LARRATT AQUATIC

FINAL REPORT Sept 9 / 2011

Source Assessment of the Regional District of North Okanagan - Greater Vernon Water Utility North Kalamalka Lake Intake

Executive Summary

The objectives of this assessment of the GVW North Kalamalka Lake Intake were to characterize the lake and its immediate watershed, identify current and forecast future drinking water hazards and vulnerabilities, characterize the risk posed by each hazard and provide recommendations to reduce impacts on the intake. This report is not provided as evidence for filtration deferral, but contributes to the research available to GVW for that purpose.

This assessment characterizes natural and man-induced hazards to drinking water quality as physical, chemical or biological. Existing research was augmented by field studies of water currents near the intake and lab studies on the fall rates of particulate contaminants. This research was used to define a proposed Intake Protection Zone (IPZ), based on a two hour travel time of water currents to the intake. The hazard assessments were then divided into those occurring inside the IPZ and those occurring outside the IPZ. The same hazard occurring outside the IPZ was given a lower risk rating than that hazard presented within the IPZ where there is less dilution and less time to react to a contaminant.

Specific recommendations and action plans were developed with the dual aim of providing the best water quality and supporting the GVW application to IHA for deferral of filtration. Key recommendations include: applying to the Province for special protection over the Intake Protection Zone; restoration of Coldstream Creek riparian areas; considering bylaws to protect the foreshore; and studying the benefits of a deeper intake.

The connectivity of Coldstream Creek to the North Arm cannot be over-stated. Agricultural activity and streamside development along this tributary that carries 80% of Kalamalka Lake's annual inflow should be seen as an extension of shoreline development and subject to management and development restrictions. After creek flows reach the lake, the main transport mechanism of surface contaminants to the N-Kal intake is seiches in the stratified (May – October) period.

Acknowledgements:

Funding by Greater Vernon Water Utilities, a function of Regional District of North Okanagan (RDNO)

Principal Author: H. Larratt, Data Management B. Larratt, Technical Illustrations R. Massey, Assistance from GVW Renee Clark, Al Cotsworth, Connie Kreuger and Tricia Brett; Assistance from DoC Craig Broderick, Alanna Dean, Mike Pethick; Members of TAC: Bryn Lord IHA, Solvej Patschke MoE.

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

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

Table of Contents

EXECUTIVE SUMMARY

1.0 Introduction....2
1.1 Study Background....2
1.2 Study Purpose....2
1.3 Study Plan....2
1.4 Definitions and Abbreviations....3
2.0 Kalamalka Lake Intake Module 1: Characterization of Source....6
2.1 Kalamalka Lake Physical Features and Watershed....6
2.2 Description of Intake, Design, Construction and Maintenance....8
2.3 Kalamalka Lake: Limnolgy, Thermal data, Seiches....11
2.4 General Water Quality & Nutrients....22
2.5 Chlorophyll-a Analyses....25
2.5 Water Chemistry Relevant to Drinking Water Safety....26
2.6 Calculation of Intake Protection Zone for North Kalamalka Lake Intake....34
2.7 Hazards Impacting the Intake Protection Zone....42
2.7.1 Water Bourne Pathogens....42
2.7.2 Sediment Contaminants....47
2.7.3 Trihalomethane Formation Potential....49
2.7.4 Cyanobacteria....49
2.7.5 Sewage/Septage....51
2.7.6 Storm Water Locations....52
2.7.7 Biofilm Development....52
2.7.8 Water Infrastructure of the North Intake....53
2.7.9 Monitoring Routine and Emergency Planning....53
2.8 SUMMARY MODULE 1: Hazard and Contaminant Identification Table....54
3.0 Kalamalka Lake Intake Module 2 Contaminant Inventory....55
3.1 Anthropogenic Potential Water Borne Hazards to GVW North Intake....55
3.1.1 Inflows....56
3.1.2 Storm Water Outfalls....57
3.1.3 Sewer Infrastructure and Septic Fields....60
3.1.4 Moorage, Docks and Powerboat Recreation....62
3.1.5 Adjacent Land Use....64
3.1.6 Vandalism and Accidental Introductions....66
3.2 Natural Contaminants or Factors that Influence Susceptibility to Contamination....68
3.2.1 Kalamalka Lake Marling....68
3.2.2 Cyanobacteria in Kalamalka Lake....68
3.2.3 Kalamalka Lake Provincial Park – Shoreline Wildlife....68
3.3 SUMMARY MODULE 2: Contaminant Source Inventory Table....69
3.4 SUMMARY MODULE 2: Hazard from Contaminants Identification Table....70
4.0 Kalamalka Lake Intake Module 7: Risk Characterization and Analysis....71
4.1 Condition of Source....75
4.2 Physical Integrity of Intake, Treatment and Distribution System....75
4.3 Risk Assessment for healthy and health compromised individuals....75
4.4 Intake Extension....75
4.5 Strength/Weakness Opportunites/Threats SWOT Analysis....77

5.0 Kalamalka Lake Intake Module 8: Recommendations 79
5.1 Source Protection Action Plan 79
5.2 High Priority Recommendations Based on Risk Rating 79
5.3 Moderate Priority Recommendations Based on Risk Rating 83
Literature Cited or Consulted 85

Disclaimer: This report is based on limited, cost-constrained research on complex lake systems. Larratt Aquatic Consulting Ltd and its associates have made a best attempt at accuracy in data collection and presentation. No liability is incurred by LAC or GVW or DoC for accidental omissions or errors made in the preparation of this report.

Figures, Tables and Appendices

Figure 2.1: Cross Section Schematic of North Kalamalka Lake Intake 12
Figure 2.2: Aerial View of Kalamalka Lk and Bathymetric Map of the North Arm 14
Figure 2.3: Seiche-Induced Temperature and Turbidity Spike (SCADA) 16
Figure 2.4: Logger Monitoring of Water Layer Temperatures for One Year and Multiple Years 18
Figure 2.5: Flows and Water Quality in Coldstream Creek (MoE Recorder) Early Spring and Summer 2008 20
Figure 2.6: Location of Coldstream Creek Freshet Plume in North Arm Kalamalka Lake 2008 – large freshet year 21
Figure 2.7: Coldstream Creek Freshet Plume 2008 in North Arm Kalamalka Lake, Cross Sections 23
Figure 2.8: Turbidity and Conductivity in Large Coldstream Ck Freshet Plume 2008 24
Figure 2.9: Temperature and Dissolved Oxygen Profiles North Arm Kalamalka Lk 25
Figure 2.10: Growing Season pH in Kalamalka Lake 1981 -2010 26
Figure 2.11: Annual Average Sodium and Chloride in Kalamalka Lake 27
Figure 2.12: Secchi Depth Range and Average in North and South Kalamalka Lake at the Intake Locations 2000 - 2009 28
Figure 2.13: Average Growing Season Monthly Total N and P 29
in Kalamalka Lake 1975 - 2008 29
Figure 2.14: Chlorophyll-a in Kalamalka Lake 1999 -2009 29
Figure 2.15: Average Growing Season Chlorophyll-a 1999-2009 30
Figure 2.16: Algae Distribution with Depth, North Kalamalka Lake 31
Figure 2.17: Average Total Organic Carbon in Kalamalka and Wood Lakes 32
Figure 2.18: Average Annual Turbidity in North Arm Kalamalka Lake, 2004 - 2009 33
Figure 2.19: Particle Size Distribution at North 20m Site April and May 2006 34
Figure 2.20: Turbidity at the GVW North Kalamalka Intake, 2008 and 2009 35
Figure 2.21 North Kalamalka Lake Total Organic Carbon, 2002 - 2010 36
Figure 2.22: Photos of Settling Velocity Experiment; Kalamalka Lake, 2009 40
Figure 2.23: Schematic Cross Section of Deployed Drogues 41
Figure 2.24: North Kalamalka Lake Drogue Trials, 2009 43
Figure 2.25: Proposed Intake Protection Zone for N-Kalamalka Lake Intake 45
Figure 2.26 *Cryptosporidium* and *Giardia* at the North Kalamalka Intake 46
Figure 2.27: *E. coli* at Kalamalka Lake Intakes (raw water) 2008, 2009 47
Figure 2.28: Summary of *E. coli* in North Kalamalka Lake Intake 2003 - 2009 48
Figure 2.29: Photo of Sediment Trap Material from Kalamalka Lake Oct 09–May10 49
Figure 3.1 Features of the North Arm, North Kalamalka Lake 59
Figure 3.2 Coldstream Ck Storm Plume Deflecting NW Toward Public Beach 60
Figure 3.3: Canada Geese and Gulls on Main Beach, September 2009 61
Figure 3.4: Location of Storm water Outfalls and GVW Kal Lake Intakes 62

Figure 3.5: Location of Near-shore Sewer Lift Stations and GVW Kalamalka 64
Lake Intakes 64
Figure 3.6: Effluent Spray Irrigation Area for City of Vernon 65
Figure 4.1: Possible Intake Locations, North Arm Kalamalka Lake 80

Table 2.1:Intensive Freshet Turbidity Sampling for North Kalamalka Lake, 2005-2008 ... 34
Table 2.2: Size and Fall Velocity Estimates for Kalamalka Lake Particulates..................... 39
Table 2.3: Drogue Results for GVW North Kalamalka Lake Intake, 2009 42
Table 2.4 Sediment under North Kalamalka Intake and Sediment Trap Data 50
Table 2.5 Lower Coldstream Creek Water Quality 2009 50
Table 2.6: Triplicate Sediment Core Results from 20 m 52
Near North Kalamalka Intake, 2001 52
Table 2.7: Bacteria in Re-suspended Sediment beneath GVW North Kalamalka Intake 52
Table 2.8: Toxins Produced by Blue-green Algae (Cyanobacteria) 54
Table 2.8 MODULE 1: Hazard and Contaminant Table – North Kalamalka Intake
....58
Table 4.2: Risks Inside Intake Protection Zone (IPZ) with the Potential to Impact
the North Kalamalka Intake 76
Table 4.3: Risks Outside Intake Protection Zone (IPZ) with the Potential to Impact
the North Kalamalka Intake 77
Table 4.4: Bacterial Results for North Kalamalka Lake 2010 79
Table 4.5: Average Water Quality Change with Current and 30 and 40 m 80
Intake Depths – 2009 data.. 80
Table 4.6: Strength/Weakness Opportunities/Threats Analysis Summary 81
of the GVW North Kalamalka Lake Intake 81

Appendix 1: Supporting Documentation 95
Appendix2: Activities Impacting the Intake Protection Zone Checklist 97
Appendix 3: *E. coli* Source Tracking in City of Kelowna Creeks Receiving Storm
Water and at Beaches 99
Appendix 4: Locations of Proposed DoC Storm Sewer Sewer Upgrades 100
Appendix5: North Kal Intake Assessment Open House Summary 101

1.0 Introduction

1.1 Study Background

On-going monitoring and research can be used to meet most of the criteria for the IHA requested Modules 1, 2, 7 and 8 of the Drinking Water Source Assessment for Greater Vernon Water (GVW) 20 m North Kalamalka Lake Intake. Because GVW funds proactive studies, monitoring and research on their intakes has been in place for years. For example, research into alternate intake depths is into its 5th year in Kalamalka Lake. All information from their intake studies and the extensive data base collected by Ministry of the Environment will be brought to bear on this Source Assessment report. Additional innovative research was undertaken to round out the data base for this Source Assessment.

1.2 Study Purpose

This report compiles new research and known data into the Source Assessment format for use identifying GVW North Kalamalka Lake Intake's strengths, its liabilities and to identify future needs to maintain excellent quality, cost-effective water supply to GVW's system. GVW is a function of RDNO.

1.3 Study Plan

This report was written using the Kalamalka Lake studies (2000 – 2010) commissioned by DLC and GVW. Reports created by Provincial agencies including Ministry of Environment were reviewed. Several reports prepared for the City of Kelowna by Hay and Company were also utilized.

The research/sampling component of this report was completed in 2009 - 2010 and it involved:

- Sediment samples were taken from beneath the intake for total coliforms and *E. coli*
- Sediment traps were deployed near the intake from October 2009 to May 2010
- A caffeine analysis was completed on the raw lake water to identify the presence/absence of dilute human outfall/septic wastes
- A drogue study of long-shore currents near the North Kalamalka Intake was conducted because no water current modeling is available for this lake as it is for Okanagan Lake
- A combination of organic and inorganic material washed off a filter from the Kalamalka Lake system was allowed to settle to determine fall velocities for its constituent particulates

1.4 Definitions and Abbreviations

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

ALGAE BLOOM: A superabundant growth of algae. Many species are capable of coloring the water or covering the surface of a lake.

ANAEROBIC or ANOXIC ZONE: A zone that develops along the sediments where decomposition of algae etc. consumes oxygen faster than it is supplied by the surrounding water. Anaerobic zones accumulate color, nutrients, tri-halomthane (THM) precursors and taste & odor.

Anions: Negatively charged ions (cations are positively charged ions).

ATP: ATP or Adenosine Tri-Phosphate is a chemical compound that breaks down to release the energy responsible for muscle contraction. It is the only useable form of energy in a body and is found in every living cell.

BENTHIC: Organisms that dwell on or are associated with the sediments.

BIOFILM: A thin, usually resistant layer of microorganisms that form on and coat surfaces such as water pipes. Biofilms usually include bacteria.

BLUE-GREEN ALGAE (CYANOBACTERIA): The family of bacteria-like algae having cyanochrome as the main photosynthetic pigment and chlorophyll as a secondary pigment. Many members of this family reproduce rapidly and some cause algae blooms. They are notorious for taste and odor problems.

CONDUCTIVITYY: Electrical conductivity of water samples is used as an indicator of how salt-free, ion-free, or impurity-free the sample is; the purer the water, the lower its conductivity.

DIATOMS: The family of algae containing chlorophyll as the primary photosynthetic pigment and having hard, silica-based "shells" (frustules). Diatoms affect filtration and produce a range of taste and odors.

DIMICTIC: Refers to a lake that has two periods of water column mixing, one in the spring and one in the fall.

DROGUE: Float used to track current paths at a depth below the water surface determined by the position of vanes (or other surface to intercept currents) suspended beneath the float.

EUTROPHIC: Refers to a nutrient-rich, biologically productive water body where concentrations of mineral and organic nutrients have reduced dissolved oxygen, producing environments that frequently favor plant over animal life.

Lake Classification by Trophic Status Indicators After Nordin 1985

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

FALL OVERTURN: In fall, surface waters cool and sink, eroding the thermocline until a wind storm mixes the entire water column.

FRESHET: Freshet is commonly referred to as "spring runoff" and is the period when accumulated winter snow melts, causing substantially increased stream flow.

GENERA: The usual major subdivision of a family or subfamily in the classification of organisms, usually consisting of more than one species.

GREEN ALGAE: The large family of algae containing chlorophyll as the primary photosynthetic pigment.

IRON RELATED BACTERIA: Non-disease-producing bacteria that grow in water and use dissolved iron as part of their metabolism.

LIMITED, NUTRIENT LIMITATION: In any environment, a nutrient or other growth requirement will limit or restrict the potential growth of organisms. For example, phosphorus usually limits algae production in lakes; if there is an increase in all of the other nutrients, no increase in algae growth will result because phosphorus is the "bottleneck". Conversely, even a small increase in the phosphorus supply will result in increased algae growth.

LIMNOLOGY: The study of freshwater; physical and chemical considerations such as lake thermal behavior, nutrient cycling, basin morphology, sediment structure, etc.

LITTORAL: Of or pertaining to the bio-geographic zone between the high and low water marks, usually the most productive area of a lake that supports rooted aquatic plants.

MACRONUTRIENT: Macronutrients are the major constituents of cellular protoplasm and usually limit biological production. (They include nitrogen, phosphorus, carbon, hydrogen sulphur.)

MARL: A marl event involves the precipitation of calcium carbonate, magnesium carbonate and calcium sulphate (gypsum) when the lake water warms or pH increases.

MESOTROPHIC: Refers to a lake or pond, etc., having a moderate amount of plant growth: the mesotrophic stage is intermediate between the oligotrophic and eutrophic stages.

METALIMNION: The water layer containing the thermocline that is between the surface epilimnion and the bottom hypolimnion.

MICRONUTRIENT: Relatively minute amounts of a micronutrient are required to maintain plant growth within its environmental constraints. These include; Mn, Fe, Co, Zn, Cu, Mo etc.

MONOMICTIC: Refers to a lake that experiences only one period of mixing that extends from fall, through the winter, to early spring.

OLIGOTROPHIC: designating or of a lake, pond, etc. poor in plant nutrient minerals and organisms and usually rich in oxygen at all depths

PAHs Polynuclear (or polycyclic) aromatic hydrocarbons: PAHs are typical components of asphalts, fuels, oils, and greases. They are produced as byproducts of fuel burning and are therefore detected in storm water. As a pollutant, they are of concern because some compounds have been identified as carcinogenic, mutagenic, and teratogenic. PAHs are also found in oily foods cooked at high temperatures.

PHYTOPLANKTON: Algae that float, drift or swim in standing water.

PHOTIC ZONE: The zone in a water body that receives sufficient sunlight for photosynthesis.

PLANKTON: Organisms that float or swim in water. Phytoplankton refers to plants; zooplankton to animals.

RIPARIAN: A riparian zone or riparian area is the interface between land and a stream or lake. Plant communities along the river margins are called riparian.

SECCHI DEPTH: The Secchi disk is used to measure water transparency in oceans and lakes. The depth at which the disk is no longer visible is taken as a measure of water transparency. This is known as the Secchi depth and is related to water turbidity.

