Source Assessment of the Cedar Heights Shuswap Lake Drinking Water Intake

October 2015

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Executive Summary

The objective of this assessment of the Cedar Heights drinking water intake was to identify current and forecast future drinking water hazards and vulnerabilities, characterize the risk posed by each hazard, and provide recommendations to reduce impacts on the intake and the drinking water supply.

Shuswap Lake is a large lake in the interior of British Columbia. The entire lake volume can be flushed every two years and as a consequence, Shuswap Lake is strongly influenced by changes in its watershed.

This assessment characterizes natural and man-induced hazards to drinking water quality as physical, chemical or biological. These risks may change over time as Cedar Heights grows and changes. Existing research was augmented by 2014-2015 field studies of water currents, water quality profiles, and algae sampling in Shuswap Lake near the intake. This research was used to define a proposed intake protection zone, based on a two hour travel time of water currents to the intake under moderate winds. The largest potential impacts identified in this study include shoreline residential use, stormwater, power boating, and watershed influences.

Shuswap Lake at Cedar Heights provides high quality water for most of the year but it is a vulnerable water source that can be impaired by many hazards.

Specific recommendations and action plans were developed with the aim of providing the best water quality. Key recommendations include: applying best management practices for shoreline protection, extending the intake to below 20 m with 3 m clearance from the substrate, and creating a new intake protection zone within the CSRD zoning by-law 900. Shuswap Lake water quality is defined by the quality of its watershed. Riparian protections along the Shuswap River and the various creeks that drain into the lake should be enhanced. Shuswap Lake and the Shuswap River watershed have many stakeholders and engaging the public on how to protect water quality through education, activities, and regulation is essential for any effort to gain traction.

Acknowledgements

Funding by the Columbia-Shuswap Regional District

Technical Advisory Committee members (see Report section 1.3).

Special thanks to Project Manager Douglas Geller, P.Geo. of Western Water Associates Ltd. for assistance in all aspects of this project and review of this report.

Suggested Reference

Self, J., and Larratt,H., 2015. Source Assessment of the Cedar Heights Drinking Water Intake. Prepared by Larratt Aquatic Consulting Ltd. Prepared for the Columbia-Shuswap Regional District.

Authors: Jamie Self H.B.Sc.; Heather Larratt H.B.Sc., R.P.Bio.

Reviewed by:

Douglas Geller, M.Sc., P.Geo

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1.0 Introduction

1.1 Study Background

Interior Health (IHA) required the Columbia-Shuswap Regional District to perform an assessment of the source of their water and their water systems at Cedar Heights, identifying the risks to drinking water quality that affect both, and steps that can be taken to improve the protection of drinking water quality for current and future consumption. This process is framed by the provincial *Comprehensive Drinking Water Source-to-Tap Assessment Guideline* (Ministry of Healthy Living and Sport, 2010).

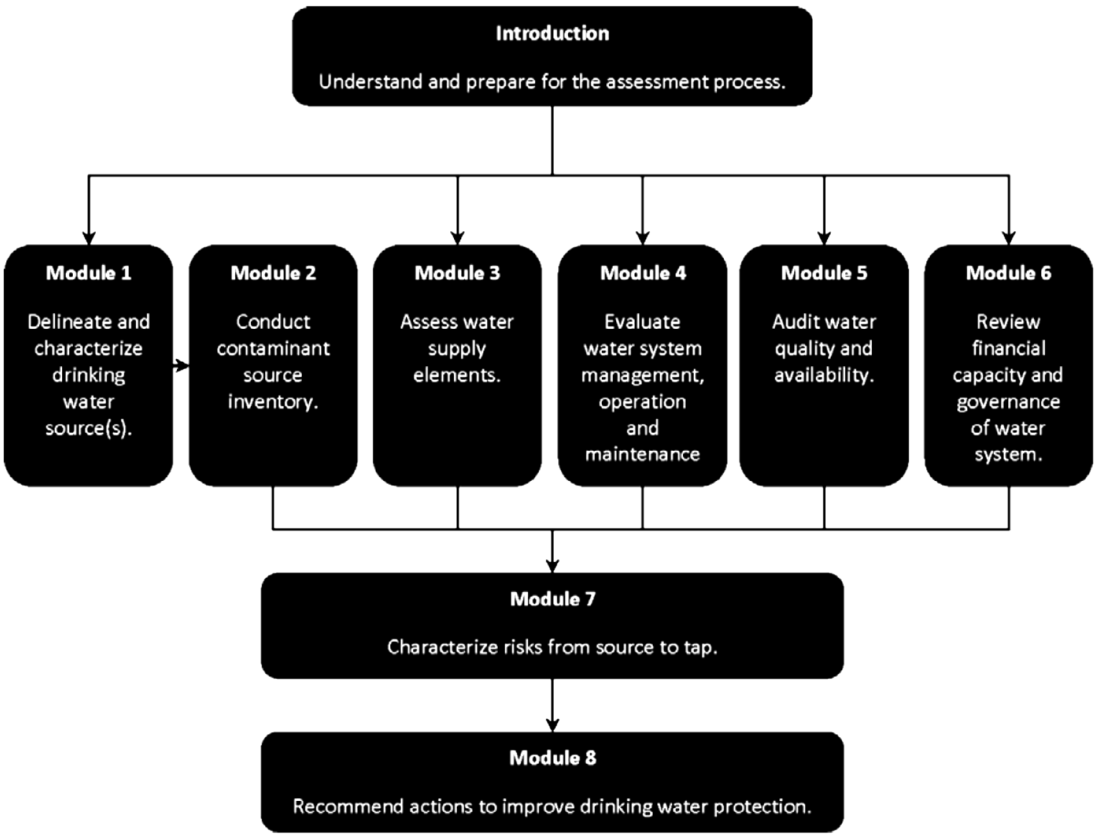


Figure 1: IHA Source Assessment Framework (Ministry of Healthy Living and Sport, 2010)

Routine monitoring and innovative research can be used to meet the requirements of Modules 1, 2, 7, and 8 of the source assessment framework.

1.2 Study Purpose

This report compiles new research and known data into the IHA Source Assessment format for use with identifying the strengths of the Cedar Heights drinking water supply and source, potential risks/threats, and recommendations to maintain and protect this water source. The report may be used to support creation of an intake protection zone, to further raise awareness about the need to protect the water source, and to inform land use planning and land use decisions on the adjoining foreshore and uplands around Cedar Heights. In addition, this report along with other measures could be used to support CSRD in pursuing filtration exclusion for the Cedar Heights source.

1.3 Study Plan and Technical Advisory Committee

This study was performed in a coordinated fashion with the intake assessments of two other nearby water sources (Sorrento and Shuswap Lake Estates). Larratt Aquatic Consulting (LAC) reviewed existing research on Shuswap Lake and the greater Shuswap watershed area and from this review, a new research program, was set up to develop data specific to the intakes. This included one year of field data collection. The 2014-2015 sampling program included:

- Vertical profiles of Shuswap Lake using a multi-meter probe that measured: temperature, dissolved oxygen (DO), pH, conductivity, total dissolved solids (TDS), and several other parameters.
- Mapping water currents around the intake using GPS and drogues.
- Collection and enumeration of Algae samples.
- Bacteria sampling from the sediment below the intakes.

CSRD formed a Technical Advisory Committee (TAC) to help inform and guide this project. The TAC met twice during the study to share information and review progress on the intake protection plans. Members of the TAC included:

Terry Langlois, Utilities Team Leader, CSRD
Dennis Dodd, Utilities Coordinator, CSRD
Dan Passmore, Senior Planner, CSRD
Terry Barker, Shuswap Lake Estates
Jerry Weihmann, Cedar Heights representative
Rob Fleming, Drinking Water Officer, Interior Health
Dennis Einarson, B.C. Ministry of Environment
Douglas Geller, Project Manager, Western Water Associates
Heather Larratt, Technical Lead, Larratt Aquatic

1.4 Definitions

Glossary: The following terms are defined as they are used in this report.

Term	Definition
Aerobes	Organisms that require >1-2 mg/L dissolved oxygen in their environment
Accrual rate	A function of cell settlement, actual growth and losses (grazing, sloughing)
Algae bloom	A superabundant growth of algae
Anaerobic/anoxic	Devoid of oxygen
Benthic	Organisms that dwell in or are associated with the sediments
Bioaccumulation	Removal of metal from solution by organisms via adsorption, metabolism
Bioavailable	Available for use by plants or animals
Cyanobacteria	Bacteria-like algae having cyanochrome as the main photosynthetic pigment
Diatoms	Algae that have hard, silica-based "shells" frustules
Fall overturn	Surface waters cool and sink, until a fall storm mixes the water column
Eutrophic	Nutrient-rich, biologically productive water body
Green algae	A large family of algae with chlorophyll as the main photosynthetic pigment
Inflow plume	A creek inflows seeks the layer of matching density in a receiving lake, mixing and diffusing as it travels; cold, TSS, and TDS increase water density
Light attenuation	Reduction of sunlight strength during transmission through water
Limitation,nutrient	A nutrient will limit or control the potential growth of organisms e.g. P or N
Limnology	The study of the physical, chemical, and biological aspects of freshwater
Littoral	Shoreline between high and low water; the most productive area of a lake
Macronutrient	The major constituents of cells: nitrogen, phosphorus, carbon, sulphate, H
Micronutrient	Small amounts are required for growth; Si, Mn, Fe, Co, Zn, Cu, Mo etc.
Microflora	The sum of algae, bacteria, fungi, *Actinomycetes,* etc., in water or biofilms
Myxotrophic	Organisms that can be photosynthetic or can absorb organic materials directly from the environment as needed
Pelagic	Open water deeper than 6 meters in a reservoir or lake (less productive)
Peak biomass	The highest density, biovolume or chl-a attained in a set time on a substrate
Periphyton	Algae that are attached to aquatic plants or solid substrates
Phytoplankton	Algae that float, drift or swim in water columns of reservoirs and lakes
Photic Zone	The zone in a water body that receives sufficient sunlight for photosynthesis
Plankton	Those organisms that float or swim in water
Reclamation	A restoration to productivity and usefulness
Reducing env.	Devoid of oxygen with reducing conditions (-ve redox) eg. swamp sediments
Residence time	Time for a parcel of water to pass through a reservoir or lake (flushing time)
Riparian	The interface between land and a stream or lake
Secchi depth	Depth where a 20 cm secchi disk can be seen; measures water transparency
Seiche	Wind-driven tipping of lake water layers in the summer, causes oscillations
Thermocline	The lake zone of greatest change in water temperature with depth (> 1°C/m); it separates the surface water (epilimnion) from the cold hypolimnion below
Zooplankton	Minute animals that graze algae, bacteria and detritus in water bodies

Lake Classification by Trophic Status Indicators

Trophic Status	chlorophyll-a ug/L	Total P ug/L	Total N ug/L	Secchi disc m	primary production mg C/m^2/day
Oligotrophic	0 – 2	1 – 10	<100	> 6	50- 300
Mesotrophic	2 – 5	10 – 20	100 – 500	3 – 6	250 – 1000
Eutrophic	>5	> 20	500-1000	< 3	>1000

Nutrient Balance Definitions for Microflora (Dissolved Inorganic N : Dissolved Inorganic P)

Phosphorus Limitation	Co-Limitation of N and P	Nitrogen Limitation
>15 : 1	<15 : 1 – 5 : 1	5 : 1 or less

After Nordin,1985

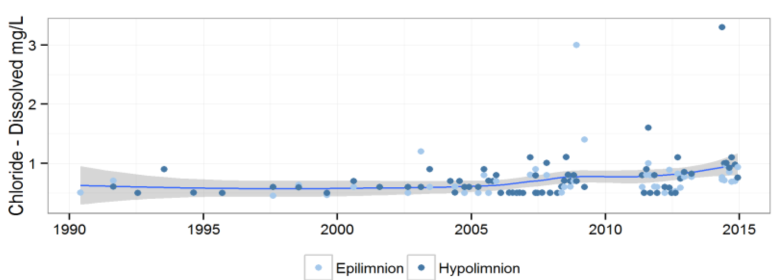
1.5 Abbreviations

Entities
CSRD=Columbia Shuswap Regional District
IHA = Interior Health Authority
LAC = Larratt Aquatic Consulting;
MFLNRO = Ministry of Forests, Lands, and Natural Resources Operations
MoE = Ministry of Environment
MoT = Ministry of Transportation and Infrastructure
OBWB = Okanagan Basin Water Board
RDNO=Regional District of North Okanagan
SLIPP = Shuswap Lake Integrated Planning Partnership

Technical Phrases, Regulations
BCERMS =British Columbia Emergency Response Management Systems
BCWQ = BC Water Quality
BMP = Best Management Practices
FIM = Foreshore Inventory mapping
GCDWQ = Guidelines for Canadian Drinking Water Quality
GUDI = Groundwater Under Direct Influence (of surface water)
IPZ =Intake Protection Zone
PPCPs = Pharmaceuticals and personal care products
SCADA =Supervisory Control And Data Acquisition (system)
SHIM = Sensitive Habitat Inventory Mapping
WTP = Water Treatment Plant

1.6 Information on Statistical Analysis

Statistical analyses were performed on data to support claims made throughout this report. The use of the word 'significantly' within this report is understood to signify that the claim being made has stood up under statistical analysis. Unless otherwise stated, all statistical analysis were performed to a confidence of 95% (p=0.05). The ± symbol refers to plus-minus the standard deviation throughout this report.



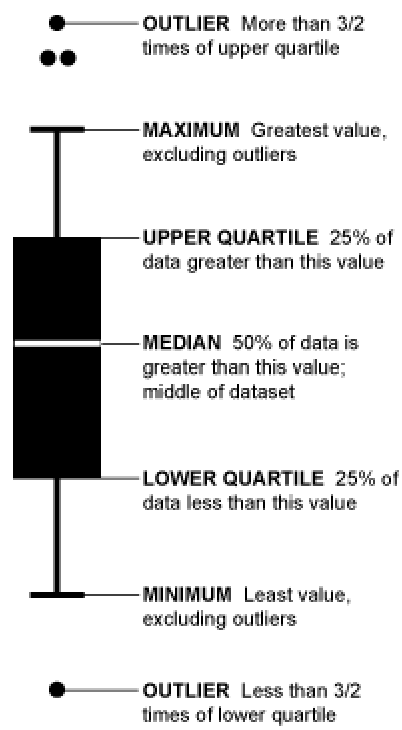


Figure i: Example scatterplot (above) includes all data for a parameter sorted by depth, LOESS polynomial trendlines and the standard errors of those trendlines are also included as a shaded area around the trendline. Dashed line indicates the reportable detection limit (RDL) for a particular parameter. Points below this line were reported as non-detectable by the lab.

Example boxplot (right) is labeled with key information.

2.0 Shuswap Lake Intake Module 1: Characterization of Source

2.1 Description of System Intake Location, Design, Construction and Maintenance

2.1.1 Water Licences

The CSRD Cedar Heights water licence allows for 414,830 m^3 of water from Shuswap Lake to be used annually. CSRD used only 111,507 m^3 in 2014.

2.1.2 Intake Location and Depth

The Cedar Heights drinking water intake is located approximately 100 m from shore in the western basin of the Main Arm of Shuswap Lake (50.888651°N, 119.394984°W) (Figure 2.1.1).

Figure 2.1.1: Map of Shuswap Lake and the Cedar Heights Intake

The intake opening is located approximately 15 m from the surface at low water level (elevation = 337 m AMSL) (Figure 2.2) and 1.5 m above the lake bed. It is protected by a fish screen.

The 120 m long 150 mm diameter HDPE intake pipe connects to the pumphouse and chlorination facility on Blind bay Road.

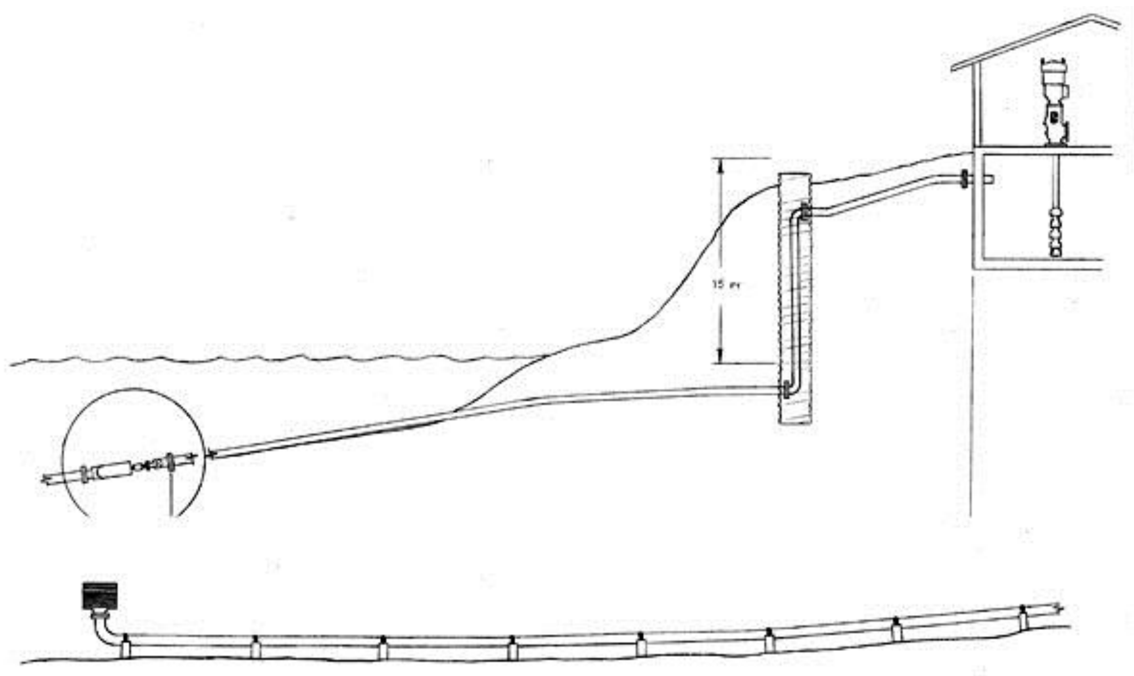


Figure 2.1.2: Schematic of Cedar Heights intake (CSRD)

Table 1.1.1 Summary of Cedar Heights intake parameters (as of 2014)

Parameter	Cedar Heights Intake
Depth (m) at low lake elevation	15
Depth (m) at average lake elevation	17
Clearance from substrate (as built) (m)	1.5
Length (m) to wet well	120
Diameter (mm)	150
Pipe material	HDPE
Year of intake installation	2008
Age of distribution system (years)	30+
Balancing reservoirs in system #	2
Number of connections (full build-out)	384
Sediment accum. in wet well (cm/year)	< 1 cm
Intake last cleaned	2013

2.1.3 Water Treatment, Distribution and Monitoring Overview

CSRD extracts water from a new intake and pumps it to a new water treatment plant. The treatment plant uses a hypochlorite solution chlorination system and ultra-violet disinfection. The disinfected water is then pumped out into the distribution system.

2.1.4 Routine Monitoring and Emergency Planning

CSRD staff monitor temperature, pH, and turbidity using automated analyzers at the pumphouse log 24 hour averages. Routine water chemistry analysis is performed monthly at CSRD's Cedar Heights Intake.

