CITY OF KELOWNA

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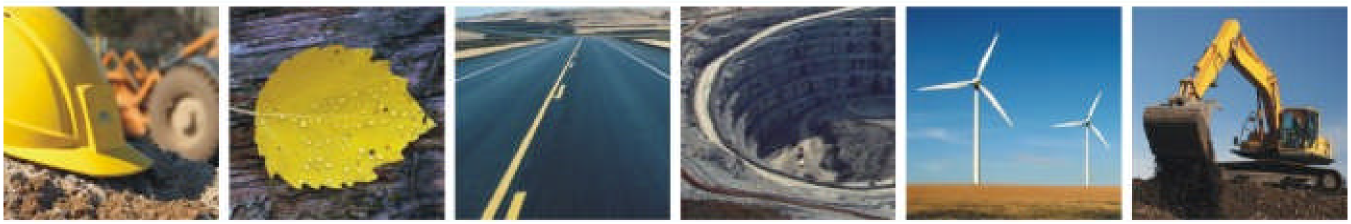
DRINKING WATER SOURCE PROTECTION



REPORT

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ACRONYMS & ABBREVIATIONS

ATV	all-terrain vehicle (ATV)
BMP	Best Management Practices (BMP)
City	City of Kelowna (City)
CFU/100mL	Coliform Forming Units/100 mL
MPN/100mL	Most Probable Number/100 mL
Hayco	Hay & Company Consultants
IHA	Interior Health Authority
KWWTF	Kelowna Wastewater Treatment Facility
MOE	Ministry of Environment
MHCSTAG	Ministry of Health Comprehensive Source to Tap Assessment Guideline
NTU	Nephelometric Turbidity Unit
N	nitrogen
P	phosphorus
PO4	phosphate
PPH	Part per hundred
PPT	Part per thousand
SIRDWT	Southern Interior Regional Drinking Water Team
UV	Ultraviolet
WRWTP	Westside Regional Wastewater Treatment Plant

1.0 INTRODUCTION

This report is prepared to support the City of Kelowna Water Utility in obtaining a "Filtration Deferral" permit from the Interior Health Authority (IHA). In order for IHA to allow the filtration deferral to proceed, IHA has requested that the City of Kelowna (City) provides more information, in addition to the Hay & Company (Hayco) October 2000 Study "Influence of Limnology on Domestic Water Intakes", to demonstrate that extending water intakes to a deeper depth is equivalent to a "watershed control program". To support this proposition, this report first addresses three modules of the Ministry of Health Comprehensive Source to Tap Assessment Guideline (MHCSTAG) including:

- Module 1 - Source Delineation & Characterization
- Module 2 - Hazard Source Inventory
- Module 7 - Risk Assessment.

The objective of Modules 1 and 2 is to review and identify the limnological threats to water security for the City of Kelowna: natural and human–derived changes to water quality at City of Kelowna's water intakes which could pose a threat to human health. Once the contaminant sources, both biological and non-biological, in Okanagan Lake have been identified, a three-dimensional hydrodynamic model is then used to investigate quantitatively the source characterization of the City's intakes and the reduction in threat to each intake if the intake were at a deeper depth. Based on the information from Modules 1 and 2 and from the modelling analysis, risk assessment will be then be developed for each of the contaminant sources based on Module 7.

2.0 SOURCE TO TAP ASSESSMENT GUIDELINE - MODULE 1 SOURCE DELINEATION & CHARACTERIZATION

The City of Kelowna Water Utility draws water from four intakes, Poplar Point, Eldorado, Cedar Creek and Swick, in Okanagan Lake. Location, length, depth and design capacity of these intakes are listed in Table 2.1. The location of these intakes, along with the major nearby creeks and wastewater treatment plant outfalls, are shown in Figure 2.1. As shown in Table 2.1, the Swick Road intake accounts for only 0.4% of the City's design intake capacity. Similarly, the Eldorado intake accounts for only 13% of the City's design intake capacity. Consequently much of the discussion in this report focuses on the Poplar Point and Cedar Creek intakes.

In a general sense, the source for the City's water is the entire Okanagan Lake, which receives water from many creeks. The 12 largest tributaries, representing 96% of the inflows to the lake, are listed in Table 2.2. The table also provides the mean annual flow rate from these creeks. The collective effect of these relatively low flow rates compared to the volume of the lake (24,644,000 m^3) is that the average residence time is about 50 years.

Creeks which are within the City of Kelowna's jurisdiction include: Kelowna, Mission, Fascieux, Wilson and Brandt Creeks. These creeks contribute 37.5% of the inflow to Okanagan Lake. Of the creeks within the City's jurisdiction, all but Mission Creek accept storm sewer inputs. The Hayco 2001 numerical modelling study, which considered the impact of flow from Lambly, Mission and Kelowna Creeks, showed that for short periods of time, of the order of a few days, especially associated with storm or rainfall events, one or more of these three creeks in the Kelowna area can represent a significantly larger than usual proportion of the water reporting to the City intakes.

Based on this hydrology and limnology information, it is concluded that the primary source of the City's water is from the inflow creeks into Okanagan Lake. The creeks' relative contribution to City's water supply depends both on how far they are from the intake, and on meteorological conditions which control the transport and dilution of water from each creek. That is, it is reasonable to expect that creeks closest to the intakes will pose the most potential threats. However, creeks can be several kilometres from the water intakes and still have an impact, as demonstrated in the simulation of the 1996 *Cryptosporidium* outbreak in Kelowna (Hayco, 2001).

3.0 SOURCE TO TAP ASSESSMENT GUIDELINE - MODULE 2 CONTAMINANT SOURCE INVENTORY

A contaminant source inventory identifies and describes land uses, human activities and other potential contaminant sources that could affect source water quality. Water quality in Okanagan Lake depends strongly on its limnology, which encompasses an integration of physical, chemical, and biological components of inland aquatic ecosystems within the drainage basin, movements of water through the drainage basin, and biogeochemical changes. The influence of physical limnology processes on water quality at the intakes was documented in the Hayco 2000 report.

In general, water quality parameters in Okanagan Lake are excellent and are closely monitored by the City. However, there are infrequent episodic contaminant threats to the water system. These threats can include physical transport of contaminant into the lake as well as those caused by the biological activities in the lake. Two examples of transport-related threats are the *Cryptosporidium* outbreak in 1996 and the introduction of contaminated water used for fire fighting at a warehouse in Kelowna in July 2010. As well, some threats are of a chronic nature, such as bacterial contamination and algal blooms, but the severity could be increasing over time. Other threats, such as the July 2010 fire fighting incident, are of a sudden and potentially severe nature.

Six primary contaminants sources identified include:

1. Creeks
2. In-Lake Algal Production
3. Wastewater Treatment Plant Discharge
4. Transportation Corridor spills
5. Boating Activities
6. Impact of Lake Physics.

Each of these contaminant sources is discussed below.

3.1 Contaminants Delivered by Creeks

Five local creeks that could have impacts on water quality within the lake, especially within the City corporate boundary, consist of Brandt's Creek, Fascieux Creek, Lambly Creek, Kelowna Creek (also known locally as Mill Creek) and Mission Creek. Approximate horizontal distances between these creeks and the City's intakes are summarized in Table 3.1.

Contaminant sources that could reduce water quality in these creeks include:

- Protozoan parasites, e.g., *Cryptosporidium* and *Giardia*
- Pathogenic bacteria
- Stormwater
- Agriculture runoff
- Industrial runoff
- Sediment loadings triggered by human activities such as mining, salvage forestry, all-terrain vehicle (ATV) and off-road motorsports, and natural event such as wildfires.

A base load of very low concentration contaminants currently enters the lake by means of the creeks. The contaminants entering the creek undergo dilution first with creek water and then with lake water. Thus, the concentration of the contaminants in the water entering the intakes is usually low and more often than not meets health criteria. However, short-lived high contaminant concentration events pose a significant threat to the water system. These events are often associated with periods of high creek flow when the loadings, which depend on flow rate and contaminant concentration, are high. In such situations, as occurred in the *Cryptosporidium* outbreak of 1996, dilution by physical limnological processes wasn't sufficient to provide protection for the residents of Kelowna.

The following sections describe the hazard scenario associated with each type of creek contaminant source. Each type of hazard is coded with a "C" value, C1, C2, etc., for later reference in a risk evaluation table. Design events will be established based on these scenarios and the Okanagan Lake numerical model will be used to simulate these design events and provide statistical information regarding the contaminant concentration at the intakes.

3.1.1 *Cryptosporidium* and *Giardia* Inflow (C1)

Cryptosporidiosis is a parasitic disease caused by *Cryptosporidium*, a protozoan parasite. It affects the intestines of mammals and is typically an acute short-term infection. It is spread through the fecal-oral route, often through contaminated water. The most common linkage is from animal feces, through surface water and then on to a water supply. Young calves, especially those not in the best of health, are often significant *Cryptosporidium* carriers. The main symptom of cryptosporidiosis is self-limiting diarrhoea in people with intact immune systems. In immuno-compromised individuals, the symptoms are particularly severe and often fatal. Despite not being identified until 1976, it is one of the most common waterborne diseases and is found worldwide. The parasite is transmitted by environmentally hardy microbial cysts (oocysts) that, once ingested, exist in the small intestine and result in an infection of intestinal epithelial tissue.

Giardia is a somewhat similar protozoan parasite, and the associated disease, giadiasis, is also known as beaver fever. The most likely pathway for *Giardia* infection is through surface water inflow to the lake, but the source of the infection is more general than *Cryptosporidium* infection, which is strongly tied to young calves.

In June 1996, the City of Kelowna experienced a significant *Cryptosporidium* outbreak. Between 200 and 300 cases of cryptosporidiosis were confirmed, although higher numbers have also been reported. Research that followed suggested the cause of the outbreak was significant spring runoff combined with major rain events during a short duration. This led to exceptionally high flows from major tributaries into Okanagan Lake. These creek flows were presumably carrying high loads of *Cryptosporidium* oocysts. The City retained Hayco in 1999 to investigate the outbreak, and to provide possible limnologically-based solutions to minimize or eliminate the threat. A hindcast of the event (Hayco, 2001) demonstrated that the appearance of high levels of *Cryptosporidium* brought into the lake by flow from the adjacent creeks, accompanied by strong winds shortly thereafter could lead to the appearance of the *Cryptosporidium*-enriched water at the City intakes, thus compromising the City's water supply.

The 2001 Hayco study concluded that the risk can be reduced, but not eliminated, by extending the intakes to deeper depths. The City selected a more reliable solution, installing ultraviolet (UV) treatment of drinking water at its major intakes, thus effectively neutralizing the *Cryptosporidium* and other protozoa. Additionally, when the Poplar Point intake was rebuilt recently, the City also took the opportunity to further reduce the risk by extending the intake to a deeper depth from a depth of 20 m to a depth of 29 m.

3.1.2 Pathogenic Bacteria Inflows (C2)

A potentially serious threat to the water supply arises from inflows of human and animal waste into the lake. In particular, the City has experienced one situation where significant amounts of *Cryptosporidium* were carried into the lake and appeared at the City's intakes, leading to human health problems. Although a wide range of pathogens are involved, the most common way to assess and monitor fecal contamination is by measuring bacterial contamination in water samples. Bacteria concentrations are expressed in either number of Coliform Forming Units/100 mL (CFU/100 mL) or as Most Probable Number (MPN/100 mL). The traditional membrane filtration test for bacterial water quality actually counts 'colonies' of bacteria and thus is reported as CFU. The newer defined substrate tests report data as MPN, which is a statistical representation of what level of bacteria is likely present in a sample. The two measurement units should be numerically quite similar for any particular sample.

Bacterial contamination is usually measured in terms of one of four parameters:

- Total coliform

  Total coliform bacteria count reflects a wide range of bacteria that can generally be found in the lake. Total coliform bacteria are not overly significant with respect to human health. Total coliform bacteria numbers vary widely with season, from 0 CFU/100 mL (none detectable per 100 mL) to several hundred CFU/100 mL.

- Fecal coliform

  Fecal coliform is a somewhat larger group of harmful bacteria than just *E. coli*. When measured separately in Lambly Creek (Larratt, 2010), fecal and *E. coli* counts were nearly identical. At other sites, such as in the lower Fraser River (Greater Vancouver Regional District 2002), the two differ by about a factor of two.

- *Escherichia coli*, generally referred to as *E. coli*.

  E. coli is a significantly different bacterium. It is considered a strong indicator of fecal contamination. The Canadian standard for drinking water is none detectable per 100 mL. On an annual basis*, E. coli* counts ranging up to two or three occur intermittently in the raw water at the City intakes.

- *Enterococcus spp*., or *Enterococci*.

  Enterococci are part of the normal intestinal flora of humans and animals but are also important pathogens responsible for serious infections. In bodies of water, the acceptable level of contamination is very low. For example in the state of Hawaii, with among the strictest tolerances in the United States, the limit for water off its beaches is 7 colony-forming units per 100 ml of water, above which the state may post warnings to stay out of the ocean. In 2004, *Enterococcus spp*. took the place of fecal coliform as the new US standard for water quality at public beaches (Jin et al., 2004). It is believed to provide a higher correlation than fecal coliform with many of the human pathogens often found in city sewage, presumably because it does not suffer the same rate of decay as *E. coli*, and hence is a more conservative tracer of human pathogens.

The City has been sampling *E. coli* and *Enterococci spp.* counts, prior to treatment, at its four intakes since 2002. The average annual and monthly *E. coli* counts at Poplar Point, Cedar Creek and Eldorado intakes, based on data between January 2002 to September 2010, are presented in Tables 3.2 and 3.3, respectively.

The underlying data is plotted as a time series for *E. coli*, and *Enterococci spp.* in Figures 3.1 and 3.2, respectively*.* To better understanding the seasonal nature of the bacterial levels at the intakes, the discharge from the Mission Creek, which is the largest tributary to the Okanagan Lake, is also plotted in both figures. Values when the measured concentration was 0.0 MPN/100 mL (or none detected) are plotted as -1.0 to indicate the overall sampling frequency and the relatively small number of occurrences of values greater than zero. It is difficult to generalize seasonal patterns, except to note that although the average raw water *E. coli* numbers are generally less than 1 or 2 MPN/100 mL, every intake except Eldorado has experienced values of to 10 MPN/100 mL. These large excursions are generally in the non-stratified period, from November to April. Specifically, the peak intake concentration at Cedar Creek intake was 48.0 MPN/100 mL, and occurred on November 21, 2002. The peak at Eldorado was 9.6 CFU/100 mL and occurred on May 27, 2010. The peak at Poplar Point was 30.6 MNP/100 mL, and occurred on April 13, 2005, and the peak at Swick was 46.6 MPN/100 mL, occurring on December 12, 2005. However, significant peaks also occur in the summer months, e.g., July 2007 at Poplar Point.

E. coli data from the wastewater treatment plants, as recorded in the City's WaterTrax system, shows that the plants have been successful in bringing the bacterial count down to none detectable per 100 mL in all samples collected to date. From 2002 to the present, the sampling results show that:

- At the Cedar Creek intake, none of 970 samples exceeded 0 MPN/100 mL.
- At the Eldorado intake, none of 650 samples exceeded 0 MPN/100 mL.
- At the Poplar Point intake, none of 1734 samples exceeded 0 MP/100 mL.
- At the Swick Road intake, none of the 1714 samples exceeded 0 MP/100 mL.

Note that 308 of the Poplar Point samples were expressed in CFU/100 mL, but it is assumed that these observations can be combined with the observations determined using the MPN method.

Risks associated with bacterial contamination will only arise when one or more components of the water treatment system fail, or in the unlikely event of a level of *E. coli*, and associated contamination, that cannot be adequately removed by the treatment plant. Consequently, large inflows from nearby creeks, which are the primary bacteria contributors to the lake, can be a threat.

To understand the nature of bacterial contamination arising from the creeks, Figure 3.3 plots fecal coliform observations between 2001 and 2010 at the four monitored creeks: Brandt's, Fascieux, Kelowna and Mission Creeks. The peak values are as follows:

- Brandt's Creek, 25,500 MPN/100 mL, on July 19, 1993 and 15,150 MPN/100 mL on July 19, 2007;
- Fascieux Creek, 34,480 MPN/100 mL on July 19, 2007;
- Kelowna Creek, 785 MPN/100 mL on September 14, 2009; and
- Mission Creek, 750 MPN/100 mL on June 15, 2007.

These are quite high values, especially for the low flow creeks: Brandt's, Fascieux and Kelowna Creeks. For both Brandt's and Fascieux Creeks, the peaks in 2007 were associated with one or two day rainfall events. For the other peak concentration events, there is no apparent correlation with rainfall.

Over the 17 year period of record, Brandt's and Fascieux Creeks generally experienced much higher fecal coliform counts than the other two. The high values tend to occur after the Mission Creek freshet peak, i.e., in the summer months. For instance, the peak in July 2007 in the Fascieux Creek fecal coliform occurs on July 19. There is a corresponding peak in the Poplar Point intake *E. coli* is on July 18. Logically, if Fascieux Creek fecal coliforms are contributing to the Poplar Point *E. coli* counts, one would expect the peak in Fascieux Creek values to occur slightly before the peak in Poplar Point intake values. However, the sampling density in time was so low, that if such a peak at Fascieux Creek occurred, it was missed: the preceding sample at Fascieux Creek was taken on June 26.

It is clear from the above discussion that the local creeks can be a significant source of *E. coli*. The creek mouths, or the Fascieux Creek wetlands, are generally stagnant areas in the summer with significant bird and pet populations. Management of these relatively stagnant areas should be given some priority, as they apparently lead to *E. coli* peaks at the water intakes. The peak *E. coli* concentration in the creeks occurs in summer typically, as shown in Figure 3.3. At such times, the creek flows are minimal, and any flow from the creeks likely pools up at the creek mouths. However, it is probable that during significant rainfall and wind events the *E. coli* enriched water could be transported away from the creek mouths, either out into the lake, or possible along the shore and pose a threat to users of adjacent beaches. This behaviour is analogous to the first flush behaviour that characterizes contaminant concentrations in storm sewer systems. The principle way to control this transport process is to reduce the amount of *E. coli* in the creeks, to the extent that such a reduction is practical.

It is worth noting that for several years now, the City has closed several beach areas to swimming, notably Sutherland Bay and the Cedar Avenue beaches, because of high bacterial counts. The above discussion of the time series data suggest that the impact of bacterial contamination in these near-shore areas can be felt at the City's water intakes.

3.1.3 Stormwater (C3, C4)

Stormwater is water that originates during precipitation events. The principal stormwater scenario is that the stormwater flows develop in response to local precipitation, and carry a wide variety of pollutants such as sand, silt, dissolved metals, pesticides, nutrients and fecal material (C3). Additionally, exceptional events can occur in which a fuel or chemical spill enters the stormwater system (C4).

Stormwater in Kelowna is mostly directed into three creeks: Brandt's Creek, Fascieux Creek and Kelowna Creek. No stormwater is currently directed into Mission Creek. The use of Best Management Practices (BMP) for stormwater by the City, including catch basins, interceptors, groundwater infiltration, wetland construction, road maintenance and educational programs, minimizes the contaminant loadings, such as oil and grease, sediment, nutrients, pathogens, etc. from entering the creeks. The City has installed extensive hydraulic and water quality works over the last 20 years to mitigate stormwater impacts. An inventory of City's Stormwater water quality treatment facilities are summarized in Table 3.4. A total of 8,455 catch basins treat first flush events by trapping that initial flow and having it retained for ground infiltration within the catch basin. For larger capture areas where high exposure to contaminants and more pervious surfaces contribute larger and potentially contaminated flows, oil and grit separators interceptors are used to capture both oily residue and sediments (17 locations). These flows receive further treatment in constructed wetlands and detention ponds (66 locations) before discharge to receiving waters. Private facilities are also required to treat their drainage flows on site (2 year storm event) for water quality before discharge to City's systems. Drainage requirements and drainage by-laws are part of the Subdivision By-law and the Storm-Sanitary Discharge By-law.

Most stormwater discharges are characterized by the first flush phenomenon, whereby the initial water that reports to the storm sewers carries high concentrations of contaminants from streets and other paved areas. As this material is cleaned from the streets, the concentration of contaminants in the stormwater, after the first flush, declines fairly rapidly. The first flush phenomenon can be quite pronounced in Kelowna and the Okanagan in general. This behaviour is primarily due to lengthy extended hot dry periods in the summer months, followed by relatively high intensity storm events which wash off accumulated contaminants from roadways.

Kelowna has a program to install ‘end-of-pipe’ treatment devices; however, these devices have their limitations in removing water soluble materials. The City also relies on infiltration of stormwater to ground for the majority of the city by way of swales, ditches, gravel shoulders and a network of perforated pipes and drywells. Most parking areas also rely on this method of stormwater disposal for the frequent storm events (i.e., 1:10-yr or less).

Hazards arise when a large amount of pollutants enters into the stormwater system over a short time period. For example, a tanker truck, which typically has capacities ranging from 21,000 L to 34,000 L, carrying fuels or chemicals can be involved in an accident and the contents of the truck could enter the stormwater system and into the creek.

A recent fire in Kelowna also demonstrates how hazardous contaminants can be introduced into the lake through City's stormwater system. Fire fighting activities at an agricultural warehouse complex in Kelowna on the evening of July 31, 2010 resulted in a large input of fertilizer, herbicides and other hazardous chemicals into the City's stormwater system and then into Kelowna Creek. The colour of the creek changed from a typical tannin-stained brown colour to an ultramarine blue green as the contaminants passed through and into the lake. The time period over which the chemicals were present in the creek was relatively small, likely less than 24 hours, the time for the stormwater to collect and arrive at the creek, and for the creek discharge to carry the contaminants to the creek mouth. Numerical modelling predicted that the contaminant cloud would initially travel northward at the surface, near shore, but would not appear in any significant concentration at the Poplar Point intake, the closest intake to Kelowna Creek. The surface movement of the contaminants was validated visually by the City staff. Figure 3.5 shows the contaminant distribution, expressed in terms of dilution, 11 hours after the contaminated stormwater flow into the lake. This particular incident occurred in the summer when the lake stratified. The stratification provided a barrier which prevents the contaminant from transporting down to the intake. Under other wind, circulation conditions or seasons, the movement of the contaminated water would undoubtedly have been different.

3.1.4 Agricultural Activities (C5)

Agricultural operations in the drainage basins produce agriculture waste. This includes manure (containing protozoa) and other wastes from farms, poultry houses and slaughterhouses, harvest waste, fertilizer, pesticides, silt and sand. Data from Lambly Creek (Larratt, 2010) indicate that episodic agricultural inputs, usually arising during rain events, continue to be a significant source of contaminants in creeks. Agricultural waste is likely to have declined during the last decade as farm-specific improvements continue to be implemented while fertilizer inputs are not anticipated to have changed significantly.