SEICHE: Wind-driven tipping of the water layers during the summer. Seiches cause the water layers to oscillate for days after a wind storm.

THERMOCLINE: The zone of greatest change in water temperature with depth (> 1^{o}C/m) that separates the surface water (epilimnion) from the underlying cold hypolimnion.

ZOOPLANKTON: Minute animals that graze algae, bacteria and detritus.

Report Abbreviations:

Entities

DLC = District of Lake Country
DoC = District of Coldstream
GVW = Greater Vernon Water
IHA = Interior Health Authority
LAC = Larratt Aquatic Consulting;
MoE = Ministry of Environment
MoTH = Ministry of Transportation and Highways
OBWB = Okanagan Basin Water Board
SIDWT = Southern Interior Drinking Water Team

Technical Phrases, Regulations

BCERMS =British Columbia Emergency Response Management Systems
BCWQ = BC Water Quality
GCDWQ = Guidelines for Canadian Drinking Water Quality
FIM = Foreshore Inventory mapping
IPZ =Intake Protection Zone
OKBS =Okanagan Basin Study
SHIM = Sensitive Habitat Inventory Mapping
WTP = Water Treatment Plant

2.0 Kalamalka Lake Intake Module 1: Characterization of Source

2.1 Kalamalka Lake Physical Features and Watershed

Kalamalka Lake is deep for its size. It has a maximum depth of 142 m and contains 1520 million m^3. Kalamalka Lake drains a small watershed, resulting in a comparatively long residence time of 55 - 65 years. Because a theoretical full exchange of water in Kalamalka Lake takes at least 55 years, only about 2% of the water in the lake is replaced each year.

Kalamalka Lake receives significant ground water inflows and submerged springs have been noted by residents along the eastern shore. This ground water input probably contributes to the marl precipitation in the lake. Kalamalka Lake's immediate watershed includes grassland / forest park; shoreline residential with modified shorelines and docks; day-use beaches; and moderate density subdivisions with roads and storm water outfalls.

Over 80% of the surface inflow to Kalamalka Lake is derived from Coldstream Creek. This creek was enhanced by diversions possibly predating the transfer of the water license to Coldstream Ranch in 1906. Its original channel from Noble Canyon to Lumby was changed and a new channel dug to connect to the existing Brewer and Caster Creek channel and on to the lake. The remaining 20% of the annual surface inflow to Kalamalka Lake comes from mesotrophic Wood Lake.

The impact of human activities on these inflows and ultimately on Kalamalka Lake can be tracked using conservative ions (Ca Na Mg K) of which Na is the best and anions (Cl SO_4 CO_3 and HCO_3) of which Cl is the best – i.e. it participates in the fewest reactions (Wetzel, 2001). Both sodium and chloride have shown a slow, steady increase since 1976, indicating increased watershed disturbance, particularly municipal wastewater and storm water run-off (Bryan, 1996). Although Kalamalka Lake has enviable water quality on the global scale, there are indicators of both positive and negative change in recent decades. Since all lakes undergo water chemistry fluctuations, the challenge before us is to protect Kalamalka Lake.

Shoreline Impacts Ecoscape Environmental Consultants estimated that 53.7% of the Kalamalka Lake shoreline or 25 km has a high level of impact. Areas of moderate impact account for 10.7% or 5.0 km and areas of low impact account for 33.3% or 15.5 km of the shoreline respectively. Impacts along the shoreline include lakebed substrate modification, riparian vegetation removal, construction of retaining walls, docks and other man-made features (Schleppe, 2010).

Impacts included:

- 360 docks
- 213 retaining walls totaling 7 km (15%) of the shoreline
- 26 breakwaters (groynes)
- 11 boat launches and 9 marinas with over 6 slips, 1 with on-water refueling
- 40% of shore length has received substrate modification

The largest land use around the lake is natural area parks (28%), followed by transportation – highway, railway, roads (23.3%). Single family areas are the third most commonly observed land use type, accounting for 22.3% of the shoreline. Stream confluences are rare around Kalamalka Lake, accounting for only 2.3% of its shoreline length. This rare but important shore type is 66% disturbed. Wetland habitats accounts for 4.5% of the shoreline and in these areas the disturbance is much less, with only 23% of the shore length impacted (Schleppe, 2010).

The predominant shore types around the lake are gravel beaches (45%) and rocky shores (27%), followed by cliff / bluff (17%) and sand beaches (3.7%). Aquatic vegetation occurs along 6.8% of the shoreline length. Of this, emergent vegetation was the most commonly observed (e.g., emergent grasses, willows, or other areas with vegetation inundated during high water) (Schleppe, 2010).

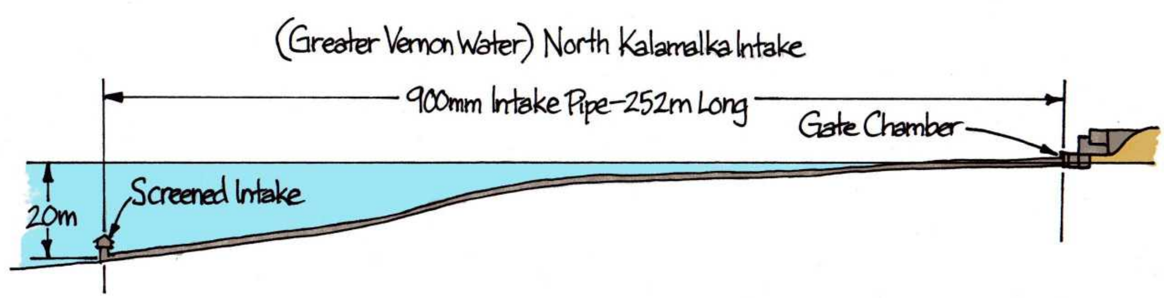
It is beyond the scope of this report to address efforts needed to prevent lake-wide chemical and nutrient impacts on Kalamalka Lake as a whole. DoC and GVW do not control their source water and instead rely on the co-operation of all agencies, residents and users. Recommendation 5.2.1 deals with available assistance from inter-agency groups.

2.2 Description of Intake: Intake Location, Design, Construction and Maintenance

The water license held by GVW allows 16,141,907 m^3 of water use per year. The full allocation is not utilized every year. For example, in 2007 less than half of the allocation was used (Clark, 2008). GVW operated both the 20 m deep North-Kal and 8 m deep East-Kal intakes; this report covers the N-Kal intake only because the E-Kal intake was removed from service in April, 2011.

Location and Depth The 20 m deep N-Kal Intake was upgraded in 1973 by replacing an old wood stave intake of similar length. The 1973 intake was 137 m long and was located 0.3 m above the substrate for an invert intake depth of 5.7 m. The intake was revised again in 1981 and is now 252 m to the chamber 275 m off-shore and 60 cm above the sediments, not allowing for sediment accumulation since construction (illustration below). The intake pipe diameter is 900 mm and it is flexible sclair pipe (weldable high density polyethylene). The approximate invert is el. 370 m.

Figure 2.1: Cross Section Schematic of North Kalamalka Lake Intake



Intake Clearance Divers report that the intake clearance is 0.6 m which is too close to the substrate and at the rapid rate of sediment accumulation in the North Arm of 62 $g/m^2/yr$, clearance will decrease over time. It is part of the diver's job to clean the screen and remove accumulated sediment in the immediate vicinity of the intake. A note on the 1973 as-built diagram states that a rock-cobble substrate dominates the intake area for 75' (23 m) off-shore and the deeper area has a soft silty substrate. Approximately every second year, a SCUBA team inspects and cleans the intake. It was last cleaned in 2007.

Protection of Pumphouse from Animals and Vandalism The pumphouse consists of a locked compound and building. It is enclosed in a chain link fence with razor wire to protect both the pumphouse and the public that frequent the adjacent beach.

N-Kal Intake Distribution System As the GVW system ages and expands, new infrastructure and replacement infrastructure are constantly under construction. The age of GVW's system is variable. Currently, the oldest surviving areas of the system were built in 1940 or later.

Water Treatment Overview

At the existing North Kalamalka Lake pump station, two 400-hp pumps were installed in 2006 to accompany two 200-hp pumps. The new pumps improved pumping capacity. In 2008, a variable frequency electric drive was installed. All surface supplies are equipped with continuous on-line turbidity meters and SCADA that relays low and high alarms to operations staff (Clark, 2009).

The new Mission Hill ultraviolet disinfection system and on-site sodium hypochlorite generation for chlorine disinfection was completed in April 2007. These processes are monitored with an array of on-line analyzers and routine sample collection. This type of treatment works effectively against protozoa such as *Giardia* and *Cryptosporidium*. These protozoa were infrequently detected in the intake water (Sec. 2.7.1). The plant has improved water quality consistency and has performed satisfactorily, bringing the water up to current IH standards and making an application for filtration deferral possible.

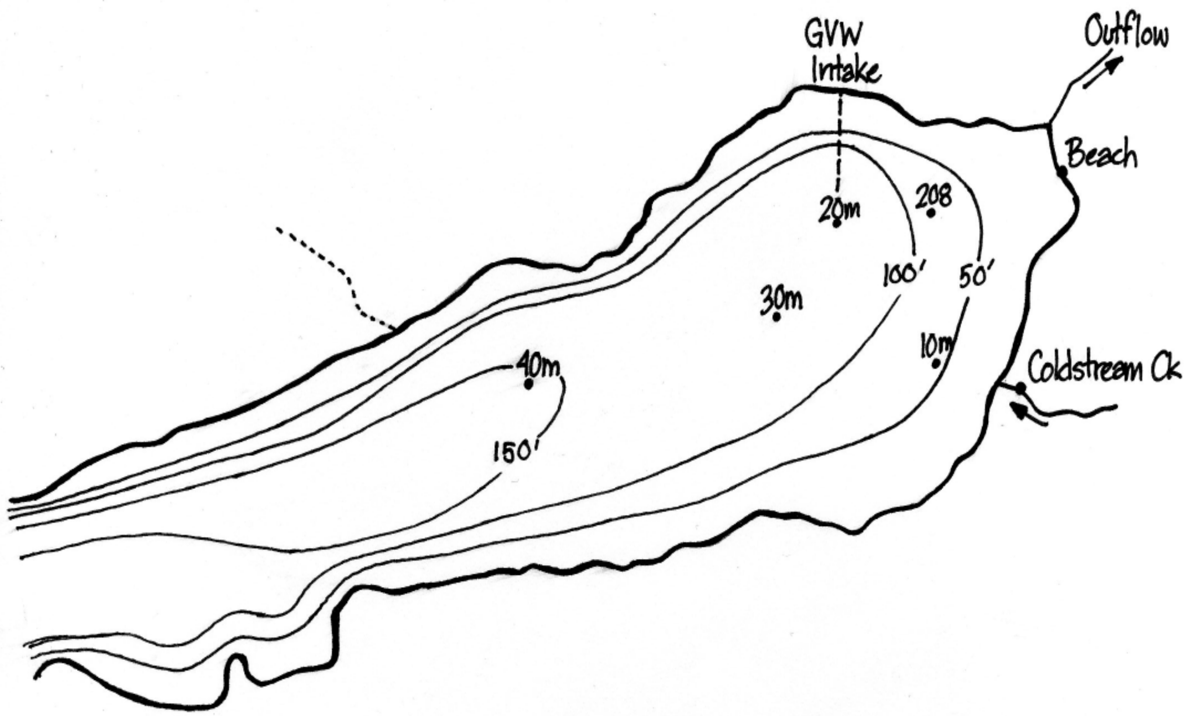
Upgrades to the system are performed based on priority in the System Water Master Plan. Like any water system, the distribution system is subject to aging, settling of suspended materials, accidental line breaks and cross-connections. On-going maintenance, repairs and monitoring are vital to any water distribution system. An emergency response plan aids in providing an appropriate and swift response to an emergency. Operation and maintenance are scheduled as part of the Capital Replacement Plan.

The Greater Vernon Water Utility All Hazards Emergency Response Plan was prepared by: Public Safety Consultants Northwest, LLC Seattle, Washington. RDNO's plan follows the guidelines of the BCERMS (*British Columbia Emergency Response Management System)* standards for response and incident management using the Incident Command System. The Water Quality Manager is responsible to review the entire Plan on an annual basis, co-ordinating the revision of the plan as needed, maintaining records of the revisions, and administering the overall plan.

Monthly monitoring reports are e-mailed to the Interior Health Drinking Water Officer.

.

Figure 2.2:
Aerial View of Kalamalka Lake and Bathymetric Map of the North Arm



2.3 Kalamalka Lake: Limnology, Thermal data, Seiches s

Kalamalka Lake Kalamalka Lake is the largest source of available potable water in the North Okanagan (A. Cotsworth, pers. comm., 2005) (Figure 2.2). Kalamalka Lake is a marl lake and has elevated concentrations of calcium and sulphate. The mid-summer marl precipitation helps control phosphorus concentrations. Most of the lake is oligotrophic with phosphorus and, occasionally, nitrogen controlling algae growth (Nordin et al, 1988). In general, nutrient concentrations at the north and south ends of Kalamalka Lake move in concert, indicating whole-lake influences are more important than localized inputs.

Coldstream Creek Inflows Coldstream Creek imports nutrients and *E. coli* bacteria to Kalamalka Lake. From Noble Canyon downstream, 45% of its riparian area needs restoration (Schleppe, 2010). Agricultural impacts on lower Coldstream Creek include stream bank erosion, surface discharge of nutrients and horse/cattle/avian fecal material as well as nitrate-enriched ground water discharge (Dill, 1972). Over decades, animal husbandry impacts both the surface and the interconnected ground water; the later acting as a long-term nutrient reservoir. In the downstream urban areas, the most obvious impacts stem from direct discharge of storm water. MoE research determined that Coldstream Creek is far more impacted in terms of nitrates and bacterial counts than other Okanagan creeks of similar size (Bryan, 1990). (Please refer to Coldstream Creek section pg 19 for more information)

Wood Lake Inflows Water generally moves northward from Wood to Kalamalka Lake through the Oyama Canal. Wind action and seiching frequently cause oscillations in the flow through the canal. In late summer and particularly in dry years, a net southerly flow occurs (MoE, 1975). In 2000, wastewater treatment replaced septic systems on Wood Lake and progressively lowered nutrient loading from Wood to Kalamalka Lake. Like Kalamalka Lake, Wood Lake periodically has marl events and they appear to be increasing in frequency. Wood Lake marled in 2008, 2009 and 2010. The marl event in September 2010 was intense, lowering both dissolved phosphorus and algae production.

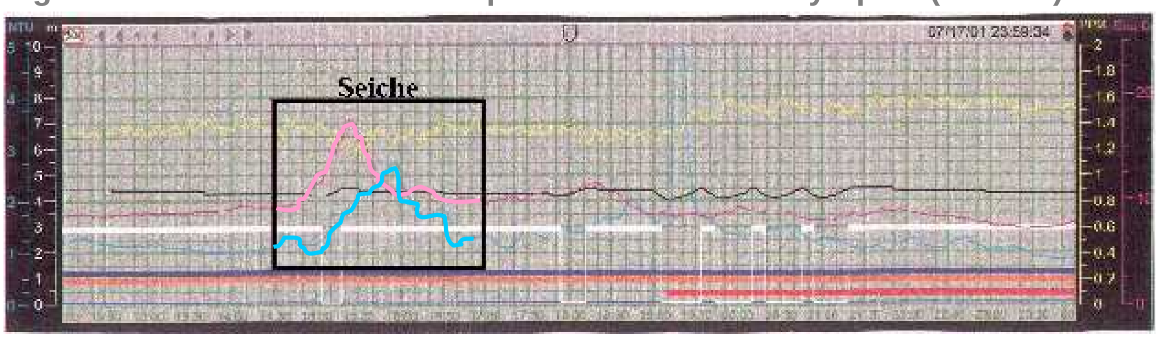
The Hiram Walker distillery opened in Winfield on May 1971 and pumped an average of 22,730 m^3/day (2.5 million gallons/day) of cooling water from Okanagan Lake into Upper Vernon Creek (Nordin et al., 1988). The cooling water flushed nutrient-rich Duck (Ellison) Lake into Middle Vernon Creek to Wood Lake and ultimately to Kalamalka Lake. This influx temporarily accelerated Kalamalka Lake's flushing rate to 37 - 42 years. The plant closed in 1992, and the flushing stopped. Kalamalka Lake reverted to its original 55 – 65 year flushing time (MoE 1985). Since the flushing time is 5 – 6 decades and the current time elapsed since the distillery closed is 2 decades, the effects of the distillery flushing may still be influencing Wood and Kalamalka Lakes.

Removal of the distillery cooling water was estimated to cause a reduction in nutrient transfer of 15% N, 23% P from Duck Lake to Wood Lake and 31% N, 32% P from Wood Lake to Kalamalka Lake (BC Research, 1974). Although the flushing water itself was of good quality, the consequent increase in Vernon Creek flows resulted in a significant increase in nutrient transfer from Duck to Wood and ultimately to Kalamalka Lake (BC Research, 1974). Normally, increasing a lake's flushing rate lowers nutrient concentrations but in this case, nutrient-rich Duck Lake water accelerated algae production in Wood Lake with a ripple effect to Kalamalka Lake. BC Research found that Kalamalka Lake algae production increased in response to Wood Lake inflows. Further, they found that an algae bloom in Wood Lake surface water could be transported into the surface water at the South end of Kalamalka Lake where it mixed slowly within the epilimnion. Dispersion of the nutrient-rich Wood Lake water within Kalamalka Lake was largely dependent on the wind (BC Research, 1974). Although there is some disagreement today about the effects of the water transfer (Walker et al., 1994 vs BC Research 1974), recent data indicates that Kalamalka Lake is probably better off without the increased flushing of high nutrient water from Hiram Walker cooling water in its drainage system.

