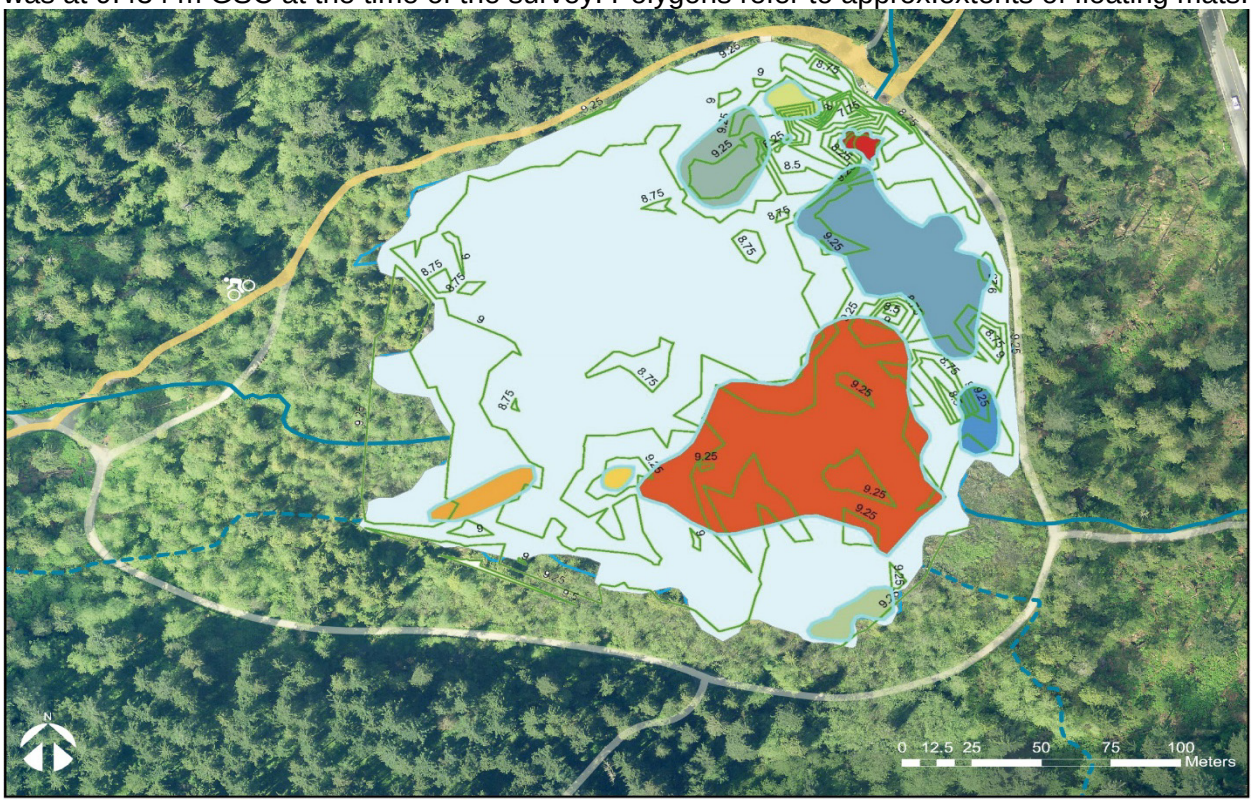



**Figure 7:** Existing floating mats and bed topography. For reference, the water surface elevation was at 9.434 m GSC at the time of the survey. Polygons refer to approx.extents of floating mats.



### 5.3.3 Outflow Conditions

Outflow from Beaver Lake into Beaver Creek is controlled by a weir outfall on the lake side of an earthen dam that was installed in the 1930s. Prior to the recent construction of beaver bafflers in June 2014, beavers regularly placed debris against the weir to raise lake levels and park staff removed the debris to prevent overtopping of the dam and inundation of the perimeter trail over the dam. The on-going debris deposition and removal cycle resulted in short-term increases in Beaver Creek discharge, which is thought to result in deterioration of in-stream habitat through scour and flushing of sediment, as well as reduced fish survival due to frequent high flow conditions. To substantiate these conclusions, short-term flow monitoring was conducted to measure discharge in Beaver Creek to:

1. Quantify the magnitude of the flow surge that regularly occurs when the debris is cleared from the weir; and
2. Quantify stream discharge to further understand the relative contribution of the municipal water supply to the hydrology of Beaver Lake.

A flow gauging weir was installed by NHC in Beaver Creek near the Pipeline road Bridge crossing on 24 January 2014. Water level was recorded using a combined RBR water level sensor and a Solinst Barologger to compensate for barometric pressure changes. A rating curve was developed for the measurement weir to relate water level to discharge based on measurements of flow made between 24 January and 06 March 2014. Flow measurements were made using a salt dilution method.

Cedar v-notch weir installed in Beaver Creek near the Pipeline Road Bridge crossing on January 24th, 2014 (left photo). The RBR sensor is housed in metal pipe and attached to a piece of rebar fixed to the streambed (lower left in left photo).

The discharge data for the period 24 January to 13 August 2014 is plotted against the water level in Beaver Lake (**Figure 1**). This data shows that cleaning the weir at the lake outlet as well as the debris forming a dam just downstream of the weir in Beaver Creek can result in flows on the order of 198 L/s, when coupled with a rain storm. Base flows were on the order of 4 L/s for the end of January and the beginning of February but rising to roughly 18 L/s for the remainder of the recorded period. **Figure 1** illustrates that a very common pattern is for the lake level to

rise steadily and then fall sharply, which is caused by beavers damming the Beaver lake outlet weir with subsequent removal of the blockage by parks staff. The discharge measurements also coincide with the creek blockages; it can be seen that when the debris is removed, the discharge increases as the lake level drops.

Following the installation of the Beaver Baffler on 03 June 2014 the fluctuations in lake level decreased significantly. In addition, the lake level was generally lower. The installation of the baffler did not noticeably change water temperatures in the lake.

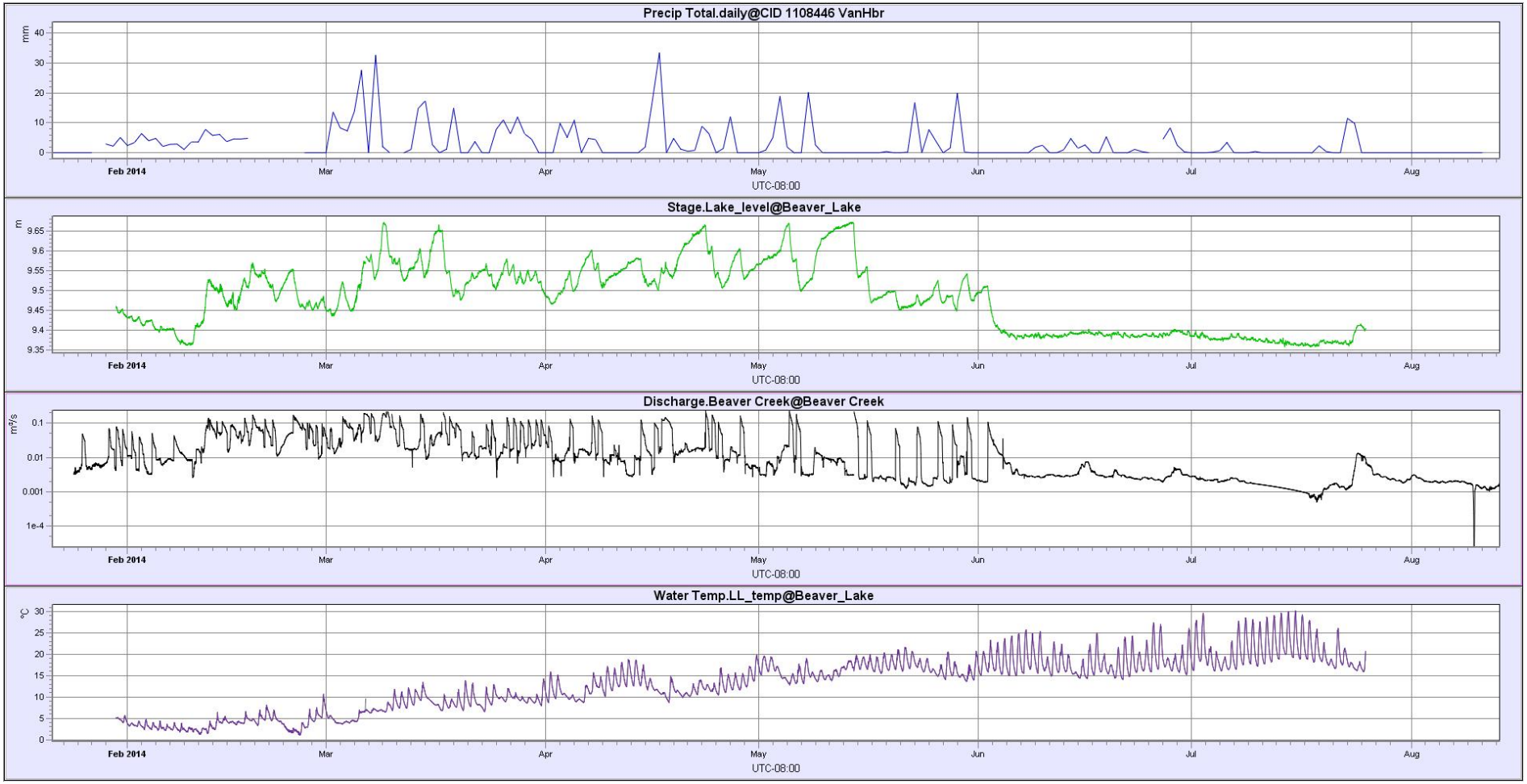
Prior to the beaver bafflers being installed on 03 June 2014, the lake and creek showed a consistent pattern of raised water levels during the night when the Beavers dammed the outflow, and high flows in the morning when the outlet was cleared by park staff. Since the installation of the bafflers, flows and lake levels have been much more consistent. Lake levels have stayed near or at the pre-baffler minimum lake levels.

Based on the current rating curve, the damming activities resulted in null flow in Beaver Creek once in August 2014; however, further data would need to be collected during summer low flows to confirm this observation. Summer low flows are in the order of 1 to 3 L/s, which suggests that all the creek flow is likely from the municipal water supply. The supply of municipal water into Beaver Creek via North Creek averages 0.86 L/s. It is not known how much water is supplied via Zoo Creek. Traditionally Zoo Creek inflows were changed seasonally; however, it is not known if this is still the case. Water temperatures at the sensor, located just below the surface near the shore, reached a peak of 30°C in the middle of July, and stayed consistently above 15°C.

Channel form is largely dependent on sediment supply and flow regime[4]. In the context of Beaver Creek, sediment supply downstream of Beaver Lake comes almost entirely from erosion of the bed and banks, with minor inputs of material that enter the stream from upland areas. In typical coastal streams, there is also a strong control exerted by the presence of large woody debris (LWD), which is typically introduced sporadically as riparian trees fall into or across the channel. LWD is present in Beaver Creek but is likely of lesser importance to sediment recruitment at the present time.

[4] Although there are many factors that determine the channel form, in this case sediment and flow regime are dominant.

**Figure 1:** Discharge data for Beaver Creek and lake level for Beaver Lake from 20 January 2014 to 13 August 2014. Daily Precipitation data from the Environment Canada Weather station at Vancouver Harbour are also shown (missing values have no data point). Water temperature data from Beaver Lake are also shown. The beaver baffler was installed on 03 June 2014.



The Beaver Creek channel is potentially very sensitive to changes in the flow regime – that is, the magnitude and frequency of large flow events, which have the capacity to mobilise sediment and erode the banks. A perception has developed that the frequent cycle of lake level increases caused by beavers and the subsequent removal of the debris that leads to rapid lowering of the lake has negatively impacted the physical habitat conditions in the channel downstream of the lake. The results of flow monitoring indicate that these hydrologic effects are not so severe. While it is recognised that the initial release of water immediately downstream of the lake weir appears turbid and chaotic, the observed channel condition does not reflect excessive high discharge events, finer bed (sand and gravel) material is retained, as well as small woody debris, and there does not appear to be an excessive amount of channel incision or bank erosion.

An important observation from the data is that the lake levels can vary by more than 0.3 m, which is likely an increase compared to pre-beaver conditions. In the past, lake levels only varied in response to rain events, and the invert of the controlling weir provided a consistent water elevation. In contrast, the beavers have historically caused the lake levels to vary much more as they block the outlet, causing the water levels to rise. The increase in lake level variability may have contributed to the mud on the lake bottom being pulled up and forming floating vegetation mats as the buoyant water lilies would have exerted an upward force on the root mass when lake levels are raised due to the beaver dams. The installation of the beaver baffler has dramatically reduced water level fluctuations, has generally lowered the lake level, and is expected to result in changes in the floating mats.

## 5.4 Water Sampling and Water Quality Results

On 04 July 2014, AquaTerra personnel collected physiochemical water parameters from Beaver Lake using a YSI-6920 multi-parameter probe. The measurements were taken concurrently along with water samples that were collected for laboratory analysis. Lake water quality parameters were measured from four (4) pre-determined sampling locations, as follows: 1) at the outflow to Beaver Creek [surface]; 2) at the outflow to Beaver Creek [lake bottom); 3) at the approximate centre of the lake; and 4) near the North Creek discharge location into Beaver Lake.

Physiochemical results are summarized in **Table 3** and specific sampling locations are provided in **Figure 9**.

**Table 3:** Summary of 04 July 2013 Physiochemical Water Results

| Date | 04-Jul-13 | 04-Jul-13 | 04-Jul-13 | 04-Jul-13 |
|---|---|---|---|---|
| Sample ID | SW-BL-01 | SW-BL-01 | SW-BL-02 | SW-BL-03 |
| Location | SW-BL-outflow-surface | SW-BL-outflow-bottom | SW-BL-centre | SW-BL-upstream |
| UTM | 489939E; 5461363N | | 489870E; 5461288N | 489803E; 5461199N |
| Temp ($^{o}$C) | 18 | 15.3 | 18.19 | 15.4 |
| Cond (mS/cm) | 0.042 | 0.047 | 0.051 | 0.052 |
| TDS (g/L) | 0.031 | 0.037 | 0.038 | 0.041 |
| Sal (PPM) | 0.025 | 0.03 | 0.03 | 0.03 |
| DO (%) | 7.4 | 3.2 | 3 | 20.4 |
| DO (mg/L) | 0.72 | 0.3 | 0.29 | 1.98 |
| pH | 5.87 | 5.93 | 5.44 | 5.8 |
| ORP (mV) | 163.5 | 6.5 | -34.4 | -12.1 |

Temperature ranged from 15.3$^{o}$C at depth or near the North Creek input (where cooler creek water mixes with warmer lake water) to in excess of 18$^{o}$C at the centre of the lake. Historical reports have recorded surface temperatures as high as 22$^{o}$C during July and August (Hatfield Consultants Ltd. 1984). Dissolved oxygen concentration was generally below 1 mg/L with the exception of the North Creek discharge (1.98 mg/L). Historical measurements during summer months also reported DO concentrations of less than 2.0 mg/L (Hatfield Consultants Ltd. 1984). For comparative purposes, salmonids typically require oxygen concentrations of at least 5 mg/L and prefer summer water temperatures of less than 15$^{o}$C. The lake bottom temperature where on-going beaver activity has a resulted in a localized deepened portion of the lake suggests that deepening a larger portion of the lake would encourage salmonid utilization, provided that oxygen levels can be maintained.

**Table 4** summarizes the optimum temperature ranges for the specific salmonids life stages per the BC Water Quality guidelines.

**Table 4:** Optimum Temperature Ranges of Specific Life History Stages of Salmonids and Other Coldwater Species for Guideline Application – Adapted from BC Water Quality Guidelines.

| Species | Incubation | Rearing | Migration | Spawning |
|---|---|---|---|---|
| Chinook | 5.0-14.0 $^{o}$C | 10.0-15.5 $^{o}$C | 3.3-19.0 $^{o}$C | 5.6-13.9 $^{o}$C |
| Chum | 4.0-13.0 $^{o}$C | 12.0-14.0 $^{o}$C | 8.3-15.6 $^{o}$C | 7.2-12.8 $^{o}$C |
| Coho | 4.0-13.0 $^{o}$C | 9.0-16.0 $^{o}$C | 7.2-15.6 $^{o}$C | 4.4-12.8 $^{o}$C |
| Pink | 4.0-13.0 $^{o}$C | 9.3-15.5 $^{o}$C | 7.2-15.6 $^{o}$C | 7.2-12.8 $^{o}$C |
| Sockeye | 4.0-13.0 $^{o}$C | 10.0-15.0 $^{o}$C | 7.2-15.6 $^{o}$C | 10.6-12.8 $^{o}$C |

**Figure 9:** Sampling Locations - 04 July 2013 Physiochemical Water Results


Lake pH was acidic (5.44 – 5.93) and is anticipated to be largely the result of decaying organic matter (DOM; humic acids) but may also include bacterial activity (hydrogen sulfide [$H_2S$] production – a weak acid) and the chemical composition of the municipal water supply. Results of the 1984 study also resulted in acidic pH values ranging from 6.05 to 6.38 (Hatfield Consultants Ltd. 1984). Specifically, increased acidity, at depth, is the result of lower oxygen levels and the formation of hydrogen sulfide (a weak acid) during decomposition of organic matter. Dredging / removal of organic mats are anticipated to mitigate pH related issues.

Conductivity is the measurement of the ability of water to conduct an electrical current. The greater the content of ions in the water, the more current the water can carry. Ions are dissolved metals and other dissolved materials. Typical conductivity ranges for coastal BC waterbodies are ~0.1 mS/cm with ranges between 0.05 – 1.5 mS/cm.

ORP is a non-specific measurement—that is, the measured potential is reflective of a combination of the effects of all the dissolved species in the medium. Reduction-Oxidation (REDOX) reactions (which are measured by ORP) occur within lakes as a result of photosynthesis and respiration often resulting in the production of hydrogen sulfide gas at the bottom of lakes, resulting in low oxygen levels and negative ORP values. In general, the more

negative the ORP value (i.e., the higher its negative ORP), the more likely it is to engage in chemical reactions that donate electrons.

Co-located surface water samples were collected for laboratory analysis and submitted under chain-of-custody. Water samples were analyzed for true colour, hardness, lab pH, anions and nutrients, total organic carbon, dissolved (bioavailable) metals, tannins & lignins, and chlorophyll A. Analytical results for each sampling location are summarized in **Table 5**.

**Table 5:** Surface Water Laboratory Analytical Results. **BOLD** – exceeds CCME Guidelines
*Italics* – exceeds BC Water Quality Guidelines

| Sample ID | | SW-BL-01 | SW-BL-02 | SW-BL-03 | BC Approved Water Quality Guidelines | CCME Guidelines for the Long-Term Protection of Aquatic Life |
|---|---|---|---|---|---|---|
| Date Sampled | | 04-JUL-13 | 04-JUL-13 | 04-JUL-13 | | |
| Time Sampled | | 00:00 | 00:00 | 00:00 | | |
| ALS Sample ID | | L1327567-1 | L1327567-2 | L1327567-3 | | |
| Matrix | Units | Water | Water | Water | | |
| **Physical Tests** | | | | | | |
| Colour, True | CU | <5.0 | <5.0 | 27.0 | | |
| Hardness (as CaCO3) | mg/L | 14.3 | 13.5 | 15.3 | | |
| pH | pH | ***6.45*** | ***6.30*** | **6.60** | 6.5 – 9.0 | 7.0 - 8.7 |
| **Anions and Nutrients** | | | | | | |
| Ammonia, Total (as N) | mg/L | 0.0229 | 0.0051 | 0.0067 | | 6.98 - 10.3 |
| Bromide (Br) | mg/L | <0.050 | <0.050 | <0.050 | | |
| Chloride (Cl) | mg/L | 4.04 | 4.35 | 5.73 | | 120 |
| Fluoride (F) | mg/L | 0.033 | 0.046 | 0.058 | 0.4 | |
| Nitrate (as N) | mg/L | <0.0050 | <0.0050 | 0.0062 | 3.0 | 0.013 |
| Nitrite (as N) | mg/L | <0.0010 | <0.0010 | <0.0010 | 0.020 | |
| Total Kjeldahl Nitrogen | mg/L | 0.735 | 0.634 | 0.676 | | |
| Total Nitrogen | mg/L | 0.735 | 0.634 | 0.682 | | |
| Orthophosphate-Dissolved (as P) | mg/L | <0.010 | <0.010 | <0.0010 | | |
| Phosphorus (P)-Total Dissolved | mg/L | 0.0110 | 0.0116 | 0.0151 | | mesotrophic |
| Phosphorus (P)-Total | mg/L | 0.039 | 0.046 | 0.038 | | |
| Sulfate (SO4) | mg/L | 2.91 | 4.19 | 4.09 | 100 | |
| Total Organic Carbon | mg/L | 12.9 | 14.8 | 14.6 | | |
| **Dissolved Metals** | | | | | | |
| Aluminum (Al)-Dissolved | mg/L | *0.105* | *0.166* | *0.151* | <0.1 | |
| Antimony (Sb)-Dissolved | mg/L | <0.00050 | <0.00050 | <0.00050 | | |
| Arsenic (As)-Dissolved | mg/L | <0.00050 | <0.00050 | 0.00058 | 0.005 | 0.005 |
| Barium (Ba)-Dissolved | mg/L | <0.020 | <0.020 | 0.024 | | |
| Beryllium (Be)-Dissolved | mg/L | <0.0010 | <0.0010 | <0.0010 | | |
| Boron (B)-Dissolved | mg/L | <0.10 | <0.10 | <0.10 | | |
| Cadmium (Cd)-Dissolved | mg/L | **<0.000010** | **0.000011** | **0.000012** | | 0.000006 |
| Calcium (Ca)-Dissolved | mg/L | 4.53 | 4.13 | 4.66 | | |
| Chromium (Cr)-Dissolved | mg/L | <0.0010 | <0.0010 | <0.0010 | | |
| Cobalt (Co)-Dissolved | mg/L | <0.00030 | <0.00030 | <0.00030 | 0.110 | |
| Copper (Cu)-Dissolved | mg/L | ***0.0049*** | ***0.0025*** | ***0.0024*** | 0.002 | 0.002 |
| Iron (Fe)-Dissolved | mg/L | ***0.556*** | ***0.703*** | ***0.579*** | 0.35 | 0.3 |
| Lead (Pb)-Dissolved | mg/L | <0.00050 | 0.00067 | 0.00065 | 0.00538 | 0.001 |
| Lithium (Li)-Dissolved | mg/L | <0.0050 | <0.0050 | <0.0050 | | |
| Magnesium (Mg)-Dissolved | mg/L | 0.73 | 0.77 | 0.89 | | |
| Manganese (Mn)-Dissolved | mg/L | 0.0642 | 0.0554 | 0.0432 | 0.7 | |