The threat from protozoa was discussed in Section 3.1.2. This threat predominantly arises from agricultural activity, usually from young calves. The threat is well-recognized by the Ministry of Forestry and Range, who manages the use of Crown grazing ranges within the Okanagan Lake watersheds. The Ministry of Forestry and Range has established Best Management Practices in Community Watersheds (Fraser, 2010) to reduce risks of fecal and *Cryptosporidium* contamination from livestock. It is not clear to what extent these practices reduce the risk of contamination: i.e., there does not appear to be a quantitative assessment of the effectiveness of these guidelines.

It should also be noted, in a brochure published by the North Okanagan Livestock Association, based on the data collected in 2003 and 2004, the wildlife account for about 2/3 of the *E. coli* contamination found in streams passing through cattle grazing regions in the North Okanagan area (http://www.cattlemen.bc.ca/docs/cattle%20grazing%20in%20watersheds.pdf).

3.1.5 Industrial Activities (C6)

Industrial operations in the drainage basins produce industrial waste. An example of industrial waste is that from SunRype and Canrim Packaging plants. The industrial wastewater from these two plants are partially treated by the Brandt's Creek Trade Waste Treatment Plant before discharging to Brandt's creek, In 2002, 72,800 m^3 of effluent with a phosphorus load of 0.05 tonnes was discharged to Okanagan Lake via Brandt's Creek. The average phosphorous concentration in the effluent stream was 0.7 mg/L, a relatively high value. As a result of increasing flows, the plant was no longer able to consistently achieve the necessary water quality to discharge into the creek. Consequently, all flows are now diverted to the Kelowna Wastewater Treatment Facility (KWWTF). The risk of an upset and effluent reporting to

Brandt's Creek is highly unlikely, since the lift station at the Brandt Creek Trade Waste Treatment Plant has a backup generator to maintain flow in the event of a power outage. It is worth noting that the discharge from the Brandt's Creek Trade Waste Treatment Plant contains high coliform (False fecal coliform) in the form of *Klebciella* which can interfere with *E. coli* results.

3.1.6 Sediment Loading (C7, C8)

The pathways by which sediment loadings enter the various creeks include human activities such as salvage harvesting, ATV and off-road motorsport (C7), and natural event such as wildfires (C8). Salvage harvesting requires increased road and drainage structures in the drainage basin. The construction, installation, maintenance and de-activation of these structures result in increases in surface erosion, which introduces sediment into the creek. ATV and off-road motorsport activities can result in loss of bank strength and trigger minor landslides carrying the sediments into the creek. Wildfires result in loss of trees, which weakens bank strength, causing significant channel change and associated transient increases in suspended sediment concentration. Increases in sediment loadings in the creek will result in increases in water turbidity. Hazards associated with elevated sediment concentrations come in several forms:

1. Elevated turbidity can interfere with plant operations such as UV treatment. A generally accepted threshold is 1.0 Nephelometric Turbidity Unit (NTU). When turbidity values are greater than 1 NTU, then one becomes concerned about the efficiency of the UV system, particularly since the appearance of 1 NTU water may be the precursor for a pulse of higher turbidity water.

2. Turbidity is often taken to be general indicator of raw water quality: processes that introduce harmful contaminants, such as the *Cryptosporidium* pulses, are associated with rainfall and increased turbidity from streams. For instance, Larratt (2010) found significant correlation between *E. coli* spikes and turbidity spikes in creeks, associated with sediment disturbances due both to human activity and rain storms.

3.2 In-Lake Algal Production (L1, L2)

Distinct from influxes of biologically-active pathogens from creeks and other runoff sources, the lake itself can act as the incubating site for another class of pathogen, a type of phytoplankton referred to as cyanobacteria or blue green algae. Many types of phytoplankton are found in Okanagan Lake. Phytoplankton are generally not toxic, and are not a health problem, although they may present aesthetic issues (L1). Certain species tend to be concentrated in the top 10 – 20 m of the water column, as revealed in chlorophyll profiles provided by Ministry of Environment (MOE), and are generally essential for maintenance of the ecology of the lake. The blue-green algae, referred to also as cyanobacteria, tend to be more uniformly distributed in the water column (Larratt 2009) and some species have the potential to be harmful because of their production of lethal cyanotoxins. The concerns with cyanobacteria and cyanotoxins are that, unlike total coliform and *E. coli*, they are difficult to remove in a treatment plant, and some species are very toxic (L2).

The concentration of cyanobacteria in lakes tends to be episodic, with large outburst of growth known as blooms. The driver for cyanobacteria blooms is typically the occurrence of elevated nutrients. Generally, phosphorus (P) is the limiting nutrient, rather than nitrogen (N). A previous Okanagan Lake water quality study conducted by Nordin (2005) indicates that the present N:P ratio of about 28:1 is in reasonable balance and would not encourage the production of cyanobacteria. Over the period of record between 1979 and 2004, Nordin noted that there is a pattern of a clear phosphorus limitation in spring and early summer and likely co-limitation by N and P in summer and fall. The record also suggested that the concentrations of total N and P have not changed significantly over time. The variation in N and P concentrations that has occurred is the result of inter-annual changes in hydrology. This variation also alters the N:P ratio with higher ratios found during periods of lower run off (Nordin 2005).

A summary of the nutrient loading estimates extracted from Hall et al. (2001) is reproduced in Table 3.5. The table shows that the major source of nutrients is from streams, especially those that pass though urban or agricultural regions. Five local creeks that could have impacts on water quality at the City's intakes are: Brandt's Creek, Fascieux Creek, Lambly Creek, Kelowna Creek and Mission Creek. All but Lambly Creek are within the City's corporate boundaries. Ranges of nitrogen and phosphorous data measured by MOE (Vic Jensen, pers. Comm.) in mg/L between 1999 and 2010 from Lambly, Kelowna and Mission creeks and from the lake upstream and downstream of the KWWTF outfall are summarized in Table 3.6. Maximum nitrogen and phosphorous values were both collected at Kelowna Creek.

Figure 3.4 shows a scatter plot of the nitrogen and phosphorous concentrations in MOE samples taken from Lambly Creek, Mission Creek and Kelowna Creek. Also shown in the lower left is a dashed box bounding values of nitrogen and phosphorous, at depths ranging from surface to 45 m, in the vicinity of the KWWTF outfall. Dunne and Leopold (1978) state that a concentration of 0.01 mg/L phosphorous as phosphate (PO4) will support algae growth and those concentrations of 0.08 to 0.10 mg/L phosphorous as PO4 will support a bloom. These phosphorous concentrations are levels for algal growth in general. Specific levels for the algal species in Okanagan Lake are not readily available, but likely similar. As Figure 3.4 indicates, concentrations capable of supporting cyanobacteria growth are generally not observed in the deep central part of the lake, but are frequently detected near the creek mouths. Despite the locally low level of nutrients, cyanobacteria can be found at the depths of the intakes, suggesting they rise to shallower depths for nutrients and sunlight, but spend some time at depth.

Cyanobacteria are not currently a problem with respect to providing safe drinking water in Kelowna, i.e., the concentrations of cyanobacteria in Okanagan Lake do not appear to have caused any human health issues so far. However, this situation could change. If nutrient loading to the lake were to increase, cyanobacteria populations could possibly rise. Such a nutrient loading increase could be driven by anthropogenic influences: nutrient from agricultural livestock waste, nutrients from increased use of fertilizer, and perhaps from recreational activities in the watershed. As well, as climate change proceeds, there may be changes in the overall algal population that could either increase or decrease the abundance of cyanobacteria. In general, the risk associated with cyanobacteria can be reduced by limiting the nutrient inputs to the creeks. Thus, various Best Management Practices need to be adhered to throughout all Okanagan Lake drainage basins, especially with respect to creek contamination. As well, Larrratt (2009) illustrated that generally, the cyanobacteria concentration decreases with depth. Thus, extending the intakes to deeper depth can reduce the risk of contamination.

3.3 Wastewater Treatment Plant Discharge (W1, W2)

The City operates the Kelowna Wastewater Treatment Plant (KWWTF) (W1) and the Regional District of Central Okanagan operates the Westside Regional Wastewater Treatment Plant (WRWTP) (W2). If one of these treatment plants suffered an upset condition, and could not maintain their standards of treatment for a period of time, water quality at one or more of City's intakes could be compromised. Approximate horizontal distances between the outfalls and City's intakes are summarized in Table 3.7.

The KWWTF uses a Bardenpho system, which biologically removes nitrogen and phosphorus, and UV treatment. Currently KWWTF discharges approximately 38 million litres per day through a multiport diffuser into Okanagan Lake at a depth of 60 m. In 2001 (Hall, 2001), the mean annual phosphorous concentration in the effluent from this plant was 0.14 – 0.15 mg/L and 3.5 mg/L nitrogen. The WRWTP also uses a Bardenpho system. It is reasonable to assume that the WRWTP nutrient concentrations are similar to those at KWWTF. The WRWTP currently discharges approximately 9.5 million litres per day through a ten port diffuser into Okanagan Lake at a depth of 60 m.

Contaminants entering the lake from the wastewater treatment plant are considered as continuous point source pollution. The transport and dispersion of the contaminants depends on the physical limnology of the lake, i.e., meteorological forcing, lake bathymetry, water level and thermal stratification. Modelling of the KWWTF outfall diffuser in the Hayco (2001) report showed that the diffuser achieved a 100:1 dilution within 21 m of the outfall, for a wide range of environmental conditions.

It should be noted that the City is undertaking a study to determine the feasibility of harnessing effluent heat from the KWWTF effluent flow to provide energy for buildings in the City and reduce greenhouse gas emissions. The net effect, as far as impact on Okanagan Lake is concerned, is that the effluent leaving the KWWTF would be cooler than it currently is. This cooling would likely change the behaviour of the treated effluent in the lake, likely causing it to transport to a deeper depth in the water column than at present. The effect is likely to be minimal, but could lead to an increased probability of effluent appearing at the City's intakes.

Hazards arise when one or more components of the treatment system fails, resulting in discharging partially un-treated liquid waste which could contain higher contaminant concentrations than the permitted concentration, into the lake.

It should be emphasized that the City has developed written procedures for and during failure for all wastewater plants including up to 30 days post failure measurement at drinking water intakes in order to detect trapped *E. coli* if present.

3.4 Transportation Corridor Spills (S1)

The William R. Bennett Bridge currently accommodates an average of 46,000 vehicles per day and is expected to accommodate more than 69,000 vehicles by 2017 (Central Okanagan Economic Development Commission. 2009).

Hazard arises in the event of a motor vehicle accident. In a small scale incident, for example putting out the fire from a motor vehicle accident occurring on the bridge can result in gasoline and fire retardant entering the lake. In a large scale incident, a tanker truck, which typically has capacities ranging from 21,000 L to 34,000 L, carrying fuels or chemicals can be involved in an accident and can result in spilling the contents of the truck into the lake. The fate of these spills in the lake depends fundamentally on the material spilled: is it immiscible, or will it mix with water? Is it heavier or lighter that water, i.e., will it float or sink? The nature of the bridge drainage system may also play a role in these scenarios. Other transportation corridor accident could involve highway and railway lines located next to the shore, such as Westside Road to the north of the bridge, and Highway 97 to the south.

3.5 Boating Activities (S2)

There have been an increasing number of marina developments and boats on the lake and a lack of on-lake facilities for local and visiting boaters. The marinas and boats may occasionally release greywater, which can contain nutrients, bacteria, viruses and a variety of chemicals, including endocrine disruptors, associated with detergents and personal care products, directly into the lake. The greywater not only reduces the water quality in the lake, but also facilitates the growth of algae, which is undesirable. Other hazards associated with boating activities are fuel spillage during fuelling operations and boating accidents, which can result in fuel being released directly into the lake.

3.6 Impact of Lake Physics

Table 3.8 summarizes hazards impacting the water quality in Okanagan Lake. The codes are arbitrary, but are used in the risk evaluation section to help classify the types of risk.

From the above discussion, it is apparent that physical limnology of Okanagan Lake affects the impacts of these hazards on water quality at City's intakes. A defining characteristic of a monomictic lake such as Okanagan Lake is that goes through an annual cycle of winter homogeneity in the vertical and the subsequent development of a thermocline in the summer.

The thermocline is a major barrier to the transport of material from the waters above the thermocline to the waters below. This can been seen when one considers the temperature profile which defines the thermocline: heat put in at the surface of the lake is generally trapped above the thermocline, leading to the high temperatures that characterize surface water in the summer. This heat readily propagates down to the thermocline, but only a limited amount moves down below, leading to the more steady, cooler temperature of the waters below the thermocline at 20 m depth and greater. Similarly, surface contaminants such as sediment, *E. coli*, cyanobacteria and *Cryptosporidium* oocysts, all of which are associated almost exclusively with the surface waters, are blocked by the thermocline form moving down to the depths of the intakes. However, as shown in the Hayco 2001 report, strong wind events can upset these conditions, and the large amplitude internal waves that develop on either side of the sill in Okanagan Lake lead to large downward motions of surface water, an ingestion of surface water into the intakes. The Hayco 2001 report also showed that the severity of this effect could be reduced by making the intake deeper, which was part of the motivation for extending the Poplar Point intake to a depth of 29 m, almost always below, or at the base of, the main summer thermocline.

In the fall as the surface cools and heat continues to propagate downward and the lake approaches the non-stratified situation. When the lake is in the non-stratified state, there is insufficient density gradient in the vertical to resist the mixing effect of wind events, and thus, energetic wind mixing in the upper part of the lake can penetrate deeper than in the summer. As the lake surface cools below 4°C, the temperature of maximum water density, the lake enters a state of static instability, and a process develops whereby the lake surface water sinks and deeper water rises to the surface. This process is referred to as lake turnover. In some lakes, where there may be a high concentration of deleterious material in the deep waters, turnover can be a major problem. In Okanagan Lake, there is no indication of significant deleterious material in the deep waters. However, turnover may be triggered by a change in weather, such as a cold front moving through and there may also be associated high winds, which could mobilize sediment. These two coincident events could lead to the appearance of turbid water at the intakes.

Note that if the mobilized sediment is associated with contaminant s such as *E. coli*, for instance from near the smaller creek mouths, the turnover event could lead to the appearance of *E. coli* at the City's intakes. With respect to oocysts, which would have been delivered to the lake in the early summer, typically, but remain viable for many months, the turnover process is capable of bringing near-surface waters down to the depths of the intakes, and hence poses a risk to the water supply. However, because the oocysts will have been moving around and mixing throughout the surface waters in the intervening months between their introduction into the lake and the turnover event, they will be considerably diluted compared to the more direct pathways that were demonstrated in the Hayco (2001) simulation of the 1996 *Cryptosporidium* event. Thus it seems that turnovers are a second order effect compared to other more direct threats to the water supply.

4.0 CONTAMINANT LOADING SCENARIOS

Seven contaminant loading scenarios were developed based on the information from the contaminant sources to assist with the risk assessment. A three-dimensional hydrodynamic model is used to evaluate these scenarios quantitatively the source characterization of the City's intakes and the reduction in threat to each intake if the intake were at a deeper depth. These scenarios are:

1. Simulate June 1996, using realistic *Cryptosporidium* concentrations, based on *Cryptosporidium* production rates given in Atwill et al. (2006), and an estimate of number of cattle, duration of flushing from feedlots (C1).
2. Simulate the June 2007 peak creek fecal coliform concentrations. The objective of this simulation is to understand the impact that bacterial loading from the creek mouths has on City's water quality (C2).
3. Simulate the July 2010 fire fighting event in which contaminated stormwater entered Kelowna Creek and into Okanagan Lake. The fire fighting event is reproduced for a January conditions when the creek flow is low and when lake stratification would be absent (C4).
4. Evaluate the difference between phosphorous concentration in the creeks, and at the intakes using the creek water dilutions computed in the 1996 (C1) and 2007(C2) simulations (L1).
5. A spill of diesel from a tanker truck on the William R. Bennett Bridge (S1).
6. A grey-water spill from a houseboat in the vicinity of Poplar Point intake (S2).
7. An upset in the Kelowna Wastewater Treatment Facility (KWWTF) (W1).

4.1 1996 *Cryptosporidium* Outbreak (C1)

The June 1996 *Cryptosporidium* outbreak simulation was conducted using realistic *Cryptosporidium* production rates. The numerical model used in this analysis consists of a grid spacing of 83 m and utilized meteorological data from the Kelowna Airport. For this simulation and all other simulations in this report, the model geometry was based on the old bridge configuration, rather than the William R. Bennett Bridge. This choice of bridge configuration is appropriate to the 1996 hindcast. It will also have minimal impact on other simulations since, except for the fuel spill simulation, contaminant movement is dominated by water velocities at depth. Three creeks were identified as potential Cryptosporidium paths to Okanagan Lake: Kelowna Creek, Lambly Creek and Mission Creek. Flows were available for Mission and Kelowna Creeks, and the flow for Lambly Creek was assumed to be 40% of Mission Creek.

To determine a realistic *Cryptosporidium* production rate, number of infected cattle, duration of flushing from feedlots and daily production per animal were estimated. The number of infected cattle, i.e. infected calves which produce *Cryptosporidium*, was estimated to be 100 for each creek's watershed. At present, there are 2,025 cow-calf pairs grazing in the watersheds of these three creeks, and the number was likely larger in 1996. 100 infected calves thus represent 15% of the total number. Using 100 infected calves as the basis, the computed *Cryptosporidium* impact is readily scaled up or down to check the sensitivity of the calculation to this number. The daily production per infected calf is estimated by Atwill et al. (2006) to be 1.4×10^5 oocysts. For this analysis, it was assumed that the oocyst production accumulated over 30 consecutive days was flushed from the feedlots into the creeks in 24 hours. It should be noted that these statistics apply to present numbers of calves, and do not take into account cattle on privately held land. The above estimates are likely representative of current potential *Cryptosporidium* loadings. Conditions in 1996 may have been more severe than those schematized above, because the current Best Management Practices developed by the BC Ministry of Forest and Range were likely not followed in 1996.

The release of the oocysts from the feedlots into the creeks occurred on June 1st at the peak of the rainstorm. The peak oocyst concentration was 350 oocysts/m^3 at Kelowna Creek, 250 oocysts/m^3 at Lambly Creek and 100 oocysts/m^3 at Mission Creek, corresponding to peak flow rates of 14 m^3/s at Kelowna Creek, 20 m^3/s at Lambly Creek and 50 m^3/s at Mission Creek.

Figures 4.1 and 4.2 present the time series of oocyst concentration between May 29th and June 15th at depths of 20 m, 30 m, 40 m and 50 m near the Poplar Point and Cedar Creek intakes, respectively. The top panel on these figures shows the oocyst concentration from Kelowna Creek. The middle panel shows the oocyst concentration from Lambly Creek and the bottom panel shows the oocyst concentration from Mission Creek. It can be seen that the maximum oocyst concentration detected at the Poplar Point intake originated from Mission Creek, and occurred about 2-3 days after the release into Mission Creek. The maximum concentration at the Cedar Creek intake occurred about a day later, and was dominated by oocysts from Kelowna Creek. Figure 4.2, in particular, highlights the risks posed by an intake at 20 m depth compared to one at 30 m depth, with respect to being able to avoid contaminants discharged at the surface. The maximum oocyst concentration and the associated dilutions over a range of depths near the two intakes are summarized in Tables 4.1 and 4.2.

Figure 4.3 presents the oocyst concentration maps at a depth of 20 m (Cedar Creek intake depth) on 8 a.m. June 4th, the time associated with maximum oocyst concentration detected at the Cedar Creek intake.

Similarly, Figure 4.4 shows the oocyst concentration maps at a depth of 30 m (Poplar Point intake depth) on 8:00 am June 4th, the time associated with maximum oocyst concentration detected at Poplar Point intake.

As shown in the Hayco (2001) report, the pathway for *Cryptosporidium* to reach the City's water intakes can be remarkably direct, e.g., the simulated *Cryptosporidium* in the Mission Creek flow reached the Poplar Point intake in a little over two days, with a dilution of about 480:1. *Cryptosporidium* from Kelowna Creek took a day longer to reach the Cedar Creek intake, but at a similar dilution.

4.2 2007 Peak Creek Fecal Coliform (C2)

Peaks of *E. coli* were measured at Brandt's Creek and Fascieux Creek and at the Poplar Point intake in July 2007.

- Brandt's Creek - An *E. coli* concentration of 15,150 MPN/100 mL was measured on July 19, 2007.
- Fascieux Creek - An *E. coli* concentration of 34,480 MPN/100 mL was measured on July 19, 2007.
- Poplar Point intake - An *E. coli* concentration of 11 MPN/100 mL was measured on July 24, 2007.

These are quite high values, especially for the low flow creeks such as Brandt's and Fascieux Creeks. These peaks in 2007 were associated with one or two day rainfall events. A numerical modelling simulation was conducted to investigate this *E. coli* phenomenon. The objective is to understand the relationship, if any, between the *E. coli* peaks at the water intakes and peaks in creek bacterial levels.

The 83 m Okanagan Lake model utilizing meteorological data from the Kelowna Airport was used in this analysis. A constant concentration of *E. coli* was assumed for Brandt's and Fascieux Creeks mouths. The maximum observed concentration on July 19 was selected and set up as the initial concentration. Since flow data for these creeks is not available, it was assumed the water bodies adjacent to the creek mouth, about 250 m in extent, act as a continuous contaminant source supplying the above concentrations over a 24 hour period. No *E. coli* die-off was assumed in this simulation.

Figure 4.5 presents the time series of *E. coli* concentration originating from Brandt's Creek (second panel) and from Fascieux Creek (third panel) at depths of 30 m (black line), 40 m (red line) and 50 m (blue line) near the Poplar Point intake. The top panel shows the wind speed at the Kelowna Airport. Also shown in Figure 4.5 is the time series of *E. coli* concentration originated from Brandt's Creek (fourth panel) and from Fascieux Creek (bottom panel) at depths of 20 m (green line), 30 m (black line), 40 m (red lien) and 50 m (blue line) near the Cedar Creek intake.

Even though a steady concentration was prescribed, several peaks are observed at the intake, as shown on Figure 4.5. It can be notice that strong winds blowing from the north-west considerably increased the *E. coli* concentration at the intake with an approximate delay of three days. Strong winds will increase the mixing, hence increases the *E. coli* in the water column that would be available for transport to the intake. Additionally, strong winds from the northwest would induce a flow to the northwest in sub-surface waters, which is the flow direction needed to carry material from the Brandt's Creek area to the Poplar Point intake. It is also seen in Figure 4.5 that material didn't arrive at Cedar Creek until a period of weak winds on the 27th and 28th of July.

