Source Assessment of the Kaleden Irrigation District Skaha Lake Drinking Water Intake

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Larratt Aquatic Consulting Ltd. 3025 Ensign Lane, West Kelowna, B.C. V4T 2Z4

Phone: 250.769.5444 Fax: 250.769.3233 Email: heather@larratt.net

Executive Summary

The objective of this source assessment of the Kaleden Irrigation District's Skaha Lake 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.

Skaha Lake is a mainstem lake on the Okanagan system. The entire lake volume is theoretically replaced every 1.2 years, making this a rapidily flushing lake that responds quickly to changes input water quality.

This assessment characterizes natural and man-induced hazards to drinking water quality as physical, chemical or biological. These risks may change over time as development around Skaha Lake changes. Existing research was augmented by 2014-2015 field studies of water currents, water quality profiles, and algae sampling in Skaha 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.

Skaha Lake water quality is defined by the quality of its watershed. City of Penticton is a major influence, as is water quality in Okanagan Lake. The largest potential impacts identified in this study include: WWTP discharge to Okanagan River (Penticton Channel), stormwater, agricultural watershed influences, residential shoreline development, and power boating. Skaha Lake provides high quality water for most of the year but cyanobacteria blooms following the fall overturn are a concern that corresponds to nutrient inputs.

Specific recommendations and action plans were developed with the aim of providing the best water quality at the KID intake. Key recommendations include: applying best management practices for shoreline protection, reducing nutrient inputs into Skaha Lake, establish a cyanobacteria decision tree, and treat stormwater before releasing into the Skaha Lake watershed.

Skaha Lake watershed and the larger Okanagan system have many stakeholders and engaging the public on how to protect water quality through education, and regulation is essential for any effort to gain traction.

Acknowledgements:

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Suggested Reference

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

Disclaimer: This report is based on limited, cost-constrained research on complex aquatic systems. Larratt Aquatic Consulting Ltd. (LAC) and its associates have striven for accuracy in data collection and presentation. No liability is incurred by LAC or KID for accidental omissions or errors made in the preparation of this report. This report was prepared by LAC for the sole use of KID. Any use by a third party requires the permission of KID.

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1.0 Introduction

1.1 Study Background

Interior Health (IHA) required the Kaleden Irrigation District to perform an assessment of the source of their water and their water systems, 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).

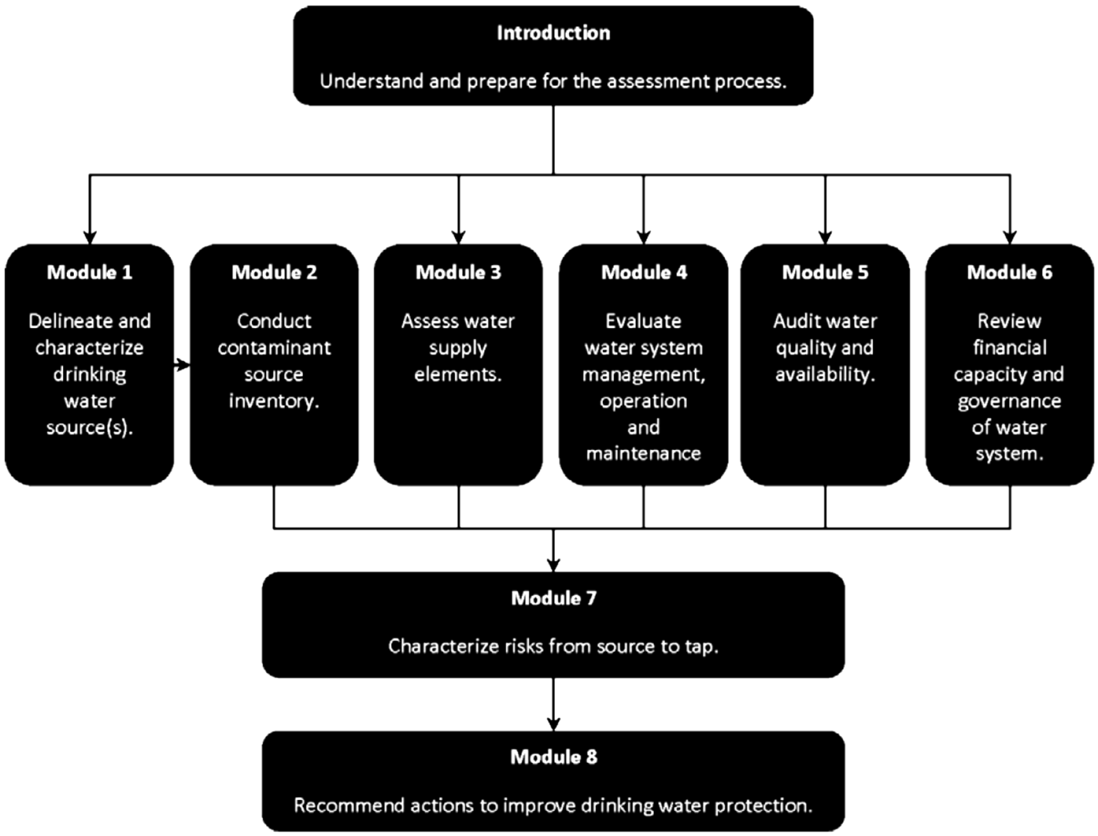


Figure 1: IHA source assessment framework (Ministry of Healthy Living and Sport, 2010)

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 Kaleden Irrigation District drinking water supply and source, potential risks/threats, and to provide recommendations to maintain and protect this water source. We have compiled all available research to date from sources including: KID, BC MoE, Canadian Water Office, RDOS, and City of Penticton.

Kaleden Irrigation District chose not to pursue filtration deferral based on the cost of 2,140,000 for UV disinfection (TRUE est 2012). Conversion to groundwater with twinning the irrigation with filtration and metering was 6.4 million, also cost-prohibitive. Thus filtration deferral or exclusion from IHA was not pursued at this time (pers comm, IHA).

1.3 Study Plan

Existing research on Skaha Lake and the greater Okanagan area were reviewed and a new research program, performed by Larratt Aquatic Consulting (LAC), was set up. The 2014-2015 sampling program included:

- Vertical profiles of Skaha Lake were performed regularly during the growing season using a multi-meter probe that measured: temperature, dissolved oxygen (DO), pH, conductivity, total dissolved solids (TDS), and several other parameters
- Temperature and light loggers were deployed in Skaha Lake near the intake from April 2014-October 2015 to monitor thermal stratification and light penetration in the water column
- Sediment traps were deployed for one year (April 2014-April 2015) to measure the rate of sediment accumulation at the intake
- Sediment bacteria samples under the intake were collected to measure potential bacteria impact from sediment disturbance at the intake
- Water currents around the intake were mapped using GPS and drogues
- Algae samples were taken in profiles in the lake on field trips and were collected monthly by KID staff from the intake
- Water temperature and conductivity were measured in the Okanagan River (Penticton Canal) with a field meter

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
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
Grey water	All waste water that does not contain sewage (e.g. cleaning water waste)
Inflow plume	A creek inflow 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	Restoration to productivity and usefulness
Redox	The reduction (-ve) or oxidation (+ve) potential of a solution
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 (> 1ºC/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
IHA = Interior Health Authority
CoP = City of Penticton
KID = Kaleden Irrigation District
LAC = Larratt Aquatic Consulting;
FLNRO = Ministry of Forests, Lands, and Natural Resources Operations
FOTO = Friends of the Oxbows
MoE = Ministry of Environment (BC MoE)
MoT = Ministry of Transportation and Infrastructure
OBWB = Okanagan Basin Water Board
PIB = Penticton Indian Band
RDOS = Regional District of Okanagan-Similkameen

Technical Phrases, Regulations
AMSL = Above mean sea level
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)
HWL = High water level
IPZ = Intake Protection Zone
LWL = Low water level
SCADA = Supervisory Control And Data Acquisition (system)
SHIM = Sensitive Habitat Inventory Mapping
WTP = Water Treatment Plant
WWTP = Wastewater 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 analyses were performed to a confidence of 95% (p=0.05). The ± symbol is used to represent the standard deviation throughout this report.

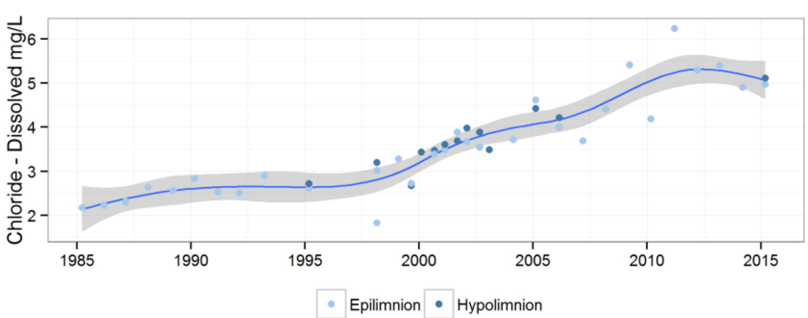
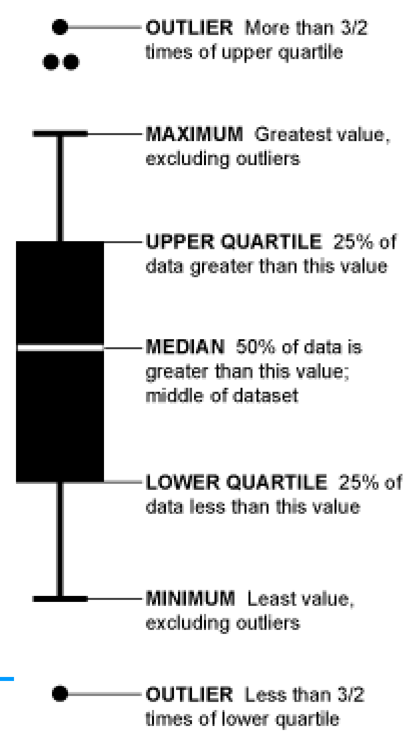


Figure i: Example scatterplot (above) includes all data for a parameter sorted by depth, polynomial trendlines and the standard errors of those trendlines are also included as a shaded area around the trendline.

Example boxplot (right) is labeled with key information.



2.0 Skaha Lake Intake Module 1: Characterization of Source

This section provides an overview of the Kaleden Irrigation District (KID) intake. It also summarizes the available data on Skaha Lake in terms of its limnology, water chemistry and biology

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

2.1.1 Water Licenses

The KID water licence allows for 2,466,960 m³ (2000 acre feet) of water from Skaha Lake to be used annually. There are two other large water systems drawing from the lake Skaha Estates and Lakeshore Heights. Additionally, there are two other small water systems with Skaha intakes and multiple other water licenses with intakes along Eastside Road.

2.1.2 Intake Location and Depth

The KID drinking water intake is located approximately 200 m from shore in the southern end of Skaha Lake (49.388269°N, 119.580515°W; Figure 2.1). The intake screens are at a depth of 22 m (313.4 m AMSL; TRUE, 2006), and have 2 m of clearance from the substrate.

Figure 2.1.1: Overview map of Skaha Lake and the KID intake

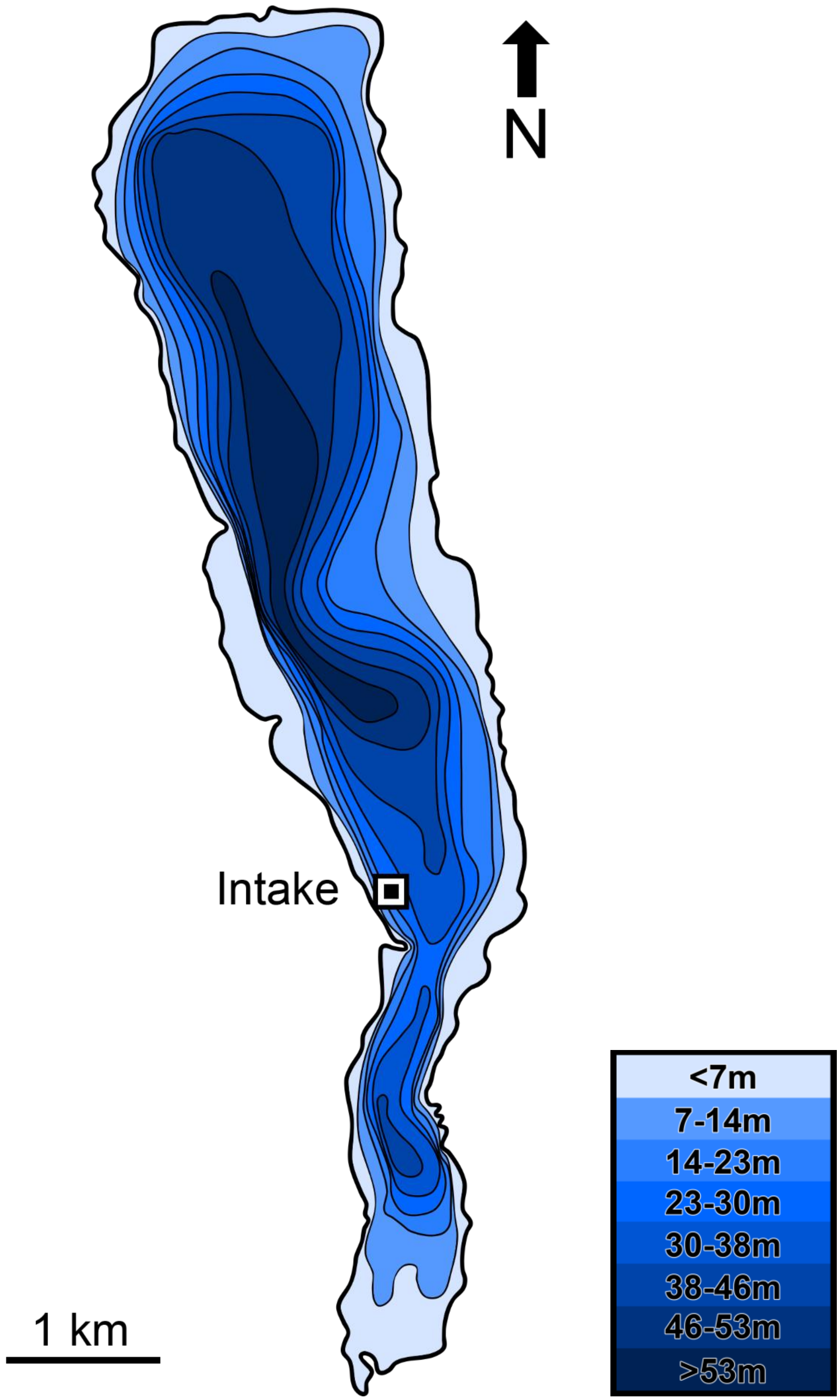


Figure 2.1.2: Bathymetric map of Skaha Lake
Based on Dept. Recreation and Conservation, 1966

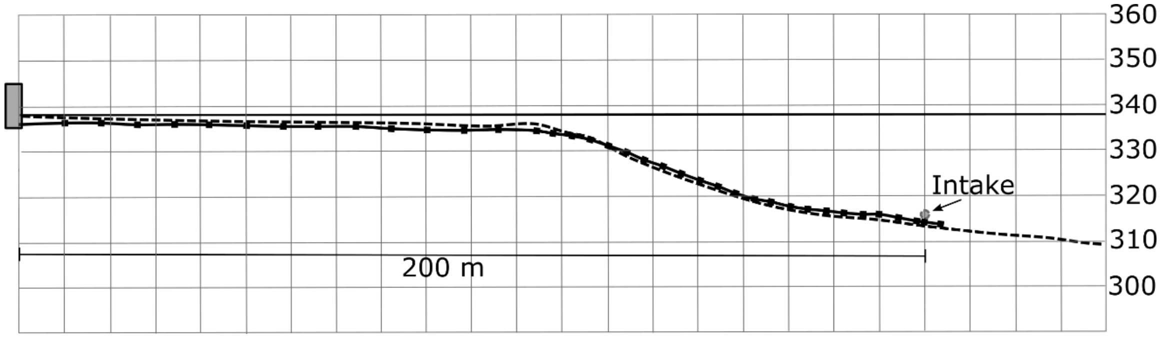


Figure 2.1.3: Schematic of KID intake
(TRUE Consulting, 2006)

Table 2.1.1 Summary of KID intake parameters

Parameter	KID Skaha Lake Intake
Depth (m) at average lake elevation	22
Clearance from substrate (as built) (m)	2
Length (m) to wet well	240
Diameter (mm)	711.2
Pipe material	HDPE
Year of intake installation	2007
Age of distribution system (years)	50
Balancing reservoirs in system #	2
Sediment accum. in wet well (cm/year)	<1 cm
Intake last cleaned	2015

2.1.3 Water Treatment, Distribution and Monitoring Overview

KID uses a hypochlorite solution chlorination system at the site of the pumphouse. A PVC pipe conveys chlorine to the mouth of the intake pipe to achieve the needed contact time for disinfection. The disinfected water is then pumped out into the distribution system.

2.1.4 Routine Monitoring and Emergency Planning

Kaleden Irrigation District staff monitor and turbidity and chlorine residual using automated analyzers at the pumphouse. Staff routine water chemistry analysis also assesses dissolved ions semi-annually. Other data such as nutrient concentrations are available from BC MoE, Penticton. A new sampling schedule would be created alongside the development of any new water treatment plant.

2.2 Limnology of Skaha Lake as it affects the intake

Skaha Lake is the fourth lake in a chain of five major lakes in the Okanagan Valley. It has controlled inflows and outflows that maintain a narrow range of 61 cm between high and low water levels (HWL = 338.02 m LWL = 337.41 m). Skaha Lake is comprised of two distinct basins separated by a bedrock sill at a depth of 24 m (Figure 2.1.1). The surrounding watershed has "benches" (glacial terraces) along the east and west shores which rise to mountainous slopes with the flat valley bottom at the north and south ends. Skaha Lake is separated from Okanagan Lake to the north by a narrow stretch of valley bottom on which the City of Penticton has developed (ILEC, N.D.).