**Table 5:** Con't.

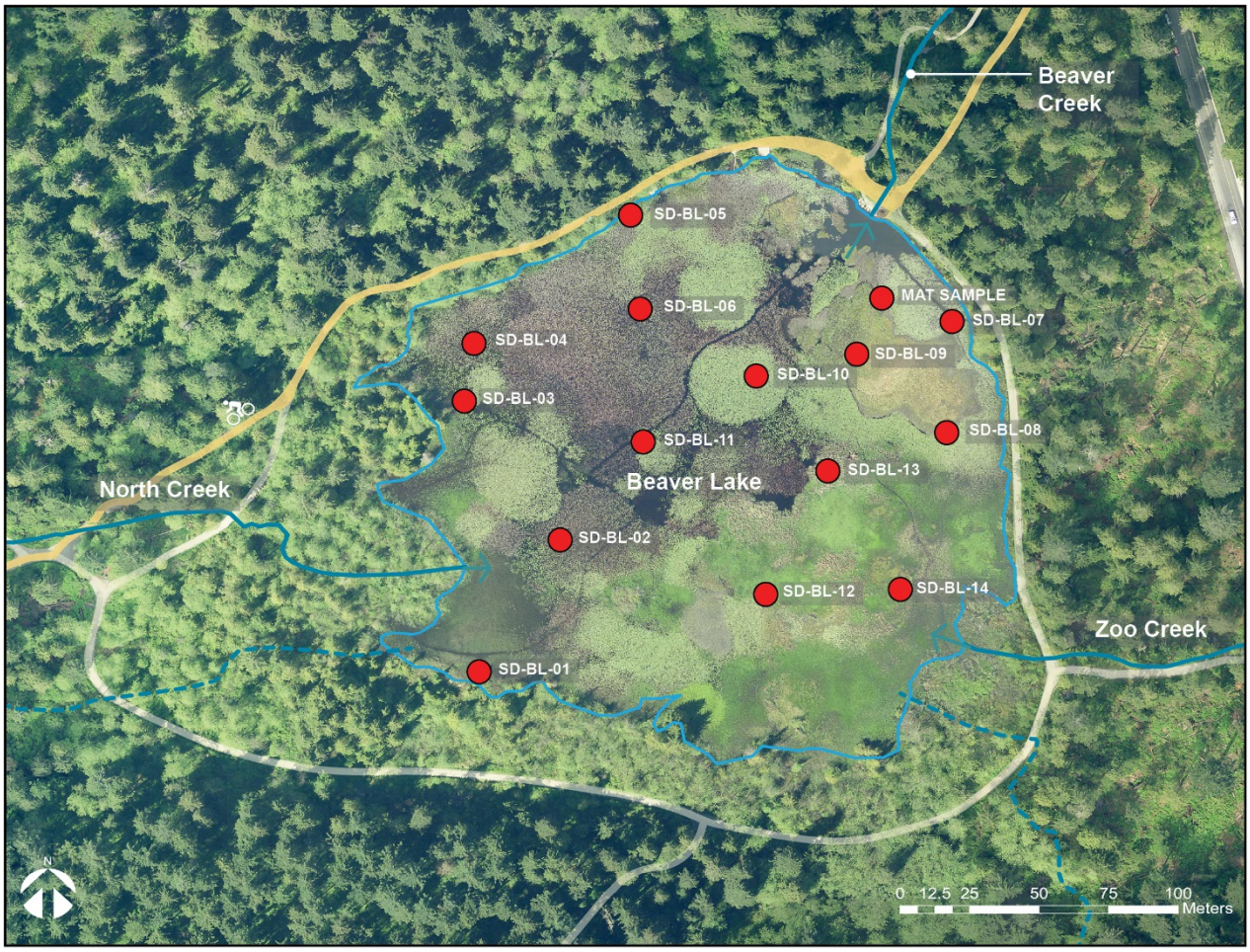
| Sample ID | Units | SW-BL-01 | SW-BL-02 | SW-BL-03 | BC Approved Water Quality Guidelines | CCME Guidelines for the Long-Term Protection of Aquatic Life |
|---|---|---|---|---|---|---|
| Mercury (Hg)-Dissolved | mg/L | <0.000010 | <0.000010 | <0.000010 | 0.00002 | 0.000026 |
| Molybdenum (Mo)-Dissolved | mg/L | <0.0010 | <0.0010 | <0.0010 | 1-2 | 0.073 |
| Nickel (Ni)-Dissolved | mg/L | <0.0010 | 0.0011 | 0.0013 | | 0.025 |
| Potassium (K)-Dissolved | mg/L | <2.0 | <2.0 | <2.0 | | |
| Selenium (Se)-Dissolved | mg/L | <0.00010 | <0.00010 | <0.00010 | 0.001 – 0.002 | 0.001 |
| Silver (Ag)-Dissolved | mg/L | <0.000020 | <0.000020 | <0.000020 | 0.00005 | 0.0001 |
| Sodium (Na)-Dissolved | mg/L | 2.7 | 3.3 | 5.3 | | |
| Thallium (Tl)-Dissolved | mg/L | <0.00020 | <0.00020 | <0.00020 | | |
| Tin (Sn)-Dissolved | mg/L | <0.00050 | <0.00050 | <0.00050 | | |
| Titanium (Ti)-Dissolved | mg/L | <0.010 | <0.010 | <0.010 | | |
| Uranium (U)-Dissolved | mg/L | <0.00020 | <0.00020 | <0.00020 | | 0.015 |
| Vanadium (V)-Dissolved | mg/L | <0.0010 | <0.0010 | <0.0010 | | |
| Zinc (Zn)-Dissolved | mg/L | <0.0050 | 0.0051 | <0.0050 | 0.033 | 0.03 |
| **Aggregate Organics** | | | | | | |
| Tannin & Lignin (as Tannic Acid) | mg/L | 6.17 | 7.00 | 4.17 | | |
| **Plant Pigments** | | | | | | |
| Chlorophyll a | mg/L | 7.14 | 10.5 | 1.08 | | |

Laboratory pH was slightly higher than the field pH, but remained below the typical range that is acceptable for salmonids use (6.5 – 9.0 – BC Water Quality Guidelines). Aluminum concentrations slightly exceeded the BC Water Quality Guidelines for aquatic life and copper and iron concentrations slightly exceeded both the BC Water Quality Guidelines and Canadian Council of Ministers of the Environment (CCME) Guidelines for the long-term protection of aquatic life. Cadmium levels were elevated relative to the CCME Guidelines for the long-term protection of aquatic life. Elevated metals concentrations in water are often the result of atmospheric deposition, point and non-point run-off sources from roadways, and re-mobilization from sediments or organic matter within a given waterbody.

## 5.5 Sediment Quality Sampling and Analytical Results

On 04 July 2013 and 11 July 2013, fourteen (14) sediment cores were advanced using a peat borer at the locations illustrated on **Figure 10**. The intent of the sediment sampling was evaluate the depth of the peat/clay interface layer to assist with determining preliminary dredging depths (discussed in Section 5.3.2) and to collect sediment samples for laboratory analysis given the historical reports of surficial sediment contamination (Section 4.3). The depth to the peat/clay interface ranged from the surface near the Beaver Creek discharge location to 1.7 m near the centre of the lake. Water depths were also assessed, and ranged from 0.2 m to approximately 1.3 m. A summary of the sediment profiles and water depths are provided in **Table 6**.

**Figure 10:** Sediment Sampling Locations – 04 and 11 July 2013




Sediment metals analytical results from 2013 indicate localized exceedences relative to the BC Contaminated Sites Regulation Sediment Quality Criteria for sensitive sites (SEDQCss) and the federal Canadian Council of Ministers of the Environment (CCME) Interim Sediment Quality Guidelines (ISQG). Exceedences included arsenic, cadmium, copper, lead, mercury and zinc. Generally, the metals contamination was limited to the organic layer, with concentrations being highest at or near the surface (surface to 0.1 m depth). These results largely mirror the 2011 Simon Fraser University (SFU) study (Faugeraux and Bendell, 2011), which identified copper, zinc and cadmium concentrations in excess of ISQG results throughout the surficial sediments within the lake, with a notable exceedence for copper when compared to the Probable Effects Level (PEL). The 2011 study collected five (5) sediment samples, which were limited to the western perimeter of the lake.

**Table 6:** Sediment Coring / Sampling Results. Depth to Peat/Clay Interface Layer by Sample Location.

| Sample ID | SD-BL-01 | SD-BL-02 | SD-BL-03 | SD-BL-04 | SD-BL-05 | SD-BL-06 | SD-BL-07 | SD-BL-08 | SD-BL-09 | SD-BL-10 | SD-BL-11 | SD-BL-12 | SD-BL-13 | SD-BL-14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Date | 04-Jul-13 | 04-Jul-13 | 04-Jul-13 | 04-Jul-13 | 04-Jul-13 | 04-Jul-13 | 11-Jul-13 | 11-Jul-13 | 11-Jul-13 | 11-Jul-13 | 11-Jul-13 | 11-Jul-13 | 11-Jul-13 | 11-Jul-13 |
| Water Depth (m) | 0.2 | 0.4 | 0.7 | 0.5 | 0.6 | 0.4 | 0.7 | 1 | 1.25 | 1.25 | 0.6 | 1.2 | 1.3 | 1.2 |
| Substrate Depth (m) | | | | | | | | | | | | | | |
| 0.0 - 0.1 | DOM | DOM | DOM | DOM | Floating Mat | Loose/ Uncons. | Peat/ Clay | Peat/ Clay | Peat/ Clay | DOM | DOM | DOM | DOM | DOM |
| 0.1-0.2 | DOM | DOM | DOM | DOM | | Loose/ Uncons. | | | | Peat | DOM | Peat | DOM | DOM |
| 0.3-0.4 | DOM | DOM | DOM | DOM | | Loose/ Uncons. | | | | Peat/ Clay | DOM | | DOM | DOM |
| 0.4-0.5 | Loose Peat | DOM | Peat | DOM | | Loose/ Uncons. | | | | | DOM | | DOM | Peat |
| 0.5-0.6 | Loose Peat | DOM | Peat | DOM | | Loose/ Uncons. | | | | | DOM | | Peat | |
| 0.6-0.7 | Loose Peat | DOM | Peat | Peat | DOM | Loose/ Uncons. | | | | | DOM | | Peat | |
| 0.7-0.8 | Loose Peat | DOM | Peat/ Clay | Peat | Peat/ Clay | Loose/ Uncons. | | | | | DOM | | Peat | |
| 0.8-0.9 | Loose Peat | DOM | | Peat | | Peat | | | | | DOM | | Peat/ Clay | |
| 0.9-1.0 | Peat | Peat | | Peat/ Clay | | Peat/ Clay | | | | | DOM | | | |
| 1.0-1.1 | Peat | Peat | | | | | | | | | DOM | | | |
| 1.1-1.2 | Peat/ Clay | Peat | | | | | | | | | DOM | | | |
| 1.2-1.3 | | Peat | | | | | | | | | Peat | | | |
| 1.3-1.4 | | Peat/ Clay | | | | | | | | | Peat | | | |
| 1.4-1.5 | | | | | | | | | | | Peat | | | |
| 1.5-1.6 | | | | | | | | | | | Peat | | | |
| 1.6-1.7 | | | | | | | | | | | Peat/ Clay | | | |
| 1.7-1.8 | | | | | | | | | | | Clay | | | |

DOM = Decaying Organic Material

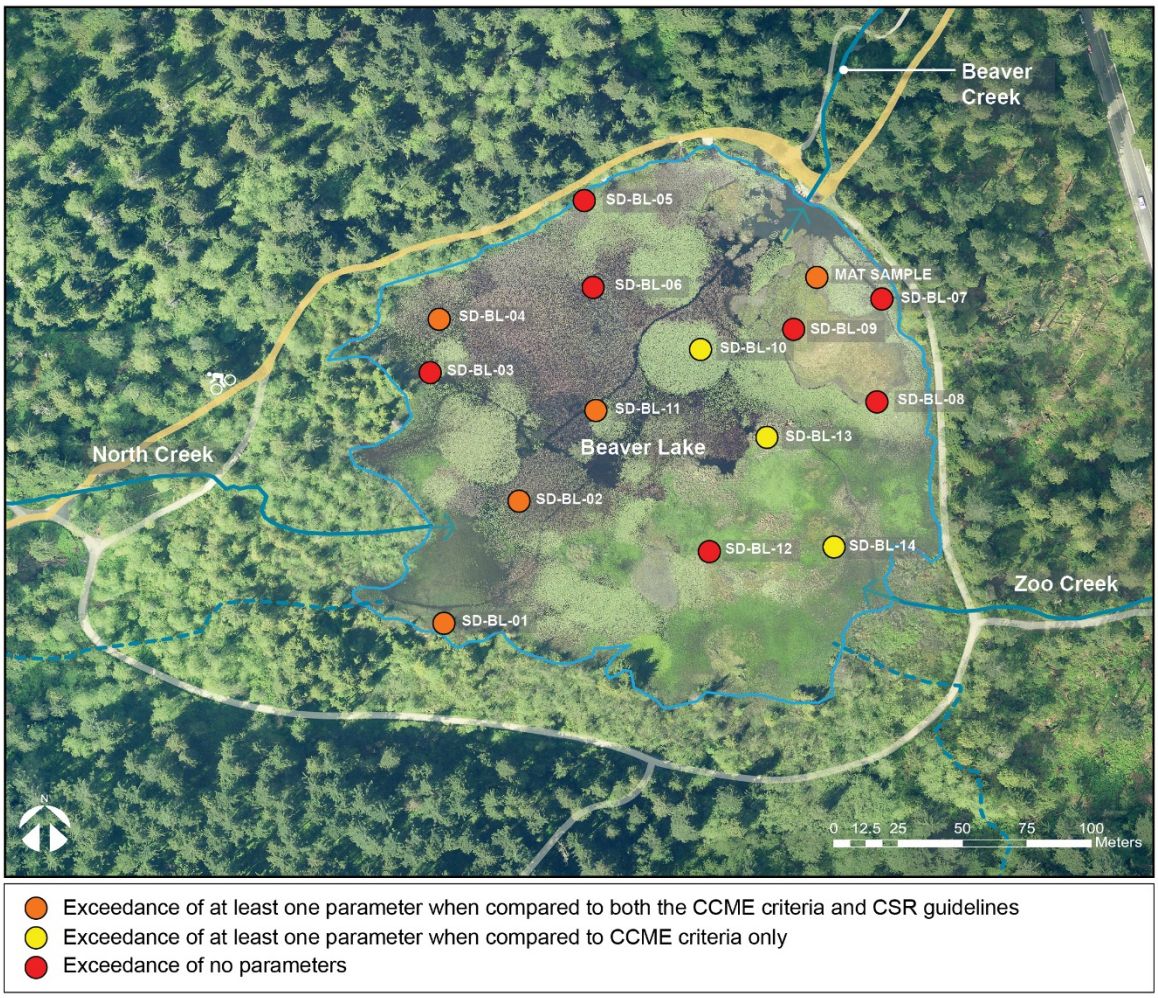
The most heavily contaminated area (BL-11) in the 2013 round of sediment testing corresponds to an area where the decaying organic matter was thickest (to a depth of 1.1 – 1.2 m). Analytical results and comparisons to applicable criteria and guidelines are included in **Appendix A**. A visual representation of exceedences is illustrated in **Figure 11**. Sediment contamination appears to be confined primarily to the deeper portion of the lake in the vicinity of the notched channel.

One of the floating organic mats was also tested to assess the update of metals, if any, from the vegetation. The mat had elevated levels of arsenic, cadmium, copper, lead, mercury and zinc (refer to **Appendix A** for results), indicating that the Fragrant Water-lily readily sequesters metals.

The 2011 SFU sediment study (Faugeraux and Bendell, 2011) concluded that spatial trends indicated no direct point source of metals, suggesting that inputs are likely of atmospheric origin, waste incineration (consisting of at least 80 years of anthropgenic inputs including industrial activities and waste incineration), and vehicle inputs via road run-off (inclusive of vehicle exhaust and tire wear).

As noted in Faugeraux and Bendell (2011), the elevated metals concentrations may have disposal implications. Because the elevated metals concentrations are limited predominantly to the surficial layer and are found intermittently throughout the lake, opportunities may exist to effectively manage the material to offset disposal costs. Consultation with a contaminated sites professional will be required prior to developing an appropriate disposal strategy.

**Figure 11:** Sediment Analytical Results. Orange indicates exceedence of at least one parameter when compared to both the CCME criteria and CSR guidelines. Yellow indicates an exceedence of at least one parameter when compared to the CCME criteria only.



# 6 Key Environmental Management Objectives

Nine (9) key management objectives have been identified by the project team and are intended to enhance existing and post-dredge environmental conditions at Beaver Lake. These management objectives are outlined below and discussed in detail in the following sections.

1) Maximize Biodiversity (Section 6.1);
2) Encourage Aquatic Life (Section 6.2);
3) Establish a Habitat Mosaic on the Landscape (Section 6.3);
4) Facilitate Fish Utilization (Section 6.4);
5) Prevent the Spread of Invasive Species (Section 6.5);
6) Minimize Maintenance Requirements (Section 6.6);
7) Utilize Plants of Ethnobotanical Relevance (Section 6.7);
8) Maintain Site Character – Beaver Management (Section 6.8); and
9) Reduce Reliance on Municipal Water Inputs (Section 6.9).

## 6.1 Maximize Biodiversity

Three (3) strategies to maximize biodiversity within the Beaver Lake watershed have been identified, by the project team, as follows:

### 6.1.1 Integrate Large Woody Debris

Strategic placement of large woody debris within and around the lake will increase wildlife utilization by amphibians, reptiles, waterfowl and wading birds. Moreover, this basic and cost-effective enhancement strategy will increase wildlife viewing opportunities for park visitors. The project team does not recommend that chainsaws be used to cut the logs placed in the wetlands. The cut ends of logs appear unnatural and provide poor habitat to invertebrates that other animals eat. Any chainsaw cuts should be buried and hidden from view.

### 6.1.2 Improve Stream Health of Zoo Creek, North Creek, and Beaver Creek

Zoo Creek is a constructed stream that is channelized along its length and serves to drain the water from the former zoo and current miniature train area. The upper reaches of the stream are buried underground in a culvert, daylighting to the west of Pipeline Road. Most of the stream is not visible to users as it is covered by dense vegetation. The stream offers marginal habitat to aquatic organisms given its uniform bank morphology, general absence of pools, and lack of riffles. Additionally, there are

localized head-cuts in Zoo Creek that are causing erosion and contributing to sedimentation within the lake.

Zoo Creek is a good candidate for stream restoration. A series of pools, riffles, and wetlands could be restored along the length of Zoo Creek. The improved habitat would greatly increase wildlife viewing opportunities, and enhance the scenic beauty of the valley. Visitors walking the Tisdall Trail would have a more exciting landscape to explore if the stream were restored.

The flows in North Creek and Zoo Creek are augmented by the municipal water supply for approximately three months during the summer. In the absence of this additional water, it is likely that these creeks would be dry. These two augmented creeks serve to contribute water to Beaver Lake and in turn, Beaver Creek, the main outflow of the lake. In 2011, the Vancouver Park Board approved a recommendation to 'continue to maintain water levels in the lake with municipal water until alternative sources can be found'. The municipal water supply needs to be maintained until adequate natural flows of the creeks can be re-established (refer to Section 6.9 for options). SPES has undertaken localized enhancements along Beaver Creek to improve habitat and access for resident Cutthroat Trout and Coho Salmon.

*Proposed Enhancement Approach:* 1) Maintain and manage municipal water supply during summer. 2) Establish pools and riffles with optional liner in pools to reduce infiltration. 3) Undertake localized riparian planting.

*Rationale:* Cutthroat Trout have been captured in North Creek and Beaver Creek during inventory surveys; however, no Cutthroat Trout have been found in Beaver since September 2011. The low dissolved oxygen, high seasonal temperatures and floating mats likely limit the ability of Cutthroat Trout to traverse the lake. Contingent on water inputs and channel enhancements, Zoo Creek could sustain a seasonal Cutthroat Trout population.

### 6.1.3 Maintain the Bog

The bog area has been restored as a result of significant commitments from SPES, its volunteer community, and funding partners. To effectively manage site environmental conditions and maximize habitat function, bog maintenance will be key during other enhancement efforts.

*Proposed Enhancement Approach:* 1) Continue restoration efforts involving removal of trees and shrubs. 2) Continue to introduce Sphagnum Moss (*Sphagnum* sp.*)* transplants and nurture Round-leaved Sundew (*Drosera capensis*) establishment. 3) Maintain water levels, particularly if the lake is de-watered during dredging efforts.

*Rationale:* SPES has been successful in restoring a 500m$^2$ of bog with healthy populations of Sphagnum Moss, Sundew, Labrador Tea (*Ledum groenlandicum*) and Swamp Laurel (*Kalmia polifolia*), which was achieved by removing the tree and shrub cover and introducing transplants of sphagnum moss collected from other areas around the lake.

## 6.2 Encourage Aquatic Life

Despite the altered Beaver Lake ecosystem, a number of native animal species continue to utilize the lake and surrounding area including Northwestern Salamander (*Ambystoma gracile*), which was regularly observed through pond-breeding amphibian surveys completed by SPES since 2007 and most recently observed during the 2014 SPES Herptile Blitz. This SPES program was started during the 2007 Storm Restoration and serves to inventory species utilizing the park's aquatic habitats. The focal species for this management objective is the Northwestern Salamander. By maintaining suitable habitats for this species, a variety of other aquatic and terrestrial species will also benefit.

*Proposed Enhancement Approach*: 1) Maintain open water by removing Fragrant Water-lily mats. 2) Establish vernal ponds (refer to Section 6.9 for details) in forests next to the existing trail. 3) Remove organic build up in lake (dry and excavate, dredge). 4) Improve water management (e.g., repair leakages through trail dam).

*Rationale*: The egg masses and larval form of Northwestern Salamander can persist with areas of dense aquatic vegetation but prefer some open water with sufficient flow and oxygen exchange. All stages in the life cycle of the Northwestern Salamander would also benefit from vernal ponds that can be constructed in the forest alongside the perimeter trail around Beaver Lake.