Limnology Every year, Kalamalka Lake begins to stratify during late March. Stratification is firmly re-established by mid-May. Thermal/turbidity disturbances at the intakes, caused by seiches (internal waves), tend to cluster in early June. The thermocline gradually drops as Kalamalka Lake heats up over the summer. During the fall, the thermocline oscillates deeper into the lake. These oscillating periods (Aug/Sept/Oct) are marked by mild taste/odor and turbidity events. Nutrients released from the sediments may stimulate algae growth by mixing into the water column during seiches. After October, the N-Kal intake withdraws water from the cooling surface layer. Mixing continues as the thermal stratification becomes increasingly fragile until storms break down the water layers during November. Thermal mixing is complete by early December (Bryan, 1990). After December, the entire lake cools as a unit until very subtle inverse stratification sets up in January.

Seiches Seiches are wind-driven tipping of lake water layers during the summer. Seiches cause the water layers to oscillate for days after a wind storm. For a fixed intake, seiches mean a rapid fluctuation in water temperature and turbidity (Figure 2.3). North or south-west winds with gusts exceeding 30 km/hr could generate a seiche on Kalamalka Lake depending on the duration of the wind event. Thermistor lines were deployed at both ends of the lake and seiche travel compared over 5 years. A typical period for the seiche wave to travel from the N end 20m sampling site to the S end 20 m site (15.4 km) was approximately 11.7hrs x 2 = 23.5 hours. Like all waves, it is not the water that moves down the lake and back, just the wave energy.

Figure 2.3: Seiche-Induced Temperature and Turbidity Spike (SCADA)



Temperature and turbidity spike measured at N-Kal Intake

-----Temp -----Turbidity

In the summer, the N-Kal intake draws from the hypolimnion water layer except during seiches when surface water is temporarily drawn down to the intake (Figure 2.3). The vertical movement of a seiche is coupled to large internal waves. These waves break at the sides of the basin like surface waves do and they are significant sources of turbulence (Wetzel, 2001). For GVW, seiches cause increased water temperature and a turbidity spike as surface water is transported with turbulence down to the intake for a period of 2-10 hours before the oscillating thermocline rises again, returning the stationary intake to the bottom water layer. The main transport mechanism of surface contaminants to the N Kalamalka Lake intake is seiches in the stratified (May – October) period.

Large summer seiches are common in Kalamalka Lake (Figure 2.4). Each year, 7 - 12 major seiches are detected by the N and S temperature logger strings. Seiche activity is always greatest in the early summer as the water layers set up and again in the early fall as the surface layer cools and loses buoyancy.

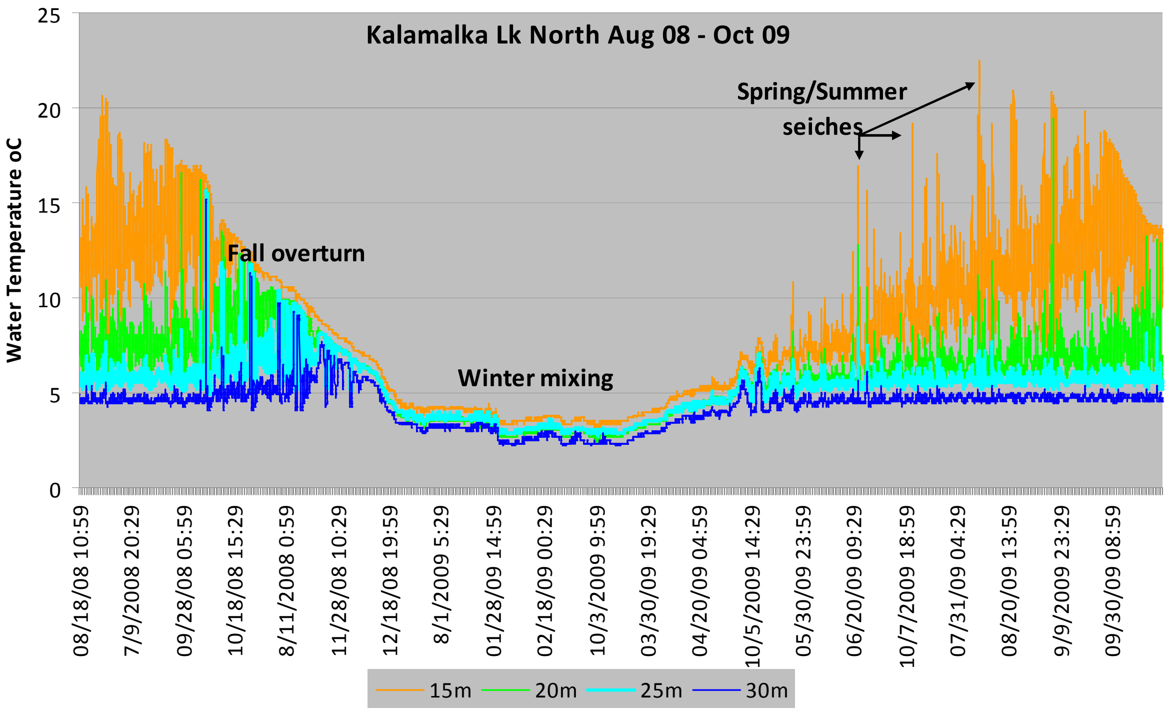
Without seiches, the summer water temperatures at the GVW North intake would be stable near 8 – 10 °C. In the most extreme seiche example to date, the N-Kal intake water temperature rose from 7.2 to 22.2 °C for five hours on July 29/30 2002. During 2008, the largest spring seiches in the N Arm were detected by temperature loggers in mid-June with a temperature fluctuation of 13°C at 15 m. At 30 m, the seiche-induced temperature spike was only 1.5°C (Figure 2.3; 2.4). The N arm dampens seiches so that an intake positioned at 30 m would be much less impacted by seiches than the existing intake at 20 m is, even though the distance between the two sites is only 500 m (Figure 2.2).

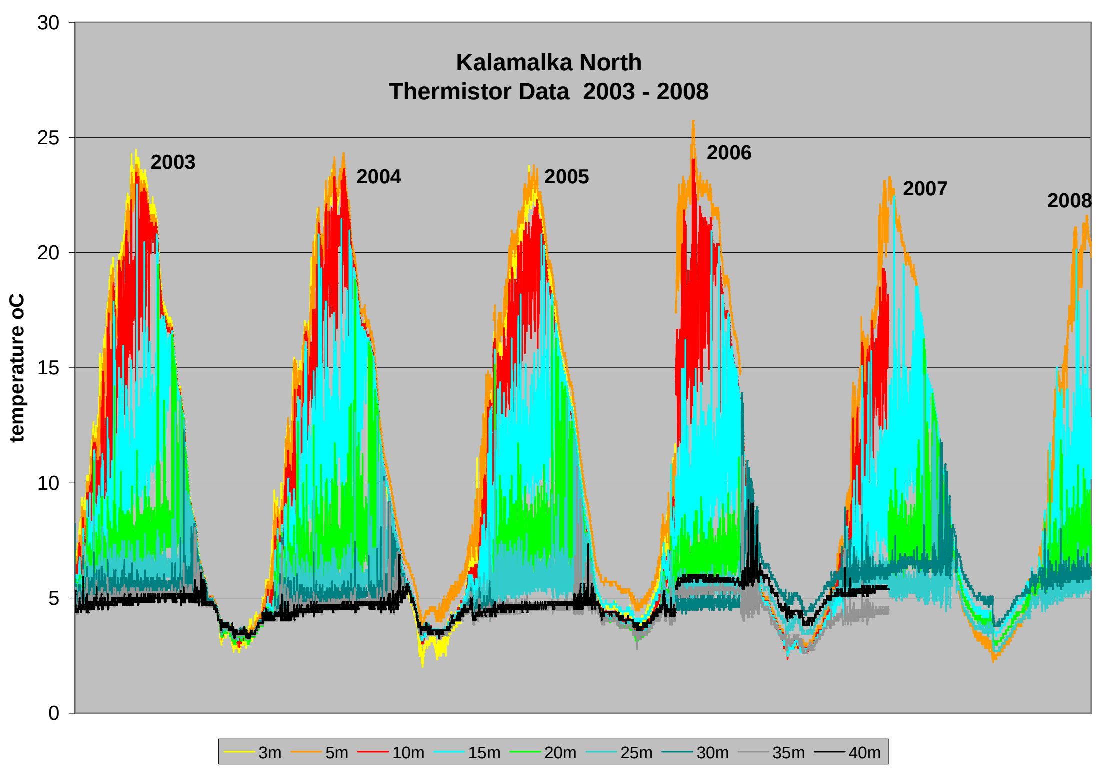
As Kalamalka Lake cools and approaches fall overturn, increased mixing thickens the surface water layer, pushing the thermocline down to the 20 m intake depth by mid-September to early October (Figure 2.4). GVW experienced a turbidity / taste and odor event in the days surrounding September 22, 2007. In this case, the turbidity particles were primarily detritus and bacteria, rather than algae. These taste and odor events may be milder since the UV disinfection plant began operation. After the thermocline mixed below 20 m, the GVW intake withdrew water from the cooling surface layer. Mixing is usually complete by early December (Bryan, 1990) and in every year of this study, mixing beyond the 40 m depth was complete by November 28.

In a warm summer, intake temperatures peak at 18.2 °C and average 8.1 °C while in a cool summer, intake temperatures peak at 11 °C and average 6.5 °C. Minimum winter water temperatures are usually near 3 °C (Clark, pers. comm., 2008).

When all the thermistor data is compiled, the long data run on the N end chain shows annual change caused by a cooling trend since 2003. Peak summer water temperatures ranged from 22 to 26°C measured at 3 m and the winter minimum ranged from 2.5 to 4.0°C. During most fall overturns on Kalamalka Lake, the impact on a 40 m intake would be a minimal 1.5 °C deviation while in others such as 2006, temperature deviated by 3 °C and would be attended by a small turbidity event of 1-2 NTU. Seiches that penetrated to 40 m were less severe and fewer than the ones that penetrated to 20 m (Figure 2.4). Seiches and water currents direct the movement of "water parcels"- discrete inflows that gather in localized areas and travel as a mass while gradually mixing with an increasing volume within the lake. For example, Coldstream Creek plumes often travel as a "river of water" within Kalamalka Lake.

Figure 2.4:
Temperature Logger Monitoring of Water Layer Temperatures for One Year and Multiple Years





Kalamalka Lake's Main Tributary - Coldstream Creek

Coldstream Creek was diverted prior to 1906 to supply water for Coldstream Ranch operations. The stream originally came out of Noble Canyon and flowed east towards Lumby, but now it flows west towards Kalamalka Lake. This change involved creating a new stream channel up to the point where the stream joined the pre-existing channel where Brewer and Craster Creeks flow toward Kalamalka Lake (Coldstream Creek Restoration Project, 2000).

Coldstream Creek has been modified by human activity over approximately 17.6 km or 89% of the surveyed stream length (Ecoscape: Drieschner and Hawes, 2009). Problems with turbidity and nutrient loading were identified in a landmark study by BC Research in 1971. Its tributaries had been similarly impacted. Land use in the Coldstream Valley consists of 1775 ha of forage, 112 ha of orchard and 13 ha of feedlot (MoE Sokal, 2009). Nitrogen and fecal bacteria concentrations are unusually high in Coldstream Creek. The SHIM exercise located 11 storm drains, 1 septic-smelling drainage and 6 direct agricultural field run-off discharges that empty into Coldstream Creek (Drieschner and Hawes, 2009). Stream bank erosion is another significant source of turbidity and nutrients, and was observed on 25% of the Coldstream Creek banks.

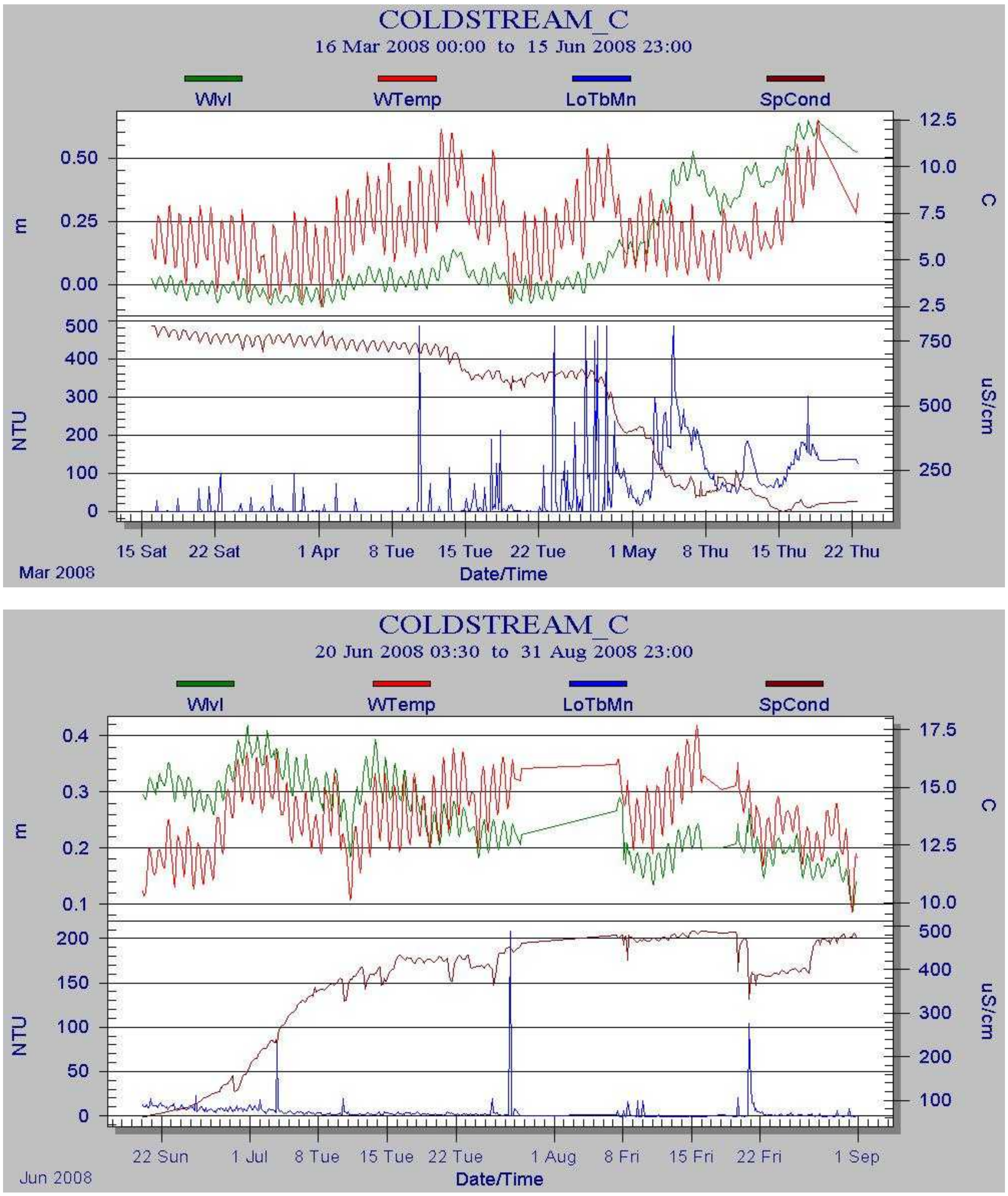
The Coldstream Creek diversion channel is now 110 years old but is still a potential source of turbidity and nutrients. Unrestricted livestock access to entire stream segments has contributed to the high bank and channel instability over the 19.8 km of stream surveyed (Drieschner and Hawes, 2009). Coldstream Creek has also been channelized with earth berms and only a narrow band of native vegetation was retained along agricultural properties. In urban areas, some residents have dumped yard waste into the creek channel (Drieschner and Hawes, 2009). Proper riparian set-backs to avoid creek damage have not been conserved and Ecoscape recommended education, re-fencing at top-of-bank, removal and re-sloping of retaining structures, and re-planting of the riparian areas with native shrubs, such as willow.

A recent MoE study employed fecal bacteria source tracking and found that fecal bacteria from livestock wastes were more abundant during higher creek flows, while dog fecal bacteria was moderately high on all sampling dates and avian fecal bacteria was the largest source (Sokal, 2009). The largest contributor of nitrate was flooding of agricultural fields during snow-melt. Run-off from the fields and ditches was observed entering the creek. Both nitrate and ammonia concentrations in Coldstream Creek periodically exceeded the BCWQG and have shown an increasing trend over the past 30 years (MoE Sokal, 2009). Their report calls for riparian restoration, restricted livestock access to the creek, education of residents, and storm water management.

Coldstream Creek is responsible for an estimated 80% of the annual surface inflow to Kalamalka Lake, with much of it occurring during freshet. In early freshet 2008, Coldstream Creek showed turbidity peaks of 500 NTU during high flows of 0.55 m^3/sec (Figure 2.5). Coldstream watershed has hydrologic impacts from riparian damage, extensive farming and storm water inflows from the urbanized area. Note the inverse correlation between flow/turbidity and conductivity in Figure 2.5.

During summer storms, Coldstream Creek responds within 24 hours with higher flows and turbidity spikes of up to 180 NTU above base flow (Figure 2.5). Storm water from the urban area and the configuration of the Coldstream Valley contribute to this rapid response to storms. A forestry road failure in the Noble Creek Canyon in 1996 exposed marine clays and temporarily increased Coldstream Creek freshet conductivity from 350-400 to 900 uS/cm (MoE database). During 2008, the conductivity ranged from 230 - 420 uS/cm during freshet.