Figure 4.5 shows that even though *E. coli* concentration was over twice as large at Fascieux Creek than at Brandt's Creek, the highest *E. coli* concentrations detected at the Poplar Point intake came from Brandt's Creek. Referring to Table 3.1, one notes that Brandt's Creek is about 2.6 km away from the Poplar Point intake whereas Fascieux Creek is 6.3 km away. Thus, the close distance between Brandt's Creek and the intake is likely the reason for these high concentrations.

Figure 4.5 also indicates that despite being a shallower intake, the *E. coli* concentration at the Cedar Creek intake, in general, was much less than that at the Poplar Point intake over the course of the simulation. While the distance between the contaminant source and the intake is likely the key reason for this observation, the fact that Brandt's Creek and Cedar Creek intake are located at different basins also contribute to the minimal *E. coli* concentration for this simulation. If the Cedar Creek intake were to be situated at 30 m deep, much lower *E. coli* concentrations would be observed.

Figure 4.6 presents the maps of *E. coli* concentration at a depth of 29 m, which corresponds to the depth of Poplar Point intake, at the time of maximum concentration at the Poplar Point intake. On average, the modelled dilution of the Brandt's Creek source at the Poplar Point intake is about 3,000:1. This small dilution reflects the relatively short pathway between a source point on the water surface and the water intake, located at a depth of 29 m, and 2.6 km away from the source. The hypothesis that the *E. coli* peaks at the intakes can be related to the creek bacterial levels has been confirmed. On July 18 and 19, rainfall of 14.2 and 13.4 mm respectively occurred, after 17 days without rain. This rainfall timing coincided exactly with the appearance of the high *E. coli* counts at the creek mouths, suggesting rainfall is a powerful indicator of *E. coli* export from the small local creeks and wetlands to Okanagan Lake. Examination of Figure 4.5 suggests that periods of northwest winds are correlated with peaks in *E. coli* at the Poplar Point intake.

It should be noted that the maximum observed concentration was selected and set up as the initial concentration for the model: 15,150 MPN/100 mL for Brandt's Creek and 34,480 MPN/100 mL for Fascieux Creek. Bacterial die-off was not included in the analyses, so that the behaviour of other pathogens with slower rates of decay than *E. coli*, could be addressed. Even without bacterial die-off, the modelled concentrations are lower than detected ones at the intake, about 10 MPN/100 mL, shown in Figure 3.1. Thus, it appears that the modelled *E. coli* loading was underestimated. However, other pathogens have slower rates of decay than *E. coli*, so the decision was made to exclude die-off.

4.3 July 31st 2010 Stewart Centre Fire (C4)

In the evening hours of July 31, 2010, a fire broke out at the Stewart Centre strip mall on Kirschner Road, Kelowna, BC and burned out seven businesses including a welding shop, sports store, restaurant, and a landscaping shop, which stored both fertilizers and pesticides.

During the fire fighting operations, an estimated three million litres of water was used. A considerable portion of this contaminated water was pumped, collected and removed from the storm sewer system for processing and disposal. Some of the contaminated water washed into storm drains and into Kelowna Creek, which drains into Okanagan Lake, the drinking water source for the City. Due to the strong stratification of the lake during summer, no contaminant reached the Poplar Point intake. A hindcast results for this event is presented in Figure 3.5.

Under other wind, circulation conditions or seasons, the movement of the contaminated water would undoubtedly have been different. To observe the contaminant levels at the intake that would occur when the lake is not stratified, the same simulation was repeated, but for a hypothetical similar incident in winter.

The hypothetical simulation involved the 12 hours release of contaminated water from midnight January 8th, 2010. The initial concentration of the Kelowna Creek flow is assumed to be 1.0 over the release period. Winds were from the south throughout the entire simulation period.

The bottom panel on Figure 4.7 presents the contaminated water concentration time series at the Poplar Point intake. The top panel represents the wind speed at Kelowna Airport and the middle panel represent the water temperature at the intake depth. Approximately 12 hours after the beginning of the release, contaminated water was observed at the intake. The peak occurred on January 9th at 6 a.m. with a concentration of 0.00009, i.e. approximately 11,000:1 dilution. Seventy-two hours after the end of the release, contaminated water concentration at the Poplar Point intake returned to the background value, zero.

Figure 4.8 presents a map of the contaminated water concentration at the depth of the Poplar Point intake (left panel) and at 40 m depth (right panel) at 6 a.m. on January 9th 2010. It can be observed that the contaminated water is pooling up in the vicinity of the Poplar Point intake and offshore of the Kelowna Yacht Club. If the intake were to be extended to 40 m deep, the concentration of the contaminated water would be reduced by about two thirds.

4.4 Phosphorus Concentration in the Creeks and at the Intake (L1)

As presented in Section 3.2, the in-lake algal production is directly linked to the level of nutrients. Generally phosphorus is the limiting nutrient rather than nitrogen. As well, the major source of nutrients is from streams, such as Brandt's Creek and Fascieux Creek, Kelowna Creek, Lambly Creek and Mission Creek.

Point Source Protection Planning (Okanagan Phosphorous Project, 1980-1990) identified phosphorus from wastewater treatment plants as being primary contributor to phosphorous loading in Okanagan Lake. The strategic plan included the rationale for funding tertiary treatment wastewater plants in all communities that have sanitary treatment facilities on Okanagan Lake. Also developed were Okanagan Phosphorous Environment Impact Area Maps which were used to delineate where septic systems could not be placed. The mapping was based on soil typing and potential for transmission of phosphorous to receiving bodies of water. Non-Point source pollution contributing to phosphorous loading is controlled by Best Management Practices in areas at risk identified by agencies and local government with a watershed approach (education and collaboration).

Simulations of 1996 for the *Cryptosporidium* outbreak (C1) and simulation of 2007 for the peak *E. coli* concentration (C2) show that any contaminant released at the creeks will likely have an impact at the Poplar Point and Cedar Creek intakes. Dilutions in the simulations conducted as part of this study ranged from 400:1 to 48,000:1, for releases occurring on the eastern part of Okanagan Lake, between Poplar Point and Mission Creek. Figure 3.4 shows that dilutions from continuous sources, such as the creeks, which brings nutrients into the lake, can be inferred to be as low as 15:1. However, the nominal creek values may already have been diluted somewhat, which would bring the overall dilution higher.

Nevertheless, persistent sources, such as the supply of nutrients over several weeks during freshet, have a relatively low dilution with respect to concentrations appearing at the Poplar Point intake, and probably also at the Cedar intake. If phosphorous levels increase in subsequent years, it is possible that blue-green algae production will increase and impact both Poplar Point and Cedar intakes. Various simulation (C1, C2) have shown that there are often strong differences in the behaviour of the basins to the north and south of the bridge. To the extent that nutrient concentrations in these basins are associated with their source creeks, then maintaining independent intakes, one in each basin, will provide some protection from harmful algal blooms.

4.5 Diesel Spill From a Tanker Trucker on the William R. Bennett Bridge (S1)

A tanker truck accident on the William R. Bennett Bridge would result in a spill of its contents into the lake. Depending on environmental conditions as well as the material spilled, different creeks and intakes can be affected by the spill. To model the fate of this spill and its extent on the Okanagan Lake, a comprehensive fuel tracking and weathering module named SPILLCALC was coupled with the three dimensional Okanagan Lake model. Below are the main physical processes incorporated into SPILLCALC:

- Horizontal spreading and diffusion.
- Advection.
- Evaporation, based on the pseudo-component approach.
- Vertical dispersion.
- Shore retention.
- Resurfacing after a storm.

To represent the likely maximum extent of the spill over July 2007, two simulations were conducted:

- Simulation A - a release of 159 m^3 (1,000 bbl) of diesel over 20 minutes on July 10th when the winds are the strongest and mainly blowing to the southeast.
- Simulation B - a release of 159 m^3 (1,000 bbl) of diesel over 20 minutes on July 21st when the winds are mainly blowing to the northwest.

4.5.1 Simulation A: Winds blowing to the Southeast

The diesel spill occurred on July 10th, 2007, at 2 a.m. and finished at 2:20 a.m. A quantity equal to 159 m^3 of diesel was released from the middle of the bridge into the Okanagan Lake. The left panel on Figure 5.10 shows the map of the diesel spill distribution on the lake surface 6 hours after the release. Due to the strong northwesterly wind, the slick was pushed towards the east shore at the south of the bridge. Because the entire slick went south, no diesel had the possibility to reach the vicinity of Poplar Point intake. After 10 hours, no diesel is left on the water: 38% evaporated and 62% was retained on the shore, due to the high retention capacity of sandy beaches. In this case, the fate of the diesel was dominated by the shore retention process.

The complete transport process of the spill can be viewed in Movie 5.6.A, included in the CD in this report.

4.5.2 Simulation B: Winds blowing to the Northwest

The diesel spill occurred on July 21st, 2007, at 9 p.m. and finished at 9:20 p.m. A quantity equal to 159 m^3 of diesel was released from the middle of the bridge into the Okanagan Lake. The right panel on Figure 5.10 presents the map of the diesel spill distribution on the lake surface 8 hours after the release. Due to southeasterly winds, the slick was pushed towards the north. After six hours, the slick reached the waters above the Poplar Point intake. After 14 hours, no diesel is left on the water: 78% evaporated and 22% was trapped on the shore. In this case, the fate of the diesel was dominated by the evaporation process. If this simulation were to occur in the winter time under the same wind conditions, it is likely that the amount of evaporation would be less, and hence the shore retention process would acquire greater importance.

The complete transport process of the spill can be viewed in Movie 5.6.B, included in the CD in this report.

4.5.3 Consequences of a Diesel Spill

Whether or not any of the spilled fuel reaches the intakes depends on the amount of water-soluble material in the fuel, and the environmental conditions at the time of the spill. Simulations in the preceding sections showed the wide variability in dilution that occurs between a spill at the surface and its appearance at the intakes, ranging from 400:1 to 48,000:1. In the case of diesel fuel, most of the spilled liquid is insoluble, and the fuel itself is lighter than water, so that no diesel would be transported to the depth of the intake. Moreover, combined with its high volatility, a diesel or gasoline spill presents low risk to impact the intake. However, if a spill occurs with a heavier material and during a storm when vertical dispersion is likely high, the material may reach the depth of one or more of the City's intakes. Indeed, either through the process of dispersion into the water column or adsorption on small sediments, heavier fractions could potentially reach the depths of the intakes. However it should be noted that the risk of spill of heavier materials is much lower than the risk of diesel spill (diesel is carried more often).

In order to illustrate the behaviour of the low concentration, but toxic, components of diesel, the following discussion of benzene is provided. The Canadian drinking guideline for benzene is 0.005 mg/L. Benzene's effective solubility in water, when the benzene is derived from a surface slick of diesel oil, is 0.0622 mg/L, based on the Environmental Protection Agency (EPA) Calculator. The various simulations in this report have identified that dilutions at Poplar Point, for a source near the bridge, range from 400:1 to 48,000:1. A dilution of only 12:1 is required to bring the soluble benzene concentration down from its maximum value, 0.062 mg/L down to the guideline value of 0.005 mg/L. Conditions in Okanagan Lake readily meet this criterion. That is, a release of diesel fuel would not lead to exceedance of the drinking water guideline for benzene, because of the low solubility and the significant amount of dilution associated with lake processes. Similar arguments apply for the other toxic constituents, in addition to the observation that the other constituents are all less toxic than benzene.

4.6 Greywater Spill From a Houseboat in the Vicinity of Poplar Point Intake (S2)

A hypothetical greywater spill from a houseboat in the vicinity of the Poplar Point intake was modelled. 200 L of greywater was assumed to be released over nine minutes on July 10, 2010. The purpose is to observe if a small quantity of contaminated water released in the vicinity of the intake could reach the intake. It is assumed that this greywater consisted of a very high concentration of *E. coli*, i.e. 1,000,000 MPN/100 mL, so its source could even be considered black water. Die-off of the *E. coli* was not implemented in this simulation. This spill is assumed to occur approximately 400 m horizontal distance from the Poplar Point intake.

The release of the greywater started on midnight July 10, 2010. During the following hour, the contaminated water was contained in a radius of approximately 50 m from the houseboat. Figure 5.9 presents a vertical profile of *E. coli* concentration at the location of the houseboat in the hour following the release. This profile shows that only the top two metres contain a significant concentration of *E. coli*, up to 2.5 MPN/100 mL. However the dilution became much too high to detect any contaminated water in the deeper layers or anywhere else in the lake. If a similar spill would occur right above the location of the Poplar Point intake, it is likely that no contaminated water would reach the depth of the intake and thus the intake. Consequently a greywater spill presents low risk to the water quality at the intake.

During the winter non-stratified period, greywater would more readily mix through the water column, so that *E. coli* concentrations would be vertically uniform, but very low, e.g., 0.2 MPN/100 mL or so.

4.7 Upset in the Kelowna Wastewater Treatment Facility (W1)

The upset in the Kelowna Waste Water Treatment facility simulation is conducted over the period between June and July 1996. It was assumed that the KWWTF normally releases specific contaminants with a nominal concentration of 1. The actual concentrations are well below appropriate guideline values, but to keep the discussion general, the nominal value approach is used. To simulate the upset, the effluent was assumed to be release with a nominal concentration of 1,000 over a three day period, from June 15th to June 18th 1996. On June 18th, the effluent concentration reverted back to 1 until the end of the simulation.

Note that the assumed upset conditions would result in a very conservative results since historically KWWTF has had failures of up to maximum a day and not as a straight line full failure. The failure has always been a gradual failure and gradual recovery due to 8-12 days solids retention time. However in this modelling scenario, the unlikely possibility of three days of full failure investigates the case that raw sewage would be bypassing for three days, which has never happened in the past. Facing a gradual failure, the KWWTF would lose some nutrient removal capability and, if clarification does not remove solids, solids particles would overflow and not be disinfected efficiently by the UV system. A failure level threshold of 25 ppm was suggested as disinfection would shut down when UV lamps are fouled. An effluent concentration range of 100,000-1,000,000 MPN/100 mL would then be expected.

Figure 4.11 presents the time series of winds and contaminated water concentration at depths of 30 m (black line), 40 m (red line) and 50 m (blue line) near the Poplar Point intake (middle panel). Also shown in the figure is the time series of contaminated water concentration at depths of 20 m (green line), 30 m (black line), 40 m (red line) and 50 m (blue line) near the Cedar Creek intake (bottom panel). The unit for the concentration at the Poplar Point intake is shown in PPT (part per thousand) and the unit for the concentration at the Cedar Creek intake is shown in PPH (part per hundred).

The concentration at both intakes starts ramping up on June 20th, five days after the beginning of the upset. It is important to notice that sporadic peaks occur during the entire simulation at Poplar Point intake, especially with the most significant one, in terms of duration and intensity, occurring during the middle of July. At the Poplar Point intake a maximum concentration of 0.004 was detected, occurring on July 13, almost a month after the upset event, and a maximum concentration of 0.02 was detected on June 26, about two weeks after the upset event, at the Cedar Creek intake, although at a greater depth, i.e., along the lakeward extension of the outfall line. At this time, the effluent concentration of 1 was being released at the KWWTF. Thus, the highly contaminated water released during upset conditions avoided being strongly mixed to background values for a two week period, at which point it re-appeared at the Poplar Point intake location, with a dilution of about 250,000:1 and at the Cedar Creek intake with a dilution of about 170,000:1. Thus an upset at the KWWTF has much bigger impact on the Cedar Creek intake than on the Poplar Point intake, for the limnological conditions (stratification and currents) occurring over the period of this simulation.

Figure 4.12 presents a map of the KWWTF effluent concentration at the depth of 29 m, the depth of the Poplar Point intake on July 13, the time when the maximum concentration was observed at the Poplar Point intake. One notes in this figure that the initial patch of contaminated water associated with the outfall has moved both north and south, but the part of the plume that moved north is characterized by somewhat higher concentrations. Similarly Figure 4.13 presents a map of the KWWTF effluent concentration at the depth of the Cedar Creek intake on June 26, the time when the maximum concentration was observed at the Cedar Creek intake. The concentration is much greater at the Cedar Creek intake than at the Poplar Point intake.

In the winter, the effluent is considerably warmer than the lake, so the effluent plume is expected to rise much more vigorously than it does in the summer, and thus rise above the depths of the City's intakes. Consequently, the summer simulation represents worst case conditions, when wastewater treatment plant effluent is most likely to report, although in a diluted form, to the City's intakes. Thus, only the summer simulation was conducted.

5.0 SOURCE TO TAP ASSESSMENT GUIDELINE - MODULE 7 RISK ASSESSMENT

A Qualitative Risk Assessment is conducted using information from Module 7 of MHCSTAG. The risk is determined as the product of likelihood and consequence. Likelihood is the chance that a hazard will compromise drinking water quality and pose a public health threat. Consequence is the combination of the severity, nature, and duration of the event, the proportion of the population affected, and type of health consequences. Tables 7.1 to 7.3 from MHCSTAG are reproduced here as Tables 5.1 to 5.3.

A Risk Characterization Table, Tables 5.4, was prepared based on Tables 5.1 – 5.3. This table was prepared in a manner consistent with a drinking water deferral application. Appendix C of the Interior Health Issue Paper: "Planning for Drinking Water Filtration Recommendation" provides specific criteria that a water supplier must demonstrate in a filtration deferral application. Those criteria relevant to source water protection are listed below:

- Background baseline levels of *Cryptosporidium* and *Giardia* adequate to establish trends, have been established;
- A watershed control program designed with the express purpose of minimizing fecal contamination in the source water has been implemented. Watershed control programs expressly intended to minimize

fecal contamination can be accomplished by completing appropriate modules of the comprehensive source to tap assessment guide developed by MOE and MOH. Modules appropriate to the water supply system will be identified by the DWO and may be included in the conditions of the operating permit.

- No more than 10% of source/raw *E. coli* samples exceed 20 /100 mL in any 6-month period;
- No more than 10% of source/raw water coliform samples exceed 100/100 mL in any 60-month period;
- Turbidity in source immediately before disinfection does not exceed 1 NTU 95% of the time in any 30-day period;
- Peak turbidity readings do not exceed 5 NTU for more than 2 days in a 1-year period.

Criteria relevant to the treatment process and relevant to the above-noted turbidity requirements are provided in a companion report by Associated Engineering (Associated Engineering, 2011).

With regard to specific risk factors, additional criteria are also relevant. Ivor Norlin, Interior Health (pers. comm.) has provided the following information regarding cyanobacteria threats.

The American Water Works Association has identified >15,000 cells/mL cyanobacteria as a benchmark for potential presence of cyanotoxin. However, the World Health Organization goes further in stating that cell concentrations from 20,000 to 100,000 cells/mL represent an increasing trend towards a moderate risk of adverse health effects in drinking water (WHO, 1999). Further, available literature suggests even where there is accurate speciation of cells there may not be a strong correlation between cell numbers and toxin producing capacity of a bloom (US CDC, 2008). For these reasons, the current Guidelines for Canadian Drinking Water Quality suggest an appropriate response to elevated cyanobacteria concentrations in source waters is to test for toxins (Health Canada, 2008). It is only with information on toxin concentrations and in consideration of the efficacy of treatment works for inactivating or removing toxins (e.g. AB MoE, 2002; WHO, 1999) that decisions to take specific action to protect public health (e.g. notification, shutting down a source, enhanced monitoring) should be made.

5.1 Inflows of *Cryptosporidium* and *Giardia* (C1)

Probability: A rare likelihood (E) was selected, since it appears that only one significant protozoa outbreak (*Cryptosporidium*) has happened in recent years.

The USEPA Long Term 2 Surface Water Treatment Rule inactivation requirements for unfiltered systems provides that raw water not exceed 10 oocysts/m^3 arithmetic mean. The *Cryptosporidium* simulations in this report easily met this requirement, the highest value being about 1 oocyst/m^3. Especially given current Best Management Practices, the chances of a repeat of the 1996 outbreak appear to be remote.

Consequence: This outbreak affected between 8,000 to 10,000 people, according to the epidemiology report from the Vancouver Centre for Disease Control (CDC). Hence the consequence is taken to be Catastrophic (5), as any protozoa outbreak could potentially make several hundred people sick and may even be fatal to persons with compromised immune systems.

Risk: High.

5.2 Pathogenic Bacteria Inflows (C2)

Probability: The criterion to be met is that no more than 10% of source/raw *E. coli* samples exceed 20/100 mL in any 6-month period. This appears to be met at all of the City's water intakes (Fig. 3.1). It should be noted that the occurrence of elevated *E. coli* counts at Poplar Point decreased with the introduction of the deeper intake. Cedar is subject to *E. coli* counts in the 20 MPN/100 mL range on occasion, buts meets the filtration deferral requirement. Thus, a possible likelihood (C) is selected. Furthermore, observed data from Lambly Creek (Larratt 2010) indicate that episodic agricultural inputs, usually arising during rain events, continue to be a significant source of contaminants in creeks. These observations indicate that the problem of bacterial inflow is not necessarily under control, and ongoing monitoring and improvements in management are important.

Consequence: The consequence is taken to be Major (4), since if concentrations exceed 20 MPN/100 mL treatment may not be effective, and there could possibly be major health problems for a city the size of Kelowna.

Risk: Very High.

5.3 Stormwater Contamination - First Flush (C3)

Probability: Modelling in this report, e.g., the Stewart Center fire simulation (C4) and the peak creek fecal simulation (C3) has demonstrated that first flush discharges generally appear at the City's intakes. However, the dilutions are quite high, generally being several thousand to 1, thus, the probability that contaminants of significant concentration, e.g. *E. coli* concentrations greater than 20 MPN/100 mL, are possible (C).

Consequence: The consequence is taken to be Moderate (3) because most bacterial pathogens will have died-off before entering the stormwater system.

Risk: High.

5.4 Stormwater Contamination - Fuel or Chemical Spill (C4)

Probability: An unlikely likelihood (D) was selected, since the occurrence of hazardous contaminants such as fuel, fertilizer, herbicides and other hazardous chemicals released into a creek is very small. It is known to have occurred only once over several years (July 30th 2010). It should be noted while modelling of this scenario in both summer and winter showed no impact at the intake; other simulations for other dates have shown that surface discharges can readily make their way to the intakes with dilutions of 100:1 or so.

Consequence: The consequence is taken to be Major (4), since any kind of hazardous contaminant that reaches the intake will likely be significantly diluted, but could still pose some health threats.

Risk: High.

5.5 Agricultural Activities (C5)

Probability: Two agricultural activities are relevant: the release of *E. coli* near creeks, which is captured in case C2, and the release of nutrients. C5 is concerned with the release of nutrients. A high likelihood (A) was initially selected, since nutrient introduction into creeks and subsequent movement into the lake is an ongoing process. However, the probability that the nutrient loading will increase to levels sufficient to change the ecology of the Okanagan Lake is considerably lower, so a likelihood of unlikely (D) was selected.