Table 2.2.1: Skaha Lake details

Parameter	Value
Surface Area	20 km²
Volume	0.558 km³
Maximum Depth	55 m
Mean Depth	26 m
Water Level Range	0.6 m
Shoreline	29.5 km
Residence time	1.2 years

Little limnological information was collected prior to 1969 when the Okanagan Basin Study was undertaken. Initiative for this comprehensive program came about primarily through complaints of deteriorating water quality in Skaha Lake as a result of sewage effluent discharged from the City of Penticton triggering cyanobacteria blooms. Tertiary treatment (nutrient removal) was added to the treatment process in 1971. Water quality in Skaha Lake subsequently improved (Schleppe et al, 2008). Today the discharge from the wastewater treatment plant (WWTP) passes through a diffuser and into the Okanagan River – a channel that delivers surface water from Okanagan Lake to Skaha Lake. The ratio of Penticton channel to WWTP effluent exceeds 10:1 (Stantec, 2007). Should this ratio drop below 10:1, for example, with the completion of the PIB 600-unit plan (under construction in 2015-onward), then the WWTP outfall would have to be relocated to an outfall in Skaha Lake. The water is very warm and would mix into the surface water layer of Skaha Lake in the summer months and it is expected to distribute throughout the lake in the unstratified fall and winter months.

The length of shoreline on Skaha Lake is 29.5 km and a significant proportion is modified. Foreshore Inventory Mapping (FIM) is a detailed inventory process used to estimate the relative proportions of disturbed and intact riparian (shoreline) habitat. Completed in 2008, the FIM analysis showed that the shoreline of Skaha Lake at Kaleden is heavily modified. Bluffs to the north and south of Kaleden were identified as high risk for slope instability (Schleppe et al, 2008). Riparian areas act as a nutrient "filter" and also improve wildlife/fishery habitat.

2.2.1 Thermal Behavior

Skaha 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. In Skaha Lake, the normal range for the summer thermocline is 5- 12 m deep. The difference in density of warm water and cold water restricts interaction between these layers throughout the stratified summer period. As the epilimnion cools in the fall, the temperature equalizes and a wind event can cause the lake to overturn. Skaha Lake mixes from the surface to the bottom each fall in late October or early November. Skaha Lake experiences limited ice cover during the winter and cold winter weather in January to February induces inverse thermal stratification. Skaha Lake, unlike like most large lakes in the Okanagan, is therefore dimictic ("twice mixing") (NHC, 2013). The last complete ice cover was in the winter of 2013/2014, but total ice-cover has not occurred regularly since the 1970's.

The results from a 2009 thermistor chain deployment in deep central basin of Skaha Lake are shown in Figure 2.2.1. This data shows typical seiche activity as the thermal layering established in early summer and again as the layering cools and loses stability during the fall overturn. Seiches transport surface water deep into the lake during the stratified period. Temperature data obtained during the study period indicates that seiches routinely reach 27 m (depth of intake) in Skaha Lake during the fall and winter.

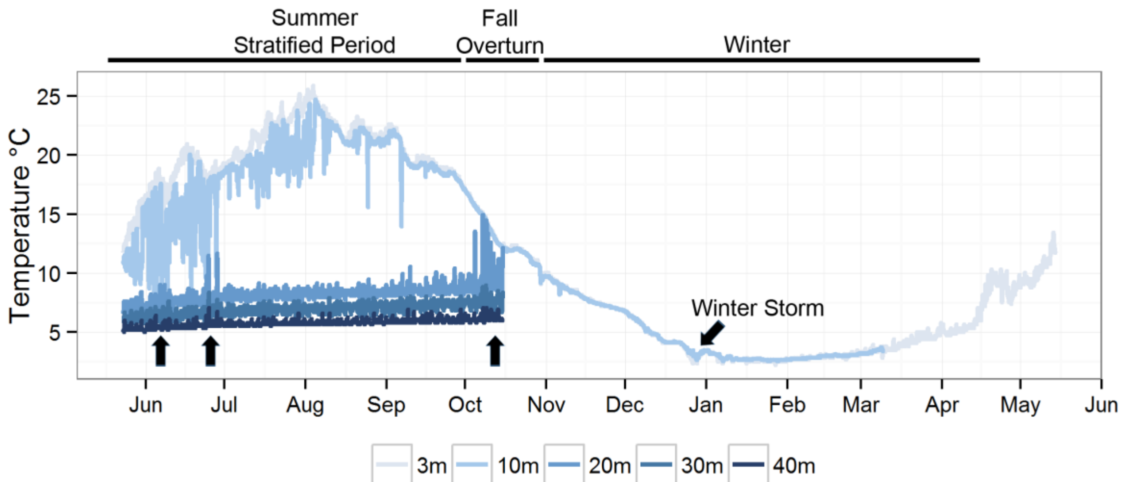


Figure 2.2.1: Thermistor data for Skaha Lake from deep central basin with major seiches marked by arrows, deep area, 2009-2010

Based on this data, a 22 m deep intake will experience occasional seiches in June and October, but should be largely exempt from them in the summer months. In contrast, shallower intakes such as the old KID intake or the 9 m deep Lakeshore Highlands intake probably experience seiches regularly. The seiches would cause increased water temperature and turbidity for a period of 3-5 hours that repeats several times over a few days with decreasing intensity. Shallow intakes will also exceed the 15ºC maximum water temperature guideline for much of the summer whereas the 22 m KID intake will not.

Over the May to October season, the number of seiches and their intensity decreases with depth according to the following table:

Table 2.2.2: Number of seiches at various depths in deep area of Skaha Lake, 2009-2010

Depth of intake	Number of seiches	Temperature change
10 m	33	10 °C
20 m	10	4.5 °C
30 m	4	2 °C
40 m	4	1 °C

Table 2.2.3: Number of seiches per month at various depths at Kaleden intake, 2014-2015

	Avg Number of Seiches		
	15 m	20 m	25 m
Jan	0	0	0
Feb	0	0	0
Mar	0	0	0
Apr	0	0	0
May	10	7	0
Jun	7	3	0
Jul	6	3	0
Aug	12	3	1
Sep	15	11	2
Oct	9	9	2
Nov	0	0	0
Dec	0	0	0

These tables can be used to determine the value of extending the existing KID intake deeper into Skaha Lake. Thermally, 30 and 40 m were very similar. Limited mixing of the deep water with the overlying warmer gradually warmed the 40 m depth by a degree to 6 °C over the summer. Similar results were obtained from a recent thermister deployment in 2014 – 2015 (Figure 2.2.2)

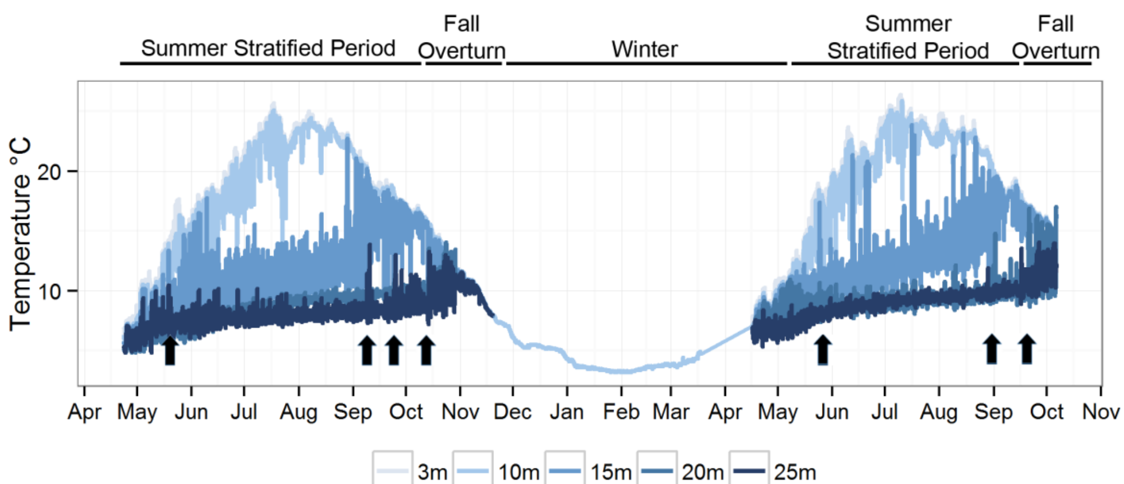


Figure 2.2.2: Temperature profile of Skaha Lake near intake from Apr 2014 – Apr 2015. Data illustrates key thermal phenomena in Skaha Lake including: stratification, seiches, and mixing.

2.2.2 Watershed Influences

The major tributary to Skaha Lake is the Okanagan River (Penticton Channel) that delivers managed surface flows from Okanagan Lake (Figure 2.2.3). The Okanagan River averaged 97% of the water entering Skaha Lake during the twelve months from April 2014 to 2015 (Water Office, 2015). The channel also receives inflow from the Penticton WWTP, and from several creeks (e.g. Shingle Creek) and stormwater discharges (Figures 2.2.3 and 2.2.4). Other tributaries include Skaha Creek, Felis Creek, Marron River, McLean Creek, Matheson Creek, and Gillies Creek (Schleppe et al, 2008). These creeks represent only a small fraction (<3%) of Skaha Lake's water budget.

These watershed influences are covered in more detail in Section 3.1.2.

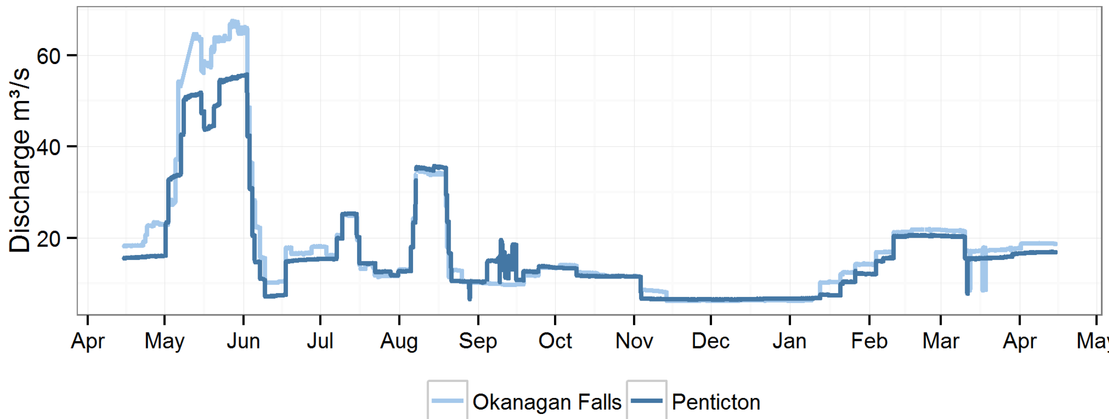


Figure 2.2.3: Discharge of Okanagan River at Penticton, 2014-2015 (Water Office, 2015)

Figure 2.2.4: Major tributaries into Skaha Lake

2.2.3 Temperature, Dissolved Oxygen, pH and TDS Profiles

Skaha Lake was sampled eight times for this Source Assessment. Surface temperatures ranged from 4.8 °C on March 18 2015 to 22.9 °C on July 2 2014. The lake was stratified until mid-November in 2014 and re-stratified by May 2015.

During the winter stratified period, the lake exhibited an inverse temperature gradient. This is because water density decreases as temperature increases above 4 °C but also decreases with temperature below 4°C. The coldest temperatures were therefore found at the surface in the winter with warmer water deeper in the water column.

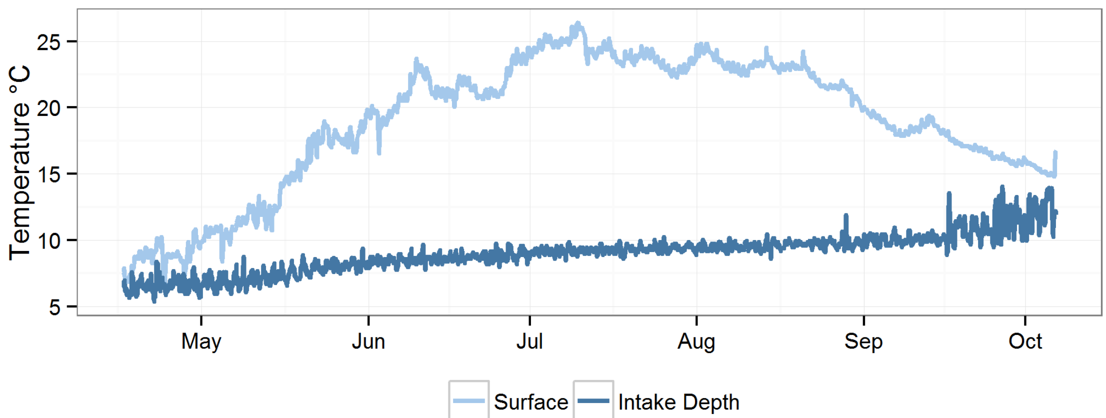


Figure 2.2.5: Temperature of Skaha Lake surface water compared to intake depth* from April to October 2015

*Data based on thermistors in lake at approximate depth of intake

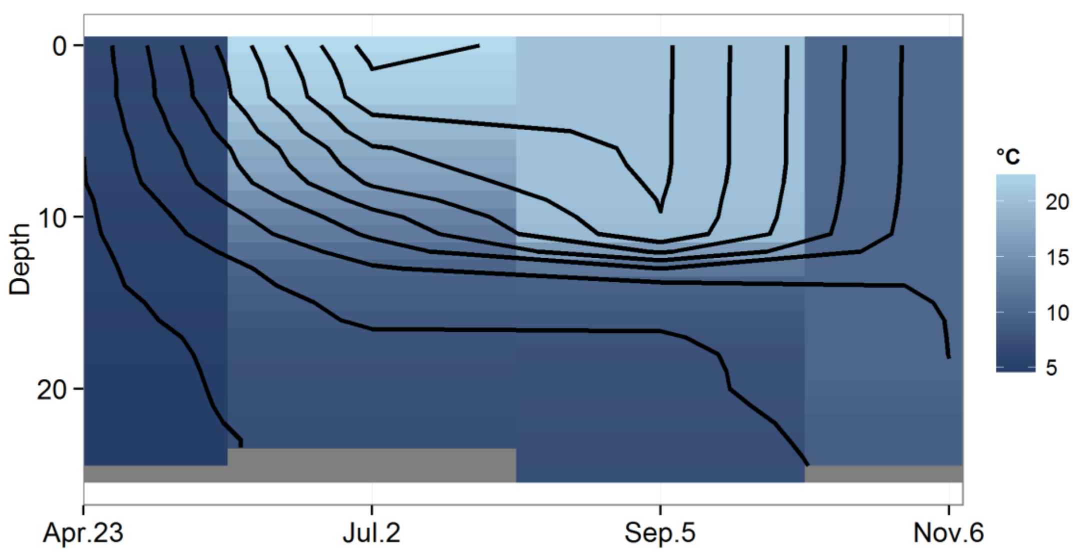


Figure 2.2.6: Temperature profile of Skaha Lake for 2014

Notes: -black lines indicate areas of same temperature (isobars)
-grey area indicates lake bottom

Surface dissolved oxygen (DO) concentrations were high in Skaha Lake throughout the year. DO peaked at the surface during the spring algae bloom at 11.9 mg/L (>100%

saturation) through photosynthesis (Figure 2.2.7). DO remained high in the epilimnion throughout the sample period. Oxygen depletion occurred in the hypolimnion during most years (MoE, and LAC data). This oxygen depletion is the result of oxygen demand exerted by the sediments as algae and other organics decompose, and by BOD in the water itself that cannot be met by gas exchange with the atmosphere. DO saturation decreased to only 68% below the thermocline on September 5 2014. Decomposition of organics carried into the lake by sources including Penticton WWTP and by algae/bacteria trapped on the density change at the thermocline led to a pronounced drop in dissolved oxygen at that depth by September during 2014 (Figure 2.2.7). Hypolimnetic oxygen depletion is common in productive lakes because the decomposition of dead algae at the bottom of the lake consumes oxygen. Skaha Lake is currently moderately productive (meso-oligotrophic), but it has been meso-eutrophic in the 1970's prior to the extensive upgrades at the Penticton WWTP.

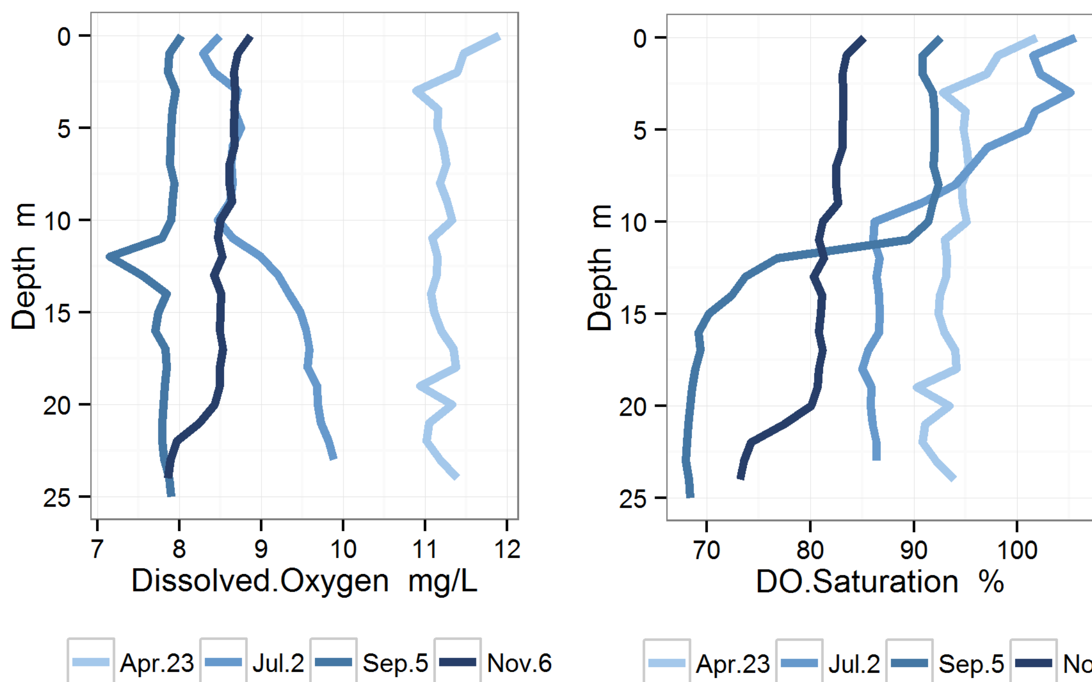


Figure 2.2.7: Dissolved oxygen profiles for Skaha Lake during 2014 illustrating high DO during spring algae blooms and low DO at the thermocline from decomposition of organics during the summer

pH in Skaha Lake ranged from 7.2 to 9.3 during the sample period. Photosynthesis consumes dissolved CO_2 (a weak acid) and increases the pH (Wetzel, 1975). Algae activity held the pH above neutral in the epilimnion during the stratified period. At the intake depth, the pH averaged 7.7 ± 0.4 from April 2014 to October 2015. Decomposition increases dissolved CO_2 concentration and produces organic acids that decrease the pH in the hypolimnion during the summer (Wetzel, 1975; Appendix 1).