Figure 2.5: Flows and Water Quality in Coldstream Creek (MoE Recorder) Early Spring and Summer 2008



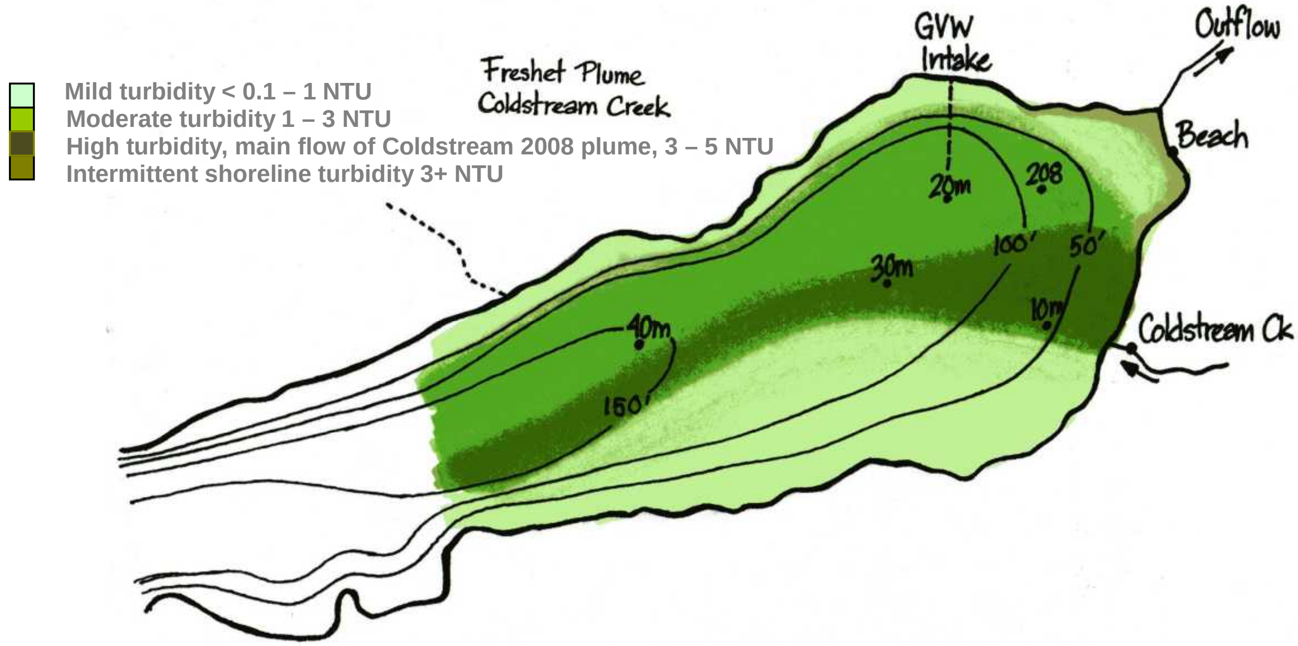
Wlvl=water level Wtemp=water temperature LoTbMn=turbidity SpCond=specific conductivity

Coldstream Creek Plume Behavior The thermal behaviour of the Coldstream Creek plume varies from year to year and particularly within each freshet. A dock constructed at the mouth of Coldstream Creek in 2005 intercepts creek water and a large sand bar is growing. The sand bar deflects a portion of the plume to the north along the public beach and around to GVW 20 m intake. The surface plume is also pushed around by storms, contributing to the periodic turbidity spikes of >10 NTU along Kalamalka Beach during freshet. The main body of the plume heads out into the lake, deflected to the right (counter-clockwise) via Coriolis force and possibly by currents flowing towards the out-flow. Turbidity rapidly declines in the plume through particulate settling and dilution after it enters Kalamalka Lake.

In April, melt water reduces conductivity in Coldstream Creek from the normal 700 – 800 uS/cm to a dilute 100 - 280 uS/cm, far less than the 400 uS/cm in the receiving Kalamalka Lake water. Low conductivity makes the plume buoyant and it travels on top of the lake water column until late freshet. The 2008 freshet plume raised turbidity over 1 - 10 NTU in the upper water column throughout the North Arm (Figure 2.4, 2.5). It was an unusually large freshet and extra monitoring provided key information on large freshet plume behaviour.

Through April and May, the N-Kal 20 m intake is below the main plume and usually has an acceptable turbidity of 0.4 – 0.8 NTU in low freshet years and 0.4 – 3.2 (average 1.5 NTU) during the large 2008 freshet. Turbidity was similar at the 20 and 30 m sites in the modest 2007 freshet but in the large 2008 freshet, higher turbidity was measured in the surface water at the 30 m site than the 20 m site because the inflow plume location (Figure 2.6). During freshet, the surface water at the 30 m site had turbidity reaching 15 NTU while the 30 m depth at that site ranged from 0.8 – 3.0 NTU with an average of 2.0 NTU, more than the 1.5 NTU average at the N-Kal 20 m site. The surface water turbidity spikes at the 30 m site are double those at the 20 m site during a large freshet – a vulnerable time when contaminants (cysts, bacteria adhered to solids (Deregnier et al, 1989; McNamara et al., 1997)) will be dropping out of the plume and settling to the intake zone below. The entire North Arm had cleared by the June 4, 2008 sample date.

Figure 2.6: Location of Coldstream Creek Freshet Plume in North Arm Kalamalka Lake 2008 – large freshet year



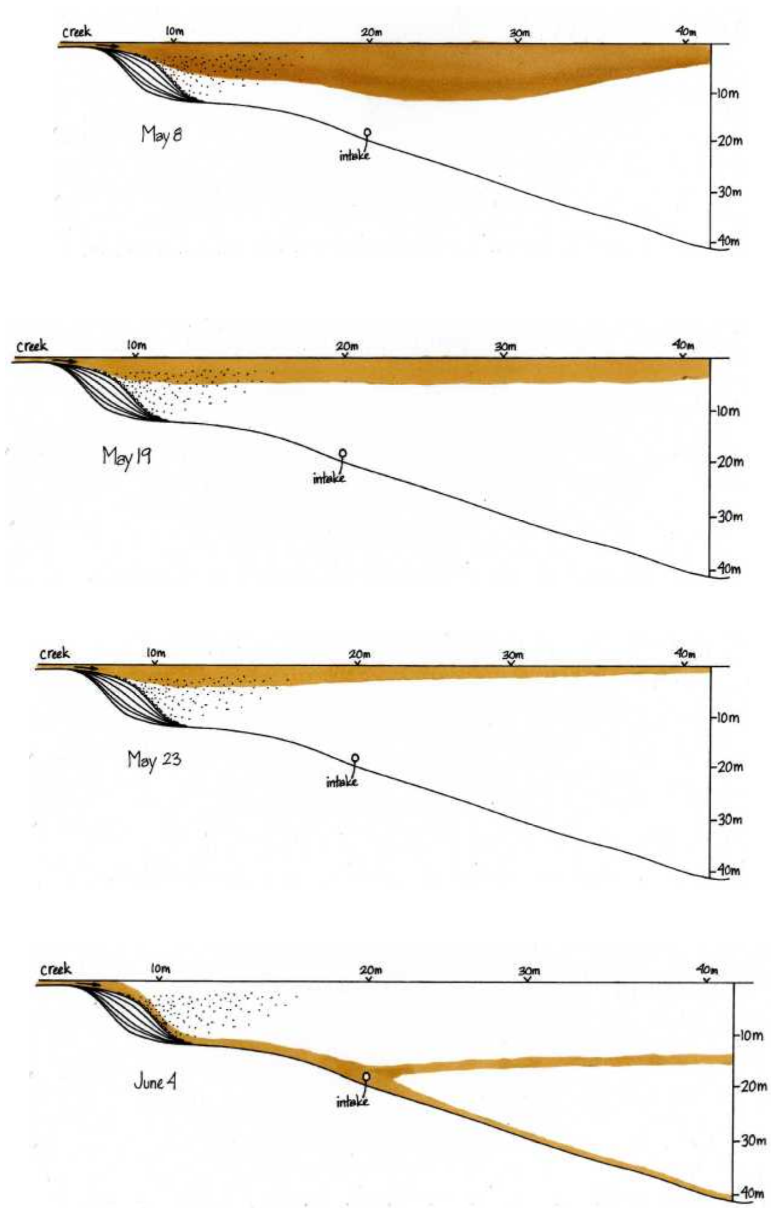
Detailed sampling on the large 2008 freshet indicated that extending the intake to 30 m would *increase* North Kalamalka Intake exposure to materials settling out from the freshet plume, as is illustrated in Figure 2.6 (based on the 2008 freshet YSI multi meter data, meter kindly loaned to this study by MoE Kamloops).

By May 23, 2008, the peak of this heavy freshet had passed. With less snowmelt dilution, conductivity rose to 416 uS/cm in Coldstream Creek by June 5, increasing plume density. Elevated turbidity was noted throughout the water column at the 10 m site. As flows subsided, Coldstream plume mixed into a wider, deeper band of water column and was less concentrated. By June 4, 2008, the diluted plume mixed to the intake depth, bringing with it a small increase in turbidity and increased risk of bacterial contamination. Turbidity was also high along the forming thermocline, indicating a condition known as interflow where a portion of the creek plume travels along the bottom of the lake and another portion is suspended in the water column. During interflow, creek water was colder (9-15^{o}C) and more dense than lake surface water (15-22^{o}C). Creek inputs sank and became trapped near the thermocline (10-16 m) with more turbid flows along the bottom of Kalamalka Lake. The series of illustrations in Figure 2.7 are based on the 2008 freshet but also incorporates information from Coldstream Creek freshet monitoring from 2000 - 2009.

Over the years of study, Coldstream Creek's plume behaved as follows;

- During early to peak freshet, it enters surface water (0-6 m) and flows across the entire arm, concentrating on the path shown in Figure 2.6. It can be visible from the shore and from the air.
- Deposition of sand and coarse particles occurs near the mouth of Coldstream Creek (Figure 2.7).
- Fines imported by the plume are distributed throughout the arm but deposition is greater where the plume is most concentrated.
- In recent years, the inflow plume splits on a sand bar (encouraged by a large dock at the mouth built in 2005) with the majority of the flow travelling out into the arm, deflected to the right by Coriolis swinging towards the public beach and eventually around to the 20 and 30 m sites (Figure 2.6).
- After the plume "cleans up" in late freshet, its conductivity increases and it mixes to depths >16 m and may include the intake depth.
- It frequently splits with part of the flow travelling along the thermocline (creek and thermocline temperatures are often <1 ^{o}C different).
- The plume enters the hypolimnion in the fall prior to overturn.

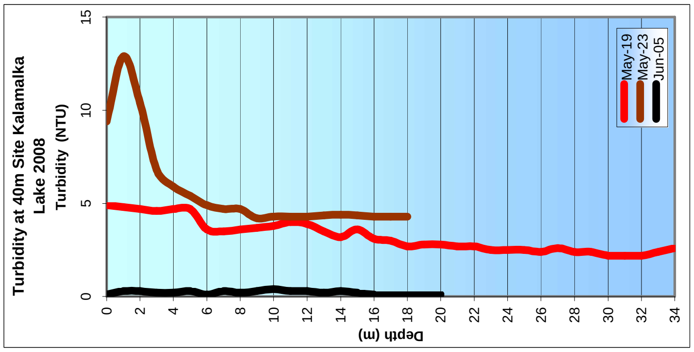
Figure 2.7: Coldstream Creek Freshet Plume 2008 in North Arm Kalamalka Lake, Cross Sections

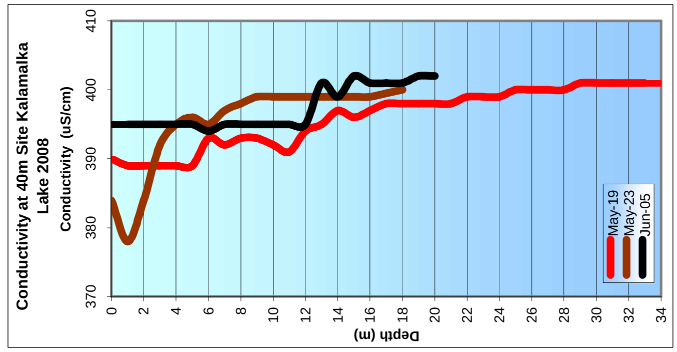


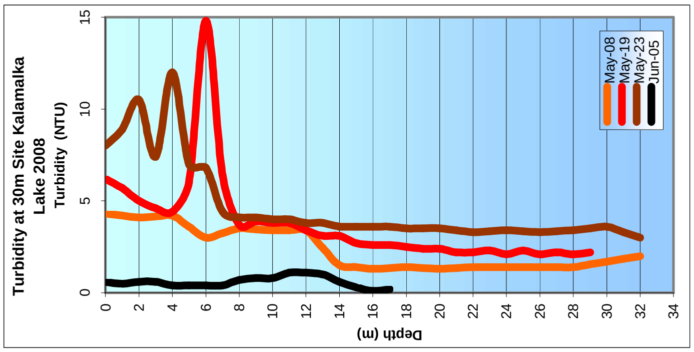
The series of illustrations in Figure 2.7 are based on the 2008 freshet. The most turbid flows are shown; the entire N arm can exceed 1 NTU throughout the freshet period. Turbidity was also high along the forming thermocline, indicating a condition known as interflow where most of the creek plume travels along the bottom of the lake but some is suspended in the water column. During interflow, Coldstream Creek water is colder (9-15°C) and more dense than lake surface water (15-22°C). Creek inputs sink and become trapped near the thermocline (10-16 m) with more turbid flows along the bottom of Kalamalka Lake.

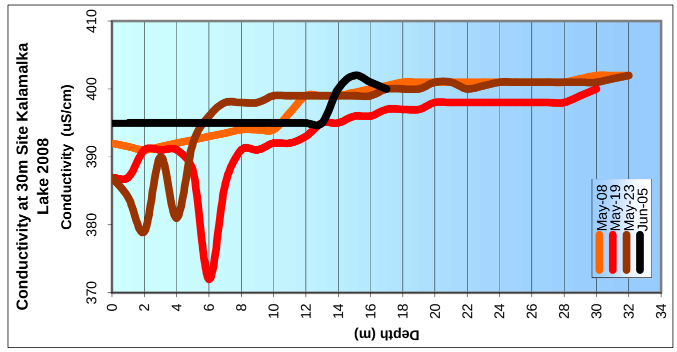
The water quality profiles in the North Arm of Kalamalka Lake cause variable water quality with depth as depicted in Figure 2.8.

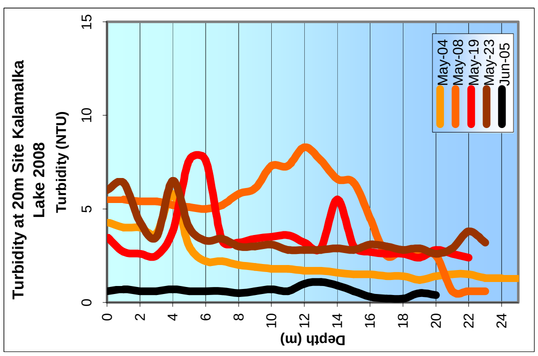
Figure 2.8: Turbidity and Conductivity in Large Coldstream Ck Freshet Plume 2008