Consequence: The consequence ranges from Insignificant (1) to Moderate (3), depending on the time frame under consideration. At present, consequences are Insignificant, and will remain so, as long as the flux of nutrients into the lake does not increase.

Risk: Low.

5.6 Industrial Activities (C6)

Probability: A rare likelihood (E) was selected, since the effluent from the Brandt's Creek Tradewaste site is now pumped to the Kelowna WWTF, and the lift station has a backup generator to maintain flow in the event of a power outage.

In the absence of a more specific value, the IHA guideline for fecal coliform, less than 20 MPN/100 mL in 90% of the samples, is selected for this scenario.

Consequence: The consequence is taken to be Major (4), since if concentrations exceed 20 MPN/100 mL treatment may not be effective, and there could possibly be major health problems for a city the size of Kelowna. These ratings could change if additional industrial activity is introduced into Kelowna.

Risk: High.

5.7 Sediment Loading - Forestry and Recreational (C7)

Probability: A value of (C) was selected, since the historical record (reported in Associated Engineering, 2011) shows that in the period from 2004 to 2009, raw water at the City's intakes readily met the IHA guideline for filtration deferral, but there is no compelling evidence to indicate that exceedances could not occur.

Consequence: The consequence is taken to be Minor (2), since the erosion due to human activities is usually confined to short periods of time and is not continuous, so that there is good opportunity for significant dilution once the sediment enters the lake. In a broader view, elevated sediment concentrations can affect the performance of treatment plants and elevated sediment levels are often viewed as indicators of declining water quality.

Risk: Moderate

5.8 Sediment Loading - Natural Event (C8)

Probability: A possible likelihood (C) was selected, since natural event such as wildfires happen and are not predictable.

Consequence: Wildfires result in loss of trees, which weakens bank strength causing significant channel change and associated transient increases in suspended sediment concentration. The consequence is taken to be Moderate (3), one grade higher than the consequences of human-related sediment loadings, because increase sediment inputs resulting from natural events could persist for a long time as the affected watershed adjusts to its new configuration. In a broader view, elevated sediment concentrations can affect the performance of treatment plants and elevated sediment levels are often viewed as indicators of declining water quality.

Risk: High.

5.9 In-lake Algal Production – Non-Cyanobacteria Contamination (L1)

Probability: The probability for non-cyanobacteria algal blooms is not high, because of the relatively low levels of nutrients in the lake. An unlikely likelihood (D) was selected, since it is relatively unlikely that algal concentrations sufficient to present health problems or problems for water treatment operations will develop. The driver for algal blooms is typically the occurrence of elevated nutrients. Generally, phosphorus (P) is the limiting nutrient, rather than nitrogen (N).

Consequence: The consequence is taken to be insignificant (1), since algal blooms not involving cyanobacteria are generally not toxic, and don't present a health problem.

Risk: Low.

5.10 In-lake Algal Production - Cyanobacteria Contamination (L2)

Probability: Two thresholds to consider are a value of 15,000 cells/mL, the threshold for short-term toxicity and 2,000 cells/mL, the threshold for chronic exposure. Larratt (2009) found that "29% of monthly intake samples contained more than 2,000 cyanobacteria cells/mL. This numbers correspond to a very low risk of acute toxicity and a low risk of chronic low dose toxicity." To accord with the risk methodology in this report, a likelihood of Possible (C) was selected.

Consequence: The consequence is taken to be Minor (2), because cyanobacteria concentrations do not appear to be close to the acute toxicity level, but are occasionally greater than the chronic low dose level.

Risk: Moderate.

Considering the available information on risks posed by algae (including cyanobacteria) a minor (e.g. small increase in operating costs) or moderate (e.g. increased monitoring) consequence rating (i.e. a 2 or 3) and overall moderate risk rating seems more appropriate in this case.

5.11 KWWTF Plant Upset (W1)

Probability: A rare likelihood (E) was selected, since many securities are already in place in the KWWTF to prevent a possible failure in the Waste Water Treatment Plant.

Consequence: The consequence was initially taken to be Moderate (3). While a possible failure would increase pathogen releases to the lake, modelling in this report found that by the time the contaminants reach the City's intakes, they are greatly diluted, and will have taken several days to arrive at the intakes, and thus not pose major health problems. However, a full range of limnological conditions was not simulated, so the consequence was increased to Major (4), to reflect the statistical uncertainty in the modelling results. It should also be noted that a short term increase in nutrient load would also possibly affect algae and cyanobacteria levels.

Risk: High

5.12 WRWTP Plant Upset (W2)

Probability: The WRWWTP is similar to the KWWTF. Consequently a rare likelihood (E) was selected.

Consequence: Similarly, the consequence was taken to be Major (4).

Risk: High.

5.13 Transportation Corridor Spill (S1)

Probability: An unlikely likelihood (D) was selected, since no such accident happened in the past. However the likelihood was set to “unlikely” instead of “rare” mainly due to a continuous increase of traffic over the bridge.

Consequence: The consequence is taken to be Moderate (3), since most of the fuel type is lighter than water and subject to high evaporation, meaning they would unlikely be able to sink and reach the depth of the water source intake. A direct impact on the environment such as beach pollution is likely to happen though.

Risk: Moderate

5.14 Boating Activities (S2)

Probability: An unlikely likelihood (E) was selected, since a very large greywater release in the vicinity of the intake is necessary in order to drive the contaminated water down to the depth of the intake. The event of a greywater release is highly probable but a greywater release of sufficient volume to affect the water intake is very unlikely.

Consequence: The consequence is taken to be Minor (2), since concentrations reaching the intake are likely to be quite low.

Risk: Low.

6.0 CONCLUSIONS

The study shows that:

- Water quality parameters in Okanagan Lake are excellent and are closely monitored by the City.
- Water quality in Okanagan Lake depends strongly on its limnology. Contaminants can be transported far from their source and thereby sources remote from the intake can sometimes be more significant than sources close to the intake.
- The City has an extensive stormwater control system with regular maintenance and monitoring in place. A system review was not part of this study.
- The City previously would investigate high coliform counts in creeks at threshold levels to determine if cross connections or septics were contaminating storm drainage inputs, and remove cross-connections if found. There currently does not appear to be a structured reporting system for this program.
- Of the six primary contaminant sources identified, pathogenic bacteria from creeks and nearshore wetlands pose the highest risk to City's water supply. This study demonstrated that transport to the intakes from Brandt, Mill and Mission Creeks poses the greatest risk.

- The City water supply system consists of four intakes, one located on the north basin and three located on the south basin. Contaminants originating in a particular basin generally report to the intake in that basin with higher concentrations than they report to the intake in the other basin. This water supply system setup provides the City with the flexibility as well as redundancy in its water supply.
- Extending water intakes to a deeper depth below the thermocline significantly reduces the risk associated with various contaminated sources. This observation should be advanced to a study phase if consistent data indicates deteriorating raw water quality at existing intake depths.
- The City of Kelowna has a number of programs that likely have a positive impact on source drinking water quality. However an integrated approach to Drinking Water Source Protection that includes planning, education, sampling and implementation is needed to track improvements.

7.0 RECOMMENDATIONS

The following recommendations are based on the information assembled in this report and on recommendations in the Interior Health Issue Paper: Planning for Drinking Water Filtration Recommendation. In order to receive approval for filtration deferral, the City must demonstrate that it meets the IHA requirement for filtration deferral. The City currently meets the fecal coliform requirements, but does not appear to meet the requirement to provide background baseline levels of *Cryptosporidium* and *Giardia*. As well, the City does not have a formal Source Water Protection Program, although it has most of the elements of one. The following recommendations, if implemented, should allow the City to meet these IHA requirements.

Some of the elements of a Source Protection Plan must involve other local governments and agencies, since modelling in this report has demonstrated the spatially far-reaching impacts of contaminants introduced by sources such as creeks within the City's jurisdiction, and sources outside the City's jurisdiction. These source protection issues that extend beyond the City's geographic jurisdiction should be addressed to the Southern Interior Regional Drinking Water Team (SIRDWT), the regionally focused provincial agency group established to address land-use issues of strategic importance for drinking water protection. Local government submits descriptions of drinking water issues to SIRDWT which they believe:

- are beyond the capacity of local government and agencies to address and/or,
- require a coordinated approach across the region that would be more efficient than at the local level.

Some specific recommendations follow. In many cases, the City has already proactively implemented the recommendations in this section.

1. Ensure sufficient frequency of sampling for *Giardia* and *Cryptospordia* to enable a baseline set of data to be established. Specific recommendations for this sampling program can be found in Associated Engineering's companion report (Associated Engineering, 2011), in Section 4, Recommendation No. 5. This is a specific requirement of the IHA filtration deferral guidelines, and should be addressed.
2. Assemble and document in a Source Water Protection Plan of all of the actions that the City currently implements to provide Source Water Protection in the urban context. Key components, identified in

this report, are: 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 Summary – Drinking Water Source Protection Plan details the components of the Source Protection Plan currently in place (2011) and the planned additions for 2012. Supportive of the Drinking Water Source Protection Plan, the City's Land Use Planning Department has recently completed Foreshore Inventory Mapping and Sensitive Habitat Inventory Mapping (SHIM-creeks), including ground-truthing. Wetland, Spring and Agricultural Ditch Mapping are currently underway. A program to annually ground-truth high risk areas is under development.

3. Besides the bacteria sampling, sediment control should be one of the target for the performance for water quality improvement. Indeed bacteria and protozoa can attach to sediment and migrate with them. Monitoring and controlling sediments combined with measurement of water turbidity will improve the water quality and likely reduce bacteria migration in the lake and the possible threats to the intakes. The City's plan for bacteria sampling, starting in 2011, includes active monitoring at high risk storm outfalls where the flows currently are not contained for treatment in existing infrastructure.

4. A formal response plan should be set up, so that an investigation and mitigation would be initiated in the event that raw water bacteria or sediment concentrations are above the defined level for more than two sampling periods. 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.

5. Develop plans or Best Management Practices to control the concentration of bacteria and other pathogens 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. Various forms of public education are needed to ensure a mindset that the lake must be protected, since it is the source of drinking water for so many people. A formal response plan should be set up, so that an investigation and mitigation would be initiated in the event that bacteria or sediment concentrations are above a defined level for more than two sampling periods. For instance, we understand that the City will search 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.

6. The City monitors fecal coliform at four City beaches, and possibly other locations. The City should continue this procedure. Currently, the City has a response plan for high coliform counts at beaches, specifically, the beaches are closed. The City should develop a response plan with respect to its intakes when near-shore coliform counts are high, for instance, providing a warning to the treatment plants that higher fecal coliform counts at the intakes may develop, particularly if there is a rain storm or strong winds. Such guidelines would need to be based on a wider selection of scenarios presented

in this report, as well as an examination of similar procedures in other jurisdictions. 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 a source of contamination that can be found.

7. Similarly 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 Brandt and Mill Creek to determine if there is an association with deterioration of raw water intake quality during those events.

8. Establish a management framework with other jurisdictions in order 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. For instance, it would be useful to identify priority creeks in terms of their impact on Kelowna's water system, and on other intakes. The numerical modelling used in this study and the previous Hayco report (2001) has helped identify such creeks.

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.

10. Continue the present practice of having redundancy in the water intakes. If the July fire fighting incident had occurred in a period of winds from the north, and the sub-surface part of the plume of contaminated water moved north towards Poplar Point, the Poplar Point plant could be shut down for a period of time. This recommendation presupposes that there would be a procedure in place to detect the type of contamination involved.

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 or not improved management could reduce these levels. This is a question that the City should explore, within calendar year 2011, with other local governments and agencies such as the Southern Interior Regional Drinking Water Team.

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.

13. When contemplating any upgrades to intake facilities, ensure that consideration is given to extending the outfall to a deeper location.

14. Above all, management practices must take into account 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 the intake. Various forms of public education are needed to ensure a mindset that the lake must be protected, since it is the source of drinking water for so many people.

8.0 CLOSURE

We trust this report meets your present requirements. Should you have any questions or comments, please contact the undersigned at your convenience.

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TABLES

Table 2.1: Location of Intakes

Intake Name	Location	Length-Dia.	Depth to Inlet Pipe	Intake Design Capacity
Poplar Point	Poplar Point Dr.	155 m – 1600 mm	29 m	181.4 ML/d
Eldorado	Eldorado Rd.	488 m – 900 mm	14 m	43.2 ML/d
Cedar Creek	Cedar Creek Pk.	267 m – 800 mm	20 m	95.0 ML/d
Swick	Swick Rd.	130 m – 200 mm	16 m	1.3 ML/d

Table 2.2: Mean Annual Inflows to Okanagan Lake from Major Tributary Streams

Tributary	Volume (Mm^3)	% of inflow	Within City of Kelowna Jurisdiction	Demonstrated Impact at Kelowna Intakes (Hayco 2001)	Storm Sewer Conduit
Vernon Creek	49,500	8.6	No	n/a	No
Deep Creek	15,500	2.7	No	n/a	No
Equesis Creek	20,500	3.6	No	n/a	No
Shorts Creek	33,500	5.8	No	n/a	No
Powers Creek	23,100	4.0	No	n/a	No
Trepanier Creek	33,500	5.8	No	n/a	No
Peachland Creek	12,500	2.2	No	n/a	No
Trout Creek	68,000	11.8	No	n/a	No
Bellevue Creek	12,500	2.2	No	n/a	No
Penticton Creek	20,600	3.6	No	n/a	No
Lambly Creek	49,000	8.5	No	Yes	No
Kelowna Creek	18,700	3.2	Yes	Yes	Yes
Mission Creek	199,000	34.5	Yes	Yes	No
Fascieux Creek	4.34 Q1:00	???	Yes	Inferred	Yes
Wilson Creek	1.76 Q1:100	???	Yes	Inferred	Yes
Brandt Creek	3.98 Q1:100	???	Yes	Inferred	Yes
Total	**555,900**	**96.5**	**> 37.5%**	**> 46%**	

Source: Nordin (2005)

Table 3.1: Approximate Horizontal Distances Between Creeks and City's Intakes (km)

Creek	Cedar Creek Intake	Eldorado Intake	Poplar Point Intake	Swick Intake
Brandt's Creek	10.6	7.9	2.63	13.3
Fascieux Creek	7.0	4.1	6.3	10.1
Lambly Creek	14.1	11.3	1.85	16.4
Kelowna Creek	9.0	6.0	4.2	11.7
Mission Creek	5.1	2.1	8.3	8.5

Table 3.2: Average *E.Coli* Counts in Raw Water at Intakes – by Year

Year	Cedar Creek (MPN/100ml)	Eldorado (CFU/100mL)	Poplar (MPN/100 mL)	Swick Road (MPN/100ml)
2002	0.96	0.36	0.64	0.64
2003	0.39	0.25	0.34	0.47
2004	0.38	0.29	0.39	1.02
2005	0.54	0.14	0.59	2.31
2006	0.82	0.53	0.51	2.19
2007	1.16	0.02	0.49	0.02
2008	1.65	0.36	0.24	1.89
2009	n/a	0.25	0.19	0.56
2010	n/a	1.26	0.15	0.28

Table 3.3: Average *E. Coli* Counts in Raw Water at Intakes – By Month

	Cedar Creek(MPN/100ml)	Eldorado (CFU/100mL)	Poplar (MPN/100ml)	Swick Road (MPN/100ml)
January	1.60	0.33	0.18	0.90
February	0.66	0.62	0.14	0.83
March	0.35	0.40	0.23	0.21
April	0.02	0.03	0.32	0.06
May	0.38	0.54	0.11	0.12
June	0.31	0.33	0.17	0.03
July	0.22	0.27	0.54	0.05
August	0.50	0.30	0.81	0.34
September	1.26	0.29	0.56	0.90
October	0.40	0.28	0.55	1.10
November	1.54	0.27	0.71	3.36
December	1.49	0.21	0.35	6.32

Table 3.4: Stormwater Collection Inventory

Asset Type	Asset Component	2007 Inventory	2010 Inventory	Change in Inventory	% Change
Facilities	Detention Ponds	61	66	5	8.2%
	Oil & Grit Separator	17	17	0	0.0%
	Pump Stations	4	4	0	0.0%
Linear	Storm Trunk (Km) Greater than 450mm	66.7	73.8	7.10	10.6%
	Storm Trunk (Km) Less than 450mm	245.4	274	28.32	11.5%
	Manhole/Drywells	6083	6150	67.00	1.1%
	Catch Basins	8455	8500	45.00	0.5%

Table 3.5: Summary of Nutrient Loading Estimates

	Nitrogen (kg/yr)	Phosphorus (kg/yr)
Stream inputs (total)	312	57
Stream inputs (biologically available)	219	29
Agriculture	0	25
Septic Tank	17	11
Stormwater	35	5
Sewage Treatment Plant	57	1.8
Total (biologically available)	328	72

Table 3.6: Summary of Nutrient Concentration Observations in Creeks near Kelowna

	Nitrogen (mg/L)		Phosphorous (mg/L)	
	Min	Max	Min	Max
Brandt's Creek	n/a	n/a	n/a	n/a
Fascieux Creek	n/a	n/a	n/a	n/a
Lambly Creek	0.03	0.34	0.005	0.025
Kelowna Creek	0.02	3.25*	0.002	0.087
Mission Creek	0.15	0.95	0.002	0.021
Okanagan Lake u/s of treatment Plant	0.16	0.40	0.002	0.009
Okanagan Lake d/s of treatment Plant	0.09	0.36	0.002	0.008

* data contains one possible outlier of 11.2 mg/L.

Table 3.7: Approximate Horizontal Distances between the Outfalls and City's Intakes (km)

	Cedar Creek Intake	Eldorado Intake	Poplar Point Intake	Swick Intake
Kelowna Wastewater Treatment Plant Outfall	6.9	4.1	6.3	9.7
Westside Regional Wastewater Treatment Plant Outfall	8.7	10.5	17.2	56

Table3.8: Summary of Identified Hazards

Code	Pathway	Source	Hazard
C1	Creek	Human, agricultural, wildlife	Fecal Bacteria
C2	Creek	Agriculture Activities & Wildlife	Protozoa
C3	Surface	Stormwater contamination	First Flush contaminants
C4	Creek	Stormwater	Fuel or chemical spill
C5	Creek	Industrial Activities	Sanitary Waste; industrial effluents
C6	Creek	Recreational Activities	Increased sediment loads
C7	Creek	Forestry	Increased sediment loads
C8	Creek	Natural Event	Increased sediment or bacterial loads
L1	Lake	Cyanobacteria contamination	Cyanobacteria blooms
L2	Lake	Algal Contamination	Algal blooms
W1	KWWTF	Kelowna WWTF	Sanitary Waste
W2	WRWWTP	Westside Regional WWTP	Sanitary Waste
S1	Surface	Transportation Corridor	Fuel or Chemical Spill
S2	Surface	Boating Activities	Greywater, boat fuel

Table 4.1: Maximum Oocyst Concentration at the Intakes

Depth (m)	Cedar Intake			Poplar Point Intake		
	Kelowna Creek	Lambly Creek	Mission Creek	Kelowna Creek	Lambly Creek	Mission Creek
20	0.854	0.002	0.276	-	-	-
30	0.102	0.004	0.174	0.136	0.126	0.208
40	0.032	0.008	0.086	0.093	0.146	0.195
50	0.025	0.008	0.071	0.073	0.096	0.116

Table 4.2: Oocyst Dilution at the Intakes

Depth (m)	Cedar Intake			Poplar Point Intake		
	Kelowna Creek	Lambly Creek	Mission Creek	Kelowna Creek	Lambly Creek	Mission Creek
20	410	125,000	350	-	-	-
30	3,400	62,500	575	2,550	1,980	480
40	10,900	31,250	1,150	3,750	1,700	500
50	14,000	31,250	1,400	4,800	2,600	850

Table 5.1: Qualitative Measures of Likelihood (after NHMRC/ARMCANZ, 2001; Berry and Failing, 2003)

Level	Descriptor	Description	Probability of Occurrence in 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%

Table 5.2: Qualitative Measures of Consequence (After NHMRC/ARMCANZ, 2001)

Level	Descriptor	Description
1	Insignificant	Insignificant impact, no illness, little disruption to normal operation, little or no increase in normal operating costs
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 modification to normal operation but manageable, operating costs increase, increased monitoring
4	Major	Major impact for small population, severe illness probable, systems significantly compromised and abnormal operation if at all, high-level monitoring required.
5	Catastrophic	Major impact for large population, severe illness probable, complete failure of systems

Table 5.3: 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

Table 5.4: Risk Evaluation of Identified Hazards

Code	Pathway	Source	Hazard	Likelihood (Table 4.1)	Consequence (Table 4.2)	Risk (Table 4.3)
C1	Creek	Agriculture Activities & Wildlife	Protozoa > 10 oocysts/m^3	E	5	High
C2	Creek	Agriculture Activities & Wildlife	Fecal bacteria > 20 MPN/100mL, > 10% of samples	C	4	Very High
C3	Surface	Stormwater contamination	First Flush contaminants	C	3	High
C4	Creek	Stormwater	Fuel or chemical spill	D	4	High
C5	Creek	Agricultural & Residential Activities	Increased nutrient loading (> 0.1 mg/L as PO_4)	D	1	Low
C6	Creek	Industrial Activities	Increased nutrient & possibly pathogen loads (> 20 MPN/100 mL)	E	4	High
C7	Creek	Forestry & Recreational	Increased sediment loads (> 1 NTU)	C	2	Moderate
C8	Creek	Natural Event	Increased sediment or bacterial loads (> 20 MPN/100 mL)	C	3	High
L1	Lake	Algal Contamination	Algal blooms	D	1	Low
L2	Lake	Cyanobacteria contamination	Cyanobacteria blooms (> 15,000 cells/mL and > 2,000 cells/mL)	C	2	Moderate
W1	KWWTF	Kelowna WWTF	Sanitary Waste	E	4	High
W2	WRWWTP	Westside Regional WWTP	Sanitary Waste	E	4	High
S1	Surface	Transportation Corridor	Fuel or Chemical Spill (> 0.005 mg/L of benzene)	D	3	Moderate
S2	Surface	Boating Activities	Greywater, boat fuel (> 10 MPN/100 mL)	E	2	Low