## 6.3 Establish a Habitat Mosaic on the Landscape

Assuming removal of Fragrant Water-lily mats, a significant area would become available for habitat enhancement and diversification. A recognized approach to improving biodiversity and habitat utilization is to increase the number of available, functional habitats within a given area. Focal species for this management objective include Great Blue Heron (*Ardea herodias fannini*) for aquatic habitats and Wilson's Snipe (*Gallinago delicata*) for adjacent upland habitats.

*Proposed Enhancement Approach*: 1) Establish a pattern of islands and open water by dredging, which will be used by a variety of marsh birds and waterfowl. 2) Construct vernal ponds in forest next to the existing trail (Section 6.9). 3) Introduce large woody debris (Section 6.1) around the lake and on constructed islands. 4) Construct nest boxes for cavity nesting bird species and bat boxes.

*Rationale*: Most of the lake is currently covered with monocultures of invasive Fragrant Water-lily and Narrow-leaf Cattail (*Typha angustifolia*) with Yellow Flag Iris (*Iris pseudacorus*) and the native Buckbean (*Menyanthes trifoliate*) around the edges. There are a very few native Yellow Pond Lily (*Nuphar polysepalem*) mixed in with the Fragrant Water-lily. Moreover, no native Broadleaf Cattail (*Typha latifolia*) was observed within the monocultures of Narrow-leaf Cattail. It is unknown if the Narrow-leaf Cattail may actually be a hybrid between the Narrow-leaf Cattail and Broadleaf Cattail.

Tall perches in the lake itself are missing and snags would occur naturally in this environment. Several tall snags of 5 m height above the water can be erected on constructed islands within the lake as was done in wetlands around Maplewood Flats across Burrard Inlet. Similarly, habitat is missing for cavity-nesting species such as Violet-green Swallow (*Tachycineta thalassina*), Black-capped Chickadee (*Poecile atricapillus*) and Chestnut-backed Chickadee (*Poecile rufescens*) and can be restored by introducing snags and nest boxes on posts around the lake.

## 6.4 Facilitate Fish Utilization

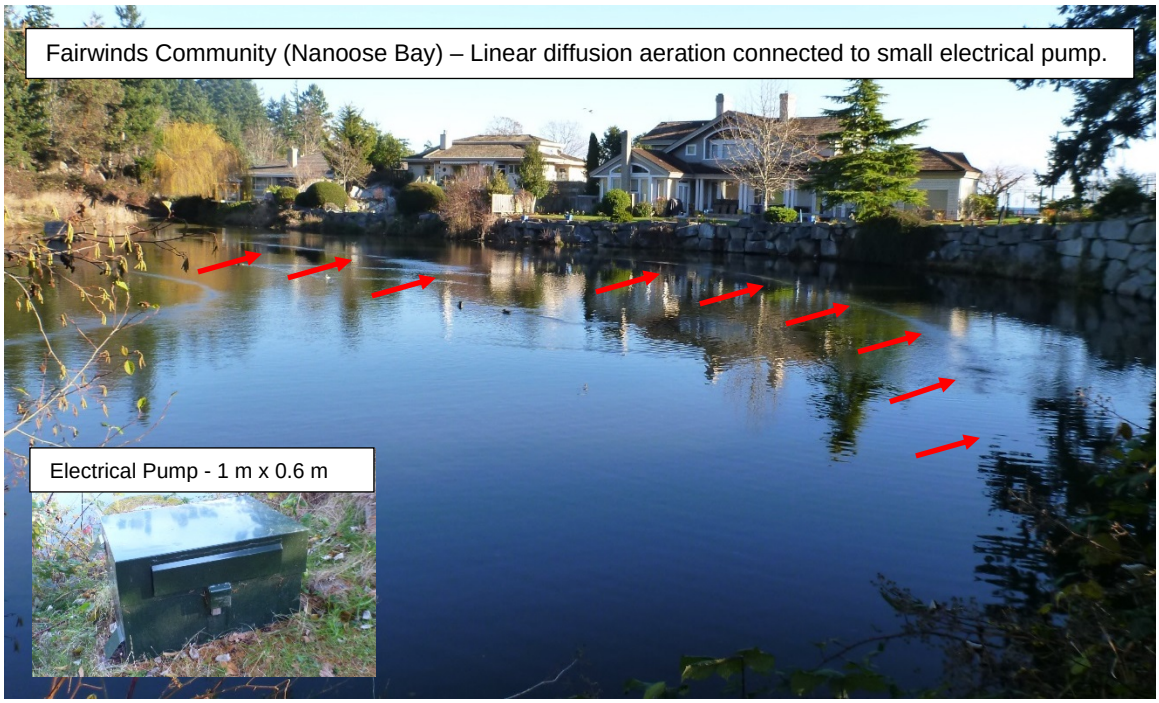
The 1984, Hatfield Consultants recommended the following modifications to Beaver Lake / Beaver Creek to facilitate fish utilization:

- Stop log cascade (current dam structure) be changed to a small step pool for a more gradual drop;
- Fish ladder of approximately five steps be constructed in place of the falls under the Pipeline Road bridge (currently underway – headed by SPES and Vancouver Park Board);
- Gravel and boulder placement in Beaver Creek to create spawning and rearing habitat;
- Removal of a culvert and insertion of a stepped stream channel to provide access to Beaver Lake; and
- Drilling and constructing a well to access an aquifer to supplement water flows into the Beaver Lake system.

*Proposed Enhancement Approach*: If Beaver Lake and connected watercourses are to be used as rearing, overwintering and/or spawning areas for salmonids, a variety of modifications will be required. Specifically, more open water must be considered to encourage more phytoplankton and, as a result, substantially more zooplankton as a food source. Currently, impassable barriers remain, preventing movement of adult salmon into the creek and there are generally no functional spawning or rearing habitats. Additionally, attempts must be made to lower the lake temperature in the summer and improve oxygen content to facilitate salmonids utilization in the lake as well as Beaver Creek.

There are low-cost, low-maintenance and highly effective ways to seasonally improve oxygen content in the lake, both for localized areas and larger portions of the lake. For example, commercial pond/lake aerators are available in a variety of models including point source aerators or linear diffusion aeration via 'bubble tubing' as shown below.

Point source aerator at Hastings Park Sanctuary Fish Pond – stocked with trout.




Fairwinds Community (Nanoose Bay) – Linear diffusion aeration connected to small electrical pump.

The project team recommends the consideration for the introduction of Chum Salmon (*O. keta*) into the system as opposed to Coho Salmon. Whereas Coho Salmon are currently released as part of educational programs, they often require two years before migrating out to sea. Given the current constraints in Beaver Creek and limited flows, juvenile Coho Salmon survivorship through to outmigration is anticipated to be very low. In contrast, Chum Salmon along the Fraser River corridor typically outmigrate shortly after emergence (March – May) between February to June each year (Groot & Margolis 1998), which would coincide with higher flows within Beaver Creek prior to supplementing with municipal water. Additionally, relative to Coho Salmon, adult Chum Salmon are better adapted at returning to their natal streams despite persistent low flow conditions (refer to photograph below), which is particularly relevant to Beaver Creek given its limited flow conveyance and supplemented water inputs.

Adult Chum returning to natal stream with low flow.

## 6.5 Prevent the Spread of Invasive Species

The aquatic vegetation species outlined in Section 3.3.1 (Fragrant Water-lily, Purple Loosestrife and Yellow-flag Iris) pose the highest risk to Beaver Lake biodiversity. The Musqueam, Squamish and Tsleil-Waututh First Nations have also identified invasive species as a significant concern and consider effective invasive species management a key priority. In the absence of effective mitigation and on-going maintenance, these

invasive species will serve to quickly re-colonize enhancement areas, adversely impacting ecological function and biodiversity.

To assess the potential for Fragrant Water-lily to re-colonize the lake following floating mat removal and dredging activities, the project team travelled to Deer Lake and Burnaby Lake, situated in Burnaby BC. Burnaby Lake had been recently dredged and Fragrant Water-lily were limited to the lakeshore and undredged areas. Rooting depths along the Fragrant Water-lily boundary at Burnaby Lake were measured at seven locations, as follows: 2.65 m; 2.45 m; 2.42 m, 2.16 m; 1.50 m; 2.30 m, and 2.36 m (average: 2.26 m). At Deer Lake, a geotextile mat had been installed along the eastern beach area (off of Sperling Avenue) approximately 15 years ago (information source: project team member, John Kirbyson – former City of Burnaby employee) and no Fragrant Water-lily or other significant aquatic vegetation was observed within the beach area. At the end of the geotextile mat, Fragrant Water-lily was documented rooting at a depth of 1.05 m.

Deer Lake, Burnaby – measuring rooting depth of water

*Focal Species*: Cutthroat Trout, sedges

*Proposed Enhancement Approach*: Remove Fragrant Water-lily from the lake, invasive knotweed from riparian areas of Beaver Creek and remove expanding edges of Narrow-leaf Cattail, Purple Loosestrife, and Yellow Flag Iris.

*Rationale*: Comments from First Nations have included concerns regarding the spread of invasive species. All knotweed species are aggressive invasive species that are almost impossible to remove once they begin to spread. The knotweed along Beaver Creek has just been introduced from an infestation along the Causeway. It has been detected early and eradication from Beaver Creek is possible. Removal of individual knotweed plants needs to continue (stem injection with glyphosate is necessary) and the area monitored to prevent it from spreading. This is important because knotweed could rapidly begin to dominate the riparian zone of the creek, expand into Beaver Lake itself, and then become the dominant vegetation around the lake. If they took over Beaver Creek and North Creek, the creeks would no longer support Cutthroat Trout.

Sedges are a keystone species that are fundamental in supporting a healthy lake. They are currently growing along the edge of the lake and on the mats of vegetation in Beaver Lake but nearby growth of Narrow-leaf Cattail and Yellow Flag Iris pose a threat. SPES

has removed some Yellow Flag Iris and Purple Loosestrife from the lake. The Narrow-leaf Cattail and Yellow Flag Iris need to be kept from displacing the sedges. Sedges should be a component of re-planting efforts. Best Management Practices are available from various sources for the removal of invasive plant species in the park, including the Stanley Park Ecology Society Invasive Plant Management Plan (SPES 2013)

The success of the Beaver Lake enhancement project will be largely contingent on the effective management of invasive plant and animal species. The project team does not anticipate that it will be feasible to completely eliminate invasive species. Moreover, complete removal of invasives would adversely affect a number of aquatic and terrestrial species currently utilizing the lake. As one of the key priorities for the project is to maximize biodiversity, the reintroduction and establishment of a variety of sensitive species will only be as effective as the precautions taken to manage invasives and prevent their spread following the completion of enhancement works. Additional information relating to the reintroduction of sensitive species and invasive species management are discussed in Section 11.3.

## 6.6 Minimize Maintenance Requirements

The project team acknowledges that Beaver Lake will continue to exist as a novel ecosystem following the completion of proposed enhancement efforts. Public accessibility and its central location will continue to make it highly susceptible to the introduction of non-native and invasive plant and animal species. One of the key environmental management objectives is to maximize ecological function while minimizing maintenance requirements. This is particularly important given that maintenance efforts may vary annually, contingent on personnel availability and funding. As such, it will be important that following enhancement efforts, the ecosystem will be able to continue to function with minimal and intermittent maintenance.

*Proposed Enhancement Approach*: Accept that some invasive species are well-established according to the Early Detection Rapid Response (EDRR) curve and that complete eradication for well-established invasive species such as Fragrant Water-lily, Narrow-leaf Cattail and Yellow Flag Iris is not an option. Alternatively, new invasions such as knotweed are a high priority for eradication to minimize maintenance implications if they are allowed to spread.

*Rationale*: The term “novel ecosystem” is an accurate description of Stanley Park’s environmental history as described by Kheraj (2013). In his book “Inventing Stanley Park: An Environmental History”, Kheraj documents how the park is a cultural landscape and not a pristine wilderness. It has seen continuous use by First Nations since time immemorial. This was followed by dramatic changes from logging, mining and European settlement. We can add to this the more recent impacts of impervious surfaces and the

introduction of invasive species. This history underscores the need to set an enhancement target that is realistic for Beaver Lake's situation and not to set a target of a natural lake with only native species, ignoring the many limitations that restrict this option.

## 6.7 Utilize Plants of Ethnobotanical Relevance

In order to appropriately incorporate plants of cultural significance to the Musqueam, Squamish and Tsleil-Waututh people into the project, community knowledge holders can be further consulted on plant selection and a final planting plan prior to enhancement / re-planting efforts. Opportunities also exist for cultural recognition and public education in connection with the ethnobotanical component of the project.

*Proposed Enhancement Approach*: 1) Plant native species and culturally significant species. 2) Utilize archaeological monitors to ensure protection of archeological and heritage resources such as Culturally Modified Trees (CMTs) and artifacts during enhancement work. 3) Explore opportunities for members of the Squamish, Musqueam and the Tsleil-Waututh First Nations to actively participate in project work including training / capacity-building opportunities alongside members of the project team.

*Rationale:* Since time immemorial, what are now referred to as "Stanley Park" and "Beaver Lake" have been of cultural and historical significance to the Squamish, Musqueam and the Tsleil-Waututh First Nations. Beaver Lake has especially been an important site for conducting ceremonies. First Nations often seek the incorporation of native species in ecological restoration, especially those of ethnobotanical significance having been used for food (e.g. Salal (*Gaultheria shallon*)), medicine (e.g. Devil's Club (*Oplopanax horridus*)), clothing (e.g. nettles (*Urtica* sp.)), housing (e.g. reed mats (*Typha* sp.)) and other cultural purposes. Input regarding selection of culturally significant plants should be obtained from Squamish, Musqueam and the Tsleil-Waututh to inform plant selecting and planting plans well in advance of the work.

## 6.8 Maintain Site Character – Beaver Management

This environmental management objective was developed prior to the installation of two beaver bafflers by the Vancouver Park Board and SPES in June 2014 (as discussed in Section 3.4). The beaver bafflers were installed to reduce the beaver damming activity and associated removal of accumulated material by park staff. Historically, material dammed at the outfall of Beaver Lake was cleared up to 2-3 times per week. In the several months following installation, the bafflers did not have to be cleared; however, material has been slowly built up along the mesh screens of the bafflers, suggesting a maintenance requirement of monthly or bi-monthly. Despite this marked improved in lake

level stability and downstream flow management, on-going management of beavers utilizing the lake will be required.

*Proposed Enhancement Approach*: Manage beaver dam construction and related water level fluctuations in the lake.

*Rationale*: The beavers utilizing the lake are an important educational component at the lake and contribute to biodiversity as well as recreational and ecological value. Despite these benefits, they can also be problematic as they interfere with the natural water flows out of the lake as a result of damming activity. Beavers respond to the sound of trickling or rushing water and will construct dams in areas where they are attracted to the sound of moving water. The Vancouver Park Board has already partially addressed the issue by using the beaver bafflers; however, some minor modifications may be required to encourage flow to enter the baffler below the typical lake elevation to further reduce the sound of flowing water. A second component to this relates to the previously discussed enhancement management objective – facilitating fish utilization (Section 6.4). The detailed project design should include a fish passage structure that will facilitate movement of salmonids between the lake and the creek while dissuading beaver activity. In Washington State, the Upper Skagit Tribe recently worked with the National Oceanic and Atmospheric Administration (NOAA) to develop and install a variety of fish passage devices that restrict beaver activity, including combinations of beaver deceivers, mesh sized to allow fish passage while preventing beaver access, and fencing off areas around fish passage structures[5]. These devices were reported to have successfully limited beaver damming activity, while allowing Chum Salmon and other salmonids to move through the beaver exclusion areas.

## 6.9 Reducing Reliance on Municipal Water Inputs

At present, municipal water is supplied to Beaver Lake via North Creek and Zoo Creek in order to maintain lake levels and provide sufficient outflow to Beaver Creek. One of the identified management objectives is to reduce future reliance on the municipal water supply. Two approaches were explored:

1. Identify alternative sources of water within the watershed that could be diverted to the lake; and
2. Develop a more sophisticated system to manage the municipal water supply inputs.

The identified options to reduce reliance on municipal water inputs are discussed in the following sections.

[5] Source: http://nwifc.org/2010/12/tribes-find-ways-to-keep-beavers-from-blocking-fish-passage/

### 6.9.1 Alternative Water Sources

Alternative sources of water that were considered include diverting grey water from existing park facilities, developing additional water storage (including stormwater detention ponds), and utilizing groundwater. The feasibility of each of these options is discussed in the following sections.

#### *6.9.1.1 Diverting Grey Water*

The project team assessed the anticipated volumes of grey water that could be diverted to the lake. Based on the marginal anticipated volume, potential adverse environmental consequences (i.e., unknown water quality), and high cost to collect and divert water to the lake, this approach was not explored further.

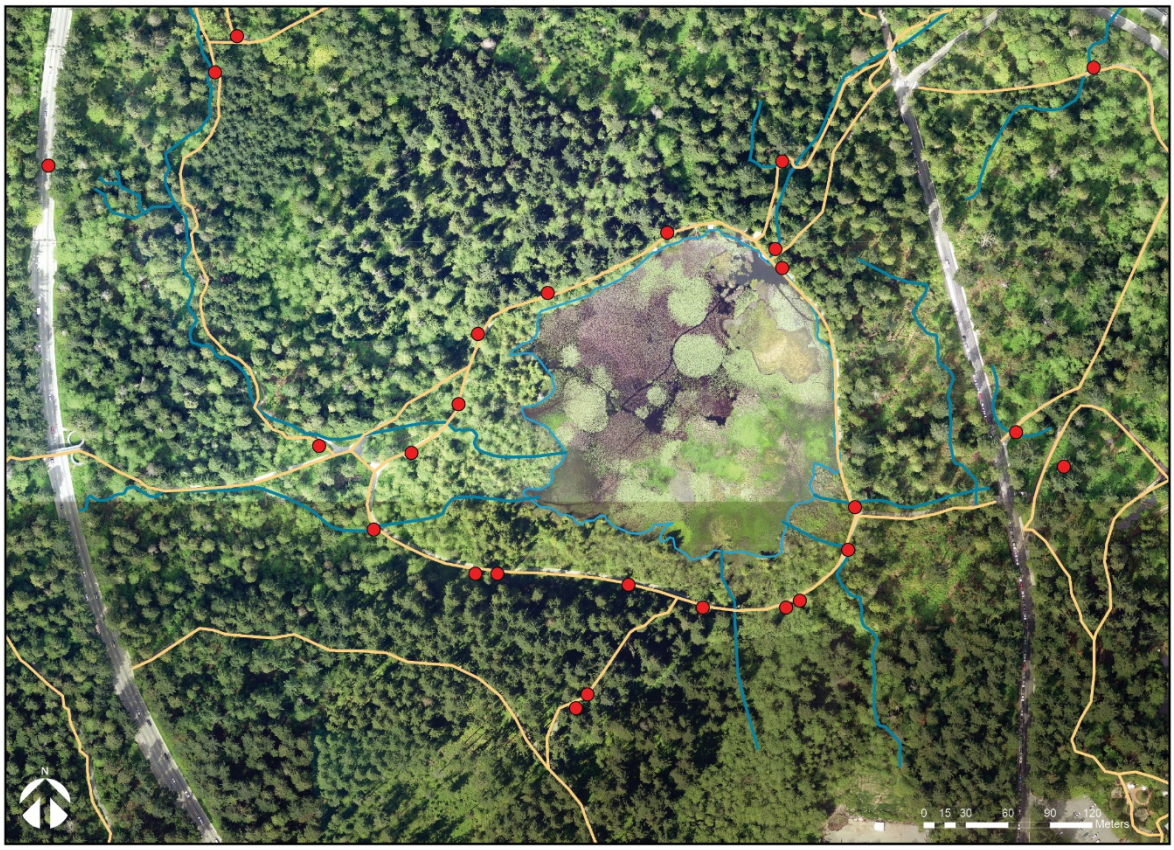
#### *6.9.1.2 Increasing Water Storage Capacity*

The project team evaluated a number of options to increase water storage capacity outside of the lake footprint, as follows:

**1) Construction of Vernal Ponds Around the Lake**

There are a number of existing low-lying areas around portions of the lake beyond the trail, which are presumably the result of historical trail building activities (i.e., the spoils from excavation were used to construct the trail). These low-lying areas could be deepened to improve year-round aquatic habitat function with a focus on amphibian and invertebrate species, and provide increased storage capacity for the lake. Although the total volume of the vernal ponds would be small relative to the lake, the detailed design could assess the permeability of the trail and underlying soils and incorporate the use of rock drains / french drains coupled with improved management of culverts (i.e., addition, removal or altering elevation of culverts) currently draining areas around the lake (**Figure 12**) to allow for controlled seepage into the lake, particularly during drier periods.

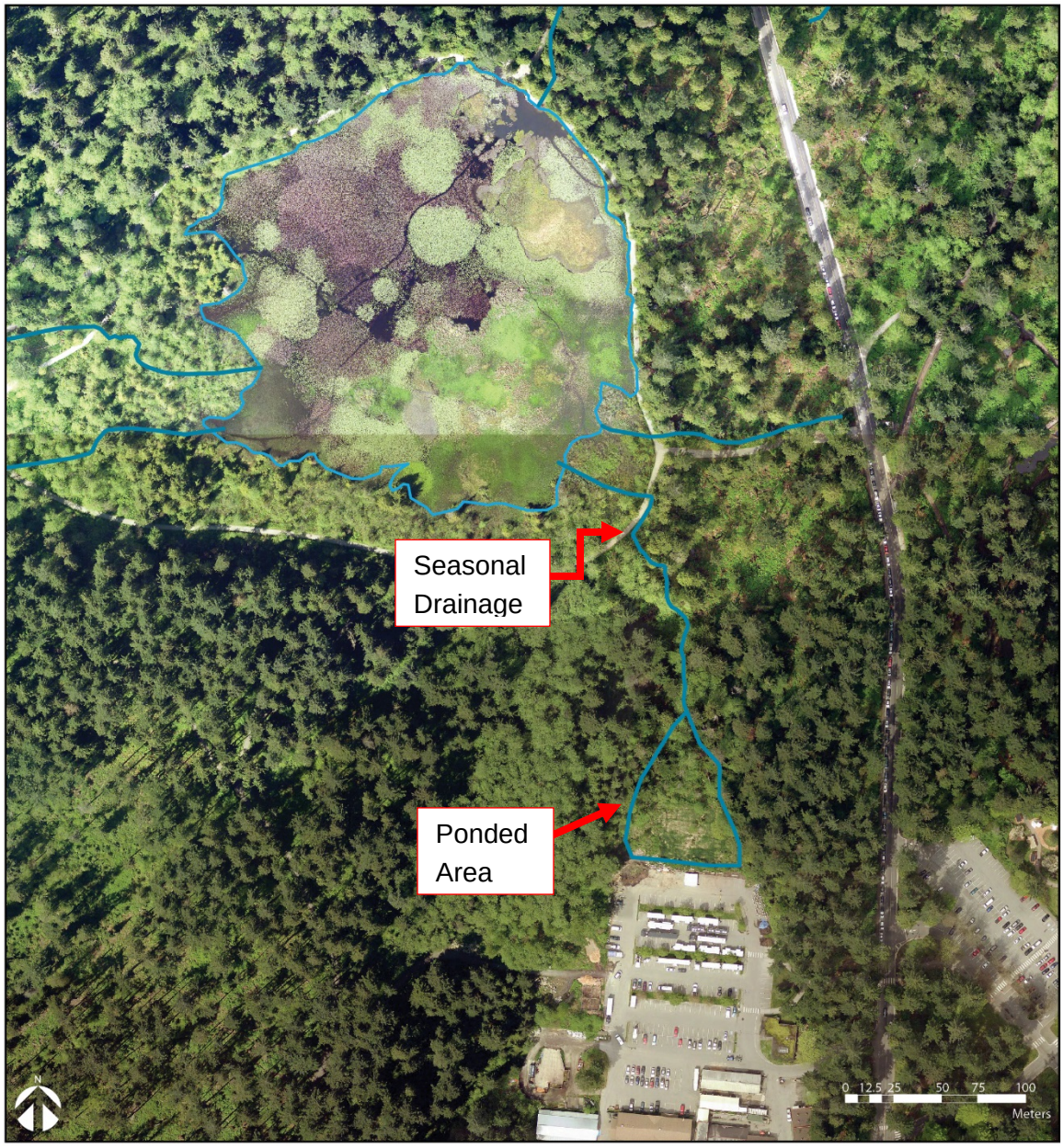
**Figure 12:** Illustration of existing culverts (red circles) in the vicinity of Beaver Lake.




