City of Kelowna – Okanagan Lake Intakes
Source Protection Report

May 2019

Prepared for City of Kelowna

Larratt Aquatic Consulting Ltd. 2605 Campbell Rd. West Kelowna B.C. V1Z 1T1
Phone: 250.769.5444 www.lakebiology.ca

Executive Summary

This report is a follow-up to the 2011 Source Assessment report (EBA, 2011) and provides additional information to support the Source Protection Plan (SPP) interactive spreadsheet. Some components of the prescribed source assessment framework were not included in the 2011 report, such as intake protection zones. This report seeks to complement the 2011 report and fulfill those components. Additional research and new developments since the 2011 report, including the 2017 and 2018 freshet floods, are also discussed and used to refine the risk ratings and recommendations from the 2011 report. As a final step, LAC used a remotely operated vehicle (ROV) to obtain clear images of the intake condition and clearance from the substrates.

Intake protection zones (IPZ) were developed for each of the intakes based on measuring water currents at each intake at different depths. The Eldorado IPZ was the largest at 33.9 ha while the Swick IPZ was the smallest at 8.2 ha. All of the IPZs were elongated along the shore based on the prevailing long-shore currents. The fastest currents measured were at Cedar Creek while Poplar Point had the slowest currents.

The intense freshets and flooding during 2017 and 2018 required a re-evaluation of risk levels established in the 2011 source assessment. Poor water quality within Okanagan Lake during both years required City of Kelowna to go on a water quality advisory. The plumes of Bear Creek, Mill Creek, and Mission Creek were observed traveling towards the Poplar Point intake and sampling during 2018 revealed a layer of turbid water directly above the intake. Bellevue Creek flows into Okanagan Lake close to the Eldorado intake and statistical analyses revealed that it regularly impacts the intake water quality. Varty Creek has a documented history of instability and impacts on the Swick intake. Watershed degradation is an ongoing concern and directly affects the City of Kelowna intakes.

Analysis of water quality data from the City of Kelowna and weather data revealed that Swick intake is affected by stormwater with elevated fecal bacteria counts during the winter but not the spring, summer, or fall. It also revealed that Eldorado intake is particularly vulnerable to seiches, sediment resuspension, and creek plumes travelling along the lake bottom. Poplar Point occasionally experiences an increase in turbidity and bacteria 2-3 days after a major rainfall event suggesting it takes this long for the Mill or Mission Creek plumes to reach that far north.

A ROV survey of the intakes commissioned in conjunction with this report revealed that low intake clearance is an issue for all of City of Kelowna's intakes. Poplar Point has only 1 m of clearance, the Eldorado intake is effectively on the bottom, while Swick and Cedar Creek have 1.5 m of clearance. Current best practices are for 2-3 m of clearance to protect intakes from sediment resuspension during seiches. Sediment at all four intakes was very easily resuspended.

All recommendations can be found in the Source Protection Plan interactive spreadsheet.

Report prepared by: Larratt Aquatic Consulting Ltd.

Jamie Self: H. B.Sc
Aquatic Biologist, R.P. Bio

Heather Larratt: H. B.Sc.
Aquatic Biologist, 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 City of Kelowna for accidental omissions or errors made in the preparation of this report. This report was prepared by LAC for the sole use of City of Kelowna. Any use by a third party requires the permission of City of Kelowna.

Table of Contents

1.1 Figures and Tables

1.0 Introduction

In 2011, City of Kelowna commissioned a source assessment report to be completed for their four Okanagan Lake domestic drinking water intakes (Figure 1-1, Table 1-1). The report focused only on modules 1,2, and 7 of the prescribed Source-to-Tap Assessment guidelines (Ministry of Healthy Living and Sport, 2010). Several important components of the guidance framework were not included in this report. City of Kelowna contracted LAC to complete these components in 2018 and to develop a Source Protection Plan. The 2011 source assessment identified 14 risks and made 14 recommendations, and these will be addressed in Sections 2.0 and 3.0 of this report.

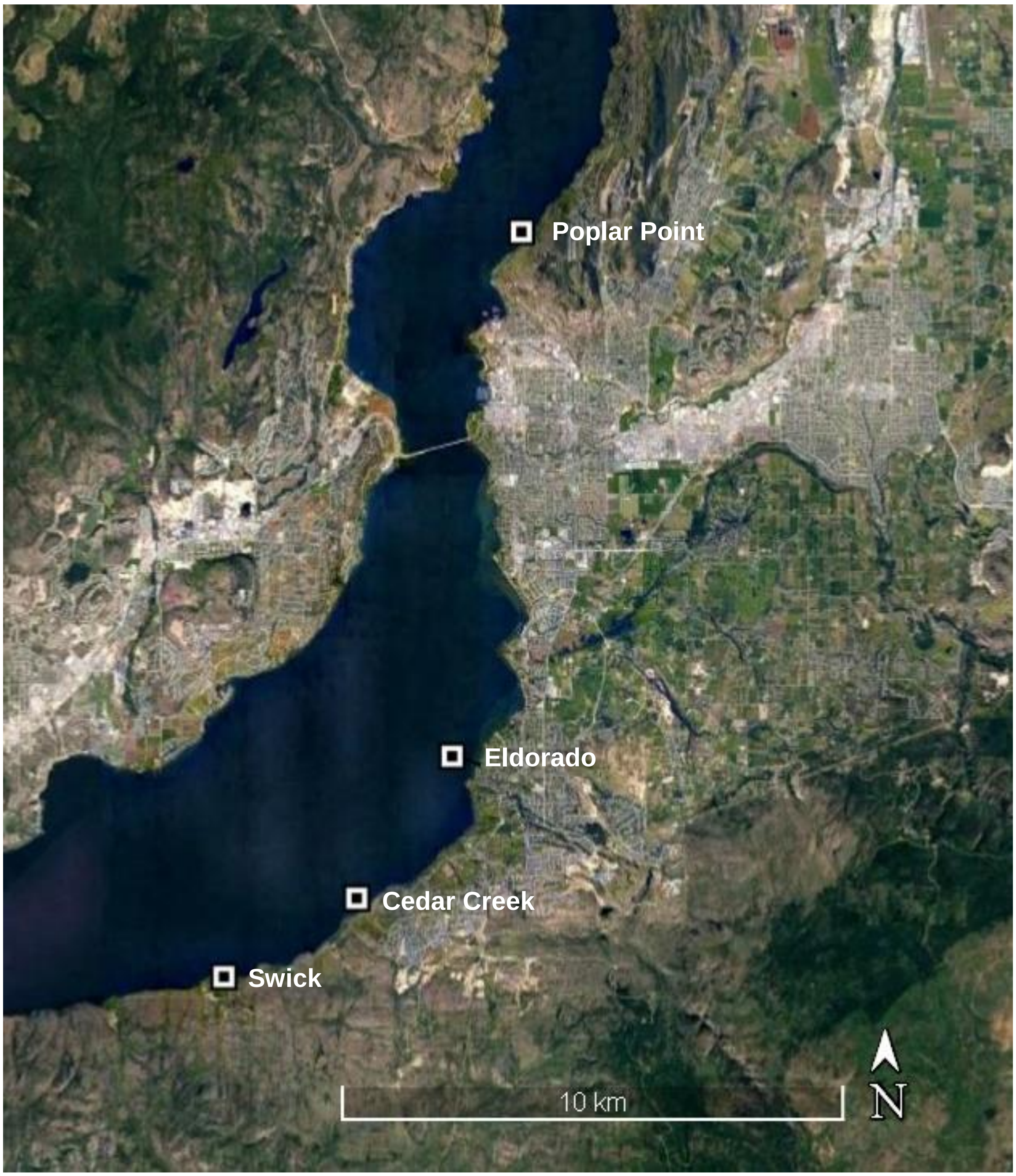

Figure 1-1: City of Kelowna Okanagan Lake intake locations

Table 1-1: City of Kelowna Okanagan Lake Intake Details

Intake /basin		Length m	Depth m	Capacity ML/day	Creek / outfall proximity within 7 km Km
Poplar Pt	N	155	25 (29)	181	2.6 km to Brandt's Ck; 1.9 km to Lambly; 6.3 km to KWWTP
Eldorado	C	488	14	43	2.1 km to Fascieux Ck; 4.1 km to Mission Ck; 4.1 km to KWWTP
Cedar	C	267	20	95	5.1 km to Mission Ck; 6.9 km to KWWTP
Swick	C	130	16	1.3	5.6 km to WWWTP

NOTE: all intakes are approximately 2 m above the lake sediments
N= North basin C= Central basin
KWWTP = Kelowna Wastewater Treatment Plant (Larratt, 2009; Hospital and Wang, 2011)
WWWTP = Westside Wastewater Treatment Plant

The 2011 *source assessment* report did not include the following components. These will be addressed in detail in this report.

- Proposed Intake Protection Zones
- Statistical analysis of water quality
- Strengths, weaknesses, opportunities, and threats (SWOT) analysis
- Risk management plans

As part of this project, LAC has also completed a Source Protection Plan. This Plan is intended to be a "living document" and is formatted as an interactive spreadsheet that allows City of Kelowna to update each action item as progress is made and to add new items over time. The Source Protection Plan is included as a stand-alone spreadsheet alongside this report.

2.0 Risks Identified in 2011 Source Assessment

The 2011 source assessment report (EBA, 2011) identified 14 major risks to City of Kelowna's Okanagan Lake drinking water intakes. These are listed in Table 2-1. New information and recent events since the original source assessment have affected the risk ratings for some of the risks identified. For example, the 2011 report identified only a moderate risk for the effect of sediment loading from forestry but flooding and major washouts during the 2017 and 2018 freshets caused by resource access roads resulted in poor water quality in Okanagan Lake and forced City of Kelowna to put on water quality advisories in both years. These watershed failures were documented in both the Mission Creek and Bear (Lambly) creek watersheds – the two largest tributaries to Okanagan Lake in the Kelowna vicinity (Figure 2-1). This changed the probability for these from C (possible) to B (likely) and the impact from 2 (minor) to 4 (major). The revised risk rating is now very high for both natural sediment loading and human caused sediment loading. Research conducted by LAC and Ecoscape on the impacts of boating to drinking water intakes revealed that power boating, particularly, wake-board/wake-surf boats can impact water intakes (Schelppe et al., 2016). The revised risk to City of Kelowna's intakes rose from low to moderate.

Figure 2-1: 2017 washout in Mission Creek watershed caused by a logging road culvert

Table 2-1: Risk Table for City of Kelowna Intakes

Risk Name	Probability	Consequence	Risk Rating	Revised Risk
Pathogenic Bacteria Inflows (C2)	C (Possible)	4 (major)	**Very High**	
Inflows of Cryptosporidium and Giardia (C1)	E (rare)	5 (catastrophic)	High	
Stormwater Contamination - First Flush (C3)	C (Possible)	3 (moderate)	High	
Stormwater Contamination - Fuel or Chemical Spill (C4)	D (Unlikely)	4 (major)	High	
Industrial Activities (C6)	E (rare)	4 (major)	High	
Sediment Loading - Natural Event (C8)	C (Possible)	3 (moderate)	High	**Very High**
KWWTF Plant Upset (W1)	E (rare)	4 (major)	High	
WRWTP Plant Upset (W2)	E (rare)	4 (major)	High	
Sediment Loading - Forestry and Recreational (C7)	C (Possible)	2 (minor)	Moderate	**Very High**
In-lake Algal Production - Cyanobacteria Contamination (L2)	C (Possible)	2 (minor)	Moderate	
Transportation Corridor Spill (S1)	D (Unlikely)	3 (moderate)	Moderate	
Agricultural Activities (Nutrients) (C5)	D (Unlikely)	1 (Insignificant)	Low	
In-lake Algal Production – Non-Cyanobacteria Contamination (L1)	D (Unlikely)	1 (Insignificant)	Low	
Boating Activities (S2)	E (rare)	2 (minor)	Low	Moderate

Note: The revised risk rating uses the same IHA-prescribed format as EBA 2011, but takes into account recent events such as the 2017 and 2018 freshet and flooding

3.0 Source Assessment Recommendations (2011)

The 2011 City of Kelowna Source Assessment contained 14 recommendations that can be found in SPP spreadsheet, Tab 5 ("Source Protection Plan"). These 14 recommendations are revised and updated below. They were incorporated into the 2018 Source Protection Plan along with several additional recommendations. Each recommendation, steps taken to date, its status, and future planned actions are documented in detail in the Source Protection Plan spreadsheet.