2.2 Limnology of Shuswap Lake as it affects the intake

Shuswap Lake is a major lake in the Southern Interior of British Columbia. It averages 40 m deep with a maximum depth of 110 m in the Main Arm (Figure 2.2.1). The entire lake contains 18.2 km^3 of water (4.8 km^3 in the Main Arm) and theoretically flushes in 2 years (Nidle and Shortreed, 1996). The Shuswap River is the main tributary to Shuswap Lake. The Shuswap River enters Shuswap Lake through Mara Lake, 29 km east of the intake. Mara Lake drains into Shuswap Lake by the Sicamous Narrows, a 1.3 km long, 100 m wide channel. Shuswap Lake's water elevation fluctuates by approximately 4 m over the course of a year. High water is reached in July after freshet and the lake gradually drops over the summer and stabilizes at the low water mark through the winter.

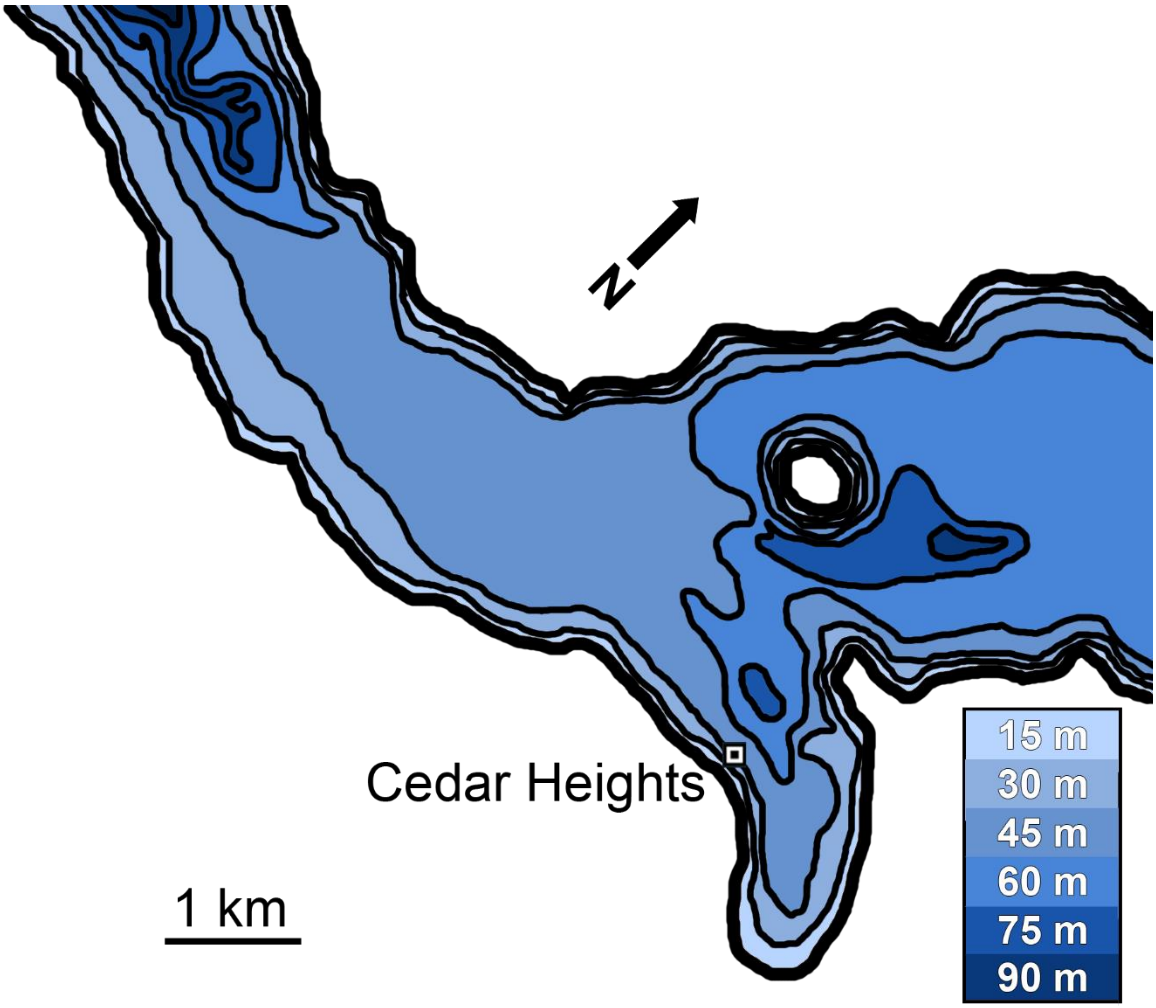
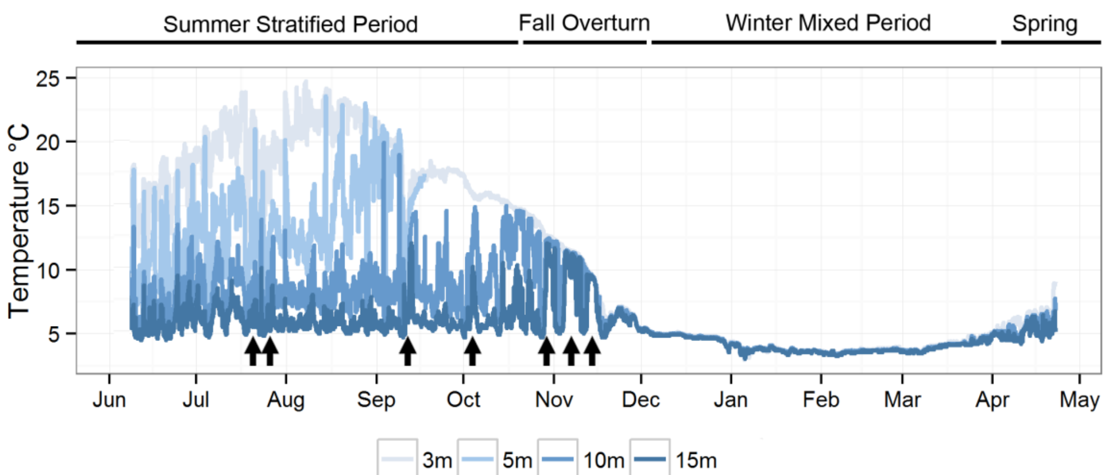


Figure 2.2.1: Bathymetric map of Shuswap Lake near the Cedar Heights intake (modified from International Pacific Salmon Fisheries Commission, 1949).

2.2.1 Thermal Behavior

Shuswap Lake exhibits stable thermal stratification every year from May to November. This is a process where the lake becomes divided vertically into two layers. The upper surface layer (epilimnion) warms from the sun while the deeper layer (hypolimnion) is isolated from the sun and remains cold. The interface between the layers is known as a thermocline. The difference in density of warm water and cold water restricts interaction between these layers throughout the stratified period. As the epilimnion cools in the fall, the temperature equalizes and a wind event can cause the lake to overturn. Shuswap Lake mixes from the surface to the bottom each fall in November and remains in a mixed state through the winter until thermal stratification re-establishes in May.



Figures 2.2.2: Temperature Profile of Shuswap Lake at Blind Bay from Jun 2014 – Jun 2015. Data highlights key thermal phenomena in Shuswap Lake including: stratification, seiches (arrows), and mixing.

Shuswap Lake experiences periodic seiches throughout the stratified periods. Temperature data obtained during the study period indicated that over 20 seiches reached 15 m (Figure 2.2.2). The shallow depth of the Cedar Heights intake will provide very little protection from surface water intrusion during seiches.

2.2.2 Watershed Influences

Shuswap Lake has a history of significant water quality impacts in its watershed. Most recently, there was major flooding in June 2012 at Sicamous that also resulted in multiple watershed failures at the same time.

Shuswap River also frequently floods fields upstream of Mara Lake and carries a large load of organics and bacteria into Mara Lake and then into Shuswap Lake (NHC, 2013). The Shuswap River and Salmon River valleys are extensively modified for agriculture. . Riparian protection from these influences are minimal to non-existent. Agriculture within the Shuswap River and Salmon River valleys is the most significant impact to water quality in Shuswap Lake.

The City of Enderby releases treated sewage effluent into the river upstream of Mara Lake while the City of Salmon Arm releases treated effluent into the Salmon Arm of Shuswap Lake

Other important disturbances in the Shuswap Lake watershed include logging, road construction, and motorized recreation. These disturbances are magnified during wet weather and can lead to major washouts.

2.2.3 Temperature, Dissolved Oxygen, pH and TDS Profiles

Shuswap Lake was sampled three times from June to September in 2014 for this Source Assessment. Surface temperatures ranged from 17.9 °C on June 5 to 24.0 °C on July 17 back to 17.9 °C on September 17 (Figure 2.2.3).

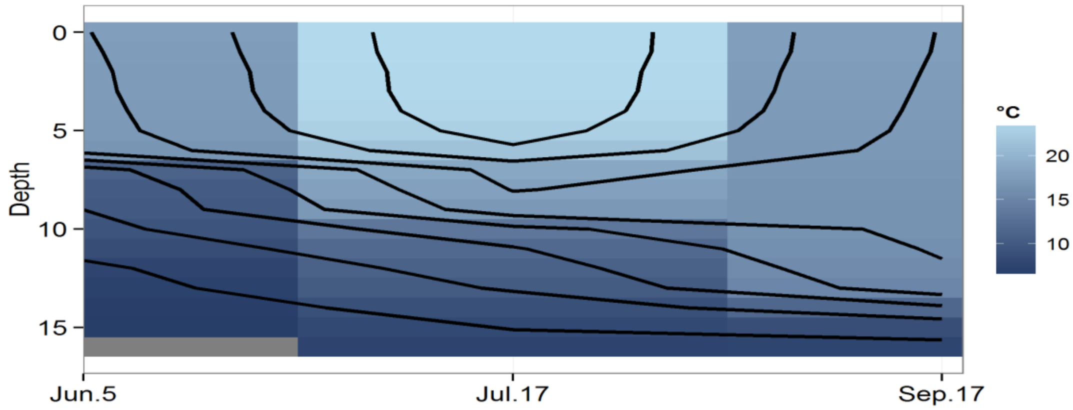


Figure 2.2.3: Temperature profile of Shuswap Lake at Cedar Heights, summer 2014

Surface dissolved oxygen (DO) concentrations were high in Shuswap Lake throughout the year. DO peaked at 8 m during July at >109 % saturation through algae photosynthesis (Figure 2.2.4). DO remained high throughout the sample period. The DO concentration was lower in the warm epilimnion in September because warm water can hold less oxygen than cold water. Shuswap Lake is oligotrophic and unproductive and as a result, oxygen depletion in the deep water did not occur at Cedar Heights.

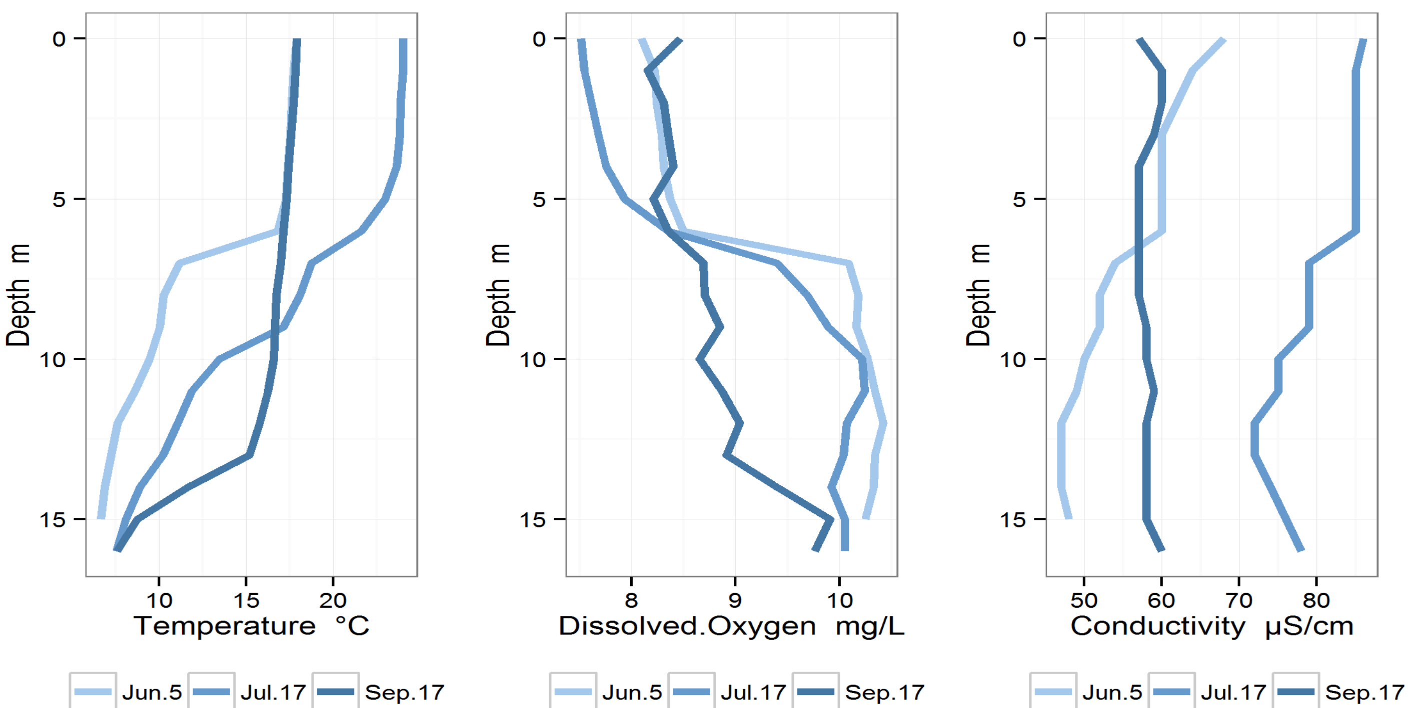


Figure 2.2.4: Temperature, dissolved oxygen, and conductivity profiles for Shuswap Lake at Cedar Heights

pH in the epilimnion of Shuswap Lake at Sorrento averaged 7.59±0.32 from 1990-2014 (MoE, 2015). There were no obvious seasonal variations in the pH data from 1990-2014 but the pH varied by over 1 pH unit during that time, a large change for a lake of this size (Figure 2.2.5). Photosynthesis consumes dissolved CO_2 (a weak acid) and increases the pH (Wetzel, 1975). Algae activity in Shuswap Lake was not high enough to dramatically alter the pH. The fluctuation in pH is likely related to long term climatic variation and watershed influences.

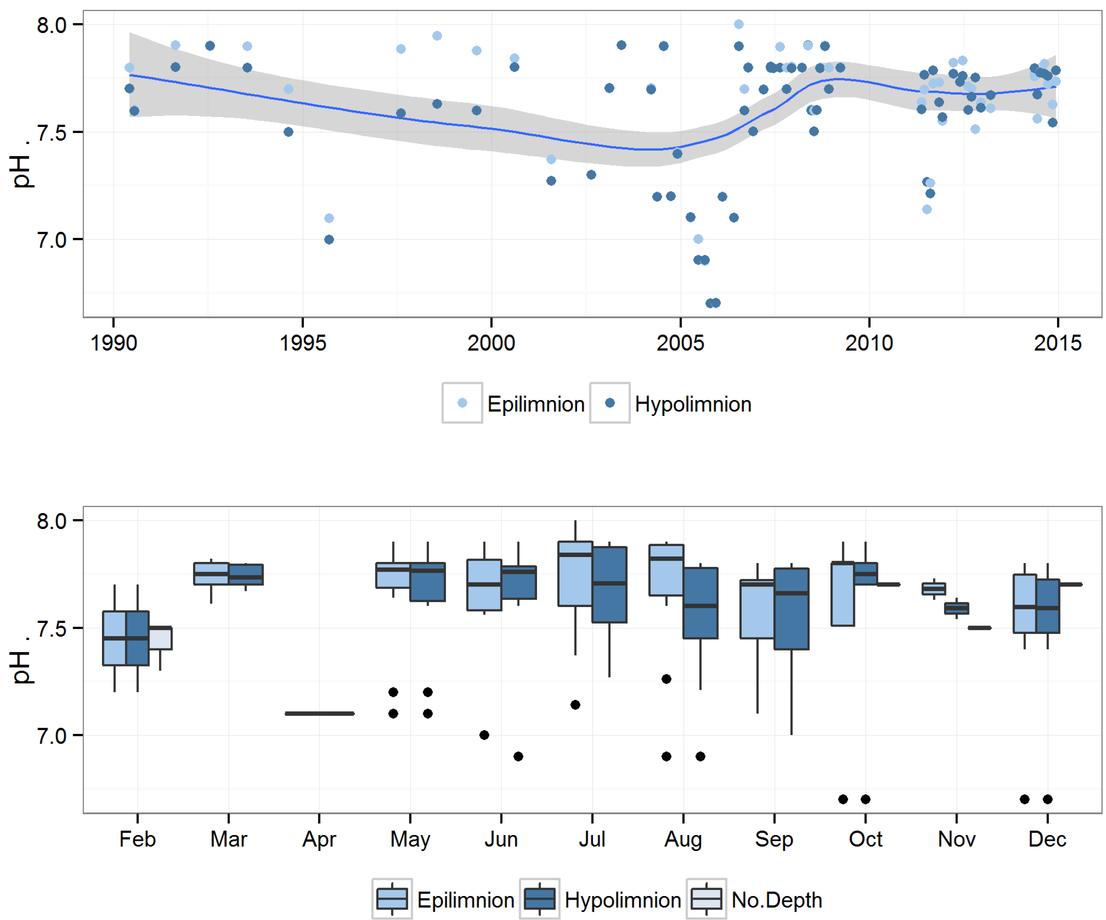


Figure 2.2.5: pH in Shuswap Lake near Sorrento, 1990-2014 (MoE, 2015)

TDS was low in Shuswap Lake, averaging only 36±7 mg/L at the surface during summer 2014. Low TDS and variable pH indicate that Shuswap Lake is weakly buffered. Some treatment processes such as coagulation, may significantly alter the pH in the distribution system (Cooke, 2003).

2.2.4 Turbidity and Water Clarity

Turbidity increases and water clarity decreases when suspended sediment or microflora (algae) growth is high. Turbidity was low in Shuswap Lake and averaged only 0.40±0.33 NTU at the surface from 1990-2014. Turbidity in the intake raw water averaged 0.34 ± 0.19 NTU. Turbidity was much higher during freshet than the rest of the year. The Cedar Heights intake is shallow and experiences regular variation in turbidity (Figure 2.2.7).

Secchi depth averaged a high 9.7 ± 0.4 m from during the summer of 2014 indicating excellent water clarity. The Secchi depth was greatest in mid summer at 10 m on July 17. Spring algae activity was insufficient to reduce water clarity in 2014 (Section 2.3.5). The moderate algae growth gradually depleted nutrients in the surface water layer over the summer causing their decline until water column mixing restored surface nutrient concentrations in late fall (Figure 2.2.8).