### 2) Collection of Water From Overflow Parking Area and Conveyance to Constructed Water Storage Feature

The project team observed an unnamed ephemeral drainage course discharging into the lake, which was reported by SPES and the Vancouver Park Board to originate from the overflow parking area for the miniature train and Stanley Park works yard area. The stormwater from this area and east of Pipeline Road are collected via numerous catchbasins and conveyed to a low-lying ponded area before continuing downslope towards the lake (**Figure 13**).

**Figure 13:** Beaver Lake, Seasonal Drainage Channel and Low-lying Ponded Area Adjacent to Parking Area.




At the time of the assessment (June 2014), the pond was dry and overgrown with Reed Canarygrass; however, an opportunity exists to excavate material from this low-lying area and line the base of the excavation with clay from the dredged lake or an impermeable liner to reduce water loss via infiltration. The result would be a stormwater storage / detention area. The approximate dimensions of the proposed ponded area are 50 m x 40 m. Assuming an average depth of 2 m, the total water storage capacity would be 4,000 $m^3$ (4,000,000 L). Given the summer municipal water input rate of 0.86 L $s^{-1}$,

this storage area would be able to provide supplementary water matching the municipal rate for over 50 days (assuming that the ponded area was at capacity). The outlet of the pond could conceivably be controlled to facilitate the release of water during the summer months. Invasive species, including Japanese Knotweed and Reed Canarygrass, were observed within and adjacent to the pond. As a result, extra precautions would have to be taken during excavation and construction of this pond to ensure that these invasives are not spread to Beaver Lake.


#### *6.9.1.3 Utilizing Groundwater Resources*

The Hatfield (1985) report identified two possible groundwater-bearing zones – a shallow aquifer in the sands and gravels that may separate the bedrock from the overlying till and the lower aquifer consisting of fractured basalts. Hatfield estimated the groundwater yield of approximately 3.5 L $s^{-1}$, which could provide flow over a 3 month period and then be allowed to recharge for the remainder of the year.

Identified areas to test for groundwater yield included the area immediately adjacent to Beaver Lake to test for the presence of sands, silts and gravels that may lie between the bedrock and till. A second location was identified to the west of the parkway where the

basalts are known to be present. The estimated well depth at this location would be up to 75 m and was anticipated to be free from the possibility of salt water intrusion.

The use of groundwater as a supplementary water supply may be costly. Moreover, drawing down the water table may have consequences on the vegetation communities in the park, recharge rates and/or an increase in salinity over time, contingent on groundwater depth and well location. Determining if the groundwater aquifer is sufficient to maintain the desired flows will require a fairly extensive field investigation. If groundwater is to be explored further as a potential supplementary water supply, the project team recommends the following:

1. Hydraulic inputs from Zoo Creek should be measured to confirm the combined municipal inputs during the drier months (July – September);
2. An annual water balance should be completed (to determine potential groundwater recharge rate) coupled with spot flow measurements; and
3. Completion of a cost/benefit analysis should be undertaken to evaluate if groundwater extraction would be cost-effective as a supplementary water supply.

### 6.9.2 Municipal Water Management

At the commencement of this investigation, the municipal water being supplied to North Creek was controlled by a tap located in a locked utility box that was turned on and off by Vancouver Park Board staff. The default setting is a ‘trickle’ of water but this is increased if dry conditions require a higher flow. The current management approach likely results in the tap being left on during periods of wet weather when additional inputs are potentially not required.

A more sophisticated system for managing the water supply could be developed that would permit the taps to be adjusted in response to water levels in Beaver Lake. Such a system would potentially include the following components that would ideally be installed such that data could be read remotely:

1. A meter on the supply taps so that the input of water is known;
2. A sensor in Beaver Lake to continuously monitor lake levels; and
3. A known relationship between the amount of water discharging from the taps and the amount of water reaching Beaver Lake and Beaver Creek.

The system would require an initial period of testing and data gathering to develop a more refined set of management protocols to maintain lake levels. Once the management protocols are established, City staff would need to be trained to implement the protocols effectively. A potentially more effective approach to reducing the use of municipal water would be to install a valve that could be operated remotely in response to sensors installed in Beaver Lake.

### 6.9.3 Beaver Lake Dam Upgrades

The elevation of water in Beaver Lake is controlled by a human built dam. The top of the dam has been made into the Beaver Lake Trail. It is believed that the dam was built in the early 1900s and is approximately 0.5 km long, with a maximum height of 1-metre. A 42-inch (107 cm) long hand held soil auger and a 48-inch (122 cm) long tile probe were used to determine the composition of the dam, which appears to have been constructed from sandy loam texture soil, with gravel on top. The base of the dam also appears to have been constructed from the same texture soil. Dams constructed from sandy loam soil are quite permeable, and do not hold water as well as dams constructed from soil that is high in clay.

Water was found to be leaking under the dam at a number of locations. The flowing water was especially noticeable along the highest portion of the dam near the water control structures. The seepage is causing Beaver Creek to lose water, affecting the elevation of water in the lake. Water is seeping through and under the dam because a compacted clay core was not constructed when the dam was built. It appears that permeable sandy loam texture soil was used to build the dam. The dam may also have been built on a permeable organic layer, which is also allowing water to move under the dam.

In 1999, Zimmerman et al., recommended replacing the dam and associated strictures, which was purportedly partially responsible for the introduction of sediments into the lake citing capacity limitations and resulting flooding. Specifically, the main culvert at the dam was estimated as having a peak flow capacity of 0.6 $m^3/s$, while the secondary culvert was estimated as having a peak flow capacity of 0.13 $m^3/s$ for a total discharge capacity of 0.73 $m^3/s$, which is significant less than the estimated 100 year flood event of 3.3 $m^3/s$. The report also notes that the logs holding the weirs and dam in place are becoming old and could stand to be replaced. If the dam were to fail at this location, much of the lake would drain.

# 7 Preliminary Design Concepts

Building on the results of the field study and the environmental management strategies presented in previous section, four (4) preliminary design concepts were developed to illustrate a range of approaches to enhancing Beaver Lake. The four concepts were intended to meet the project vision:

> *"To create a diverse and healthy ecosystem that provides passive recreation opportunities for the public, maximizes native biodiversity, respects cultural significance and requires minimal ongoing integration to maintain its integrity."*

The following objectives were used to guide the designs:

1. **Biodiversity:** The primary approach to maximizing biodiversity is to create a mosaic of habitat types in the Beaver Lake ecosystem consisting of restored open water, islands and functional riparian habitat.
2. **Recreation:** Passive recreation that is non-consumptive, with little or no disturbance, and includes walking, relaxation and nature appreciation.
3. **Low Maintenance:** The restoration strategy is intended to establish self-perpetuating plant associations and communities appropriate for the site.

Balancing these objectives, as well as capital and maintenance costs, the four concepts were intended to provide a slate of options, each of which focused on a different iteration of the core objectives. In addition to the four options presented, eighteen (18) enhancement and management strategies were presented, which could each be applied to any of the concepts. Providing four varied "futures" for the lake, it was envisioned that the final plan would likely be a hybrid design, incorporating various features from the different designs.

## 7.1 Preliminary Concepts

The four preliminary concepts are presented on the following pages.

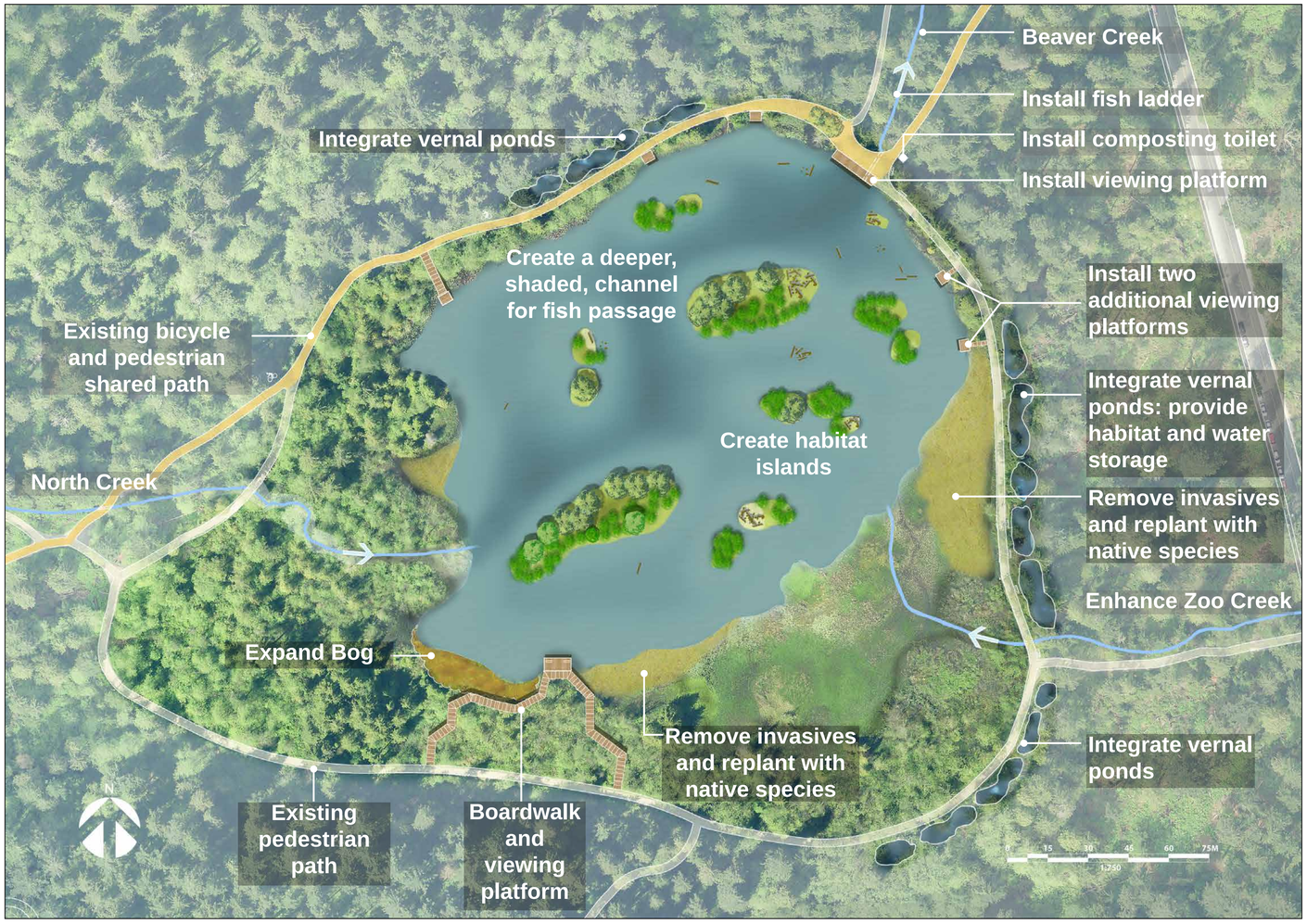
- **Concept 1: Islands and Viewing Platforms** – Maximizes Habitat Creation and Biodiversity (**Figure 14**)
- **Concept 2: Open Water and Floating Boardwalk** – Increases Passive Recreation but Reduces Wildlife (**Figure 15**)
- **Concept 3: Open Water and View Tower** – Creates Less Habitat and Biodiversity but Represents the Lowest Capital Cost (**Figure 16**)
- **Concept 4: Islands and View Tower** – Balances Habitat Creation and Biodiversity with Cost Considerations (**Figure 17**)

The strengths and weaknesses of each preliminary concept in regards to ecological values, recreation and interpretive opportunities, maintenance and cost implications are detailed in **Table 7**.

# Figure 14: CONCEPT 1 | ISLANDS AND VIEWING PLATFORMS

*Maximizes Habitat Creation and Biodiversity*

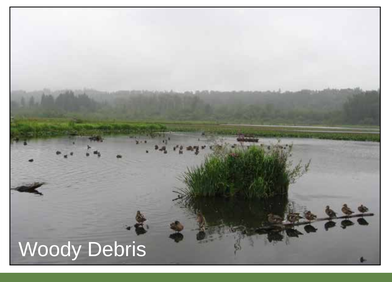
November 2013




- *Seeks to maximize biodiversity. Islands provide habitat for mammals, birds, amphibians, reptiles, fish and insects - including both common and sensitive (species-at-risk) species. Vernal ponds, and improvements to Zoo Creek further enhance habitat.*
- *Fish ladder and 5 metre deep channel from Beaver Creek to North Creek increases potential for year round salmon habitat.*
- *2.6 hectares of open water, to a maximum depth of 5m.*
- *High volume of sediment and clay removal and disposal.*
- *Moderate-High Lake Longevity (assumes periodic invasive species management around islands and edge areas following dredging to a maximum depth of 5m).*
- *Boardwalks, five additional viewing platforms and a composting toilet.*


Habitat Mosaic and Boardwalk


Vernal ponds


Woody Debris


Salmon habitat

**Strengths**

- Highest increase in animal diversity.
- Highest increase in plant diversity.
- Increases habitat for fish.
- Islands and woody debris provide for turtle basking/ nesting and shorebird/waterfowl habitat.
- Reduces prevalence of non-native invasives such as fragrant water lily and narrow leaf cattail.
- Vernal ponds improve wildlife, especially amphibian, habitat and reduce runoff into the lake.
- Zoo Creek stream restoration diversifies wildlife habitat.
- Increased opportunities for the lake to be used for re-introduction of species at-risk e.g. western painted turtle.
- Installed fish ladder in Beaver Creek and deepening of channel through lake to reduce water temperature would allow for salmon to travel from Beaver Creek to North Creek year round.
- Islands with trees shade and cool the channel and reduce evapotranspiration.
- Deeper water (max 5 metres) prevents recolonization by lilies.
- Expansion of bog increases plant diversity.

**Weaknesses**

- Islands may contribute to more rapid infilling of lake over time, but should be mitigated by overall depth increase.
- Requires most extensive sediment and clay removal and disposal.
- Longest length of excavation and invasive species removal work (2-3 months).

- Greatly increases wildlife viewing and interpretive opportunities.
- Replicates natural coastal BC wetlands.
- Additional platforms and boardwalks expand viewing opportunities, educational and interpretive programming.
- Boardwalks provide additional interpretive opportunities.
- Vernal ponds, bog expansion and stream restoration increase wildlife viewing along trail, adding to the ecological experience of visiting Stanley Park.
- Composting toilet expands the range of programming and enhances visitor experience.

**Relative Costs**

- Highest enhancement capital cost. $$$$
- High facilities capital cost. $$$
- Low - moderate maintenance cost. $-$$


**Section 1: Vernal ponds, path, viewing platform and habitat island**

Vancouver Board of Parks and Recreation | Stanley Park Ecology Society 25 Connecting people with nature since 1988

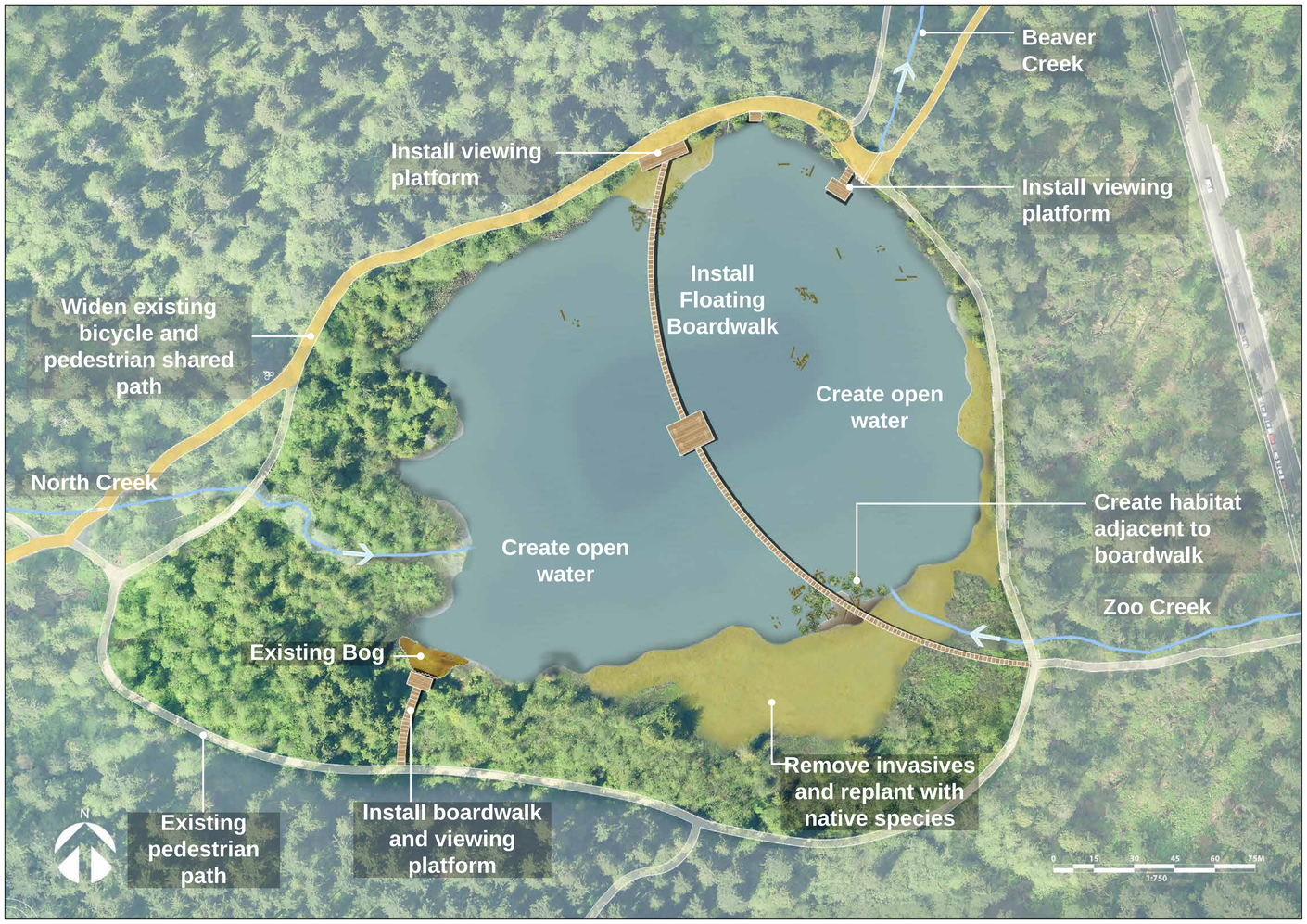
**Ecological and Culturally Sensitive Enhancement Plan for Beaver Lake**

AQUATERRA Environmental Ltd. | Bianchini Biological Services | Dig It! | HEMMERA | LEES+Associates Landscape Architects and Planners | nhc northwest hydraulic consultants

# Figure 15: CONCEPT 2 | OPEN WATER AND FLOATING BOARDWALK

*Increases Passive Recreation but Reduces Wildlife*

November 2013




- *Seeks to remove all non-native plant species and replant with natives.*
- *Does not support fish.*
- *3.15 hectares of open water, to a maximum depth of 1.5m.*
- *Low volume of sediment removal and disposal.*
- *High Lake Longevity (assuming on-going invasives removal following dredging to a maximum depth of approximately 1.5m).*
- *2m wide floating boardwalk across the lake with central platform and two additional viewing platforms.*

**Strengths**

- Least increase in animal diversity.
- Moderate increase in plant diversity.
- Maximized removal of non-native plant species limits recolonization of invasive fragrant water lily.
- Woody debris enhances habitat.

- Boardwalk facilitates wildlife viewing and provides interpretive and passive recreation opportunities for visitors.
- Widened shared path on north edge of lake would reduce user conflicts.

- Removal of 100% non-natives and management would result in slowest future lake infill.
- Lowest volume of sediment removal and disposal.
- Short period of excavation and invasive species removal work (~1 month).

**Weaknesses**

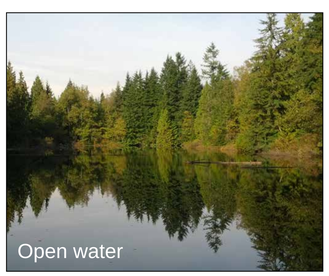
- A large investment of habitat reconstruction and extensive on-going maintenance is required.
- Negative impact on biodiversity by eliminating all non-native species.
- Human use of boardwalk across the lake would disturb wildlife, especially those requiring larger habitat patches and intolerant of disturbance (e.g. American bittern).
- Not suitable for salmon.

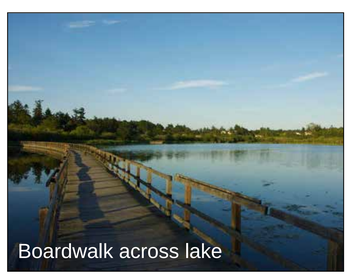
- Significant ongoing invasive and non-native species management.
- Canada geese droppings on boardwalk could require additional maintenance.