FIGURES

NOTES

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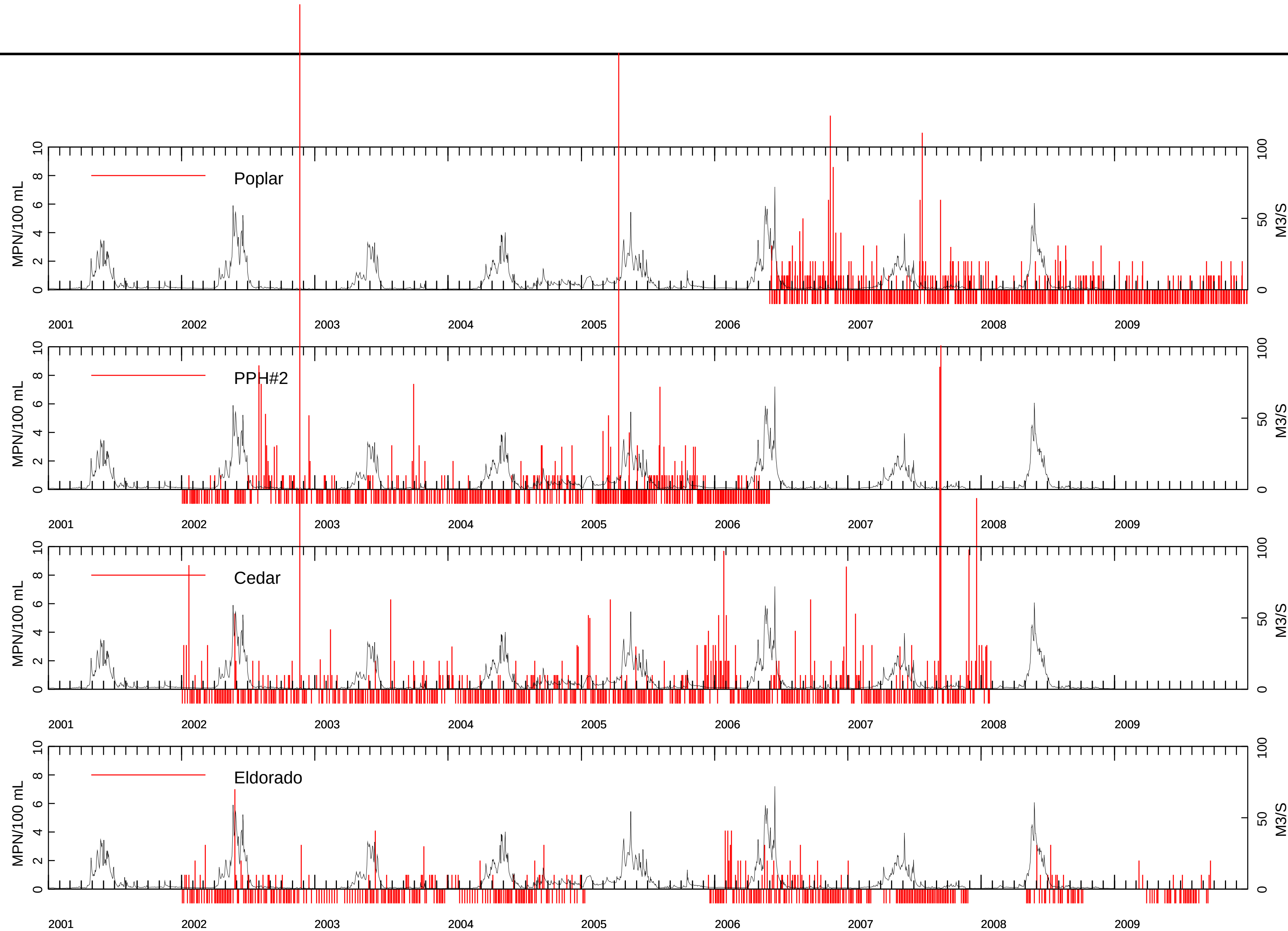
DRINKING WATER SOURCE PROTECTION

Creeks, Intakes and Outfalls Locations

PROJECT NO.	DWN	CKD	APVD	REV
V13201297	EW	JAS	JAS	0

OFFICE	DATE
EBA-VANC	March 30, 2011

Figure 2.1



NOTES

- Values of 0 MPN/100mL plotted as -1 MPN/100 mL
- Mission Creek flows plotted as thin black line

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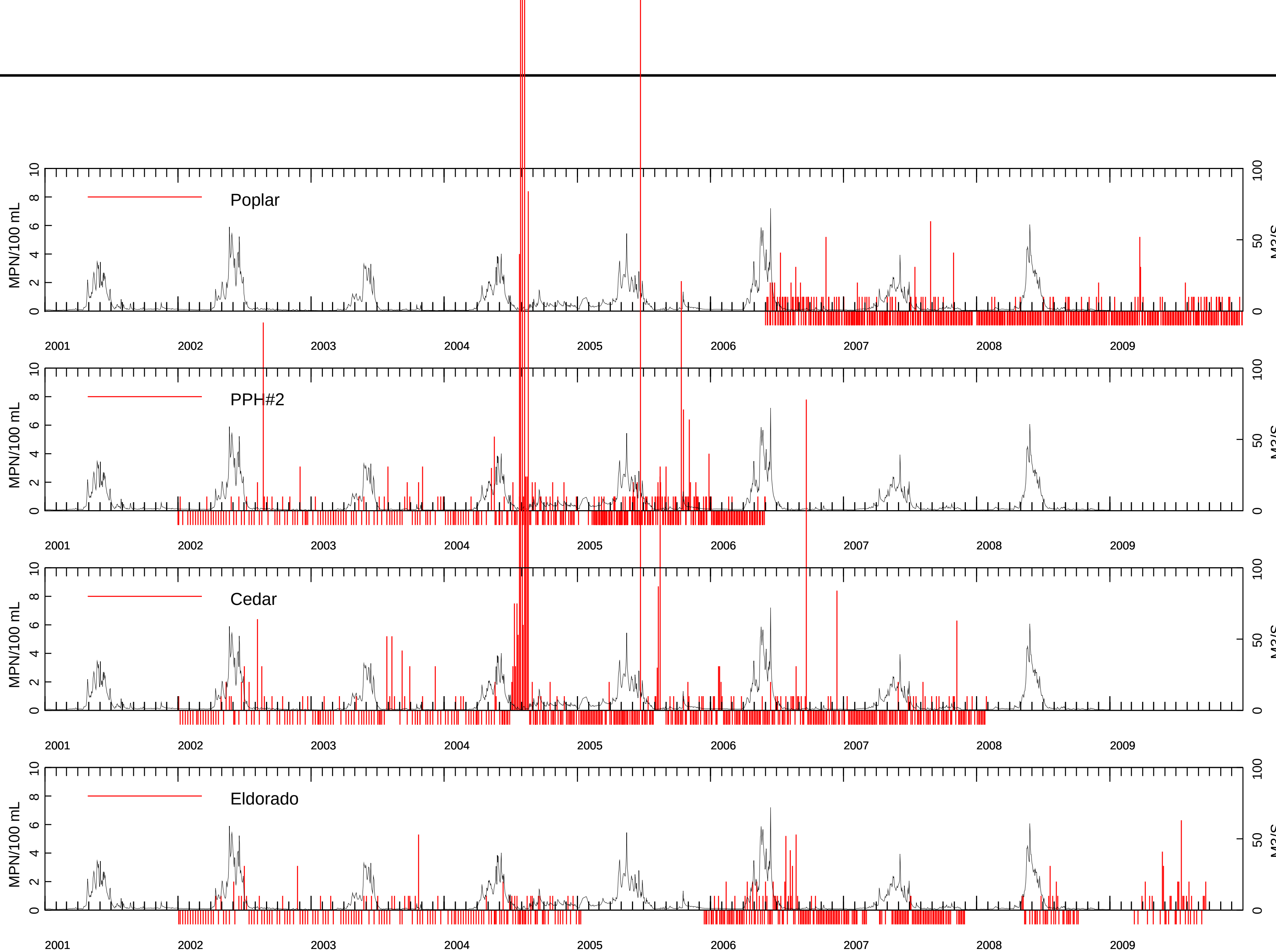
E_coli Observations from 2001 to 2009
City of Kelowna Intakes

PROJECT NO.	DWN	CHK	APVD	REV
V13201297	JAS	EW	EW	0

OFFICE	DATE
EBA-VANC	March 2011

Figure 3.1

Fri May 13 14:06:32 2011:V:\V13201297 Kelowna Source Water Protection\working\JAS\WQ\intakes



NOTES

- Values of 0 MPN/100mL plotted as -1 MPN/100 mL
- Mission Creek flows plotted as thin black line

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Enterococcus Observations from 2001 to 2009
City of Kelowna Intakes

PROJECT NO.	DWN	CHK	APVD	REV
V13201297	JAS	JAS	JAS	0

OFFICE	DATE
EBA-VANC	March 2011

Figure 3.2

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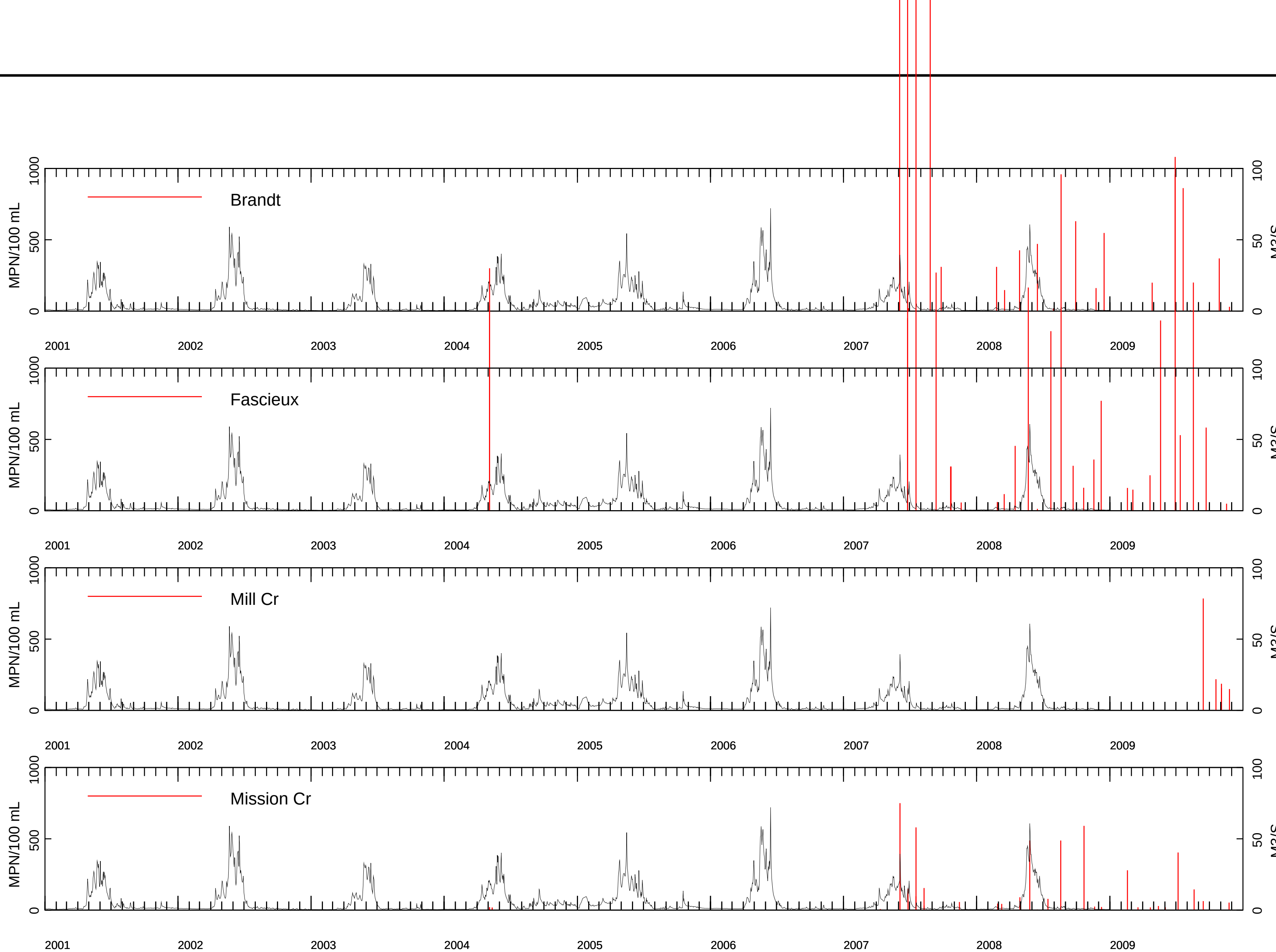

NOTES

- Values of 0 MPN/100mL plotted as -1 MPN/100 mL
- Mission Creek flows plotted as thin black line

STATUS
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DRINKING WATER SOURCE PROTECTION

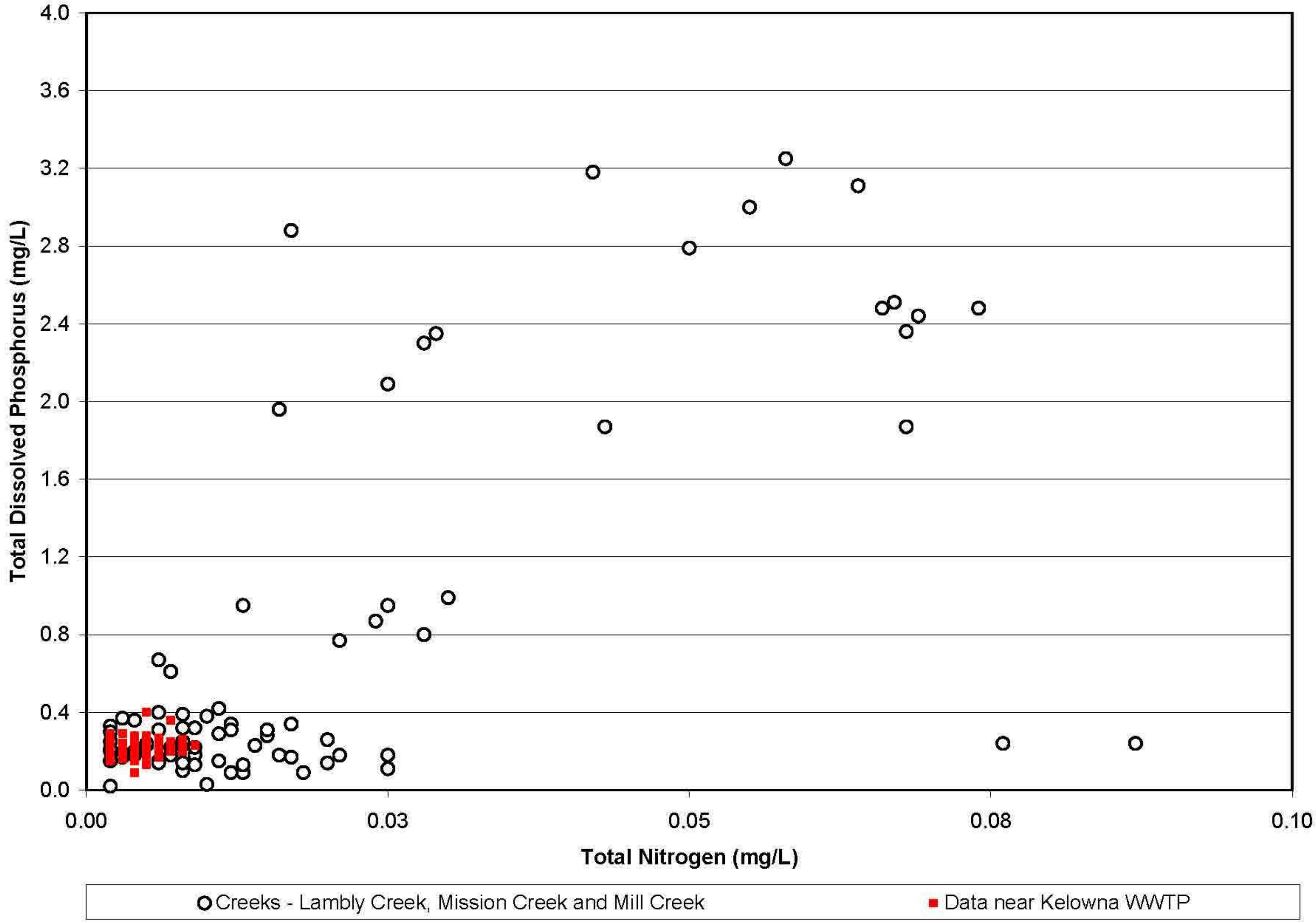
Fecal Coliform Observations from 2001 to 2009
Creek Mouths

PROJECT NO.	DWN	CHK	APVD	REV
V13201297	JAS	EW	EW	0

OFFICE	DATE
EBA-VANC	March 2011

Figure 3.3

Fri May 13 14:05:42 2011:V:\V13201297 Kelowna Source Water Protection\working\JAS\WQ\creeks



NOTES	CLIENT: City of Kelowna	CITY OF KELOWNA DRINKING WATER SOURCE PROTECTION
		Total Dissolved Phosphorus (mg/L) vs Total Nitrogen (mg/L)

PROJECT NO.	DWN	CKD	APVD	REV	
V13201297	EW	JAS	JAS	0	Figure 3.4
OFFICE: EBA-VANC	DATE: March 30, 2011				

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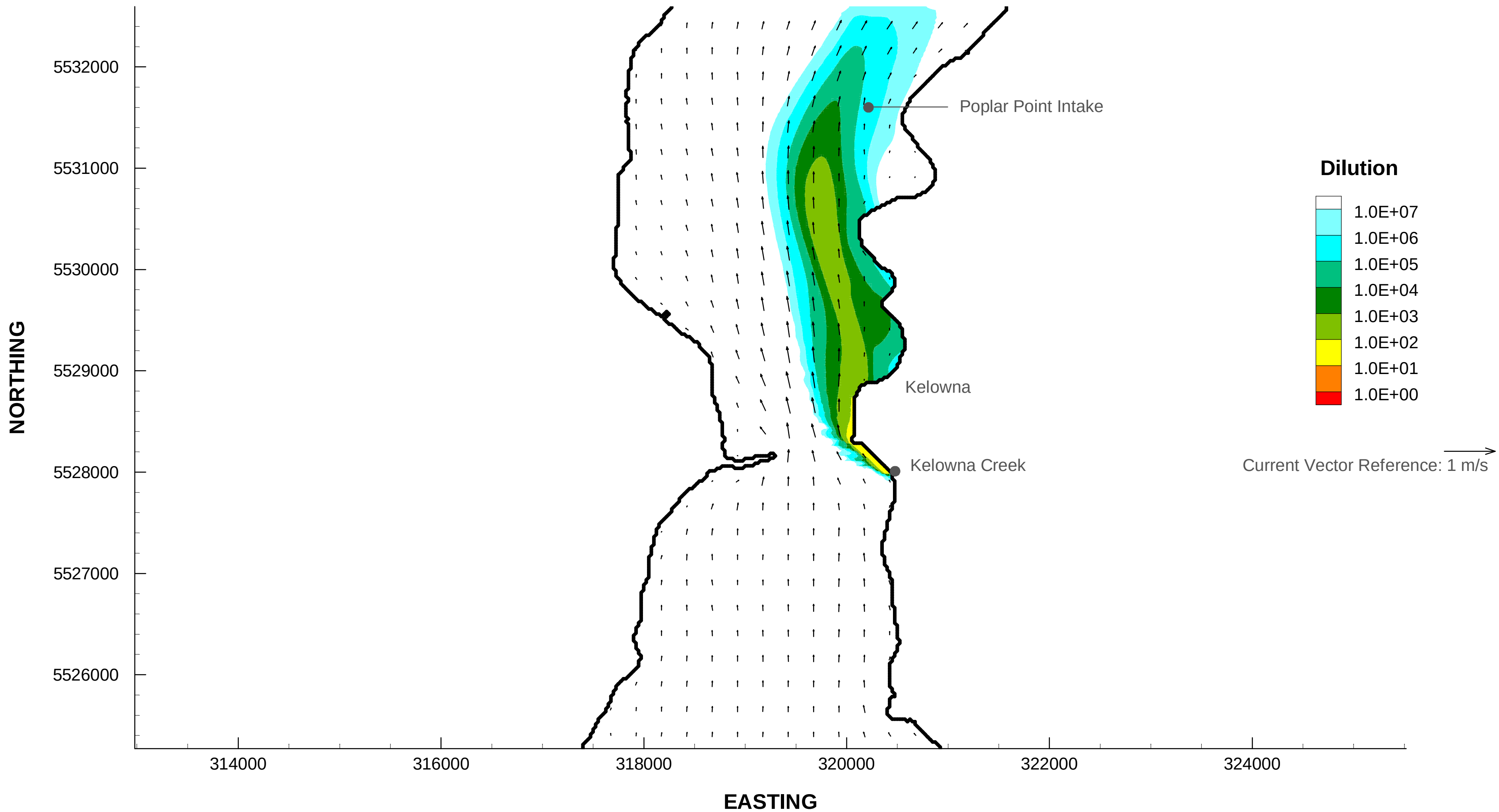
V:\V13201297 Kelowna Source Water Protection\Report\2011_04_01 - April\Figures\processing\Fig3_4.lay

13 May 2011 14:10:19



NOTES

- The spill started on August 1st, 2010, at 00:00am.
- The spill lasted for 12 hours, ending on August 1st, 2010, at 12:00pm.