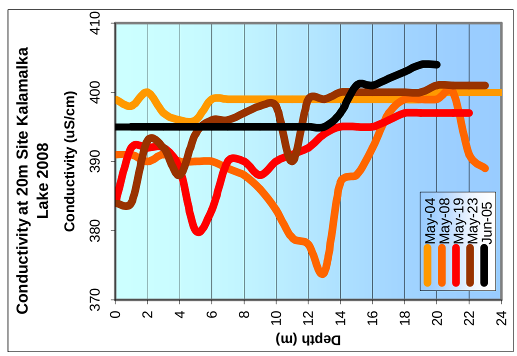


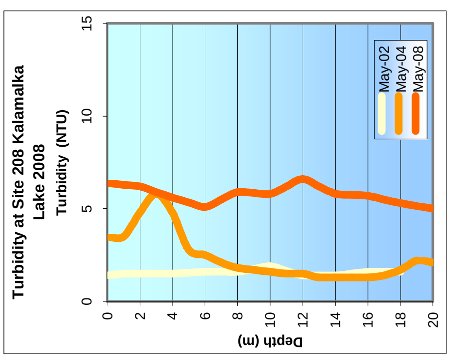


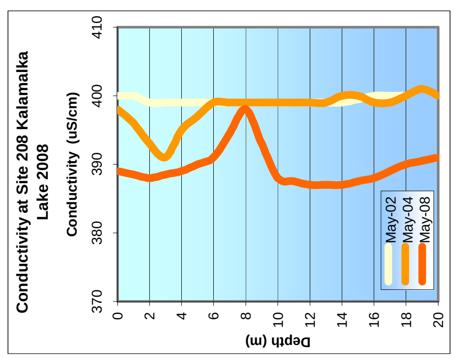


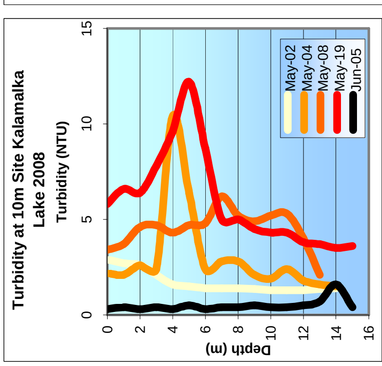


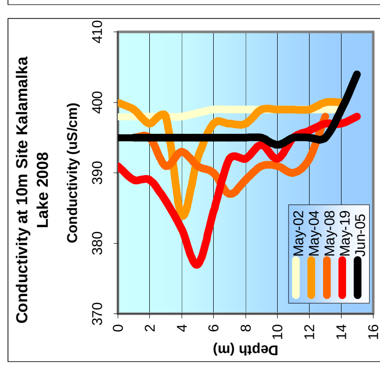








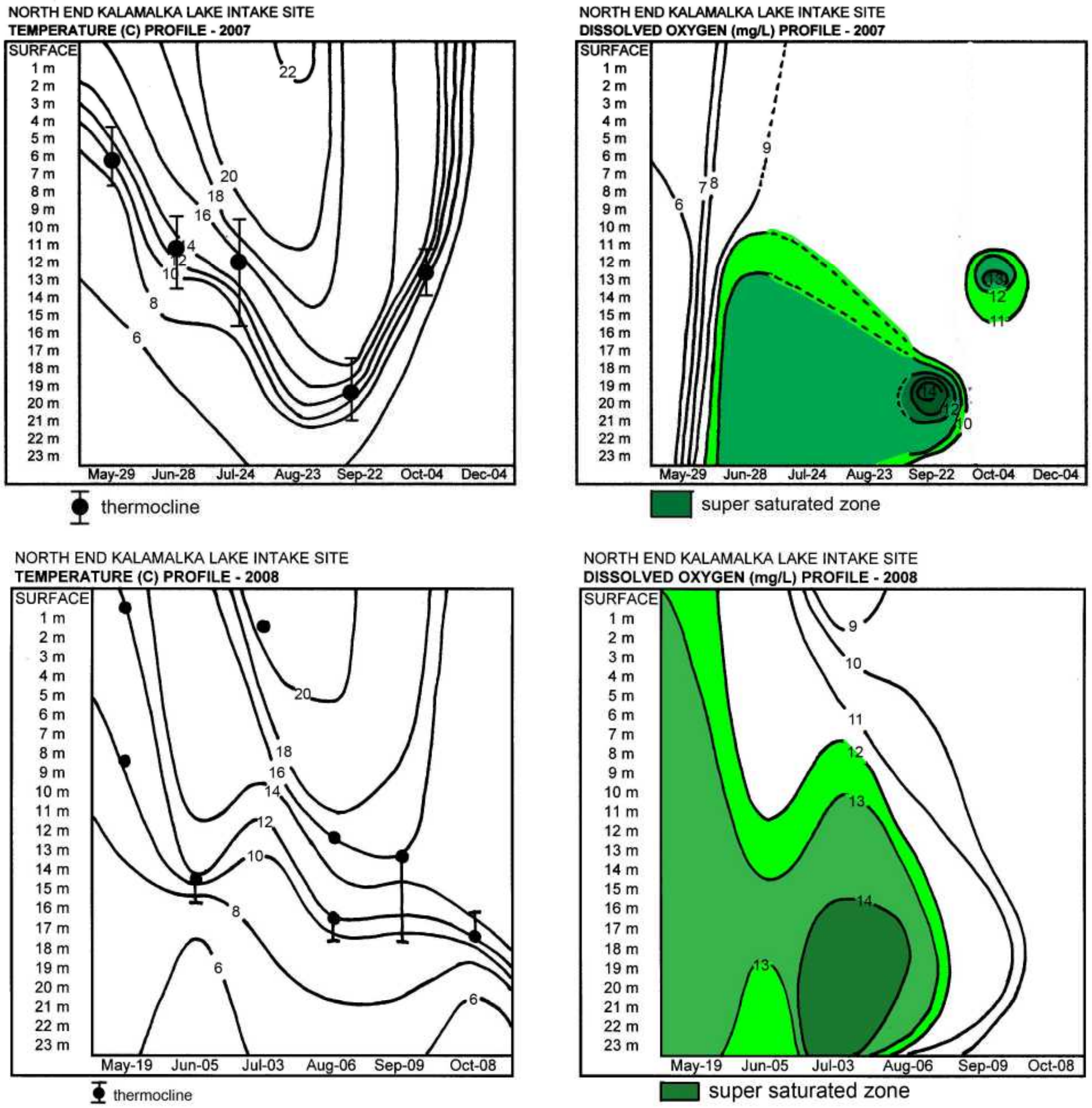




Turbidity and Conductivity in the 2008 Coldstream Creek Freshet Plume

Temperature and Dissolved Oxygen Profiles Through every summer 1999 - 2010, dissolved oxygen concentrations were excellent (i.e. never oxygen-depleted) throughout the Kalamalka Lake water column (Figure 2.9). The large 2008 freshet delayed stratification. It also imported nutrients and caused a large microflora crop in 2008, which increases the size of the super-saturated zone. The more typical 2007 diagram is provided for comparison with the heavy 2008 freshet year (Figure 2.9).

Figure 2.9:
Temperature and Dissolved Oxygen Profiles North Arm Kalamalka Lake



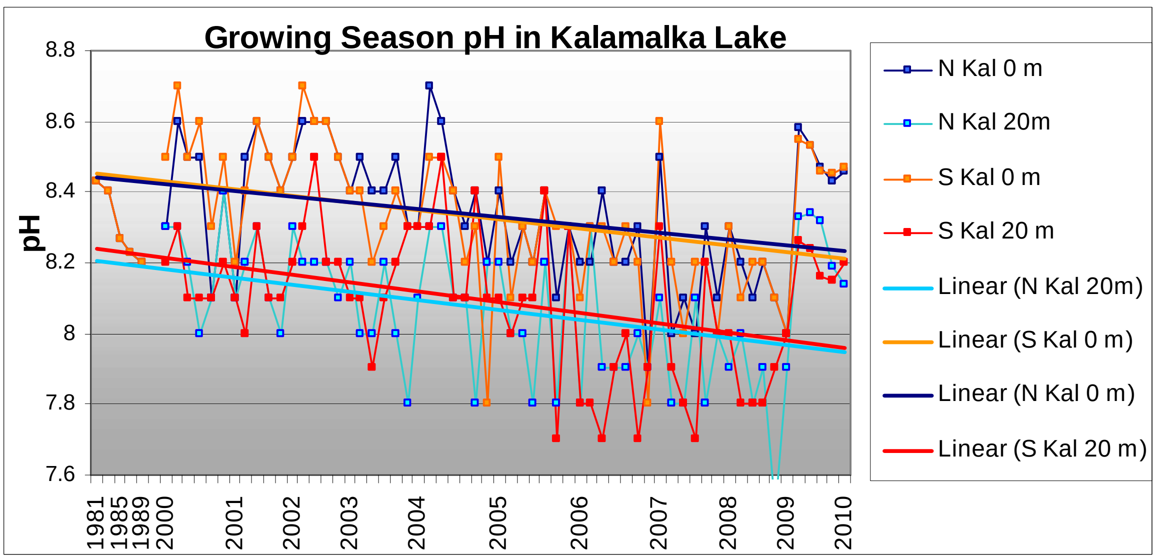
The super-saturation period correlates to increased turbidity at the Kalamalka Lake intakes. North Arm secchi depths average 3 - 4 m in the spring to 6 - 8 m in the late summer/fall, for a photic zone of 8 - 16 m. Years with larger freshets have shorter secchi depths, more turbidity and greater super-saturation zones as photosynthetic bacteria and cyanobacteria take advantage of the greater nutrient concentrations.

2.4 General Water Quality & Nutrients

Every year, the single greatest impact on water quality in Kalamalka Lake was the size of the freshet, with its variable imports of nitrogen, phosphorus, pH, calcium, sulphate and organic/inorganic particulates (MoE data, Larratt 2009). Low inflow years imported far less phosphorus to Kalamalka Lake since P adheres to soil particles. Large freshets result in unusually large microflora densities for several years. In general**,** nutrient concentrations at the North and South ends of Kalamalka Lake moved in concert, indicating whole-lake influences such as freshet (P) or ground water (N) nutrient inflow.

pH pH appears be in slow decline. The trend toward lower pH may signal a reduction in the intensity of the marl precipitation events. Overall, the linear regression trend lines still show decreasing pH but there is considerable pH oscillation (Figure 2.10).

FIGURE 2.10: Growing Season pH in Kalamalka Lake 1981 - 2010



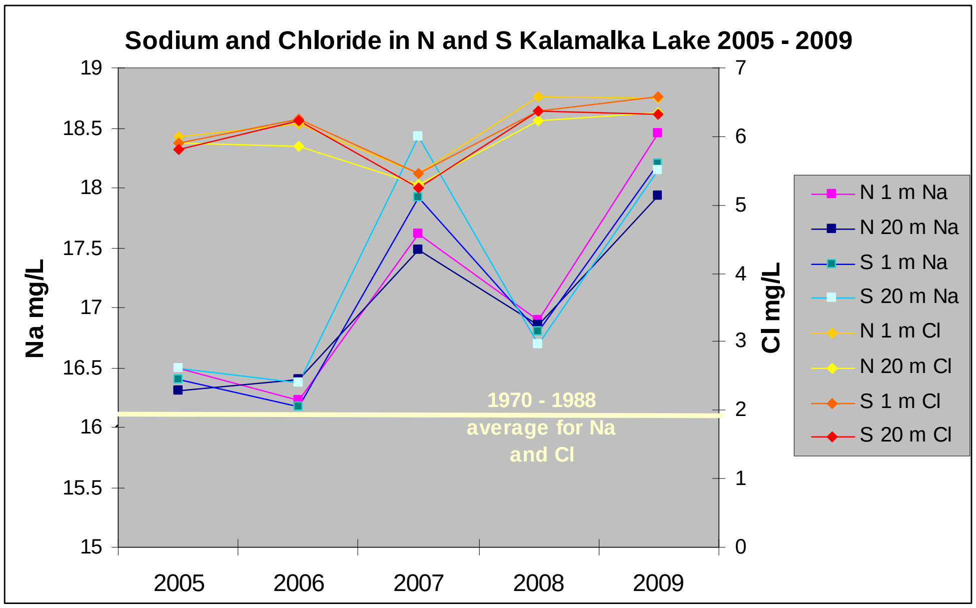
NOTE: This graph emphasizes data from 2000 to present

If the lower pH trend detected in this data is genuine, it could have repercussions on the summer marl precipitation events and ultimately increase the nutrient balance of Kalamalka Lake. However, the 2010 summer marl event was one of the strongest in 15 years.

Sodium and Chloride The presence of dissolved sodium and chloride give an indication of animal, human, and storm water impact on a lake system. In the case of Kalamalka Lake, donation of these metals from marine shales in the Noble Canyon section of the Coldstream Valley is an additional natural source. Sodium averaged 16.1 mg/L in the MoE 1970-1988 data set and has slowly increased since then to a range of 16.3 to 18.5 during 2005 - 2009. Unlike sodium, chloride concentrations increased three-fold since 1970 – 1988 when it averaged 1.88 – 2.01 mg/L (Figure 2.11). The 2005-2009 average ranged from 5.2 – 6.5 mg/L. Road salt is typically the largest human source of chloride (Wetzel, 2001).

Storage of road salt beside the Greater Vernon Recycling and Disposal Facility by Argo Road Maintenance for MoTH from 1997 to 2007 salinized the ground water between the storage location and Hwy 97 and beyond, down-gradient. Chloride has also been detected at the old highway (Kal Lakeview Road) below Hwy 97 through two water quality monitoring wells that RDNO samples periodically. Extensive ground water sampling would be required to determine the proportion of the salinization coming from these two sources. Consultants have predicted that the road salt from the old unlined storage location could take until 2020 before chloride concentrations drop to background concentrations in the local ground water regime (N. Kohnert, pers. comm., 2010). MoE data indicates that Coldstream Creek water is also a source of chloride. It is routinely at or above 10 mg/L Cl, because of storm water and agricultural runoff into Coldstream Creek (Sokal, 2010).

Figure 2.11: Annual Average Sodium and Chloride in Kalamalka Lake



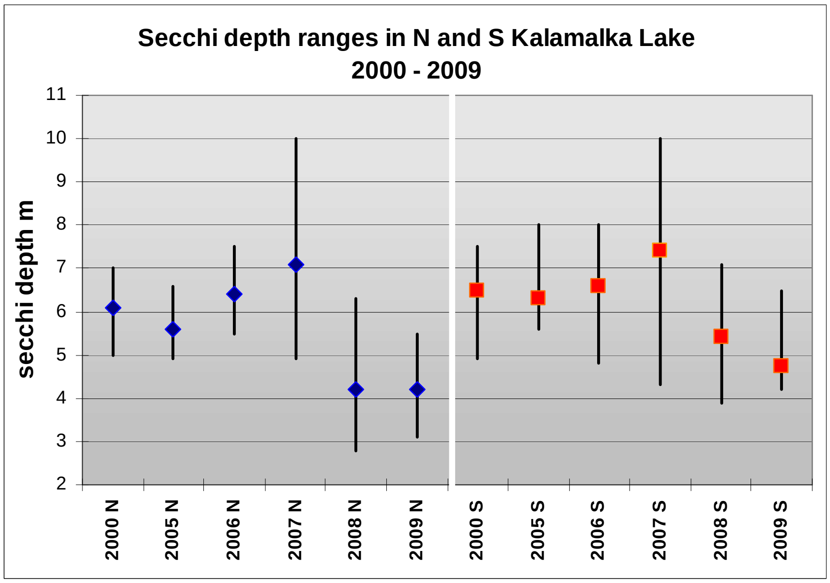
Dissolved sodium and chloride ion concentrations are increasing in Kalamalka Lake, pointing to negative human impact on water quality as opposed to climatic factors (Ashley et al., 1998).

Metals and Pesticide Scans An annual A-to-Z metals scan is completed by GVW on the North Intake water from Kalamalka Lake, and no metals exceed the CDWG maximum acceptable concentration or the aesthetic objective. Similarly, a full volatile organic compound and pesticide scan completed on November 06/2008 showed all paramters were below the detection limits (Clark, 2009).

Marl Precipitation The spectacular colors in Kalamalka Lake are the result of light diffraction by micro-crystals of marl. Every summer, a spike in bottom water turbidity, alkalinity, conductivity and calcium concentrations and increased surface water clarity heralds the marl (calcium carbonate + gypsum) precipitation. Marl precipitation depends on interrelated lake conditions including water temperature, calcium concentrations, algae growth and pH. The marl event literally occurs over night, with the dates ranging from July 20 (1998) to August 6 (2008). It is a mixed blessing; raising turbidity as high as 2 NTU but lowering algae production.

Historic secchi depths measured 6–7 m in 1935 and 3.8–10.7 m (avg 6.5 m) from 1975–1988 (Bryan, 1990). From 2000-2010, growing season secchi depths ranged from 2.8 m during spring freshet algae production to 10.1 m after the marl precipitation – a similar range to Bryan's work. Large freshet years such as 2008 had lower overall secchi depths, particularly at the North end (Figure 2.12).

Figure 2.12: Secchi Depth Range and Average in North and South Kalamalka Lake at the Intake Locations 2000 - 2009

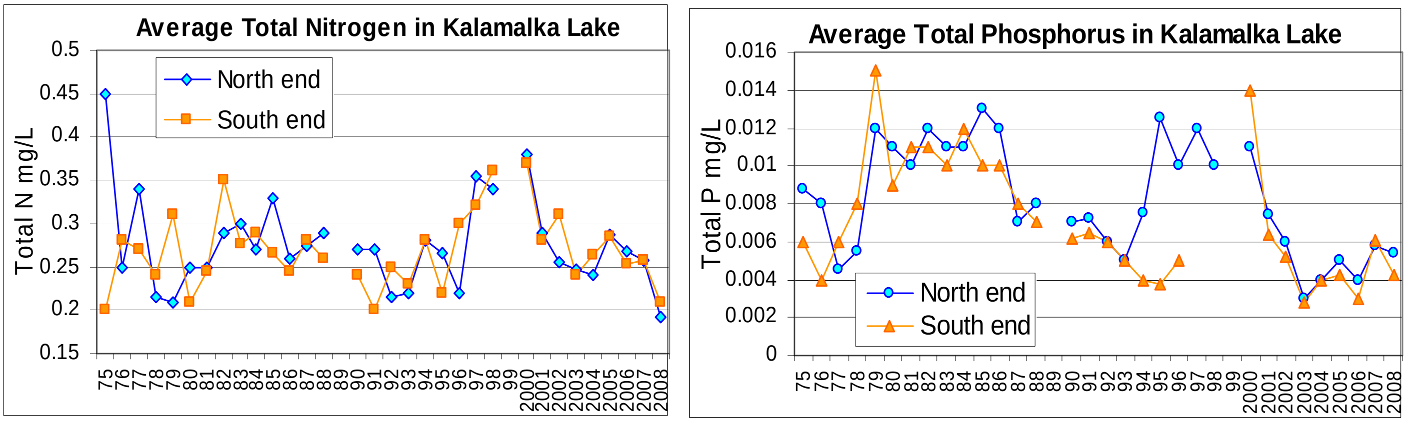


Nutrients Nutrients are important to water quality because they direct microflora production. Their concentrations at the North and South ends of Kalamalka Lake move in concert, indicating whole-lake influences such as freshet nutrient inflow via Coldstream Creek (80%) and inflows from Wood Lake (20%). Wood Lake is a periodic source of organic nitrogen and phosphorus to Kalamalka Lake. Within Kalamalka Lake, the arms are more productive than the main body of the lake.

The main body of Kalamalka Lake is currently oligotrophic. Available phosphorus concentrations control the growth of microflora in the lake, according to the formula that P is limiting when the nitrogen to phosphorus ratio falls below 14:1 (Nordin, 1985). Although Kalamalka Lake is phosphorus-limited, co-limitation with nitrogen was also possible as the greatest algae growth was obtained in test cultures by adding both nitrogen and phosphorus (OKBS,1974).