TDS data were moderate in Skaha Lake, averaging 134 ± 8 ppm at the surface over the course of the study period (Appendix 1).

2.2.4 Turbidity and Water Clarity

Turbidity increases and water clarity decreases when high concentrations of suspended sediment or microflora (algae) growth are present. Secchi depth averaged a moderate 6.7 ± 0.8 m from April 2014 to April 2015. The Secchi depth was greatest 7.6 m on November 6 2014. In the MoE database, secchi depth averaged 5.6 ±1.8 m from 1985-2015 with an increasing trend (Mann-Kendall, p=0.003). Skaha Lake experienced intense algae activity that reduced water clarity in the spring and early summer (Section 2.3.5). 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. Water clarity was also high during the winter months (averaged 7.0 m) when algae productivity was low (Figure 2.2.8). Turbidity in the chlorinated intake water rarely exceeds 0.5 NTU according to KID staff and measured only 0.3 NTU on November 4, 2015.

Table 2.2.4: Summary of KID Turbidity Data for Skaha Lake: 2008-2015

	Intake
Average	0.44
Min	0.30
Max	0.70
Std.Dev	0.13

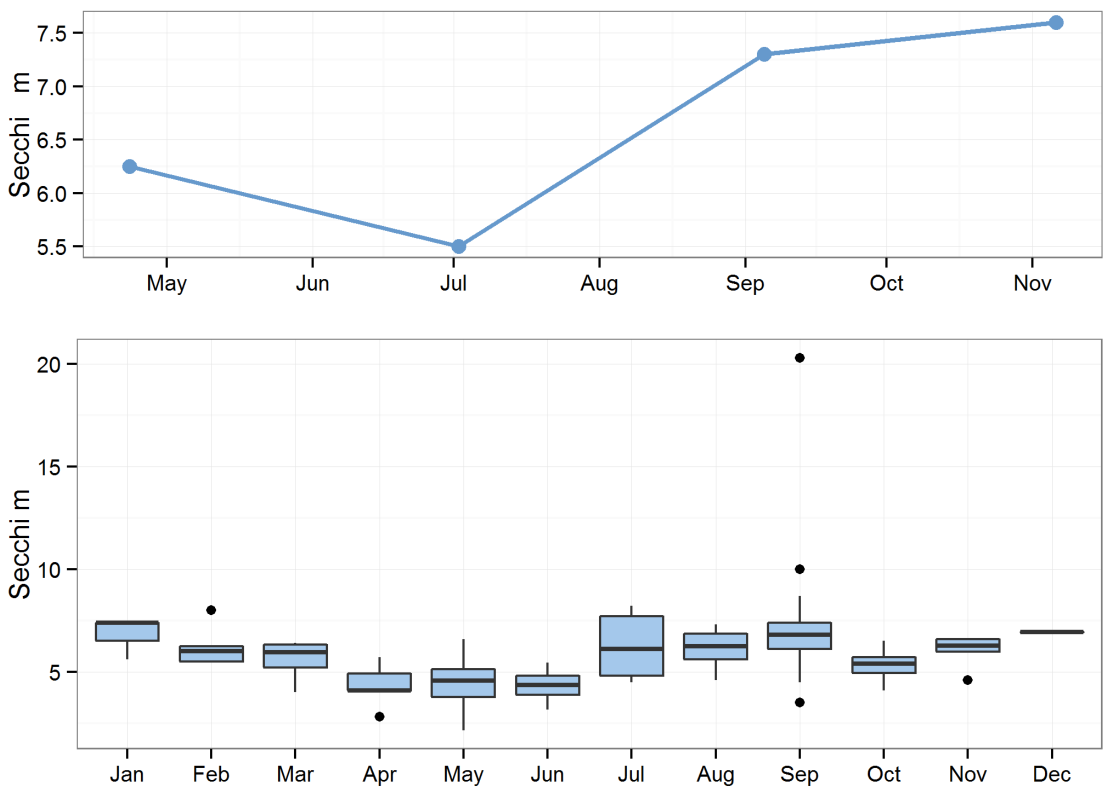


Figure 2.2.8: Secchi depth in Skaha Lake near intake during 2014 (top) and monthly secchi depth from the MoE database from 1985-2015 (bottom)

2.2.5 Nutrients

Nutrients support and determine the nature of aquatic ecosystems. Skaha Lake is an oligo-mesotrophic lake (moderately productive). It receives nutrient-enriched discharges from the Penticton WWTP and from septic systems, agriculture, shoreline development, etc. As of 1980, BC MoE estimated that the WWTP accounted for 20% of the total phosphorus load, septic accounted for 15%, agriculture 3% and natural sources 62% (Jensen and Epp, 2007). However, the natural sources may include nutrient recycling from the substrates that have accumulated nutrients originating from human activity or from watershed damage. Within the last few decades, Skaha Lake has likely been subjected to gradually increasing annual nutrient loads and is gradually responding to the anthropogenic-induced changes to the Okanagan region. With a very short residence time of 1.2 years, Skaha Lake is very responsive to changing nutrient loads. It can be rapidly degraded and rapidly restored.

Nitrogen and phosphorus are considered the most important nutrients in most lake systems (Wetzel, 2001). 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 Skaha Lake was 59 **:** 1 (Table 2.2.5). Dissolved nutrients are readily available for use by algae and comparing them can give a better sense of nutrient conditions in a lake. The DIN:DP ratio in 2015 was only 4:1, indicating that dissolved inorganic nitrogen is the limiting nutrient. Nitrogen limitation can encourage nuisance blooms of cyanobacteria. Nitrogen has been stable over the past 25 years while phosphorus in the epilimnion of Skaha Lake has significantly decreased from 1985 – 2015 (Mann-Kendall, $p<0.001$; Figure 2.2.9). The WWTP has had several upgrades such that it currently operates at the technological limits for nutrient removal (e.g. PO_4 discharge at an annual limit of 0.11 mg/L). With annual inflows from Okanagan Lake of 97%, nutrient conditions in Okanagan Lake exert a huge influence on Skaha Lake. Since 2002, total nitrogen has increased in Skaha Lake (Mann-Kendall, $p=0.02$). The currently allowable annual average discharge from the WWTP is 6.0 mg/L TN. Flood years, such as 1997 and 2012, increased phosphorus loading to Skaha Lake, presumably from watershed sources – the largest and presumably natural contributor to the nutrient budget of Skaha Lake. While the more easily managed P loading from WWTP's throughout the Okanagan have decreased from 60,000 to 2,500 kg annually (1970 – 2000), loading from septic sources doubled from 8,000 to 16,000 kg annually and accounts for approximately ¼ of the total annual load (Jensen & OBWB,2007). Increased nutrient loads, particularly increased DP, can increase the frequency and severity of algae blooms.

Table 2.2.5: Average nitrogen and phosphorus concentrations (mg/L) in Skaha Lake: 1985-2015 (MoE, 2015)

	Combined		Epilimnion		Hypolimnion	
	TN	TP	TN	TP	TN	TP
Average	0.217	0.069	0.216	0.044	0.218	0.010
Min	0.06	<0.002	0.09	<0.002	0.06	<0.002
Max	0.936	0.10	0.341	0.10	0.936	0.047
StdDev	0.069	0.009	0.044	0.012	0.085	0.006

Nutrient concentrations can vary significantly throughout the year (Figure 2.2.10). Dissolved nitrogen starts the growing season the same in the surface and deep waters. Algae consume nitrogen from the surface waters during the spring diatom bloom (section 2.3.5) but thermal stratification prevents replenishment from the hypolimnion. Decomposition and low oxygen conditions result in an increase in dissolved nutrients in the hypolimnion which can fuel algae blooms in the fall when the lake overturns (section 2.2.1).

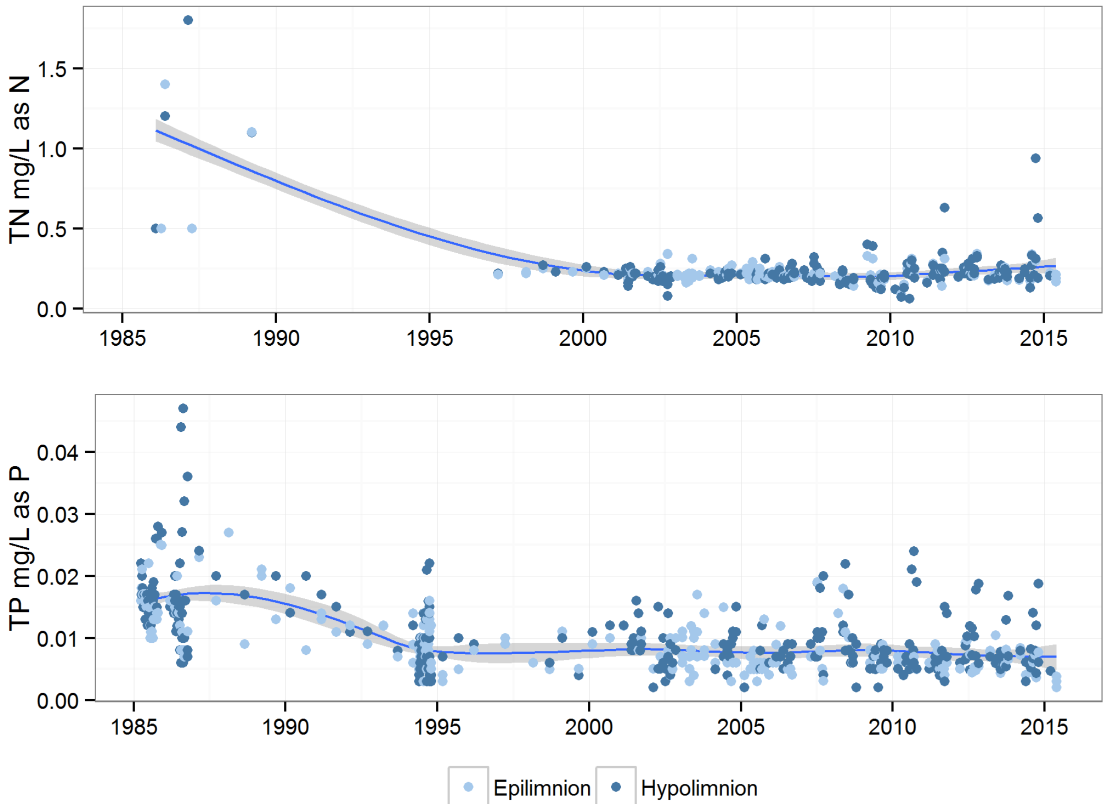


Figure 2.2.9: Nitrogen and phosphorus concentrations in Skaha Lake, 1985-2015 (MoE, 2015)

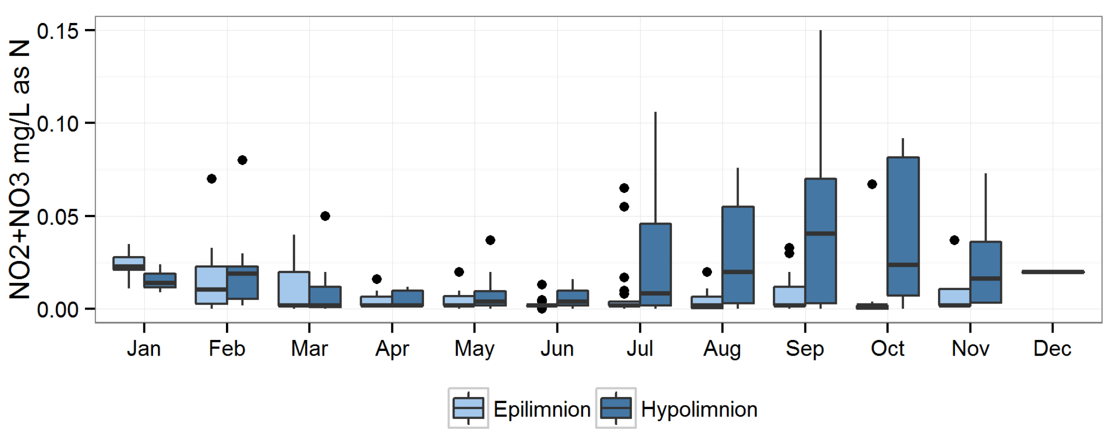


Figure 2.2.10: Nitrate + nitrate in Skaha Lake by month, 1990-2015 (MoE, 2015)

The interim management target for Skaha Lake spring total phosphorus objective is 15 µg/L, set by the BC Ministry of Environment. This guideline was met in 94% (301/309) of Skaha Lake samples from 2000-2015. For reference, the Okanagan Lake background level is 0.01 mg/L TP

2.2.6 Chloride

Dissolved chloride can be used to indicate human interference on an aquatic system. Road salt is the most significant human source of chloride in most cases (Wetzel, 2001). Chloride averaged 3.5 ± 1.1 mg/L from 1985 to 2015 with a long-term increasing trend (Mann-Kendall, $p<0.001$; Table 2.2.6, Figure 2.2.11).

The greatest chloride loading was to Skaha Lake during freshet because salt that had built up on the roadsides over the winter is washed into the lake (Figure 2.2.11). Recommended winter road salt rates average 60 – 130 kg/two-lane kilometer in BC (MoE BMP 1998)..

Table 2.2.6: Summary for chloride concentrations in epilimnion and hypolimnion of Skaha Lake: 1985-2015 (MoE, 2015)

Chloride (mg/L)	Epilimnion	Hypolimnion
Average	3.5	3.7
Min	1.8	2.7
Max	6.2	5.1
StDev	1.1	0.7

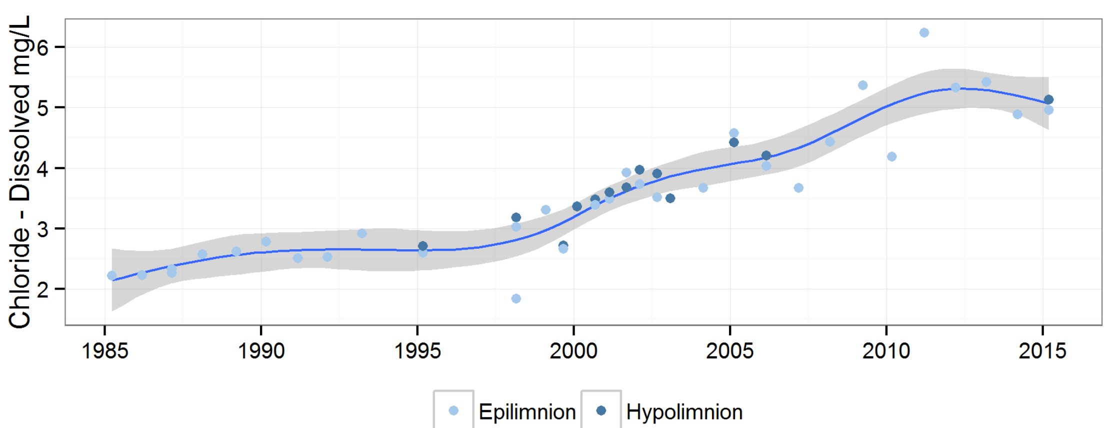


Figure 2.2.11: Chloride concentrations in Skaha Lake from 1985-2015, (MoE, 2015)

2.2.7 Metals

Routine sampling is carried out by KID annually. Skaha Lake has not exceeded the Guidelines for Canadian Drinking Water Quality during sampling for metals by the Kaleden Irrigation District (data for 2008-2015).

2.2.8 UV Transmissivity

Ultraviolet (UV) light at 254 nm is lethal to many microorganisms, particularly *Cryptosporidium* and *Giardia* (Shannon et al, 2008). UV treatment is often considered as a secondary treatment option alongside chlorination if the source water is sufficiently transparent to UV light at that wavelength. Most UV treatment reactors are designed to operate efficiently on water with UV transmissivity of greater than 75% (Phelan, 2013). Chlorinated intake water UVT in the KID intake measured 89% on November 4, 2015. This is an excellent result and indicates that Skaha Lake water is suitable for UV treatment.

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

2.3.1 Protozoan Pathogens in Water Column

The Kaleden Irrigation District is currently considering additional treatment and source water options and is therefore not required to sample for *Cryptosporidium* or *Giardia* oocysts at this time. The current risk associated with protozoan pathogens to Skaha Lake as a source of drinking water is unknown and likely low. Identification of the potential sources, levels and seasonal fluctuations of Cryptosporidium and Giardia is required for water suppliers using surface water sources and key for selection of appropriate treatment process (J Ekkert, pers comm. 2016).

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 only 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 greater than 10 % of samples.

The low number of bacterial sample results does not provide sufficient confidence to make any conclusions regarding the bacteriological water quality (NHMRC, 2011). The current configuration of the Kaleden Irrigation District intake does not allow for routine raw water sampling that could support their source water quality monitoring because they chlorinate at the mouth of the intake. If a raw water line was installed, raw water bacteriology would be helpful to determine bacteriological water quality changes throughout the year and more specifically during turnover and settling, and to identify seasonal patterns or sporadic disturbance events (J. Ekkert, pers comm. 2016).

Detectable bacterial counts in Skaha Lake were concentrated near the substrate and on the thermocline. None of the samples exceeded the 20 CFU *E. coli* /100 mL suggested guideline for raw water (2009). Total coliforms in Skaha Lake were very low throughout most of the year, with an average <1 CFU/100mL from 2008-2015. During the annual water chemistry sampling on November 4, 2015, there were no detectable bacteria in the intake water. The bacterial profiles shown in Table 2.3.1 show the expected increase in bacterial numbers near the substrate. Virtually 99% of all bacteria within a lake reside in the uppermost centimeter of substrate. Most of the reported *E. coli* occurred in the bottom samples but none of them exceeded the IHA raw source water criteria. Total coliforms were very numerous in the bottom samples because they are a soil organism.