Table 2.2.1: Summary of MoE Turbidity Data for Shuswap Lake near Sorrento: 1990-2014

Turbidity (NTU)	Epilimnion	Hypolimnion
Average	0.40	0.36
Min	0.10	0.14
Max	2.80	2.71
StdDev	0.33	0.37

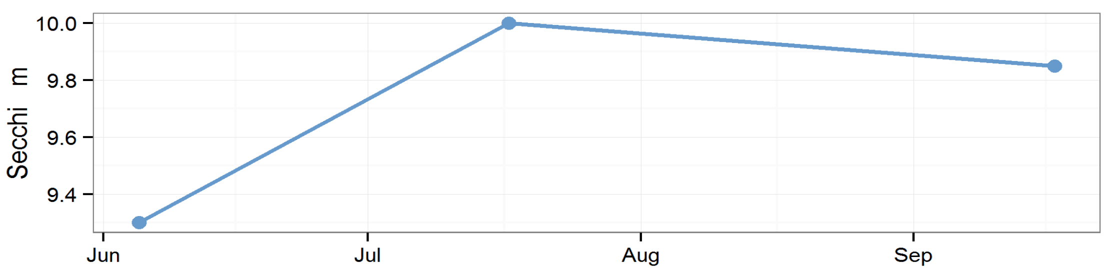


Figure 2.2.6: Secchi depth in Shuswap Lake near Cedar Heights intake, 2014

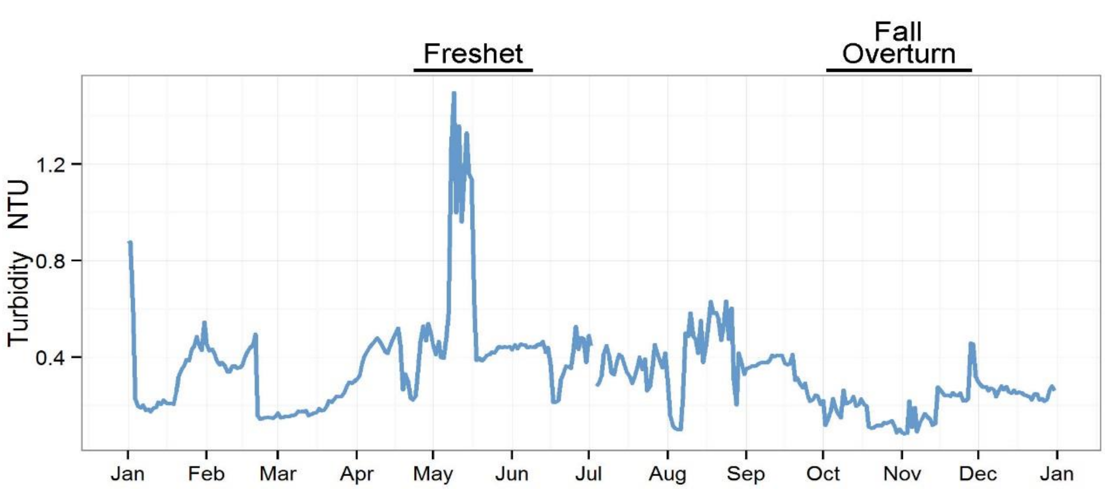


Figure 2.2.7: 24 Hour Average Turbidity at Cedar Heights Intake with Major Features Highlighted, 2014

2.2.5 Nutrients

Nutrients support and determine the nature of aquatic ecosystems Shuswap Lake is an oligotrophic lake (NHC, 2014). Despite receiving nutrient-enriched discharges from parts of its watershed, particularly the Shuswap and Salmon River watersheds. Within the last few decades, Shuswap Lake has likely been subjected to gradually increasing annual nutrient loads and is slowly responding to the anthropogenic-induced changes to the Shuswap River drainage basin. (NHC, 2014).

Nitrogen and phosphorus are considered the most important nutrients in most lake systems (Wetzel, 2001). Total nitrogen (T-N) increased in both the epilimnion and the hypolimnion of Shuswap Lake from 1990-2014 (Mann-Kendall, $p<0.001$ and $p=0.015$ respectively; Figure 2.2.9).

The ratio of nitrogen to phosphorus is a major factor determining what types of algae will establish as the base of the food chain. The total nitrogen to total phosphorus ratio for Shuswap Lake was 21 : 1 from 1990-2014 (Table 2.2.2). This means phosphorus is the limiting nutrient. Phosphorus limitation can discourage nuisance blooms of cyanobacteria. Phosphorus concentrations have been stable since 1990 in Shuswap Lake (Mann-Kendall, $p=0.74$; Figure 2.2.9) but recent research suggests that the nutrient load in Shuswap Lake may be increasing (NHC, 2014). Flood years, such as 1997 and 2012, increased phosphorus loading to Shuswap Lake. Increased nutrient loads can increase the frequency and severity of algae blooms. The 2014 SLIPP final report identified Blind Bay as an area of intermediate concern (SLIPP, 2014). This was because elevated nitrate levels were detected in near shore water quality samples compared to the main body of the lake.

Table 2.2.2: Average nitrogen and phosphorus concentrations in Shuswap Lake: 1990-2014 (MoE, 2015)

	TN (mg/L)				TP (mg/L)			
	Avg	Min	Max	StdDev	Avg	Min	Max	StdDev
Epilimnion	0.14	0.02	0.33	0.05	0.006	0.002	0.100	0.015
Hypolimnion	0.18	0.09	0.40	0.06	0.007	0.002	0.100	0.018

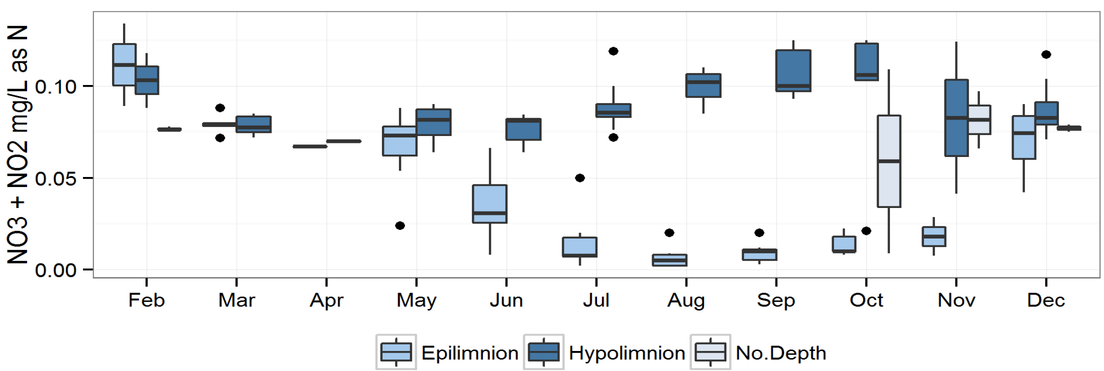


Figure 2.2.8: Monthly dissolved inorganic nitrogen in Shuswap Lake near Sorrento, 1990-2014.

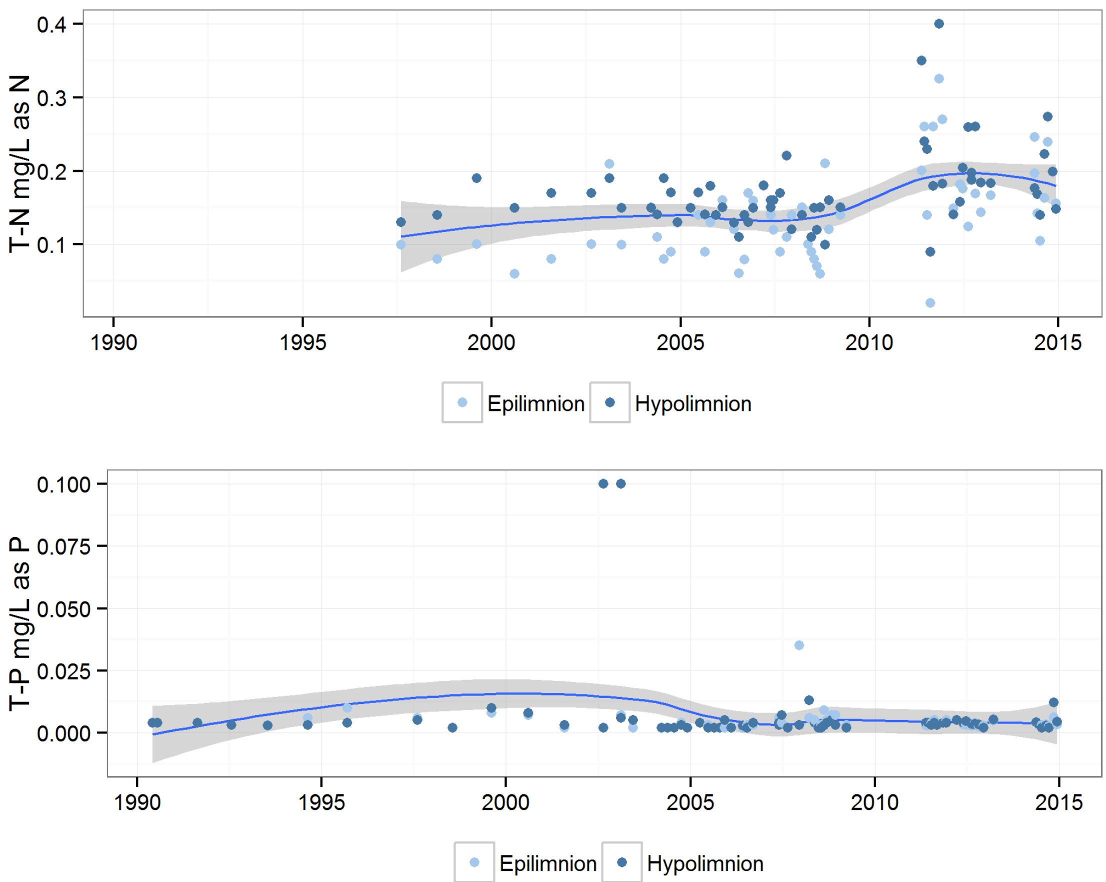


Figure 2.2.9: Nitrogen and phosphorus concentrations in Shuswap Lake, 1990-2014 (MoE, 2015)

2.2.6 Chloride

Dissolved chloride can be used to indicate human impact on an aquatic system. Chloride averaged 0.7±0.3 mg/L from 1990 to 2014 (Table 2.3). The chloride concentration increased during 1990-2014 (Mann-Kendall, p=0.002). Chloride-rich winter road runoff is the main source of chloride to lakes in British Columbia.

Table 2.3: Summary for chloride concentrations in epilimnion and hypolimnion of Shuswap Lake: 1990-2014 (MoE, 2015)

Chloride (mg/L)	Epilimnion	Hypolimnion
Average	0.7	0.8
Min	0.5	0.5
Max	3.0	3.3
StDev	0.3	0.4

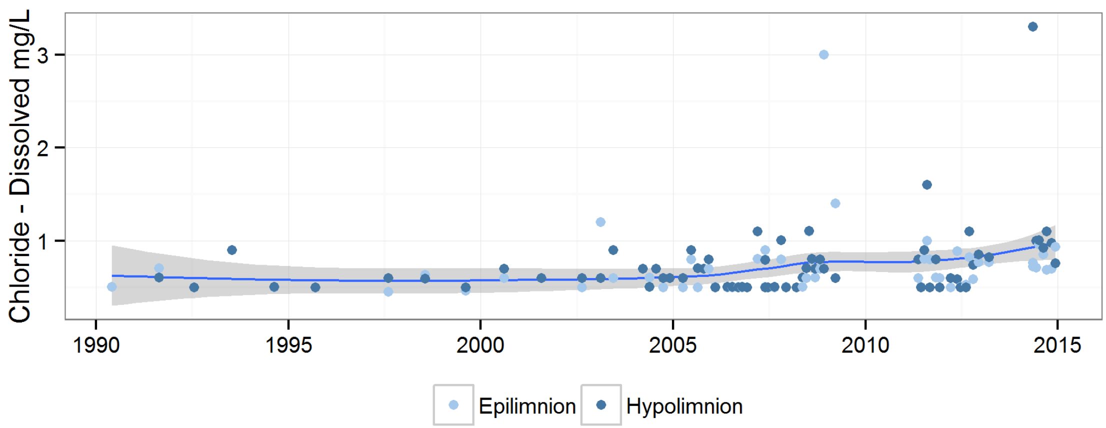


Figure 2.2.10: Chloride concentrations in Shuswap Lake, 1990-2014 (MoE, 2015)

2.2.7 Metals

The area is not industrialized and so neither CSRD nor MoE sample for metals in Shuswap Lake near Cedar Heights. Studies of downstream Kamloops Lake have indicated that heavy metals concentrations are very low and not a concern to drinking water quality (MacDonald et al, 1998).

2.3 Biology of Shuswap Lake with the potential to impact the intakes

2.3.1 Protozoan Pathogens in Water Column

CSRD does not sample for protozoan pathogens. They are most commonly found in rivers and streams where animals have access to the water. They are likely to be a very small risk to the Cedar Heights intake because there no major streams or rivers flowing into Shuswap Lake near the intake.

2.3.2 Bacteria in Water Column

Total coliforms are a broad category of soil and sediment bacteria that indicate the amount of bacterial loading in the water. *E. coli* (*Escherichia coli*) are found in warm-blooded animal wastes and they serve as an indicator of fecal contamination. Only a few of the thousands of *E. coli* strains are disease-causing, however, if *E. coli* are present, the presence of other bacteria pathogens can be statistically correlated. The presence of other pathogenic bacteria such as *Campylobacter* may be correlated, while *E. coli* counts do not correlate well with viruses or other pathogens (Carter et al. 1986; Keith et al, 1999). For reference, the recommended long-term average is not above 10 *E. coli* CFU/100 mL in raw source water.

CSRD does not regularly sample bacteria concentrations in its raw water but the data available indicate that total coliforms and *E.coli* are both low at the Cedar Heights intake. Total coliforms averaged 2 ± 2 CFU/100mL while *E.coli* was consistently below detection from June 2011 to June 2012.

2.3.3 Bacteria in Sediments

In a lake, 99% of the bacteria population will be associated with the upper few centimeters of sediment. *E. coli*. can persist in lake sediment but cannot reproduce under those conditions. A sample of Shuswap Lake sediment near the intake contained no detectable total coliforms or *E. coli* per 100 mL on June 3 2015. Under normal circumstances, these bacteria are isolated from the water column and would not impact the intakes. However, a large seiche (internal wave) may agitate the sediment and re-suspend some of these bacteria into the water column. Intakes that are less than 2 m from the sediment can be affected by sediment bacteria during a seiche (Larratt, 2010).

The bottom of Shuswap Lake drops off quickly beyond the intake. This, in combination with strong currents that run parallel to the shore (see Section 2.5 for a discussion on water currents), means that organic material does not build up on the lake bottom around the Cedar Heights Intake. This is likely why there were no coliform bacteria detected in the Cedar Heights intake sediment sample on June 3 2015.

2.3.4 Sediment Contaminants

Hazardous materials used in the past will not persist in the water column but lake sediments can act as a repository. For example, some pesticides such as DDT and mercury-based materials. Because of burial, their contact with the water column today should be minimal under normal circumstances. Wave turbulence in shallow areas will suspend sediments, while burrowing fish and aquatic insects could disturb materials deeper in the sediment column. Having re-suspended sediment enter the intake is undesirable. It increases turbidity and possibly introduces small concentrations of sedimented contaminants. Exact sediment accumulation rates for Shuswap Lake vary by location and time of year. Traps measured the accumulation of sediment in nearby Blind Bay intake from June 2014 to June 2015. They averaged 5.5 mm/year of sediment, of which 16% was organic material. At this rate it should only take a decade to effectively cover contaminated sediment and prevent their re-suspension in most cases (Larratt, 2010).

2.3.5 Algae in Shuswap Lake

Algae form an important baseline for the food webs in every lake. Algae densities periodically impact source water quality during blooms. When blooms are not present, algae densities in Shuswap Lake do not adversely impact water quality from a drinking water perspective (Figure 2.3.2). There were no major algae blooms in Shuswap Lake during 2014. In the surface water, peak diatom algae growth occurs in early spring. The diatoms *Asterionella* sp. and *Cyclotella* spp. were most numerous in Shuswap Lake at Cedar Heights during spring 2014 (Figure 2.3.1). Algae concentrations decline through the summer and into the fall as nutrients and vitamins are depleted from the epilimnion (Figure 2.2.8).

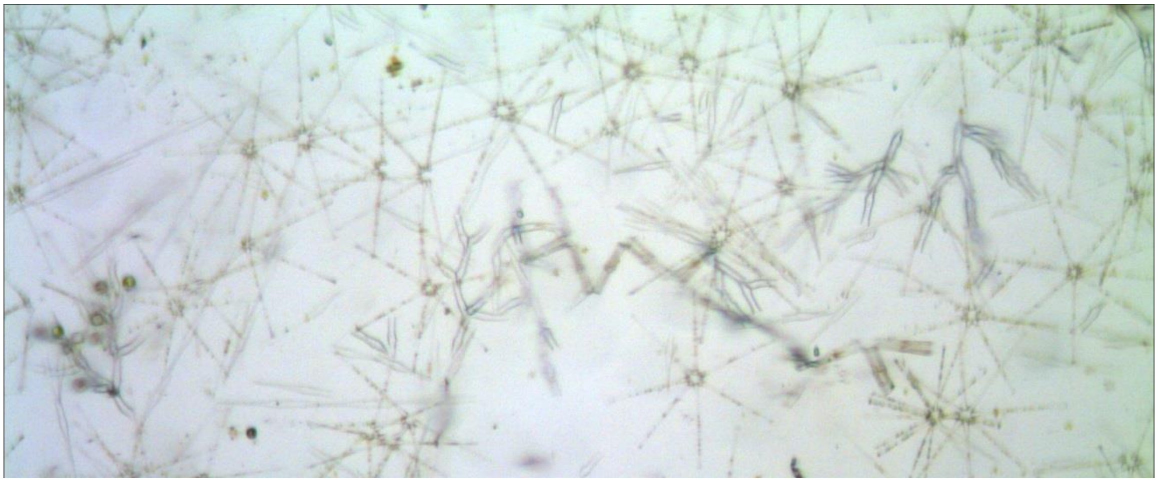


Figure 2.3.1: *Asterionella* sp. at 100x magnification in Shuswap Lake on June 5 2014

Shuswap Lake receives considerable microscopic organic material from its watershed, particularly the Shuswap River. This serves as food for certain types of yellow-brown algae (chrysophyte) such as *Urogenopsis* sp. that formed large blooms in 2008 (NCH, 2013). Unlike cyanobacteria, yellow-brown algae do not create toxins and are not directly harmful to health. However, blooms of yellow-brown algae can create serious taste and odor problems. Treatment of any algae bloom with chlorine disinfection can create harmful trihalomethanes (THMs). Diatoms and some species of yellow-brown algae produce microscopic silica shells that do not decompose and can clog water filters.

The sum of all impacts on its watershed cause Shuswap Lake to produce algae populations that regularly exceed the guideline of 2.5 µg/L chlorophyll-a (NHC, 2013). Unless watershed damage and nutrient enrichment can be reversed it is likely that there will be more frequent algae blooms in the future that will degrade drinking water quality (NHC, 2013). Filter clogging would be worst during algae blooms. Both outcomes would impact drinking water quality. On-going agricultural initiatives including the Shuswap Watershed Water Quality Program (SWWQP), can hopefully address these water quality impact vectors.