Table 3-1: Summary of Source Assessment Recommendations (revised in 2018)

Number	Recommendation from 2011 Source Assessment (EBA, 2011)	Risks Targeted	Class	Cumulative Risk	Action Steps
1	Conduct baseline sampling for Giardia and Cryptospordia as required by IHA Filtration Exclusion guidelines. Reommended sampling protocols can be found in 2011 report Associated Engineering, Section 4, Recommendation No. 5.	C1	Monitoring	High	Sample Giardia and Cryptosporidium regularly
2	Prepare a Source Water Protection Plan that explains the actions that the City currently implements to provide Source Water Protection in the urban context. Key components (EBA 2011) include: extensive water testing at source and in treated water; stormwater management infrastructure; plans to deepen water intakes; beach fecal coliform monitoring; investigation and repair of sewer cross-connections; incorporation of nutrient reducing processes and ultraviolet de-activation in sewage treatment plants. The City's Land Use Planning Department has recently completed Foreshore Inventory Mapping and Sensitive Habitat Inventory Mapping (SHIM-creeks). Wetland, Spring and Agricultural Ditch Mapping are currently underway (2011). A program to annually ground-truth high risk areas is under development.	All	Planning	Very High	Develop Source Protection Plan to document City of Kelowna's progress in addressing these recommends -Water testing -Stormwater management -Deepen intakes -Beach bacteria testing -check for cross connections -UV treatment at WWTP
3	Sediment control is key to water quality improvement because bacteria and protozoa can attach to sediment and migrate with them. Controlling sediments combined with monitoring of water turbidity and indicator bacteria can reduce bacteria migration into the lake and lower possible threats to the intakes. The City's 2011 plan for bacteria sampling includes monitoring at high risk storm outfalls where the flows currently are not contained for treatment by existing infrastructure.	C2, C3, C6, C7, C8, S2	Monitoring	Very High	Monitor suspended solids/turbidity in inflowing creeks and in Okanagan Lake; monitor bacteria in inflows including stormwater outfalls & creek plumes
4	A raw water bacteria or turbidity/suspended solids concentration above the defined level for more than two sampling periods, should trigger investigation of its source and mitigation where practical. The City's Water Quality Deviation Response Plan is being amended to include active monitoring triggered by elevated turbidity for immediate sampling at the mouths of Brandt Creek and Mill Creek. The City also installed conductivity meters in April 2011 at the Cedar and Poplar Point intakes, to function in a supportive manner to the turbidity–triggering protocol.	C2, C3, C6, C7, C8, S2	Planning Monitoring	Very High	Establish response plan for high bacteria/turbidity results Monitor mouths of Brandt's and Kelowna (Mill) creeks
5	Develop a response plan to assess bacteria/pathogen concentrations that develop along the Kelowna shoreline in summer, for instance at the mouths of Fascieux Creek and Brandt's Creek. There may be opportunities to reduce these contaminant levels through physical changes or public education, e.g., discourage feeding wildlife. The City searches our sewer cross-connection problems when bacterial levels at the creek mouths are in the 25,000 – 40,000 MPN/100 mL range. The City's existing Summary – Drinking Water Source Protection Plan includes beach, storm water and creek sampling. It will be amended to do 5 in 30-day sampling for the same period as water intake Cryptosporidium sampling.	C2, C3, C5, C6, C7, S2	Public Education	Very High	Develop Public Education on: Protecting Okanagan Lake as a drinking water source, and not feeding shoreline wildlife
6	The City monitors fecal coliform at four City beaches and other locations, and should continue this procedure. Currently, the City closes beaches if high coliform counts occur. The City should develop intake guidelines when near-shore coliform counts are high, particularly if there is a rainstorm (stormwater influx) or strong winds (seiche) and provide a warning to the treatment plants that higher fecal coliform counts at the intakes may develop. The City will monitor fecal coliform at Fascieux Creek during first flush events (anticipation 3-4 events per year) in 3-4 locations to determine if high fecal coliform counts (> 25,000 CFU) are frequent and have an identifiable source of contamination.	C2, C3, C6, C7, C8, S2	Monitoring	Very High	Establish cross communication with intake operators when high bacteria counts are detected somewhere that could reach them (i.e. creek mouth, stormwater outfall, etc). This should be part of the response plan identified in recommendation 4. Continue to sample fecal bacteria at beaches
7	A stormwater response plan should be developed that will deal with the elevated contaminants in storm water during the first flush stage. Again, the first step is to ensure that the treatment plant is aware that elevated contaminants may report to the City's intakes. The City will document rain events in association with first flush for Brandts and Mill creeks to determine if there is an association with deterioration of raw water intake quality during those events.	C3, C4	Planning Analysis	High	Develop a stormwater response plan Seek to manage first flush problems within stormwater system (e.g. more retention) Analyze correlation between storms and water quality at intakes

Number	Recommendation	Risks Targeted	Class	Cumulative Risk	Action Steps
8	Establish a management framework with other jurisdictions to develop a lake-wide program to reduce threats to the water system of any water purveyor drawing from Okanagan Lake. Modelling has demonstrated that contaminants that appear at the City's intakes could have come from areas outside the City's jurisdiction. Similarly, contaminants delivered by creeks within the City's jurisdiction could influence the intakes of other water purveyors. Thus, the City should work with other local governments and organizations such as the Southern Interior Regional Drinking Water Team to identify water quality threats and opportunities for improvements. Priority should be given to creeks with the potential to impact a water system, and on other intakes. The numerical modelling used in this study and the previous Hayco report (2001) has helped identify these creeks.	All	Interjurisdictional Cooperation	Very High	Work with other jurisdictions to manage entire lake system Identify problem sources of poor water quality that affect intakes
9	The City of Kelowna will review its Summary-Drinking Water Source Protection Plan annually to assure that it is consistent with the goal of Filtration Deferral. The City is also evaluating its watershed education programs (yellow fish program, adopt-a-stream and goose-waterfowl abatement) to ensure that Clean Water in our Watershed (Lake) messaging can once again become a priority.	All	Planning Public Education	High	Annually update SPP Watershed education programs/Public education for protecting Okanagan Lake and aquatic ecosystems (see recommendation 5)
10	Continue the present practice of having redundancy in the water intakes. If the July (2010) fire fighting incident had occurred in a period of winds from the north, and the sub-surface part of the contaminated water plume moved north towards Poplar Point, the Poplar Point plant could be shut down for a period. This recommendation presupposes that there would be a procedure in place to detect the type of contaminant involved.	All	Infrastructure Monitoring	Very High	Maintain redundancy in intakes Continue rigourous monitoring program to detect contaminants
11	Work with the BC Ministry of Agriculture to maximize the effectiveness of Best Management Practices for cattle to minimize the potential input of Cryptosporidium, E. coli and nutrients into the lake. For instance, Larratt (2010) found significant fecal coliform levels in Lambly Creek. A valid question would be whether improved management could reduce these levels. This is a question that the City should explore, within 2011, with other local governments and agencies such as the Southern Interior Regional Drinking Water Team.	C1, C2, C5	Interjurisdictional Cooperation	Very High	Lobby Ministry of Agriculture to improve/reduce range lands within watersheds that supply drinking water.
12	The configuration of the City's intakes in two separate basins should be retained, since the likelihood for simultaneous contamination of both basins is lower than the likelihood for contamination of a single basin. As presented in the simulations, when one intake receives contaminated water above the threshold, the other usually receives water that is less contaminated.	All	Infrastructure	High	Maintain redundancy in intakes (back-up water supply)
13	When contemplating any upgrades to intake facilities, ensure that consideration is given to extending the outfall to a deeper location.	C1, C2, C3, C4, C5, C6, C7, C8, L1, L2, S1, S2	Infrastructure	High	Conduct cost/benefit analysis of extending intakes intakes if infrastructure upgrades are planned
14	Above all, management practices must consider that while generally lake physics provides good dilution to reduce the risk from lake-borne contaminants, under some circumstances; these dilutions are quite low, of the order 480:1. Thus, contaminants released several kilometres from an intake can appear with fairly low dilution at a City intake. Public education is needed to ensure a mindset that the lake must be protected, since it is the source of drinking water for so many people.	C1, C2, C3, C4, C6, C7, C8, L1, L2, W1, W2, S1, S2	Monitoring	High	Continue regular monitoring programs. Engage in intensive sampling if unusual readings at any of the intakes are detected

4.0 Intake Protection Zones

The source assessment process identified potential risks to City of Kelowna's intakes. This process involved identifying sources of contamination, where contaminants are introduced into the lake, how currents and mixing within the lake affect where contaminants move through the lake, and specifically, their travel near a drinking water intake.

An intake protection zone (IPZ) defines the area where the intake should take precedence over every other use or consideration. It 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 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 Okanagan Lake. Nonetheless, a decision must be made on the acceptable time-safety factor that would give City of Kelowna reasonable time to react to an emergency such as a spill. The two-hour safety factor was used in the IPZ calculations in this report while a 5 hour buffer zone was also produced. 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 Okanagan Lake could theoretically impact a City of Kelowna 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 and finally into the entire area of concern – Okanagan Lake and its contributing watershed.

IHA recommend a minimum 100 m buffer zone around the intake. A 100 m circle would provide only 46 minutes of protection at Poplar Point and only 21 minutes of protection at Cedar Creek based on the fastest drogue recorded at each site (Table 4-1). 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.

Table 4-1: Intake Protection Zones Details

Intake	Depth (m)	100m Protection Time (mins)	Fastest Drogue (m/hr)	Fastest Drogue at Intake Depth (m/hr)	Area of proposed IPZ (ha)
Poplar Point	29	46	141	53	11.1
Eldorado	14	27	220	213	33.9
Cedar Creek	20	21	291	203	16.8
Swick	16	38	160	128	8.2

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). Water currents were fastest at Cedar Creek with a 5 m drogue travelling nearly 600 m in 2 hours while Poplar Point had the slowest currents measured (Table 4-1). The depth at Poplar Point provides added protection with the maximum speed measured at the intake depth (30 m drogue) of only 53 m/hr. The proposed IPZs are not perfect circles because the water currents around the intakes flowed more often towards one direction (Orange zones in Figure 4-1, Figure 4-3). The Eldorado IPZ is the largest at approximately 34 ha. However, the Eldorado intake pipe is over 500 m long and so the proposed IPZ lies >200 m offshore. The majority of the Cedar Creek IPZ also lies offshore but it is connected to shore at the mouth of a seasonal creek and boat launch. The flowing water from the creek and boating activity can move potential contaminants at greater speeds than simple water currents would suggest.

In addition to the proposed IPZs, a 5 hour buffer zone was also generated. These are cyan areas in Figure 4-1 to Figure 4-4. The 5 hr buffer should be considered as an area of high risk around the intake where land use can impact the intake but where a contaminant spill would not be an immediate threat to the intake.