Table 2.3.1: Total coliform, background coliform, and *E. coli* results from Skaha Lake Profiles, 2009

2009	May 24			July 2			Oct15			
Depth	Total Coliforn CFU/100mL	Background C(CFU/100mL	E. coli CFU/100mL	Total Coliforn CFU/100mL	Background C(CFU/100mL	E. coli CFU/100mL	Total Coliforn CFU/100mL	Background C(CFU/100mL	Fecal coliform: CFU/100mL	E. coli CFU/100mL
RDL	1	200	1	1	200	1	1	200	1	1
0 m	<1		<1	1		<1	1		<1	<1
10 m	46	DGT200	<1	DGT2	DGT200	<1	DGT1	DGT200	<1	<1
20 m	<1	DGT200	<1	DGT4	DGT200	<1	TNTC With		1	1
30 m	<1		<1	DGT9	DGT200	<1	7	DGT200	<1	<1
40 m	1	<200	<1	30	DGT200	<1	4		3	2
bottom	40	DGT200	1	O.G. with		<1	O.G. with		8	8

NOTE: DGT= detection greater than TNTC= too numerous to count RDL=reported detection limit OG=overgrown With = with total coliforms

NOTE: IHA's proposed guidelines for filtration deferral states:

- No more than 10% of raw source water *E. coli* samples should exceed 20 CFU/100mL in any 6 month period (consecutive weekly sampling preferred). and
- No more than 10% of raw source water total coliform samples should exceed 100 CFU/100 mL in any 6 month period (consecutive weekly sampling preferred).

A second area of bacterial concentration was the thermocline. Total coliforms congregated at the thermocline depth of 10 m on all three 2009 dates (Table 2.3.1). Bacteria and fine particulates can get "hung up" on the density change near the thermocline and their rate of sinking drops significantly.

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 Skaha Lake sediment near the intake contained 7.3 MPN/100mL total coliforms and undetectable *E. coli* on May 5 2015 (Figure 2.3.3). These counts are very low for lake sediments. Under normal circumstances, these bacteria are isolated from the water column and would not impact the intake. 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). This is not expected to be a significant risk to the KID intake.

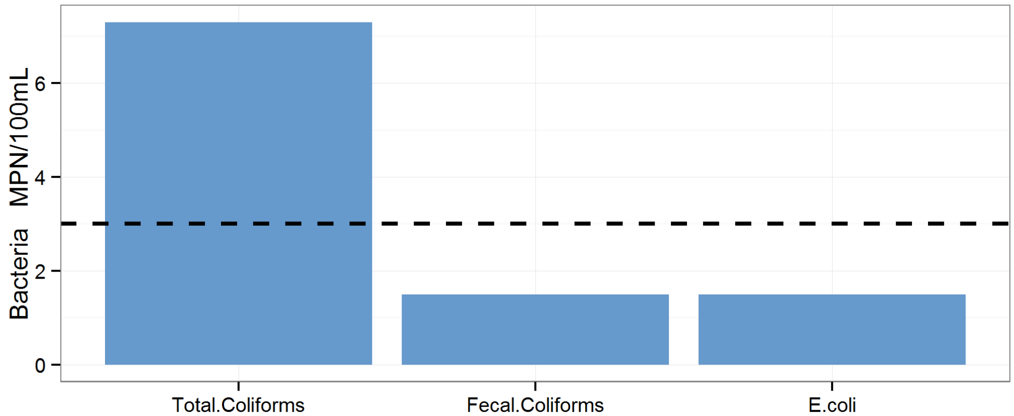


Figure 2.3.3: Sediment bacteria below KID intake, May 5 2015
Data below the dashed line represent non-detectable bacteria concentrations and is presented as ½ RDL
NOTE: MPN = most probable number

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 persist for decades. 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. Sediment accumulation rates for Skaha Lake were calculated from our sediment capture equipment in Skaha Lake, deployed from April 2014 to April 2015. For reference, sedimentation rates for Okanagan Lake range from 58 g/m²/yr in deep open water to 177 g/m²/yr in shallow areas. In Skaha, we estimate the rate to be 154 g/m²/ near the KID intake based on sediment data collected from 2014-2015. 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 Skaha Lake

Algae form an important baseline for the food webs in every lake. Chlorophyll-a concentration is used a measure of algae concentration and decreased from 1985-2015 (Mann-Kendall, p<0.001; Figure 2.3.4).

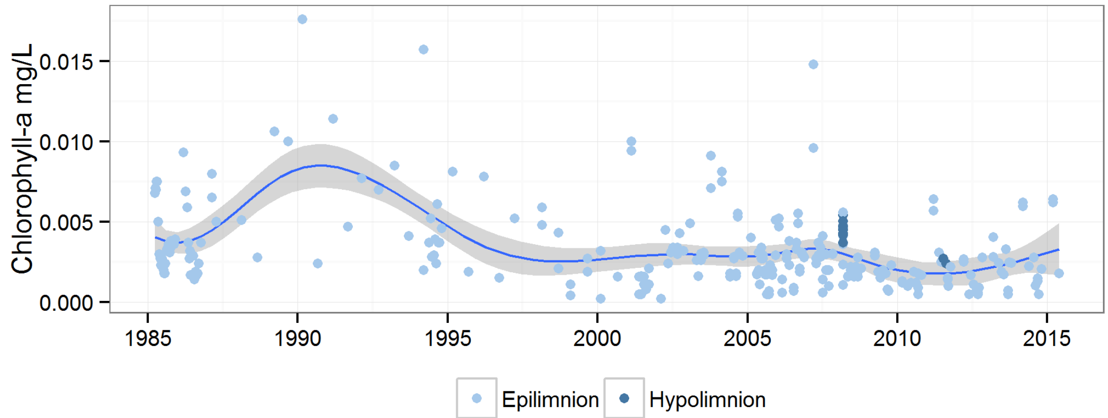


Figure 2.3.4: Chlorophyll-a concentration in Skaha Lake, 1985-2015 (MoE, 2015)

Algae results from all years of study to date demonstrated a cyanobacteria dominance of Skaha Lake. They were represented by a shifting range of filamentous and single-celled species. Diatoms produced more biomass than the cyanobacteria in the spring months, but at all other times of year, cyanobacteria were dominant both numerically and in terms of biomass produced (Figure 2.3.5). Although the WWTP and septage accounts for an estimated 20% and 15% respectively of the annual nutrient load, while natural sources contribute 62%, it may be easier to address the human-caused nutrient load. For example, the City of Penticton has installed stormwater interceptors along the oxbows. If the net load of nutrients gradually increases in Skaha Lake with increasing volumes of effluent, and stormwater from the growing population of Penticton, or from watershed damage such as ranching practices in riparian areas, it is reasonable to expect a resumption of the cyanobacteria blooms seen in Skaha Lake in the past. Both the severity and the frequency of cyanobacteria blooms will respond to the nutrient load and the N:P ratio.

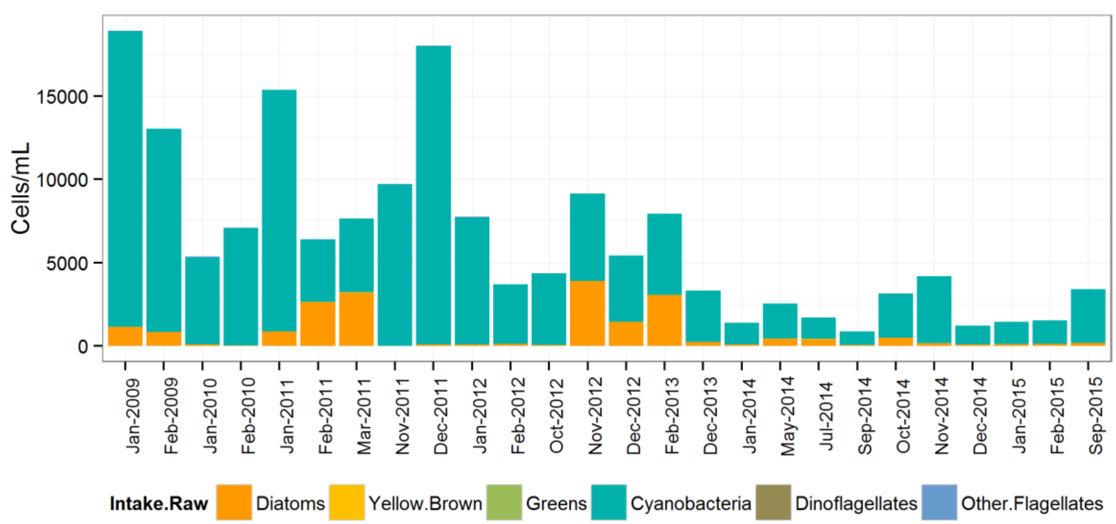


Figure 2.3.5: Raw water algae concentrations at the KID intake, 2009-2015

Several taxa found in the summer months (e.g. *Anabaena* spp.) are exclusive to high nutrient lakes*.* Mid-summer algae numbers were relatively low. This is known as the “clear phase" in large lakes where circulating nutrients become depleted and algae productivity stalls in the main volume of the lake (Figure 2.2.10). In Skaha Lake, the clear phase is very pronounced and spans July through September (Figure 2.2.8 and 2.3.6).

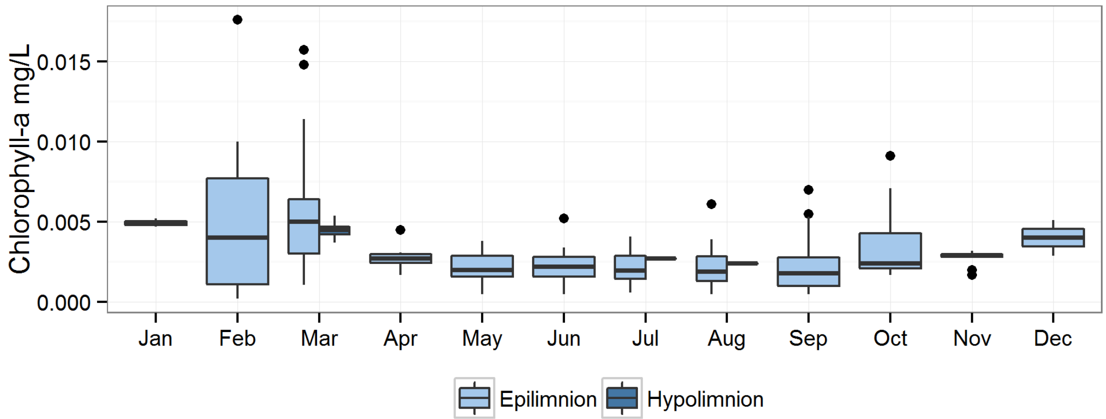


Figure 2.3.6: Monthly chlorophyll-a concentration in Skaha Lake, 1985-2015 (MoE, 2015)

With the fall overturn commencing in mid-October, nutrients from the hypolimnion replenished the epilimnion and algae production increased dramatically, led by filamentous cyanobacteria (Figure 2.3.7). Late fall and early winter cyanobacteria blooms periodically affect KID's intake generating taste and odour problems (Figure 2.3.5). Taste and odour problems have been associated with cyanobacteria counts >10,000 cells/mL at Kaleden. Fall and winter algae production eclipsed spring production in, suggesting that the algae/cyanobacteria blooms persist through the winter, consuming nutrients through the dark months and limiting their supply for the following spring. Both historic and recent algae studies agree with the result found in this study; productivity increases in Skaha Lake from the fall through the winter with the peak production between October and March. High algae productivity following fall overturn appears to be typical of Skaha Lake since the 1960's (Figure 2.3.6).

The intake raw water samples contained higher algae concentrations than samples taken in open water at the same depth (Figure 2.2.7). This occurred because the samples were not collected on the same dates at the same times and in-lake conditions can change rapidly by seiches and mixing at fall overturn. This phenomenon has been observed at other lake intakes.

Deeper intakes will provide cooler water with less algae during most months. Because the cyanobacteria are low light tolerant, there were months where the cyanobacteria count would be lower in a shallow intake, but the overall algae load decreased with depth. In addition to intake depth, location on the lake also plays a part in intake algae counts, as does intake clearance from the substrate.

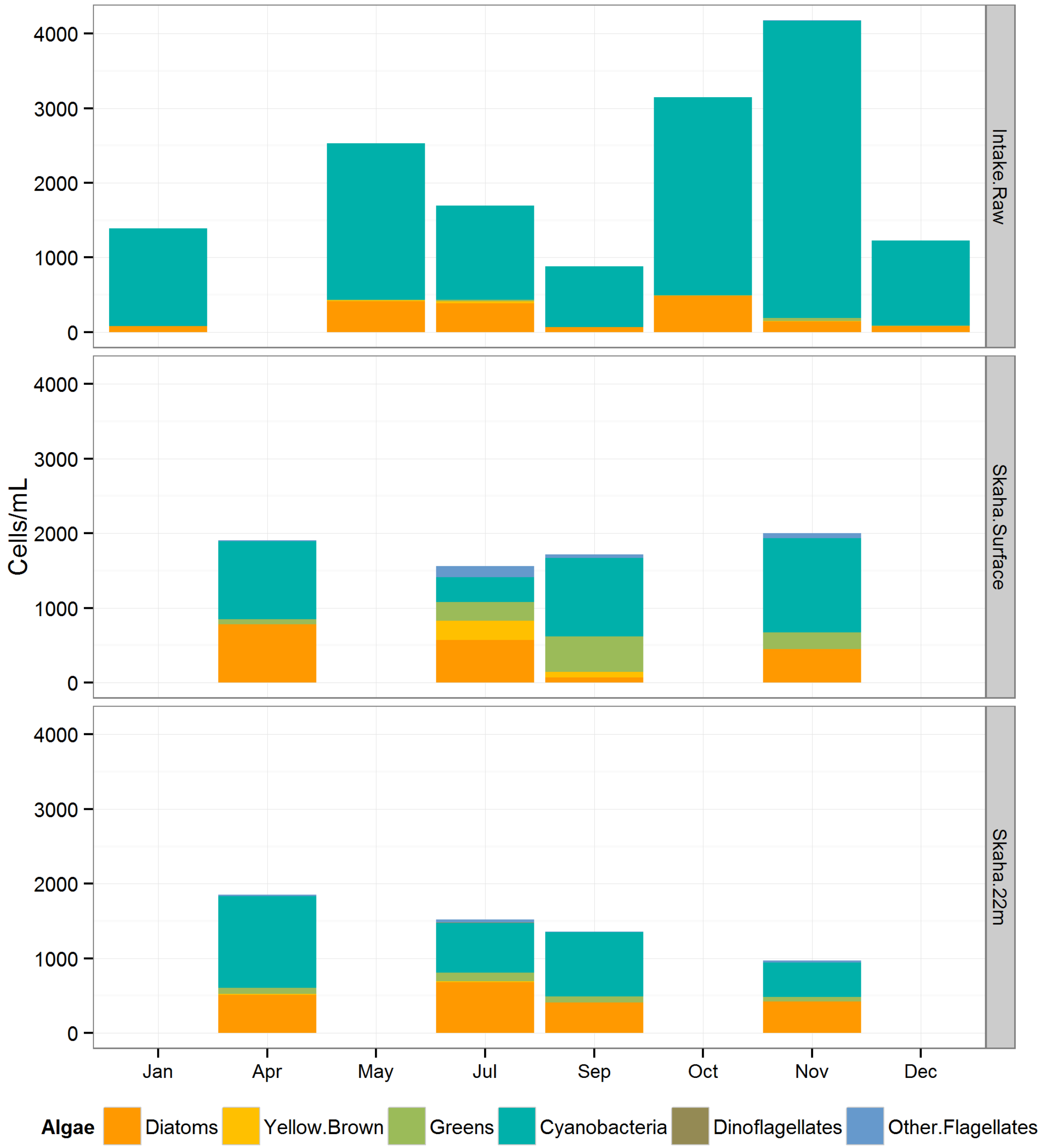


Figure 2.3.7 Algae concentrations in Skaha Lake and the KID intake during 2014

Cyanotoxin Exposure

The risk of cyanotoxin exposure is low during most years. The risk is highest during the winter months at all depths because the water column is circulating nutrients accumulated in the hypolimnion during the summer. Frequently, these blooms will be heralded by an offensive taste and odor. Very sensitive individuals (immune compromised, those with existing nervous, renal or hepatic conditions) should be notified and they may wish to consider adding an activated carbon filter to their household water line. Assuming the disinfection byproducts to be less toxic than the parent cyanotoxin molecules in Skaha Lake water, the chlorine dose could be doubled during a cyanobacteria bloom and would attack microcystins and saxitoxins, but cylindrospermopsins can break up into byproducts that remain toxic. The increased chlorine dose should be bench-tested prior to implementation. The cyanotoxins that could be present can be worked out in advance from the cyanobacteria species forming the bloom before increasing the chlorine dose is attempted. THM's (section 2.3.6) should be monitored because increased chlorination tends to increase their production.

Table 2.3.2: Problems caused by Skaha Lake cyanobacteria

Common Skaha Lake Cyanobacteria	Toxins	Taste and Odor when Moderate / Abundant	
Anacystis /Microcystis	LPS MC BMAA	grassy /septic	
Anabaena circinalis, planktonica*	LPS CYL MC ATX BMAA NEO SAX	musty / septic	Geo
Gomphosphaeria spp.	None known	grassy / grassy	
Planktolyngbya	LYN APL LPS CYL SAX BMAA		MIB
Oscillatoria spp.	LYN APL LPS MC ATX BMAA SAX	grassy / musty, spicy	Geo MIB
Planktothrix spp. *very toxic*	LYN APL LPS MC ATX BMAA SAX	grassy / musty, spicy	Geo MIB
Pseudanabaena sp.	LPS MC	musty / musty	Geo MIB
Synechococcus sp.	LPS MC BMAA	musty	Geo MIB

Dermal toxins = LYN lyngbyatoxin-a; APL aplsiatoxins; LPS lipopolysaccharides
Liver toxins = CYL cylindrospermopsins; MC microcystins; NOD nodularins
Nerve toxins = ATX anatoxins; BMAA B-N-methylamino-L-alanine;
NEO neosaxitoxins; SAX saxitoxins

Taste-and-Odor = GEO geosmin; MIB 2-methylisoborneol
Geosmin and 2MIB are detectable at less than 5-10 ng/L among sensitive individuals, far below the detection limit of most lab assays, however, taste alone is not considered to be a reliable indicator of cyanotoxin presence in all lakes (Falconer et al.,1999; Graham et al., 2008, Graham et al., 2010).

2.3.6 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, 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. KID plans to implement THM sampling starting in 2016.