STATUS
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DRINKING WATER SOURCE PROTECTION

Surface Contaminant Dilution
11 Hours after Start of Spill

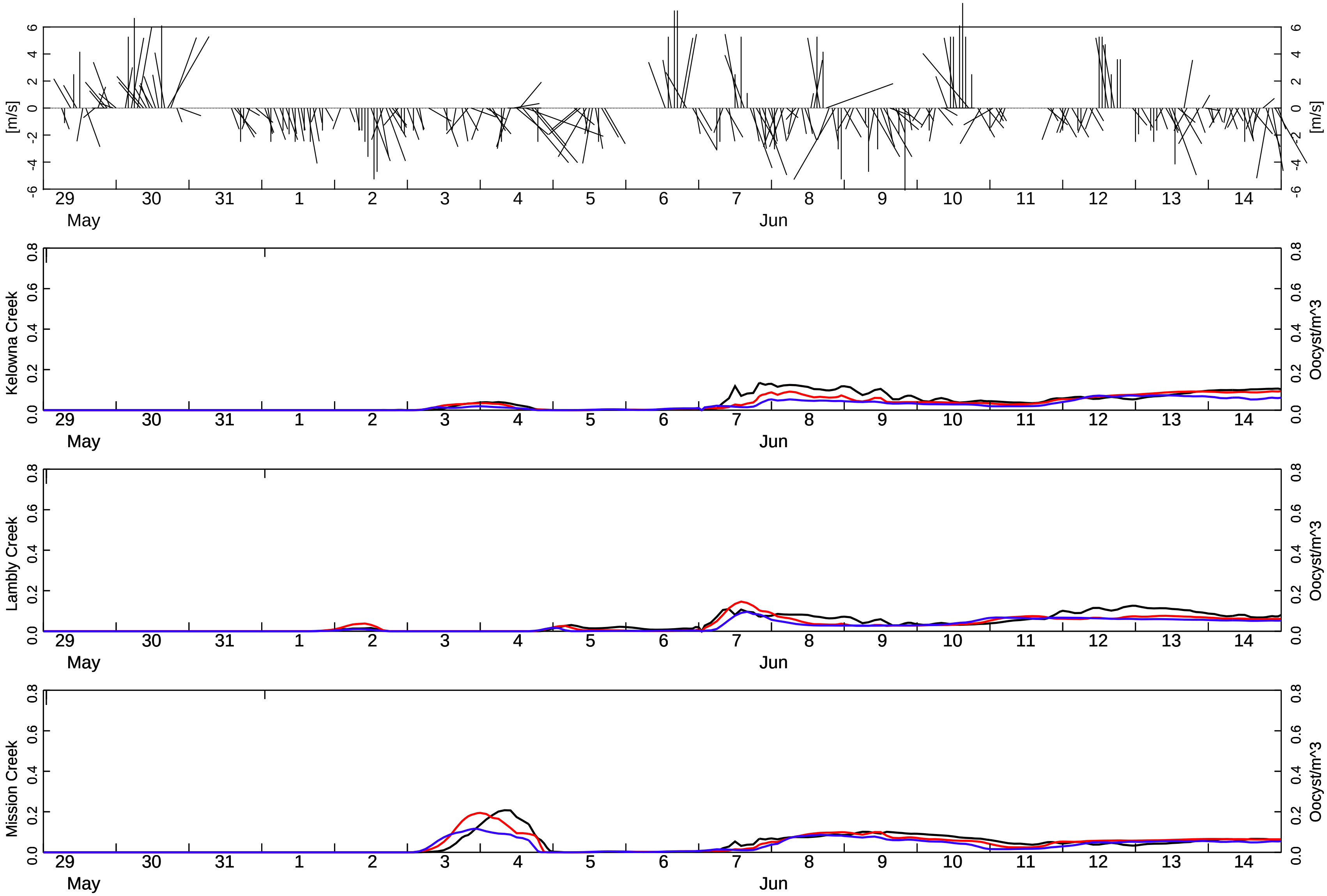
PROJECT NO.	DWN	CKD	APVD	REV
V13201297	AL	JAS	JAS	0

OFFICE	DATE
EBA-VANC	March 31, 2011

Figure 3.5

V:\V13201336 Kelowna_Mill_Creek_Fire\working\AL\H3D\25m_fine_TSS\summer\Fig3_5.lay

13 May 2011 14:11:38



NOTES

30 m
40 m
50 m

STATUS
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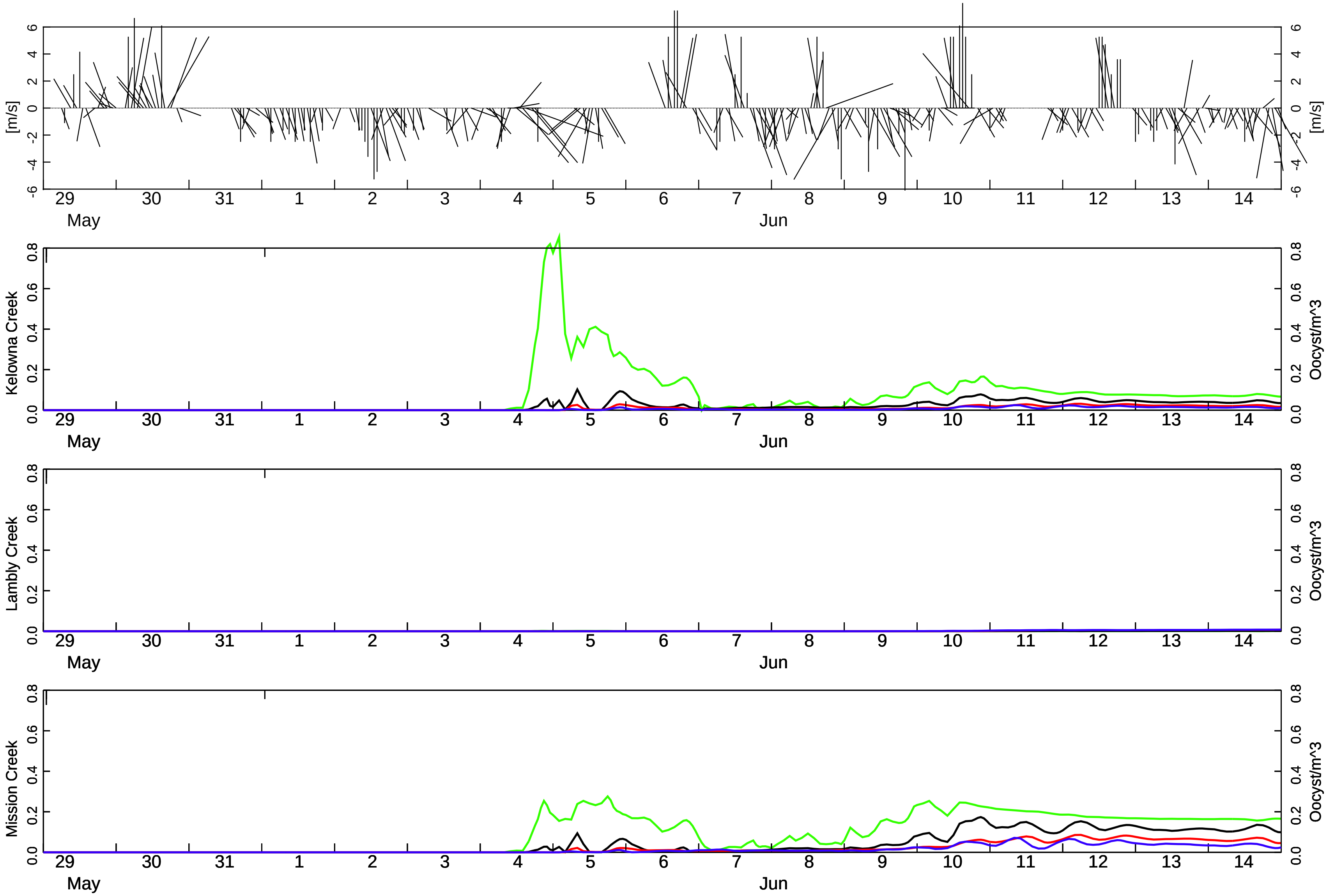
CITY OF KELOWNA
DRINKING WATER SOURCE PROTECTION

1996 Cryptosporidium Outbreak (C1)
Oocyst Concentration near Poplar Point Intake

PROJECT NO.	DWN	CHK	APVD	REV
V13201297	EW	JAS	JAS	0

OFFICE	DATE
EBA-VANC	April 2011

Figure 4.1



NOTES

20 m
30 m
40 m
50 m

STATUS
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DRINKING WATER SOURCE PROTECTION

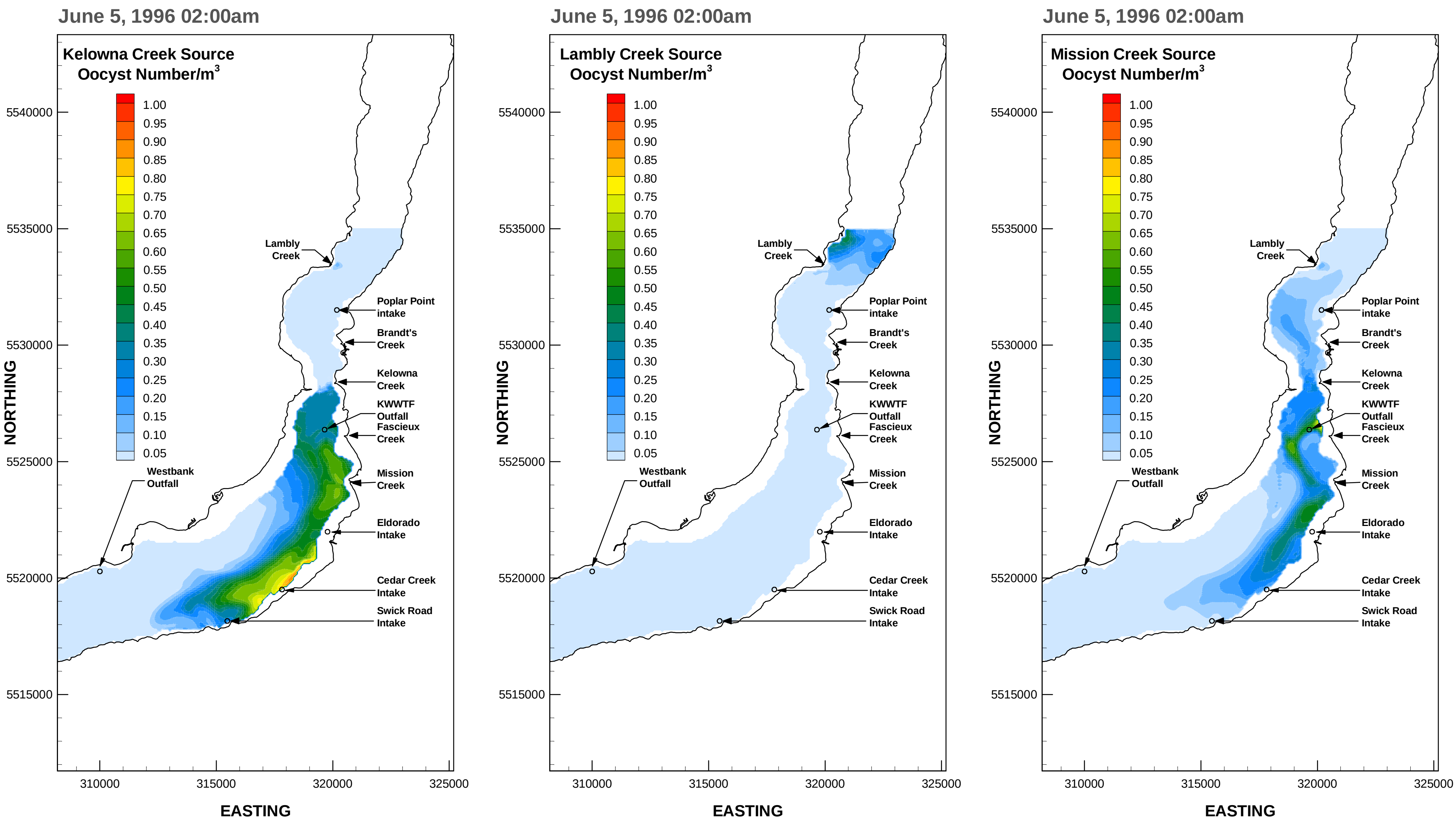
1996 Cryptosporidium Outbreak (C1)
Oocyst Concentration near Cedar Creek Intake

PROJECT NO.	DWN	CHK	APVD	REV
V13201297	EW	JAS	JAS	0

OFFICE	DATE
EBA-VANC	April 2011

Figure 4.2

Fri May 13 14:00:40 2011:V:\V13201297 Kelowna Source Water Protection\Report\2011_04_01 - April\Figures\Chapter4\Figure4.2



NOTES

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1996 Cryptosporidium Outbreak (C1)
Oocyst Concentration Map at 20 m
(Cedar Creek Intake Depth)

PROJECT NO.	DWN	CKD	APVD	REV	
V13201297	EW	JAS	JAS	0	**Figure 4.3**
OFFICE	DATE				
EBA-VANC	April 2011				

STATUS
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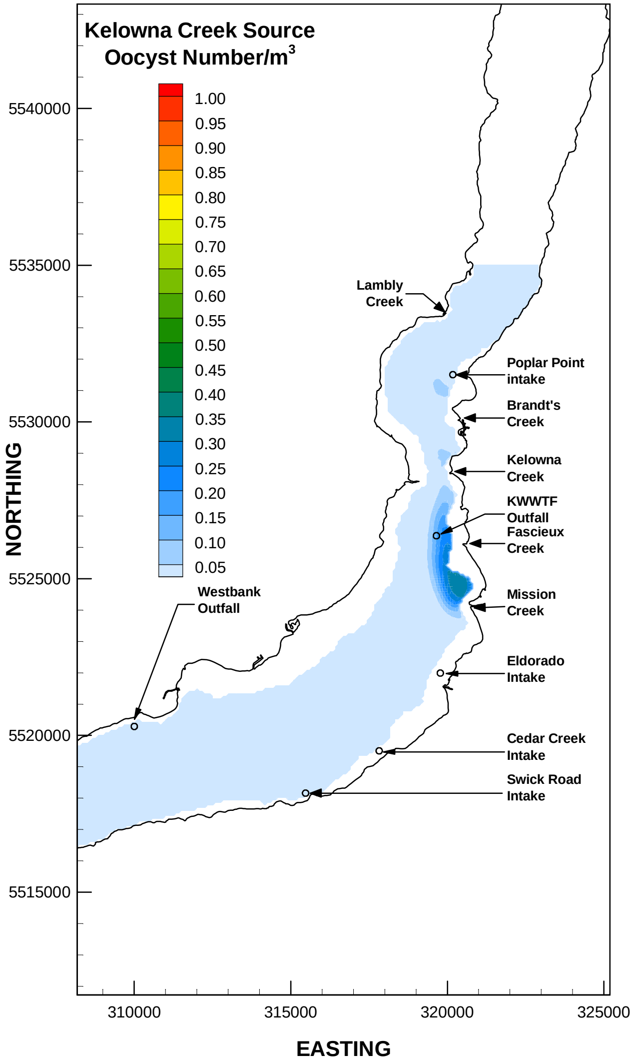
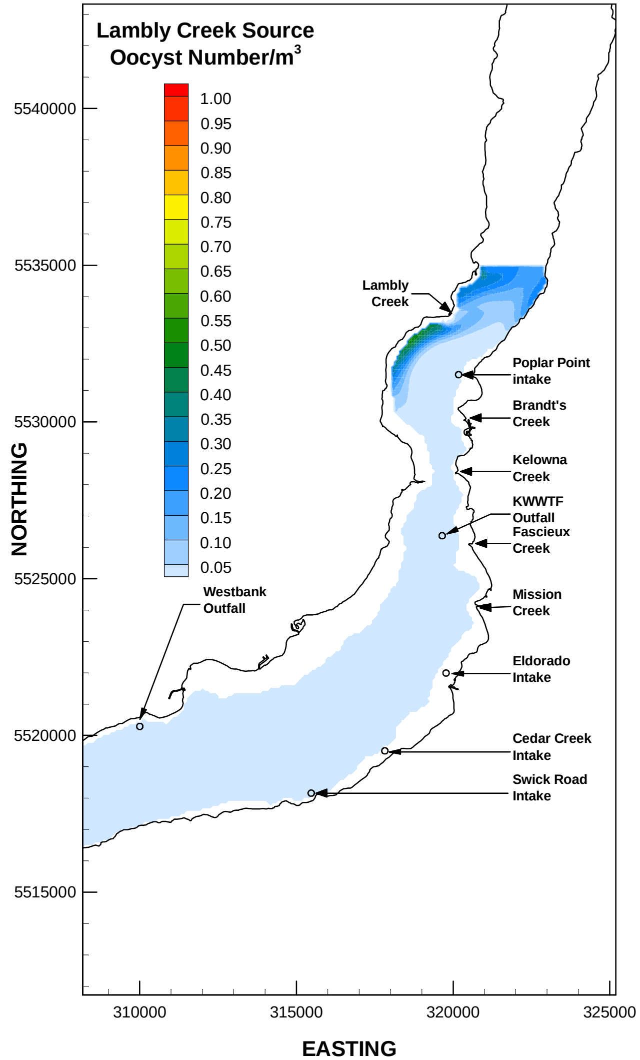
V:\V13201297 Kelowna Source Water Protection\Report\2011_04_01 - April\Figures\Chapter4\Figure4.3\Fig4_03.lay

13 May 2011 14:12:35

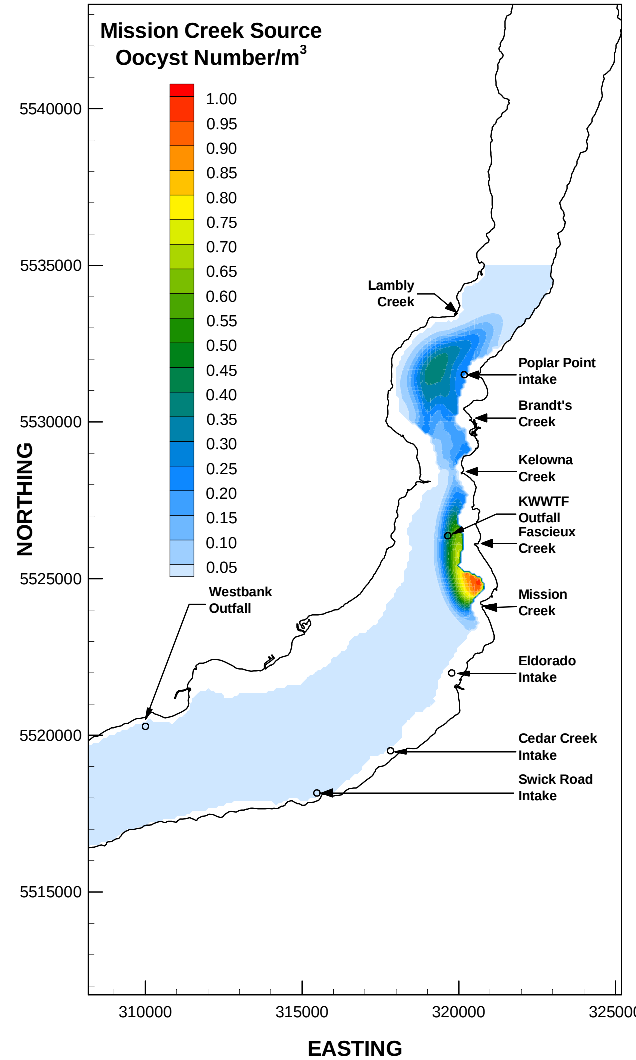
June 4, 1996 08:00am



June 4, 1996 08:00am



June 4, 1996 08:00am



NOTES

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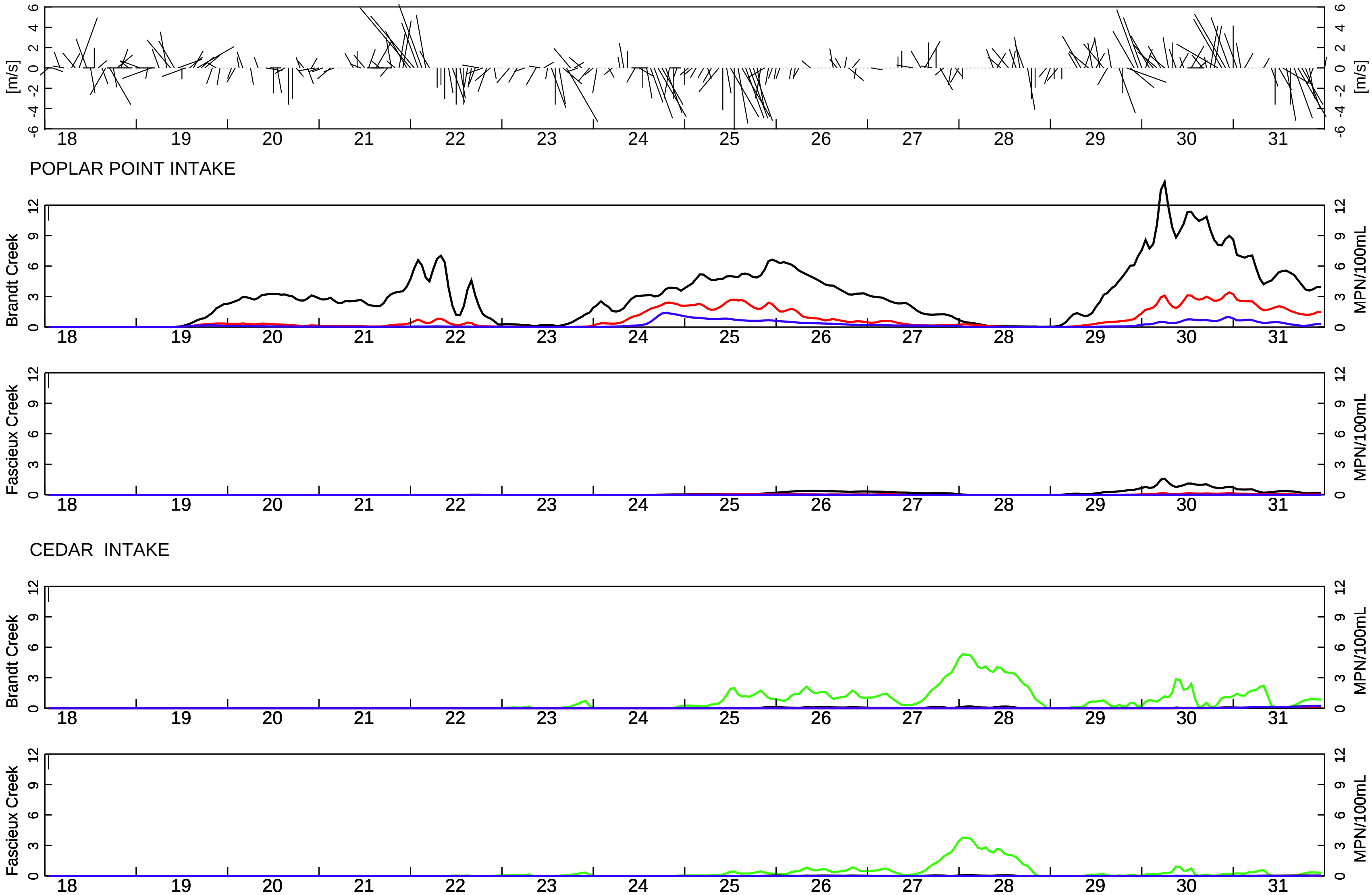
1996 Cryptosporidium Outbreak (C1)
Oocyst Concentration Map at 30 m
(Poplar Point Intake Depth)

PROJECT NO.	DWN	CKD	APVD	REV
V13201297	EW	JAS	JAS	0

OFFICE	DATE
EBA-VANC	April 2011

Figure 4.4



NOTES

20 m
30 m
40 m
50 m

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DRINKING WATER SOURCE PROTECTION