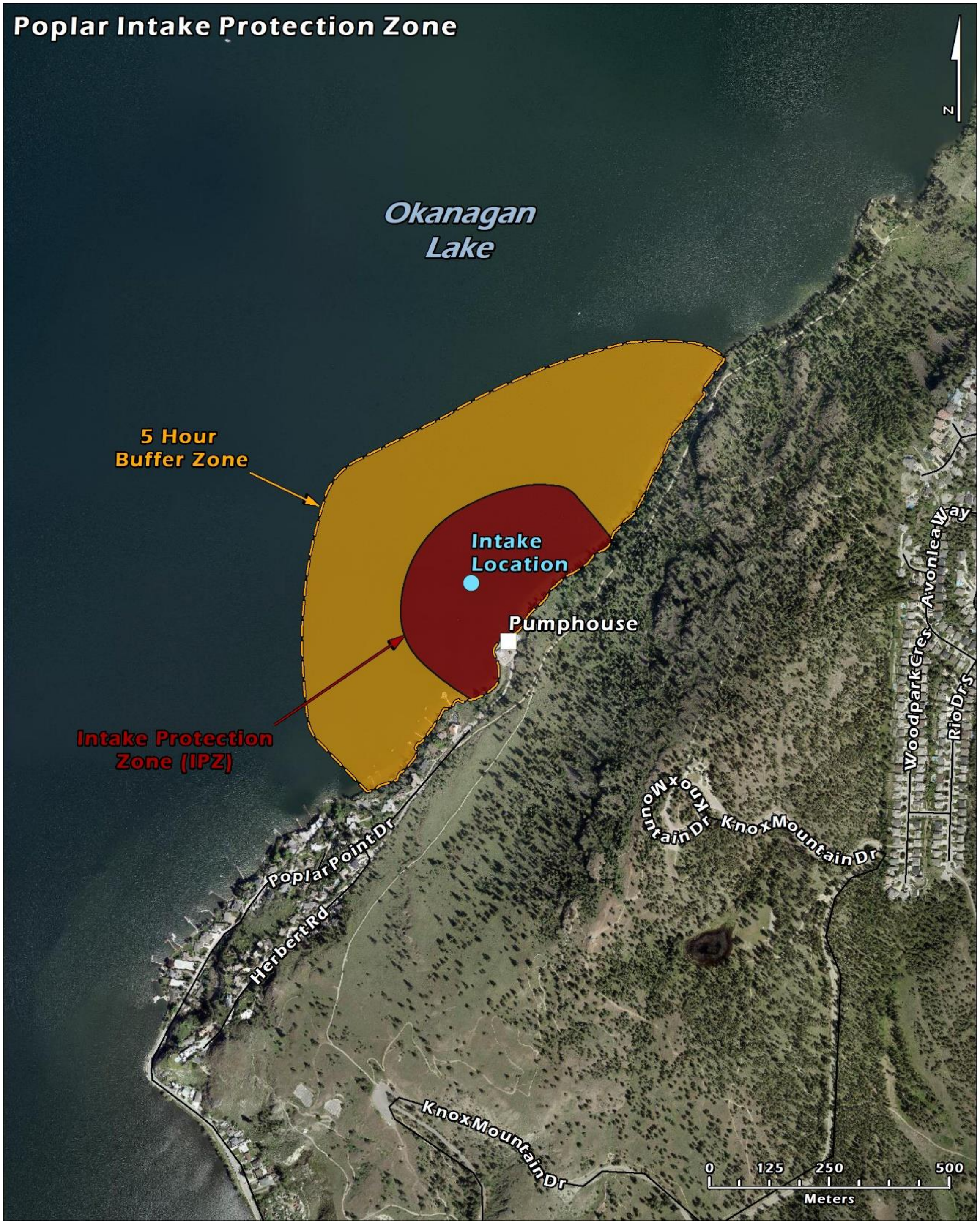

Figure 4-1: Proposed Poplar Point intake protection zones

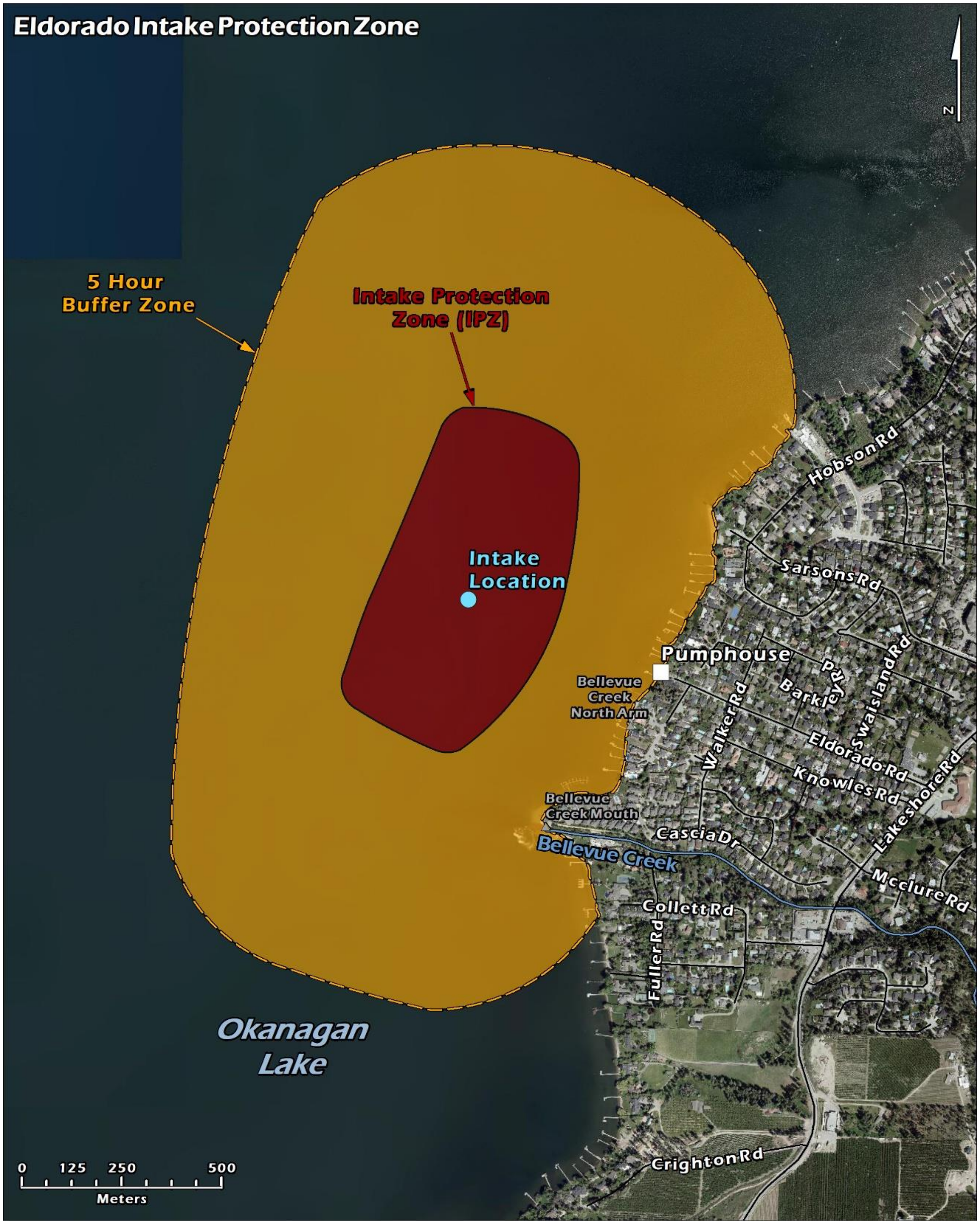

Figure 4-2: Proposed Eldorado intake protection zones

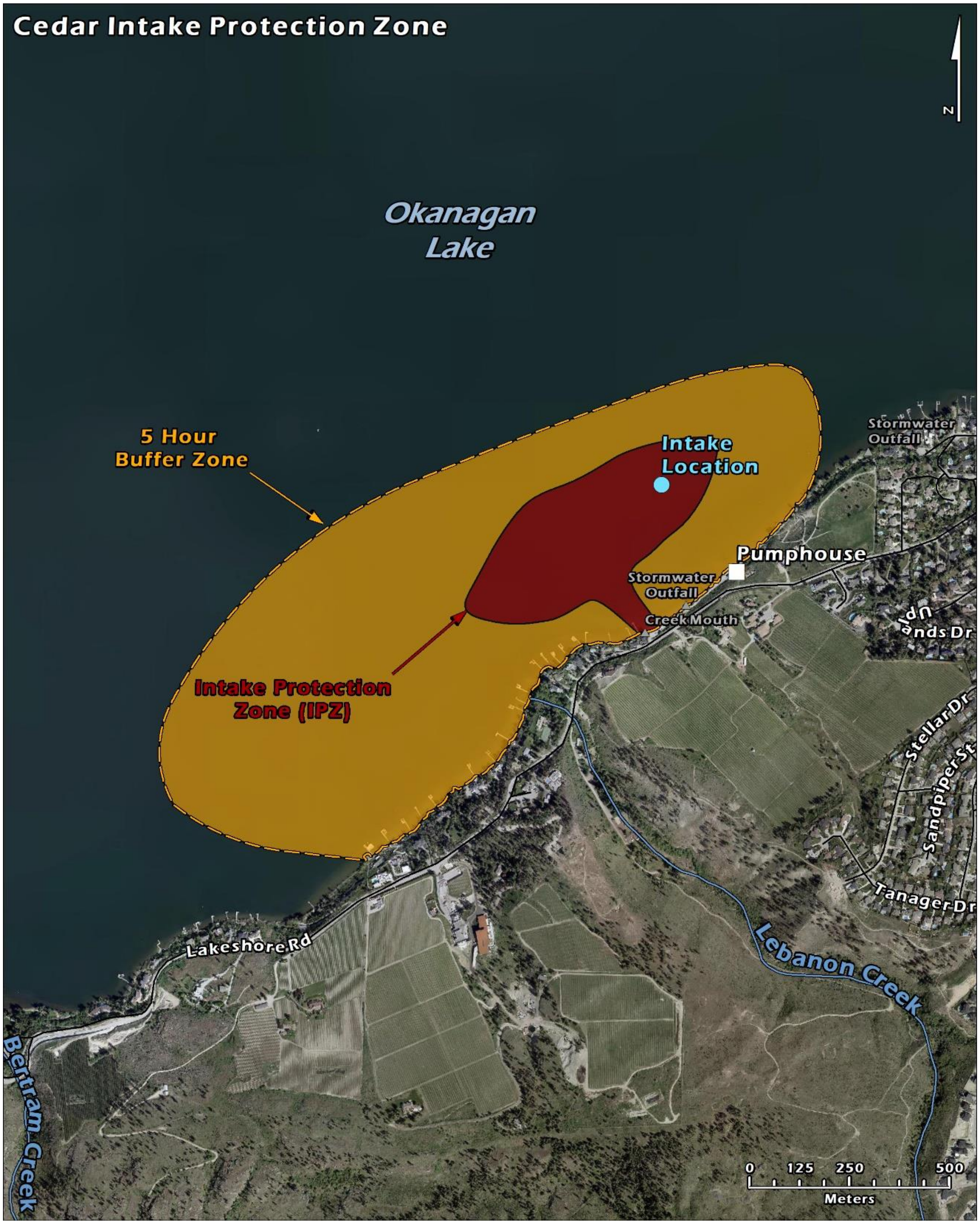

Figure 4-3: Proposed Cedar Creek intake protection zones

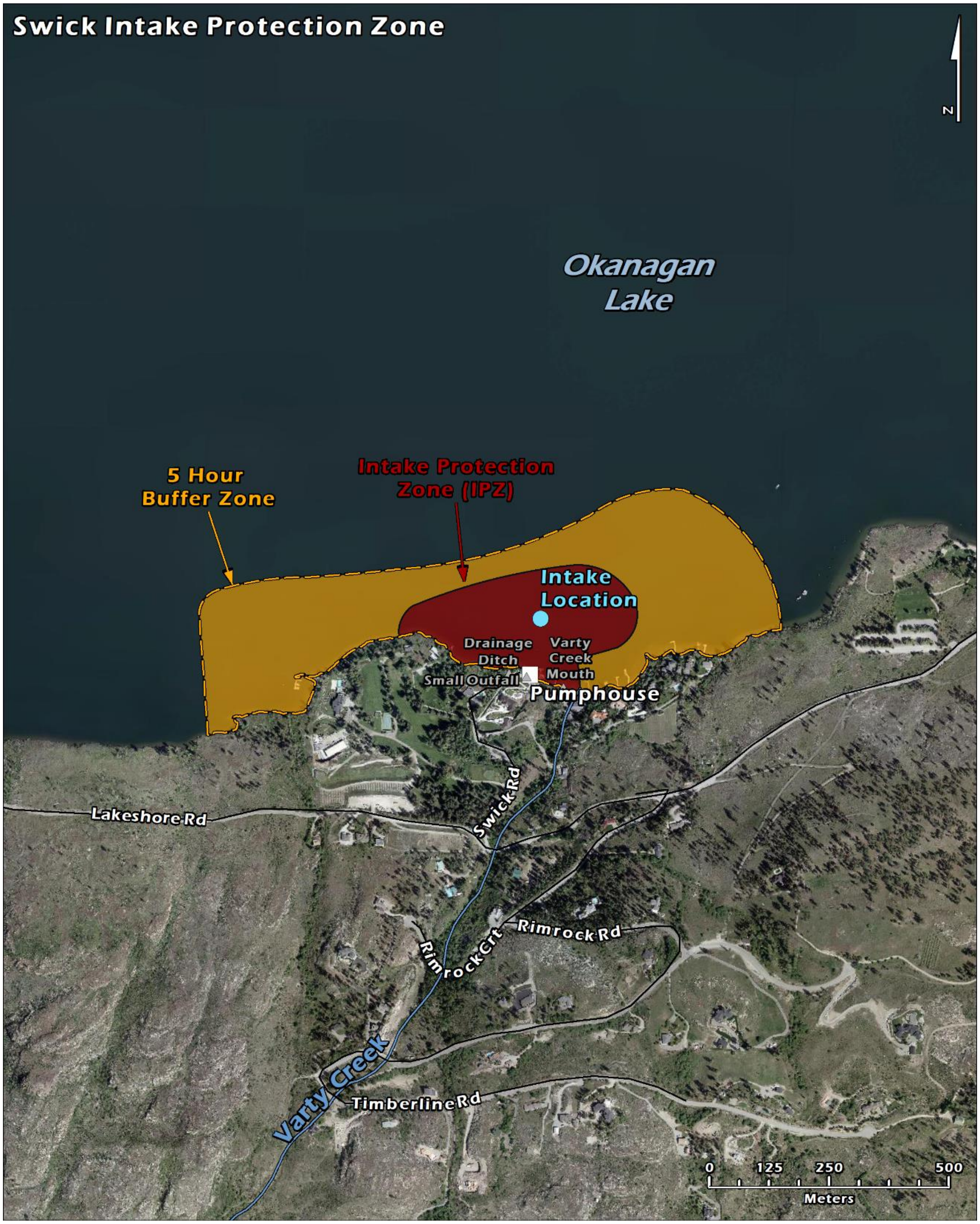

Figure 4-4: Proposed Swick intake protection zones

5.0 Freshet Plumes and Flooding

City of Kelowna's intakes and Okanagan Lake are vulnerable to the negative effects of a large freshet and resultant flooding. The 2017 and 2018 freshets were exceptional in their intensity, duration, and the amount of suspended sediment that was delivered to Okanagan Lake. Additional monitoring conducted by LAC for City of Kelowna revealed that turbid creek plumes will affect water quality at the intakes in both years (LAC, 2017). In the 2011 source assessment report, sediment loading was considered a relatively minor risk to the intakes but the large freshets of 2017 and 2018 and associated flooding caused landslides within several local watersheds, resulting in increased turbidity within Okanagan Lake. Shoreline flooding saturated current and abandoned septic fields. Water pumped from properties with a flooded septic field contained elevated *E.coli* concentrations based on LAC sampling. Nearly all water suppliers that use Okanagan Lake water had to put Water Quality Advisories and/or Boil Water Advisories on during 2018 because of a significant reduction in water quality.

Table 5-1: Creeks that negatively impacted intakes during 2017 and 2018

Intake	Creeks that affected a CoK intake
Poplar Point	Bear Creek, Brandt's Creek, Mill Creek, Mission Creek
Eldorado	Bellevue Creek, Mission Creek
Cedar Creek	Unnamed creek by boat launch
Swick	Varty Creek

5.1 Mill (Kelowna) Creek

Sampling in May 2017 revealed that the Mill Creek freshet plume is buoyant and can be deflected by the bridge to the south despite prevailing northward currents along the Kelowna lakeshore (Figure 5-1, Figure 5-2). Sampling in May 2018 revealed a submerged plume of highly turbid (>10 NTU) water at 10 m that had travelled as far north as the Poplar Point intake. This turbid water layer was likely a combination of Mill Creek, Mission Creek, and to a lesser extent Brandt's Creek plumes moving northward with the longshore currents at the depth that corresponded to the inflowing water density. Despite the large distances between the creek mouths and the intake (5 km for Mill Creek and 9 km for Mission Creek), the plumes travelled north past Poplar Point. This effect was highlighted in recommendation #14 in Table 3-1.