2.3.7 Biofilm Development

Biofilms develop 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 Skaha Lake intake is below the thermocline throughout the summer and pulls cold water into the distribution system (Figure 2.2.5).

Biofilm development should be minimized by the cold temperature but large organic loads during bloom phases provide food for biofilms. According to KID staff, the Kaleden intake occasionally suffers biofouling.

2.4: Human Influences of Water Quality

2.4.1 Sewage, Septage, and Stormwater

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. Similarly, stormwater can be highly contaminated.

Sewer Kaleden does not have a sewage outfall in Skaha Lake but the City of Penticton releases tertiary treated effluent into Skaha Lake (Summit, 2013). With recent upgrades, the WWTP released 365 kg/year of phosphorus and 13,322 kg/year of nitrogen in 2013 (R.Craig, Pers. Comm, 2015).

The Okanagan Basin Implementation Plan has established minimum flows for the Okanagan River Channel of 3.0 m^3/sec during all months of the year. Usually the lowest flows occur during the winter and again in the summer. The rate of dilution with Okanagan Lake water in the channel exceeds 10:1 (Stantec, 2007). The resultant plume should enter the epilimnion of Skaha Lake and travel east or west along the shore depending on wind conditions (Table 2.4.1, Figure 2.4.1). Density calculations indicate that the plume should enter Skaha Lake and mix with the epilimnion volume during the stratified period and mix into the full water column during the unstratified periods (Table 2.4.1).

Table 2.4.1: Penticton channel plume

Date 2015	Penticton Channel			Lake Surface			Plume will
	Temperature °C	Conductivity um/cm^2	Salinity	Temperature °C	Conductivity um/cm^2	Salinity	
January 22	3.73	286	0.14	2.94	290	0.14	Dive & mix
September 4	16.97	286	0.14	19.23	284	0.14	Float & mix
October 6	14.57	289	0.14	14.69	288	0.14	Mix

The City of Penticton sewage outfall may be extended into the deep water of Skaha Lake in the future. Currently the volumes are falling as residents adopt water conservation, and as of 2015, they averaged 10-12 ML/day and the recommendation is a 25 ML/day threshold to trigger consideration of the outfall extension (R. Craig, Pers. comm. 2016) During the stratified period (May-Nov), the extended outfall plume should mix into the hypolimnion. This will likely increase nutrient concentrations in the hypolimnion during the stratified period, and possibly an exaggeration of the cyanobacteria blooms during the un-stratified fall/winter/early spring period. The full impact of this potential change are not considered in this report.

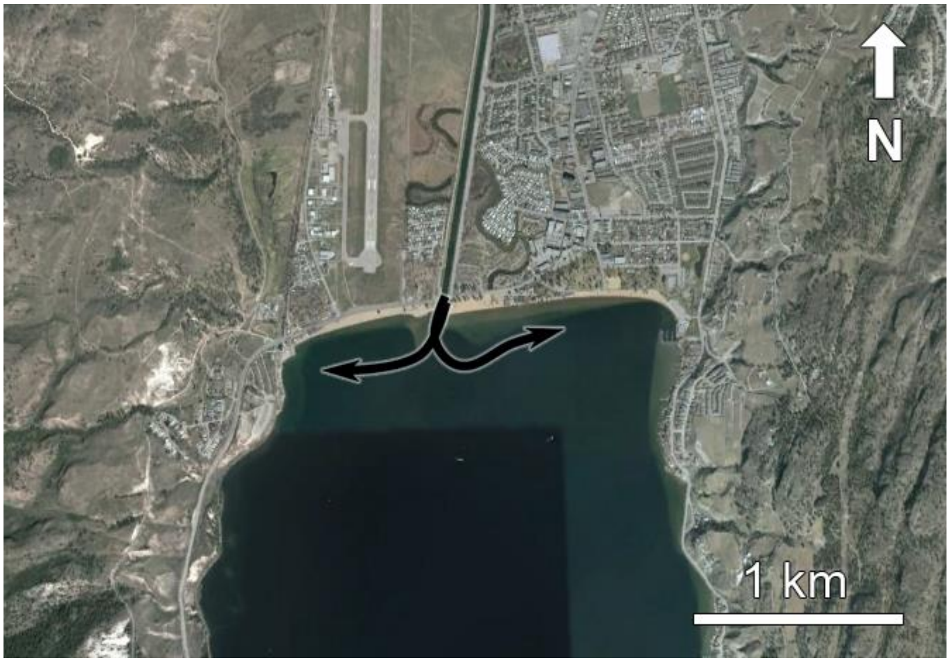


Figure 2.4.1: Estimated path of Okanagan River plume in Skaha Lake

There is a plan underway to build sewer lines around the south basin of Skaha Lake to connect additional properties to the Okanagan Falls WWTP. The sewer line will allow numerous properties that are on septic systems to be connected to municipal sewer. This should reduce the amount of nutrients entering the lake from residential septic systems. The failure of a sewer lift station associated with the planned pipelines could cause raw sewage to enter the lake. There is also a very small risk that the pipe may leak raw sewage directly into the lake. These risks are small relative to the ongoing issue of septic nutrient enrichment but should still be mitigated with redundant systems.

Septage Septage is the mixture of sludge, fatty materials, and wastewater present in septic tanks. It is periodically pumped out by licensed companies. The concentrations of possible pollutants are high in septage and include 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.

There are numerous lakeside properties around Skaha Lake that use septic systems. These areas are serviced by onsite disposal systems consisting primarily of septic tanks and tile fields. Septage pumped out of septic tanks in the City and Regional District was disposed at the Campbell Mountain Landfill until September 2008, but this facility is closed and a new facility was constructed at the Penticton WWTP. All septage has been diverted to the WWTP since that time. This does not include the septage that reports directly to the lake through the septic fields. Septic efficiency also depends on how well the system was constructed and is maintained.

Further efficiency problems with lakeside septic systems can occur during periods with high groundwater levels when as many as one-half of all septic tanks in operation do not function correctly (Crist et al., 1999). Major overland flooding on Skaha Lake does not occur, however, infiltrating subsurface flows from the steep valley sides could increase the impact from septic fields and farms. More 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 that are not, or cannot, be connected to a municipal sewer system. The threat from human septage in the vicinity of the KID Skaha Lake intake is not known, however, RDOS is at the grant application stage of converting Kaleden to sewer. With a sewer line comes other challenges - mainly that there is likely to be more subdivision of existing properties. Development would increase stormwater runoff unless on-site treatment is mandated.

Skaha Lake is a very popular recreational boating destination and another potential source of septage (black-water) is improper disposal from yachts, cabin cruisers, and houseboats (if any). Disposal of black-water is illegal and hopefully uncommon. On-lake disposal of grey water (all other waste water), however, is still not illegal in BC lakes.

Stormwater As with most Okanagan municipalities, there is almost no stormwater treatment before those flows enter natural drainage courses that ultimately report to Skaha Lake. Untreated stormwater can carry many types of contaminants including petroleum products, PAHs, nutrients and fecal material. Penticton represents the largest source of stormwater to Skaha Lake. Many Penticton stormwater outfalls discharge to Okanagan River or via drainage courses to Skaha Lake (Summit, 2013). Without exception, samples collected during the 2012 Penticton stormwater study showed increased nutrient and contaminant loads after passing through urban areas. The greatest concentrations occurred during ‘first flush events’, defined as runoff-producing rain events of >5mm occurring after two to three weeks of insignificant runoff (Summit, 2013). Average Penticton stormwater samples ranged from 0.009 – 3.40 mg/L nitrate, 0.006 – 0.22 mg/L T-P, 0.92 – 24.21 mg/L Cl, 0.5 – 41.2 NTU and very high microbial counts of 6 – 13,400 CFU/100 mL (Summit, 2013). The City has installed storm interceptors along the oxbows in recent years. Their effectiveness at removing nutrients and pollutants is not known, but will be connected to removing suspended sediment.

Stormwater can also be impacted by poor land use practises. For example, nutrient loading to Okanagan River can be excessive as was noted in an OBWB study which identified nutrient loading from an upper Shingle Creek cattle ranch. The ranch would also be a source of bacterial contamination to the water course and ultimately to Skaha Lake.

Kaleden is a low density area with relatively few impermeable surfaces. This should reduce the amount of stormwater generated. Stormwater flows into unlined ditches. There is one stormwater outflow at the base of Lakehill Rd, 200 m from the intake. It is unlikely that much stormwater will ever report directly to the lake via this outfall and infiltration into the ground will serve to partially treat any water that reports subsurface. To date, there have been no specific studies or analysis done to identify impacts on Skaha Lake caused by stormwater runoff. A calculation of the load (as opposed to concentrations) is needed to allow a ranking of nutrient and contaminant inputs to Skaha.

Figure 2.4.2: Stormwater outfalls near KID water intake

Buildable land is valuable in the area surrounding Skaha Lake and surrounding the KID intake in particular, but future development should conform to best management practices (BMPs) to reduce the amount of stormwater, to retain it on site if possible, and to treat it before releasing it into Skaha Lake (Table 2.4.2). Recommending stormwater treatment is beyond the scope of this report. Table 2.4.2 provides a list of treatment BMPs approved by the US EPA in its comprehensive guide to stormwater BMPs (EPA, 2004).

Table 2.4.2: Stormwater management BMPs (EPA, 2004)

Categories	Best Management Practices
Ponds	-Extended detention basin (dry) -Retention pond (wet) -Wetland pond -Infiltration pond
Wetlands	-Surface flow -Aerobic/anaerobic -Subsurface flow
Infiltration	-Infiltration trench -Infiltration pond -Permeable pavements -Bioretention
Vegetative Biofilters	-Grass swales -Filter strip / Buffer -Bioretention
Filters	-Sand filter -Permeable filter -Media filter -Underground filter

2.4.2 Agriculture

Skaha Lake is surrounded by lands developed for agriculture. In the Kaleden area there are numerous orchards and vineyards. These types of agriculture are a very low risk to the intake. The main agricultural risk is ranching along the Okanagan River at Penticton and within the McLean Creek watershed. Intense cattle activity has been documented in and around the oxbows next to Penticton Airport. Nutrients from the cattle manure will infiltrate to the groundwater and report to Okanagan River and Skaha Lake via subsurface flows. It is also possible that bacteria and protozoan pathogens may be transported into Okanagan River via surface flows, given the proximity of the oxbow to the main channel. While these activities may be phased out in the future, they are active today and are likely contributing contamination in the form of nutrients, microorganisms and sediments.

Friends of the Oxbows recently established a partnership with the Penticton Indian Band (PIB) and have been in discussions with the local and PIB reps regarding resolution of this situation (B. Shepherd, Pers. comm., 2016),

Figure 2.4.3: Intensive cattle ranching around oxbow lake adjacent to Okanagan River at Penticton (Photo: Bruce Shepherd)

Additionally, ranching in the watershed along Shingle Creek and McLean Creek have been identified as having riparian damage and would be susceptible to increasing nutrient and/or pathogen loading to Skaha Lake. Finally, other tributaries such as Skaha, Felix, Gillies and Matheson creeks, while not likely as high, should still be taken into consideration as potential contaminant sources, particularly during freshet and stormflow periods.

2.4.3 Animals

Over the last 6 months of 2015, there was a resurgence of beaver activity along the shoreline on both sides of the KID Pumphouse. There was an active lodge down at Sickle Point in summer 2015, and perhaps the one to the south of Ponderosa Point was reactivated as well. Beavers and muskrats can carry protozoan parasites and other fecal pathogens. Additionally, the pocket beach just to the south of the pumphouse has been a popular spot for folks to bring their horses down for a swim during the summer (Bruce Sheppard, pers comm 2016). Like dogs, horses can also introduce fecal pathogens to the shallows near the intake.

2.4.4 Natural Gas Leak

There is a submerged high pressure natural gas line in Skaha Lake. The gas line travels down the midline of the lake from southeast of Penticton to northwest of Okanagan Falls passing within 300 m of the intake. A leak from the intake would be unlikely to impact the intake but would function as an aerator, lifting deep water to the surface. Skaha Lake is large and even a large leak should not significantly affect the stability of the thermocline during the stratified period. Natural gas (methane) would bubble to the surface and enter the atmosphere. A small percentage of the gas may dissolve into the water column but this should not persist, and to some degree, this occurs naturally with methane generated by decomposition of organic materials in lake substrates.

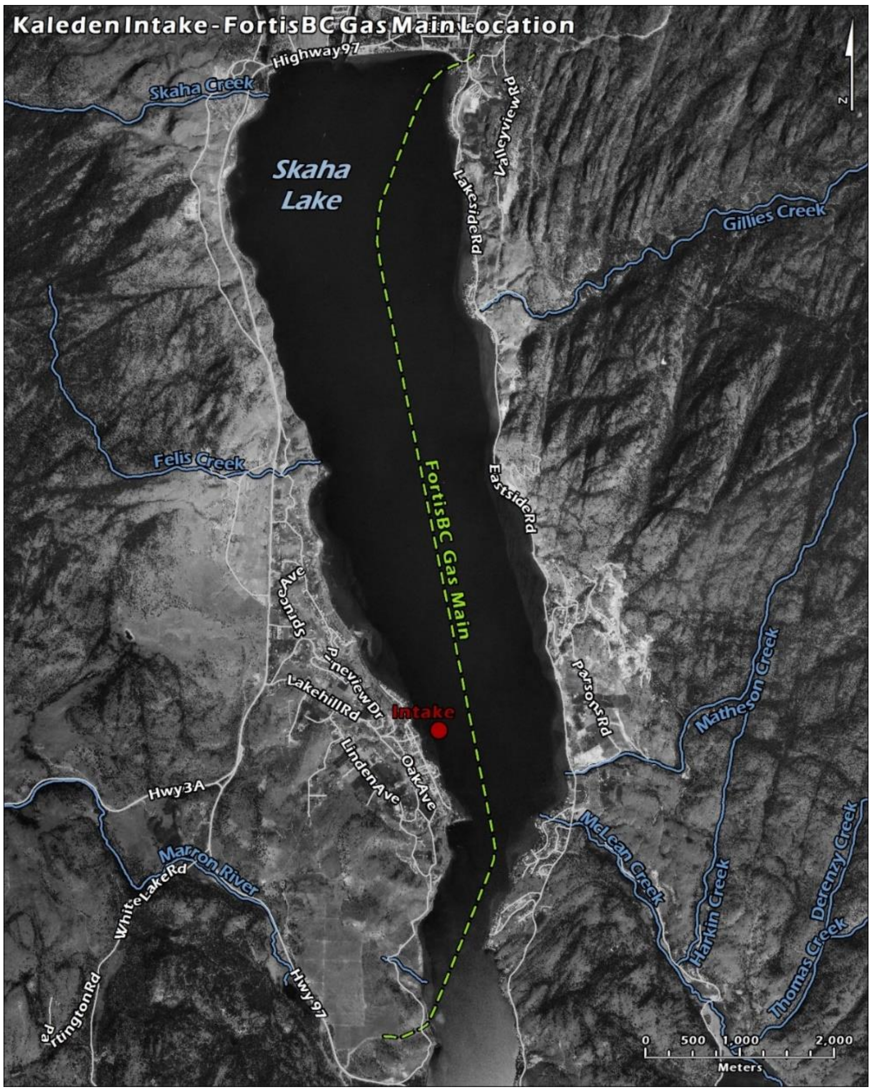


Figure 2.4.4: FortisBC gas line in Skaha Lake and the KID intake (FortisBC, 2015)

2.4.5 Near-Shore Hydrocarbon Storage

A 200 gallon fuel tank is located near the high water line at the Ponderosa Point Resort. An accidental spill of this magnitude could cause a large slick until it evaporated, and does have the potential to contaminate a large volume of water.

2.5 Calculation of Intake Protection Zone for Skaha Lake Intake

The source assessment process should identify potential risks associated with the surface water – sources of contamination, where contaminants are introduced into the lake, how currents and mixing within the lake affect how these contaminants move through the lake, and more specifically near the intake.

An intake protection zone (IPZ) defines the area where the KID 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 minimum starting point defined by IHA for an intake protection zone 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 Skaha Lake. None the less, a decision must be made on the acceptable time-safety factor that would give the Kaleden Irrigation District reasonable time to react to an emergency such as a spill. The 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 central Skaha 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 – Skaha 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, resulting in more rapid evacuation from the water column.

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
Organic clumps (detritus)	< 100 microns	0.35 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 2003; 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 motions of water 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 Kaleden Irrigation District intake is currently 2 m above the sediment in Skaha Lake and should be protected from most sediment transported by vertical currents except during a large seiche.

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 KID 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 2.5.1).

2.5.4 Water Currents (Horizontal transport)

Currents in Skaha 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 3 occasions and at several depths to document the water currents in Skaha Lake around the KID intake. Drogues were used before stratification established in April, during the peak of stratification in July, and near the end of stratification in September. Each drogue was tracked using GPS for several hours.

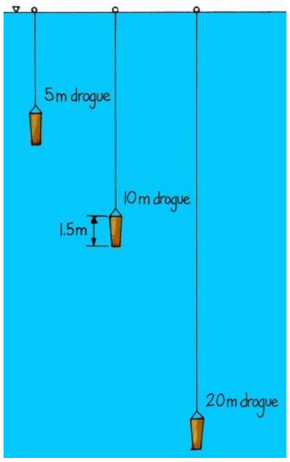


Figure 2.5.1: Schematic of drogues

2.5.5 Drogue Travel in Skaha Lake near Intake

Drogues generally travelled parallel to shore from the north towards the south (Figure 2.5.2). Shallow 5 m drogues indicate that the surface currents move with the wind. Deeper currents moved more slowly than surface currents as they do in most lakes. The difference between the average and mode (most common value) directions for the drogues indicates the amount of directional variability in water currents at that depth (Table 2.5.2).