Spring nutrient concentrations in Kalamalka Lake provide a good forecast of the nutrients available to support plant growth during the growing season. High run-off years import more total phosphorus to Kalamalka Lake, often as a result of particulate phosphorus inputs. For example, the early 1980's were wet years and phosphorus concentrations were higher (Ashley et al., 1999). High freshet years also act to increase N concentrations because N is poorly retained by Okanagan soils and nitrate migrates with ground water (Dill, 1972). High runoff years with more ground water input are more likely to boost Kalamalka Lake's nitrogen content than low runoff years. The large freshets of 1999 and 2000 resulted in nutrient peaks that were not repeated in the following years (Figure 2.13).

FIGURE 2.13: Average Growing Season Monthly Total N and P in Kalamalka Lake 1975 - 2008



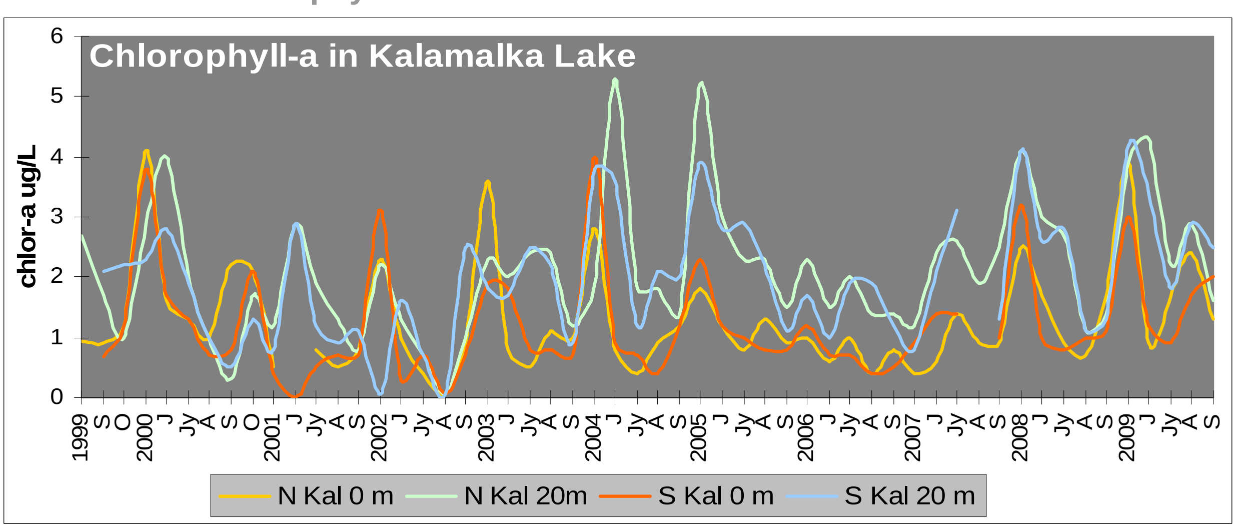
NOTE: MoE objective = 0.008 mg/L TP for Kalamalka Lake (Nordin et al, 1988)

Since marl co-precipitates phosphorous, the timing of the marl precipitation in Kalamalka Lake affects algae growth. Ironically, algae growth also influences the marl precipitation by raising pH. The other trigger for marl precipitation is water temperature. Warm, dry years such as 2002-2004 favour earlier and larger marl precipitation (Walker et al., 1993). Marl precipitation not only limits phosphorus availability, it also shades the water column and removes B12 vitamins (Larratt et al., 2008). These all act to limit algae production in Kalamalka Lake relative to Okanagan Lake, despite their similar summer nutrient concentrations.

With full lake mixing, nitrate concentrations are restored in December to the winter maxima and trigger increased blue-green algae growth each year. Over the past century, water quality was relatively stable in Kalamalka Lake (Bryan, 1980). Its unique marl precipitation protects Kalamalka Lake from phosphorus loading arising from human activities.

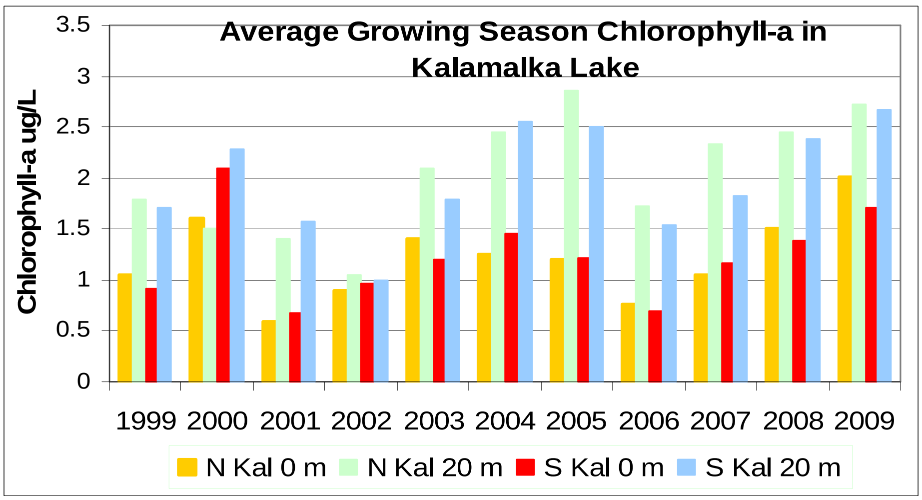
Chlorophyll-a Analysis Chlorophyll-a analyses provide a means to estimate microscopic plants and bacteria that contribute to the primary production of Kalamalka Lake. Chlorophyll-a concentrations increased over 1971–1998 (MoE database), paralleling an increase in phosphorus concentrations. Figure 2.14 shows spring peaks in microflora production as measured by chlorophyll-a. Algae production stalls after the annual marl precipitation removes phosphorus from solution.

FIGURE 2.14: Chlorophyll-a in Kalamalka Lake 1999 - 2009



Figures 2.14 and 2.15 were highlighted to show the similarities between productivity of the N and S ends of Kalamalka Lake. There is far more similarity by depth than by location. On most dates, the productivity of the 20 m bottom water was far higher than the surface water. Samples collected from 30 and 40 m contained less chlorophyll-a than samples from 20 m (Larratt, 2008). To realize the benefit of lower algae production at the 30 or 40 m sites, a new intake should be positioned at least 3 m above the substrate. Historically, chlorophyll-a measured 1.80 ug/L at S Kalamalka, 1.26 ug/L in Kalamalka main basin and 4.42 ug/L in Wood Lake (Bryan, 1990). Kalamalka Lake samples are slightly elevated today above the historic norm.

Figure 2.15 Average Growing Season Chlorophyll-a 1999-2009

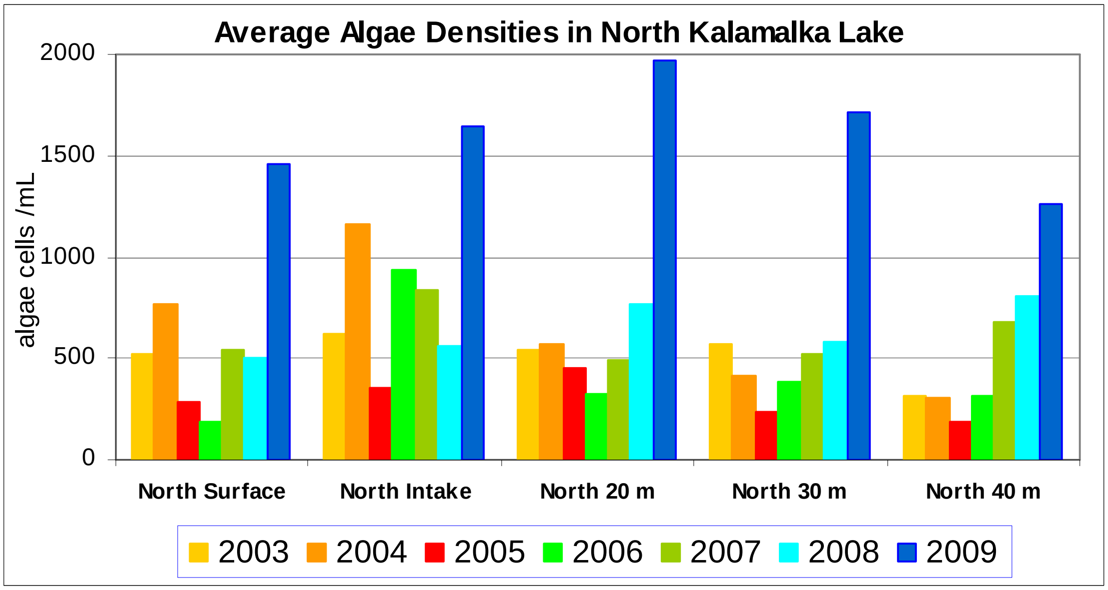


2.5 Water Chemistry Relevant to Drinking Water Safety

Algae Analyses Kalamalka Lake experiences a spring diatom/blue green algae bloom, a summer lull and a smaller fall bloom led by blue-green algae (cyanobacteria). Within this general pattern, there is considerable year-to-year variation. Research since 2000 shows the prevalence of blue-green algae appears to be increasing, particularly in results from 2009 (Figure 2.16). MoE data also shows a gradual increase in the blue-green component since the 1970's. Every year, a total of 13 -15 blue-green cyanobacterial species are counted in Kalamalka Lake and every year they are dominated by *Lyngbya limnetica* and *Anacystis cyanea.* There is considerable variation in the dominance of the other species from year to year. These problematic algae produce taste and odor and possible chronic low dose cyanotoxin exposure.

Large freshets play a crucial role in water quality and algae production, particularly in the North Arm. Algae counts in the N-Kal intake are frequently higher than counts collected near the surface or from 20 m in the lake near the intake (Figure 2.16). The clearance of the GVW intake from the sediments is implicated since the Lake Country S-Kal 20 m intake has smaller algae counts and is spaced 2 m from the bottom versus GVW's intake that is only 0.6 m from the substrate.

FIGURE 2.16: Algae Distribution with Depth, North Kalamalka Lake

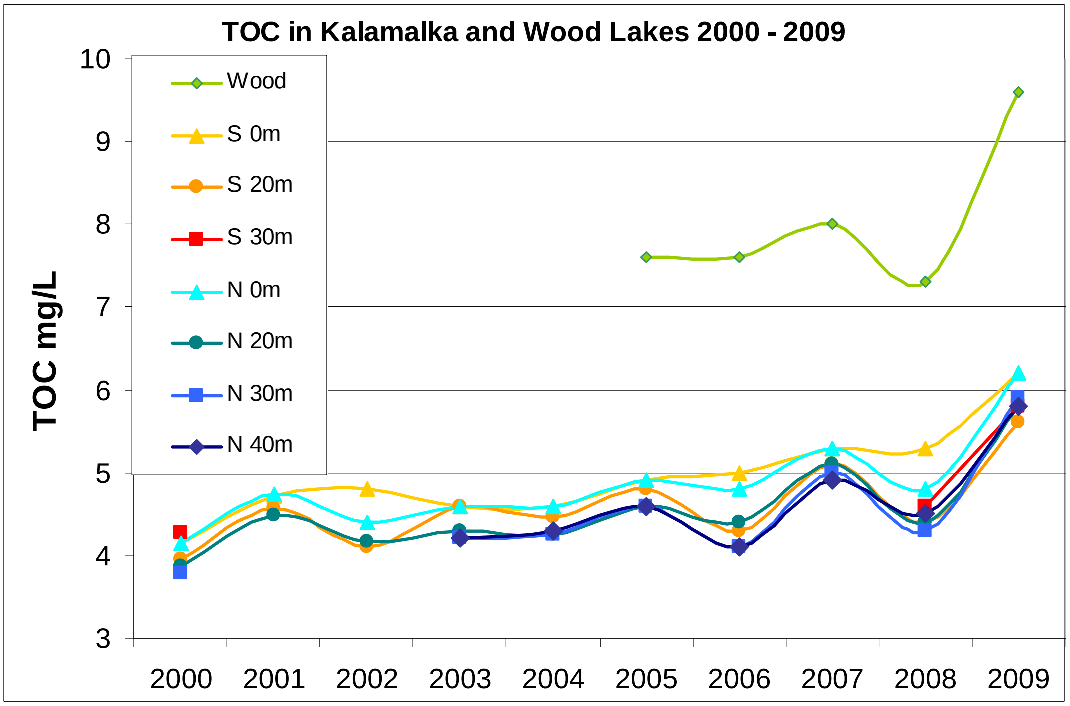


NOTE: Figure 2.16 shows high algae numbers at the 20 m intake due to seiches and the smallest concentrations at 40 m

In some years, there is far less algae at North 40 m than at N 30 or N 20 m, but in the 2007 and 2008 samples, there was no advantage to a deeper site over the current intake in terms of reducing the amount of algae entering GVW's distribution system. The annual Kal Lk study has also demonstrated that there is rarely a significant difference between the algae counts at North 30 m versus N 20 m (Figure 2.16). There is however, an average of 18% less chlor-a at 30 versus 20 m. It is important to note that summer samples from 30 and 40 m still contained 200 – 1000 cells/mL of blue-green algae (cyanobacteria) and these algae have small amounts of chlorophyll-a.

Total Organic Carbon (TOC) Total organic carbon measures microflora and dissolved organic molecules and for that reason, TOC concentrations move together with algae growth. Historic TOC's are comparable to recent TOC measurements, however TOC appears to be trending upward since 2007 (Figure 2.17). In the 1980's, TOC averaged 6.2 mg/L in the South end of Kalamalka Lake, and 2.6 mg/L in the main body of the lake (Bryan, 1990). Organic carbon concentrations exceeded the BC water quality criteria of 4.0 mg/L through most of the growing season every year. In all cases, TOC decreased with depth, however, the water quality advantage of a 40 m intake over the existing 20 m intake would be minor, at an estimated 0.1 – 0.2 mg/L TOC difference.

Figure 2.17: Average Total Organic Carbon in Kalamalka and Wood Lakes



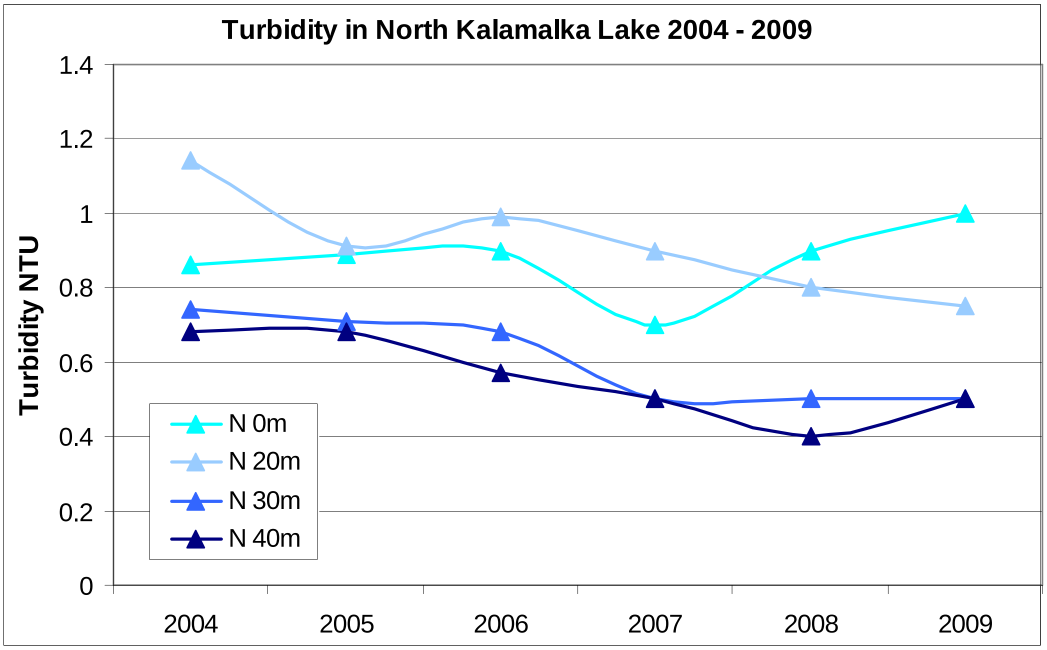
Taste and Odor An offensive sloughy/earthy/mossy/weedy taste and odour problem triggered complaints commencing in late June 1999. Algae are the most common cause of off-tastes and odours in surface waters (Mallevaille and Suffet, 1987). Living algae excrete organic substances and some of these cause tastes and odours. Decomposition of these compounds and the algae cells themselves constitutes yet another potential source of taste and odour-causing compounds in water supplies.

High algae counts and complaints of fishy or musty taste and odor in Kalamalka Lake water are correlated. Blue-green cyanobacteria and other algae produce a musty, decaying taste and odour when they are decomposed by *Actinomycetes*. During the lake-wide 1999 taste and odor event, cyanobacteria counts exceeded 1700 cells/mL at the intakes. The periodic taste and odour problems occurring in Kalamalka Lake are usually caused by unusually high cyanobacteria concentrations, possibly made worse by *Actinomycetes* decomposers and seiche-suspended detritus.

Less frequently, a seiche-induced turbidity/odor event can occur, as on the week of September 22, 2007. In this case, the turbidity particles were primarily detritus and bacteria, rather than algae. An intake right on the bottom of Kalamalka Lake would be much more vulnerable to taste and odor events than one placed 3 m from the substrate.