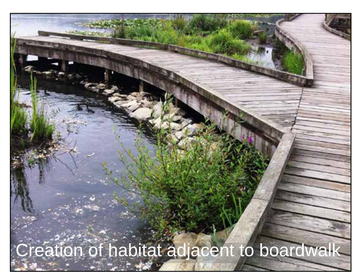
**Relative Costs**

- Low - moderate enhancement capital cost. $$
- Highest facility costs. $$$$
- Highest maintenance costs due to maximized on-going management of non-native plants. $$$$


**Section 2: Floating boardwalk**


Open water

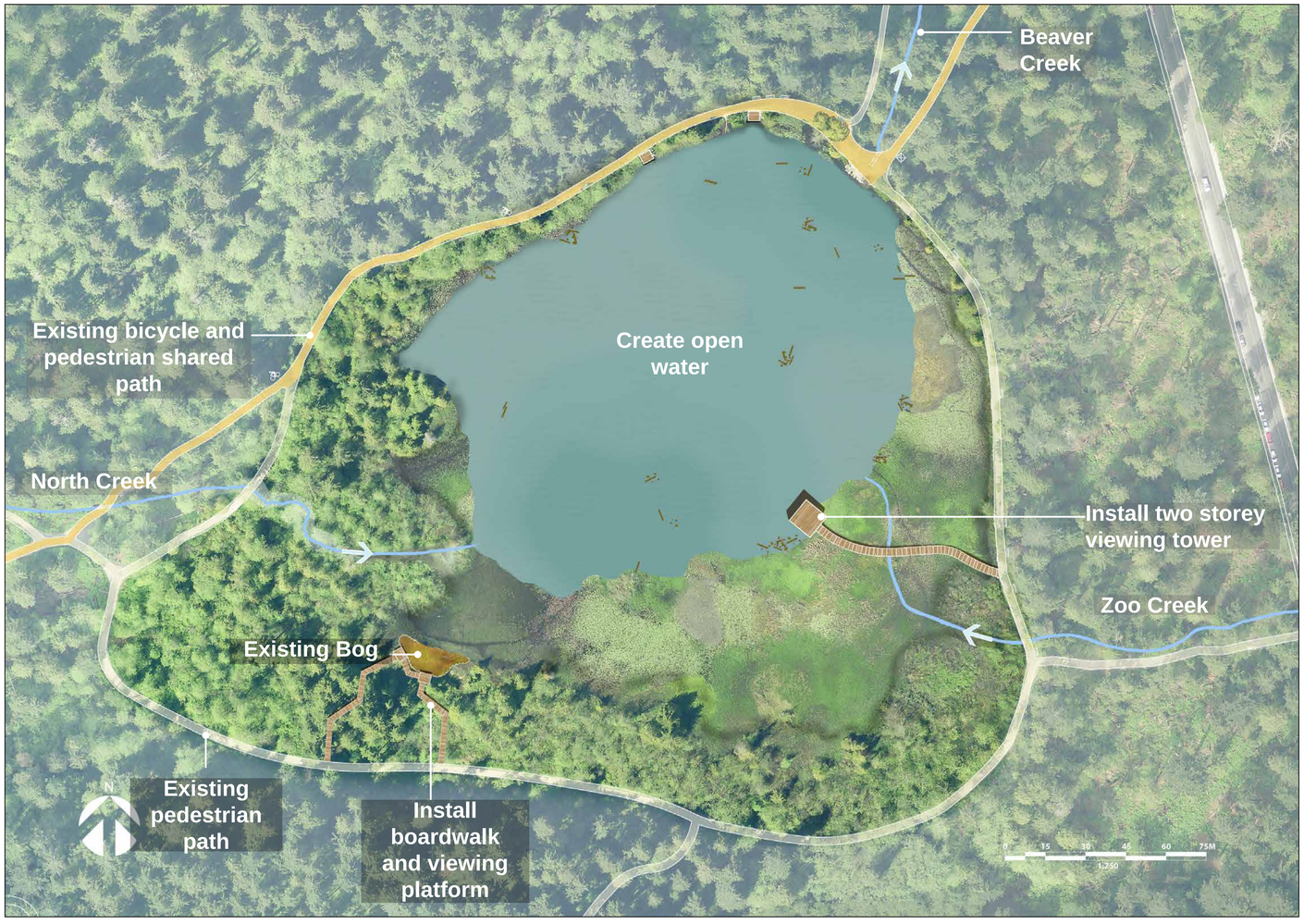

Boardwalk across lake


Creation of habitat adjacent to boardwalk

# Figure 16. CONCEPT 3 | OPEN WATER AND VIEW TOWER

***Low Habitat Creation and Biodiversity but Lowest Enhancement Capital Cost***

November 2013




- *Seeks to remove vegetation, sediment and decaying organics from the lake and reduce, but not eradicate, the invasive fragrant water lilies.*
- *Does not support fish.*
- *2.25 hectares of open water, to a maximum depth of 1.75m.*
- *Moderate sediment removal and disposal. Some fragrant water lilies would return annually and may lead to more rapid infilling of the lake if not managed.*
- *Low-Moderate Lake Longevity (assumes periodic invasives species management following dredging to a maximum depth of 1.75m).*
- *Two storey viewing tower and loop boardwalk trail to bog.*

**Strength**

- Moderate increase in animal diversity.
- Reduces invasive fragrant water lily and narrow leaf cattail.
- Woody debris provides for increased habitat.
- Combination of open water and maximized riparian area provide habitat benefits.

- Creates a deep open water lake appearance.
- Tower provides a unique viewing opportunity.

- Short period of excavation and invasive species removal work (~ 1.5 months).

**Weaknesses**

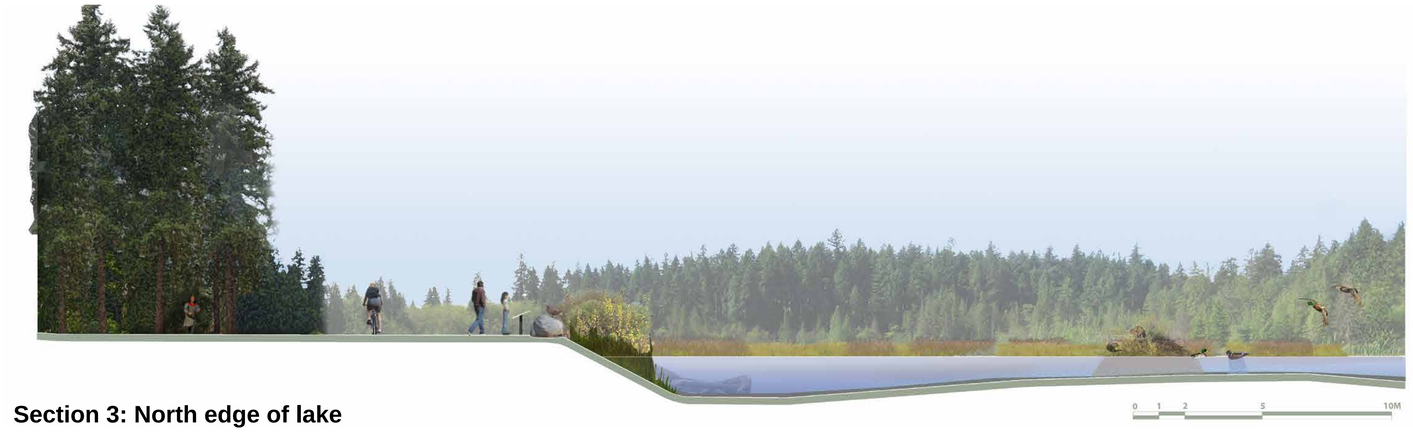
- Does not remove all water lily. Water lily will re-grow and mats will return without regular, ongoing management.
- View tower in this location may disturb wildlife.
- Does not increase plant diversity.
- Not suitable for salmon.

- Decreases wildlife viewing opportunities due to few places for animals to hide, feed, or nest.
- No increase in wildlife habitat and viewing opportunities along the trail.

- As fewer of the invasive lilies will be removed, the lake will infill more rapidly than other restoration options without regular, ongoing management.

**Relative Costs**

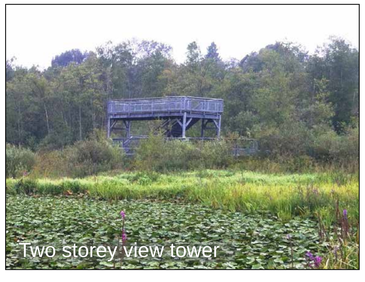
- Lowest enhancement capital cost. $
- Low - moderate facility costs. $$
- Low - moderate maintenance cost. $-$$




**Section 3: North edge of lake**


Annual Lilies


Open water


Two storey view tower

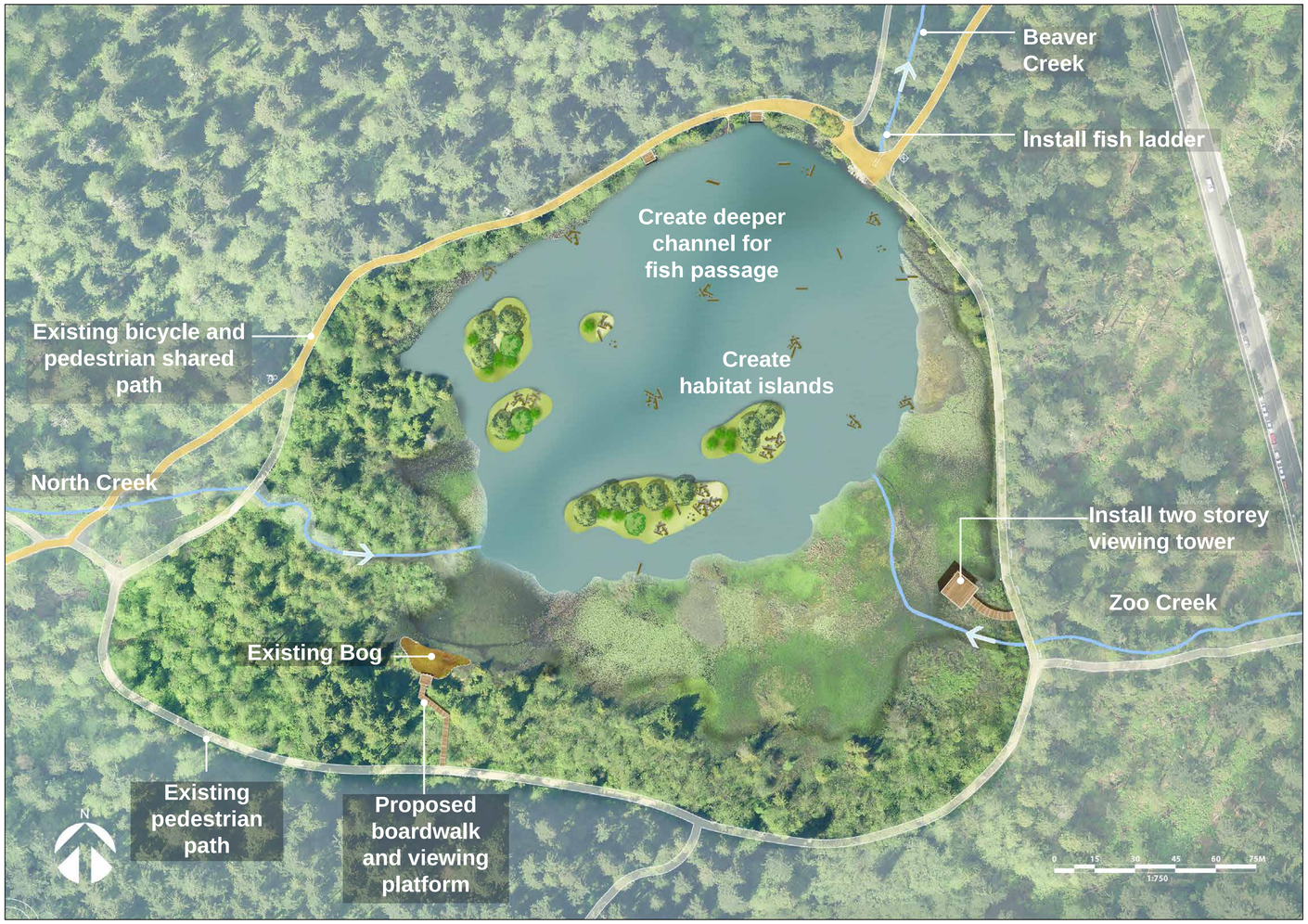
Ecological and Culturally Sensitive Enhancement Plan for Beaver Lake

Vancouver Board of Parks and Recreation | Stanley Park Ecology Society 25 Connecting people with nature since 1988 | AquaTerra Environmental Ltd. | Bianchini Biological Services | Dig It! | Hemmera | LEES+Associates Landscape Architects and Planners | nhc northwest hydraulic consultants

# Figure 17. CONCEPT 4 | ISLANDS AND VIEW TOWER

***Balances Habitat Creation and Biodiversity with Cost Considerations***

November 2013




- *Seeks to remove vegetation, sediment and decaying organics from the lake and reduce, but not eradicate, the invasive fragrant water lilies. Excavated soil is used to create habitat islands for mammals, birds, amphibians, reptiles, fish and insects.*
- *A clear passage of 1.75m depth is created from Beaver Creek to North Creek to encourage seasonal fish movement through the lake.*
- *2 hectares of open water, to a maximum depth of 1.75m.*
- *Moderate sediment removal and disposal. Some fragrant water lilies would return annually and may lead to more rapid infilling of the lake if not managed.*
- *Low Lake Longevity (assumes periodic invasive species management around islands and edge areas following dredging to a maximum depth of 1.75m).*
- *Two storey viewing tower and boardwalk trail to bog.*

**Strengths**

- High increase in animal diversity.
- High increase in plant diversity.
- Islands encourage turtle basking/ nesting and use by shorebird, waterfowl and song birds.
- Woody debris provides increased habitat.
- Reduces invasive fragrant water lily and narrow leaf cattail.
- Fish ladder in Beaver Creek and deepening of channel through lake to reduce water temperature allows for seasonal movement of salmon to travel from Beaver Creek to North Creek.
- Islands with trees shade and cool the channel and reduce evapotranspiration.

- Increases wildlife viewing opportunities.
- Replicates natural coastal BC wetlands.
- Creates a deep open water lake appearance.
- The tower provides a unique viewing opportunity.

**Weaknesses**

- Reduces, but does not eliminate, invasive species.
- Does not increase wildlife habitat and viewing opportunities along the trail.
- Moderate length of excavation and invasive species removal work (1.5 - 2 months)

**Relative Costs**

- Moderate - high enhancement capital cost. $$ - $$$
- Lowest facility costs. $
- Lowest maintenance cost. $


**Section 4: View tower and edge of lake**


Annual Lilies


Open water


Two storey view tower

Ecological and Culturally Sensitive Enhancement Plan for Beaver Lake

Vancouver Board of Parks and Recreation | Stanley Park Ecology Society 25 | AquaTerra Environmental Ltd. | Bianchini Biological Services | DIG IT! | Hemmera | LEES+Associates Landscape Architects and Planners | nhc northwest hydraulic consultants

**Table 7:** Comparison of Preliminary Designs

The concepts included a range of approaches for meeting ecological and recreational objectives, and for appealing to differing aesthetic preferences. The following table provides a summary comparison of the four concepts. The second column describes the range of approaches provided through the four concepts.

| OBJECTIVES | RANGE OF APPROACHES | CONCEPT 1 \| ISLANDS AND VIEWING PLATFORMS | CONCEPT 2 \| OPEN WATER AND FLOATING BOARDWALK | CONCEPT 3 \| OPEN WATER AND VIEW TOWER | CONCEPT 4 \| ISLANDS AND VIEW TOWER |
|---|---|---|---|---|---|
| **Overarching Approach** | | *Maximizes Habitat Creation and Biodiversity* | *Increases Passive Recreation but Reduces Wildlife* | *Low Habitat Creation and Biodiversity but Lowest Enhancement Capital Cost* | *Balances Habitat Creation and Biodiversity with Cost Considerations* |
| **Ecological Values** | | | | | |
| *Removal of invasive and non-native species* | ▪ Concepts range in the recommended extent of invasive and non-native species removal. Some rely more heavily on ongoing management; others on one-time removals. | *Strengths*<br>▪ Highest increase in animal diversity.<br>▪ Highest increase in plant diversity.<br>▪ Increases habitat for fish.<br>▪ Islands and woody debris provide for turtle basking/ nesting and shorebird/waterfowl habitat.<br>▪ Reduces prevalence of non-native invasives, such as Fragrant Water-lily and Narrow Leaf Cattail.<br>▪ Vernal ponds improve wildlife, especially amphibian, habitat and reduce runoff into the lake.<br>▪ Zoo Creek stream restoration diversifies wildlife habitat.<br>▪ Increased opportunities for the lake to be used for re-introduction of Species-at-Risk e.g., Western Painted Turtle.<br>▪ Installed fish ladder in Beaver Creek and deepening of channel through lake to reduce water temperature would allow for salmon to travel from Beaver Creek to North Creek year-round.<br>▪ Islands with trees shade and cool the channel and reduce evapotranspiration.<br>▪ Deeper water (max. 5 metres) prevents recolonization by lilies.<br>▪ Expansion of bog increases plant diversity. | *Strengths*<br>▪ Least increase in animal diversity.<br>▪ Moderate increase in plant diversity.<br>▪ Maximized removal of non-native plant species limits recolonization of invasive Fragrant Water-lily.<br>▪ Woody debris enhances habitat.<br><br>*Weaknesses*<br>▪ A large investment of habitat reconstruction and extensive on-going maintenance is required.<br>▪ Negative impact on biodiversity by eliminating all non-native species.<br>▪ Human use of boardwalk across the lake would disturb wildlife, especially those requiring larger habitat patches and intolerant of disturbance (e.g. American Bittern).<br>▪ Not suitable for salmon. | *Strengths*<br>▪ Moderate increase in animal diversity.<br>▪ Reduces invasive Fragrant Water-lily and narrow leaf cattail.<br>▪ Woody debris provides for increased habitat.<br>▪ Combination of open water and maximized riparian area provide habitat benefits.<br><br>*Weaknesses*<br>▪ Does not remove all Fragrant Water-lily. Water-lily will re-grow and mats will regenerate without regular, ongoing management.<br>▪ View tower in this location may disturb wildlife.<br>▪ Does not increase plant diversity.<br>▪ Not suitable for salmon. | *Strengths*<br>▪ High increase in animal diversity.<br>▪ High increase in plant diversity.<br>▪ Islands encourage turtle basking/nesting and use by shorebird, waterfowl and song birds.<br>▪ Woody debris provides increased habitat.<br>▪ Reduces invasive Fragrant Water-lily and Narrow-leaf Cattail.<br>▪ Fish ladder in Beaver Creek and deepening of channel through lake to reduce water temperature allows for seasonal movement of salmon to travel from Beaver Creek to North Creek.<br>▪ Islands with trees shade and cool the channel and reduce evapotranspiration.<br><br>*Weaknesses*<br>▪ Reduces, but does not eliminate, invasive species. |
| *Habitat creation* | ▪ Concepts range in the levels of plant and animal diversity that they would be expected to yield.<br>▪ Some strive for year round fish habitat and passage; others focus on seasonal fish use, and some do not focus on fish at all. | | | | |

| OBJECTIVES | RANGE OF APPROACHES | CONCEPT 1 \| ISLANDS AND VIEWING PLATFORMS | CONCEPT 2 \| OPEN WATER AND FLOATING BOARDWALK | CONCEPT 3 \| OPEN WATER AND VIEW TOWER | CONCEPT 4 \| ISLANDS AND VIEW TOWER |
|---|---|---|---|---|---|
| **Overarching Approach** | | *Maximizes Habitat Creation and Biodiversity* | *Increases Passive Recreation but Reduces Wildlife* | *Low Habitat Creation and Biodiversity but Lowest Enhancement Capital Cost* | *Balances Habitat Creation and Biodiversity with Cost Considerations* |
| **Recreational Values** | | | | | |
| *Recreation opportunities* | Concepts focus primarily on passive recreation such as walking, nature viewing, and educational programming.<br><br>All concepts retain the existing cycling path along the north side of the lake. None extend the cycling path around the lake as this would be disruptive to wildlife and would reduce the quiet, contemplative nature of the trail. One concept widens the shared use section of the trail.<br><br>In all cases, bollards or boulders, as well as additional signage, are recommended to limit the extent of unsanctioned cycling around the remainder of the lake.<br><br>The perimeter trail is currently heavily used by runners and joggers. None of the designs aim to restrict their use. | | ▪ Widened shared path on north edge of lake would reduce user conflicts. | | |
| *Structures* | A range of structures are included in all of the concepts. These range from simple interventions such as small, at grade platforms, to a multi-storey view tower, to varied lengths and complexities of boardwalks around the perimeter of the lake, to a floating boardwalk that crosses the lake. | ▪ Two boardwalks, including a loop to the bog, five additional viewing platforms, and a composting toilet. | ▪ A 2m wide floating boardwalk across the lake with a central platform and two additional viewing platforms. | ▪ A two-storey viewing tower and looped boardwalk trail to the bog. | ▪ A two-storey viewing tower and boardwalk trail to the bog. |

| OBJECTIVES | RANGE OF APPROACHES | CONCEPT 1 \| ISLANDS AND VIEWING PLATFORMS | CONCEPT 2 \| OPEN WATER AND FLOATING BOARDWALK | CONCEPT 3 \| OPEN WATER AND VIEW TOWER | CONCEPT 4 \| ISLANDS AND VIEW TOWER |
|---|---|---|---|---|---|
| **Overarching Approach** | | *Maximizes Habitat Creation and Biodiversity* | *Increases Passive Recreation but Reduces Wildlife* | *Low Habitat Creation and Biodiversity but Lowest Enhancement Capital Cost* | *Balances Habitat Creation and Biodiversity with Cost Considerations* |
| *Interpretive opportunities* | Additional interpretive signage is recommended in all four concepts. Design and installation of interpretive signs may become part of a broader, park-wide signage initiative.<br><br>All concepts provide opportunities for programming and signage that celebrates the cultural history of the lake and its surroundings.<br><br>The four concepts include a range of spaces for interpretive and educational programming, and in one case, toilet facilities nearby. | ▪ Greatly increases wildlife viewing and interpretive opportunities.<br>▪ Vernal pond creation, bog expansion and stream restoration all serve to increase wildlife viewing along trail, and add to the ecological experience of visiting Stanley Park.<br>▪ Additional platforms and boardwalks expand viewing opportunities, educational and interpretive programming.<br>▪ Boardwalks provide additional interpretive opportunities.<br>▪ Composting toilet expands the range of programming and enhances visitor experience. | ▪ Boardwalk facilitates wildlife viewing and provides interpretive and passive recreation opportunities for visitors. | ▪ Decreases wildlife viewing opportunities due to the few places available for animals to hide, feed, or nest.<br>▪ No increase in wildlife habitat and viewing opportunities along the trail.<br>▪ The tower provides a unique viewing opportunity. | ▪ Increases wildlife viewing opportunities.<br>▪ Does not increase wildlife habitat and viewing opportunities along the trail.<br>▪ The tower provides a unique viewing experience. |
| Aesthetics | | | | | |
| | In all four concepts, the removal and addition of vegetation, and the siting of islands, benches, viewpoints and platforms, were evaluated in light of their potential effects on site aesthetics and views made available to visitors. | | | | |
| | Each concept offers a different extent of open water. Concepts range from proposing completely open water across the lake, to replicating the wetlands characteristic of coastal BC.<br><br>The level of preference for open water versus a mosaic of islands was queried through the public questionnaire. | ▪ Replicates natural coastal BC wetlands.<br>▪ 2.6 hectares of open water, to a maximum depth of 5m. | ▪ 3.15 hectares of open water, to a maximum depth of 1.5m. | ▪ Creates a deep, open water lake appearance.<br>▪ 2.25 hectares of open water, to a maximum depth of 1.75m. | ▪ Replicates natural coastal BC wetlands.<br>▪ Creates a deep open water lake appearance.<br>▪ 2 hectares of open water, to a maximum depth of 1.75m. |

# 8 First Nations Consultation

## 8.1 First Nations

The project team initiated consultation with the Musqueam Indian Band, Squamish Nation and the Tsleil-Waututh First Nation in April 2013 prior to the onset of work. Engagement was based on an acknowledgment and respect for the strong connection of these First Nations to Beaver Lake and the surrounding lands and waters. An information board was developed in consultation with each of the First Nations (**Figure 18**).