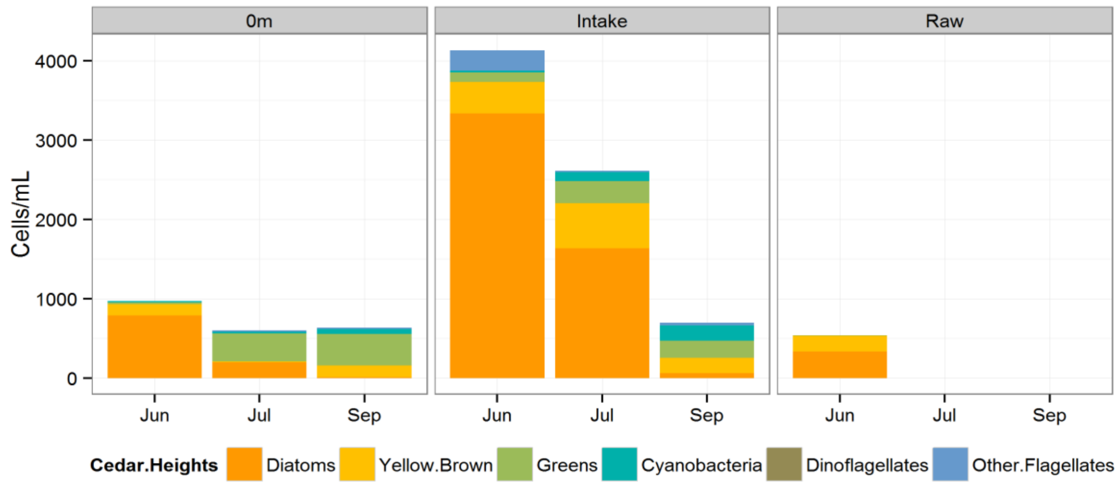


Figure 2.3.2: Algae counts from Shuswap Lake at Cedar Heights samples: 2014

2.3.6 Cyanobacteria in Shuswap Lake

Most species of cyanobacteria are capable of producing cyanotoxins and their presence can impact water quality. Fortunately, Shuswap Lake does not experience intense cyanobacteria activity that many other interior British Columbia lakes suffer. Relatively low phosphorus concentrations push the lake away from cyanobacteria growth and towards yellow-brown algae and diatoms (Figure 2.3.2). Records indicate this has been the normal state for Shuswap Lake (NHC, 2013).

2.3.7 Taste and Odor

Shuswap Lake is can experience taste and odor problems from seasonal algae blooms. Periodic yellow-brown algae blooms gives water a fishy smell and taste. For example, the severe bloom in spring 2008 resulted in a significant taste and odor event. All chrysophyte species generate aldehydes and ketones (n-heptanal, 2,4-heptandienal) that cause fishy taste and odor problems for drinking water and lake-based recreation. Some species also release unique toxins that affect gill-breathing aquatic organisms, mainly fish and clams (Yang et al. 2012). Yellow-brown algae are not dangerous to human health and are only of aesthetic concern in drinking water. Cyanobacteria blooms can affect water quality and cause an offensive musty taste. Cyanobacteria can be a concern to human health but there are no records of cyanobacteria blooms in Shuswap Lake.

2.3.8 Tri-halomethane Formation Potential

Tri-halomethanes (THMs) are produced during chlorination of water containing high total organic carbon. Production of THMs is related to water temperature, contact time, concentration of organics, and chlorine dose. The maximum allowable concentration (MAC) of THMs in drinking water according to the Guidelines for Canadian Drinking Water is 0.1 mg/L. CSRD does not sample for THMs at Cedar Heights.

2.3.9 Biofilm Development

Biofilms are communities of bacteria and other aquatic micro-organisms that develop on submerged substrates and inside water pipes. Biofilm development is most severe when warm surface water is used. The Guidelines for Canadian Drinking Water Quality recommend water remain below 15 °C to minimize biofilm development. The Cedar Heights intake is shallow and pulls in water above the guideline during each summer.

2.4 Human impacts on Shuswap Lake with potential to impact the intake

2.4.1 Sewage/Septage

Sewage and septage routinely carry pathogens, organic matter, grease, nitrates, ortho-phosphorus, heavy metals, inorganic salts, pharmaceuticals and personal care products (PPCP's), cleaners, paints, auto wastes, petroleum hydrocarbons, PAH's and more, hence the need to prevent it from contaminating drinking water sources. There are no sewage effluent outfalls into Shuswap Lake near the Cedar Heights intake. However, there are numerous properties around the intake and throughout the Blind Bay area that use septic systems.

Septage is the mixture of sludge, fatty materials, and wastewater present in septic tanks. It is periodically pumped out by licenced companies. The concentrations of possible pollutants is high in septage and includes disease-causing organisms, nutrients and grease (Crist et al., 1999).

The volume of water that flows into an average septic tank is on the order of 140 to 150 gallons per day per person and it moves through the soil to the shoreline. Soil adsorption in an effective septic field is able to reduce soluble organic carbon, ammonia, but only about 25-50% of the phosphorus load and minimal removal of PPCP's or complex chemicals. Greater septic field efficiencies (80-90%) can occur during the late summer and early fall, because the unsaturated depth of soil was the greatest (Crist et al., 1999).

Further problems with lakeside septic systems can occur during high water (June – July) when as many as one-half of all septic tanks in operation do not function correctly (Crist et al., 1999). Major overland flooding occurs in June and July every 10 – 15 years and it could increase the impact from septic fields or informal disposal sites at farms or residences (Cooperman, 2012). Modern package treatment plants can produce a cleaner effluent and may be the best choice for properties with septic fields within 30 m of the lakeshore.

The threat from human sewage/septage in the vicinity of the Cedar Heights intake is not known.

Shuswap Lake is a very popular recreational boating destination and another potential source of septage (black-water) is improper disposal from houseboats, yachts, and cabin cruisers (NHC, 2013). Disposal of black-water is illegal and hopefully uncommon. Greywater (all waste water up to but not including black-water) is a major concern because it is unregulated and can contain as much bacteria and chemicals as black-water.

2.4.2 Stormwater Locations

Untreated stormwater can carry many types of contaminants including petroleum products, PAHs, and fecal material. Most stormwater in Cedar Heights goes to unlined ditches and then either into the ground or into it flows into the nearest stream channel.

The use of open ditches throughout Cedar Heights is beneficial in reducing stormwater but future development should conform to best management practices (BMPs) to reduce the amount of stormwater; retain it on site if possible; and treat it before releasing it into Shuswap Lake. Recommending stormwater treatment is beyond the scope of this report.

2.5 Calculation of Intake Protection Zone for the Cedar Heights Intake

An intake protection zone defines the area where the intake should take precedence over every other use or consideration and defines the areas of land and water where special care must be taken in the use and handling of potential contaminants to prevent them from accidentally entering the lake and affecting the intake.

The size of an intake protection zone should be based on the existing and potential hazards, and on the speed with which they can be transported to the intake, both horizontally and vertically. Vertical transport is dominated by fall rates and seiches while horizontal movement in lakes is dominated by wind-driven currents and inflow plumes.

The default intake protection zone defined by IHA is a 100 m radius around the end of the intake. The protection zone should be modified from a circle to reflect consistent influences on water travel near the intake such as stream inflows, water currents and seiche patterns. A second layer of protection zone could be imposed on adjacent land development where subsurface (waste water, irrigation water) and surface (storm water) flows delivered to the intake protection zone would be significantly impacted by the land development.

The minimum intake protection zone safety factor recorded in the Lake Ontario Source Study is 2 hours and 1 km radius (Langan, 2007). Lake Ontario is a large lake with heavy industrial use, and not analogous to Shuswap Lake. None the less, a decision must be made on the acceptable time-safety factor that would give CSRD a reasonable timeframe to react to an emergency such as a spill. A two hour safety factor was used in the calculations in this report. The maximum speed of water transport at the surface and at the intake depth were then used to estimate the intake protection zone.

The proposed IPZ does not encompass the entire area capable of impacting the intake, rather it delineates the highest risk area. In a severe storm, a spill anywhere in the west basin of Shuswap Lake could theoretically impact the intake. An intake protection zone based on two hours of water travel under normal wind conditions represents the minimum safety factor recommended in this study. An IPZ should be understood as a critical protection area nested into a larger area of concern (north basin) and finally into the entire area of concern – Shuswap Lake and its contributing watershed.

2.5.1 Vertical Transport – Fall Velocity

When mixtures of solids and water are introduced into a lake, dissolved material remains suspended indefinitely and diffuse, while particulate material settles out according to its fall velocity (Table 2.5.1).

The fall velocity of fine clay is slow at 0.0011cm/s (0.04 m/hr or about 1 m/day), and for *E. coli* bacteria it is far lower at 0.00354 m/day (Hayco, 2009; USGS 2007). For example, it would take several weeks for clay to settle through the water column, unless it clumped with other materials and accelerated. It could take years for bacteria to settle out based strictly on fall velocity. Fortunately, their fall velocity will be accelerated by clumping with other suspended materials.

Table 2.5.1: Size and Fall Velocity Estimates for Lake Particulates

Material	Size	Fall velocity
Inorganic		
Sand	>63 – 100 microns	> 100 m/day
Silt	4 – 63 microns	21 m/day
Clay	0.1 – 4 microns	1 m/day
Biological		
Organic clumps	> 100 microns	>100 m/day
Large algae and diatoms	22 – 70 microns	< 50 m/day
Small algae	6 – 14 microns	<1 m/day
Lrg filament cyanobacteria	5w x 200l microns	0.1 m/day
Sm filament cyanobacteria	1w x 100l microns	>0.007 m/day
Giardia / crypto cysts	4 – 8 microns	0.02 - 0.1 m/day
Bacteria – *E. coli*	0.7 – 10 microns	>0.0035 m/day

(Dia and Boll, 2006; USGS 2007; Hayco, 2009; Larratt 2010)

2.5.2 Vertical Transport - Vertical Currents

There are no persistent vertical currents in a lake; the direction of vertical currents oscillates following the upward and downward water motions in the lake (Hayco, 2009). Vertical currents generated by a strong wind event can theoretically reach 5 m/sec within a seiche. However, a typical maximum vertical velocity for a vertical water current after a strong wind is 0.08 cm/sec (3 m/hr). A sustained current of this magnitude could still transport fine material suspended in the water column or disturbed from the sediments to the surface in 4 hours from a depth of <12 m (Hayco, 2009). The Cedar Heights intake is currently 1.5 m above the sediment in Shuswap Lake and could be vulnerable to sediment transported by vertical currents.

2.5.3 Vertical Transport - Seiche Transport and Autumn Overturn Turbulence

Vertical transport of particulates in lakes follows predictable patterns. During the summer stratified period with no seiche activity, sediments that fall in the epilimnion would vary with depth while below the thermocline, sediment fall should keep a constant accumulation rate. In practice, waves erode the shallows and mixing transfers the sediment to deeper water. A storm can increase sediment concentrations at the Cedar Heights intake by seiche disturbance and by wave turbulence-mixing transfer. Normal wind-driven currents in deep areas of a lake are unlikely to create sufficient turbulence to destroy the boundary water layer near the sediment surface and bring the sediment into suspension. However, rapid current reversals and increased velocity at the thermocline occurs during a seiche or when the wind driving a current suddenly drops. These abrupt changes in water velocity could re-suspend sediment. Seiche-driven sediment re-suspension decreases linearly with depth (Hilton et al., 1986).

During the autumn overturn, near-bottom sediment traps in lakes collect 2-4 times more material than shallow traps due to lake bed re-suspension (Larratt, 2010). During spring and fall high seiche periods, over half of the material in traps was re-suspended material. The greatest turbulence was associated with fall overturn (destratification) (Larratt, 2010). The height to which settled materials can be re-suspended depends on their particle size. Because material on the substrate tends to clump, the height of its re-suspension is usually only a few meters and the rate of return to the substrate is rapid – usually a matter of hours (Table 2.6).

2.5.4 Water Currents (Horizontal transport)

Currents in Shuswap Lake near the intake are variable and influenced by wind. Horizontal currents are the strongest in the top 5 m of most lakes. Drogues (Figure 2.5.1) were used on three occasions and at several depths to document the water currents in Shuswap Lake around the Cedar Heights intake. Each drogue is tracked using GPS for several hours.

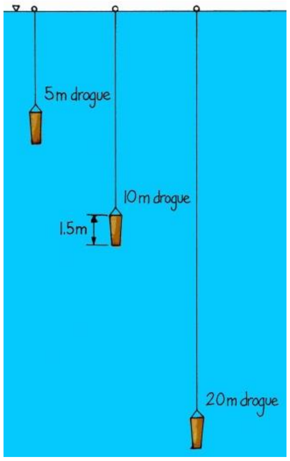


Figure 2.5.1: Schematic of Drogues

2.5.5 Drogue travel in Shuswap Lake near Cedar Heights intake

Drogues generally travelled eastward along the shore. Shuswap Lake is within a narrow valley and prevailing winds blow towards the east. These winds generate long-shore currents that flow west to east on most occasions. Surface waters are more readily influenced by the winds and flowed eastward on all three sampling trips in 2014 (Table 2.5.2, Figure 2.5.2). Shallow currents were generally faster and decreased with increased depth. Deep water currents were more erratic than surface currents because of the effect of the lake bottom. Surface currents encounter the shoreline and are forced to change direction travelling south east and south west.

Table 2.5.2: Summary statistics of Shuswap Lake drogues near Cedar Heights

	Speed (m/hr)				
Depth	Average	Min	Max	StdDev	Direction
5m	246.2	33.7	637.4	300.9	E
10m	108.0	41.4	211.5	76.5	E
20m	78.9	15.5	267.2	106.5	S

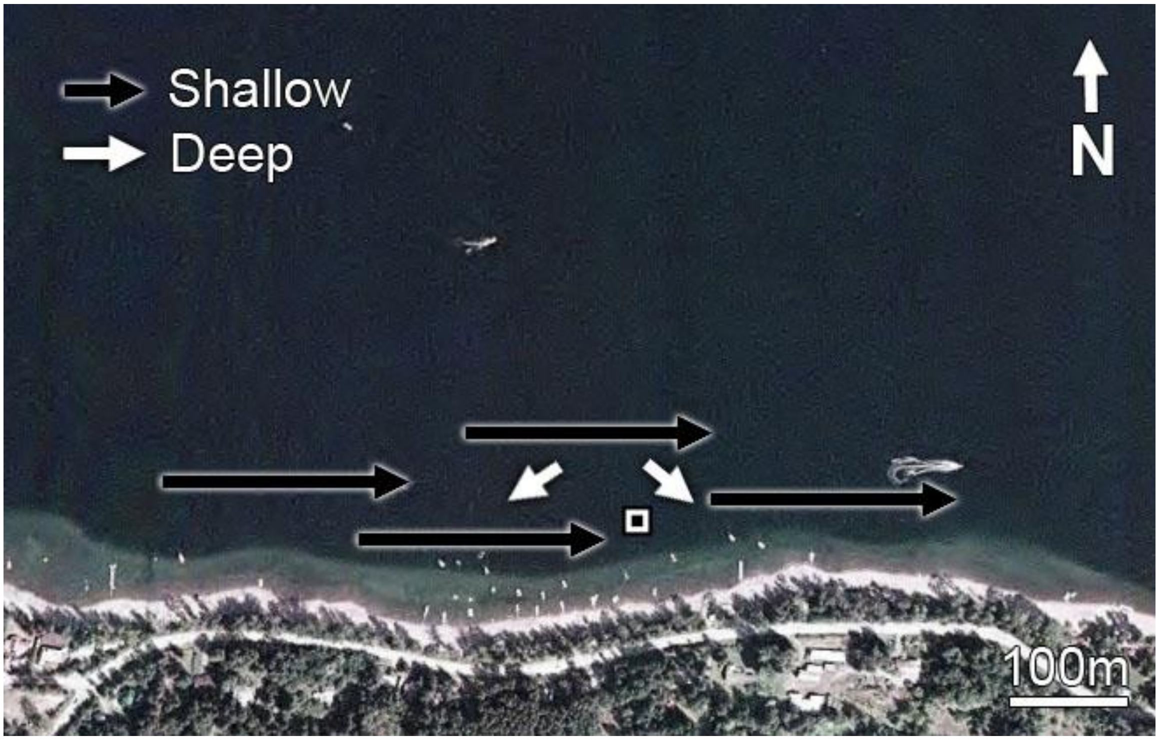


Figure 2.5.2: Typical Pattern of Water Currents for Shuswap Lake around the Cedar Heights Intake

The 5 m drogues travelled the fastest and averaged 246±301 m/hr. They consistently travelled east along the shore (Figure 2.5.3). Wind and longshore currents were important factors in the direction of the shallow drogues. Cedar Heights is very exposed to wind and during a period of strong winds on July 17 2014 the 5 m drogues reached a speed of over 630 m/hr. This is very fast for lake currents.

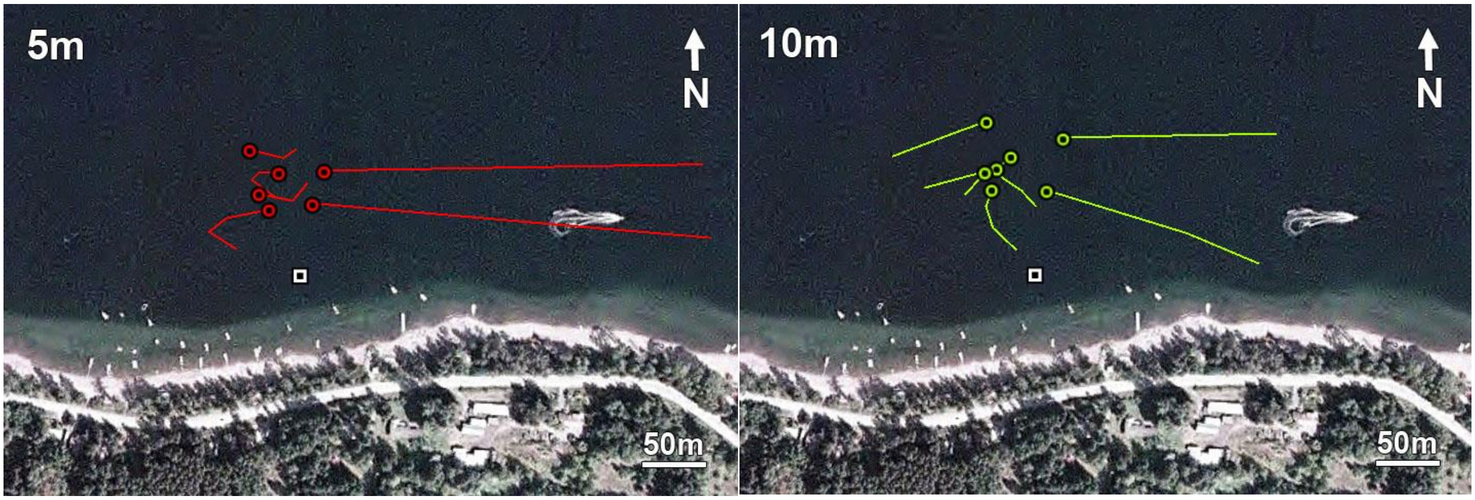


Figure 2.5.3: 5 and 10 m drogues in Shuswap Lake at Cedar Heights

The 10 m drogues averaged 108±77 m/hr. Currents at 10 m were more variable than the wind driven surface currents, occasionally traveling south and west (Figure 2.5.3).