Turbidity For an oligotrophic lake, turbidity is naturally high in Kalamalka Lake, ranging from 0.4 – 1.2 NTU during July to October. This natural turbidity is due in part to the annual summer marl precipitation (Figure 2.18). Other natural sources of turbidity include freshet plumes, seiches, lake overturn and algae blooms. Annual turbidity averaged 0.73 NTU in Kalamalka from 1973 – 1989. Kalamalka Lake turbidity appears to have risen slightly from that average since then.

Figure 2.18:
Average Annual Turbidity in North Arm Kalamalka Lake, 2004 - 2009



The average annual turbidity shown in Figure 2.18 indicates that 20 m has the highest turbidity except in high productivity years such as 2008 and 2009. Turbidity at 30 and 40 m was similar and was consistently lower than shallow water turbidity. During a heavy freshet, the 30 m depth showed turbidity >3 NTU and exceeded the 20 m site during peak freshet (Figure 2.8).

IHA currently requires a water quality advisory when turbidity exceeds 3.5 NTU for the North intake because it has UV disinfection and chlorination. The shallow East intake is not in use and may be converted to an exclusively agricultural water source. While freshet caused brief turbidity spikes, summer turbidity exceeding 1.0 NTU was measured at both intakes in the July to September period during most summers with the marl precipitation (Figure 2.18).

The 20 m summer samples with turbidity exceeding 1 NTU contained precipitated marl and also contained higher concentrations of blue-green alga *Lyngbya limnetica* and detritus. Conversely, the 40 m depth usually had lower cyanobacteria counts than the 20 or 30 m depths (Larratt, 2009b). Turbidity generally decreased with depth. A 30 or 40 m intake would have lower turbidity than the existing intake.

The difference in turbidity between a small and large freshet can be appreciated in Table 2.1, where a high freshet can have 4 times the peak turbidity of a low freshet. Figure 2.19 shows the difference between no plume impact at 20 m on suspended particles on Apr 29th, and the same site with plume impact on May 12th, 2006.

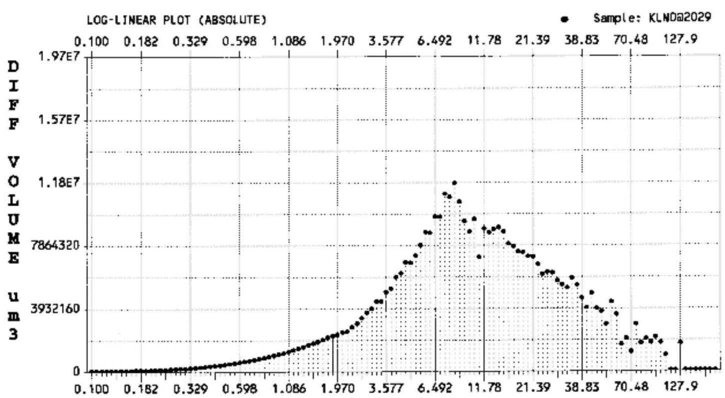
Table 2.1:
Intensive Freshet Turbidity Sampling for North Kalamalka Lake, 2005-2008

Turbidity NTU	Coldstream Creek	Plume 0 m	10 m N	Lake outflow	20 m N	30 m N
2005-***avg freshet***						
April 27	27	8.7	0.7		0.8	
April 29	54.5	14.8	0.3		0.1	
May 12	18	4.4	1.4		0.1	
2006-***avg freshet***						
April 21	37.9	31.8	2.6		2.5	2.0
April 26	29	17.3	1.4		0.75	0.40
May 10	9.6	8.3	1.2		0.80	0.75
2007-***low freshet***						
April 11	36.3	22.4	0.6	2.8	2.2	
April 30	11.1	1.0	0.6	n/s	0.3	
May 8	30	9.2	0.5	1.2	0.6	
2008-***high freshet***						
May 2	34.8	21.8	2.9	1.9		
May 4	**120.9**	**112.8**	10.4	5.8	1.4	2.2
May 8	63.7	46.4	5.2	5.3	2.5	1.7
May 23	**106.8**	**70**	5.8	6.6	2.6	3.6

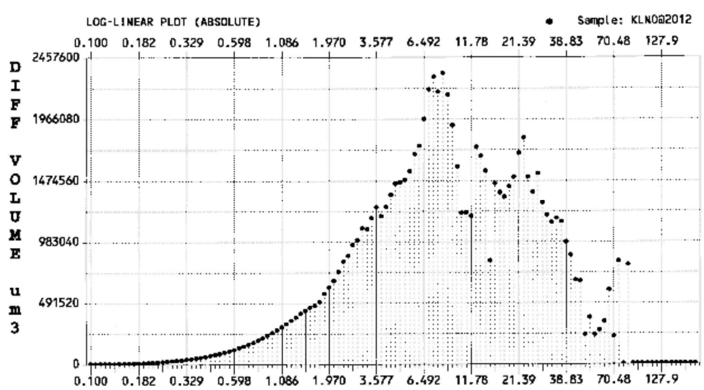
Note: YSI multimeter profile data

Figure 2.19: Particle Size Distribution at North 20m Site April and May 2006

N 20m April 29th (no plume impact)



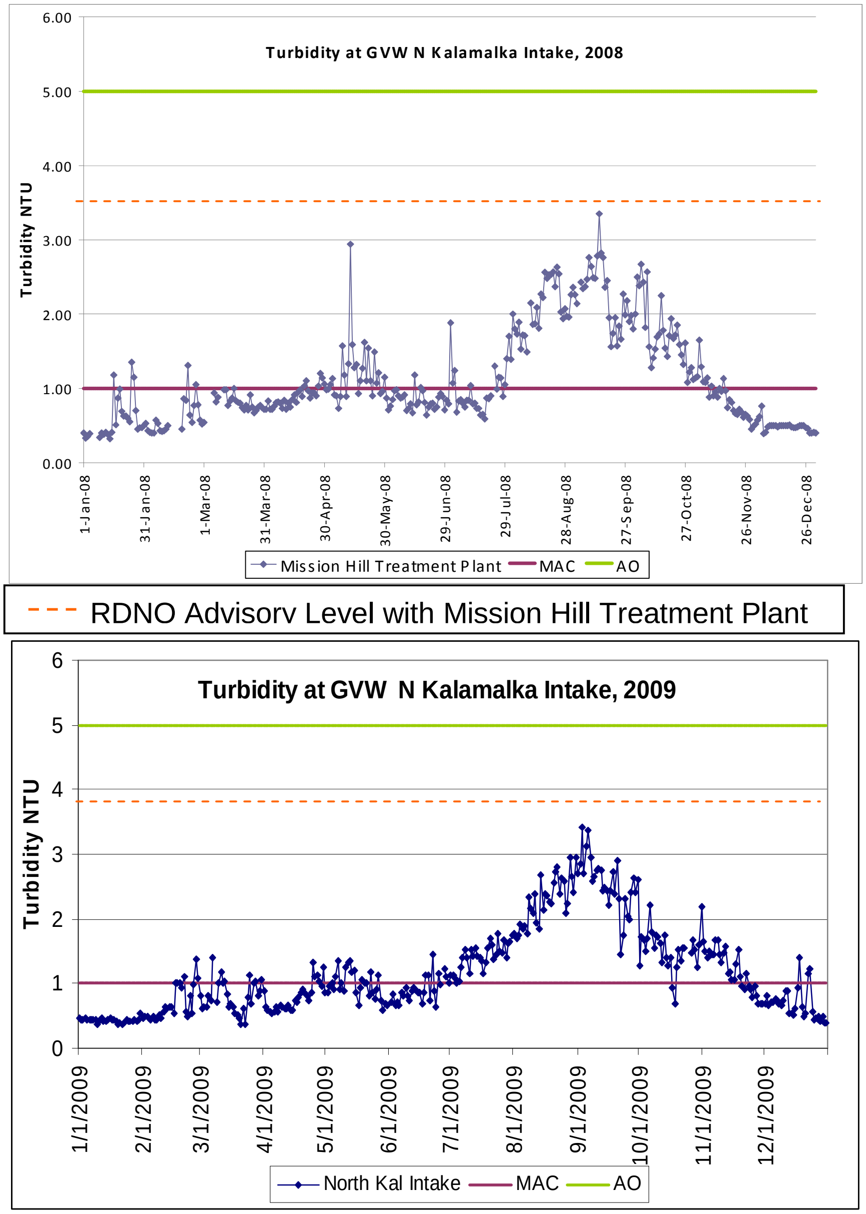
N 20m May 12th (plume impact)



2008's freshet was late and large. Turbidity in the Coldstream Ck mouth measured 35 - 121 NTU and the plume measured 30 – 113 NTU out in front of the creek mouth. (Please refer to pg 16-19 for a discussion of creek plume behaviour). Turbidity at the intake site and depth ranged from 1.4 – 2.6 NTU while the N 30 m site and depth averaged about 20% higher at 1.7 – 3.6 NTU (Table 2.1). The freshet plume sampling agrees with the monthly summer sampling; Coldstream Creek periodically has a greater impact on the N-30 m site than the existing N-20 m intake site. *Extending the intake to 30 m would actually increase GVW's exposure to freshet turbidity during a large freshet.* In general the 40 m samples had the lowest turbidity and averaged half of the surface or 20 m turbidity in monthly summer samples (Figure 2.18).

While freshet caused brief turbidity spikes, summer turbidity exceeding 1.0 NTU was measured throughout Kalamalka Lake in the June to August during most summers (Table 2.1). Turbidity exceeding 2 NTU occurs in August at the North intake every summer (Figure 2.20). The 20 m summer samples with high turbidity contained precipitated marl and also contained higher concentrations of blue-green alga *Lyngbya limnetica* and detritus.

Figure 2.20:
Turbidity at the GVW North Kalamalka Intake, 2008 and 2009



NOTE: MAC = Maximum allowable concentration; AO = Aesthetic Objective

Heavier particles like sand and silt settle out rapidly but finer ones remain suspended in the Coldstream plume after it enters Kalamalka Lake (Larratt, 2009). The lighter particles that remain suspended longer include algae, bacteria and microbes such as *Cryptosporidium parvum* and *Giardia lamblia* cysts. Their slow settling rate approximate Stoke's Law and were experimentally determined to be 0.27 µm s^{-1} and 0.67 µm s^{-1} for *C. parvum* and *G. lamblia*, respectively (Dia and Boll, 2006). Both cyst types have been detected in the North Arm and the probable source is Coldstream Creek inflows. Similarly, *E. coli* have also been detected at the N-Kal intake (Clark & Brett, 2005).

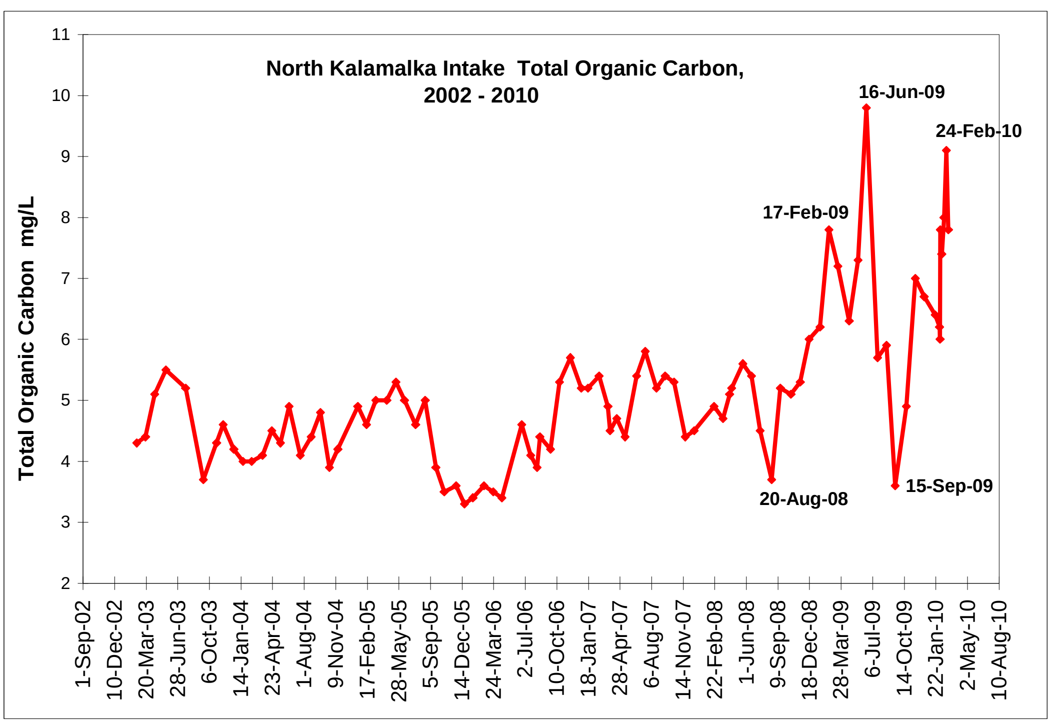
Based on storm data captured thus far in the annual Kalamalka Lk study, the response time between a summer rain event and turbid Coldstream Creek flow is less than 24 hours. This rapid reaction time is accelerated by storm water from the subdivisions adjacent to Coldstream Creek. Storm-induced seiches set up within hours of a storm and both the turbid inflow and the seiche combine to elevate turbidity for about one week at the North and East intakes, both located in the N Arm. Nutrients injected by storm flows had a more subtle, long-lasting effect on Kalamalka Lake than the turbidity effect.

A final cause of high turbidity (>5 NTU) was rototilling for milfoil control in the vicinity of the North intake during 2007. Rototilling on the north beach area is "upstream" of the GVW intake due to the general flow of water in Kalamalka Lake. Water samples collected from the GVW intake on December 4 during rototilling had the highest organic detritus and fine silt counts ever encountered in Kalamalka Lake water samples. These sediment components accumulate in aquatic plant beds. Since December is usually a low turbidity time of year, rototilling should be deferred to the freshet months to avoid additional turbidity notifications.

Transmissivity The UV transmissivity of Kalamalka Lake water is important to the new Mission Hill Water Treatment Plant. It uses 44 J/cm^2 to achieve the required log reduction of pathogens through disinfection.

UV transmissivity (UVT) is affected primarily by the organic carbon content of the source water. The turbidity in Kalamalka Lake is primarily inorganic, thus turbidity and UVT are not consistently related because dissolved organic molecules lower transmissivity but do not affect turbidity. Since organic carbon concentrations are important to UVT levels, the recent changes to the oscillations in total organic carbon measurements have become more extreme in recent years and will likely affect UVT (Figure 2.21). The cause of the TOC spikes is not known but may relate to increased inputs from Coldstream Creek.

Figure 2.21 North Kalamalka Lake Total Organic Carbon, 2002 - 2010



Most sample sites on Kalamalka Lake have their lowest (poorest) transmissivity in June and October. Spring transmissivity is lowered by the freshet to as little as 66% in the surface water in the North Arm. A UV transmissivity of only 66% is too low for effective UV disinfection. It is fortunate for GVW that the freshet plume is buoyant. Overall UV transmissivity ranged from 86 – 95 % in Kalamalka Lake with an average at the intakes of 90-91%. For example, in 2009 the minimum UV transmittance was 87.2% and the maximum was 94.4%, with an average of 91.2% (based on 101 samples).

In the turbidity range of 0.35 to 0.80 NTU, Kalamalka Lake UV transmissivity was stable at 88% - 94%. Unlike turbidity, there was no significant difference between transmissivity at the 20 m, 30 m and 40 m depths during 2006 through 2009. Kalamalka Lake UV transmissivity was not adversely affected by the marl precipitation because algae counts decline as marl particles increase. While the turbidity/transmissivity advantage of an intake at N 40 m versus N 30 m is minor during most of the growing season, there is a clear advantage to intake locations further from Coldstream Creek inflow during freshet and during intense summer storms.

2.6 Calculation of Intake Protection Zone for North Kalamalka Lake Intake

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

The decision on the size of an intake protection zone should be based on the existing and potential hazards, and on the speed with which they can be transported to the intake, both horizontally and vertically. Vertical transport is dominated by fall rates and seiches while horizontal movement in lakes is dominated by wind-driven currents and inflow plumes. The default intake protection zone defined by IHA is a 100 m radius around the end of the intake. The protection zone should be modified from a circle to reflect consistent influences on water travel near the intake such as stream inflows, water currents and seiche patterns. A second layer of protection zone could be imposed on adjacent land development where subsurface (waste water, irrigation water) and surface (storm water) flows delivered to the intake protection zone would be significantly impacted by the land development.

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

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

Vertical Transport – Fall Velocity When mixtures of solids and water are introduced to a lake, the dissolved material remains suspended indefinitely and diffuses, while the particulate material settles out according to its fall velocity. April/May 2005/6 samples from Kalamalka Lake’s North end were sent to UBC Mining Lab for particle size analysis on an Elzone 280 PC. Particle sizes were generally small with all particles from N-Kalamalka Lake reported as less than 75 microns in diameter. All samples exhibited a bimodal size distribution where the smallest particles of marl peaked below the detection limit of 1.1 micron diameter (Larratt, 2005). The second peak recorded larger particles carried by freshet flows and large algae from the lake. Very fine (<1.5 microns) particles of marl are abundant and increase the turbidity and sedimentation rate of Kalamalka Lake.

Large particles of sand introduced from creek or storm water outfall plumes settle out almost immediately while finer sand/silt is transported further into Kalamalka Lake. Very small particles remain suspended, including algae and may include microbes such as *Cryptosporidium* and *Giardia* cysts. Both cyst types and *E. coli* have been detected in the North Arm of Kalamalka Lake and the probable source is Coldstream Creek inflows (Clarke & Brett, 2005). The potential for plume-introduced contaminants to remain suspended in the North Arm of Kalamalka Lake is high.