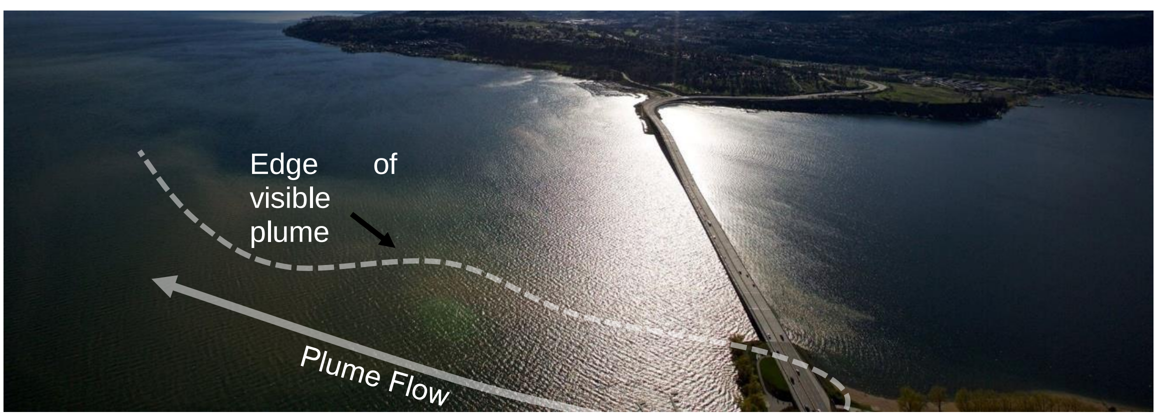

Figure 5-1: Mill Creek plume flowing south as seen from the air on May 6, 2017
Photo by Kelowna Now News

Figure 5-2: Mill Creek plume observed flowing north across Kelowna waterfront on May 8, 2017

Photo courtesy of Castanet News

5.2 Bear Creek

Bear Creek is the third largest tributary of Okanagan Lake and flows into the lake directly across from the Poplar Point intake (1.7 km from creek mouth to intake, Figure 5-3). Typically the Bear Creek plume enters Okanagan Lake and travels northward along the west shore of Okanagan Lake. However, during the intense 2017 freshet, the plume was observed travelling out into the middle of the lake to the north of the Poplar Point intake (Figure 5-3). A change to wind from the north could have pushed the plume directly over the Poplar Point intake. Even if the plume was travelling many meters above the intake depth, fine sediment and associated bacteria would drop out of the plume and gradually descend to the intake depth.

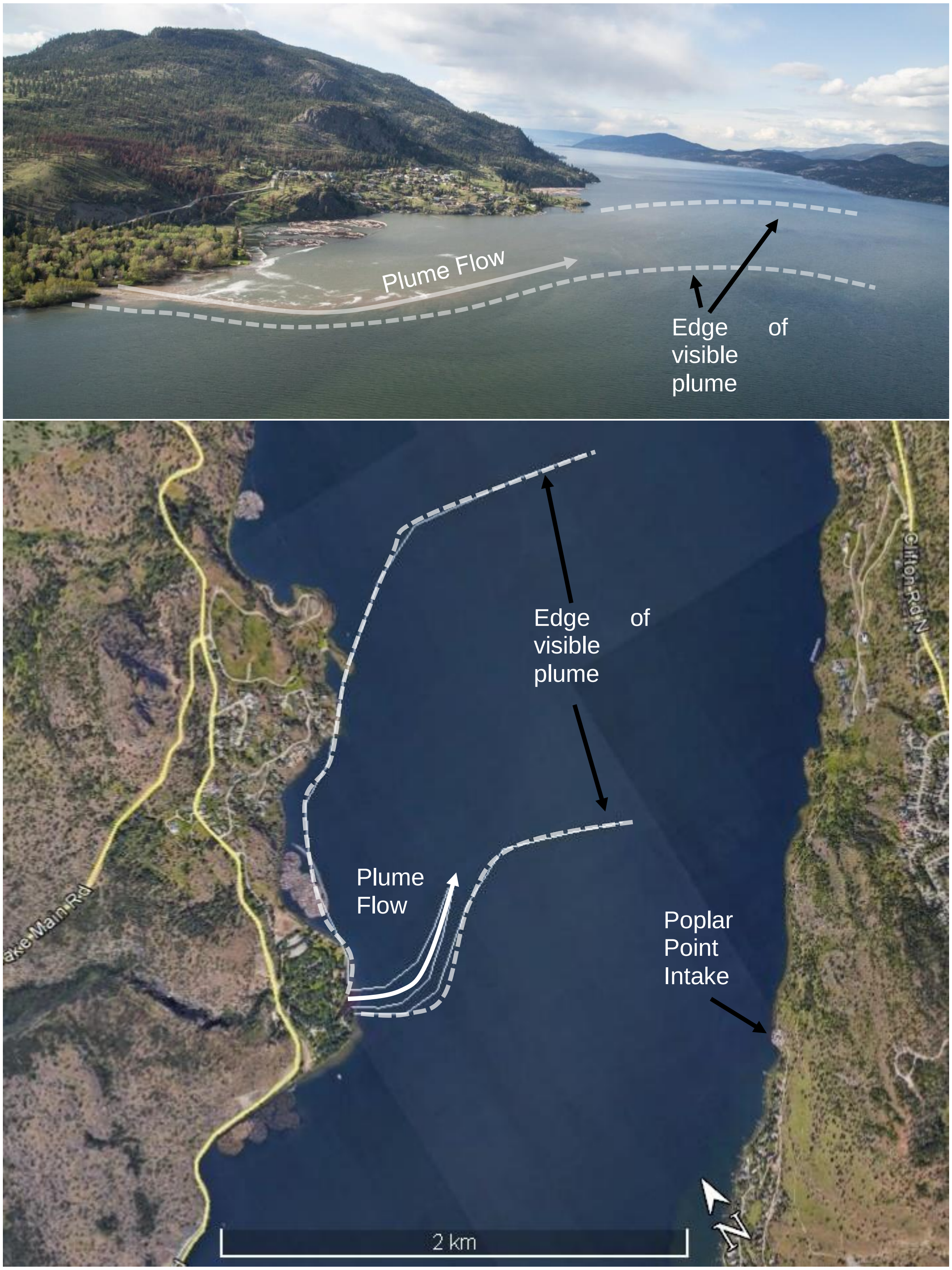

Figure 5-3: Aerial photo of Bear Creek plume on May 6, 2017 (top) and map interpretation (bottom)

Note: Top photo by Kelowna Now News

5.3 Mission Creek

Mission Creek is the largest tributary to Okanagan Lake, providing approximately 1/3 of the total annual inflows (Nordin, 2005). The mouth of Mission Creek is 2 km north of the Eldorado Intake. There have been several major landslides within the Mission Creek watershed in recent years that have impacted water quality in Okanagan Lake, including 2017 and 2018 (Figure 5-4). Fortunately, the Mission Creek plume typically travels northward along the Kelowna foreshore, carried by longshore currents. This causes issues for the Cook Road boat launch which must be regularly dredged but is of a lower concern to the Eldorado intake. However, the size of Mission Creek does mean it should always be carefully monitored. A large plume as occurred on May 6, 2017 in conjunction with a strong wind from the north could easily push the plume towards the Eldorado intake.