The 20 m drogues were slower than the 5 and 10 m drogues and averaged only 79±107 m/hr (Figure 2.4.4). Drogues at 20 m travelled south during calm conditions but were driven east at high speed (>260 m/hr) during the windy weather on July 17. This indicates that the Cedar Heights intake is vulnerable to impacts from a large area along the shoreline.

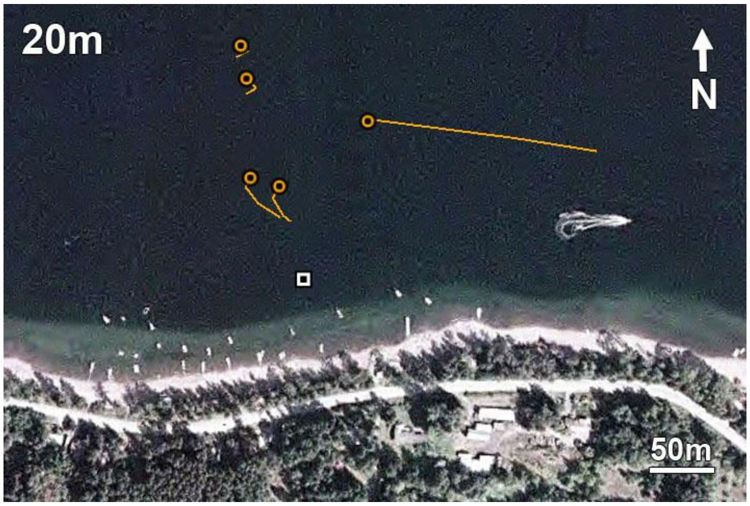


Figure 2.4.4: 20 m drogues in Shuswap Lake at Cedar Heights

2.5.6: Calculation of Proposed Intake Protection Zone (IPZ)

The preceding discussion of vertical and horizontal currents in Shuswap Lake and their ability to transport contaminants was combined with the drogue behavior, wind patterns and modeled current behavior to define the proposed intake protection zone.

IHA recommend a default minimum 100 m buffer zone around the intake. A 100 m circle would provide less than 10 minutes of protection under the fastest drogue recorded. No sampling was performed during extreme weather events but it is safe to assume that under these conditions contaminants would travel faster than normal. Two hours is considered to be sufficient time to respond to a contaminant spill and shut off an intake before the distribution system could be affected (Langan, 2007). In two hours, the fastest drogue at the intake depth travelled >500 m. The fastest overall drogue (5 m) travelled >1200 m in two hours. We based the recommended IPZ on the 20 m drogue because this was closer to the intake depth. The proposed IPZ is not a perfect circle because the water currents around the intake flowed parallel to shore (Orange zone in Figure 2.5.5). The red zone in Figure 2.4.5 the reverse of what the drogues actually travelled centred on the intake. The proposed IPZ lies close to shore and affects many properties including a major marina.

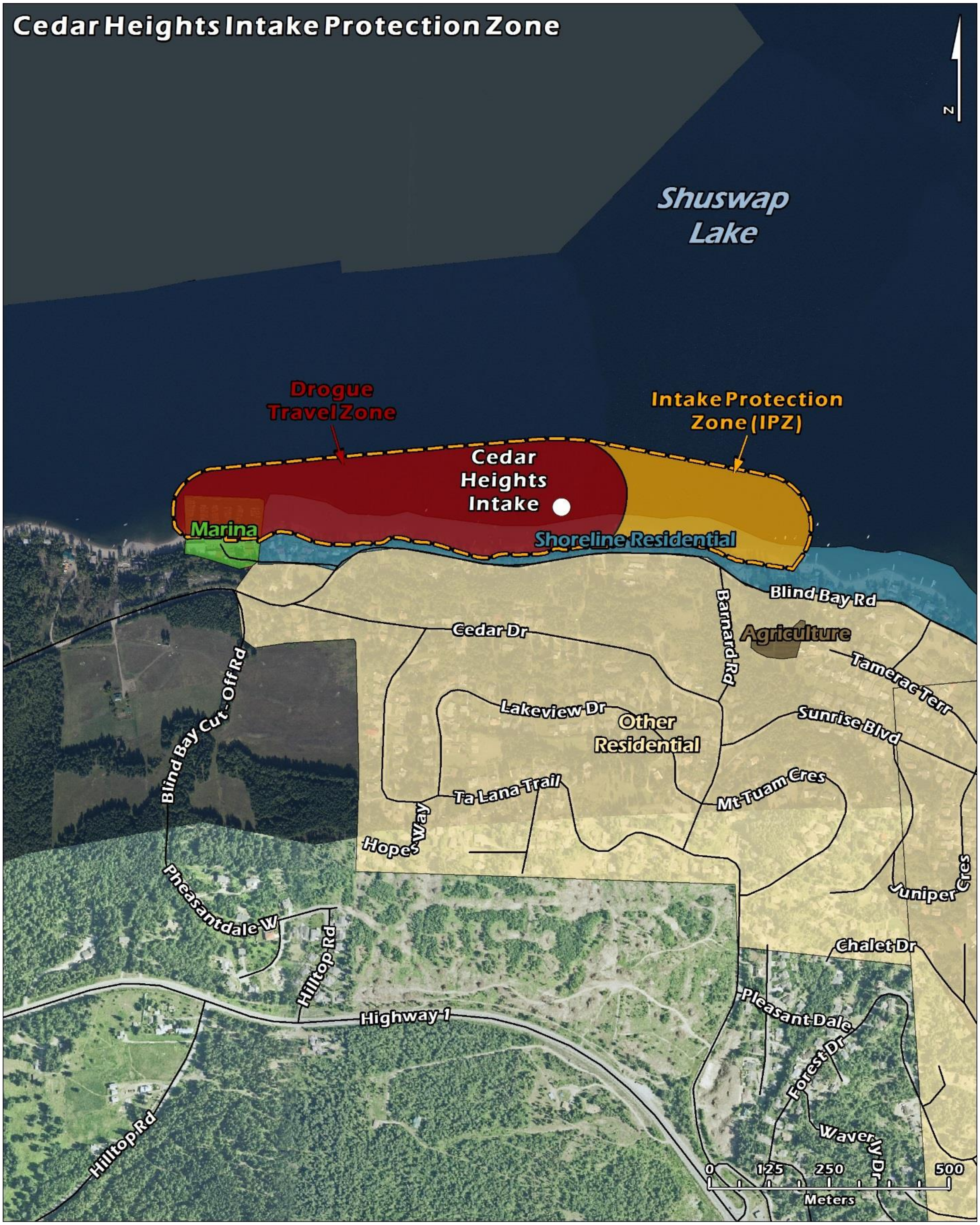


Figure 2.5.5: Proposed scheme for Intake Protection Zone (red+orange) for the Cedar Heights drinking water intake. Red represents the inverted distance of the fastest drogues at intake depth in 2 hours combined with minimum 100 m IHA buffer where travel was <100 m.

Table 2.8 MODULE 1: Hazard and Contaminant Table - Summary Table of Risks

Report section	Drinking Water Hazard/Contaminant	Possible Effects	Existing Preventative Measures/Barriers
	Physical		
2.2.4 2.5.1	Sediment re-suspension from substrates via seiches, currents, on-shore winds	Increased turbidity can compromise disinfection treatment potentially causing illness if pathogens or heavy metals are present	1.5 m clearance of intake from substrate is insufficient to protect against strong seiche turbulence (see Figure 2.2.7)
2.2.1 2.5.3	Seiche transport during storms	Intake is affected by surface water intrusions throughout the year, increasing the risk of exposure to surface water chemical and biological contaminants	Intake depth at 12 m (elevation = 333 m) and is near the summer thermocline and should experience frequent surface water intrusions throughout the summer
2.5.1 2.5.4 2.5.5	Water currents	Water currents in Shuswap Lake at Cedar Heights can carry contaminants at speeds in excess of 630 m/hr at the surface	Intake location below the thermocline where currents are much slower for most of the stratified period
2.2.2	Watershed	• Increased turbidity during freshet and rainy periods, potential for landslides in the watersheds that can severely impact water quality in Shuswap Lake • Nutrient loading upstream in Shuswap and Salmon River basins can affect biological production in the Lake • Logging within the Blind Bay area will increase runoff and may increase risk of landslides	• No major tributaries enter Shuswap Lake near the Cedar Heights intake • Watershed awareness is increasing • No industrial activities
2.2.2 2.4.1	Drought low water levels or shoreline flooding	Wet well stranding or flooding of septic fields, yards, causing introduction of contaminants	
	Chemical		
2.2.4 2.2.5 2.4.2	Storm water	Transport of nitrogen, pesticides road surface contaminants, pathogens, salt	• Infiltration in ditches • Use of permeable surfaces is common • Oil interceptors required in commercial and industrial parking lots • Encourage property owners and developers implement measures to limit stormwater entering sewers and river systems. • Riparian Development Permit Area protection outlined in the CSRD OCP for all properties <30m from high water mark • Lakes 100m Development Permit Area
2.4.1	Septage from local septic fields, sewage from municipal system, boat and RV disposal	Exposure to: pathogens, organic matter, nitrates, heavy metals, inorganic salts, endocrine disrupters, personal care products, cleaners, paints, medications, auto wastes, PAHs	• Health Act's Sewer System Reg. = 30m set-backs from lake. • Riparian Development Permit Areas: <30 m from high water mark or ravine banks
2.4.2	Petroleum hydrocarbons	Deliberate or accidental spill or use of gas-powered boats, boat launches, contamination from stormwater outfalls in vicinity of the intake	• Dilution and evaporation of spills • Oil Interceptors required for stormwater drains in commercial and industrial parking areas
2.2.4 2.3.7 2.5.1	Turbidity	Interferes with disinfection; generally low with occasional spikes	Increased chlorine, public notification
2.3.8	Taste/odor chemicals	Reduced aesthetic; periodic problem	Increase chlorination
2.2.7 2.4.2	Heavy metals and pesticides	Bioaccumulation through chronic exposure	Shuswap Lake specific risks largely unknown; trend in Okanagan is decreasing levels of these contaminants

Report section	**Drinking Water Hazard/Contaminant**	**Possible Effects**	**Existing Preventative Measures/Barriers**
	Biological		
2.3.5 2.3.6	Cyanobacteria	Chronic low-dose exposure to cyanotoxin; health impacts vary with toxin type	Chlorination provides some protection
2.3.5	Algae blooms	Taste and odor events; impaired aesthetics; THM production during chlorination	Chlorination provides some protection
2.3.9	THM precursors (algae, organic material	Organic material (TOC) can react with chlorine to create THMs that are carcinogenic after long-term exposure	TOC load is moderate in Shuswap Lake
2.3.2	Viruses –pathogenic	Acute illness through water-borne exposure	Chlorination & UV Disinfection
2.3.2	Bacteria (*E. coli*, fecal)	Illness through water-borne exposure	Chlorination & UV Disinfection
2.3.1	Protozoa -pathogenic	Illness through water-borne exposure	Chlorinaton & UV Disinfection
2.3.10	Biofilm	Shields pathogens from disinfection, dislodged biofilm can clog filters	Cl residual; pipeline flushing twice per year

3.0 Shuswap Lake Intake Module 2 Contaminant Inventory

3.1 Anthropogenic Potential Water-Borne Hazards to Cedar Heights Intake

A wide range of human activity occurs in the vicinity of the Cedar Heights Intake, predominated by lakeshore residential, boat-based recreation, roads, and agriculture. The degree to which these activities can affect the intake is based on their proximity and risks they pose. Important features are marked in Figure 3.1. These features are discussed in the following sections 3.1.1 – 3.1.8.

Figure 3.1: Potential hazards to water quality in the vicinity of the Cedar Heights intake. Similar land uses are colour coded.

3.1.1 Intake Depth

Intake depth defines the exposure to shallow and deep-water contaminants. The time of year (stratified or unstratified) affects the potential impacts of each hazard. An intake that is located below the summer thermocline is protected from most surface contaminants during the stratified period. Seiches can push surface water down to the depth of an intake but deeper intakes are affected by seiches less frequently. Recreational boating predominantly occurs during the summer when Shuswap Lake is stratified. This should insulate a deep intake (>20 m) from boating-related chemical or waste spills during the busiest time of year. Algae growth is most intense near the surface and decreases as depth increases. Deeper intakes are less affected by fouling from algae growth and the negative impacts of surface algae blooms. Fall overturn mixes surface water throughout the water column and would affect an intake at any depth. The Cedar Heights intake is relatively shallow (<15 m) and would provide limited protection against surface contamination even during the stratified period.

3.1.2 Inflows and Stormwater Outfalls

There are no major stormwater outfalls or creeks that enter Shuswap Lake near the Cedar Heights intake. Runoff from Blind Bay Road and shoreline properties likely flows directly into the lake without treatment. These are relatively small sources of runoff but because of the shallow intake depth and closeness to shore they do pose a risk to intake water quality.

3.1.3 Agriculture

Agricultural impacts on the intake are regional in nature, for example nutrient enrichment of Shuswap Lake. Shuswap Lake's watershed is extensively developed for agriculture. The Shuswap and Salmon River valleys are used for forage, crops, and animal farming without adequate riparian buffer along the rivers. There is only limited agriculture near the Cedar Heights intake.

3.1.4 Invasive Mussels

Invasive zebra and quagga mussels (dreissenid mussels) originated in eastern Europe but have since spread throughout much of North America. Dreissenid mussels pose a serious threat to the Shuswap system. Shuswap Lake is ranked high on the main risk factors for a dreissenid mussel infestation (Table 3.1). Dissolved calcium levels are low in Shuswap Lake for dreissenid mussels but the high bacteria and algae concentrations would provide ample food for the filter feeding mussels. Shuswap Lake's popularity as a recreational boating destination greatly increases the probability of the introduction of dreissenid mussels to the region. Adult dreissenid mussels average only 1-2 cm in length but will cover every available submerged surface up to 10 cm thick. Water intakes are ideal to the mussels because they provide a hard surface to attach to and a steady flow of suspended food as water is drawn into the pipe. Mussels will colonize the entire length of the pipe and potentially clog it if the intake openings are not protected with chlorine. Dislodged mussel shells can also damage pumps and other equipment. CSRD is working with the Okanagan Basin Water Board to educate the public on the potential impacts of invasive mussels within the region. The Clean Drain Dry program should be adopted and vigorously promoted.

Table 3.1: Risk of zebra/quagga mussels to Shuswap Lake (based on Mackie 2010 and MoE 2015)

	Risk for Mussels				Shuswap Lake
	High	Mod	Low	V Low	
Dissolved oxygen (mg/L)	8-10	>9 (High)	4-6	< 4	10 (High)
Mean Summer Temperature (°C)	18 - 25	Mod-High	9-16	< 8 or >30	Mod-High
T-Calcium (mg/L)	25 - 125	13 (Low)	9-20	< 9	16 (Low)
pH	7.5 - 8.7	7.6 (High)	6.5 - 7.2	<6.5 or >9.0	7.6 (High)
Conductivity (µs/cm)	>83	91 (High)	22 - 36	< 22	112 (High)

3.1.5 Moorage, Docks, and Powerboat Recreation

Shuswap Lake is a major recreational boating destination. Thousands of people come each summer to boat. Recreational boating increases the potential for petroleum and waste spills into a lake. The seasonal nature of Shuswap Lake's boating industry means that many boats come from out-of-province. This makes introduction of invasive species (e.g. dreissenid mussels) a greater risk. House-boating is particularly popular. Sicamous advertises itself as "The Houseboat Capital of Canada". Houseboats are frequent sources of greywater contamination (e.g. wash water). Properly maintained and operated houseboats should not release raw sewage into the lake but there is no guarantee that best practices are followed by renters.

The shoreline of Shuswap Lake around the Cedar Heights intake has numerous docks and one large marina to accommodate the summer recreational boating community. The approval process for private docks is not under the jurisdiction of the CSRD. Rather, it is through MFLNRO and their Private Moorage Guidelines, found at:
http://www.for.gov.bc.ca/Land_Tenures/crown_land_application_information/program_areas.html
Provincial moorage guidelines can be found at:
http://www.env.gov.bc.ca/wld/documents/bmp/BMPSmallBoatMoorage_WorkingDraft.pdf
The Large Lake Protocol "zone(s)" in front of the foreshore in question can be found at:
http://www.env.gov.bc.ca/okanagan/esd/ollp/documents/Foreshore-protocol-May2009.pdf

The main risk to water quality from all forms of power-boating and moorage is petroleum spills during refueling. One liter of gasoline can contaminate up to 1,000,000 litres of groundwater (Env Canada, 2010). The process of petroleum contamination in surface water is quite different from groundwater and actual impacts would be less. Gasoline floats on water and rapidly evaporates. Heavier oils would persist in the water and could gradually build up in sediments. There is a large marina 650 m from the intake that is within the proposed IPZ. Operators spilling fuel during refueling at a dock nearer to the intake have a potential to impact water quality. The depth of the intake makes petroleum spills a lower risk than greywater or sewage spills.

3.1.6 Septic Fields and Package Treatment Plants

All shoreline residential in the Cedar Heights area are on septic systems. There is the potential for malfunctioning septic systems to seep into the ground and eventually into Shuswap Lake. SLIPP documented localized increases in nutrients along the shores of Blind Bay, likely a result of septic systems (SLIPP, 2014)

3.1.7 Adjacent Land Use

Land use around the intake has a major potential to impact water quality at the intake. The type of land use greatly determines the scale of the impact. Residential properties typically have more permeable surfaces (e.g. lawns and gardens) and a lower impact on the lake than do commercial or industrial land uses with a greater proportion of land as paved parking. Permeable surfaces reduce runoff that could carry contaminants into the lake. Runoff from adjacent land use is a concern for the Cedar Heights intake because it is shallow and close to shore.

Shoreline Properties

The shoreline around the intake is fully built up with residential. The CSRD OCP provides protection for riparian areas. Under section 12.3 (Lakes 100 m Development Permit Area) and 12.4 (Riparian Areas Regulation Development Permit Area), riparian areas within 100 m of the high water mark face additional development requirements to ensure the protection of the riparian areas. Development within a Riparian Assessment Area requires a report from a “Qualified Environmental Professional”. There is an existing large marina with a marine fuel station within the proposed IPZ.

The entire shoreline at Cedar Heights is either fully developed for housing or disturbed in some way. Thus, the overall level of shoreline disturbance around the intake is high. Most shoreline properties have a dock and there are numerous moorage buoys along the shoreline as well. There are numerous houses, and some condo buildings along the shore.

Ideally, shoreline development should reflect the objectives and guidelines of the Best Management Practices produced by the Province of BC, as well as local government guidelines, including but not limited to the following list:

- Develop with Care: Environmental Guidelines for Urban and Rural Land Development in British Columbia, March 2006.
- Standards and Best Practices for Instream Works, March 2004.
- Wetland Ways: Interim Guidelines for Wetland Protection and Conservation in British Columbia, July 2009.
- Best Management Practices for Amphibians and Reptiles in Urban and Rural Environments in British Columbia, November 2004.
- Best Management Practices for Installation and Maintenance of Water Line Intakes, July 2006.
- Best Management Practices for Lakeshore Stabilization, July 2006
- Best Management Practices for Tree Topping, Limbing and Removal in Riparian Areas.
- Best Management Practices for Small Boat Moorage on Lakes, July 2006.
- Homeowners Firesmart Manual: BC Edition.
- Riparian Factsheet: Agricultural Building Setbacks From Watercourses in Farming Areas, February, 2011, Order No. 823.400-1
- CSRD Official Community Plan (revised 2015)
- Sewerage System Standard Practice Manual

3.1.8 Vandalism and Accidental Introductions

Vandalism is always a risk that should be mitigated against. Obvious potential targets such as fuel and chemical storage should be protected. Other less obvious structures like portable outhouses should also be protected and maintained because of the threat for raw sewage entering the lake.