These Nations also have clearly articulated interests in the project area that fall beyond the scope of the Beaver Lake Enhancement consultation program and are engaging with the City of Vancouver and other levels of government in broader discussions related to these interests.

## 8.2 Key Consultation Objectives

Key objectives of First Nations consultation and engagement in support of the Beaver Lake Enhancement project have been to:

- Engage First Nations to determine potential impacts of the project in relation to their interests;
- Seek to incorporate traditional ethnobotanical and community knowledge into project planning;
- Engage with First Nations regarding cultural and spiritual considerations in relation to the project;
- Ensure considerations and provisions for culturally and spiritually defined values or practices are integrated into enhancement options;
- Inform the design of the preferred concept option based on input from First Nations; and
- Provide information about project development as it becomes available, including design concept options and environmental studies

# Figure 18. SINCE TIME IMMEMORIAL: FIRST NATIONS IN THEIR OWN WORDS

November 2013

## xʷməθkʷəy̓əm
## Musqueam First Nation

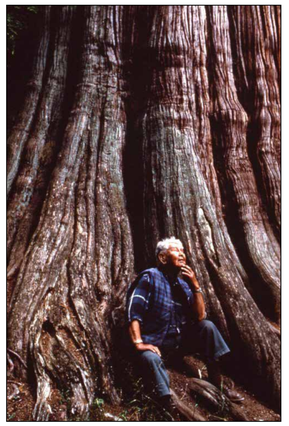
**www.musqueam.bc.ca**

The Musqueam people have been present in our traditional territory since time immemorial. Musqueam artifacts over 9,000 years old have been found in our territory, which includes all of present day Vancouver, extending north-west up Howe Sound and east up the Fraser Valley and to the South Arm of the Fraser River and still occupies what is now Vancouver and its surrounding areas.

Our ancestral language is hən̓q̓əmin̓əm̓, one of the 10 Central Coast Salish languages, and is often referred to as the Downriver dialect of Halkomelem because it is geographically situated between the two other major dialects of the same language.

The oral history of the Musqueam people that has been handed down through generations talks about our traditional territory, how we have always used the resources of the land for fishing, hunting, trapping, and gathering to maintain our livelihood. Musqueam oral history tells of a connection to these lands and waters since time immemorial.

χʷay̓χʷəy̓, spapəyəq̓, ʔəy̓əlxən, χaʔχcə… these are just a few of our names for sites in and around what is now known as Stanley Park, an area once known for its abundant natural resources and spiritual sites.



Photos courtesy of Musqueam Indian Band

## Sḵwx̱wú7mesh
## Squamish First Nation

**www.squamish.net**

Kayachten (Welcome) The Squamish people invite you to witness the beauty of our lands and waters, this area is known as Axachu7 (Beaver Lake). A prominent story from this area recounts the origins of a sacred mask used by Coast Salish peoples. You are invited to learn more of the rich history of the village sites and place names throughout Stanley Park, a place where our People flourished and lived since time immemorial.

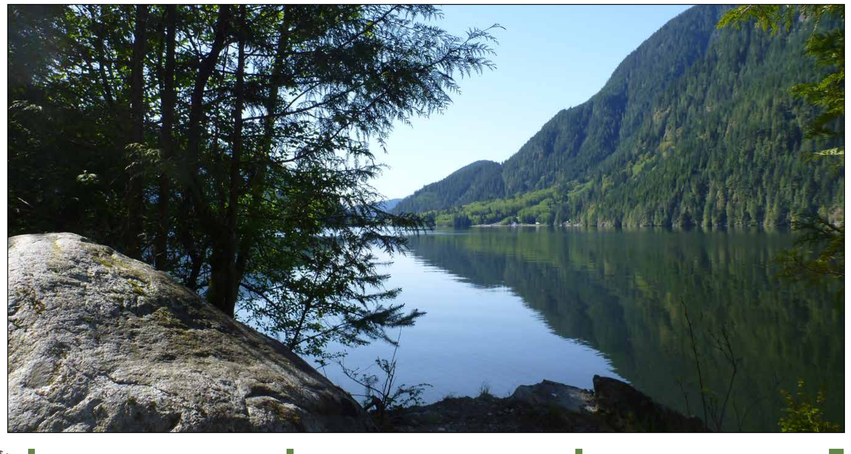
Photos courtesy of Lisa Wilcox

## səl̓ilwətaʔɬ
## Tsleil-Waututh First Nation

**www.twnation.ca**

We are the Tsleil-Waututh Nation, “The People of the Inlet” and have lived in and along the waters of Burrard Inlet and the Salish Sea, including what is now Stanley Park, since time out of mind. The first Tsleil-Waututh people were created from Burrard Inlet. Before contact with Europeans, the Tsleil-Waututh population was great, with villages of long houses stretching for kilometres along the Inlet. Today we are a Nation almost 500 people strong, based in North Vancouver along the shores of Burrard Inlet.
The traditional territory of the Tsleil-Waututh Nation was a veritable land of plenty. Tsleil-Waututh elders taught that when “the tide was out, the table was set.” We have always been here, and we will always be here. Our People are here to care for our land and water.

Tsleil-Waututh people have acted as the stewards of the lands and waters of Burrard Inlet for thousands of years. It is now, and has always been the birthright and the obligation of the Tsleil-Waututh people to care for the lands and waters of our territory and to restore them to their prior state.



## 8.3 Consultation and Engagement Activities

Consultation and engagement activities for the Beaver Lake Enhancement project included the following:

- On- and off-site meetings to ensure the integration of First Nations knowledge and provisions for culturally and spiritually defined values or practices. Meetings were also an opportunity to identify and address concerns, share information, and obtain input on enhancement concepts;
- Letters, emails and phone communications;
- A site visit to Beaver Lake for First Nations representatives to share knowledge, identify concerns and priorities, and to ask the technical team questions related to data collection, studies, design considerations and development of conceptual design options;
- Cultural education event for City and project team staff hosted by the Squamish Nation. The event was intended to improve attendees understanding of the Squamish Nation and the history of the area inclusive of the project area, as well as to provide essential information to the project team in order for them to undertake their assessment in a manner respectful of Squamish culture and history. Musqueam and Tsleil-Waututh expressed an interest in undertaking a similar event but have suggested doing so outside of the project engagement process, as part of their broader engagement with the Vancouver Park Board;
- Opportunities for review of draft reports, enhancement concepts, and to provide input; and
- Review and comment of the draft reports, which were provided to First Nations for review and comment in September 2013 and October 2013. Tsleil-Waututh responded to the draft reports in a letter dated November 14, 2013. Squamish and Musqueam provided comments via email.

## 8.4 Comments, concerns and Interests Raised during First Nations Engagement

Key comments, concerns, and interests expressed by First Nations during this phase of the Beaver Lake Enhancement project are summarized in **Table 8**.

**Table 8:** Summary of First Nations Interests, Issues and Concerns Relating to the Beaver Lake Enhancement Project as well as Stanley Park and City Wide Initiatives.

| Summary of First Nations Interests, Issues and Concerns | | City Wide | Stanley Park | Beaver Lake Specific |
|---|---|---|---|---|
| **Archaeology** | Concern that the Vancouver Board Board does not have a comprehensive archaeological assessment for Stanley Park. | | X | |
| | Concern that Culturally Modified Trees may be damaged and not mapped within project area and park. | | X | X |
| | Request for First Nations monitors to participate in any archaeological work. | X | X | X |
| | Concern that dredging may impact archaeological material previously undisturbed by historic dredging. | | | X |
| | Request that sediment be sampled for archaeological material. | | | X |
| | Request that the Vancouver Park Board hire an archaeological firm to undertake an Archaeological Impact Assessment for the project. | | | X |
| | Concern related to the lack of federal legislation for heritage protection and request for BC Archaeology Branch permit to be acquired. | X | X | X |
| | Request to obtain First Nations heritage permit from each Nation prior to commencement of construction or Archaeological Impact Assessment. | X | X | X |
| | Concern that any activities by the creek may impact archaeology. | | | X |
| | Concern that disturbance of existing pathway around lake will impact archaeology. | | | X |

**Table 8:** Con't.

| Summary of First Nations Interests, Issues and Concerns | | City Wide | Stanley Park | Beaver Lake Specific |
|---|---|---|---|---|
| **Recognition** | Opportunities for interpretive signage – all First Nations. | | X | X |
| | First Nations involvement in eco tours. | | X | X |
| | Request for signage that includes traditional plant name and English translation. | | X | X |
| **Cultural/Spiritual** | Ensure cultural work (appropriate ceremony) occurs prior to commencing construction at Beaver Lake. | | | X |
| | Concern that design features may impact the sacred nature of the site (i.e. boardwalk across lake, toilet). | | | X |
| | Importance of recognizing significance of area to First Nations and according appropriate respect and cultural sensitivity during planning and construction. | | | X |
| **Environmental** | Request to address invasive plant issue. | | X | X |
| | Concern with method for invasive plant removal and request to ensure appropriate disposal. | | | X |
| | Interest in developing First Nations capacity in invasive plant removal through work on project, park & other projects. | X | X | X |
| | Plant indigenous plants and obtain First Nations input on plant list. | | X | X |
| | Concern with introduction of muskrat – not considered native to area. | | | X |

**Table 8:** Con't.

| Summary of First Nations Interests, Issues and Concerns | | City Wide | Stanley Park | Beaver Lake Specific |
|---|---|---|---|---|
| | Request for copies of authorizations, amendments, variations, assessments and all Materials Safety Data Sheets (MSDS) to be on site and shared with First Nations. | | | X |
| | Provide list of approvals, licenses, permits and regulatory requirements to First Nations. | | | X |
| | Ensure appropriate steps taken should there be contamination on site. | | | X |
| | Ensure Environmental Management Plan (EMP), emergency and spill response. | | | X |
| | Ensure dust control if required. | | | X |
| | Ensure erosion and sediment control measures are in place. | | | X |
| | Keep a spill kit on site. | | | X |
| | Take appropriate steps for in-stream work. | | | X |
| | Ensure protection of Species-at-Risk. | | | X |
| | Monitor vibration and noise. | | | X |
| | Concerns with beaver management and request for input into future measures. | | | X |

**Table 8:** Con't.

| Summary of First Nations Interests, Issues and Concerns | | City Wide | Stanley Park | Beaver Lake Specific |
|---|---|---|---|---|
| **Project benefits** | Interest in contracting opportunities during construction. | | | X |
| | Interest in training, employment opportunities (monitoring, fieldwork, construction). | | | X |
| **Funding for participation in project review** | Request for funding to facilitate First Nation's review of project and provision of input. | | | X |
| **General** | Overall concern with approach to engagement and lack of consultation with First Nations with respect to planning for Stanley Park – First Nations want to be involved in broader management of park rather than on specific projects and/or initiatives. | | X | |
| | Request for ongoing, meaningful communication and involvement as project advances. | | | X |

In November 2013, the First Nations were provided with the preliminary enhancement concepts for review and input. All three First Nations reviewed the options. Tsleil-Waututh Nation provided a formal written response via letter dated 18 February 2014 in which Concept 1 was outlined as their preference with Concept 4 as a second choice. Musqueam and Squamish also provided comments during meetings and via email on the enhancement options, with Concept 1 being preferred. First Nations did not support the inclusion of a composting toilet at the Lake or Concept 2 due to the boardwalk feature that extended across the water.

# 9 Public Open Houses and Public Input

Two open houses were held to seek public input on the preliminary Beaver Lake Enhancement concepts. The first open house was held on 21 November 2013, 4 - 8 pm at the Coal Harbour Community Centre followed by a second open house on 23 November 2013, 12 - 4 pm, at the West End Community Centre. The presentation panels and the comment sheet were available on-line prior to the first open house and public announcements / signage were made at Beaver Lake, in the media, and on-line. The four enhancement concepts were also on display at the Vancouver Park Board Office at 2099 Beach Avenue from 25 November 2013 until 02 January 2014. The public was asked to review the panels and fill out a comment sheet, which was available at the open houses and on-line until 31 December 2013; 570 comment sheets were received by 10 January 2014.

## 9.1 Invasive Species Management

The majority (66%) of respondents supported attempting to control the worst of the invasive plant species and increasing habitat biodiversity, while 26% supported trying to eliminate all invasive species and accept higher levels of ongoing maintenance (and associated costs) to keep the lake free of invasive species. Five percent of respondents had other suggestions, which included making the ecosystem as robust and diversified as possible, doing the minimum, and simply leaving things alone.

In response to the specific question about invasive water lilies, 78% supported deepening the lake at greater initial cost to limit the spread of invasive water lilies that now cover most of the lake while only 10% supported maintaining the current shallow depth of the lake and accepting higher costs for on-going maintenance to continually remove them. Nine percent of respondents had other suggestions, which included concerns relating to potential impacts to the other plant and animal life, didn't know, or to simply leaving things alone.

## 9.2 Amount of Open Water

The majority (77%) of respondents supported a balance of open water and islands, while 16% supported as large an area of open water as possible. The suggestions from the remaining 6% were related primarily to improving local ecology, limiting the number of constructed islands, taking the most cost-effective approach, and letting nature take its course.

## 9.3 Fish Utilization

A large majority (74%) of respondents felt it was better to deepen the lake to facilitate salmonid utilization within the lake while 14% supported maintaining the current shallow depth. The remaining 9% of respondents supported salmonid utilization only if they were there historically (i.e., prior to human intervention), and if it would benefit a diverse array of species. Of those respondents that supported salmonid utilization, almost half (46%) of respondents supported deepening the lake more significantly at greater initial cost to accommodate salmon throughout the year compared to approximately one-third (31%) of respondents, who only supported deepening the lake enough to accommodate salmon seasonally. The remaining 13% of respondents either didn't know which was better or didn't support salmon.

## 9.4 Beaver Utilization

The majority (70%) of respondents supported temporarily relocating beavers during lake enhancement, and releasing them back to the lake when works are complete along with some design changes to limit the negative impacts of their activities. Fewer respondents (16%) supported relocating the beavers elsewhere. The remaining 10% of respondents wanted the beavers left in place during enhancement, would choose beavers over salmon, were of no opinion, or suggested that the beavers engineer their own solutions to the lake's problems.

## 9.5 Beaver Lake Bog

A bog has been carefully restored by SPES and numerous volunteers at the south-west end of the lake. The area is currently not readily accessible to the public. A majority (68%) of respondents supported keeping access to the bog restricted to protect its fragile vegetation from people and dogs. A smaller percentage (22%) of respondents supported building a boardwalk to the bog to allow people to experience this unique habitat and have views over the bog to the lake. The other 7% of respondents

supported a boardwalk to the bog but stated that dog access should be restricted or the boardwalk should be set back away from the bog to minimize potential negative impacts.

## 9.6 Recreational Amenities

### 9.6.1 Benches

There are currently fourteen (14) benches around the lake perimeter, which are frequently utilized during good weather. The majority (54%) of respondents supported keeping the existing number of benches, while over a third (35%) supported having more benches around the lake. Of the other 6%, most supported more varied seating opportunities, more complementary furnishings like tables and waste receptacles, with a marginal increase in benches.

### 9.6.2 Viewing Structures and Viewing Tower

In response to a question about viewing structures, which are expensive to build and maintain but can provide a variety of viewing opportunities, the majority (66%) of respondents supported having more viewing platforms around the shore of the lake while only 10% of respondents supported THE installation of a two-storey tall viewing tower. Of the remaining 20% of respondents, comments included keeping the same number of viewing structures as currently present, including a small increase in viewing structures (e.g., between 1 and 4 more), ensuring structures are small and have low impact on the overall natural aesthetic, and foregoing any additional infrastructure that will require long term maintenance.

Of those who supported the idea of a viewing tower, 32% of respondents supported it set back from the water's edge to minimize impact on habitat while only 7% of respondents supported it at the water's edge to maximize viewing potential. Twenty-two percent of respondents supported either option. The remaining 39% of respondents did not answer this question, which may indicate a lack of support for either.

In response to the question as to whether the public would prefer the idea of a floating boardwalk to viewing platforms, there was very little support for either. Thirteen percent of respondents said they would prefer a floating boardwalk and 20% of respondents said they would support a two-storey tall viewing tower. A majority (39%) of respondents did not answer this question which may indicate a lack of support for either option.

### 9.6.3 Washrooms

The closest washroom to Beaver Lake is located over 700 m from the outfall to Beaver Creek and key programming / educational areas. Installing a toilet for greater convenience was supported by 50-percent of respondents, while a slightly smaller number (42%) supported keeping the area as natural as possible and not installing a toilet. The remaining respondents supported a toilet but closer to the entrance to trails, rather than at the lake.

## 9.7 Priority Lake Enhancement Attributes

Respondents were asked to rank the top five of thirteen attribute options the lake should have in order of highest priorities. Results are as follows, in order of priority ranking:

1. Have areas of open water with some islands for a more diverse lake experience and habitat for birds and turtles undisturbed by human proximity;
2. Provide nesting sites and ponds around the trails suitable for species that need extra support to thrive in Stanley Park;
3. Improve the creeks flowing into and out of Beaver Lake for fish habitat;
4. Maintain and possibly increase the unique bog habitat at the south-west end of the lake;
5. Maintain as large an area of open water as possible;
6. Encourage richer aquatic life in the lake to increase diversity;
7. Support salmon species moving into and through the lake;
8. Attempt to remove all invasive plant species from the lake;
9. Accept some level of non-native plant species in the lake;
10. Install woody debris (snags) and large logs in the lake for birds and turtles;
11. Install a toilet in moderate proximity to the lake;
12. Install more opportunities to view wildlife (e.g. viewing tower, boardwalks and viewing platforms) around the lake; and
13. Expand the amount of interpretive signage around the lake.

The public was asked which of the four conceptual options most closely resembles their ideal future for the lake, noting the ultimate plan will likely be a hybrid design incorporating various features from all four. The majority 58% preferred Concept 1 with

islands and viewing platforms (feature of Concepts 1 and 4). 77% supported an option with a mixture of open water and islands. There was very low support for options with structures, and without islands.

58% - Concept 1 - Islands and Viewing Platforms (maximizes habitat creation and biodiversity with highest enhancement capital cost)

19% - Concept 4 - Islands and View Tower (balances habitat creation and biodiversity with cost considerations)

10% - Concept 3 - Open Water and View tower (low habitat creation and biodiversity but lowest enhancement capital cost)

6% - Concept 2 - Open Water and Floating Boardwalk (increases passive recreation but reduces wildlife)

# 10 Finalized Conceptual Design

The final concept builds upon the preferred preliminary concept: **Concept 1** – Islands and Viewing Platforms, which includes the following key attributes:

- Constructed islands, which provide habitat for mammals, birds, amphibians, reptiles, fish and insects - including both common and sensitive (Species-at-Risk) species;
- Vernal ponds (new and deepened existing ponds), and improvements to Zoo Creek and North Creek to further enhance habitat. Beaver Creek enhancements are currently underway as part of a separate project.
- A fish ladder and a 5 m deep channel through Beaver Lake, connecting Beaver Creek with North Creek and increeasing the potential for year round salmonid utilization;
- Approximately 2.6 hectares of open water, to a maximum depth of 5 m. This maximum depth will allow fish passage, and will slow the recolonization of invasive Fragrant Water-lily in the absence of maintenance; and
- A boardwalk and four additional viewing platforms to increase viewing and interpretive opportunities.

The following sections provide a detailed overview of the features of the finalized conceptual design including Ecological Features (Section 10.1.1), Recreation and Interpretive Features (Section 10.1.2), Infrastructure Features (Section 10.1.3); Trail

Features (Section 10.1.4); Interpretative Signage Features (Section 10.1.5); and Aesthetic Considerations (Section 10.1.6).

## 10.1 Features of the Finalized Conceptual Design

### 10.1.1 Ecological Features

The finalized conceptual design seeks to maximize biodiversity while minimizing maintenance through the acceptance of an altered, novel ecosystem. This principle accepts that some invasive species are already well established within and around Beaver Lake. Moreover, because Beaver Lake is a fairly accessible site and one of the few open water bodies within the City of Vancouver, it is also occasionally used by the public to discard of exotic pets and plants, which often have invasive attributes. These aforementioned factors make the complete eradication of invasive species a cost prohibitive, long-term maintenance option that would result in chronic disturbances to the lake. The park is a cultural landscape and not a pristine wilderness, underscoring the need to set a realistic enhancement target for Beaver Lake, rather than an unachievable natural lake with only native species. Following initial enhancement, the focus is placed on effective management and field surveys to minimize the recolonization of invasive species.