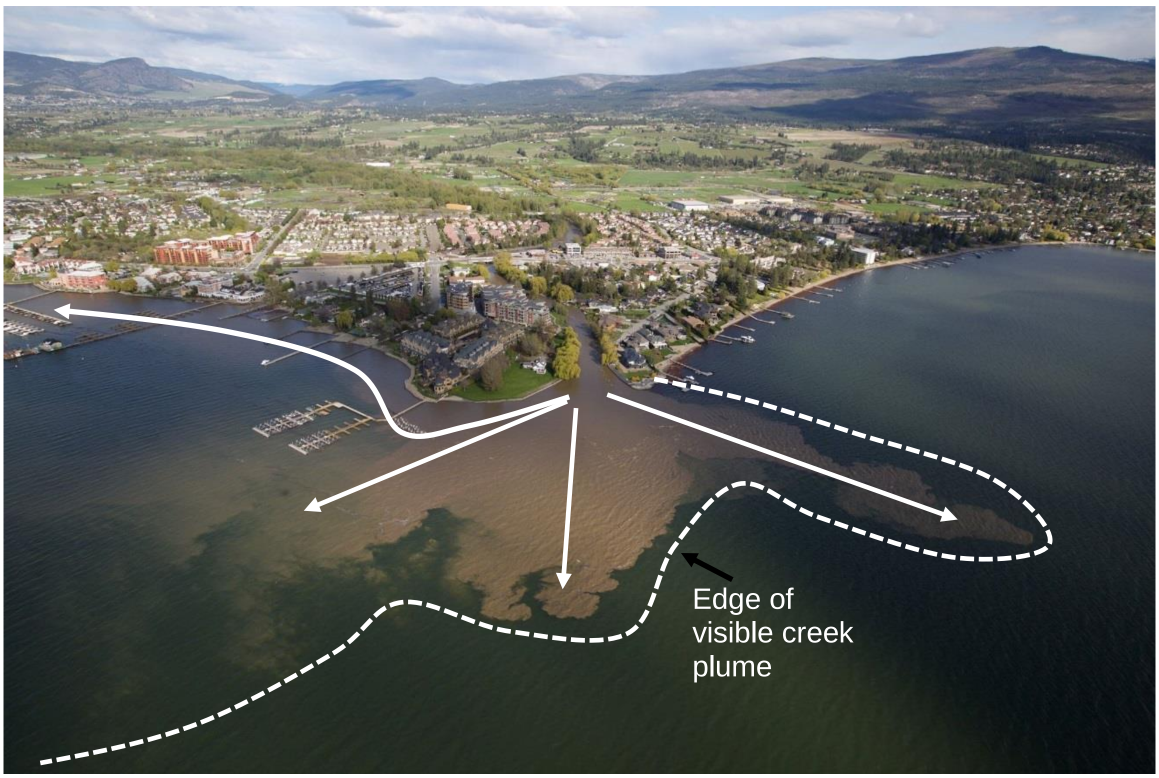

Figure 5-4: Mission Creek plume on May 6, 2017 following major landslide in upper watershed

Note: Photo by Kelowna Now News

5.4 Bellevue Creek

Bellevue Creek is a smaller creek that flows into Okanagan Lake only 650 m south of the Eldorado intake (Figure 4-1, Figure 5-5). Bellevue Creek is a major stormwater conduit for City of Kelowna and the prevailing longshore currents direct its plume towards the intake. On May 6, 2017 a major plume was observed entering Okanagan Lake and heading directly towards the intake (Figure 5-5). The Eldorado intake is relatively shallow (14 m at full pool) and is likely affected by the Bellevue Creek plume, particularly during freshet. Fortunately, spring is a low demand period and City of Kelowna can shut off the Eldorado intake to avoid freshet impacts.

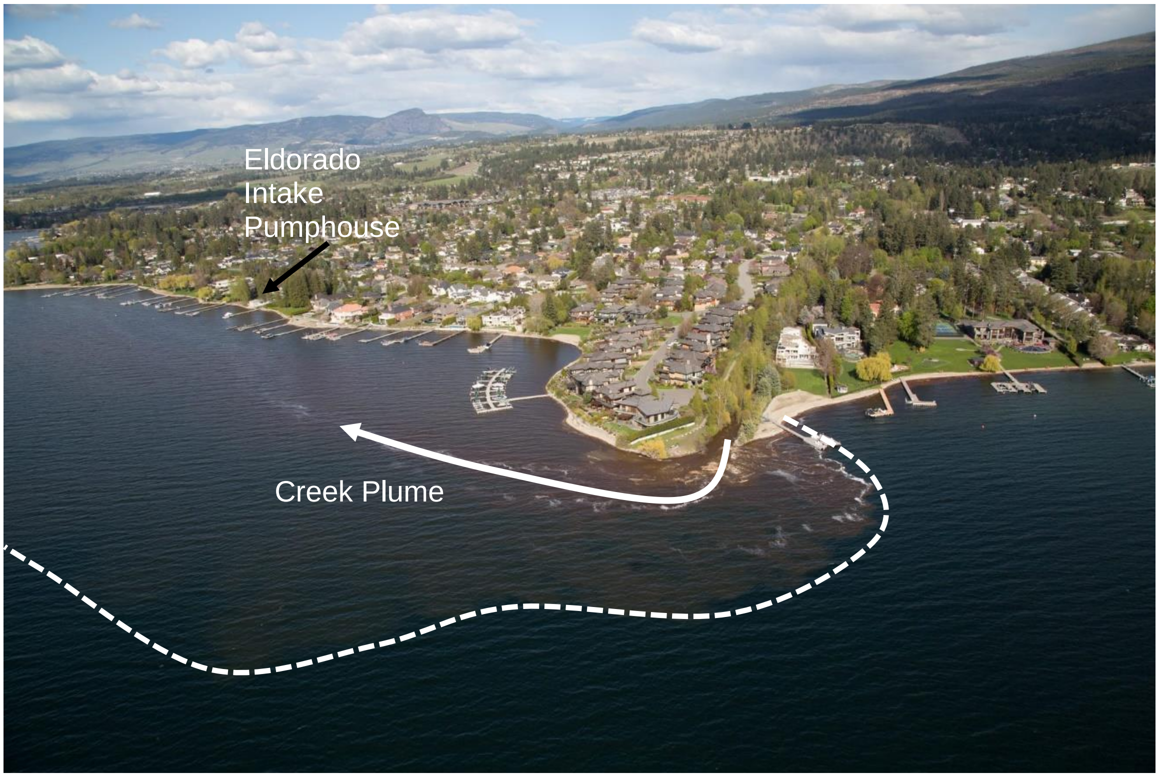

Figure 5-5: Bellevue Creek plume on May 6, 2017
Note: Photo by Kelowna Now News

5.5 Varty Creek

Varty Creek is a small creek that flows into Okanagan Lake adjacent to the Swick Intake (Figure 4-3, Figure 5-6). In March 2017, a storm triggered a landslide below a new development along Varty Creek (Figure 6-3). The debris flow negatively affected the intake for several days and permanently altered the shoreline (Figure 5-6). The proximity of Varty Creek to the intake, with its documented history of watershed instability, presents an ongoing risk to the Swick Intake.

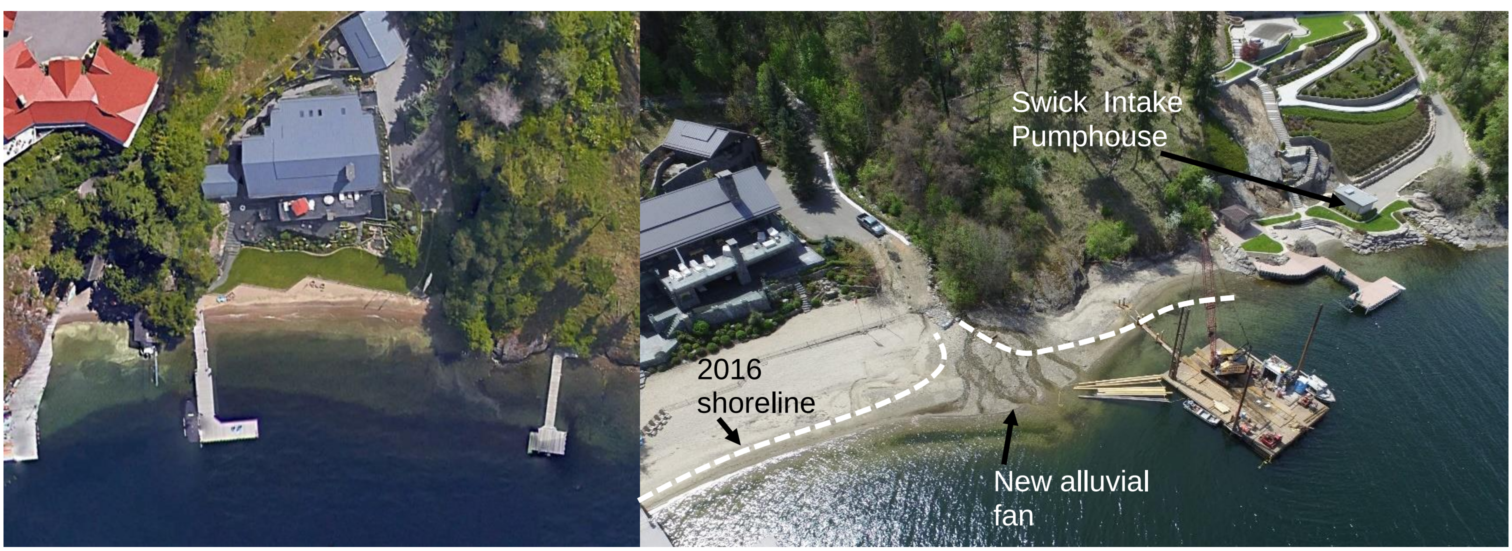

Figure 5-6: Varty Creek mouth, before (2015) and after 2017 landslide

5.6 Cedar Creek Stormwater

The Cedar Creek intake is not close to any main creeks but there is a small creek that receives stormwater and flows into the Lake 370m south of the intake (Figure 5-7). This is the only stormwater discharge within the proposed IPZ for Cedar Creek. There are two other stormwater outfalls within 500 m of the intake (Figure 4-3). Water currents at Cedar Creek reduce the likelihood of these other stormwater outfalls affecting the intake within 2 hours but do not eliminate the risk.

Figure 5-7: Creek with stormwater flowing into Okanagan Lake at Cedar Creek intake, May 4, 2018

6.0 Statistical Analysis

Mapping data and modeling by Hayco (EBA,2011) suggest strongly that City of Kelowna intakes can be negatively impacted by creeks and stormwater. Raw water data from City of Kelowna, weather data (temperature, precipitation) and Mission Creek flow data (a proxy for all creeks in Kelowna) were analyzed to support the modeling and mapping data.

Bacteria results did not correlate well with creek flow and precipitation data but did weakly match temperature data using standard correlation calculations ($R<0.35$). This is a common natural trend because bacteria grow better in warmer water and doesn't necessarily indicate contamination. However, closer examination of the data revealed that Poplar Point experienced spikes in *E.coli* 2-3 days after rain events in 2016, 2017, and 2018, suggesting that a creek plume (possibly Mission and/or Mill Creek) had taken that long to reach the intake. The highest *E.coli* counts at Poplar Point were a low 9 CFU/100mL on May 29, 2018.