Invasive species can be an expensive problem for a water purveyor. Dreissenid mussels can be brought into a lake as either visible adults (1 cm) or microscopic larvae (veligers). They can attach themselves to intake structures and clog pipes. A boat was removed from Shuswap Lake in 2012 that had adult dreissenid mussels still attached. Testing revealed that all of the mussels on that boat were likely dead before it was launched into the lake but the scenario illustrates how vulnerable Shuswap Lake is to their introduction (Klassen, 2012).

3.2 Natural Factors that Have Potential to Impact Intake

Not even pristine watersheds and lakes provide completely risk-free drinking water. Natural conditions in and near Shuswap Lake also affect the water quality it provides. The most important of these natural factors are covered in this section.

3.2.1 Flooding

Shuswap Lake experiences periodic seasonal flooding. Lake level rises by several meters each spring. Wet years with a late freshet can produce major flooding such as occurred in 2012 at Sicamous. Creeks that flow into Shuswap Lake also experience occasional flooding. Most development in Cedar Heights is well above the high water mark and is unlikely to be affected by even large fluctuations in the water level.

3.2.2 Algae Blooms

Shuswap Lake is classified as oligotrophic and experiences spring algae blooms and occasionally produces major algae blooms. Diatoms and yellow-brown algae dominated in Shuswap Lake throughout the study period (2014-2015). Yellow-brown algae formed a massive bloom in 2008 that caused a severe taste and odor event. High concentrations of yellow-brown algae produce a “fishy” taste. Diatoms are large and grow in microscopic shells (frustules). These shells persist even after the organism dies and will readily reduce water filter efficiency and life expectancies. Filter clogging would be worst during algae blooms. Blooms of algae increase the TOC concentration in a lake and that can increase THM production during water chlorination.

3.2.3 Shoreline Wildlife

Wildlife are less likely to introduce pathogens to a watershed than humans and their domestic animals. Through travel, people and pets are exposed to a far wider range of pathogens than wildlife that live in one locale. Often pathogen and fecal indicator concentrations are higher in domestic animal feces than in wildlife feces (Cox et al, 2005). However, wildlife can become infected by introduced pathogens and make the pathogen endemic. The majority of the pathogens detected in watercourses were originally introduced by humans and their pets or domestic animals. Wildlife, particularly rodents, are known carriers of the protozoans *Cryptosporidium* and *Giardia*, and less frequently *Toxoplasma* is encountered. Other infections are possible and every effort should be made to prevent their introduction.

Wildlife that habituate the shoreline, such as muskrat, are a greater concern than animals that do not live near the Shuswap Lake shoreline. In an American study, Bitto and Aldras (2009) found 65.9% of the tested muskrats were positive for *Giardia spp*., 50% were positive for *Cryptosporidium spp*., and 29.3% were infected with both parasites. These findings suggest the muskrat may be an important reservoir host for both *Cryptosporidium spp*. and *Giardia spp*. The prevalence of enteric parasitic infection is rising throughout the world. Wildlife may contribute to *Cryptosporidium* contamination in the water but may not have major public health significance because they are generally infected with non-human-pathogenic species and genotypes (WHO, 2009). However, infectivity studies have demonstrated the potential for cross-transmission exists between rodents and cattle (Donskow et al., 2005). Rodents pose a potential threat as a maintenance reservoir for *Cryptosporidium* because of their close proximity to humans and livestock (Zeigler et al., 2007).

3.2.4 Cyanobacteria in Shuswap Lake

Cyanobacteria densities in Shuswap Lake intakes never exceed the WHO and AWWA recommended guidelines of 2000 cells/mL (WHO, 1999). Nutrient enrichment in the Shuswap watershed may push Shuswap Lake to the point where cyanobacteria dominate several decades from now (NHC, 2013). Fortunately, one of the most likely cyanotoxins that can be produced by cyanobacteria (microcystins) are degraded by chlorine but at twice the dose required for disinfection and pH must be near neutral (Hudnell, 2008). UV disinfection is also helpful but again, the UV dose to deactivate microcystins is greater than the dose for general water disinfection (Larratt, 2009).

Tables 3.2 – 3.3 summarize Module 2 into Contaminant Source Inventory Tables (Ministry of Healthy Living and Sport, 2010).

Table 3.2 SUMMARY MODULE 2: Contaminant Source Inventory

Contaminant Source and Type	Owner/ Jurisdiction	Location	Distance to intake	Possible Contaminants	Contaminant Transport Mechanism	Comments
Inflows						
Flooding	n/a	Can occur throughout watershed	Many locations	Sediment, nutrients, pesticides, bacteria and pathogens	currents	Most likely in May/June/July
Landslides	n/a	Can occur throughout watershed	Many locations	Sediment, debris, nutrients, bacteria and pathogens	Currents and fall overturn	Most likely in May/June/July or during thunderstorms
Overland flow	n/a	many locations	Diffuse	Sediment, pathogens, fertilizers, pesticides	currents	Only in storms or freshet
Sewage						
Septic fields	various	Various private properties	100 m +	Septage*	-subsurface seepage -septic failure during flooding	-Documented problem in the Blind Bay area (SLIPP, 2014)
Storm Water						
Runoff from Blind Bay Road and shoreline properties	CSRD, property owners	Many locations	100 m+	PAHs, salt, bacteria, pathogens, nutrients, sediment, accidental spills, pesticides	Currents, wind	-Runoff from road and properties flows untreated into Shuswap Lake within the proposed IPZ
Boating						
Motorboats	Various	Throughout the lake	n/a	PAHs, greywater, petroleum, aquatic invasive species, garbage	Currents, seiches, wind wakes	Very popular in Shuswap Lake, can cause wake erosion
Boat launches	Private Marina	West of intake	650 m	PAHs, petroleum, aquatic invasive species, sediment	Currents, wind	Unlikely to directly impact intake in and of themselves but boats launched from them can have huge impact
Houseboats	Various		n/a	PAHs, greywater, petroleum, aquatic invasive species, garbage, raw sewage,	Currents, seiches, wind	Very popular in Shuswap Lake
Marinas and Boat Docks	Various	All along shoreline of Shuswap Lake at Cedar Heights	100 m+	PAHs, greywater, petroleum, aquatic invasive species, garbage	Currents, wind	One large marina within the proposed IPZ

Contaminant Source and Type	Owner/ Jurisdiction	Location	Distance to intake	Possible Contaminants	Contaminant Transport Mechanism	Comments
Land Use						
Beaches	CSRD, private properties	Entire shoreline of Shuswap Lake at Cedar Heights is exposed beach at low water	100 m+	Garbage, PAHs, nutrients, bacteria, pathogens, sediment	currents seiches	*E coli* testing would determine potential impact
Stormwater	CSRD, private properties	Many locations	100 m +	PAHs, salt, bacteria, pathogens, nutrients, sediment, accidental spills, pesticides	Overland flow, currents, seiches	100% of shoreline is developed
Shoreline residential	CSRD, Private properties		100 m+	PAHs, salt, bacteria, pathogens, nutrients, sediment, accidental spills, pesticides	Currents, overland flow, stormwater	All properties on septic systems
Natural						
Waterfowl	BC	near shore, docks	n/a	pathogens	Currents, falling vertically	Can carry antibiotic resistant E. coli
Cyanobacteria	BC	throughout	n/a	Cyanotoxins	seiches	greatest concern in July – Oct
Wildlife	BC	throughout	n/a	wildlife pathogens	currents	Low concern
Algae Blooms	BC	Throughout	n/a	Taste and odor, increased TOC, THMs,	Currents, seiches, wind	Major bloom in 2008 demonstrates risk

Pesticides includes: herbicides, insecticides, fungicides, rodenticides, and avicides; Many pesticides are highly toxic and are mobile in sub-surface flows
PAHs includes: fuels, oil, grease, asphalt (auto wastes also include: transmission fluid, antifreeze, battery acid)
***Septage/sewage** includes: pathogens, organic matter, THM precursors, nitrates, nutrients, heavy metals, inorganic salts, pharmaceuticals, personal care products, cleaners, paints, medications, auto wastes, PAHs
Pathogens includes: bacteria, viruses, fungi, protozoan parasites

Table 3.3 Summary MODULE 2: Hazard from Contaminants Identification Table

Contaminant Source and Type	Possible Contaminants	Existing Preventative Measures and Barriers	Possible Preventative Measures and Barriers
Inflows			
Flooding	Sediment, nutrients, pesticides, bacteria and pathogens	Shuswap Lake outflow is unregulated, little can be done.	Identify and remove hazardous materials from flood-prone areas (paint, fuel, fertilizer) some flooding is inevitable on Shuswap Lake
Landslides	Sediment, debris, nutrients, bacteria and pathogens	RDNO working to implement recommendations in the Shuswap River Watershed Sustainability Plan	-Study and remediation is on-going for the Shuswap River. -Reduced logging in areas with steep slopes within the Shuswap watershed
Overland flow	Sediment, pathogens, fertilizers, pesticides	Chlorine and UV disinfection, SCADA	-Restrict fertilizer use on near shore properties -Discourage over-watering -Connect all residences to municipal sewer and deactivate septic fields -Liaise with RDNO to achieve same along upstream. Identify substandard systems and encourage upgrades (Ministry of Health, 2006)
Sewage			
All properties in Cedar Heights on septic	Septage*	None	Monitor for poorly performing septic systems and encourage owners to upgrade deficient systems
Storm Water			
Runoff from Blind Bay Road and shoreline properties	PAHs, salt, bacteria, pathogens, nutrients, sediment, accidental spills	None	-Riparian restoration along shoreline of Cedar Heights and stormwater capture for Blind Bay Road
Boating			
Motorboats	PAHs, greywater, petroleum, aquatic invasive species, garbage	None	-Install boat cleaning stations -Prohibit lakeside refueling except at regulated fueling stations -Do not permit new fueling stations in Shuswap Lake -Encourage boaters to behave responsibly to protect drinking water source (Appendix 4) -MoE Compliance & Enforcement -Educate and encourage public reporting of polluters.
Boat launches	PAHs, petroleum, aquatic invasive species, sediment	-Private boat launch enables control over vessels entering the lake, can train staff to inspect for invasive species	-Increase monitoring/education at boat launches with summer students and encourage same with other local governments. (SLIPP) -Install boat cleaning stations and signage directing boaters to those sites -Install emergency equipment (e.g. spill kit) -Educate boaters on BMPs (Clean, Drain, Dry – Appendix 4) -Increase awareness of risk of aquatic invasive species through signage and outreach
Houseboats	PAHs, greywater, petroleum, aquatic invasive species, garbage, raw sewage	None	-Encourage boaters to behave responsibly to protect drinking water. -Create educational activities for children -Encourage voluntary retention of greywater with small monetary reward system -Educate houseboat business on risks of aquatic invasive species -Educate users and encourage effective maintenance of houseboats to prevent sewage entering the lake

Contaminant Source and Type	Possible Contaminants	Existing Preventative Measures and Barriers	Possible Preventative Measures and Barriers
Land Use			
Beaches	Garbage, PAHs, nutrients, bacteria, pathogens, sediment	None	-Restrict new marinas within Cedar Heights -Educate shoreline residential homeowners about how to protect the water quality -Educate boaters on how operate vessels to prevent shoreline erosion -Public signage for education on hazards and how to make a difference -Encourage reporting of polluters
Stormwater	PAHs, salt, bacteria, pathogens, nutrients, sediment, accidental spills, pesticides	None	-Improve retention and infiltration capacity of stormwater systems within Cedar Heights
Shoreline residential	Pesticides, fertilizers	-Mostly large lots with relatively abundant permeable surfaces	-Restrict new docks and marinas within the proposed IPZ -Restrict shoreline alterations -Cosmetic fertilizers and pesticides by-law -Monitor for deficient septic systems (see Sewage above)
Natural			
Waterfowl	pathogens	None	-Install 75 cm tall fences between grass and shoreline to discourage geese from congregating in the vicinity of the intake
Cyanobacteria	Cyanotoxins	-Emergency monitoring available as needed -Chlorination of drinking water	-Restore and increase riparian buffers -Reduce nutrient inputs into Shuswap Lake -Encourage adjacent jurisdictions to do the same
Wildlife	wildlife pathogens	Riparian buffers, chlorination and UV disinfection online	Restore and increase riparian buffers throughout the Shuswap watershed
Algae Blooms	Taste and odor, increased TOC, THMs,	-Emergency monitoring available as needed -Chlorination of Drinking water	-Reduce nutrient inputs into Shuswap Lake -Encourage adjacent jurisdictions to do the same

4.0 Shuswap Lake Intake Module 7: Risk Characterization and Analysis

The intent of Module 7 is to connect the contaminant hazards identified in Modules 1 and 2 with an evaluation of the existing source protection and water treatment barriers. The focus of this report is on the Shuswap Lake water source itself. Module 7 uses the following set of tables to assign risk.

Table 4.1: Module 7 Hazard and Risk Tables

Qualitative Measures of Hazard

Level of Risk	Descriptor	Description	Probability of occurrence within next 10 years
A	Almost certain	Is expected to occur in most circumstances	>90%
B	Likely	Will probably occur in most circumstances	71-90%
C	Possible	Will probably occur at some time	31-70%
D	Unlikely	Could occur at some time	10-30%
E	Rare	May only occur in exceptional circumstances	<10%

Qualitative Measures of Consequence

Level	Descriptor	Description
1	Insignificant	Insignificant impact, no illness, little disruption to normal operation, little or no increase in operating cost
2	Minor	Minor impact for small population, mild illness moderately likely, some manageable operation disruption, small increase in operating costs
3	Moderate	Minor impact for large population, mild to moderate illness probable, significant modifications to normal operation but manageable, operating costs increase, increased monitoring
4	Major	Major impact for small populations, severe illness probable, systems significantly compromised and abnormal operation if at all, high level of monitoring required
5	Catastrophic	Major impact for large population, severe illness probable, complete failure of systems

Qualitative Risk Analysis Matrix

Likelihood	**Consequences**				
	1 Insignificant	**2 Minor**	**3 Moderate**	**4 Major**	**5 Catastrophic**
A almost certain	Moderate	High	Very High	Very High	Very High
B likely	Moderate	High	High	Very High	Very High
C possible	Low	Moderate	High	Very High	Very High
D unlikely	Low	Low	Moderate	High	Very High
E rare	Low	Low	Moderate	High	High

Risk Characterization and Analysis

A potential hazard occurring outside the IPZ was given a lower risk rating than the same hazard occurring within the IPZ where there would be less dilution and less time for the CSRD to react. Table 4.2 summarizes the hazards and assign a risk level based on likelihood and consequence of each hazard. For ease of assessment, the hazards have been grouped by typical source.

Seasonal Variation in Hazard and Risk Analysis

The largest variation in the risk of hazards presented to the Cedar Heights intake is affected by the thermal conditions within Shuswap Lake. The possible contaminant distribution will be very different during the stratified portion of the year (May – October) versus the mixed portion (November – April). Please refer to section 2.2 for more information.

If contaminants are suspended in the surface water under calm weather conditions during the stratified summer season, the intake is protected because the surface water layer is buoyant and does not mix with the deeper cold water at the depth of the intake. However, the intake is relatively shallow and a wind event can tip the water layer (a seiche) and deliver surface water to the intake. As intake depth increases, it becomes progressively better protected from seiches. The Cedar Heights intake is currently at 12 m (elevation 333 m AMSL) and would experience frequent seiches (>20 per summer) of varying intensity during the stratified seasons (Figure 2.2.2). It is therefore vulnerable to a potential contaminant in the surface water layer.

If contaminants are heavier than the density of the surface water layer, they will drop until they reach the depth that matches their density or they settle at a rate determined by their density, particle size, water temperature, etc.

From the late fall to early spring, Shuswap Lake is freely mixing. No thermal barrier protects the intake from buoyant contaminants, but more dilution is available.

Characterization Table: MODULE 7 Part 1:

Table 4.2: Risks with the potential to impact the Cedar Heights intake

Drinking Water Hazard	Likelihood Level	Consequence Level	Risk Level	Inside IPZ?	Comments/ Assumptions
Inflows					
1) Seiche transport during storms	A	2	High	Yes	Intake only 1.5 m above sediments, at risk of seiche impacts
2) Flooding	C	3	High	Yes	Shuswap Lake water level is uncontrolled and fluctuates several meters a year
3) Landslides	C	2	Moderate	No	Landslides appear fairly common within the Shuswap watershed but their impacts at Cedar Heights would be very minor
4) Overland flow	A	1	Moderate	Yes	Overland flow will account for a very small amount of water entering Shuswap Lake at Cedar Heights
Sewage					
5) Septic fields	A	3	Very High	Yes	Identified as problem in SLIPP
6) Yacht and houseboats	B	1	Moderate	Yes	Unlikely event with high potential localized impact but volume of sewage from a single boat would be quite low reducing consequence level
Storm Water					
7) Runoff from Blind Bay Road and shoreline properties	B	1	Moderate	Yes	Volume of water likely to be very small, drains a residential area only
Boating					
8) Waste, garbage spill	B	1	Moderate	Yes	Depending on spill location and type, emergency response may be needed
9) Fuel spill	D	1	Low	Yes	Unlikely event with low impact expected when spill occurs during stratified period
10) Wake erosion	B	1	Moderate	Yes	Deep wakes near the intake can re-suspend sediment and accelerate shoreline erosion, creating plumes that can affect intakes with low clearance above sediments
11) Introduce invasive species	B	5	Very High	Yes	Introduction of dreissenid mussels would be catastrophic to environment and local economy.
Land Use					
12) Beaches	B	2	High	Yes	Disease-carrier swims at beach or beach-goer releases contaminant. Numerous docks also create potential for chemical or petroleum spills
13) Shoreline residential	B	2	High	Yes	Storing hazardous materials near high water line should not occur
14) Marinas	B	2	High	Yes	Spill or release of invasive species at the marina could reach the intake in under 2 hours
Natural					
15) Waterfowl	A	1	Moderate	Yes	These birds can carry pathogens that are difficult to medically treat
16) Cyanobacteria	E	3	Moderate	Yes	Chronic low-dose exposure to cyanotoxins >2000 cells/mL undesirable but unlikely because cyanobacteria are not dominant in Shuswap Lake
17) Wildlife	D	3	Moderate	Yes	Many species can be carriers of *Cryptosporidium* and *Giardia*
18) Algae Blooms	B	3	High	Yes	Algae increase: TOC, THM precursors, taste and odor, chlorine consumption

4.1 Condition of Source

Shuswap Lake provides high quality water throughout most of the year. Water quality deteriorates each spring during freshet and at fall overturn. For example, turbidity averaged <0.5 NTU in Shuswap Lake according to MoE data (1990-2014). Spring algae blooms may also reduce water quality and can produce taste and odor events as occurred in 2008. It is important that steps be taken to preserve and rehabilitate the watershed to protect this important but vulnerable source of drinking water. Riparian restoration projects will be among the most important projects that improve water quality in the Shuswap system. Watershed protection is the first line of defense in a multi-barrier approach to drinking water protection.