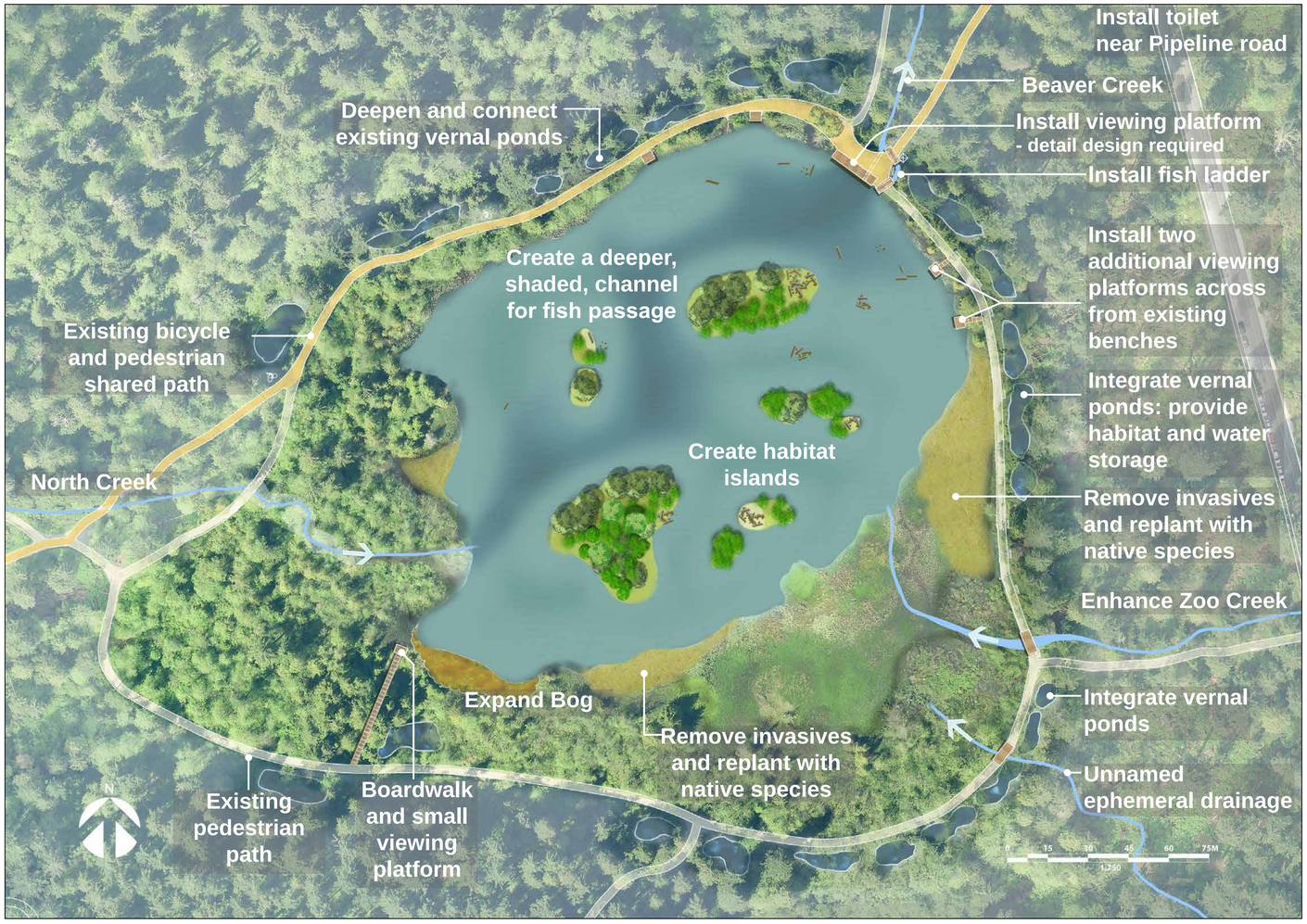
The finalized conceptual design builds on guiding principles to:

- Create more open water;
- Create a habitat mosaic and support Species-at-Risk;
- Improve the stream health of Zoo, North and Beaver creeks;
- Encourage aquatic life;
- Prevent the spread of invasive species;
- Create a long-term beaver strategy;
- Support and maintain native species;
- Support salmon species;
- Install geotextile fabric;
- Aerate water;
- Maintain the bog; and
- Reintroduce extirpated species.

Further details and rationale are found in Section 6. The finalized conceptual design is illustrated in **Figure 17A** and **Figure 17B**. Details guiding the finalized conceptual design are summarized in **Table 9**.

# Figure 17A. FINAL CONCEPT | SITE PLAN

October 1, 2014

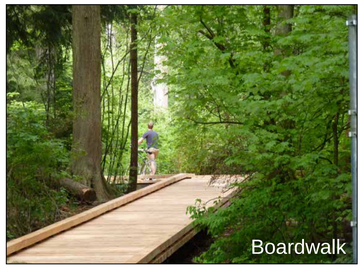



- Increase in animal diversity.
- Increase in plant diversity.
- Increases utilizable fish habitat.
- Islands and woody debris provide for turtle basking/nesting and shorebird/ waterfowl habitat.
- Reduces prevalence of non-native invasive species such as fragrant water lily and narrow leaf cattail.
- Vernal ponds improve wildlife, especially amphibian habitat and modulate runoff into the lake.
- Zoo Creek stream restoration diversifies wildlife habitat.
- Increased opportunities for the lake to be used for re-introduction of species at-risk e.g. western painted turtle.
- Installed fish ladder in Beaver Creek and deepening of channel through lake to reduce water temperature would allow for salmonids to travel from Beaver Creek to North Creek year round.
- Islands with trees shade and cool the channel and reduce evapotranspiration.
- Deeper water (max 5m) prevents recolonization by invasive lilies.
- Expansion of bog increases plant diversity and educational value.
- Short sections of boardwalk, bridges and larger culverts allow for improved creek crossings across the perimeter trail into the lake.

- Increases wildlife viewing and interpretive opportunities.
- Replicates natural coastal BC wetlands.
- Additional platforms and bog boardwalk expand viewing opportunities, educational and interpretive programming.
- The bog boardwalk provides additional interpretive opportunities.
- Vernal ponds, bog expansion and stream restoration increase wildlife viewing along trail, adding to the ecological experience of visiting Stanley Park.
- A nearby toilet expands the range of programming and enhances visitor experience.

- Islands may contribute to more rapid infilling of lake over time, but should be mitigated by overall depth increase.
- Requires extensive removal and disposal of decaying organic matter, sediment and clay.

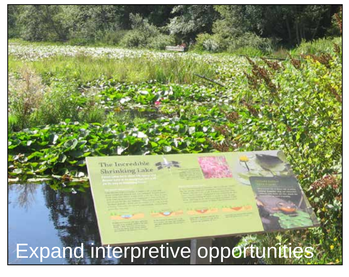
- *Seeks to maximize biodiversity. Islands provide habitat for mammals, birds, amphibians, reptiles and insects - including both common and sensitive (species-at-risk) species. Vernal ponds and improvements to Zoo Creek further enhance habitat.*
- *Fish ladder and 5m deep channel from Beaver Creek to North Creek increases potential for year round salmonid habitat.*
- *2.6 hectares of open water, to a maximum depth of 5m.*
- *Large volume of sediment, clay and decaying organic matter removal and disposal.*
- *Moderate-High Lake Longevity (assumes periodic invasive species management around islands and edge areas following dredging).*
- *Boardwalk and four additional viewing platforms increase viewing and interpretive opportunities.*


Boardwalk


Vernal ponds


Woody Debris


Salmon habitat


Expand interpretive opportunities


Long term beaver strategy


Maintain and expand bog

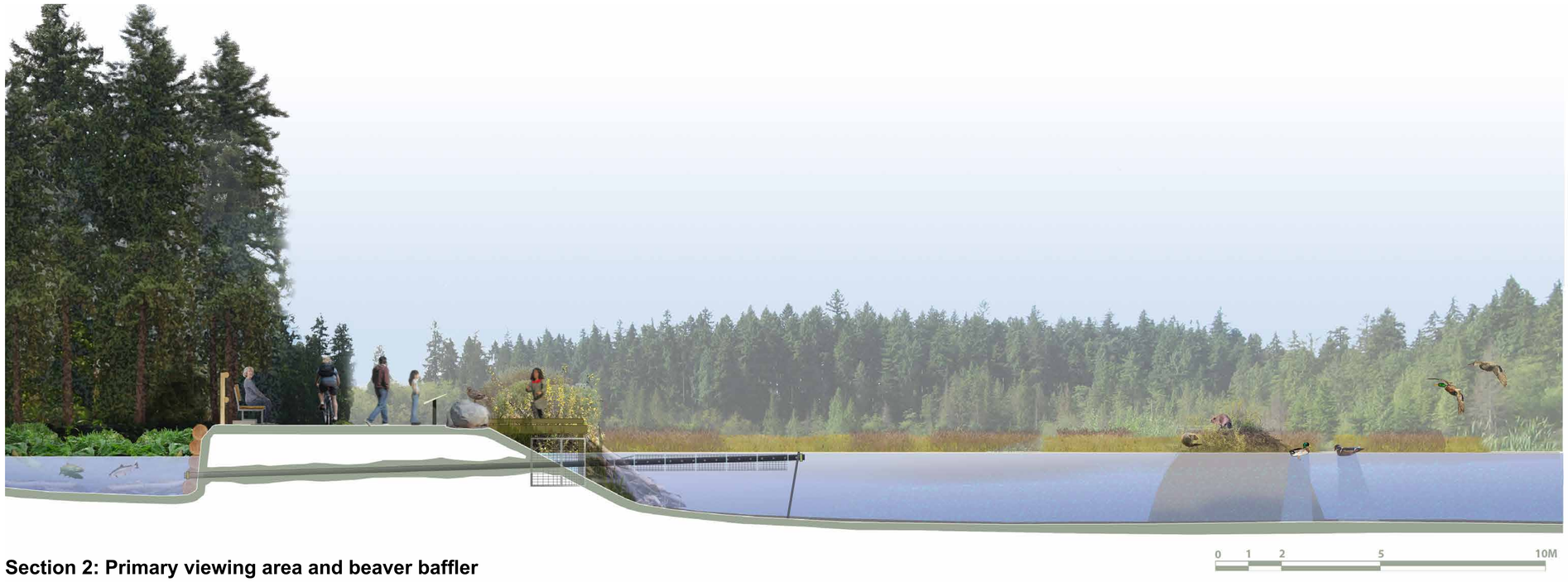
Ecological and Culturally Sensitive Enhancement Plan for Beaver Lake

VANCOUVER BOARD OF PARKS AND RECREATION | STANLEY PARK ECOLOGY SOCIETY 25 Connecting people with nature since 1988 | AQUATERRA ENVIRONMENTAL LTD. | BIANCHINI BIOLOGICAL SERVICES | DIG IT! | HEMMERA | LEES+Associates Landscape Architects and Planners | nhc northwest hydraulic consultants

# Figure 17B. FINAL CONCEPT | ILLUSTRATIVE SECTIONS

October 1, 2014


**Section 1: Vernal ponds, path, viewing platform and habitat island**




**Section 2: Primary viewing area and beaver baffler**

**Table 9:** Enhancement Strategies and Approaches Guiding the Finalized Conceptual Design.

| STRATEGY | APPROACH | RATIONALE | REPRESENTATIVE PHOTOGRAPH |
|---|---|---|---|
| *Create more open water* | Reduce invasive aquatic plants, focusing on the removal of Fragrant Water-lily and Narrow-leaf Cattail. | These plants have formed a thick floating mat of organics that covers most of Beaver Lake. Left unchecked the lake will continue to infill, until it becomes forest. |  |
| *Create habitat mosaic and support species at risk* | • Establish pattern of islands and open water.<br>• Create vernal ponds.<br>• Introduce snags.<br>• Create turtle nesting sites on islands.<br>• Install bird nest boxes and large logs. | Expand the number of habitats to attract a range of species including Great Blue Heron, Western Painted Turtle, Red-legged Frog, and Pacific Water Shrew. Offer a variety of habitats with approximately 50% open water. |  |
| *Improve stream health of Zoo, North and Beaver Creeks* | • Improve riparian zone plantings.<br>• Establish natural pools and riffles. | Improve fish habitat and augment Zoo Creek and North Creek to help supply water to Beaver Lake. |  |

**Table 9:** Con't.

| STRATEGY | APPROACH | RATIONALE | REPRESENTATIVE PHOTOGRAPH |
|---|---|---|---|
| *Encourage aquatic life* | • Remove Fragrant Water-lily to create and maintain more open water.<br>• Establish vernal ponds next to trail.<br>• Remove organic build-up in lake.<br>• Repair dam leakages. | Egg masses and tadpoles for the Northwestern Salamander require open water in lake and streams. All stages of amphibian life would benefit from vernal ponds. Vernal ponds would also increase water storage in the watershed. |  |
| *Prevent the spread of invasive species* | Remove invasive Japanese Knotweed, Giant Hogweed, Narrow-leaf Cattail, Purple Loosestrife and Yellow Flag Iris. | Focus on early eradication. Remove Narrow-leaf Cattail and Yellow Flag Iris to encourage high habitat value sedges. |  |
| *Minimize maintenance: acceptance of an altered ecosystem* | • Accept that some invasive species are well established and their complete eradication is not a cost effective, long term option.<br>• Focus on effective management and field surveys to minimize recolonization. | The park is a cultural landscape and not a pristine wilderness. This underscores the need to set a realistic enhancement target for Beaver Lake, rather than an unachievable natural lake with only native species. |  |

**Table 9:** Con't.

| STRATEGY | APPROACH | RATIONALE | REPRESENTATIVE PHOTOGRAPH |
|---|---|---|---|
| *Create long term beaver strategy* | Widen the outflow to Beaver Creek with a rock drain or similar beaver resistant fish passage structure, to prevent the beavers' continued damming and resultant flooding of the trail. | The beavers regularly block the main pipe through which water flows to Beaver Creek causing flooding and irregular downstream flows. Replacing the pipe with a rock drain would allow gradual seepage, undetectable to the beavers so they would no longer try to block it with dams.<br><br>A baffler was put in place in June 2014. Future design will further incorporate the baffler into the path and viewing area. |  <br>  |
| *Support and maintain native species* | Relocate beavers and other native species during enhancement and return them upon completion. | Six beavers currently live in a lodge on the lake. They have created a small area of open water near the water control structures by cutting water lilies, shrubs and trees. This natural control of vegetation by aquatic mammals should be facilitated in the future. |  |

**Table 9:** Con't.

| STRATEGY | APPROACH | RATIONALE | REPRESENTATIVE PHOTOGRAPH |
|---|---|---|---|
| *Maintain the bog* | • Continue restoration efforts involving removal of trees and shrubs<br>• Introduce Sphagnum Moss.<br>• Maintain water levels. | SPES has been successful in restoring a small area of bog at the south end of the lake. |   |
| *Reintroduce extirpated species* | Assess species that have or likely occurred historically within the park and evaluate the option for reintroduction, contingent on habitat suitability determined through detailed habitat design. | Reintroducing species, e.g. Red-legged Frog and Western Painted Turtle, would increase biodiversity, restore natural ecosystem function, encourage other species, and even aid in the management of invasive plant species. |  |
| *Aerate water* | Install aerators situated so they are not visually obtrusive or operate only at night. | The use of aerators would improve water movement and oxygenation during the summer. |  |

**Table 9:** Con't.

| STRATEGY | APPROACH | RATIONALE | REPRESENTATIVE PHOTOGRAPH |
|---|---|---|---|
| *Support salmon species* | • Install fish ladders to allow fish passage into Beaver Lake.<br>• Deepen the channel between Beaver and North Creeks and deliver more water to the lake during the summer.<br>• Introduce Chum rather than Coho Salmon. | Coho are annually released into Beaver Creek have been unable to return to spawn. Beaver Creek is effectively cut-off from Beaver Lake and North Creek, which has a resident Cutthroat Trout population. |  |
| *Install geotextile fabric* | • Install geotextile fabric in portions of the lake to control invasive Fragrant Water Lilies and other non-native aquatic plants and control turbidity. | Geotextile fabric has been successfully used at other lakes in the Lower Mainland. The fabric is anchored out of sight, approximately 10 cm below the lake bottom. |  |

### 10.1.2 Recreation and Interpretive Features

The finalized conceptual design embraces and extends opportunities for educational and interpretive programming and passive recreation while respecting the natural character and solitude many seek, and find, at Beaver Lake.

As described on the following pages, the finalized conceptual design builds on principles to:

- Incorporate plants of ethnobotanical relevance;
- Install additional boardwalks and viewing platforms;
- Expand interpretive signage; and
- Install a public toilet nearby.

### 10.1.3 Infrastructure Features

Small platforms are to be integrated at lake level in order to provide additional sites for interpretive signage, programmed activities, and wildlife viewing. Limited in size and height, these platforms are intended to have a low impact on the aesthetics of the lake, as well as minimal impact on the ecology of the site. Large structures are not included as they might obstruct views and wildlife behavior, including flight and nesting patterns. Structures are sited for minimal ecosystem fragmentation, and will consist of the following:

- A short in-out boardwalk with a small viewing platform is integrated at the bog to allow visitors to visit this unique, restored ecosystem while imposing minimal impact;
- Two small, additional viewing platforms are integrated into the lake edge, mirroring the two existing platforms. The placement, proximity and size of the platforms are optimal for elementary school programming; and
- An additional viewing platform is proposed at the inflow from Beaver Creek. Building upon the existing viewpoint and interpretive sign, this area will highlight the beaver dam, future fish ladder and views across the lake, while concealing beaver control mechanisms.

A toilet is recommended near Pipeline Road – away from the lake – but within an easy walk from the lake. This will further facilitate school and all ages programming at the lake as well as ease of toilet maintenance.

At this time, a significant number of additional benches is not recommended, but staff should monitor bench use over time to evaluate whether more are needed in the future.

### 10.1.4 Trail and Boardwalk

Previous high level studies, including the 2010 State of the Park Report for the Ecological Integrity of Stanley Park, suggested decommissioning of some or all of Beaver Lake's perimeter trail, and replacing it with boardwalks. However, further study during this project indicated that the trail is in fact acting as a dam, regulating the elevation of the water in Beaver Lake.

In the future, consideration could be given to short sections of boardwalks at key creek crossings (shown on final concept plan), as well as formalized vernal ponds and connectivity of this water source to the lake via culverts. However, it is not recommended that the majority of the trail be converted to boardwalk. While it may facilitate increased instantaneous water flow into the Lake, the absence of the trail would reduce the retention capacity of the surrounding areas, thereby reducing the discharge into Beaver Creek following rainfall events. Vernal ponds will add additional storage capacity, allowing water to more gradually infiltrate into the lake.

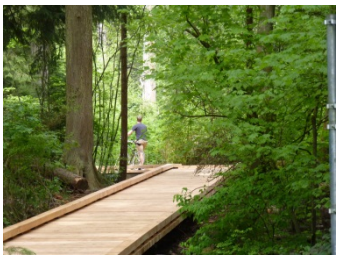
Bicycle access on the perimeter trail (Beaver Lake Trail) should remain restricted to the north-west of the lake, between Beaver Trail and Lake Trail access points, as shown on the final concept. Bollards, boulders and additional signage are recommended to clearly demarcate where bicycles are and are not permitted. Bicycle racks should be added at these trail intersections to encourage cyclists to dismount and explore the lake on foot. There are currently no plans to modify the length, overall width or surface treatment of the trail.

### 10.1.5 Interpretive Signage Features

Interpretive signage, and interactive opportunities such as an app/QR code tour of the lake, will be incorporated in the future. Signage should be placed to not interfere with views out to the lake. The interpretive signage will provide opportunities for consideration of the cultural and environmental history and features of the lake and its surroundings.

Recreational, interpretative, infrastructure, trail and signage features are summarized in **Table 10**.

**Table 10:** Recreational, Interpretative, Infrastructure, Trail and signage Strategies and Approaches Guiding the Finalized Conceptual Design.

| STRATEGY | APPROACH | RATIONALE | REPRESENTATIVE PHOTO(S) |
|---|---|---|---|
| *Incorporate plants of ethnobotanical relevance* | • Plant native and culturally significant species.<br>• Have observers for culturally modified trees (CMTs) and artifacts during enhancement work.<br>• Consider providing opportunities to aboriginal youth for project implementation. | The park as a whole is of cultural significance for the First Nations of the Musqueam, Squamish and Tsleil-Waututh who have occupied the site for centuries. First Nations representatives will be present on the site during this work to identify artifacts and culturally modified trees that will be preserved. |  <br>  |
| *Install additional boardwalk and viewing platforms* | Provide a boardwalk and viewing platforms to provide more ecologically sensitive access than gravel trails. | Expanding viewpoints to Beaver Lake will increase interpretive and passive recreation opportunities. Providing additional small platforms will facilitate more children's programming. |  <br>  |

#### 10.1.6 Aesthetic Considerations

While balancing ecological, recreational and interpretive programming needs, and cultural sensitivities, the preferred concept seeks to preserve the natural character of the site through increased levels of management, achieving a balance of open water and habitat islands, and providing unobtrusive amenity elements. The removal and addition of vegetation and the location of islands, new platforms, and benches capitalize on providing visitors with a range of viewpoints around the lake.

### 10.2 Estimated Dredge and Invasive Mat Removal Volumes

Dredging is currently proposed in the area impacted by invasive Fragrant Water-lily as well as the northern boundary of the area dominated by Narrow-leaf Cattail for a total open water area of 2.6 hectares. Assuming an average depth to the peat/clay interface of 0.54 m (data provided in **Table 6**), the dredge volume would be approximately 14,040 $m^3$. The proposed 5 m deep channel (i.e., 4 m deep excavated channel with 1 m of standing water above the top-of-channel) connecting Beaver Creek and North Creek over a distance of approximately 250 m (and assuming 2:1 – Horizontal:Vertical slopes) would require the removal of approximately 4,000 $m^3$ of additional material.

The estimated volume of invasive Fragrant Water-lily to be removed is 5,000 $m^3$ – 8,000 $m^3$, assuming a total impacted area of 2 hectares and an average mat thickness of 0.25 – 0.40 m (as described in Section 5.3.2).

## 11 Next Steps

### 11.1 Detailed Design

The next phase of work will involve using the finalized conceptual design to develop a detailed design, which will include the dredging limits by area, establishing a preferred method of dredging, delineating the invasive lily mat removal limits and associated methodology, as well as vernal pond construction, re-planting details, and ancillary design components.