At Cedar Creek and Eldorado intakes, *E.coli* peaked at 16 CFU/100mL and 6 CFU/100mL respectively. All three intakes averaged <1 CFU/100mL from 2016-2018. These are all very good results and do not indicate that fecal contamination is an issue at any of these intakes. Swick, however, appears to experience pulses of *E.coli* during the winter months. These *E.coli* pulses do not correspond with increases in turbidity but almost always follow a precipitation event such as rain on snow, suggesting that stormwater is reaching the intake. Interestingly though, *E.coli* results were typically non-detect during the spring-fall period even though stormwater would still presumably be entering the lake at the same sites. Elevated *E.coli* during the winter is unusual and suggest that winter stormwater in the area is frequently contaminated with feces (Figure 6-1). It is probable that Varty Creek is the vector for these bacteria.

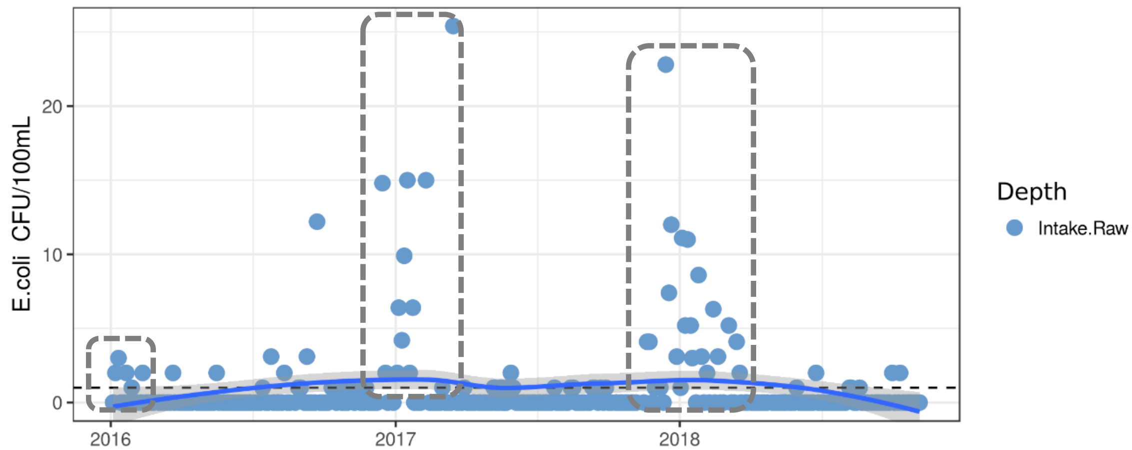

Figure 6-1: E.coli counts in Swick intake raw water, 2016-2018
Note: winter pulses of *E.coli* highlighted

Turbidity at Poplar Point was least affected by creek flow and weather with a correlation coefficient of effectively 0. This is because Poplar Point is farthest from a creek (Bear Creek does not typically flow across the lake) and from stormwater outfalls, and it is also the deepest intake. Turbidity still demonstrated seasonal variability with higher values during freshet (Figure 6-2). Eldorado was highly affected by creek flow (likely from Bellevue Creek) with a correlation of R=0.59 and frequently exceeded 1.0 NTU, often after rainfall events (Figure 6-3). Swick and Cedar Creek were also affected by creeks (R=0.53 and R=0.55 respectively). These data confirm the Hayco model results.

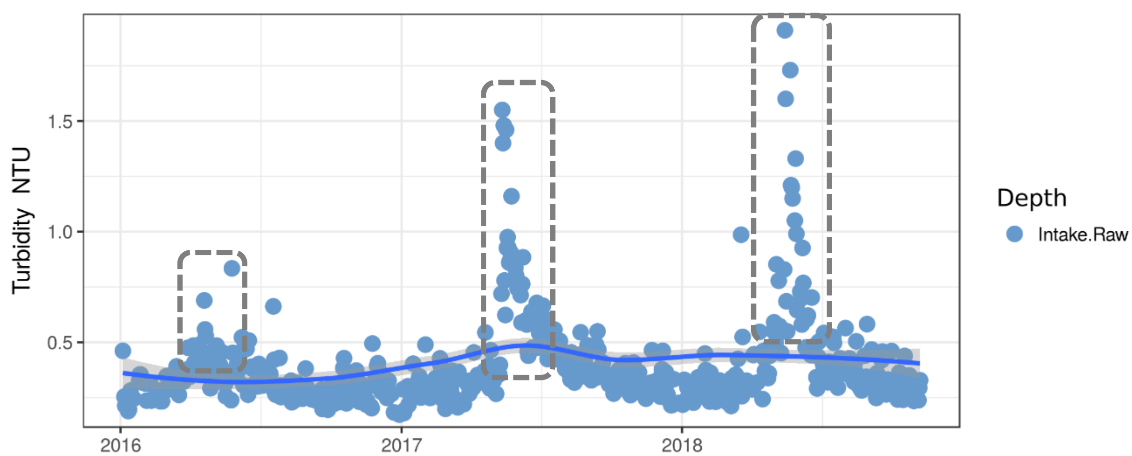

Figure 6-2: Raw water turbidity at Poplar Point with freshet highlighted, 2016-2018

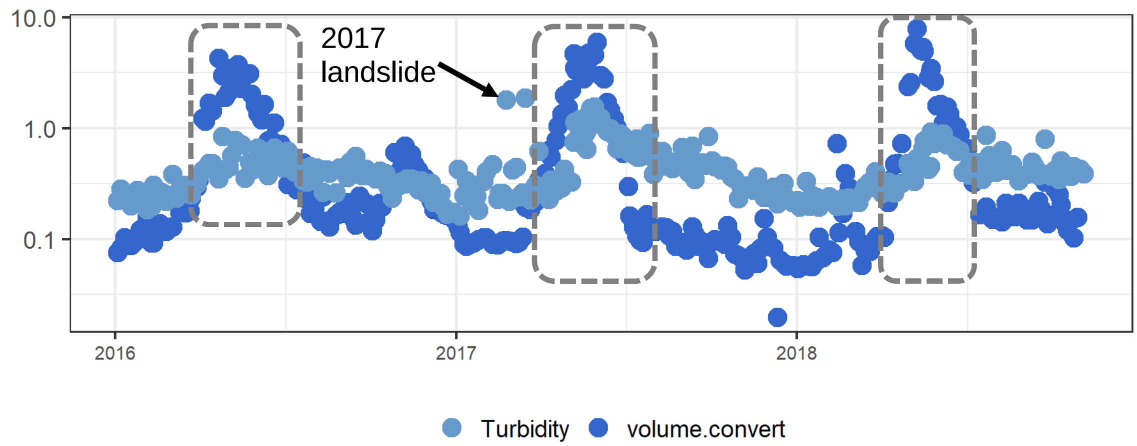

Figure 6-3: Turbidity in Swick raw water compared to Mission Creek flow with freshet highlighted

Note: Y-axis is log scale and volume data has been scaled to fit with turbidity for visual effect, relationship between data is unaffected.

7.0 Strengths, Weaknesses, Opportunities, and Threats (SWOT)

A SWOT analysis was conducted for each of the City of Kelowna Intakes. They are summarized in the following tables:

7.1 Poplar Point

Table 7-1: Strengths, weaknesses, opportunities, and threats summary of the Poplar Point intake

Strengths	Weaknesses
▪ Deepest intake for City of Kelowna (29m) ▪ Largest intake for City of Kelowna ▪ Intake in excellent condition based on Dec 2018 ROV survey ▪ Intake below the thermocline most of the growing season (May – October) ▪ Zero marinas, docks, or stormwater outfalls within proposed IPZ ▪ SCADA system monitors flow, turbidity, and chlorine residual ▪ Water operators have appropriate training levels and training is on-going ▪ Appropriate IHA directed water quality monitoring is reported ▪ Up to >40 years of water quality and limnology records by MoE and others on Okanagan Lk ▪ City of Kelowna maintains extensive database of monitoring data that is easily searchable ▪ OCP requires development in riparian areas to perform an environmental assessment ▪ City of Kelowna by-laws require all new developments to retain stormwater on-site ▪ Intake uses chlorine + UV for two forms of disinfection ▪ Emergency response plan in place that can react to a spill within 2 hours ▪ 24-hour video surveillance of all facilities	▪ Intake currently has only 1 m clearance from sediments (2-3 m is preferred) ▪ Recreational and shoreline development pressures are increasing ▪ No back-up water supply available ▪ Okanagan Lake algae population often dominated by diatoms in the spring that would impair filtration efficacy without pretreatment ▪ Not currently protected against invasive mussels ▪ City of Kelowna has no jurisdiction on Mission, Bear, Mill creek watersheds beyond their boundaries

Opportunities	Threats
▪ Apply for License of Occupation or other designation over Intake Protection Zone from Front Counter BC ▪ Establish IPZ zone in City of Kelowna zoning by-law ▪ Add IPZ to City of Kelowna GIS so that all departments are aware of them for planning ▪ Encourage shoreline replanting & riparian restoration ▪ Encourage infiltration and rainwater capture for all residences, commercial, and parking lots. ▪ Public Education about Okanagan Lake as a water source (get help from NGO's) and include campaigns targeted at seasonal residents and tourists ▪ 2017-2018 flooding/WQ issues are opportunity to engage with public about risks to our water sources ▪ Extending chlorine line to end of intake would protect intake from invasive mussels (survey already conducted)	▪ Extensive lake flooding unlikely but has occurred recently (2017 and to a lesser extent, 2018) ▪ Watershed degradation on all Central Okanagan creeks is ongoing issue ▪ Climate change will likely increase summer demand and reduce reliability of source water with more frequent watershed failures ▪ Okanagan Lake has history of nuisance cyanobacteria blooms ▪ Climate change increases the risk of regional wildfire and resultant long-term watershed damage ▪ Nutrient enrichment and degradation of watershed will encourage algae blooms and reduce water quality in Okanagan Lake ▪ Increasing population pressures for lake recreation, particularly motorized craft ▪ Inadequate enforcement of recreation polluters (yachts) foreshore modification violations ▪ Introduction of invasive mussels would cause irreparable damage to Okanagan Lake and to the City's infrastructure ▪ Vandalism and break-ins at CoK facilities (has occurred at other Okanagan water suppliers in recent years)

7.2 Eldorado

Table 7-2: Strengths, weaknesses, opportunities, and threats summary of the Eldorado intake

Strengths	Weaknesses
▪ Intake in good condition based on Dec 2018 ROV survey ▪ Intake is >500 m from shore ▪ Proposed IPZ lies entirely offshore because of line intake pipe ▪ SCADA system monitors flow, turbidity, and chlorine residual ▪ Water operators have appropriate training levels and training is on-going ▪ Appropriate IHA directed water quality monitoring is reported ▪ Up to >40 years of water quality and limnology records by MoE and others on Okanagan Lk ▪ City of Kelowna maintains extensive database of monitoring data that is easily searchable ▪ OCP requires development in riparian areas to perform an environmental assessment ▪ City of Kelowna by-laws require all new developments to retain stormwater on-site ▪ Intake uses chlorine + UV for two forms of disinfection ▪ Emergency response plan in place that can react to a spill within 2 hours ▪ 24-hour video surveillance of all facilities	▪ Shallow intake (14m) is vulnerable to surface contamination most of the year ▪ Intake has only 0.3 m of clearance (2-3 m is preferred) and is highly vulnerable to seiches and creek plumes that travel along lake bottom ▪ Bellevue Creek flows into Okanagan Lake near intake and affects intake, particularly if plume is denser (colder) than lake water and sinks to the lake bottom ▪ Turbidity frequently exceeds 1.0 NTU ▪ Intake sits at average thermocline depth in late summer and gets frequent seiches ▪ Recreational and shoreline development pressures are increasing ▪ No back-up water supply is currently available ▪ Okanagan Lake algae population often dominated by diatoms in the spring that would impair filtration efficacy without pretreatment ▪ Low capacity intake ▪ Not currently protected against invasive mussels
Opportunities	**Threats**
▪ Apply for License of Occupation or other designation over Intake Protection Zone from Front Counter BC ▪ Establish IPZ zone in City of Kelowna zoning by-law ▪ Add IPZ to City of Kelowna GIS so that all departments are aware ▪ Encourage shoreline replanting & riparian restoration ▪ Encourage infiltration and rainwater capture for all residences, commercial, and parking lots. ▪ Public Education about Okanagan Lake as a water source (get help from NGO's) and include campaigns targeted at seasonal residents and tourists ▪ 2017-2018 flooding/WQ issues are opportunity to engage with public about risks to our water sources ▪ Extending intake into deeper water would reduce impact of surface water on water quality ▪ Extending chlorine line to end of intake would protect intake from invasive mussels (survey already conducted)	▪ Extensive lake flooding unlikely but has occurred recently (2017) ▪ Mission Creek watershed degradation is ongoing issue ▪ Climate change will likely increase summer demand and reduce reliability of source water with more frequent watershed failures and wildfire damage ▪ Okanagan Lake has history of nuisance cyanobacteria blooms ▪ Nutrient enrichment and watershed degradation 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 mussels would cause irreparable damage to Okanagan Lake and to the City's infrastructure ▪ Vandalism and break-ins at CoK facilities (has occurred at other Okanagan water suppliers in recent years)