4.2 Physical Integrity of Intake, Treatment and Distribution System

Disinfection is currently provided by hypochlorite solution addition and UV to the raw lake water. Regular monitoring is conducted using automated equipment and by trained staff. Like any water system, the distribution system is subject to aging, settling of suspended materials, accidental line breaks and cross-connections. On-going maintenance, repairs and monitoring are vital to any water distribution system. Operation and maintenance are scheduled as needed.

CSRD flushes all parts of the distribution system twice a year and fully cleans storage reservoirs as needed.

4.3 Risk Assessment for Healthy and Health-compromised Individuals

On the whole, water quality from Shuswap Lake is high and meets the needs of healthy individuals most of the time. People with compromised immune systems could profit from another pathogen barrier such as boiling their drinking water. Based on existing monitoring of bacteria, protozoa and THMs, the risk posed by these materials is below the guidelines that usually have a ten-fold safety margin built into them.

4.4 Additional Treatment Options

4.4.1 Intake Extension

Shallow intakes are usually more vulnerable to surface water contamination than deeper intakes. For this reason CSRD should consider extending their intake from 12 to >20 m depth with 3 m of clearance above the sediment. The intake currently sits within the photic zone and could be a growth substrate for periphyton. Extending shallow intakes to 20 m or deeper provides protection from most urban and agricultural impacts.

Extending the intake in Shuswap Lake would be an expensive undertaking and further research on the potential benefits of a deeper intake would be required before action could be taken.

4.5 Strength,/Weakness, Opportunities, Threats Analysis

Table 4.5: Strength, weakness, opportunities and threats analysis of the Cedar Heights intake

Strengths	Weaknesses
▪ New treatment at pumphouse installed in 2010 ▪ Rapid flushing (2 years) of Shuswap Lake means potential contaminants move quickly through the system ▪ Low concentrations of cyanobacteria for most of the year ▪ No creeks or major stormwater outfalls near intake or within proposed IPZ ▪ SCADA system monitors temp and turbidity ▪ Chlorination for disinfection using hypochlorite that is safer than chlorine gas ▪ UV disinfection installed and operational ▪ Water operators have appropriate training levels and training is on-going ▪ Appropriate IHA directed water quality monitoring is reported ▪ Up to 40 years of water quality and limnology records by MoE and others ▪ CSRD has a WQ deviation response plan and an emergency response plan ▪ OCP requires development in riparian areas to perform an environmental assessment	▪ Intake has only 1.5 m of clearance and is only 12 m below the average lake water level ▪ One large marina, multiple private docks, and other shoreline modifications alter sediment transport near intake ▪ Lack of municipal control over activities near or in the proposed IPZ ▪ Shoreline currents can be very quick at Cedar Heights, thus a large area can impact the intake ▪ Recreational and shoreline development pressures are increasing ▪ No back-up water supply available ▪ Shoreline is fully developed; land use within proposed IPZ is mainly urban residential ▪ Shuswap Lake vulnerable to algae blooms that can create taste and odor problems and impair operation of water treatment systems ▪ Shuswap Lake algae population often dominated by diatoms that would impair filtration efficacy ▪ *Cryptosporidium* and *Giardia* not monitored
Opportunities	**Threats**
▪ Pursue Licence of Occupation or other designation over Intake Protection Zone from FLNRO ▪ Encourage shoreline replanting & riparian restoration ▪ Encourage infiltration and rainwater capture for all residences, commercial, and parking lots. ▪ Public Education about Shuswap Lake as a water source (get help from NGO's) and include campaigns targeted at seasonal residents and tourists	▪ All shoreline and urban properties within Cedar Heights are on septic systems ▪ Documented increase in nutrients at Blind Bay caused by septic systems (SLIPP, 2014) ▪ Algae blooms in spring and fall can impair water quality and reduce water treatment efficacy. ▪ Nutrient enrichment and degradation of watershed will encourage algae blooms and reduce water quality ▪ Increasing population pressures for lake recreation, particularly motorized craft ▪ Flooding of tributaries is a major threat and cannot be reliably predicted ▪ Landslides in the watershed appear to be becoming more frequent and more severe ▪ Inadequate enforcement of recreation polluters (houseboats, yachts) foreshore modification violations ▪ Introduction of invasive species would cause irreparable damage to Shuswap Lake and to the regional economy

5.0 Cedar Heights Intake Module 8: Recommendations

The summation of Modules 1, 2 and 7 led to the recommendations to protect source water quality at the Cedar Heights intake presented here as Module 8. All identified high-risk potential impacts to the intake are addressed in these recommendations. The numbered hazards from Table 4.2 addressed by each recommendation are shown in the Risk box attached to each recommendation below.

5.1 Source Protection Action Plan

The only items worth placing into a source protection action plan are those that can be realistically achieved both from financial and practical standpoints. Improvements that provide the best cost-benefit for risk reduction are itemized below. Additional protection measures intended to protect unimpaired areas are also provided. All of these recommendations require the co-operation of applicable governments, residents, recreators and developers. With so many stakeholders involved CSRD has limited ability to protect their source water. Therefore, collaboration is very important.

The following recommendations can be prioritized and applied to a timeline by staff and councils using SMART principles (Specific Measurable Achievable Realistic Time-bound). IHA and CSRD can work out the time line as they progress through the intake protection planning process. It is recommended that a technical stakeholder group be formed to work collaboratively to bring these recommendations forward. Municipal partners could develop terms of reference and invite stakeholders.

5.2 High Priority Recommendations Based on Risk Rating

5.2.1 Establish Intake Protection Zone (IPZ)

Risk	Stakeholders	Outcome Desired
3, 4, 5, 7, 15, 16, 17, 18, 19	CSRD, FLNRO, DFO	Enhanced protection of water source in vicinity of intake to provide 2 hours to respond to contamination entering the lake
Action 1	Seek to have new zone created in CSRD zoning by-law for IPZ (See example zone in Appendix 7)	
Action 2	Apply to Front Counter BC for Licence of Occupation of the proposed IPZ	
Action 3	Erect signage at Shuswap Marina boat launch indicating IPZ offshore	
Action 4	Educate public about changes to acceptable uses within the IPZ and ways they can be involved in protecting their water source	
Action 5	Work with Shuswap Marina to educate staff and boaters on how to operate differently within the IPZ (see 5.2.7)	

5.2.2 Extend intake to >20 m depth at low water level and increase clearance to 3 m above sediment

Risk	Stakeholders	Outcome Desired
3, 4, 5, 7, 15, 16, 17, 18, 19	CSRD	Intakes below 20 m with >3 m clearance from the sediment experience greatly reduced impacts from seiches
Action 1	Conduct study to evaluate the water quality (temperature, turbidity, bacteria, algae, etc.) at potential intake extension sites (*CSRD plans to budget for this in 2016*)	
Action 2	Seek funding from BC and federal governments	

5.2.3 Protect against aquatic invasive species

Risk	Stakeholders	Outcome Desired
12	All users of the lake	Prevent introduction of harmful aquatic invasive species such as, zebra and quagga mussels, into Shuswap Lake
Action 1	Engage in public awareness campaign on dangers of aquatic invasive to environment and economy and cooperate with OBWB and BC Invasive Species Council on existing programs (*in progress*)	
Action 2	Install signage at all boat launches within the district displaying types of invasive species to watch out for and the BMPs to follow to prevent the spread (*in progress*)	
Action 3	Fund summer student program to staff major boat launches during summer busy season and inspect boats prior to launching. Consider approaching other jurisdictions in the Shuswap basin that could be affected to help (*in progress*)	
Action 4	Consider potential of installing chlorine ejection at mouth of intake to protect against mussels. System doesn't need to be installed unless mussels arrive but being prepared can cut response time and reduce potential impacts on water system.	
Action 5	Work with local marinas to educate staff and boaters on dangers of invasive species and how to prevent their spread (*in progress*)	

5.2.4 Reduce stormwater inflow into Shuswap Lake

Risk	Stakeholders	Outcome Desired
1, 2, 4, 5, 7	MoT, CSRD, property owners	Elimination of untreated stormwater entering Shuswap Lake
Action 1	Intercept stormwater with infiltration ditches and ponds	
Action 2	Seek to treat stormwater with retention ponds and wetlands	
Action 3	Educate public about stormwater and how to reduce the amount generated at the house level	
Action 4	Offer rainwater capture barrels to property owners	

5.2.5 Expand CSRD's Septic Smart program to Cedar Heights to monitor efficacy of septic systems

Risk	Stakeholders	Outcome Desired
3, 5, 6, 8, 14, 17, 19	CSRD, IHA	An inventory of existing septic systems within Cedar Heights, particularly lakefront properties, that would enable CSRD to identify deficient systems and push for their upgrade
Action 1	Perform survey of septic systems in Cedar Heights and evaluate their efficacy (*in progress*)	
Action 2	Identify properties with deficient septic systems and work with property owners to improve septic system functionality	
Action 3	Build community sewer system (*Planning underway*)	

5.2.6 Work with local marinas to educate public on how to reduce impact of powerboating on intake

Risk	Stakeholders	Outcome Desired
6, 10, 14	CSRD, local marinas	Boating community would be aware of the intake and be invested in protecting water quality
Action 1	Slow boats down near intake so wakes do not disturb sediment into the intake	
Action 2	Educate public on the IPZ and how to behave within it such as refueling and waste/garbage management best management practices	

5.2.8 Protect and improve shorelines from negative side effects of development

Risk	Stakeholders	Outcome Desired
2, 4, 5, 7, 12, 13	CSRD, property owners	Shorelines throughout Cedar Heights would be naturalized with riparian vegetation that would serve to protect the shoreline from erosion and to reduce the impact of stormwater and runoff on the lake
Action 1	Educate homeowners on the value of riparian vegetation	
Action 2	CSRD should lead by restoring riparian vegetation on its own shoreline properties	

5.3 Moderate Priority Recommendations Based on Risk Rating

The following recommendations address predominately "moderate" risk ratings as identified in Table 4.2 to 4.5.

5.3.1 Implement cosmetic pesticide ban

Risk	Stakeholders	Outcome Desired
3, 5, 14	CSRD	Reduce use of pesticides and their release into Shuswap Lake via stormwater system
Action 1	Create by-law banning use of cosmetic pesticides in CSRD	
Action 2	Follow up by-law with educational campaign featuring environmentally safe alternatives	

5.3.2 Lobby neighboring jurisdictions to protect water

Risk	Stakeholders	Outcome Desired
3, 4, 5, 7, 15, 16, 17, 18, 19	CSRD	Much of the Shuswap Lake watershed is out of CSRD's jurisdiction. Enhanced protections in greater Shuswap Lake watershed would improve water quality at the Cedar Heights intake. The frequency of watershed failures is much more frequent than what would be expected in a pristine watershed. (3 incidents in the past five years)
Action 1	Encourage neighboring jurisdictions within the Shuswap Lake watershed to increase protections that would benefit water quality at Cedar Heights (e.g. riparian buffers, stormwater treatment)	

5.3.3 Information sharing

Risk	Stakeholders	Outcome Desired
3, 4, 5, 7, 12, 15, 16, 19	CSRD, MoE, RDNO, DFO, District of Sicamous, City of Enderby, City of Salmon Arm	Information is critical to efforts to improve water quality throughout the watershed. A central index of a who gathers which data and where that data can be obtained would prevent duplication of efforts and allow the various stakeholders to easily learn from each other's work
Action 1	Share intake data with other water purveyors, and with MoE and utilize the extensive MoE data base for Shuswap Lk water. This information exchange could prevent duplication of effort, and provide faster answers to water quality issues.	

5.3.4 Continue to be involved in what comes next after SLIPP

Risk	Stakeholders	Outcome Desired
6, 7, 13, 14, 15	CSRD	Continued involvement of CSRD in water quality monitoring and research throughout the Shuswap Basin
Action 1	Work with other jurisdictions including MoE, DFO, and RDNO to pursue further research on water quality and the potential impacts to water quality within the Shuswap Basin	

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Appendix 1: Data Collected for Blind Bay Intake Source Assessments

All data used in the formation of this report can be found in:
“Blind Bay Source Assessment Data Transfer File.xlsx”

Appendix 2: Supporting Documentation

Boat launch still closed after heavy rains cause raw sewage overflow into Okanagan Lake

Monday, August 17th, 2009 | 2:10 pm

The Gellatly Bay Boat Launch will remain closed due to water quality concerns after testing revealed a small amount of contaminate entered Okanagan Lake Friday from an overflowing wastewater main. The public is advised not to use the boat launch or enter waters near the launch until the District of West Kelowna advises it is safe to do so.

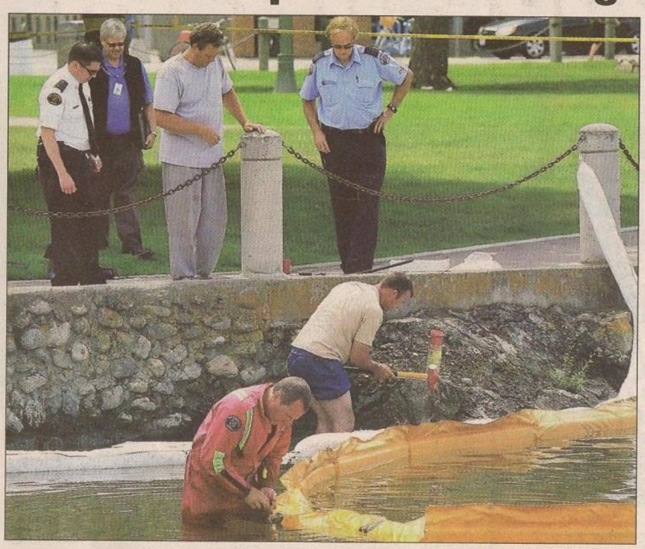
On August 14, heavy rainfall caused a nearby Regional District of Central Okanagan wastewater main to overflow into Okanagan Lake. Regional District staff are working with Interior Health and the Ministry of Environment. Water samples will be taken near the Gellatly Bay Boat Launch and analyzed daily. Water samples have also been taken from waters near the Marina Park Beach and Willow Beach areas and will be analyzed, but given water currents, proximity of the spill and the small amount of contaminate involved, there are no concerns at this time that these waters are affected.

www.kelownacapnews.com Wednesday, June 23, 2010 capital news A3

NEWS

▼ KELOWNA

Authorities quick to control gasoline leak into lake



SEAN CONNOR/CAPITAL NEWS

KELOWNA FIREFIGHTERS work Monday afternoon at Kerry Park to contain a gasoline fuel tank leak into Okanagan Lake.

JENNIFER SMITH
STAFF REPORTER

A gasoline leak from a land-based tank had the City of Kelowna, the fire department and Petro-Canada staff hopping Monday morning as fuel spilled into Okanagan Lake.

It is not known exactly how much gasoline leaked into the water, but city staff say they believe they caught it early and are hoping the damage is minimal.

"We discovered a very small leak, actually in the wall (along the shore)," said Todd Cashin, City of Kelowna's environment division.

To the point where city officials were called in, Cashin said he believes the spill only contained about a water bottle's worth of gasoline, perhaps 200 milliliters; although, all of the details are still under investigation.

The municipality was contacted by concerned citizens who smelled gas in the downtown area at approximately 8 a.m. and city crews were on scene almost immediately.

The Integrated Land Management Bureau, the provincial Ministry of Environment and the federal Ministry of Environment were all contacted as fire crews set up a boom and absorbent pads to contain the spill.

While the exact source of the leak is under investigation, the city could say the spill's source is around a fuel tank used by Kelowna Marina that is buried under Kerry Park. Details on who is responsible for the tank, its maintenance and so forth have yet to be released, though Cashin confirmed the tank itself is a relatively new one.

The site is complicated because it sits on territory once occupied by ferry docks, so the crews working in the area must go slowly to ensure they don't disrupt live infrastructure lines or hit dormant ones once used to service the docks.

A Petro-Can truck was brought in to siphon off the remains of the gas in the tank Monday morning, leaving the tank empty, but crews are still poking around to ascertain whether more fuel leaked into the ground and exactly what caused the leak.

Fire crews used a silly putty-like sealant to damn the leak spilling into the lake upon arrival.

Unfortunately, gasoline, even in small amounts, does diffuse very quickly, meaning a clean up effort will be required.

Kerry Park sits right beside the brand new Stuart Park where the native riparian shoreline is being restored, but the good news Tuesday was that the lake had been entirely protected.

City officials said more information would be forthcoming Wednesday as the exact source of the leak becomes clear.

jsmith@kelownacapnews.com

Fire-Fighting Stormwater Contaminates Mill Creek and City Beach, 2010

Fire's toxic chemical trail leaves questions

Aug 4, 2010

KATHY MICHAELS
CONTRIBUTOR

When fire crews attacked flames overtaking Stewart Centre Saturday night, their focus wasn't on how local waterways would suffer from the toxic mixture of chemicals they unleashed.

Now, as beaches are cordoned off and images of dead fish rising to the top of local streams make the rounds, the environmental impact is front and centre.

"This might be a wake-up call for everyone to step back and look at our procedures and do the things we need to do to protect fish waterways and ensure safe water for wildlife and people," said Patrick Whittingham, vice-president of the Oceola Fish and Games Club.

"That (dead) fish was a canary in the coal mine. We see the fish that have died off, but we don't know enough about the smaller organisms and what impact this will have on them now, and down the road."

Trouble is, as his club co-hort Rick Simpson put it, you're "damned if you do, damned if you don't."

"What were those guys supposed to do, let the whole block burn down?" he said.

According to Jason Brolund, assistant chief of the Kelowna Fire Department, his crews had a good idea about the chemicals they'd be dealing with and their potential hazard, when they headed into the blaze.

"We knew it was going to take water, and that the water would come out contaminated, but the fire department and province at large follows the B.C. emergency response management system," explained.

That set of principles prioritizes the safety of responders first, then the preservation of life, protecting public life, government infrastructure, property, then the environment comes into play.

"The decisions we made that night were tough," he said.

"It was about keeping people safe and fighting the fire—things were flying left, right and centre and we made decisions about protecting exposures on either side… there were 30 to 40 other busineseses that were saved and they could be impacted if we didn't use water to put it out."

With the decision made to deluge flames a call was made to city crews to mitigate the impact of the pesticide, nitrate and glycol mixture that started to trickle into the storm drain system upstream near Lindahl Street, between Springfield Road and Sutherland Avenue.

Their vacuum trucks were on scene, sucking up waste 45 minutes after the first blaze broke.

Unfortunately, they didn't realize they hadn't stopped the flow until the next morning when a resident along Mill Creek noticed the water had changed colour.

Others noticed dead fish on the banks, and as the situation became clear, beaches were closed to swimming.

"In catastrophic situations like that, even the measures the city has in place won't help deal with that volume of water that quickly," said Rick Wagner, environmental emer-

SEE TOXIC A4

SEAN CONNOR/CAPITAL NEWS

VADING UP to his waist in Mill Creek near the entrance to Okanagan lake, an environmental remediation worker nspects and removes debris from the creek after hazardous chemicals from the Stewart Centre fire on Saturday night vere washed into the creek through the city's drainage system from the water used to douse the blaze.