Table 2.5.2: Summary statistics of Skaha Lake drogues

	Speed (m/hr)				Direction	
Depth	Average	Min	Max	StdDev	Average	Mode
5m	141.8	62.5	256.8	92.2	SE	S
10m	89.8	36.8	236.1	74.0	NE	NE
20m	66.8	25.5	105.2	34.3	SE	S/SE
30m	36.8	20.2	53.3	23.4	E/SE	E/SE

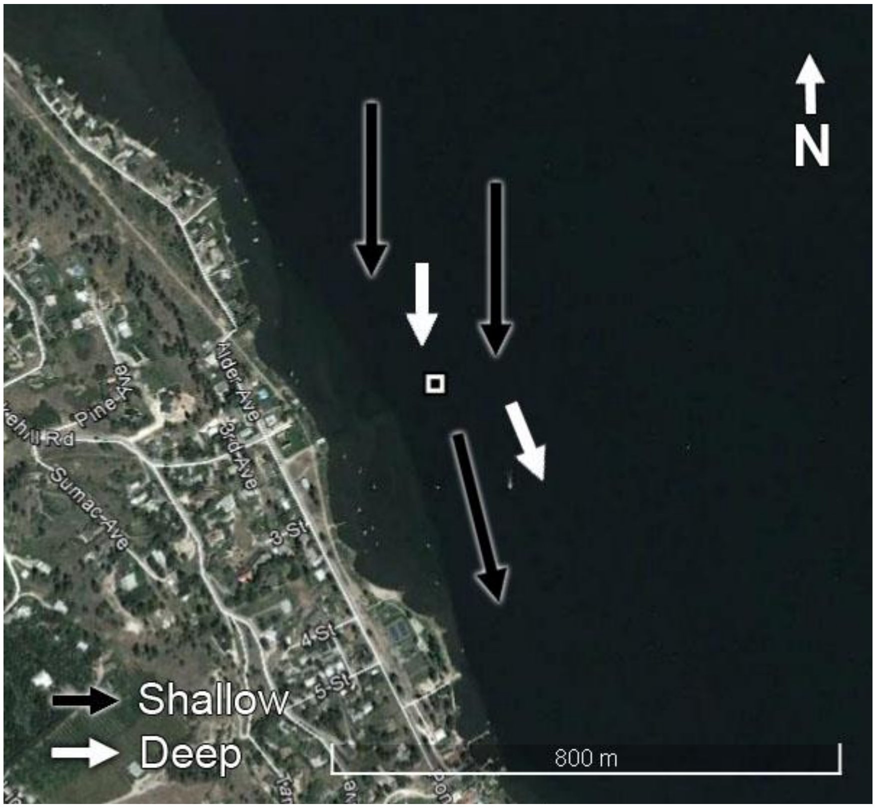


Figure 2.5.2: Typical pattern of water currents for Skaha Lake around the KID intake

The 5 m drogues travelled at the widest range of speeds and averaged 142 ± 92 m/hr. Most travelled south indicating the predominant direction of winds and currents at the Kaleden intake (Figure 2.5.3). On April 23 2014 there were strong southerly winds that caused the 5 m drogues to move northwards.

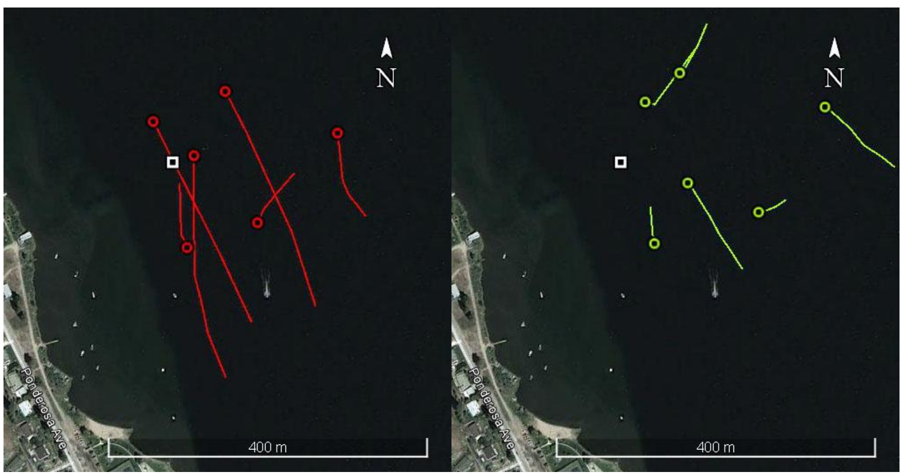


Figure 2.5.3: 5 and 10 m drogues in Skaha Lake: 2014

The 10 m drogues averaged 90 ± 74 m/hr and were the most variable in direction. 10 m currents were above the thermocline for most of the stratified period, and were readily influenced by wind (Figure 2.5.3). The 10 m drogues were slower to respond to current wind conditions than the 5 m drogues and on one occasion while the winds were from the north (September 5) they travelled in the opposite direction as the 5 m drogues.

The 20 m drogues were slower than the 5 and 10 m drogues and averaged only 67 ± 34 m/hr. Water currents at 20 m frequently carried the drogues south parallel to shore but during strong northerly winds they were carried north along with all the other drogues (Figure 2.5.4).

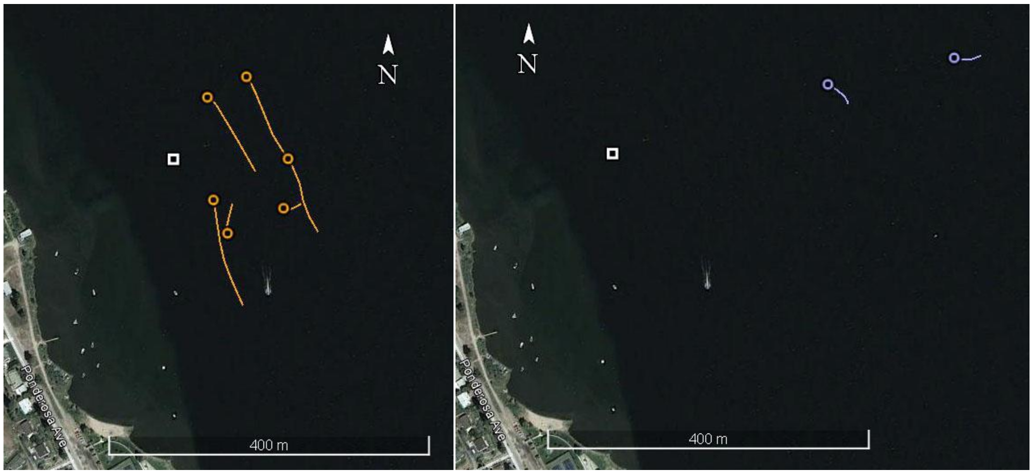


Figure 2.5.4: 20 and 30 m drogues in Skaha Lake: 2014

The lake bottom is less than 30 m at the intake and so 30 m drogues had to be placed quite far from shore. These drogues represent potential currents that a deeper intake may face. The 30 m drogues averaged 37 ± 23 m/hr and mostly travelled parallel to shallower currents (Figure 2.5.4).

2.5.6: Calculation of Proposed Intake Protection Zone (IPZ)

The preceding discussion of vertical and horizontal currents in Skaha 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 minimum 100 m buffer zone around the intake. A 100 m circle would provide only 23 minutes of protection under the fastest drogue recorded on Skaha Lake. No sampling was performed during extreme weather events but it is safe to assume that under these conditions contaminants would travel faster than what we measured.

Two hours is considered to be sufficient time to respond to a contaminant spill and take appropriate action such as shutting off an intake before the distribution system could be affected (Langan, 2007). In two hours the fastest drogue at the intake depth travelled 210 m. The fastest overall drogue (5m depth) travelled 513 m in two hours. This is the minimum recommended IPZ. The proposed IPZ is not a perfect circle because the water currents around the intake flowed more often towards the south and parallel to the shore (Orange zone in Figure 2.5.5).

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

Table 2.5.3 MODULE 1: Hazard and contaminant table - summary table of risks

Report section	Drinking Water Hazard/Contaminant	Possible Effects	Existing Preventative Measures/Barriers
	Physical		
2.2.1 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	Intake has 2 m clearance above the substrate
2.2.1 2.5.2 2.5.3	Seiche transport during storms	Intake is affected by surface water intrusions several times/year, increasing the risk of exposure to surface water chemical and biological contaminants	Intake depth at 22 m (elevation = 315 m) and is below the thermocline for most of the summer when Skaha Lake is busiest with boat traffic
2.5.1 2.5.4 2.5.5	Water currents	Water currents in Skaha Lake can carry contaminants at speeds in excess of 250 m/hr at the surface (slower at the intake depth)	Intake location below the thermocline where currents are 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 Skaha Lake • Contamination upstream in Okanagan River can affect intake during unstratified periods	• Intake below the thermocline through the summer
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	Water level of Skaha Lake is controlled, minimizing annual variation
	Chemical		
2.2.2 2.2.4 2.2.5 2.2.6 2.4.1 2.4.2	Stormwater	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.
2.4.1 2.4.2	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 Assessment Areas: 30 m from high water mark or ravine banks
2.4.1 2.4.3	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 2.3.5 2.4.1 2.5.1	Turbidity	Interferes with disinfection; generally low with occasional spikes	Increased chlorine, public notification
2.3.5 2.3.6	Taste/odor chemicals	Reduced aesthetic; periodic problem	Increase chlorination
2.2.7 2.4.1	Heavy metals and pesticides	Bioaccumulation through chronic exposure	Skaha Lake specific risks largely unknown; trend in Okanagan is decreasing levels of these contaminants
	Biological		
2.3.5 2.3.6	Cyanobacteria	Chronic low-dose exposure to cyanotoxin; health impacts vary with toxin type	Depth of intake; chlorination provides some protection
2.3.5	Algae blooms	Taste and odor events; impaired aesthetics; THM production during chlorination	Depth of intake; chlorination provides some protection
2.3.6	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 Skaha Lake, KID will being regular THM sampling in 2016
2.3.2	Viruses –pathogenic	Acute illness through water-borne exposure	Chlorination
2.3.2	Bacteria (*E. coli*, fecal)	Illness through water-borne exposure	Chlorination
2.3.1	Protozoa -pathogenic	Illness through water-borne exposure	-
2.3.12	Biofilm	Shields pathogens from disinfection, dislodged biofilm can clog filters	Cl residual; pipeline flushing twice per year and as required

3.0 Skaha Lake Intake Module 2 Contaminant Inventory

3.1 Anthropogenic Potential Water-Borne Hazards to Skaha Lake Intake

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

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. The intake is located below the summer thermocline and is protected from most surface contaminants during the stratified period. Seiches can push surface water down to the depth of the intake. Recreational boating predominantly occurs during the summer when Skaha Lake is stratified. This should insulate the intake 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. At 22 m the KID intake probably receives enough light to have algae growing directly on the screens. Skaha Lake receives organic carbon from the Penticton WWTP throughout the year but during the summer, the Okanagan River travels along the surface of the lake above the thermocline and is therefore isolated from the intake. Fall overturn mixes surface water throughout the water column and would affect an intake at any depth.

3.1.2 Inflows and Stormwater Outfalls

The Okanagan River is by far the largest inflow into Skaha Lake, accounting for 97% of the water that enters the lake. The Okanagan River also receives most of the City of Penticton’s stormwater and delivers it directly into Skaha Lake 7.2 km from the intake (Figure 3.1.2). The river is well outside of the IPZ but because of its volume this represents the largest potential impact to the intake.

Okanagan River receives untreated storm water drainage into the channel, as well as agricultural drainage from feed lots. Both Shingle and Ellis Creek report to the River and their watersheds have agriculture, feed lots, forestry, rangeland, and recreational activities that could be contributing sources of nutrients, sediments, microorganisms and other contaminants into Skaha Lake.

Two small creeks flow into Skaha Lake 1.5 km from the intake (Figure 3.1.2). Both creeks likely contain some untreated agricultural and residential stormwater. These represent microorganism and nutrient contaminant risks.

There are two stormwater outfall within the IPZ. One at the base of Lakehill Road (Section 2.4.1, Figures 2.5.5 and 3.1.1) and the other at the north end of Pioneer Park. There are also two road runoff channels near the intake and several stormwater outfalls in the south end of Skaha Lake. Stormwater is under the jurisdiction of MoT.

Figure 3.1.1: Land uses with potential to hazard water quality in the vicinity of the KID intake

Figure 3.1.2: Major rivers and creeks into Skaha Lake

3.1.3 Agriculture

Skaha Lake's watershed includes hundreds of hectares of agricultural development, dominated by grapes and tree fruit. These are a low risk type of agriculture that should not impact water quality. However, between Penticton Airport and Okanagan River, intense cattle ranching occurs that likely leaches nutrients and possibly other contaminants into the river and then into Skaha Lake (Section 2.4.2).

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 Okanagan system including Skaha Lake. Skaha Lake is ranked high on the main risk factors for a dreissenid mussel infestation (Table 3.1). Dissolved calcium levels in Skaha Lake are ideal for dreissenid mussels, and high bacteria and algae concentrations would provide ample food for the filter feeding mussels. Skaha 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 particularly appealing 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. Fortunately, the KID intake is already fitted with a chlorine line to the mouth of the pipe. Although the dose would likely increase if mussels invade Skaha Lake, at least no additional and expensive retro-fitting would be required. RDOS 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.

Table 3.1: Risk of zebra/quagga mussels to Skaha Lake (based on Mackie, 2010)

	Risk for Mussels				Skaha Lake
	High	Mod	Low	V Low	
Dissolved oxygen (mg/L)	8-10	6-8	4-6	< 4	8-10 (High)
Mean Summer Temperature (°C)	18 - 25	16 - 18	9-16	< 8 or >30	High
T-Calcium (mg/L)	25 - 125	20 - 25	9-20	< 9	33 (High)
pH	7.5 - 8.7	7.2 - 7.5	6.5 - 7.2	<6.5 or >9.0	7.9 (High)
Conductivity (µs/cm)	>83	37 - 82	22 - 36	< 22	273 (High)

3.1.5 Moorage, Docks, and Powerboat Recreation

Skaha Lake is an important recreational boating destination. Recreational boating increases the potential for petroleum and waste spills into a lake and the erosion from wakes. The seasonal nature of Skaha 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.

There are no marinas near the KID intake but the shoreline of Skaha Lake at Kaleden has numerous private docks and buoys and there is a public boat launch 500 m SW of the intake. This boat launch has a concrete ramp that was poorly designed, so boaters launch small craft on the natural shoreline adjacent to it. The approval process for private docks is not under the jurisdiction of the Kaleden Irrigation District nor the RDOS. Rather, it is through federal and provincial authorities, such as 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. While 1 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 one on water marine gas station at the Skaha Lake Marina in Penticton. This fuel station is 7 km from the intake and is very unlikely to impact the intake. Operators spilling fuel during refueling at a dock nearer to the intake have a greater potential to impact water quality. The depth of the intake and lake stratification makes summer petroleum spills a lower risk to the KID intake than greywater or sewage spills.

3.1.6 Septic Fields and Package Treatment Plants

Most shoreline residential in the Penticton urban area is connected to the municipal sewer system. At Kaleden all properties, including shoreline properties, are on septic systems. Please refer to section 2.4.1 for more information on septage.

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 low concern for the Skaha Lake intake because there are no properties with paved parking lots within the proposed IPZ.

Shoreline Properties

The RDOS OCP provides protection for riparian areas. Under section 14.3.2, Riparian Assessment Areas are all areas within 30 m of the high water mark. Development within a Riparian Assessment Area requires an environmental assessment. This is important protection if the shoreline gets re-developed because riparian buffer zones protect the shoreline from erosion and flooding, reduce the amount of runoff reaching the lake, and filter any runoff that does make it to Skaha Lake. There are no major industrial or commercial land uses within the proposed IPZ or along Skaha Lake near Kaleden.

There are multiple shoreline campgrounds along the shore of Skaha Lake near Kaleden. These sites have large septic systems that may leach nutrients into the Lake, particularly during the high use summer period.

There is ongoing development of land adjacent to the Penticton Channel and the upstream tributaries Shingle and Ellis Creeks. Skaha Lake has a short residency time and the Okanagan River at Penticton represents the vast majority of inflows to Skaha Lake. Anything that impairs water quality in the Okanagan River channel will affect Skaha Lake and therefore the KID intake. Unless an impact is very large it is unlikely to be detectable at the KID intake but watershed degradation can reduce water quality slowly over time.

Shoreline Disturbance and Land Use

The entire shoreline within the proposed IPZ and on either side of it is either developed or disturbed in some way. The overall level of shoreline disturbance around the intake is moderate. Nearly all riparian vegetation within the IPZ has been removed to facilitate development

Highway 97 runs above Skaha Lake along the west shore and Eastside Road runs along east shore. Highways and major roads are major sources of runoff. Neither of these roads should impact the intake directly but runoff, particularly from Eastside Road, will report directly to Skaha Lake. There is always some oil on a road from traffic but automobile accidents could result in fuel or other contaminants leaking into Skaha Lake as well.

Skaha Lake is in a steep valley and most of the suitable land along its shores have been developed. New growth will mean re-developing existing sites or developing more difficult sites. In general, development is to 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
- RDOS Area D-1 Official Community Plan (revised 2014)
- Sewerage System Standard Practice Manual

Natural Gas Line

There is a major natural gas main in Skaha Lake that runs only 300 m from the intake (Section 2.4.3). It is unlikely that this line would rupture. In the event that it did leak near the intake, the intake may need to be shut off until the leak is fixed.

Eastside Road

Eastside Road is a major road along the eastern shore of Skaha Lake. It runs directly along the shore of the Lake with little or no riparian buffer. It is 1.3 km from the intake at the closest point. This is well outside of the IPZ but the road is a major transit route for septic pumping trucks servicing houses along the east side of Skaha Lake. A crash involving a truck containing raw sewage occurred on October 26 2015. Fortunately, no raw sewage was released into the lake in that case.

3.1.8 Vandalism and Accidental Introductions

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

KID facilities have suffered multiple break-ins recently. Increased security should be deployed to deter would-be vandals.

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). Or they can migrate in from upstream lakes. They can attach themselves to intake structures and clog pipes. A boat was removed from Okanagan Lake in 2012 and one from Kalamalka Lake in 2013, and both had adult dreissenid mussels still attached. Testing revealed that all of the mussels on these boats were likely dead before they were launched into the lake but the scenario illustrates how vulnerable Okanagan lakes are to their introduction.

3.2 Natural Contaminants or Factors that Influence Susceptibility of Skaha Lake to Contamination

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

3.2.1 Flooding

Skaha Lake never experiences seasonal flooding because its inflow and outflow are controlled. The range between the high water mark at 338.02 m and the low water mark at 337.41 is only 0.61 m. However, the small creeks that flow into Skaha Lake can experience occasional flooding/ bank failures in their watersheds.