7.3 Cedar Creek

Table 7-3: Strengths, weaknesses, opportunities, and threats summary of the Cedar Creek intake

Strengths	Weaknesses
▪ Moderate intake depth (20m) ▪ Second largest intake for City of Kelowna ▪ Most of shoreline around intake is parkland ▪ Intake below the thermocline most of the growing season (May – October) ▪ IPZ is mostly offshore ▪ Zero marinas within proposed IPZ ▪ SCADA system monitors flow, turbidity, and chlorine residual ▪ Water operators have appropriate training levels and training is on-going ▪ Appropriate IHA directed water quality monitoring is reported ▪ Up to >40 years of water quality and limnology records by MoE and others on Okanagan Lk ▪ City of Kelowna maintains extensive database of monitoring data that is easily searchable ▪ OCP requires development in riparian areas to perform an environmental assessment ▪ City of Kelowna by-laws require all new developments to retain stormwater on-site ▪ Intake uses chlorine + UV for two forms of disinfection ▪ Emergency response plan in place that can react to a spill within 2 hours ▪ 24-hour video surveillance of all facilities	▪ Seasonal creek that receives stormwater discharges within proposed IPZ ▪ Intake occasionally affected by winter stormwater ▪ Recreational and shoreline development pressures are increasing ▪ No back-up water supply available ▪ Okanagan Lake algae population often dominated by diatoms in the spring that would impair filtration efficacy without pretreatment ▪ Not currently protected against invasive mussels ▪ Sediment is very fine and easily re-suspended ▪ Intake has a 1.5 m clearance from the substrates (2-3 m is preferred) ▪
Opportunities	**Threats**
▪ Apply for License of Occupation or other designation over Intake Protection Zone from Front Counter BC ▪ Establish IPZ zone in City of Kelowna zoning by-law ▪ Add IPZ to City of Kelowna GIS so that all departments are aware ▪ Encourage shoreline replanting & riparian restoration ▪ Encourage infiltration and rainwater capture for all residences, commercial, and parking lots. ▪ Public Education about Okanagan Lake as a water source (get help from NGO's) and include campaigns targeted at seasonal residents and tourists ▪ 2017-2018 flooding/WQ issues are opportunity to engage with public about risks to our water sources ▪ Installation of chlorine line to end of intake for protection against invasive mussels (survey already conducted) ▪ Intake extension into deeper water possible	▪ Extensive lake flooding unlikely but has occurred recently (2017) ▪ Watershed degradation is ongoing issue ▪ Climate change will likely increase summer demand and reduce reliability of source water with more frequent watershed failures ▪ Okanagan Lake has history of nuisance cyanobacteria blooms ▪ 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 mussels would cause irreparable damage to Okanagan Lake and to the City's infrastructure ▪ Vandalism and break-ins at CoK facilities (has occurred at other Okanagan water suppliers in recent years)

7.4 Swick

Table 7-4: Strengths, weaknesses, opportunities, and threats summary of the Swick intake

Strengths	Weaknesses
▪ Intake currently has 1.2 m clearance from sediments ▪ Intake is in good condition based on Dec 2018 ROV survey ▪ No marinas within proposed IPZ ▪ SCADA system monitors flow, turbidity, and chlorine residual ▪ Water operators have appropriate training levels and training is on-going ▪ Appropriate IHA directed water quality monitoring is reported ▪ Up to >40 years of water quality and limnology records by MoE and others on Okanagan Lk ▪ City of Kelowna maintains extensive database of monitoring data that is easily searchable ▪ OCP requires development in riparian areas to perform an environmental assessment ▪ City of Kelowna by-laws require all new developments to retain stormwater on-site ▪ Intake uses chlorine + UV for two forms of disinfection ▪ Emergency response plan in place that can react to a spill within 2 hours ▪ 24-hour video surveillance of all facilities	▪ Shallow intake (16m at full pool) ▪ Very close to mouth of Varty Creek (stormwater conduit) ▪ Receives pulses of stormwater with elevated fecal bacteria during the winter ▪ Recreational and shoreline development pressures are increasing ▪ No back-up water supply available ▪ Okanagan Lake algae population often dominated by diatoms in the spring that would impair filtration efficacy without pretreatment ▪ Intake not protected against invasive mussels
Opportunities	**Threats**
▪ Apply for License of Occupation or other designation over Intake Protection Zone from Front Counter BC ▪ Establish IPZ zone in City of Kelowna zoning by-law ▪ Add IPZ to City of Kelowna GIS so that all departments are aware ▪ Encourage shoreline replanting & riparian restoration ▪ Encourage infiltration and rainwater capture for all residences, commercial, and parking lots. ▪ Public Education about Okanagan Lake as a water source (get help from NGO's) and include campaigns targeted at seasonal residents and tourists ▪ 2017-2018 flooding/WQ issues are opportunity to engage with public about risks to our water sources ▪ Raw water sampling line could be retrofitted into chlorine injection line for protection against invasive mussels	▪ Varty Creek watershed has documented history of instability and impact on the intake ▪ Varty Creek receives stormwater ▪ Elevated fecal bacteria counts in stormwater during winter ▪ Okanagan Lake has history of nuisance cyanobacteria blooms ▪ Watershed degradation is ongoing issue ▪ Extensive lake flooding unlikely but has occurred recently (2017) ▪ Climate change will likely increase summer demand and reduce reliability of source water with more frequent watershed failures ▪ 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 mussels would cause irreparable damage to Okanagan Lake and to the City's infrastructure ▪ Vandalism and break-ins at CoK facilities (has occurred at other Okanagan water suppliers in recent years)

8.0 Risk Management Plans

Risk Management Plans (RMP) are legal tools that the City of Kelowna can use to enforce source protection on persons or businesses whose activities within City boundaries pose a significant threat to the quality or quantity of a drinking water source. This would include Okanagan Lake, and tributaries to it. RMPs can also be applied to groundwater where groundwater recharge zones are identified. Mapping of vulnerable areas within City limits is key to the RMP exercise.

Examples of significant threats include:

1) transport and storage of hazardous materials
2) septic and sewage collection/storage near water
3) sewer outfalls, stormwater outfalls
4) The application and storage of agricultural materials (manure, herbicides, pesticides, fertilizers)
5) The application, storage and handling of road salt.
6) The storage of snow.
7) The handling and storage of fuel.
8) The handling and storage of a dense non-aqueous phase liquid (DNAPL) or organic solvent.
9) The management of run-off that contains chemicals used in the de-icing of aircraft.
10) An activity that takes water from an aquifer or a surface water body without returning the water taken to the same aquifer or surface water body.
11) An activity that reduces the recharge of an aquifer.
12) The use of land as livestock grazing or pasturing land, an outdoor confinement area or a farm animal yard, or dairy.

RMP's can prevent high risk activities in hydrologically vulnerable areas of the City. RMP's can be used to prevent accidents such as the 2010 warehouse fire where hazardous chemicals/fertilizers mixed with water used to fight the fire and drained into Mill Creek.

To ensure enforceability, an RMP can be linked to land-use approvals, zoning by-laws, and environmental impact assessments. The City of Guelph has developed a guidance document for developing RMPs and has prescribed the following process (City of Guelph, 2016). City of Kelowna staff can consider adapting their process.

Briefly, an RMP development process involves:

- Step 1 – City staff identify that a RMP apply to a given activity or proposed activity
- Step 2 – City staff consults with landowner/operator
- Step 3 – City staff determines whether a RMP is required
- Step 4 – City staff determines RMP category and requirements
- Step 5 – City staff and landowner/operator negotiate/prepare/agree to RMP
- Step 6 – City staff issues Notice of Acceptance of RMP
- Step 7 – Landowner/Operator implements RMP and monitors its effectiveness

9.0 Conclusions

The City of Kelowna operates four drinking water intakes into Okanagan Lake. These are from largest to smallest: Poplar Point, Cedar Creek, Eldorado, and Swick. The 2011 source assessment report (EBA, 2011) focused on modules 1,2, and 7 of the prescribed drinking water source assessment framework. City of Kelowna contracted LAC to complete module 8 and also to create a Source Protection Plan.

Intake protection zones (IPZ) were developed for each of the intakes based on measuring water currents at each intake at different depths. The Eldorado IPZ was the largest at 33.9 ha while the Swick IPZ was the smallest at 8.2 ha. All of the IPZs were elongated along the shore based on the prevailing long-shore currents. The fastest currents measured were at Cedar Creek while Poplar Point had the slowest currents.

The intense freshets and flooding during 2017 and 2018 required a re-evaluation of risk levels established in the 2011 source assessment. Poor water quality within Okanagan Lake during both years required City of Kelowna to go on a water quality advisory. The plumes of Bear Creek, Mill Creek, and Mission Creek were observed traveling towards the Poplar Point intake and sampling during 2018 revealed a layer of turbid water directly above the intake. Bellevue Creek flows into Okanagan Lake close to the Eldorado intake and statistical analyses revealed that it regularly impacts the intake water quality. Varty Creek has a documented history of instability and impacts on the Swick intake. Watershed degradation is an ongoing concern and directly affects the City of Kelowna intakes.

Analysis of water quality data from the City of Kelowna and weather data revealed that Swick intake is affected by stormwater with elevated fecal bacteria counts during the winter but not the spring, summer, or fall. It also revealed that Eldorado intake is particularly vulnerable to seiches, sediment resuspension, and creek plumes travelling along the lake bottom. Poplar Point occasionally experiences an increase in turbidity and bacteria 2-3 days after a major rainfall event suggesting it takes this long for the Mill or Mission Creek plumes to reach that far north.

An ROV survey of the intakes commissioned in conjunction with this report revealed that low intake clearance is an issue for all of City of Kelowna’s intakes. Poplar Point has only 1 m of clearance, the Eldorado intake is effectively on the bottom, while Swick and Cedar Creek have 1.5 m of clearance. Current best practices are for 2-3 m of clearance to protect intakes from sediment resuspension during seiches. Sediment at all four intakes was very easily resuspended.

All recommendations can be found in the Source Protection Plan interactive spreadsheet.

10.0 Literature Cited

City of Guelph. (2016). *Preparing Risk Management Plans*. Retrieved from http://guelph.ca/wp-content/uploads/SWP_RiskManagementGuidance.pdf

EBA. (2011). *City of Kelowna Drinking Water Source Protection*. Kelowna, B.C.

Johnston, V. (2017). *November 2017 Inspection Report*. Kelowna, B.C.

Langan, J. (2007). *Lake Ontario Intake Assessments*.

Ministry of Healthy Living and Sport. (2010). *Comprehensive Drinking Water Source-to-Tap Assessment Guideline*. Retrieved from http://www.health.gov.bc.ca/protect/source.html

Nordin, R. N. (2005). *Water Quality Objectives for Okanagan Lake*. North Saanich BC.