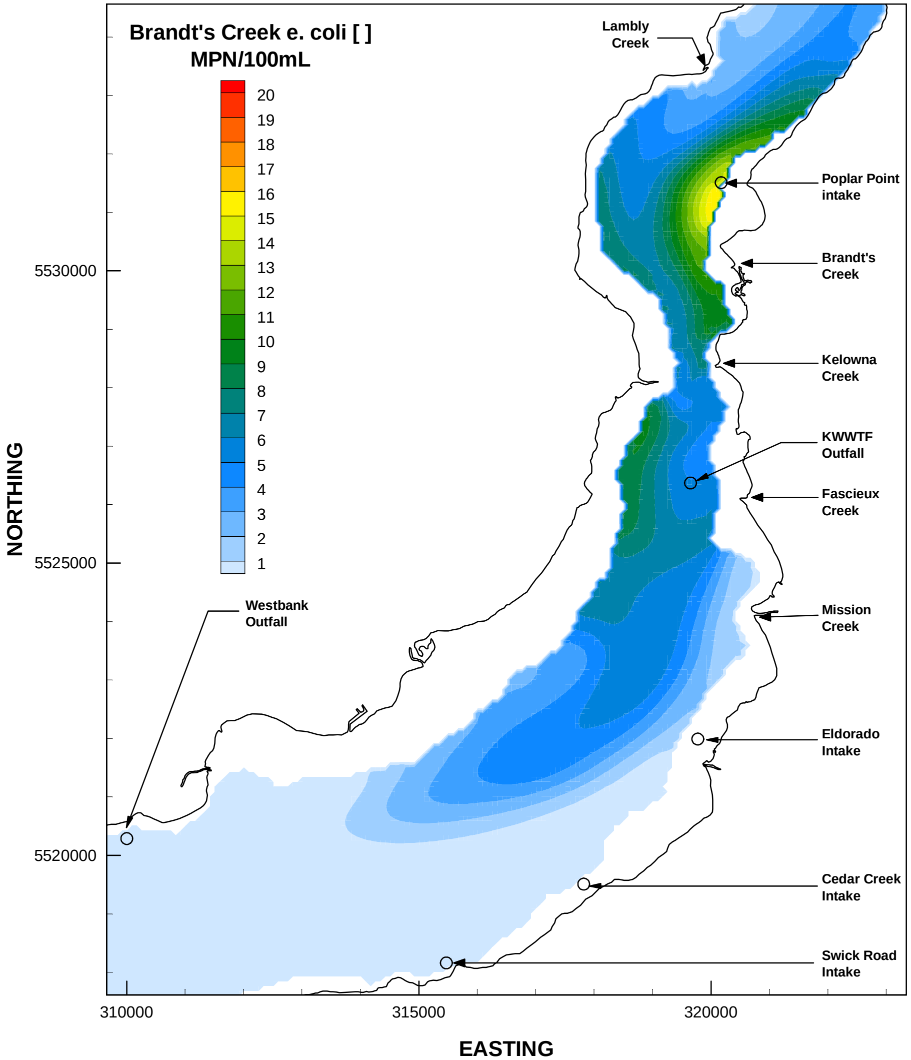
2007 July Peak Creek Fecal Coliform (C2) e. coli Concentration at the Intakes

PROJECT NO.	DWN	CHK	APVD	REV
V13201297	EW	JAS	JAS	0

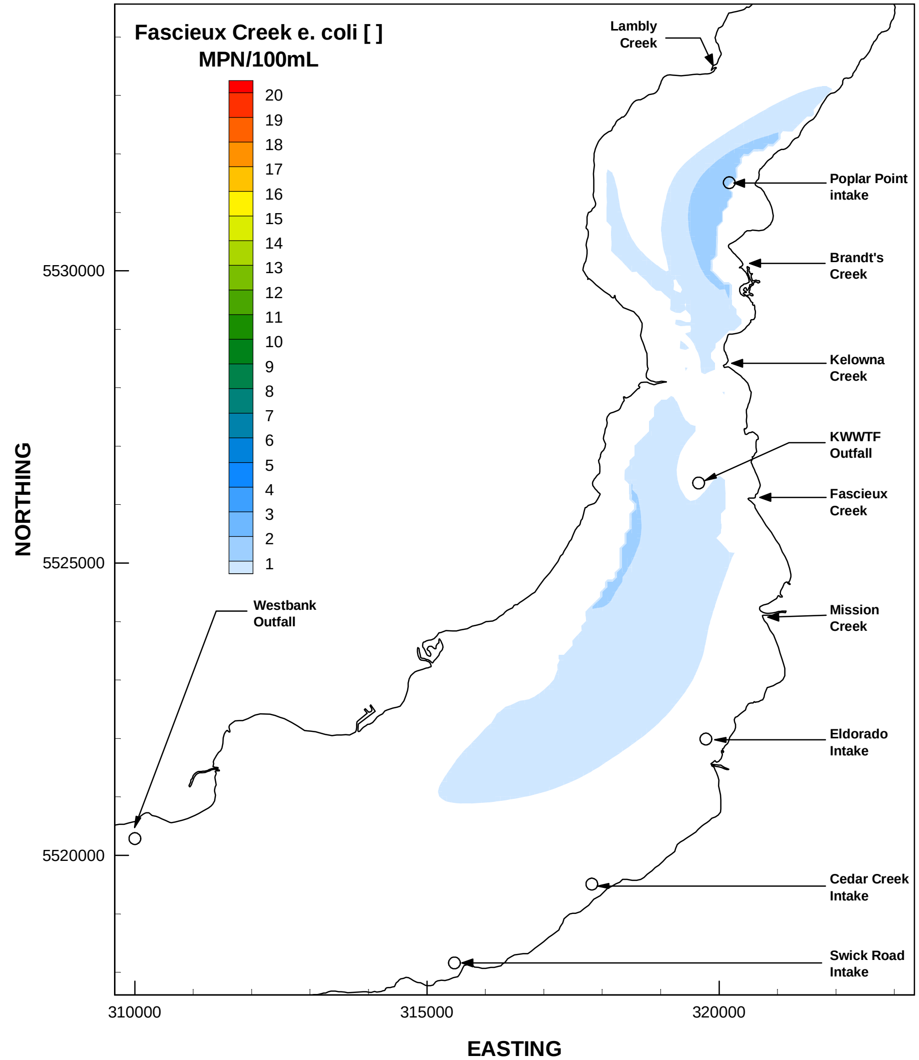
OFFICE	DATE
EBA-VANC	April 2011

Figure 4.5

July 30, 2007 6:00am



July 30, 2007 6:00am



NOTES

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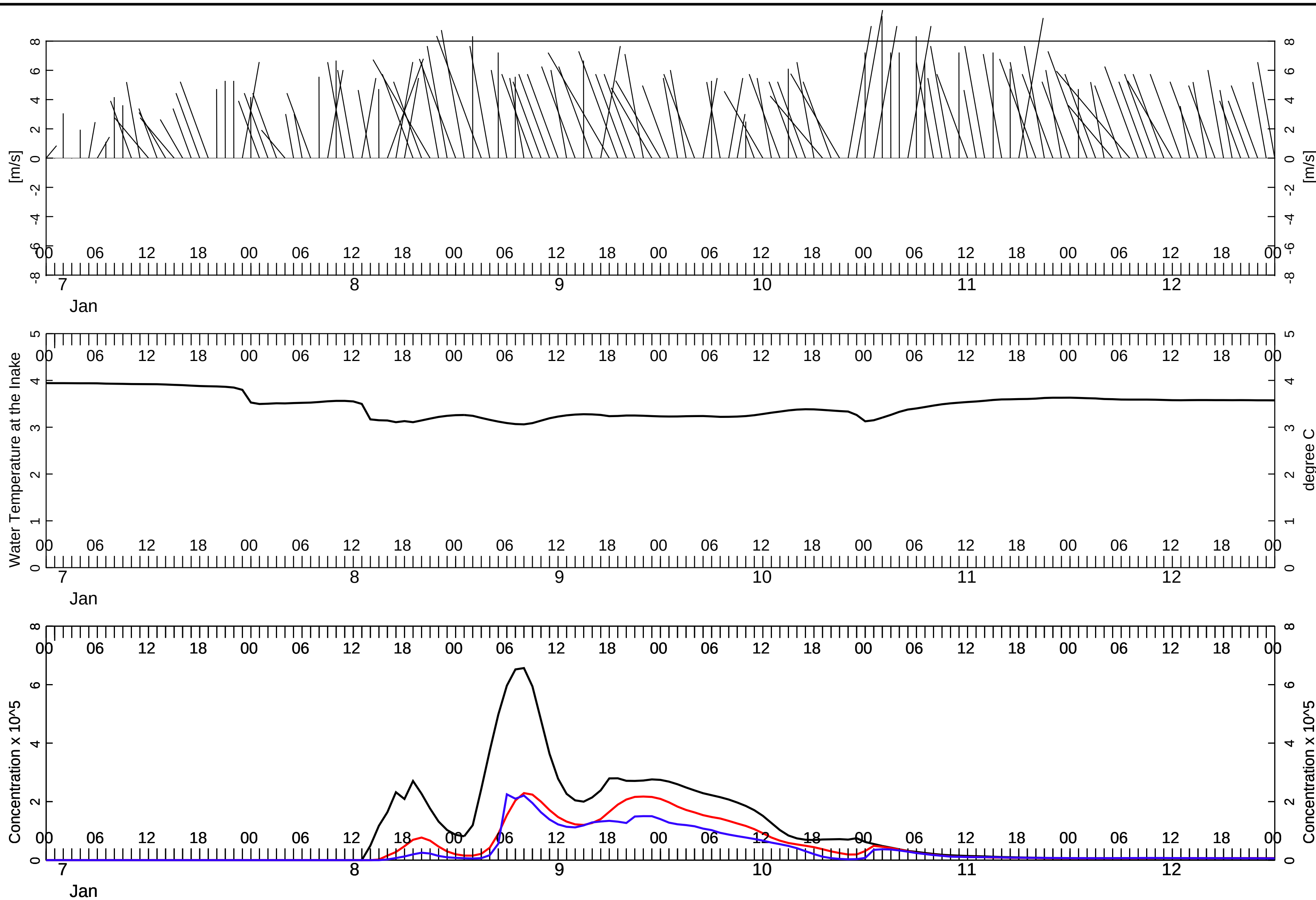
DRINKING WATER SOURCE PROTECTION

2007 Peak Creek Fecal Coliform (C2) e. coli Concentration at 29 m Depth

PROJECT NO.	DWN	CKD	APVD	REV
V13201297	EW	JAS	JAS	0

OFFICE	DATE
EBA-VANC	April 2011

Figure 4.6



NOTES

30 m

40 m

50 m

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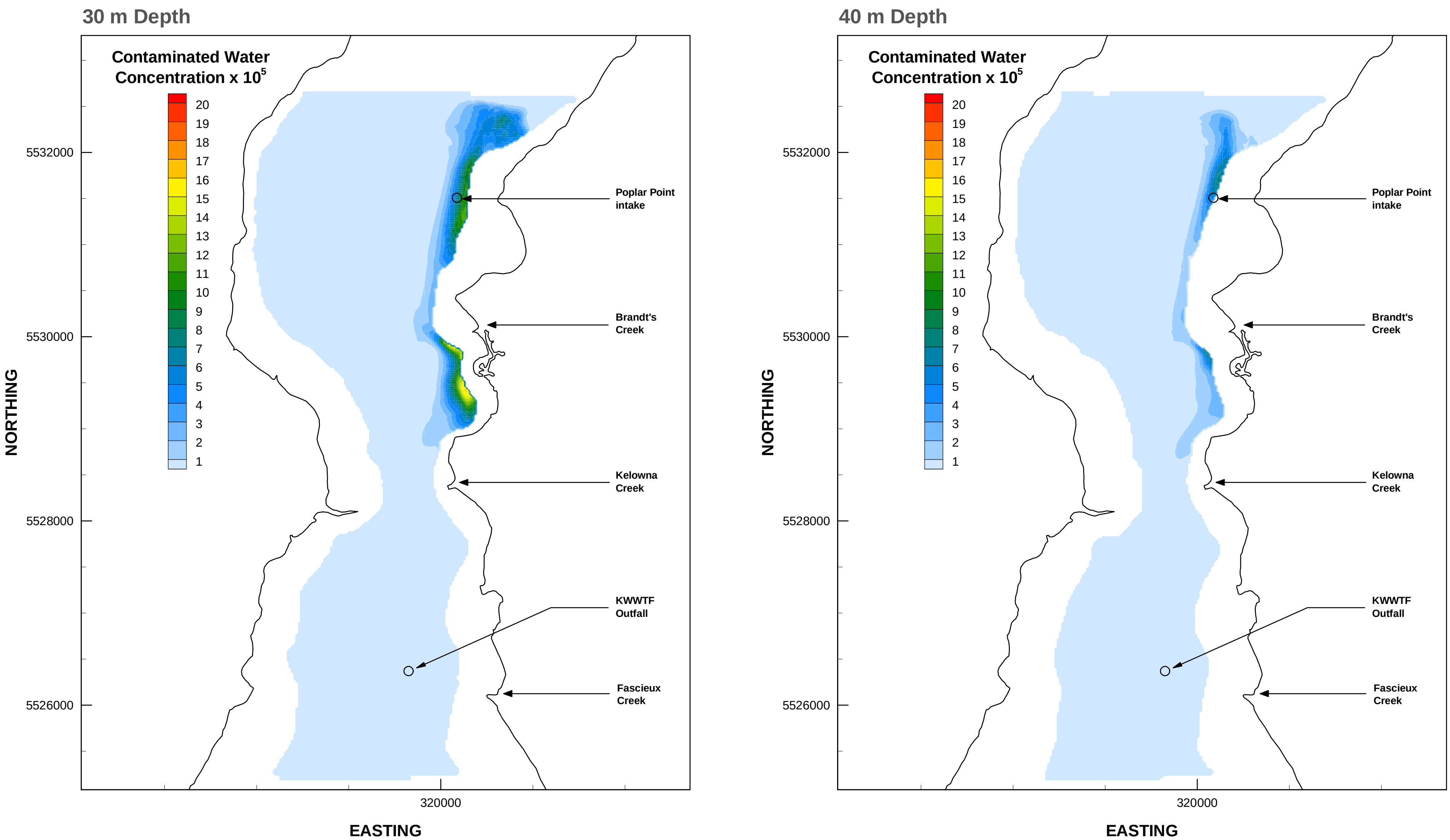
Synthetic Contaminated Stormwater Event (C4)
Poplar Point Intake Contaminant Concentration

PROJECT NO.	DWN	CHK	APVD	REV
V13201297	EW	JAS	JAS	0

OFFICE	DATE
EBA-VANC	April 2011

Figure 4.7



NOTES

STATUS
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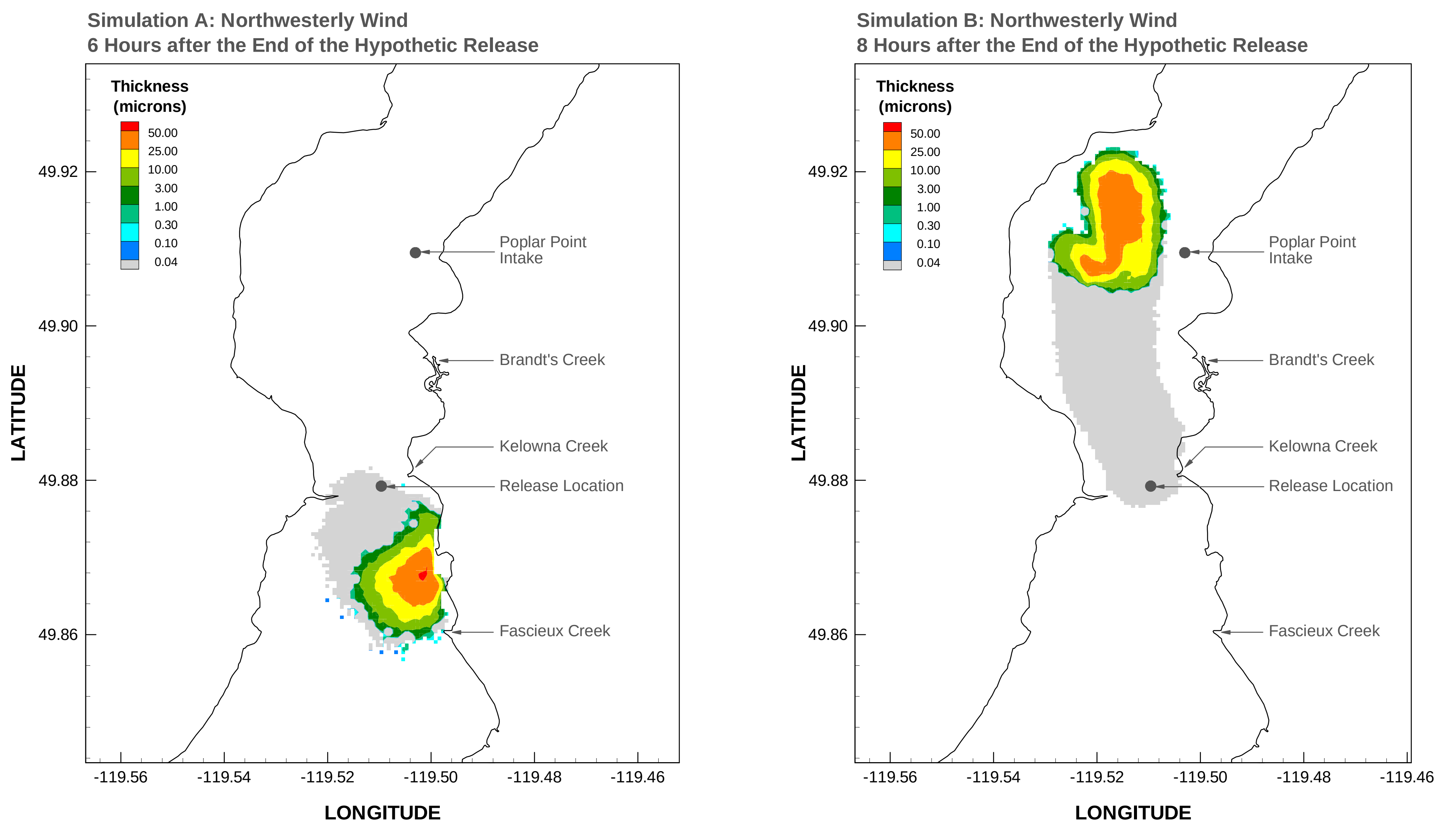
DRINKING WATER SOURCE PROTECTION

Synthetic Contaminated Stormwater Event (C4) Contaminated Stormwater Maps

PROJECT NO.	DWN	CKD	APVD	REV
V13201297	EW	JAS	JAS	0

OFFICE	DATE
EBA-VANC	April 2011

Figure 4.8



NOTES

Swept Area

STATUS
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DRINKING WATER SOURCE PROTECTION

Diesel Spill from a Tanker Truck (S1)
Lake Surface Diesel Fuel Distribution Maps

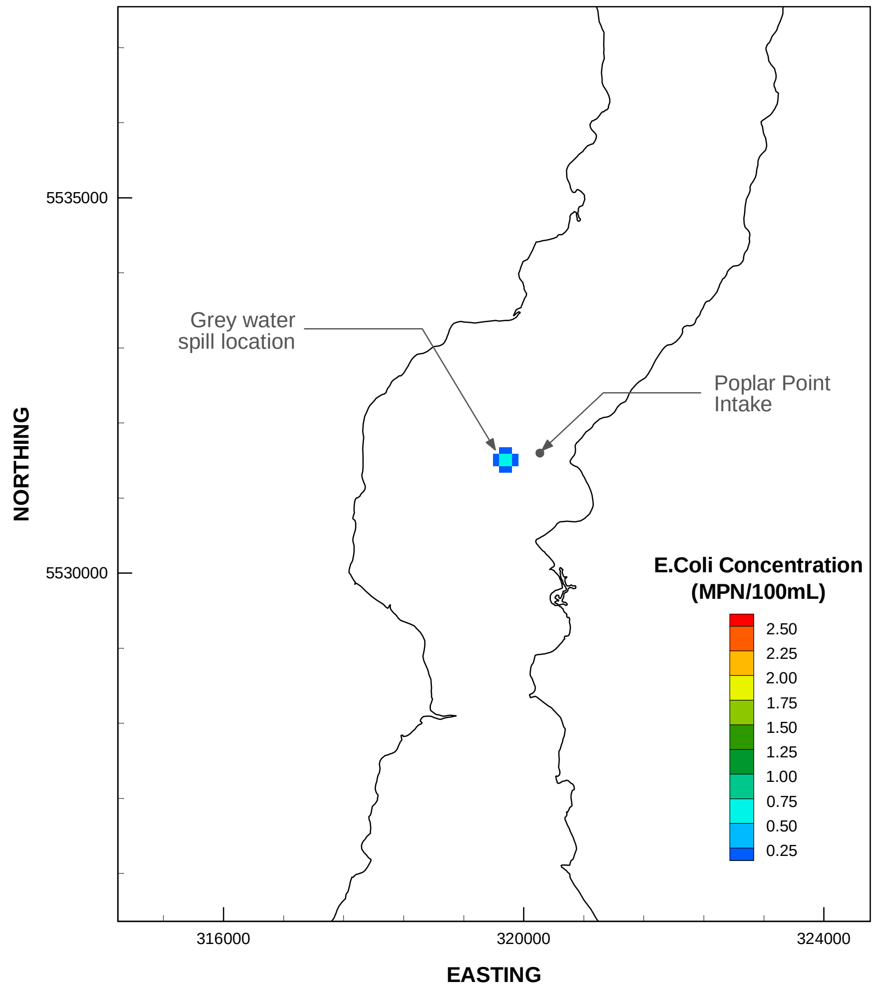
PROJECT NO.	DWN	CKD	APVD	REV
V13201297	AH	JAS	JAS	0

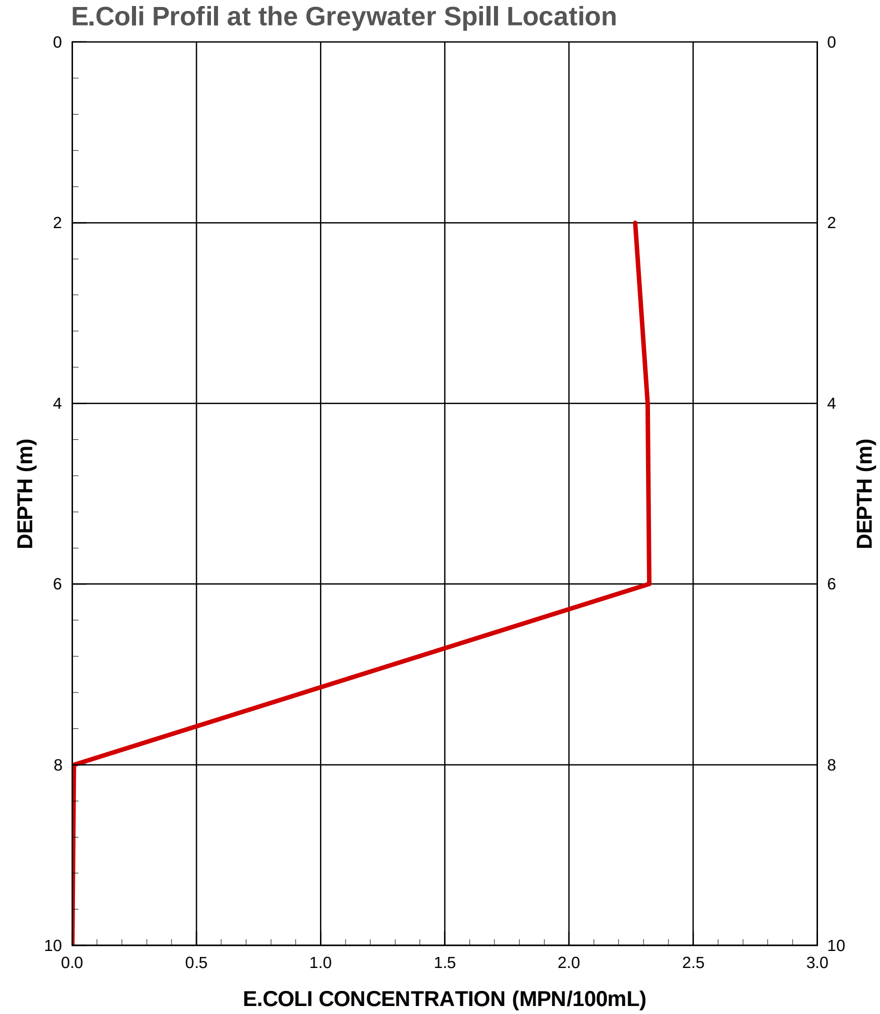
OFFICE	DATE
EBA-VANC	March 31, 2011

Figure 4.9

V:\V13201297 Kelowna Source Water Protection\working\AH\Simulations_2007\spillcalc\Fig4.09.lay

13 May 2011 14:17:03





NOTES

- E.Coli concentration profile at the greywater spill release point, based on an initial concentration of 1,000,000 E.Coli per 100 mL.