3.2.2 Landslides

The shoreline of Skaha Lake at Kaleden north and south of the intake is made up of sedimentary bluffs. These slopes are rated high for potential instability (Schleppe et al, 2008). Irrigation on the uphill side of these slopes can significantly increase the risk of a slope failure. A landslide into Skaha Lake would significantly impact the water quality at the intake.

3.2.3 Cyanobacteria and Algae Blooms

Skaha Lake is meso-oligotrophic and experiences spring algae blooms and winter cyanobacteria blooms. Occasionally, these blooms create noticeable taste and odor events and possible toxicity concerns. Blooms of algae increase the TOC concentration in a lake and that can increase THM production during water chlorination.

Cyanobacteria densities in Skaha Lake intakes commonly exceed the WHO and AWWA recommended guidelines of 2000 cells/mL (WHO, 1999). Nutrient enrichment upstream of Skaha Lake may push Skaha Lake to the point where cyanobacteria resume domination as they did in the 1970's (Nordin, 2005). Continuously improving wastewater technology is being counter-balanced by regional growth so that nutrient loads are beginning to climb again after decades of stability and decline (Section 2.2.5).

Cyanotoxins produced by cyanobacteria in Skaha Lake include a variety of neurotoxins and hepatotoxins (Table 2.3.2)

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) (Table 3.2).

Please refer to Section 2.3.5 for more information.

Table 3.2: Treatments effective in cyanotoxin removal or deactivation

Cyanotoxin	Chlorine	UV	GAC/PAC	DAF	Ozone
Aplisiatoxins				(Y)	
Microcystins	Y	Y	Y	(Y)	Y
Cylindrospermopsins	Y-by			(Y)	
Lipopolysaccharides				(Y)	
Anatoxins		(Y)	(Y)	(Y)	Y
Saxitoxins	(Y)		(Y)	(Y)	Y

Y=yes (Y)= partial removal Y-by = toxic by-products
GAC=Granular activated carbon; PAC= Powdered activated carbon; DAF= Dissolved air floatation

3.2.4 Shoreline Wildlife

Wildlife are less likely to introduce pathogens to a watershed than humans and their domestic animals (dogs, horses). 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 beaver and muskrat, are a greater concern than animals that do not live near the Skaha 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*. Recent studies, employing bacterial source tracking, have identified a higher proportion of wildlife contributors than originally thought. Based on studies (Graczyk et al., 2008; Quah et al., 2011, Zahedi et al., 2015), it appears that waterfowl can pick up infectious *Cryptosporidium* oocysts from their habitat and can carry and deposit them in the environment, including drinking water sources.

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 (Feng et al., 2007). 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). Rats have recently become problematic to some homeowners along the Kaleden waterfront (pers comm. Bruce Shephard).

Table 3.3 SUMMARY MODULE 2: Contaminant source inventory

Contaminant Source and Type	Owner/ Jurisdiction	Location	Distance to intake	Possible Contaminants	Contaminant Transport Mechanism	Comments
Inflows						
Creek plumes	n/a	Two creeks across the lake from the intake	1.4 km 1.5 km	Nutrients, bacteria, pathogens, PAHs, sediment, road salt, runoff	Currents Seiches	-Plumes diluted at intake -Main Impact during freshet during peak flows
Okanagan River	n/a	Upstream of Skaha Lake	7.2 km	Nutrients, bacteria pathogens, TOC, sediment	Wind Currents	Flows into epilimnion during summer
Flooding	n/a	Can occur throughout watershed	Many locations	Sediment, nutrients, pesticides, bacteria and pathogens	Currents	Skaha Lake itself cannot flood but watershed can experience flash flooding
Landslides	n/a	Can occur throughout watershed	>500 m, Many locations	Sediment, debris, nutrients, bacteria and pathogens	Wind Currents Fall overturn	Bluffs to the north and south of intake are rated as high risk of failure
Overland flow	n/a	many locations	Diffuse	Sediment, pathogens, fertilizers, pesticides	Currents	Only in storms or freshet
Sewage						
Septic fields	various	Various private properties	250 m +	Septage*	-subsurface seepage -septic failure during flooding	-All of Kaleden and Lakeshore Heights are on septic systems
Septic trucks	Various	Many locations	250 m +	Septage*	Wind Currents	At least one accident with a sewage truck in 2015 occurred on Eastside Rd.
Boat waste	Various	Throughout the lake	Many locations	Septage*	Currents, wind, seiches	Skaha is a popular boating destination
Storm Water						
Overland flow	RDOS, MoT	Many locations	>200 m	PAHs, salt, bacteria, pathogens, nutrients, sediment, accidental spills, pesticides	Currents Wind Seiches	Currently two outfalls within IPZ
Okanagan River	n/a	Upstream of Skaha Lake	7.2 km	Bacteria, pathogens, nutrients, sediment, accidental spills, salt, pesticides	Currents	Most of Penticton's stormwater ends up in this river

Contaminant Source and Type	**Owner/ Jurisdiction**	**Location**	**Distance to intake**	**Possible Contaminants**	**Contaminant Transport Mechanism**	**Comments**
Boating						
Motorboats	Various		n/a	PAHs, greywater, petroleum, aquatic invasive species, garbage	Currents, seiches, wind wakes	Very popular in Skaha Lake, causes wake erosion
Boat launches	RDOS	SW of intake	500 m	PAHs, petroleum, aquatic invasive species, sediment	currents	Boat launch was poorly designed and people use the sandy shoreline adjacent to concrete ramp
Houseboats	Various		n/a	PAHs, greywater, petroleum, aquatic invasive species, garbage, raw sewage,	Currents, seiches, wind	Not popular on Skaha Lake
Marinas and Boat Docks	Various	All along shoreline of Skaha Lake	200 m+	PAHs, greywater, petroleum, aquatic invasive species, garbage	Currents, wind	>5 docks within the IPZ but no marinas within 5 km of the intake
Land Use						
Beaches	RDOS	Kaleden Pioneer Park	380 m	Garbage, PAHs, nutrients, bacteria, pathogens, sediment	currents seiches	Relatively small beach, most shoreline is vegetated to some degree
Near-shore subdivisions	RDOS		200 m +	fertilizers pesticides PAHs spills	Currents, overland flow	Entire shoreline within IPZ is developed
Near-shore campgrounds	RDOS	N and S of intake	900 m +	Garbage, PAHs, nutrients, bacteria, pathogens, sediment	Currents, seiches, overland flow	Likely leach nutrients into lake during summer
Agriculture	OIB, RDOS	Throughout Okanagan River valley	500m +	Sediment, fertilizer, manure, bacteria, pathogens, pesticides,	Overland flow, flooding, currents, seiches	Skaha Lake is within an agriculturally impacted valley system.
Natural						
Waterfowl	BC	Near shore, docks	n/a	pathogens	Currents, falling vertically	Can carry antibiotic resistant E. coli
Cyanobacteria	BC	Throughout Skaha Lake	n/a	Cyanotoxins	Seiches, live naturally at intake depth	Often form blooms during the winter after fall overturn (Oct-Mar)
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	Frequent winter blooms

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 3.4 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			
Creek plumes	Nutrients, bacteria, pathogens, PAHs, sediment, road salt, runoff	Creeks are small and very low volume	-Riparian protection and restoration
Okanagan River	Nutrients, bacteria pathogens, TOC, sediment	None	-Enhanced riparian restoration -Reduce amount of untreated stormwater released to river and connected creeks -Move cattle ranching away from river, follow BMP's
Flooding	Sediment, nutrients, pesticides, bacteria and pathogens	Skaha Lake inflow and outflow are regulated	Riparian restoration in watershed
Landslides	Sediment, debris, nutrients, bacteria and pathogens	RDOS has identified high risk areas of Skaha Lake shoreline	-Riparian restoration and vegetation of at risk slopes -Avoid development and overwatering of these areas
Overland flow	Sediment, pathogens, fertilizers, pesticides	Chlorine disinfection	-Restrict fertilizer use on near shore properties -Discourage over-watering -Liaise with neighboring jurisdictions
Sewage			
Septic fields	Septage*	None	-Connect Kaleden and Lakeshore Highlands to Okanagan Falls WWTP
Septic trucks	Septage*	None	-Connect Kaleden and Lakeshore Highlands to WWTP
Boat Wastes	Septage*	None	-Have designated well publicized site for collecting boat sewage waste on land
Storm Water			
Overland flow	PAHs, salt, bacteria, pathogens, nutrients, sediment, accidents	-Open ditches collect stormwater	-Riparian restoration along Kaleden waterfront -Treatment wetlands at stormwater outfalls
Okanagan River	PAHs, salt, bacteria, pathogens, nutrients, sediment, accidental spills, groundwater	None	-Enhanced riparian restoration -Reduce amount of untreated stormwater released to river and connected creeks -Move cattle ranching away from river and oxbows
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 Skaha Lake -Encourage boaters to behave responsibly to protect drinking water source (Appendix 4) -Educate and encourage public reporting of polluters.
Boat launches	PAHs, petroleum, aquatic invasive species, sediment	-Signage at boat launches on invasive species -Clean Drain Dry signage -Launches are otherwise uncontrolled	-Increase monitoring/education at boat launches with summer students and encourage same with other local governments -Install boat cleaning stations and signage directing boaters to those sites -Modify Pioneer Park boat launch -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 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	District cleans beaches of garbage and large debris	-Restrict new marinas within Skaha Lake -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
Shoreline residential	Pesticides, fertilizers, nutrients, bacteria, sediment	-RDOS requires environmental assessment of any project that will be within 30 m of high water mark	-Encourage riparian protection and restoration -Restrict new docks and marinas within the proposed IPZ (refer to App 7 for proposed restrictions) -Restrict shoreline alterations -Cosmetic fertilizers and pesticides by-law
Near-shore subdivisions	fertilizers pesticides PAHs spills	-Standard development approval process but no aquatic protections required	-Ensure any future developments take potential effects on the lake seriously and adhere to BMP's -Require future developments to have on-site stormwater treatment and/or retention. -As much as possible reduce removal of covering vegetation when developing new properties -Require stripped vegetation to be re-planted right away to reduce upland invasive species through municipal bylaw -Ensure minimum 30 m riparian protection zones
Agriculture	Sediment, fertilizer, manure, bacteria, pathogens, pesticides,	None	-Increase size of vegetated riparian buffer zones between tilled or fertilized fields and waterways -Use fencing to keep livestock away from the Okanagan River and oxbow lakes
Natural			
Waterfowl	pathogens	None	-Install 75 cm tall fences and/or riparian vegetation 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 Skaha Lake -Encourage adjacent jurisdictions to do the same because most nutrients come from upstream of Skaha Lake
Wildlife	wildlife pathogens	Riparian buffers tat intercept surface runoff	Restore and increase riparian buffers, noting that these will not deter some animals and will encourage beaver and muskrat
Algae Blooms	Taste and odor, increased TOC, THMs,	-Emergency monitoring available as needed -Chlorination of Drinking water	-Reduce nutrient inputs into Skaha Lake -Encourage adjacent jurisdictions to do the same because most nutrients come upstream of Skaha Lake

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

4.0 Skaha 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 Skaha 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 Kaleden Irrigation District to react. Tables 4.2 and 4.3 summarize 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 KID intake is affected by the thermal conditions within Skaha 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 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, even in the summer, 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 Skaha Lake intake is currently at 22 m (elevation 315 m AMSL) and should experience regular seiches of varying intensity during the stratified seasons. It is therefore not immune 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. If a contaminant enters Skaha Lake that plunges to the deep water layer during the summer, it will be confined there and the potential dilution of the surface water layer volume will not be available.

During the late fall, and early spring, Skaha Lake is freely mixing. No thermal barrier protects the intake from buoyant contaminants, but more dilution is available. Ice cover is rare

Okanagan River inflow plume is important because it carries WWTP discharge and stormwater. The depth to which the Okanagan River plume sinks varies over the course of a year. The river plume enters the epilimnion during the stratified period and should float over the intake. During the winter the plume should enter the lake and spread throughout the water column.

Characterization Table: MODULE 7 Part 1:

Table 4.2: Risks with the potential to impact the KID intake

	Contaminant Source and Type	Liklie-hood	Consequ-ence	Risk	Inside IPZ?	Comments
	Inflows & Water Currents					
1	Sediment Resuspension	B	2	High	Yes	Intake has 2 m of clearance above sediments
2	Seiche transport during storms	A	2	High	Yes	Intake at 22 m and has 2 m of clearance above sediments
3	Okanagan River	A	3	Very High	No	Major inflow to Skaha Lake carries significant amounts of stormwater and treated sewage effluent from Penticton
4	Flooding	E	3	Moderate	No	Skaha Lake is controlled and very unlikely to flood. Watershed flooding is possible and could impact the intake
5	Landslides	C	4	Very High	Yes	Bluffs north and south of the intake are rated high for instability
6	Overland flow	C	2	Moderate	Yes	Kaleden is a low density area with large percentage of permeable ground to reduce water flow
7	Subsurface drainage, groundwater	B	1	Moderate	Yes	Stormwater infiltration in Kaleden should report to lake and could negatively impact water quality in Skaha Lake
	Sewage					
8	Septic fields	A	1	Moderate	Yes	Skaha Lake is surrounded by properties on septic fields
9	Septic trucks	A	2	High	No	Eastside Rd. is a major route for septic pumping trucks. One accident occurred on Oct 26 2015.
10	Yachts 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					
11	Runoff from roads and houses	A	2	High	Yes	Unlined ditches should allow stormwater to infiltrate before reaching Skaha Lake
12	Okanagan River	A	3	Very High	No	Major inflow to Skaha Lake carries significant amounts of stormwater and treated sewage effluent from Penticton
	Boating					
13	Waste, garbage spill	A	2	High	Yes	Depending on spill location and type, emergency response may be needed
14	Fuel spill	C	2	Moderate	Yes	Unlikely event with low impact expected when spill occurs during stratified period
15	Wake erosion	A	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
16	Introduce invasive species	B	5	Very High	Yes	Introduction of dreissenid mussels would be catastrophic to environment and local economy.
	Land Use					
17	Beaches	C	2	Moderate	Yes	Disease-carrier swims at beach or beach-goer releases contaminant. Numerous docks also create potential for chemical or petroleum spills
18	Shoreline residential	B	2	High	Yes	Storing hazardous materials near high water line should not occur; nearest is only 250 m away
19	Agriculture	C	3	High	No	Nearest agriculture is 500 m away and is low-risk tree fruits and vineyards, but along Shingle and Ellis Creeks, and around the oxbows along Okanagan River, intensive cattle ranching occurs that could affect Skaha Lake

	Contaminant Source and Type	Liklie-hood	Consequ-ence	Risk	Inside IPZ?	Comments
	Natural					
20	Waterfowl	A	1	Moderate	Yes	These birds can carry pathogens that are difficult to medically treat
21	Cyanobacteria	B	3	High	Yes	Chronic low-dose exposure to cyanotoxins >2000 cells/mL undesirable, blooms common during winter in Skaha Lake
22	Wildlife	D	2	Low	Yes	Many species can be carriers of *Cryptosporidium* and *Giardia*
23	Algae Blooms	B	3	High	Yes	Algae increase: TOC, THM precursors, taste and odor, chlorine consumption
	Other					
24	Vandalism	B	3	Mod	Yes	KID facilities have suffered multiple break-ins recently

4.1 Condition of Source

Skaha Lake provides good quality water throughout most of the year. Water quality deteriorates each fall after the lake overturns. Nutrients released into the hypolimnion during low oxygen conditions that form each summer fuel cyanobacteria blooms throughout the winter. The cyanobacteria blooms occasionally cause taste and odor problems at Kaleden.

4.2 Physical Integrity of Intake, Treatment and Distribution System

Disinfection is currently provided by chlorine gas addition to the raw Skaha Lake water. Contact time is achieved in the intake pipe and distribution system. Regular monitoring is conducted using automated equipment and by trained Kaleden Irrigation District 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.

The Kaleden Irrigation District flushes all parts of the distribution system twice a year and fully cleans storage reservoirs every three years.

4.3 Risk Assessment for Healthy and Health-compromised Individuals

On the whole, water quality from Skaha Lake is good 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. KID does not currently achieve the required 3-log removal of protozoan pathogens and the 4-log removal of viruses credits. Based on existing monitoring, the risk posed by bacteria, protozoa, and THMs is low.

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, the Kaleden Irrigation District extended their intake to 22 m depth in 2007. Extending shallow intakes to 20 m or deeper provides protection from most urban and agricultural impacts.

Intakes near 20 m are in the ideal depth range for Skaha Lake. Results from samples at 40 m or deeper were also good during the stratified period but extending an intake may not be justified because most of the cyanobacteria issues are anticipated during the unstratified period when the water column is circulating, making intake depth less relevant.

4.4.2 UV Water Disinfection

Skaha Lake is well suited for UV disinfection. Most UV systems are designed for 75% UV transmittance at the germicidal 254 nm wavelength. Skaha Lake averaged >85% transmittance according to KID records. UV disinfection is particularly effective against *Cryptosporidium* and *Giardia* oocysts. Adding UV disinfection to the existing chlorination plant would give dual disinfection required by IHA if KID decides to stay with a surface source and does not choose a GUDI well instead.

4.4.3 Water treatment plant

Adding a water treatment plant (e.g. membrane filtration, dissolved air-floatation) to the treatment train would increase water quality in the KID system. Water treatment plants can remove nearly all suspended material (algae cells, bacteria, protozoa, organic and inorganic particulates) and in turn reduce the amount of chlorine and/or UV required to disinfect the water.