Schleppe, J., Larratt, H., & Plewes, R. (2016). *Kalamalka and Wood Lake Boat Capacity Study on Source Waters*.

Trout Unlimited. (2018). Yellow Fish Road Program. Retrieved November 16, 2018, from https://tucanada.org/yellow-fish-road/

11.0 Appendices

11.1 Appendix 1: Drogue Travel in Okanagan Lake near Intakes

Poplar Point

Drogues generally travelled parallel to shore SW to NE (Table 11-1). Shallow 5 m drogues indicate that the surface currents move with the wind. The 30 m drogues were the exception and they tended to travel perpendicular to shore. This is a common phenomenon when surface currents encounter the shore, sink, and return at depth. Deeper currents moved more slowly than surface currents as they do in most lakes. The fastest drogues measured were at 10 m but the 5 m drogues had the highest minimum speed.

Table 11-1: Summary statistics of Poplar Point drogues

		Speed (m/hr)			Dominant
Depth	Average	Directions	Max	StdDev	Directions
5m	47.2	7.3	131.8	31.1	NE
10m	56.1	3.2	141.0	41.9	SW
20m	36.7	1.7	108.6	25.7	N/NE
30m	28.7	4.9	52.8	13.4	SE

Figure 11-1: 5 and 10 m drogues at Poplar Point

Figure 11-2: 20 and 30 m drogues at Poplar Point

Eldorado

Drogues generally travelled parallel to shore on a north-south axis (Table 11-2). 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 fastest drogues measured were at 5 m with a steady decline with depth. Drogues at 20 m were still recorded at over 170 m/hr because of strong longshore currents in the area.

Table 11-2: Summary statistics of Eldorado drogues

		Speed (m/hr)			Dominant
Depth	Average	Min	Max	StdDev	Directions
5m	141.5	4.8	220.4	69.4	S
10m	132.3	48.6	213.0	57.4	S
20m	107.8	66.3	176.9	29.4	SW

Figure 11-3: 5 and 10 m drogues at Eldorado

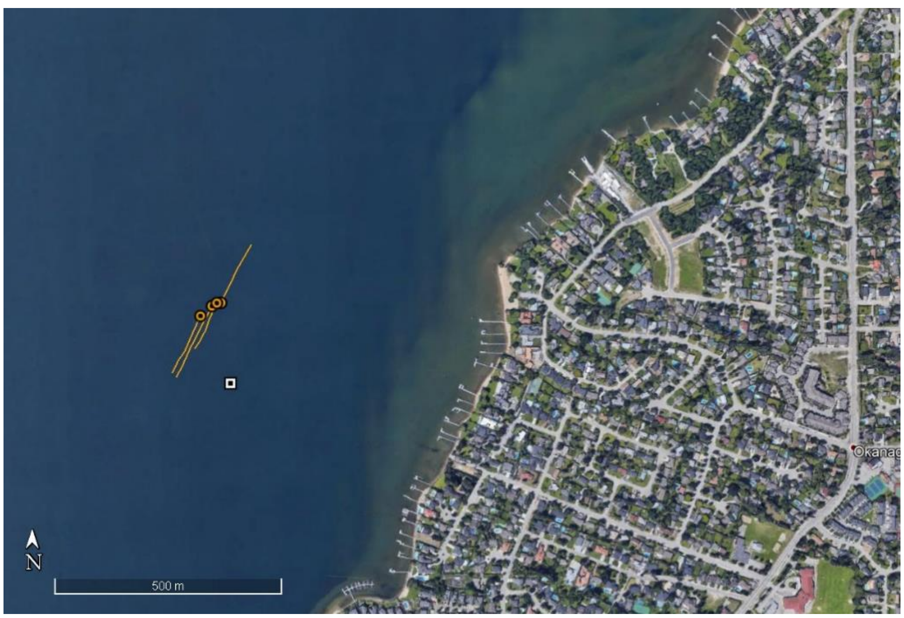

Figure 11-4: 20 m drogues at Eldorado

Cedar Creek

Drogues consistently travelled parallel to shore SW to NE (Table 11-3). Differing weather conditions and winds from the north did not affect drogue travel indicating a strong prevailing northward current in this area. Deeper currents moved more slowly than surface currents as they do in most lakes. The fastest drogues measured 5 m while the 10 m and 20 m drogues had similar average speeds.

Table 11-3: Summary statistics of Cedar Creek drogues

	Speed (m/hr)				Dominant
Depth	Average	Min	Max	StdDev	Direction
5m	158.1	8.0	291.4	91.4	NE
10m	68.3	13.1	126.6	31.8	E
20m	77.7	17.9	203.2	46.3	NE

Figure 11-5: 5 and 10 m drogues at Cedar Creek

Figure 11-6: 20 m drogues at Cedar Creek

Swick

Drogues generally travelled parallel to shore west to east (Table 11-4). Shallow 5 m drogues moved most erratically. This was likely caused by winds and currents interacting with the steep shoreline and forming turbulence patterns. Deeper currents moved more slowly and consistently eastward than surface currents. The fastest drogues measured were at 5 m while the 10 m and 20 m drogues had similar average speeds.

Table 11-4: Summary statistics of Swick drogues

	Speed (m/hr)				Dominant
Depth	Average	Min	Max	StdDev	Direction
5m	91.2	55.2	159.7	28.1	E
10m	55.6	9.4	127.9	40.0	E
20m	38.3	1.4	118.3	34.7	E

Figure 11-7: 5 m, 10 m, and 20 m drogues at Swick

11.2 Appendix 2: ROV Survey of Okanagan Lake Intakes

Poplar Point

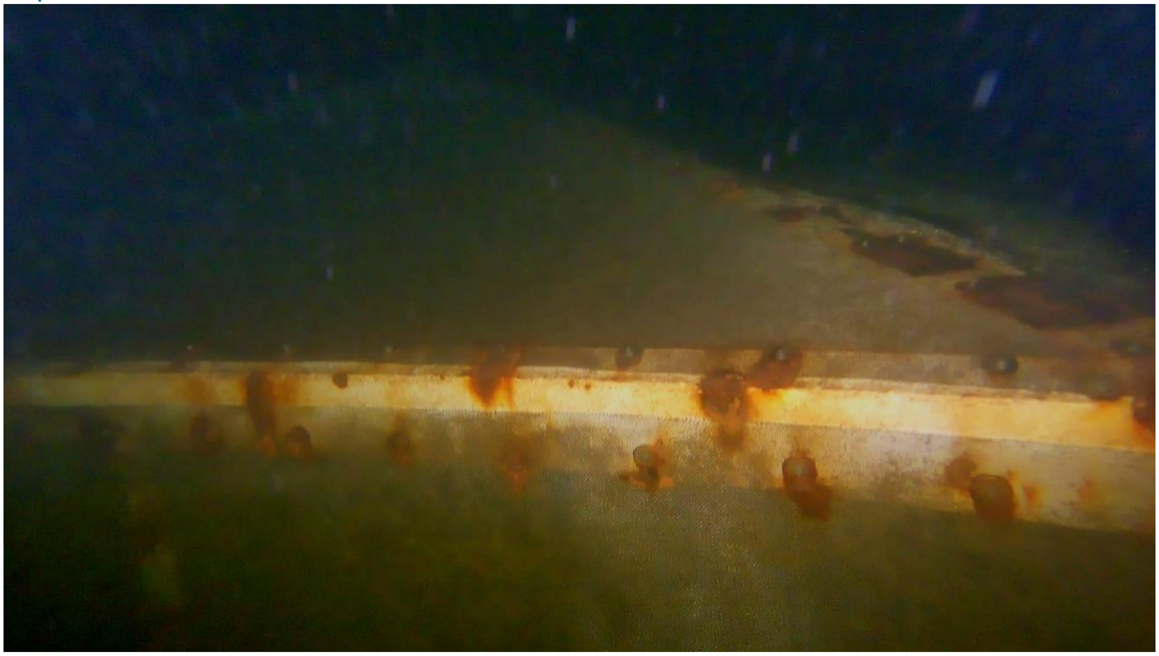

Figure 11-8: Screen capture from survey of Poplar Point intake, focusing on top of south screen

Table 11-5: Poplar Point Intake measurements

	Poplar Point
Sediment Depth	32.0m
Bottom of Screens	31.2m
Top of Screens	28.9m
Clearance	~1m
Height of screen	2.3m
Latitude	49.918042°
Longitude	-119.488932°

Eldorado

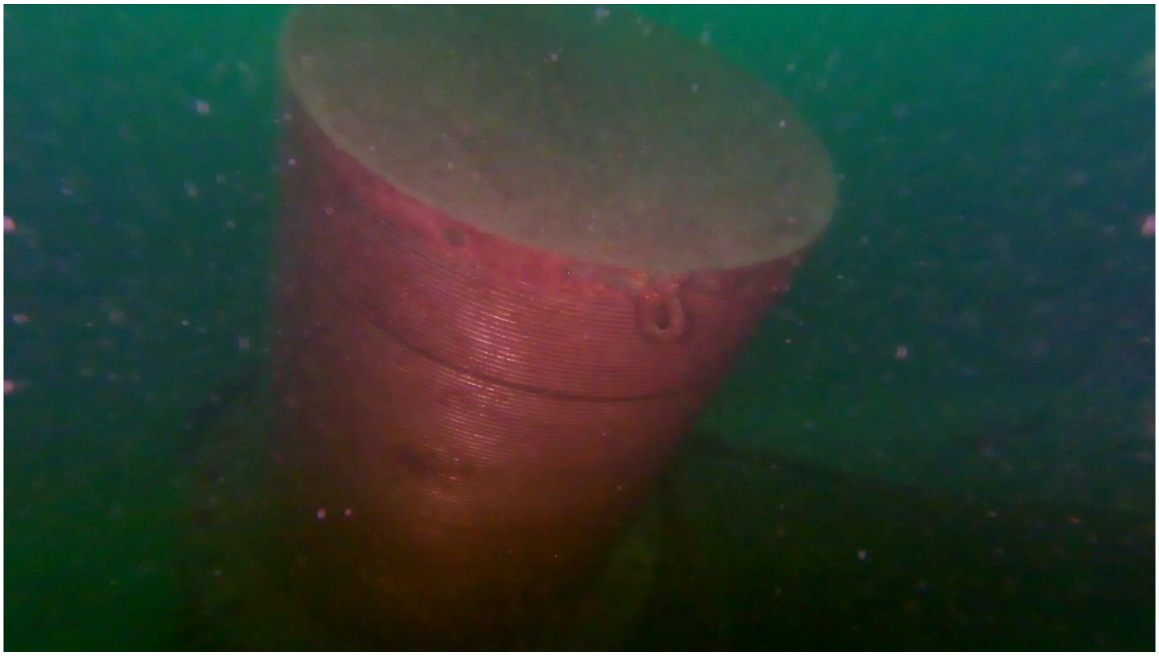

Figure 11-9: Screen capture from survey of Eldorado intake screen

Table 11-6: Eldorado Intake measurements

	Eldorado
Sediment Depth	13.0m
Bottom of Screens	12.7m
Top of Screens	12.0m
Clearance	0.3m
Height of screen	0.7m
Latitude	49.824209°
Longitude	-119.507581°

Cedar Creek

Figure 11-10: Screen capture from survey of Cedar Creek intake screen

Table 11-7: Cedar Creek Intake measurements

	Cedar Creek
Sediment Depth	21.7m
Bottom of Screens	20.1m
Top of Screens	18.9m
Clearance	1.5m
Height of screen	1.2m
Latitude	49.799261°
Longitude	-119.534377°

Swick

Figure 11-11: Screen capture from survey of Swick intake without ROV lights (top) and with lights (bottom)

Table 11-8: Swick Intake measurements

	Swick
Sediment Depth	16.3m
Bottom of Screens	15.1m
Top of Screens	14.6m
Clearance	1.2m (probably 1.5m originally)
Height of screen	0.5m
Latitude	49.785236°
Longitude	-119.571065°