- An ecoli concentration of 0 was measured at the Poplar Point intake and anywhere else.

STATUS
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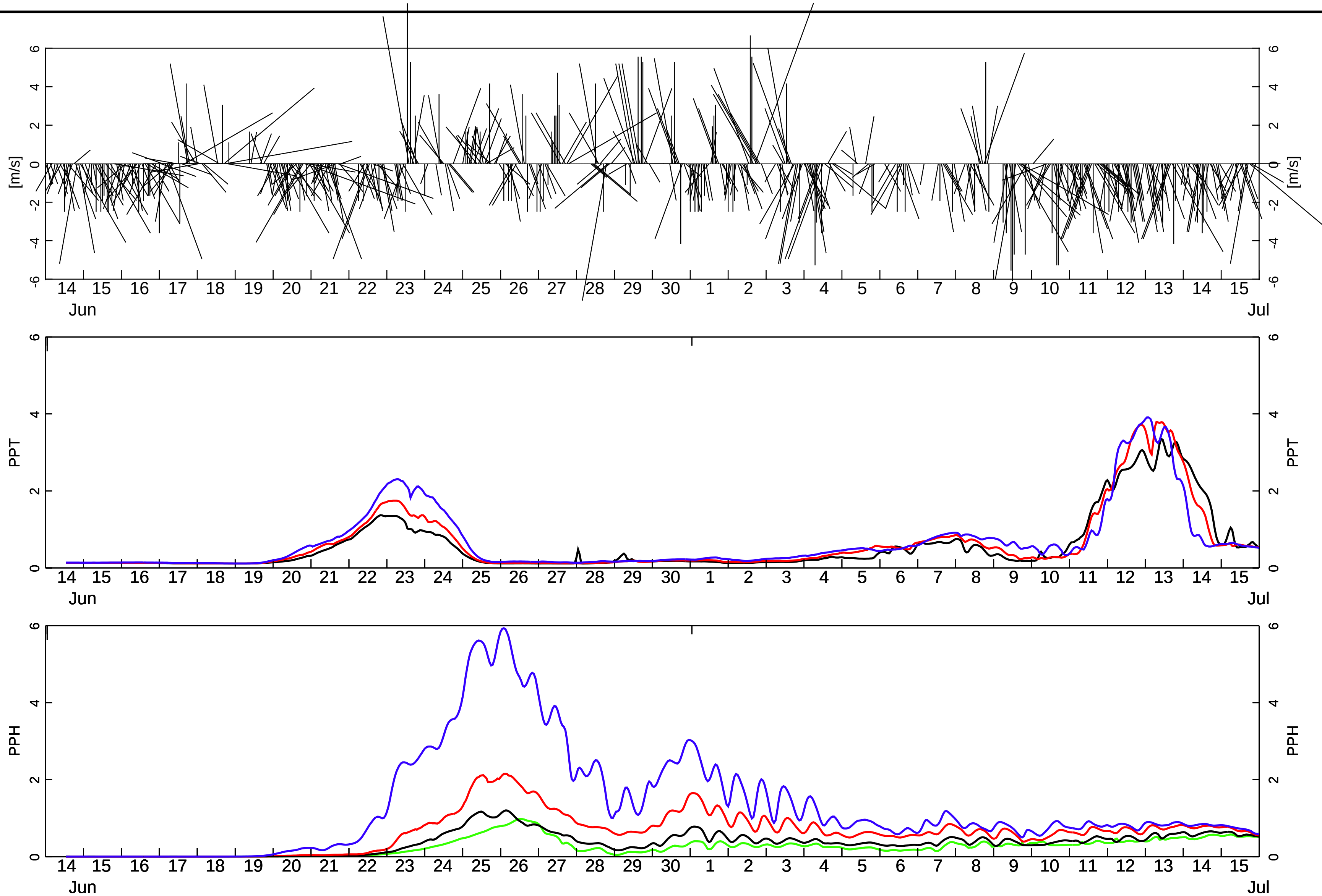
DRINKING WATER SOURCE PROTECTION

Greywater Spill in the Vicinity of Poplar Point Intake (S2)
E .Coli Con. Map and Profile

PROJECT NO.	DWN	CKD	APVD	REV
V13201297	AH	JAS	JAS	0

OFFICE	DATE
EBA-VANC	March 31, 2011

Figure 4.10



NOTES

20 m

30 m

40 m

50 m

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DRINKING WATER SOURCE PROTECTION

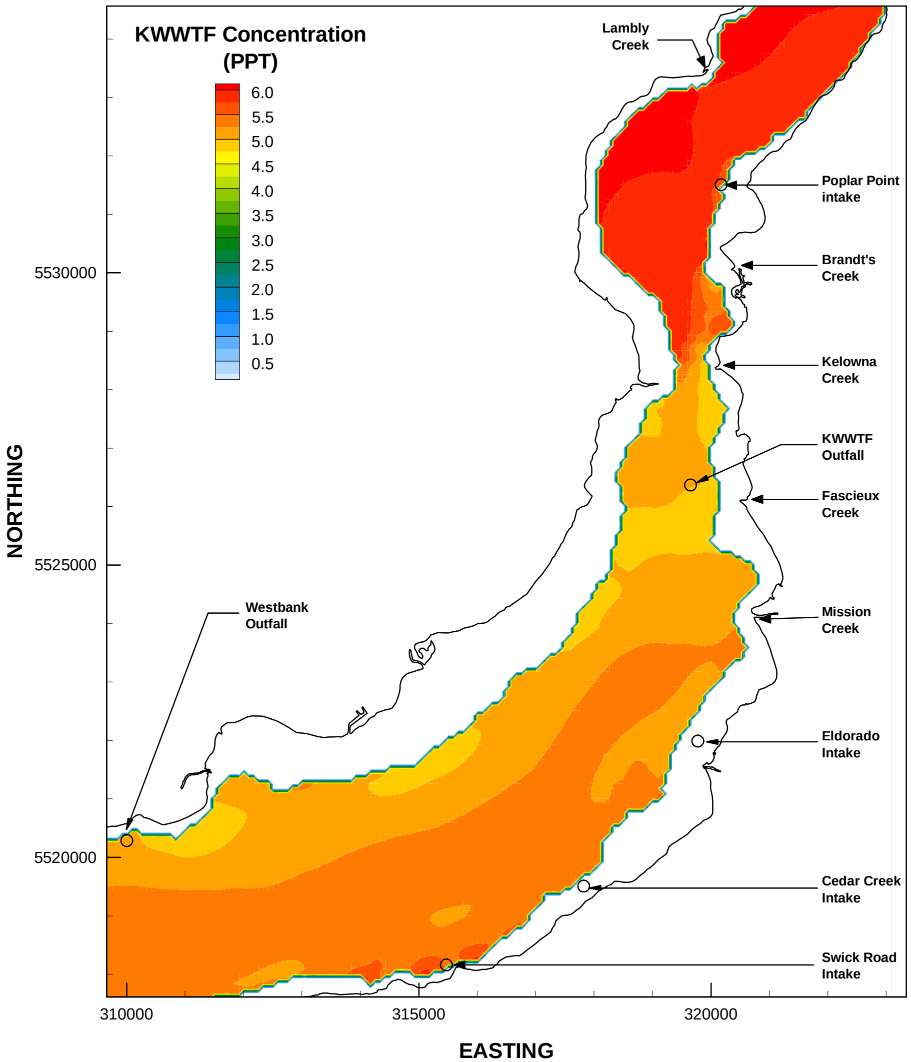
Upset in the KWWTF (W1)
Effluent Concentration Near the Intakes

PROJECT NO.	DWN	CHK	APVD	REV
V13201297	EW	JAS	JAS	0

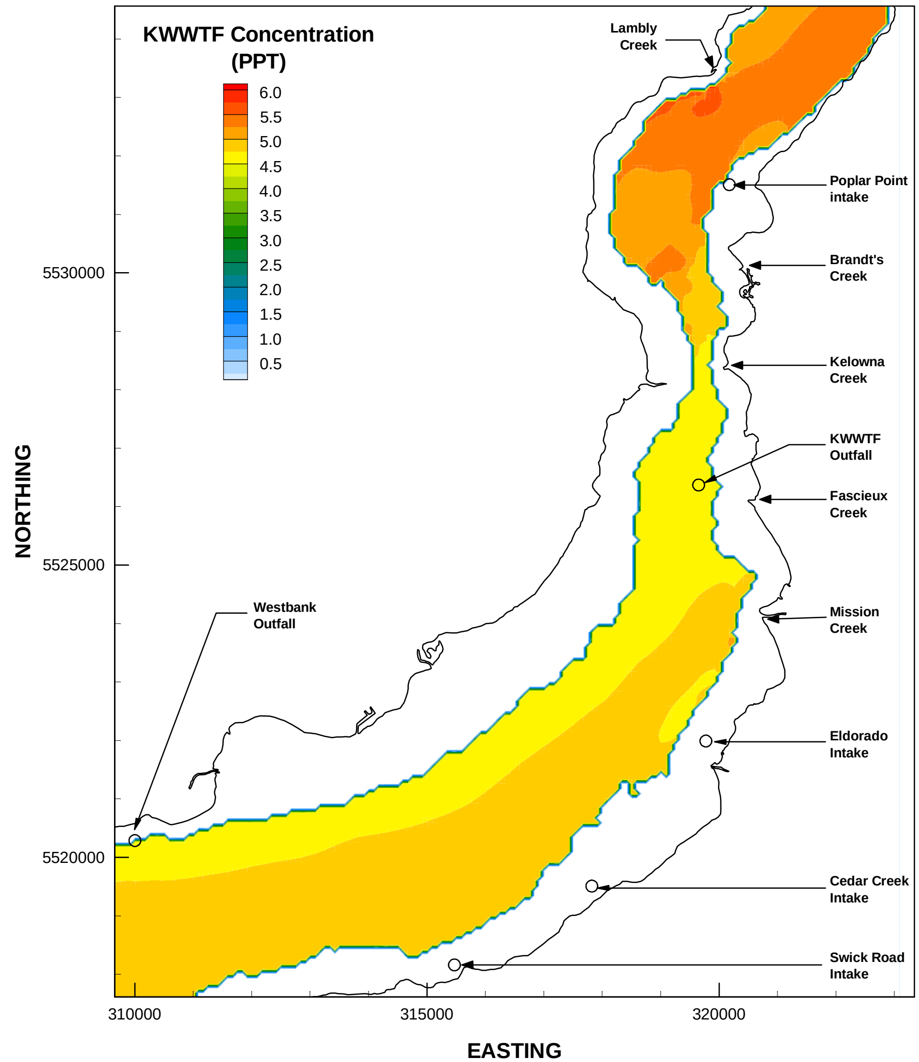
OFFICE	DATE
EBA-VANC	April 2011

Figure 4.11

July 13, 1996 12:00pm, Depth = 30 m



July 13, 1996 12:00pm, Depth = 40 m



NOTES

STATUS
ISSUED FOR USE

CLIENT

City of Kelowna

A TETRA TECH COMPANY

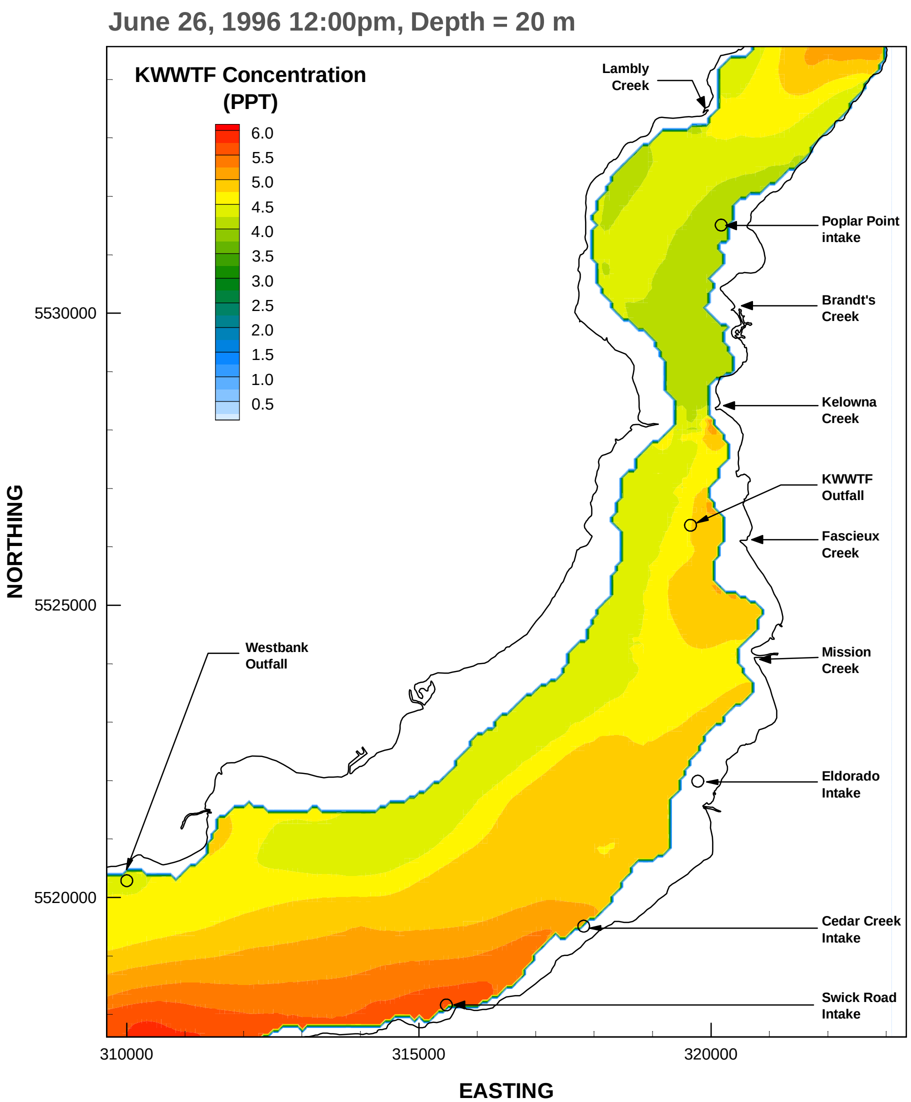
CITY OF KELOWNA
DRINKING WATER SOURCE PROTECTION

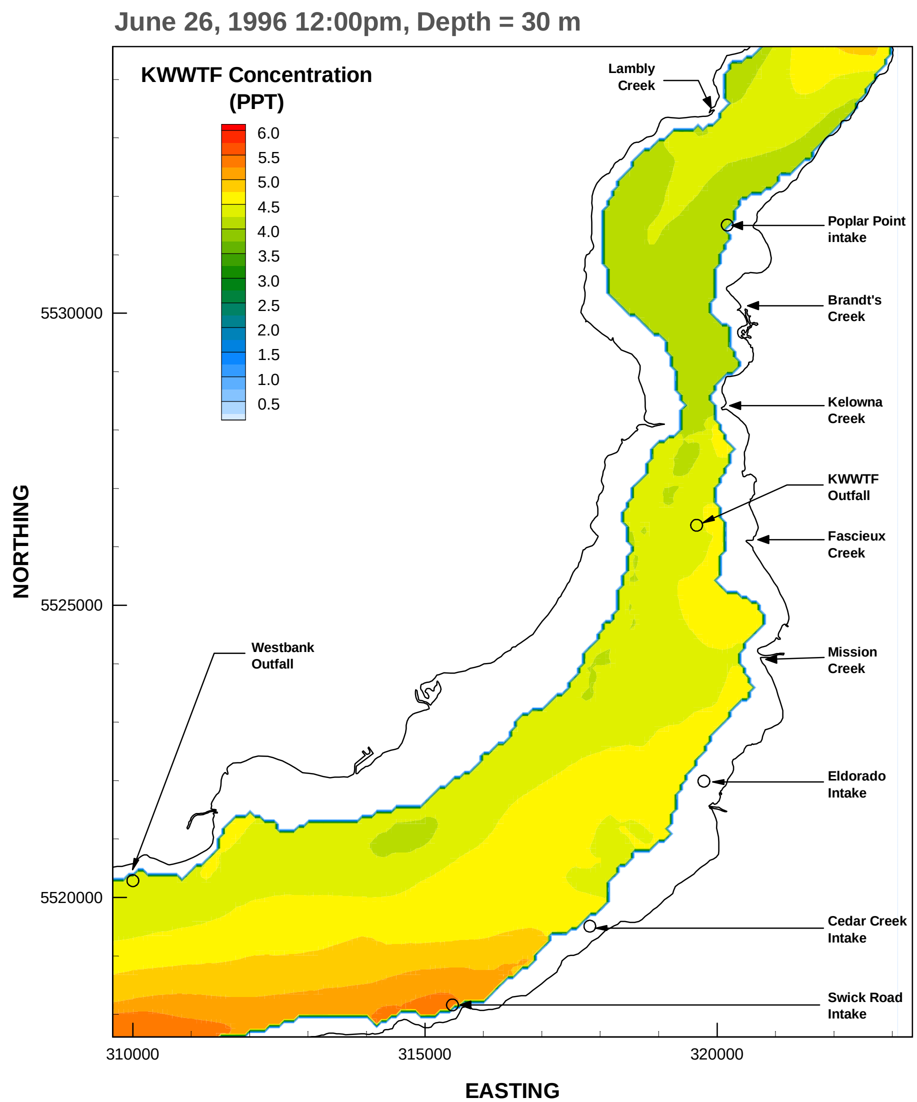
Upset in the KWWTF (W1) - Poplar Point Intake Effluent Concentration Maps

PROJECT NO.	DWN	CKD	APVD	REV
V13201297	EW	JAS	JAS	0

OFFICE	DATE
EBA-VANC	April 2011

Figure 4.12





NOTES

STATUS
ISSUED FOR USE

CLIENT

City of Kelowna

A TETRA TECH COMPANY

CITY OF KELOWNA
DRINKING WATER SOURCE PROTECTION

Upset in the KWWTF (W1) - Cedar Intake Effluent Concentration Maps

PROJECT NO.	DWN	CKD	APVD	REV
V13201297	EW	JAS	JAS	0

OFFICE	DATE
EBA-VANC	April 2011

Figure 4.13

APPENDIX A

APPENDIX A EBA'S GENERAL CONDITIONS

GENERAL CONDITIONS

DESIGN REPORT

This Design Report incorporates and is subject to these “General Conditions”.

1.0 USE OF REPORT AND OWNERSHIP

This Design Report pertains to a specific site, a specific development, and a specific scope of work. The Design Report may include plans, drawings, profiles and other support documents that collectively constitute the Design Report. The Report and all supporting documents are intended for the sole use of EBA’s Client. EBA does not accept any responsibility for the accuracy of any of the data, analyses or other contents of the Design Report when it is used or relied upon by any party other than EBA’s Client, unless authorized in writing by EBA. Any unauthorized use of the Design Report is at the sole risk of the user.

All reports, plans, and data generated by EBA during the performance of the work and other documents prepared by EBA are considered its professional work product and shall remain the copyright property of EBA.

2.0 ALTERNATIVE REPORT FORMAT

Where EBA submits both electronic file and hard copy versions of reports, drawings and other project-related documents and deliverables (collectively termed EBA’s instruments of professional service), only the signed and/or sealed versions shall be considered final and legally binding. The original signed and/or sealed version archived by EBA shall be deemed to be the original for the Project.

Both electronic file and hard copy versions of EBA’s instruments of professional service shall not, under any circumstances, no matter who owns or uses them, be altered by any party except EBA. EBA’s instruments of professional service will be used only and exactly as submitted by EBA.

Electronic files submitted by EBA have been prepared and submitted using specific software and hardware systems. EBA makes no representation about the compatibility of these files with the Client’s current or future software and hardware systems.

3.0 ENVIRONMENTAL AND REGULATORY ISSUES

Unless so stipulated in the Design Report, EBA was not retained to investigate, address or consider, and has not investigated, addressed or considered any environmental or regulatory issues associated with the project specific design.

4.0 CALCULATIONS AND DESIGNS

EBA has undertaken design calculations and has prepared project specific designs in accordance with terms of reference that were previously set out in consultation with, and agreement of, EBA’s client. These designs have been prepared to a standard that is consistent with industry practice. Notwithstanding, if any error or omission is detected by EBA’s Client or any party that is authorized to use the Design Report, the error or omission should be immediately drawn to the attention of EBA.

5.0 GEOTECHNICAL CONDITIONS

A Geotechnical Report is commonly the basis upon which the specific project design has been completed. It is incumbent upon EBA’s Client, and any other authorized party, to be knowledgeable of the level of risk that has been incorporated into the project design, in consideration of the level of the geotechnical information that was reasonably acquired to facilitate completion of the design.

If a Geotechnical Report was prepared for the project by EBA, it will be included in the Design Report. The Geotechnical Report contains General Conditions that should be read in conjunction with these General Conditions for the Design Report.

6.0 INFORMATION PROVIDED TO EBA BY OTHERS

During the performance of the work and the preparation of the report, EBA may rely on information provided by persons other than the Client. While EBA endeavours to verify the accuracy of such information when instructed to do so by the Client, EBA accepts no responsibility for the accuracy or the reliability of such information which may affect the report.