4.5 Strengths, Weaknesses, Opportunities, and Threats Analysis

Table 4.3: Strengths, weaknesses, opportunities, and threats summary of the Kaleden Irrigation District Skaha Lake intake

Strengths	Weaknesses
▪ Rapid flushing (1.2 years) of Skaha Lake means potential contaminants don't last in the system ▪ Intake currently has 2 m clearance from sediments ▪ Intake below the thermocline most of the growing season (May – October) ▪ One marina, few docks, all distant from intake ▪ Extensive lake flooding unlikely ▪ SCADA system monitors flow, turbidity, and chlorine residual ▪ Chlorination commences at mouth of intake, protecting it from invasive mussels ▪ Water operators have appropriate training levels and training is on-going ▪ Appropriate IHA directed water quality monitoring is reported ▪ Up to 30 years of water quality and limnology records by MoE and others on Skaha Lk ▪ Kaleden Irrigation District has a WQ deviation response as a part of its emergency response plan ▪ OCP requires development in riparian areas to perform an environmental assessment ▪ Water quality suitable for UV disinfection ▪ Emergency response plan in place that can react to a spill within 2 hours	▪ High concentrations of cyanobacteria in winter that can create taste and odor problems and impair operation of water treatment systems ▪ Two stormwater outfalls within proposed IPZ ▪ Most stormwater from Penticton flows untreated into the Okanagan River and then into Skaha Lake ▪ Most shoreline properties are not connected to a municipal sewer service and have septic ▪ KID lacks control over activities near or in the proposed IPZ ▪ Recreational and shoreline development pressures are increasing ▪ No back-up water supply available ▪ Skaha Lake algae population often dominated by diatoms in the spring that would impair filtration efficacy without pretreatment ▪ *Cryptosporidium* and *Giardia* not monitored but unlikely to be a problem
Opportunities	**Threats**
▪ Apply for License of Occupation or other designation over Intake Protection Zone from Front Counter BC ▪ Establish IPZ zone in RDOS zoning by-law (see appendix 7) ▪ Encourage shoreline replanting & riparian restoration ▪ Old KVR rail line could be renovated as cycling path with riparian restoration ▪ Encourage infiltration and rainwater capture for all residences, commercial, and parking lots. ▪ Public Education about Skaha Lake as a water source (get help from NGO's) and include campaigns targeted at seasonal residents and tourists ▪ UV disinfection alongside chlorination would ensure dual disinfection ▪ KID is considering new water treatment options ▪ KID has land for upgraded water treatment plant	▪ Algae blooms after fall overturn can impair water quality and increase cost of chlorination ▪ Nutrient enrichment and degradation of watershed will encourage algae blooms and reduce water quality ▪ Increasing population pressures for lake recreation, particularly motorized craft ▪ Inadequate enforcement of recreation polluters (yachts) foreshore modification violations ▪ Introduction of invasive species would cause irreparable damage to Skaha Lake and to the Penticton/Kaleden economy ▪ Potential future in-lake sewer line south of Kaleden ▪ Stormwater outfalls near the intake ▪ Vandalism and break-ins at KID facilities ▪ Extension of Penticton sewage effluent pipe into Skaha Lake

5.0 Skaha Lake Intake Module 8: Recommendations

The summation of Modules 1, 2 and 7 led to the recommendations to protect source water quality at the Skaha Lake intake presented here as Module 8. All identified high-risk potential impacts to the KID 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. KID cannot act on each recommendation on its own and so the various players involved with realizing each recommendation are identified as stakeholders.

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. KID has no jurisdiction over its watershed, restricting their ability to protect their source water. Therefore, collaboration with regional districts 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 Kaleden Irrigation District 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
5, 6, 8, 10, 11, 13, 14, 15, 17, 18, 19	RDOS, KID, FLNRO, DFO, MoE	Enhanced protection of water source in vicinity of intake to provide 2 hours to respond to contamination entering the lake
Action 1	Consult with RDOS to have new zone created in RDOS OCP and/or zoning by-law for IPZ (See example zone with activity restriction ideas in Appendix 7)	
Action 2	In consultation with the province, apply to Front Counter BC for License of Occupation over the proposed IPZ and/or apply for a foreshore lease (may also provide authority over docks, that RDOS currently dos not have)	
Action 3	Erect signage at Kaleden waterfront and Pioneer Park boat launch indicating the location of the IPZ	
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	Endorse RDOS OCP protections against damaging developments along shoreline adjacent to IPZ, specifically those on or near the unstable bluffs north of Kaleden	

5.2.2 Potential for water treatment with UV disinfection

Risk	Stakeholders	Outcome Desired
1, 2, 8, 9, 10, 12, 17, 20, 22	KID	UV disinfection in conjunction with chlorine provides two treatment barriers and is effective against viruses, bacteria, and protozoan pathogens. It is suitable for KID based on water quality and algae samples.
Action 1	KID has obtained preliminary estimates of construction costs for UV treatment and it was found to be cost prohibitive in 2012. Other options are being pursued.	

5.2.3 Extend intake and increase clearance to ≥3 m above sediment

Risk	Stakeholders	Outcome Desired
1, 2	KID	Intakes with ≥3 m clearance from the sediment experience greatly reduced impacts from seiches (see section 2.2.1)
Action 1	If and when the intake is extended, consider increasing the intake clearance above sediment to ≥3 m, if future KID needs dictate.	

5.2.4 Protect against aquatic invasive species (AIS)

Risk	Stakeholders	Outcome Desired
16	All users of the lake	Prevent introduction of harmful aquatic invasive species such as, zebra and quagga mussels, into Skaha Lake (KID has Cl- to end of intake
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	
Action 2	Install signage at all boat launches within the district, particularly at the Skaha Lake boat launches, displaying types of invasive species to watch out for and the BMPs to follow to prevent their spread	
Action 3	Work with OBWB summer student program to put students at Skaha Lake boat launches and encourage the Province to expand their AIS initiatives	
Action 4	Ensure chlorine line on the intake is in good working order and can create a small plume around the opening of the intake (this is acceptable to DFO if mussels are detected)	

5.2.5 Reduce nutrient inputs to Skaha Lake

	Stakeholders	Outcome Desired
3, 4, 6, 7, 8, 11, 12, 18, 19, 21, 23	RDOS, City of Penticton, PIB, RDCO, City of Kelowna, FOTO, property owners	Decrease nutrient concentrations in Skaha Lake to reduce the intensity of algae blooms and concentration of potentially harmful cyanobacteria. This is an important issue for KID.
Action 1	Riparian restoration throughout the Skaha Lake watershed (e.g. Shingle Creek, McLean Creek) will reduce the amount of nutrients entering the lake. This involves multiple agencies	
Action 2	Endorse on-going improvements to Penticton WWTP to remove nutrients	
Action 3	Support RDOS on their plans to expand the sewer system to properties on Skaha Lake	
Action 4	Support RDOS and other initiatives to reduce amount of untreated stormwater entering Okanagan River at Penticton	
Action 5	Endorse new study of nutrient budget for Skaha Lake (last done by MoE in 2002)	

Action 6	Endorse investigation of potential impacts from extension of WWTP outfall into Skaha Lake or alternate technology. (triggered at 25 ML/day from WWTP)
Action 7	KID should work with RDOS to be well-informed on the proposed sewer for Kaleden, currently at the grant application stage.

5.2.6 Treat stormwater before releasing it into environment

Risk	Stakeholders	Outcome Desired
3, 6, 7, 11, 12, 18	RDOS, City of Penticton, PIB, MoT property owners	Reduction in volume of untreated stormwater entering Skaha Lake. Stormwater on areas within RDOS is under the jurisdiction of MoT
Action 1	KID should dialogue with RDOS on OCP policy statements on stormwater (subdivision servicing bylaw standards come from MoT) especially on developments near or within IPZ.	
Action 3	Encourage MoT to add stormwater detention ponds, soak-away zones and treatment systems to stormwater prior to outfalls flowing into Skaha Lake	

5.2.7 Reduce risk of slope failure at bluffs north and south of Kaleden

Risk	Stakeholders	Outcome Desired
5	RDOS, KID, PIB, property owners	Bluffs currently identified as high risk of failure would not collapse into Skaha Lake
Action 1	Educate property owners on nature of instability and activities that can accelerate erosion and slope instability (e.g. irrigation, construction, runoff) Vegetate slopes as possible to increase stability; Regularly monitor slopes for movement or changes	

5.2.8 Clean-up preparedness for contaminant spill

Risk	Stakeholders	Outcome Desired
3, 4, 6, 8, 9, 10, 13, 14	RDOS, KID, PIB, MoE, MoT, DFO	Preventing petroleum or pathogen contamination within IPZ
Action 1	RDOS, KID, and other partners co-operate to provide a clean-up kit for a petroleum hydrocarbon (gas/oil etc.) spill into Skaha Lake. It could be stored at the Fire Hall or Fire Boat and/or at the boat launches and marina. Spills should be reported and cleaned up in accordance with the Spill Reporting Regulation (B.C. Reg.263/90).	
Action 2	Review emergency response plan for <2 hr IPZ notification (Note that a 200 G fuel tank is located near the HWL at Ponderosa Point Resort)	
Action 3	Communicate emergency response plan to parties involved in response	

5.2.9 Improve riparian protection along Okanagan River and Skaha Lake

Risk	Stakeholders	Outcome Desired
3, 4, 5, 6, 8, 11, 12, 18, 19	RDOS, KID, City of Penticton, FOTO property owners	Improved riparian protection around Skaha Lake and along Okanagan River such that flooding, erosion, development impacts are reduced (RAR is provincial legislation)
Action 1	Encourage the RDOS and City of Penticton to work with lakeshore/streamside property owners and on the disputed lands to establish new and enhance existing riparian setbacks for the benefit of all, noting that they have limited jurisdiction and RAR 10-15-30m setbacks may be best approach – please refer to RDOS and City OCP policy statements for more information.	

5.2.10 Cyanobacteria decision tree

Risk	Stakeholders	Outcome Desired
21	KID	A decision tree for cyanobacteria blooms would benefit KID because this is the most frequently encountered potential toxin source and KID has no alternate water source.
Action 1	Note increase in musty taste and odor or turbidity or decreased chlorine residuals	
Action 2	Collect 1 liter algae sample and send to LAC or other qualified lab	
Action 3	If bloom is detected >2000 cells/mL of a toxin-producing species, increase chlorine dose and take THM sample, notify IHA who have microcystin detection kits available (actions 1-3 should take under 3 days to complete).	
Action 4	Notify IHA and post an advisory if >15,000 cells/mL of a toxin producer occur and take weekly microcystin-LR samples until cell counts drop below 15,000 cells/mL	
Action 5	If microcystin-LR test is positive, IHA may issue a do not touch warning for the water supply until bloom subsides	
Action 6	KID may wish to implement a routine cyanobacteria sampling program	

5.2.11 Work to educate the public on how to reduce impact of powerboating on intake

Risk	Stakeholders	Outcome Desired
13, 14, 15, 16	KID, RDOS, City of Penticton, lakeshore property owners within IPZ	Boating community would be aware of the intake and be invested in protecting water quality
Action 1	Encourage boaters to slow boats down near intake and the foreshore so wakes do not disturb sediment into intake	
Action 2	Educate public on the IPZ and how to behave within it (e.g., refueling and waste management BMPs)	
Action 3	Educate Skaha Lake boaters to: -watch for at-risk behaviors (illegal dumping of wastewater, garbage, etc.) -take invasive species threat seriously and to train their staff to spot contaminated boats and to refer that boat to Penticton decontamination station -Out of province boats should provide a certificate of AIS inspection before they are allowed to launch -educate staff and users that the drinking water intake is theirs as well and it is up to them to protect it -do not include a marine fueling station or allow on-water refueling within the IPZ -do not allow discharge of greywater within or near the marina, or in the IPZ and discourage on the entire lake	

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, 4, 6, 7, 11, 12, 18	RDOS, KID, City of Penticton, property owners	Reduce use of pesticides and their release into Skaha Lake
Action 1	Encourage individual property owners to adopt pesticide-free attitude	
Action 2	Encourage a by-law banning use of cosmetic pesticides in RDOS	
Action 3	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, 6, 8, 9, 10, 11, 12, 18, 19	RDOS, KID, City Penticton, MoE, RDCO, City of Kelowna, FLNRO, MoT, DFO, PIB	Much of the Skaha Lake watershed is out of RDOS's jurisdiction. Enhanced protections in greater Okanagan Lake watershed would improve water quality at the KID intake.
Action 1	Encourage neighboring jurisdictions within the Skaha Lake watershed to increase protections that would benefit water quality at Kaleden (e.g. riparian buffers along lake and tributaries, stormwater treatment)	

5.3.3 Information sharing

Risk	Stakeholders	Outcome Desired
2, 3, 4, 5, 6, 8, 9 , 10, 11, 12, 13, 14, 18, 19, 21, 23	RDOS, OBWB, KID, City Penticton, RDCO, MoE, FLNRO, MoT, DFO, PIB	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 Skaha Lake water. This information exchange could prevent duplication of effort, and provide faster answers to water quality issues especially regarding the value of intake depth.	

5.3.4 Monitor waterfowl usage near intake

Risk	Stakeholders	Outcome Desired
20	RDOS, KID	Reduction in waterfowl use of beach and water around KID intake
Action 1	Continue to monitor for waterfowl use around intake.	
Action 2	If waterfowl use becomes intense, consult with specialist, and encourage participation in the egg addling program	

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Personal Communications:

Randy Craig, AWWTP Supervisor, City of Penticton, January 2015.

Judi Ekkert Specialist Environmental Health Officer, April 2016

Bruce Shepherd, K.I.D. Board Member, TAC member, March 2016.

Appendix 1: Data Collected for Kaleden Irrigation District Intake Source Assessment

All data used in the formation of this report can be found in:
"KID Source Assessment Data Transfer File.xlsx"

Appendix 2: Filtration Exclusion

BC /Interior Health Drinking Water Regulatory Framework and CDWQG - Canadian Criteria for Exclusion of Filtration in Water Works Systems

There are several themes in common between the IHA and the Canadian criteria for filtration deferral or exclusion. These are relevant to water purveyors wishing to pursue a filtration exclusion or deferral.

BC /Interior Health Authority (IHA) Drinking Water Regulatory Framework

In 2006, the IHA developed the 4-3-2-1-0 treated drinking water objective based on the Drinking Water Protection Regulation. It stands for:

4. 4-log (99.99%) inactivation of viruses
3. 3-log (99.9%) inactivation of protozoa (*Giardia* and *Cryptosporidium*)
2. 2 independent disinfection treatment processes
1. <1 NTU turbidity
0. 0 total fecal coliform and *E. coli*

In February 2008, the IHA released an issue paper titled, "Planning for Drinking Water Filtration". <u>IHA now accepts proposals from water purveyors for filtration deferral or exclusion.</u> Not all water systems will meet the criteria. Candidate water purveyors must meet the 4-3-2-1-0 as well as the CDWQG filtration exclusion criteria (provided below). Their proposal must define their watershed control program and dual treatment processes. The IHA also requires supporting source monitoring data trended over a minimum of one year.

Canadian Drinking Water Quality Guidelines - Canadian Criteria for Exclusion of Filtration in Water Works Systems

Filtration of a surface water source or a groundwater source under the direct influence of surface water may not be necessary if *all* of the following conditions are met:

1. Overall inactivation is met using a minimum of two disinfectants:
    - ultraviolet irradiation or ozone to inactivate cysts/oocysts;
    - chlorine (free chlorine) to inactivate viruses; and
    - chlorine or chloramines to maintain a residual in the distribution system.

    Disinfection should reliably achieve at least a 99% (2-log) reduction of *Cryptosporidium* oocysts,* a 99.9% (3-log) reduction of *Giardia lamblia* cysts and a 99.99% (4-log) reduction of viruses. If mean source water cyst/oocyst levels are greater than 10/1000 L, more than 99% (2-log) reduction of *Cryptosporidium* oocysts and 99.9% (3-log) reduction of *Giardia lamblia* cysts should be achieved. Background levels for *Giardia lamblia* cysts and *Cryptosporidium* oocysts in the source water should be established by monitoring as described in the most recent "Protozoa" guideline document, or more frequently during periods of expected highest levels (e.g., during spring runoff or after heavy rainfall).

2. Prior to the point where the disinfectant is applied, the number of *Escherichia coli* bacteria in the source water does not exceed 20/100 mL (or, if *E. coli* data are not available, the number of total coliform bacteria does not exceed 100/100 mL) in at least 90% of the weekly samples from the previous 6 months.

3. Average daily source water turbidity levels measured at equal intervals (at least every 4 hours), immediately prior to where the disinfectant is applied, are around 1.0 NTU but do not exceed 5.0 NTU for more than 2 days in a 12-month period. Source water turbidity also does not show evidence of protecting microbiological contaminants.

4. A watershed control program (e.g., protected watershed, controlled discharges, etc.) is maintained that minimizes the potential for faecal contamination in the source water.
5. Expected average annual total tri-halomethanes at locations in the distribution system furthest from treatment should not exceed 0.100 mg/L.

Source:
http://www.hc-sc.gc.ca/ewh-semt/pubs/water-eau/turbidity/index-eng.php#33

Appendix 3: 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 businesess 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

WADING UP to his waist in Mill Creek near the entrance to Okanagan lake, an environmental remediation worker inspects and removes debris from the creek after hazardous chemicals from the Stewart Centre fire on Saturday night were 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 4: 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 5: 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 A5.1: 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 6: 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.

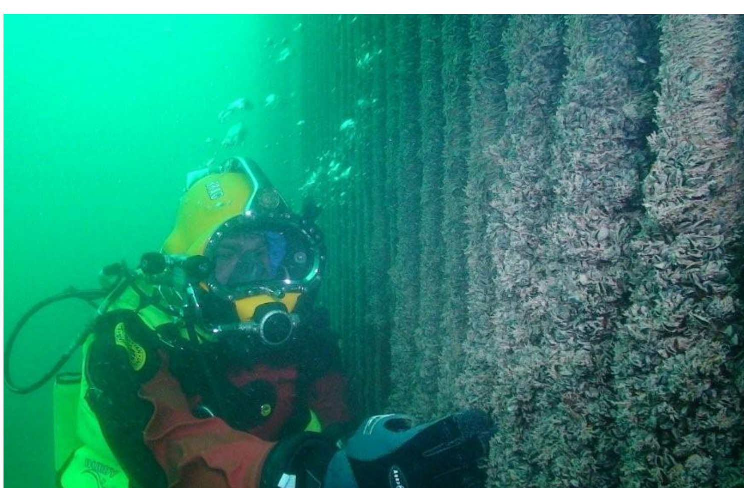
Research has shown that mussels shut their valves as soon as the detect chlorine and open only after chlorine dosing is stopped. Under continuous chlorination mussels are constrained to keep the shell valves shut and they starve. Zebra mussels subjected to continuous chlorination at 1-3 mg/L showed 100% 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 10^{o}C, compared to only 19 days at the same 0.50 mg/L chlorine dose but at a warmer 25^{o}C (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 7: Example of IPZ Zoning By-Law

Example Intake Protection Zone for Zoning By-Law

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

IPZ

1.1 IPZ - Intake Protection Zone

.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_____________