Marina gas bar flames light up sky by Contributed - Story: 68372
Dec 11, 2011 / 1:11 am

Flames were reaching into the sky as the Kelowna Fire department responded to a fire on the docks of the old Kelowna Marina gas bar. Platoon Captain Tim Light says, "Three engines, a rescue vehicle and a command vehicle responded with 15 personnel." According to Light the first engine extinguished the fire with two hand lines and approximately 1000 gallons of water. Fire investigators will be on scene tomorrow to try and determine the cause and origin of the fire. Light says, "At this time the fire is deemed to be suspicious in nature, but the fire department will know more after a thorough investigation in the morning."

Appendix 3: Activities Impacting the Intake Protection Zone Checklist

Municipal

- Minimize shoreline clearing for beaches especially with adjacent grassed areas (attracts geese)
- Re-locate storm water outfalls to discharge outside of intake protection zone
- Encourage developers to capture and use storm water on their properties
- Stop or limit the use of fertilizers, pesticides on municipal spaces

Residential Yard Maintenance, Landscaping & Gardening

• Minimize the disturbance of shoreline areas by maintaining natural vegetation cover.
• Minimize high-maintenance grassed areas.
• Replant lakeside grassed areas with native vegetation.
- Do not import fine fill or sand for beaches.

• Use paving stones instead of pavement.
• Stop or limit the use of fertilizers, pesticides.
• Don't use fertilizers in areas where the potential for water contamination is high, such as sandy soils, steep slopes, or compacted soils.

Agriculture

• Locate confined animal facilities away from water bodies and storm water system.
Divert incoming water and treat outgoing effluent from these facilities.
• Construct adequate manure storage facilities.
• Do not spread manure during wet weather, on frozen ground, in low-lying areas prone to flooding, within 3 m of ditches, 5 m of streams, 30 m of wells, or on land where runoff is likely to occur.
• Install barrier fencing to prevent livestock from grazing on stream banks.
• If livestock cross streams, provide graveled or hardened access points.
• Provide alternate watering systems, such as troughs, dugouts, or nose pumps for livestock.
• Maintain or create a buffer zone of vegetation along a stream bank, river or lakeshore and avoid planting crops right up to the edge of a water body.
• Limit the use of fertilizers and pesticides

Onsite Sewage Systems

• Inspect your system yearly, and have the septic tank pumped every 2 to 5 years
• Use phosphate-free soaps and detergents.
• Avoid septic additives and house-hold cleaning chemicals
• Don't put toxic chemicals (paints, varnishes, thinners,waste oils, photographic solutions, or pesticides) down the drain because they can kill the bacteria at work in your onsite sewage system and can contaminatewaterbodies.
• Conserve water: run the washing machine and dishwasher only when full and use only low-flow
showerheads and toilets.

Auto Maintenance

• Use a drop cloth if you fix problems yourself.
• Recycle used motor oil, antifreeze, and batteries.
• Use phosphate-free biodegradable products to clean your car. Wash your car over gravel or grassy areas, but not over sewage systems.

Boating

• Do not throw trash overboard or use lakes or other water bodies as toilets.
• Use biodegradable, phosphate-free cleaners instead of harmful chemicals.
• Conduct major maintenance chores on land.
• Use four stroke engines, which are less polluting than two stroke engines, whenever possible. Use an electric motor where practical.
• Keep motors well maintained and tuned to prevent fuel and lubricant leaks.
• Use absorbent bilge pads to soak up minor oil and fuel leaks or spills.
• Recycle used lubricating oil and left over paints.
• Check for and remove all aquatic plant fragments from boats and trailers before entering or leaving a lake.
• Do not use metal drums in dock construction. They rust, sink and become unwanted debris. Use polystyrene (completely contained and sealed in UV-treated material) or washed plastic barrel floats.
• When within 150 m of shore adjust your speed accordingly to prevent waves from eroding banks. Adhere to British Columbia’s Universal Shoreline Speed Restriction which limits all power-driven vessels to 10 km/hr within 30 m of shore. Exceptions to this restriction include:• vessels traveling perpendicularly to shore when towing a skier, wakeboard, etc.

-After BC Lake Stewardship Society 2008

Appendix 4: Clean, Drain, Dry – A Recipe for Effective Boat and Equipment Decontamination from Aquatic Invasive Species

Source: Self, J., Larratt, H. 2013. Limiting the Spread of Aquatic Invasive Species into the Okanagan. Prepared for the Okanagan Basin Water Board and the Glenmore-Ellison Improvement District.

This program has attempted to identify a simple, inexpensive decontamination protocol effective against all of the aquatic invasive species currently threatening the Okanagan system. In the event that you discover or suspect mussels on your boat, please do not launch and contact Matthias Herborg (BC Ministry of Environment AIS Coordinator) immediately (250-356-7683). A detailed start-to-finish guide for cleaning boats, equipment, and gear, based on this research project is provided below:

CLEAN

1. **Park the boat away from waterways** or stormwater drainage for vessel inspection and cleaning.
2. **Remove *all* plants and mud from boat**, trailer, and all equipment. Dispose of all material in the trash.
3. **Thoroughly inspect all exposed surfaces on the vessel and trailer**. If any adult mussels are found, scrape them off and kill them by crushing them. Dispose of the remains in a sealed bag the trash. Alert Matthias Herborg (BC MoE) @ 250-356-7683 *immediately*. If you can, please take a picture with your cell phone of the suspected mussels. PLEASE do not launch until your entire boat has been decontaminanted.
4. **Carefully feel the boat's hull for any rough or gritty spots** - these may be young mussels.
5. **Wash the boat**'s hull, trailer, equipment, bilge, and any other exposed surfaces with high-pressure, hot water. Collect all wastewater and dispose of away from waterways and stormwater drainage systems. The hot water (>60°C) should be in contact with all areas of the boat for at least 1 minute to kill mussels (>2 minutes for 45°C water, available at car washes). Flush engine cooling system and bilge system with hot water (>60°C for >1 minute) or salt water (>100 mg/L for >5 minutes) if the engine is marine-certified. *Complex engine systems may require a professional mechanic*.
6. **Clean *all* items that have been in the water** make sure that all items that have been in the water, including anchors, ropes, life jackets, etc., are inspected, cleaned and dried. Soak in >100 mg/L salt water for >1 hour, rinse and dry for 1 week in the sun. Thoroughly clean all fishing and recreational equipment using hot water (>60°C for 1 minute), salt water (>100 mg/L for >1 hour), or pine oil cleaner (50% >5 minutes).

DRAIN

7. **Drain all water from the boat** (pull all plugs), including the motor, motor cooling system, live wells, ballast tanks, bladders, bilges, and lower outboard units. Rinse as outlined above.

DRY

8. **Empty and dry all** buckets and dispose of all bait in trash receptacles. Please do not take bait home, leave it on the ground or dump it in any waterway.
9. **Dry outdoors** - Dry boats and gear outside or in dry, well-ventilated area for at least a week (more in mild, wet weather, about 18 days) Watch absorbent surfaces – if they stay damp they can keep AIS alive.

10. **Clean and dry** personal belongings, clothing, and footwear that have come in contact with the water.
11. **Wash, dry and brush pets** that have been in the water.

Precautions during decontamination:
1. Waste wash water should always be collected, treated, and disposed of properly and NOT be allowed to enter waterways or storm water drainage systems.
2. Please observe all manufacturers precautions found on the labels of cleaning products and equipment.
3. Water above 45°C can scald and appropriate precautions should be observed.

Table 3.4: Examples of Appropriate Decontamination Solutions for the Highest Probability

Gear	Best Decontamination Solution
Big Boats / yachts	Flush bilge, ballast, water systems with 5% bleach solution then rinse with clean water (consult with manufacturer) Power wash entire hull with 45-60 °C water for 5 minutes
Small power boats	Wash boat down inside and out with 50% pine-oil or 5% TSP cleaner and rinse and dry outdoors; drench carpeted trailer runners with cleaner and make sure they dry
Non-motorized boats	Wash boat down inside and out with 50% pine-oil or 5% TSP cleaner and rinse and dry outdoors
Felt Soled Waders	Soak boots in 1% salt solution for at least 60 minutes, rinse and dry in the sun for one week

Invasive mussels can permanently wreck a boat's engine and steering systems. Done properly, CLEANING, DRAINING and DRYING boats and gear will improve their longevity and performance. Choose the cleaning solution best suited to the material, and consult the manufacturer when in doubt.

Appendix 5: Methods of Invasive Mussel Control for Water Supplies

Source: Self, J., Larratt, H. 2013. Limiting the Spread of Aquatic Invasive Species into the Okanagan. Prepared for the Okanagan Basin Water Board and the Glenmore-Ellison Improvement District.

Physical Control

Drawdown and exposure: If the infestation is within an impoundment with water level control capability, drawdown may be a viable control technique. Removing all water from a lake or pond and allowing it to dry completely for a week in summer may eliminate the zebra mussel infestation; however, this technique involves many technical and biological issues. A drawdown of a reservoir or pond could result in the eradication of many desirable plant and fish species. An effort could be made to capture and relocate desirable species, but this would likely be an expensive and lengthy undertaking. The water pumped out of the impoundment would have to be filtered or otherwise treated to ensure no small eggs or larvae escaped to other water bodies. Alternatively, it may be possible to hold the water in a separate basin or to dispose of the water in a way that limits risk of zebra mussel transfer (e.g., ground water infiltration). However, drawdown and exposure will not be a viable option in most cases.

Physical removal Physical removal of the mussels using manual or mechanical scrapers and/or high pressure water jets can be used on a small, localized scale with success, but are not likely to be successful against large infestations. Physical removal causes minimal impact on native species, however it is unlikely to provide 100% eradication of all Dreissena life stages.

Suffocation Dreissena mussels need oxygen to survive. If the oxygen level drops below the lethal limit of mussels, they will die off. Lakes with anaerobic zones will not allow the mussels to infest the deeper water. Deliberately inducing anaerobic conditions is a technique that is usually confined to industrial applications.

Thermal treatment Hot water can kill zebra mussels, although many other aquatic organisms can also be harmed as well. Industrial and public utilities are experimenting with thermal controls for zebra mussels, and on a localized basis this approach may have merit. Generally, though, thermal treatments are best used to decontaminate boats.

Hot water can be used to keep intakes clear and is also becoming the treatment of choice for decontaminating boats. Hot water has a relatively low environmental impact in short duration treatment periods. It can be mitigated by rapid mixing with ambient water with an outfall diffuser. Hot water sprays at ≥60°C for 1 minute or 80°C for ≥5 seconds were 100% lethal to adult zebra mussels (Morse, 2009). Thus, presently recommended spray temperatures of 60ºC may not be 100% effective unless the spray is applied for more than 10 seconds (Morse, 2009). In other work, adult quagga mussels were exposed to hot-water sprays at 20, 40, 50, 54, 60, 70, and 80°C for 1, 2, 5, 10, 20, 40, 80, and 160 seconds. In yet another recent work, Beyer et al., (2011) tested the acute upper thermal limits three aquatic invasive species; adult zebra mussels, quagga mussels, and spiny water fleas (Bythotrephes longimanus), employing temperatures from 32 to 54°C and immersion times from 1 to 20 minutes. Immersion at 43°C for at least 5 minutes was required to ensure 100% mortality for all three species, but due to variability in the response by Bythotrephes, a 10 minute immersion was recommended. Overall there were no significant differences between the three species in acute upper thermal limits. Heated water can be an efficient, environmentally sound, and cost effective method of controlling aquatic invasive species potentially transferred by boats (Beyer et al., 2011).

Electricity Control of zebra mussel veligers in a river might be possible using an electric dispersal barrier. Plans are under way to eventually develop a barrier that will also be effective against various planktonic organisms such as zebra mussel veligers. If proven effective in the Illinois River, similar control tactics could feasibly be applied other rivers (Stoeckel et al., 2004; Hovarth et al., 1996).

Biological Control
Biological controls that are currently researched include selectively toxic microbes and parasites that may play a role in management of Dreissena populations (Molloy 1998). For example, Pseudomonas fluorescens, a common soil bacteria, is harmless to humans but toxic to zebra mussels. Other prospective biological approaches to controlling Dreissena populations may be to disrupt the reproductive process, by interfering with the synchronization of spawning by males and females in their release of gametes (Snyder et al. 1997). Another approach would be to inhibit the planktonic veliger from settling, since this is the most vulnerable stage in the life cycle (Kennedy. 2002). Biological control so far has not been effective in controlling *Dreissena* species.

Alternatively, augmenting or introducing natural predators may be considered, but is not likely to result in the eradication of the infestation. The change in ecosystem dynamics due to introductions of new organisms or the augmentation of present organisms may be detrimental to the overall health of the ecosystem in some cases, so extreme care must be taken with this approach. Predation by migrating diving ducks, fish species, and crayfish may reduce mussel abundance, though the effects can be short-lived (Bially and MacIsaac, 2000). An exception may be certain fish species, like freshwater drum, which prey upon zebra mussels effectively. As with most biological predator-prey interactions, cycles of abundance are typically set up and eradication is unlikely, but some measure of control can be achieved.

Chemical Control
There are no known chemical controls suitable for use against invasive mussels in an open environment. If the target area is small and water exchange can be controlled, it may be possible to apply some of the harsher chemicals with limited impacts to non-target populations in the lake, but great care must be taken and this approach has generally not been applied. The US Army Corps of Engineers has published a "Zebra Mussel Chemical Control Guide" that can be accessed at: http://el.erdc.usace.army.mil/zebra/pdf/trel00-1.pdf

Adult mussels can be especially challenging to control chemically since they may sense some chemicals in the water and close their shells for weeks, thus limiting their exposure. A summary of the most commonly used chemicals follows:

Copper Effective control of Zebra mussel larvae can be obtained within one day of exposure to a copper-containing algaecide at concentrations much lower than allowable dosage for treatment of algal blooms. The study found that an early life stage called the trochophore can be killed in the laboratory after just a few hours using copper exposures of 0.02 mg/L copper ion while killing adults with the algaecide was not possible after 24 hours exposure at 5 mg/L. Even after 96 hours of continuous exposure, it took almost 2 mg/L to kill most of the adults and that copper dose would likely have unintended ecological impacts. Such a strategy would need to be coordinated with spawning events and repeated seasonally for several years (the approximate life expectancy of adult mussels) to achieve effective control zebra mussel populations (Kennedy, 2002).

Chlorine: Pre-chlorination has been the most common treatment for control, but if this method is used to control both zebra and quagga mussels the amount of chlorine used may reach hazardous levels (Grime, 1995). Chlorine kills adult zebra mussels through asphyxiation and limited glycolysis over a prolonged period of exposure. Primary concerns with chlorine are its toxicity to non-target organisms and the production of carcinogenic trihalomethanes from dissolved organic materials.

Research has shown that mussels shut their valves as soon as the detect chlorine and open only after chlorine dosing is stopped. Under continuous chlorination mussels are constrained to keep the shell valves shut and they starve. Zebra mussels subjected to continuous chlorination at 1-3 mg/L showed 100% mortality after 25 days, while those subjected to intermittent chlorination at 1 mg/L showed very little or no mortality during the same periods (Rajagopal et al., 2003).

Mussel mortality also varies with water temperature. Mussels exposed to 0.25 mg/L chlorine residual took 45 days to reach 100% mortality whereas those exposed to 3 mg/L chlorine took 10.5 days. The effect of water temperature on D. polymorpha mortality in the presence of chlorine was significant. For example, it took 43 days to reach 95% mortality using 0.5 mg/L residual chlorine at 10ºC, compared to only 19 days at the same 0.50 mg/L chlorine dose but at a warmer 25ºC (Rajagopal et al., 2002).

Potassium: Potassium chlorate ($KClO_3$) or Potassium chloride (KCl) can be used to selectively kill invasive mussels, since toxicity data indicates that the target concentration is not lethal to non-target organisms other than freshwater mollusks (e.g., the threshold effect concentration for potassium is 272.6 ppm for Ceriodaphnia and 426.7 ppm for fathead minnows) (Aquatic Sciences, 1997). Elevated potassium levels in the range of 10-15 ppm have been reported as lethal to other freshwater mussel species over a few-week period. For example 1 to 4 applications of a 12% liquid potassium stock solution mixed from potassium chloride were proposed to kill a zebra mussel infestation in a flooded quarry. The proposed treatment would require 128,000 kg of active ingredient to treat 200,000,000 gallons of water (131,000 kg of dry muriate of potash) (USFWS, 2005). The magnitude of this application highlights the challenge of treating an infested water body.

Other potential methods of chemical control include: radiation, filtration, removable substrates, ozone, antifouling coatings, etc. A straining and ultraviolet (UV) light system was installed at Hoover Dam. The strainer removes large mussels followed by treatment with UV light to kill or disable veligers from settling (Willett, 2011).

Examples of Zebra and Quagga Mussel Infested Habitats


Appendix 6: Marina Environmental Best Management Practices

Summary Excerpt from the US EPA document “Best Management Practices for Marina Facilities – February 2012”

All major repairs (e.g., stripping, fiberglassing) must be performed in the Vessel Maintenance Area
-All blasting and spray painting must be performed within the enclosed booth or under tarps
-Keep all bottom paint chips and run off from entering surface waters.
Use tarps, filter fabrics or closed loop pressure wash treatment systems
for bottom paint removal operations.
- Use vacuum sander
- Use high-volume low-pressure spray paint guns
- Use drip pans with all liquids
- Reuse solvents
- Store waste solvents, rags, and paints in covered containers

Keep Fuel Out of the Water
-Do Not Top Off Tank
-Listen and Anticipate When Tank is Full
-Wipe up Spills Immediately

Do Not Discharge Sewage
-Please use our clean, comfortable restrooms while you are in port
-Nutrients and pathogens in sewage impair water quality

Think Before You Throw
The following items may not be placed in this dumpster:
- Oil
- Antifreeze
- Paint or varnish
- Solvents
- Pesticides
- Lead batteries
- Transmission fluid
- Distress flares
- Loose polystyrene peanuts
- Hazardous waste

Marine Sanctuary - This marina provides food and shelter for young fish
- Prevent oil spills!
- Keep bilge clean!
- Use oil absorption pads!
-Help by recycling or properly disposing of used oil, antifreeze, solvents, cleaners, plastics, and other wastes.

No Fish Scraps
Please do not discard fish scraps within the marina basin
-Use designated fish cleaning stations
-Bag the scraps and dispose of in dumpster or at home

Appendix 7: Example IPZ Zoning By Law

Example Intake Protection Zone for Zoning By-Law

Based upon CSRD's zoning by-law "Lakes Zoning By-Law 900"

1.1 IPZ - Intake Protection Zone

IPZ

.1 Permitted Uses:

a) Water utility intake pipe

b) Park

c) Floating dock or floating swimming platform including removable walkway for use by pedestrians, swimmers, anglers, paddleboarders, etc. Boat moorage not permitted within IPZ.

.2 Regulations

Column 1 **Matter Regulated**	Column 2 **Regulation**
(a) Density Maximum number of docks	• 1 dock per adjacent waterfront parcel
(b) Size of floating dock or floating platform	• Floating dock or floating platform must not exceed 24 m² in total upward facing surface area • Floating dock or floating platform must not exceed 3 m in width in any portion of the structure • Removable walkway surface must not exceed 1.5 m in width at any point
(c) Location and Siting of dock or floating platform	• Floating dock or floating platform can be located within the IPZ zone if the entirety of the adjacent parcel's shoreline is within the IPZ zone.

___________end of report_____________