### 11.2 Construction Staging

A number of both key and ancillary finalized conceptual design components can be undertaken independently of the dredging and invasive lily mat removal works. Specifically, works such as vernal pond construction, restoration of creeks, bog maintenance, interpretive signage, washroom construction, fish passage enhancement,

and beaver management / maintenance can occur at any time contingent on available funding. As the various project-related components are completed, they can ultimately be incorporated into the detailed design moving forward, or conversely, staged work could proceed following completion of a detailed design to ensure that early works are conducted efficiently and in a manner that would not adversely affect other, subsequent enhancement works.

## 11.3 Invasive Species Management Options

### 11.3.1 Digging / Manual Removal

An excavator can be used to remove invasive aquatic plants and deepen portions of Beaver Lake. The bucket on the machine can be used to remove live plants, the floating organic mats, and to create open pools of water. Where possible, water should be made deep enough so that Fragrant Water-lily and Narrow-leaf Cattails cannot grow. The digging can create a naturally appearing pattern of open water that would increase biodiversity.

Our research found that the non-native Narrow-leaf Cattails can grow in water up to 1-metre deep, and Fragrant Water Lilies in water up to 2.65 m deep (average 2.26 m). Therefore, to assist in inhibiting Fragrant Water-lily re-colonization, attempts should be made to deepen the lake to a minimum of 2.26 m, where possible. Due to the thin organic layer in numerous areas, this may only be possible in some areas and may require the use of geotextile fabric or sand to prevent the glaciomarine clay from affecting water quality.

### 11.3.2 Fabric for Weed Control

The placement of fabric on the bottom of a lake can help control the growth of non-native invasive plants such as Fragrant Water-lily and Narrow-leaf Cattail Approximately 15-years ago, the City of Burnaby anchored geo-textile fabric in the shallow water at Deer Lake along what was once their swimming beach to control the growth of cattails and water lilies. It was found that only two small patches of Fragrant Water-lily were growing on the treated areas when the team visited the site. Dense growths of Narrow-leaf Cattail and Fragrant Water-lily were found in areas of the Burnaby Lake that were not treated.

Fabric has been used to control aquatics in lakes in Wisconsin according to Dr. Ken Ashley with BCIT. However, there is a concern where the fabric is placed over an organic layer. Gas escaping from the decomposition of the organics can float the fabric. Greatest success is realized by placing the fabric on a lake bottom that does not have an

organic layer. Therefore, it may be necessary to use heavy equipment to remove the thick organic layer before placing the fabric.

Placing the fabric may reduce the need to dig deep in the lake to create open water. An excavator could be used to remove water lily and Narrow-leaf Cattail from several areas in Beaver Lake. Thick fabric could anchored on the bottom of the lake using 12-inch long landscape spikes, or sand bags. Monitoring could be done to determine if plants would grow over the fabric.

Possible advantages of using fabric to control aquatic plants includes a reduction in sediment removal volume and maintenance requirements. A disadvantage is that wildlife species such as turtles and frogs may not be able to dig into the bottom of Beaver Lake where the fabric is used.

### 11.3.3 Herbicide Application

Herbicide can be efficiently used to control aquatic plants such as Fragrant Water-lily and Narrow-leaf Cattail. The chemical Glyphosate with an added surfactant, which is sold under the name Rodeo, can be applied by spraying the leaves of aquatic plants during the growing season. The application of glyphosate can be expected to be a highly effective and a low cost means of controlling aquatic plants in Beaver Lake. Glyphosate is registered for Forestry use in British Columbia. However, this option has limited feasibility for use in Stanley Park as the Vancouver Park Board has a policy limiting the use of herbicides and it is anticipated that public response to using herbicides in a natural or wetland area would be negative.

Other disadvantages to using herbicide to control aquatic plants include:

1. The recently sprayed plants will appear brown in color until they decompose;
2. The use of herbicide may be controversial; and
3. Herbicides may need to be applied every couple of years, resulting in on-going maintenance and potential adverse effects to aquatic and terrestrial inhabitants. As such, herbicide application may only be a shorter-term solution relative to dredging.

## 11.4 Dredging Options

Dredging may be used to remove vegetation and to deepen portions of Beaver Lake, creating areas of open water. It may be necessary to use a specialized cutter-suction dredger to remove the organic mat and clay soil from Beaver Lake. Some dredging

projects employ the use of pits near the work site to separate soil from water, however, mechanical means of treating the slurry are now available. It may be possible to construct a temporary pipeline to carry the material that is removed to a barge on the ocean for disposal.

Organic soil, mineral soil, and vegetation could be removed in a pattern that would create an attractive mosaic of islands and peninsulas that would be pleasing to visitors, and improve habitat for wildlife. Dredging can be an expensive operation. A component of the high cost involves the disposal of the large quantities of soil that are removed.

The process of dredging can harm aquatic life. Fish and amphibians can be killed by the operation. The water in Beaver Lake may also become turbid during dredging, requiring appropriate mitigation.

## 11.5 Design and Disposal Constraints

Sediment and invasive lily mat analytical results have identified localized metals exceedences. This data will require review by a contaminated sites specialist, to establish appropriate disposal or management options, which may limit the ability to directly dispose of material or utilize material elsewhere within Stanley Park.

## 11.6 Assessment of Impacts and Mitigation Strategies

The consulting team recommends that an impact assessment be completed once the detailed design, staging, dredging method, and disposal details have been confirmed to identify potential impacts, prescribe appropriate mitigation strategies and confirm appropriate monitoring and salvage requirements.

## 11.7 Environmental Management

The project team is eager to be involved in subsequent phases of the project. During the detailed design phase, the project team recommends discipline managers, which should be responsible for project-related tasks relating to the various project-related components, as follows:

*First Nations Discipline Manager*

- Informing First Nations of project-related tasks and schedules, as details become available.
- Coordinating First Nations archaeological monitoring.

- Collating a comprehensive ethnobotanical vegetation list for re-planting and flagging Culturally Modified Trees (CMTs).

*Hydrogeotechnical Discipline Manager*

- Liaising with dredging company to validate dredging methodology, dredging areas, dredging depths and managing turbid water, water quality, and off-site disposal of material.
- Design input relating to creek enhancement.
- Design input relating to aeration and geotextile placement.
- Contributing to review of designs and implementation relating to vernal ponds and options to reduce reliance on municipal water.

*Landscape Architecture Discipline Manager*

- Designing, coordinating and overseeing placement and construction of viewing platforms, central viewing area, washroom, and trail improvements.
- Designing and coordinating construction of boardwalk to the bog.
- Design of signage, with review and input from the Vancouver Park Board and SPES.

*General Project Manager / Environmental Discipline Manager*

- Coordinating all Discipline Managers.
- Liaising with SPES, the Vancouver Park Board, and regulatory agencies.
- Coordinating sediment characterization and disposal determination.
- Coordinating environmental monitors and reporting.
- Coordinating salvage efforts, including types of salvage, salvage timelines, relocation details and humane euthanasia of non-native/invasive species.
- Acquiring appropriate provincial, federal and municipal permits (e.g., *Water Act*, DFO Authorization, General Wildlife Permit, Wildlife Salvage Permit, etc.).
- Coordinating invasive vegetation removal.
- Coordinating habitat enhancement efforts including construction of islands and vernal ponds as well as coordinating re-planting details.

## 11.8 Archaeological Monitoring Requirements

The project in located within an area of known cultural heritage significance and therefore, project planning and implementation will proceed in a way that ensures protection of cultural heritage resources and with involvement of First Nations. An appropriate archaeological assessment should be undertaken by a professional archaeology firm with the involvement of Musqueam, Squamish and Tsleil-Waututh

representatives. The project team acknowledges First Nations connection to the project area and the importance of undertaking archaeological work in an inclusive, cultural sensitive and respectful manner. Appropriate protocols should be respected and implemented, with consideration given to time and resources required for cultural work.

## 11.9 Environmental Monitoring Recommendations

An Independent Environmental Monitor (IEM) that is a Qualified Environmental Professional (QEP) and a member in good standing of the College of Applied Biology should be involved in all aspects of the project situated within 30 m of Beaver Lake, Beaver Creek, Zoo Creek and North Creek to determine the need, if any, for water quality testing and assessing potential impacts to fish, fish habitat and wildlife. Contingent on the type of work, monitoring may be undertaken on a full-time or part-time basis, at the discretion of the monitor and project manager (and contingent on regulatory requirements).

During invasive vegetation removal and dredging operations, environmental monitoring should be undertaken on a full-time basis to monitor water quality and to ensure that water to Beaver Creek is maintained during the works. During the initial de-watering works and removal of sediment and invasive vegetation, a team of biologists is anticipated to be required to undertake a thorough salvage of aquatic species from the lake. Invasive aquatic species should be humanely euthanized, whereas native species should be kept on-site in large aerated totes or temporarily relocated off-site. Prior to the onset of salvage efforts, a General Wildlife Permit and Animal Care Permit are required, which will stipulate the handling and euthanasia techniques for captured invasive species.

In addition to the proposed monitoring recommendations outlined above, the project team recommends a representative from SPES be involved during the invasive vegetation and dredging aspects of the project, including regular inspections to ensure that the work and monitoring comply with the Best Management Practices, mitigation measures, and design constraints defined in subsequent project phases.

# 12 References

Clague, J. J. (1994). Quaternary stratigraphy and history of south-coastal British Columbia. In J.W.H. Monger (Ed.), *Geology and Geological Hazards of the Vancouver Region, Southwestern British Columbia* (pp. 181–192). Geologic Survey of Canada Bulletin 481.

Faugeraux, D and Bendell, L. 2011. Sediment Characteristics of Beaver Lake and Implications for Remediation: A Pilot Project. Simon Fraser University. (unpublished).

Groot, C. and Margolis, L. (1991). Pacific Salmon Life Histories. Vancouver: UBC Press.

Hatfield Consultants Limited (1984). *Beaver Lake-Creek Enhancement Study*. Prepared for Vancouver Board of Parks and Recreation and Salmonid Enhancement Program. Vancouver. 78 pp.

Kaufman, S.R. and W. Kaufman. 2007. Invasive Plants – Guide to Identification and the Impacts and Control of Common North American Species. Stackpole Books. 458 pp.

Kerr Wood Leidal and Associates. 1999. Stanley Park Stormwater Management Plan. File: 714.001.

Kheraj, S. 2013. Inventing Stanley Park: An Environmental History. UBC Press.

Lashek J, Schmidt T, Schaffeild T. 1999. A study of disposal options and sediment quality for proposed dredgate in Beaver Lake. In: Capilano College Environmental Science Program. Beaver Lake Ecological Studies: Stanley Park, Vancouver, B.C.

MineralsEd (2012). *Stanley Park GeoTour*. A collaboration between MineralsEd and the Geological Survey of Canada. Tour led by Bob Turner, Marianne Quat and Chris Loewen of the GSC. 20 pp.

Pejchar, L. and H. A. Mooney. 2009. Invasive species, ecosystem services and human well-being. *Trends Ecol. Evol.* 24:497–504

Resources Inventory Committee (RIC). 1998. Standards for Marsh Birds: Bitterns and Rails. Standards for Components of British Columbia's Biodiversity No. 7. Prepared by Ministry of Environment, Lands and Parks Resources Inventory Branch for the Terrestrial Ecosystem Task Force Resources Inventory Committee.

(SPES) Worcester R. 2010. State of the Park Report for the Ecological Integrity of Stanley Park. A report by the Stanley Park Ecology Society. 229 pp. http://stanleyparkecology.ca/wp-content/uploads/downloads/2012/02/STATE-OF-THE-PARK-REPORT-for-EI-in-SP_Final2.pdf

Stanley Park Ecology Society. 2013. Stanley Park Ecology Society Invasive Plant Management Plan. 100pp. http://stanleyparkecology.ca/wp-content/uploads/downloads/2014/06/SPES_StanleyParkISMP_5June2014.pdf

Steele M. 1988. The first 100 years: an illustrated celebration. Vancouver (BC): The Vancouver Board of Parks and Recreation.

Vancouver Board of Parks and Recreation. 2009. Stanley Park forest management plan. Vancouver (BC): Vancouver Board of Parks and Recreation. 49 pp.

Vancouver Park Board (VPB). 2012. Park Board Strategic Framework – Mission, Vision, Directions, Goals and Objectives. 42 pp.

Young, Stephen L., "Ecosystem Services: The Significance of Contributions by Invasive Plant Species" (2012). *West Central Research and Extension Center, North Platte.* Paper 24. http://digitalcommons.unl.edu/westcentresext/24

Zimmerman, A. McIhagga, C., Jarock, C., Rogers, D. 1999. A Study of the Beaver Lake Watershed: Historical Sedimentation, Contemporary Ecology and Hydrology with Predictive Modelling. UBC Environmental Sciences.

# APPENDIX A

SUMMARY OF APPLICABLE STUDIES AND REPORTS

# Available Beaver Lake Studies - Ecological and Culturally Sensitive Restoration Project

| Report Title | Author(s) | Organization(s) | Date | Digital (D)/ Hardcopy (H) | Fungi | Aquatic Plants | Terrestrial Plants | Invasive Plants | Terrestrial Ecosystems | Aquatic Ecosystems | SAR | Fish | Invertebrates | Amphibians | Reptiles | Songbirds | Wading / Shorebirds | Raptors | Mammals | Other / Details |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Beaver Lake Bog: Vegetation Survey | De Luca, S., and denHartigh, C. | Capilano College Environmental Science Program | 2013 (March - April) | D | | | | | | | | | | | | | | | | Vegetation Survey - bog to southwest of Beaver Lake |
| Plankton Species List | SPES | SPES | 2013 (Apr) | D | | | | | | | | | X | | | | | | | Excel spreadsheet |
| Owl Survey Data | SPES | SPES | 2008-2013 | D | | | | | | | | | | | | | | X | | Excel spreadsheet |
| Bat Survey Data | SPES | SPES | 2008-2013 | D | | | | | | | | | | | | | | | X | Excel spreadsheet |
| Beaver Lake Bird Species List and Monthly Bird Count Database | SPES | SPES | 2005-2012 | D | | | | | | | | | | | | X | X | X | | Excel spreadsheets |
| Habitat Associations of Fish in Beaver and North Creeks, Stanley Park BC | SPES | SPES | 2012 (Apr) | D | | | | | | | | X | | | | | | | | Data Compilation |
| Terrestrial Gastropods of Stanley Park | SPES | SPES | 2012 (Jun) | D | | | | | | | | | X | | | | | | | |
| Fish Survey Data | SPES | SPES | 2010-2012 | D | | | | | | | | X | | | | | | | | Excel spreadsheet |
| Small Mammal Survey Data | SPES | SPES | 2012 | D | | | | | | | | | | | | | | | X | Excel spreadsheet |
| Beaver Lake Bog Restoration Final Report | Worcester, R., and Titaro, B. | SPES | 2012 (Jan) | D | | | | | | | | | | | | | | | | Summary of restoration efforts in bog adjacent to Beaver Lake. |
| No Bogs Allowed - Aesthetics, Authenticity and the 'Swampification' of Beaver lake - 1937-2012 | Clarkson, M. | | 2012 (Apr) | H | | | | | | | | | | | | | | | | First Nation and Traditional Bog Use and Restoration Overview |
| Eagle Nest Monitoring | SPES | SPES | 2004-2012 | D | | | | | | | | | | | | | | X | | PDF File |
| Stanley Park Ecological Action Plan | Planning & Operations - Vancouver Board of Parks & Recreation | Planning & Operations - Vancouver Board of Parks & Recreation | 2011 (Jan) | D | | | | | | | | | | | | | | | | Restoration of Beaver Lake incl. recommended hydraulic dredging |
| Sediment Characteristics of Beaver Lake and Implications for Remediation: A Pilot Project | Faugeraux, D., Bendell, L. | Simon Fraser University | 2011 | D | | | | | | | | | | | | | | | | Sediment Information and Dredging Implications |
| Aquatic Invasive Plants in Stanley Park | Bajwa, N. and Anand, E. | | 2011 | D | | X | | | | | | | | | | | | | | Powerpoint slide presentation |
| Fungi Species List | Bioblitz | Bioblitz | 2011 | | X | | | | | | | | | | | | | | | Excel spreadsheet |
| Beaver Lake Water Chemsitry | Winston, E., Mosi, A. | Langara College | 2011 | D | | | | | | | | | | | | | | | | Water Quality Chemistry Findings |
| Amphibian and Reptile Monitoring Program in Stanley Park | SPES, BA Blackwell, SPRPSC, UBC | SPES | 2011 | D | | | | | | | | | | X | X | | | | | |
| State of the Park Report for the Ecological Integrity of Stanley Park | Worcester, R. | SPES | 2010 | D | | X | X | | X | X | X | | X | X | X | X | X | X | X | Data-gap filling initiatives |
| Beaver Lake Vegetation Survey Data | SPES, BA Blackwell, SPRPSC, UBC | SPES | 2010 | D | | X | X | | | | | | | | | | | | | Excel spreadsheet |
| Amphibian Monitoring Data | SPES | SPES | 2007-2010 | D | | | | | | | | | | X | | | | | | Excel spreadsheet |
| Breeding Bird Data | SPES | SPES | 2007-2010 | D | | | | | | | | | | | | X | X | X | | Excel spreadsheet |
| Stanley Park Forest Management Plan | SPES, BA Blackwell, SPRPSC, UBC | SPES, BA Blackwell, SPRPSC, UBC | 2009 | D | | | X | X | | | | | | | | | | | | |
| A Preliminary Field Study of Ground-dwelling Invertebrates from Stanley Park | Yagi, H. | Douglas College | 2008 | D | | | | | | | | | X | | | | | | | |
| Identifying Potential Pacific Water Shrew Habitat in Stanley Park through GIS Analysis | Green, R.N. and Leigh-Spencer, S. | BA Blackwell & Associates and Ecologic Consulting | 2007 | D | | | | | | | X | | | | | | | | | |
| Evaluation of Fish Species and Fish Habitat in Beaver Lake, Vancouver BC. Part of Volume I | Gennai, A., Karjala, D., Keeling, T., Yadao, T. | Capilano College Environmental Science Program | 1999 | H | | | | | | | | X | | | | | | | | |
| Plankton in the Water Column and Sediments of Beaver Lake: An Evaluation to determine lake trophic status and successsional stage. Part of Volume I. | Doyle, D., Lemmon, S., Smorong, D., Smyth, J. | Capilano College Environmental Science Program | 1999 | H | | | | | | | | | X | | | | | | | |
| An Assessment of Gaseous Production from Beaver Lake Sediments. Part of Volume I. | Brigden, S., de Melo, L. Raggett, J. | Capilano College Environmental Science Program | 1999 | D/H | | | | | | | | | | | | | | | | Gaseous production from Beaver Lake Sediments |
| Amphibian Survey of the Beaver Lake Area in Stanley Park. Part of Volume II. | Lindskoog, K., Quinlan, C., and Robertson, R. | Capilano College Environmental Science Program | 1999 | H | | | | | | | | | | X | | | | | | |
| A Study of Aquatic Vegetation in Beaver Lake and Options for Vegetation Control. Part of Volume II | Kim, D. Loveys, J. and Sharpe, M. | Capilano College Environmental Science Program | 1999 | H | | X | | | | | | | | | | | | | | |
| Stanley Park Stormwater Management Plan | Wong.S., Wood, J.A. | Kerr Wood Leidal & Associates Ltd. | 1999 | D | | | | | | | | | | | | | | | | Stormwater Management |
| A Study of the Beaver Lake Watershed: Historical Sedimentation, Contemporary Ecology and Hydrology with Predictive Modelling | Zimmerman, A., McIhagga, C., Jarock, C., Rogers, O. | UBC Environmental Sciences | 1999 | D/H | | | | | | | | | | | | | | | | Sedimentation, Hydrology and Predictive Modelling |
| A Study of Disposal Options and Sediment Quality for Proposed Dredgate in Beaver Lake. Part of Volume I. | Lashek, J., Schmidt, T., Schoffield, T. | Capilano College Environmental Science Program | 1998 | D | | | | | | | | | | | | | | | | Sediment Quality |
| Characterization of Beaver Lake bog areas in Stanley Park. Part of Volume I. | Worcester, T., Coulson, K., McDonald. B. | Capilano College Environmental Science Program | 1998 | D | | | | | | | | | | | | | | | | Study of bog area adjacent to Beaver Lake |
| Beaver Lake Ecological Study: A Comparison of Species Diversity Between an Unmanaged Area and a Managed Area in the mature forest stands adjacent to Beaver Lake. Part of Volume II. | Perry, L., Pregitzer, M., West, J. and Kara. N. | Capilano College Environmental Science Program | 1998 | H | | | X | | X | | | | | | | | | | | |
| A Preliminary Presence/Absence and Habitat Quality Survey of Amphibians in the Beaver Lake Area of Stanley Park. Part of Volume II. | Worthington, K. Wood, K. Stennett, L. Gordon, S. | Capilano College Environmental Science Program | 1998 | H | | | | | | | | | | X | | | | | | |
| A Standardized Bird Survey Protocol for Beaver Lake. Part of Volume II. | Flannery, M., Lewis, K. and Romich, M. | Capilano College Environmental Science Program | 1998 | H | | | | | | | | | | | | X | X | X | | |
| Beaver Lake Bathymetric Survey | Stewart, J.M. | | 1997 | D | | | | | | | | | | | | | | | | Bathymetric Survey |
| Comparative EA of Lions Gate Crossing Options related to Stanley Park & First Nations | Coast River Environmental Services | Fisheries and Aquatic Resources | 1995 | D/H | | | | | | | | | | | | | | | | |
| Stanley Park & First Narrows Environmental Assessment Draft Report | Robertson Environmental | Robertson Environmental Services | 1994? | Available? | | | | | | | | | | | | | | | | |
| Stanley Park Regeneration Program | Beese WJ, Paris, GJ. | Vancouver Board of Parks/Rec & MacMillan Bloedel | 1989 | D/H | | | X | | X | | | | X | | | X | X | X | X | |
| A Technical and Economic Feasibility Study of the Beaver Lake Creek Enhancement Project | Hatfield Consultants | Hatfield Consultants | 1985 | D | | | | | | | | | | | | | | | | |
| Beaver Lake - Creek Enhancement Study | Hatfield Consultants | Hatfield Consultants | 1985 | H | | | | | | | | | | | | | | | | Part of BLEEP Binder |
| A Work plan to carry out a salmonid enhancement and an interpretive program for the Beaver Creek System, Stanley Park | Hatfield Consultants | Hatfield Consultants | 1983 | H | | | | | | | | | | | | | | | | Part of BLEEP Binder |
| Notes on the Life History of Ambystoma gracile | Watney, G. | Copeia (journal). Vol. 1941, No. 1 pp. 14-17 | 1941 | D | | | | | | | | | | X | | | | | | |