The fall velocity of fine clay is small at 0.0011cm/s (0.04 m/hr or about 1 m/day); for marl it is about 0.6 m/day and for *E. coli* bacteria it is far smaller at 0.00354 m/day (Hayco, 2009; USGS 2007). For example, it will take several weeks for clay to settle through the water column, unless it clumps with other materials and accelerates. Marl particulates are in the same size-range as bacteria but they readily clump with bacteria and other organics, and settle out of the water column gradually over a period of months. It could take years for bacteria to settle out based strictly on fall velocity. Fortunately, their fall velocity will be accelerated by clumping with other suspended materials. Bacteria can also be consumed by zooplankton and deactivated by sunlight or simply by aging (Wetzel, 2007).

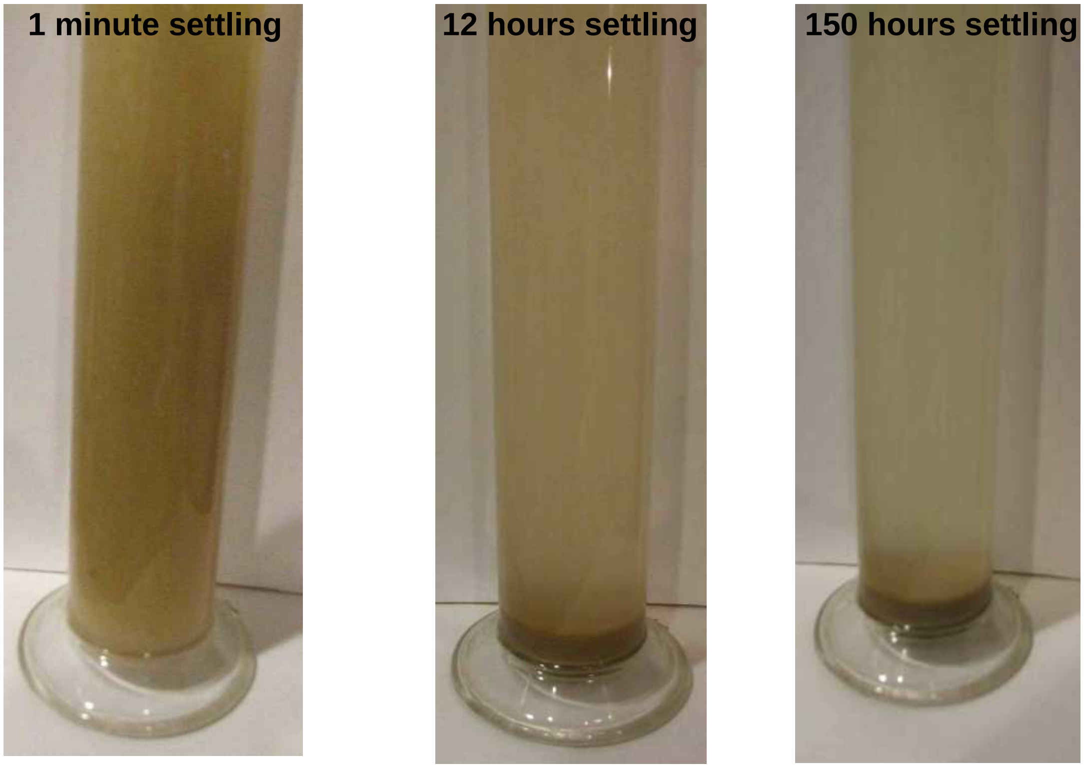
A fall-rate experiment was conducted on material rinsed from brewery water filters collecting material from the N-Kal intake (Table 2.2). Particulates were suspended in a 1 L, 75 cm tall graduated cylinder (Figure 2.22). The solution was allowed to settle and microscope samples were drawn off at 1 minute, 1 hour, 12 hours, 70 hours and 150 hours. The large clumps of organic material settled within an hour, leaving marl, bacteria, filamentous cyanobacteria, flagellates and small diatoms. After 70 hours of settling, bacteria and fine filamentous cyanobacteria (*Lyngbya*) were still suspended. Finally, after 150 hours of settling, marl and filamentous cyanobacteria were still suspended and bacteria were growing in the water column. Table 2.2 summarizes fall velocities from this experiment and from established fall rates in 10 - 20^{o}C water.

Table 2.2: Size and Fall Velocity Estimates for Kalamalka Lake Particulates

Material	Size	Fall velocity
Inorganic		
Sand	>63 – 100 microns	> 100 m/day
Silt	4 – 63 microns	21 m/day
Clay	0.1 – 4 microns	1 m/day
Marl	<1.5 microns	0.6 m/day
Biological		
Organic clumps	> 100 microns	>100 m/day
Large algae and diatoms	22 – 70 microns	< 50 m/day
Small algae	6 – 14 microns	<1 m/day
Lg filament cyanobacteria	5w x 200l microns	0.1 m/day
Sm filament cyanobacteria	1w x 100l microns	>0.007 m/day
Giardia / crypto cysts	4 – 8 microns	0.02 - 0.1 m/day
Bacteria – *E. coli*	0.7 – 10 microns	>0.0035 m/day

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

Figure 2.22: Photos of Settling Velocity Experiment; Kalamalka Lake, 2009



Vertical Transport - Vertical Currents Vertical currents generated by a strong wind event can theoretically reach 5 m/sec with a seiche. However, with a typical maximum vertical velocity of 0.08 cm/sec (3 m/hr) for a water current after a strong wind, fine material suspended in the water or disturbed from the sediments could potentially be transported to the surface in 8 hours from a depth of 25 m (the depth near the North intake). There are no persistent vertical currents in a lake; the direction of vertical currents oscillates following the upward and downward water motions in the lake (Hayco, 2009).

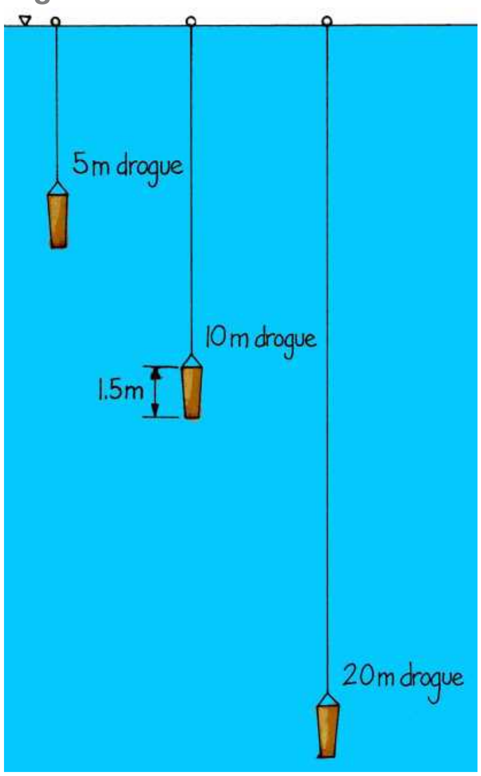
Vertical Transport - Seiche Transport and Autumn Overturn Turbulence
Vertical transport of particulates in lakes follows predictable patterns. During the summer stratified period with no seiche activity, sediments that fall in the epilimnion would be in proportion to depth while below the thermocline,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

During the autumn overturn, near-bottom sediments traps in lakes catch 2-4 times more material than shallow traps due to re-suspension from all over the lake bed. During spring and fall high seiche periods, over half of the material in traps is re-suspended material. The greatest turbulence is associated with the fall overturn (destratification).

The height to which the settled materials can be re-suspended depends on their particle size. Because material on the substrate tends to clump, the height of its re-suspension is usually only a few meters and the rate of return to the substrate is rapid – usually a matter of hours (Table 2.2). Finer material such as marl and bacteria that are re-suspended from the sediments will travel further and remain suspended longer.

Water Currents (Horizontal transport) Like most lakes**,** currents in Kalamalka Lake show a seasonal variability that is strongly related to wind speed. Horizontal water currents are strongest in the top 5 meters of most lakes. There was no existing water current information for Kalamalka Lake other than the annual Kalamalka study's tracking of the Coldstream Creek plume, so a drogue study was undertaken for this report. Drogues consist of a large surface to intercept and be carried by lake currents, attached by a thin line to a small float. Drogues were released at selected depths and tracked by GPS for several hours under a range of moderate wind conditions (Figure 2.23).

Figure 2.23: Schematic Cross Section of Deployed Drogues



The drogue studies conducted as part of this report measured water currents in the immediate vicinity of the intake. Drogues were deployed in the North Arm of Kalamalka Lake on September 14, 17 and September 29, 2009 (Table 2.3). The thermocline over these dates ranged from 12-14 m. Wind speeds were low, ranging from 0 – 10 km/hr. The relationship between wind speed and water current speed was measured by the drogues and is similar to the standard energy transfer estimate of 1.5 - 2% (Wetzel, 2001).

Drogue Travel in Kalamalka Lake North near N-Kal Intake: The shallow 5 m drogues showed water movement at 5 m tends to be in the direction of the wind. Speed of water movement tended to decrease with depth. At 10 m water appeared to move in many different directions and with varying speeds. The two 10 m drogues that were tracked at the same time tended to move in different directions. At 20 m, water movement was slower and on Sept 17 the 20 m drogue moved in all directions. It is reasonable to expect that wind energy impacts the whole water column with extremely variable water movement and significant turbulence. The white circle on Figure 2.25 represents two hours of travel at 5 m water based on the highest observed water speed or 8 hours of travel at the highest observed speed at 20 m. Water currents at 10 m can move almost as fast as the 5 m water at times. It can also be expected that with sustained wind speeds above 10 km/hr, water could be quite turbulent throughout the water column. Winds exceeding 10 km/hr are common, occurring many times each month, but were not present when the drogues were deployed (Figure 2.24).

The direction of travel of the drogues was scattered, reflecting the effect of the bays, points and shallows deflecting the wind-driven currents (Figure 2.24). Contradictory travel in different water layers is often observed and is the result of seiches, deflected currents or a change in wind direction. The surface 5 m will change directions and velocity faster than deeper water can.

Table 2.3:
Drogue Results for GVW North Kalamalka Lake Intake, 2009.

	Sept 14		Sept 17		Sept 29	
Depth m	m/hr	direction	m/hr	direction	m/hr	direction
5	38	W	24	NNW	89	NE
5	37	W	38	NNE	80	NE
10	18	W	26	WSW	73	NE
10	14	SSE	26	NNW	42	NE
20	21	SW	10	ALL	16	ESE

Figure 2.24 North Kalamalka Lake Drogue Trials, 2009

White Line = 5 m drogue
Blue line = 10 m drogue
Yellow Line = 20 m drogue
Dot = start point

The drogues were not used during an intense storm, but currents are estimated to reach surface speeds of up to 9.5 cm/s (342 m/hr) in the open reaches of Kalamalka Lake in a storm. The currents would slow and deflect as they reached the North Arm. Both the drogue and temperature logger studies confirm that extensive mixing and turbulence occurs as currents travel into the North Arm.

The speed of travel for surface contaminants is important because materials can fall vertically or be transported downward by seiches in the North Arm. Doubling the wind speeds that were measured by the drogues covers 80% of the wind events expected in a year. Doubling the fastest drogue indicates that a surface contaminant could traverse a 100 m intake protection zone in 33 minutes. Conversely, to achieve the two hour guideline, the intake protection zone radius would have to be a minimum of 320 m (Figure 2.25). The shape of the intake protection zone is circular because water current travel is highly variable as turbulence swirls in the end of the North Arm. There are numerous locations for contaminant introduction, also arguing in favor of a circular intake protection zone (IPZ). The extension along the shoreline is included in the IPZ because of the frequent storm water plumes discharged by Coldstream Creek visible on aerial photos. Coldstream Creek is a major transporter of contaminants into the North Arm. If the N-Kal intake was re-positioned at 40 m or deeper, the IPZ would be smaller because water travels slower at depth than it does near the surface of a lake.

Long-shore water currents driven by wave action are temporary and frequently reverse the angle that they are striking the shore, making them a weak transport mechanism of potential contaminants over long distances of shoreline (Wetzel, 2001; Hayco, 1999). The GVW North intake is 252 m to the chamber that is 275 m off-shore and that distance protects the intake from particulates transported by wave-generated long shore currents (Figure 2.25).

There is a substantial reduction of surface contaminant risk resulting from an increase in the depth of the intakes (Hayco, 2000). The area that can contribute contaminants to an intake shrinks as the intake depth increases and the Intake Protection Zone would also shrink.

The proposed Intake Protection Zone is not the only instrument available to DoC and RDNO for the protection of Kalamalka Lake. For example, the District of Coldstream has approved a zoning amendment to create a water zone. The intent of the W1 Zone is to "provide for the recreational enjoyment of upland property owners and foreshore public access as defined by Provincial regulations with minimizing impact on fish, wildlife and vegetation communities." All of these zoning protection instruments are limited in their scope and do not provide absolute protection. True protection requires the cooperation of all governments, residents and visitors to Kalamalka Lake and its watershed.

Figure 2.25: Proposed Intake Protection Zone for N-Kalamalka Lake Intake

A: The white circle encompasses the area that the fastest drogues traveled in two hours with light winds.

B: The black shape encompasses the area water currents can travel in two hours with 80 % of the wind events that occur on Kalamalka Lake and is the recommended Intake Protection Zone (IPZ) (320 m radius). The extension connecting Coldstream Creek to the intake area is included in the IPZ because it covers the path of storm plumes.

C: The red line represents the area recommended by the TAC for inclusion in the Intake Protection Zone based on limnology and jurisdiction. It allows a larger protection "buffer" for the intake.

An Intake Protection Zone that included the area water currents can travel in wind storm events in two hours or in freshet would include the entire North Arm of Kalamalka Lake. The proposed IPZ is within the DoC boundaries.

2.7 Hazards Impacting the Intake Protection Zone

Contaminants that are injected within the intake protection zone have the greatest potential to impact the intake water quality and the least available dilution.

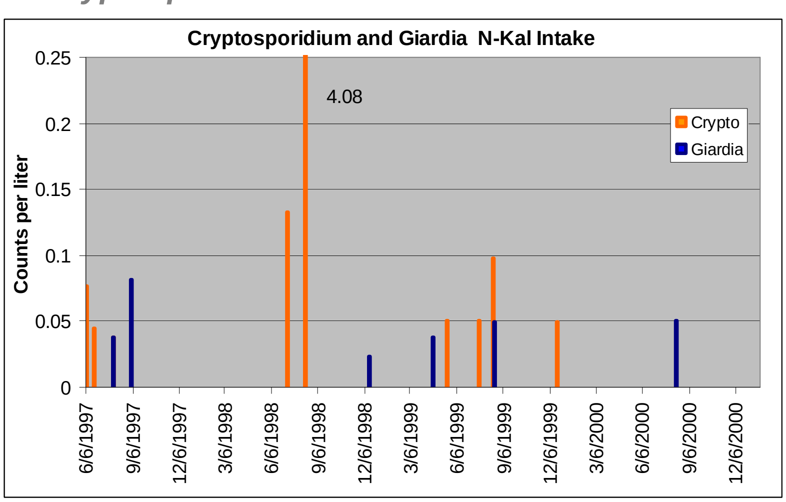
2.7.1 Water-Bourne Pathogens

Cryptosporidium and Giardia

(Oo)cysts are routinely found in Canadian source waters (Health Canada, 2010). The internal protozoan parasites *Cryptosporidium* and *Giardia* were infrequently detected in the intake water from the North Arm of Kalamalka Lake. Routine methods available for the detection of cysts and oocysts suffer from low recovery rates and do not provide any information on their human infectivity, preventing the development of a maximum acceptable concentration (Health Canada 2010). In N-Kal intake, the percentage of samples with <0.075 oocysts/L from 1997 to 2000 was 93.2% for *Cryptosporidium* and 98.3% for *Giardia* (Figure 2.26). Disinfection should reliably achieve at least a 99% (2-log) reduction of *Cryptosporidium* oocysts, and a 99.9% (3-log) reduction of *Giardia lamblia* cysts (Health Canada, 2010). Typically, *Giardia* concentrations in surface waters ranged from 2 to 200 cysts/100 L (Health Canada, 2010; USEPA 1998). Dechesne and Soyeux (2007) found that *Giardia* concentrations in source waters across North America and Europe ranged from 0.02 to 100 cysts/L, while *Cryptosporidium* concentrations ranged from 0.006 to 250 oocysts/L. Out of the entire 144 sample set spanning 1997 to 2003 for the North Arm, 20 (14%) C*rypto* samples and 18 (13%) *Giardia* samples had detectable cysts/oocysts. Of those only 2 *Cryptosporidium* samples and no *Giardia* samples exceeded 20 cysts/100 L. The detectable cysts/oocysts occurred together in 47% of the positive samples and they were clustered, predominantly in freshet (GVW database, accessed 2010).

Currently available protozoan enumeration methods underestimate the number of organisms present and do not provide any information on their capacity to cause illness in humans (Gov. Canada, 2004). Where monitoring for oocysts is not feasible, *E. coli* can be used as an indicator of their presence and treatment requirements. It has been proposed by the U.S. EPA that treatment known to achieve 3-log reduction of oocysts is adequate, provided average concentrations of *E. coli* do not exceed 10 colony-forming units(cfu)/100 mL in lakes or 50 cfu/100 mL in flowing streams (Gov. Canada, 2004). To date, the N-Kal intake can exceed this stringent 10 cfu proposed guideline, particularly in the spring and fall (Figure 2.26; 2.27).

Figure 2.26 *Cryptosporidium* and *Giardia* at the North Kalamalka Intake

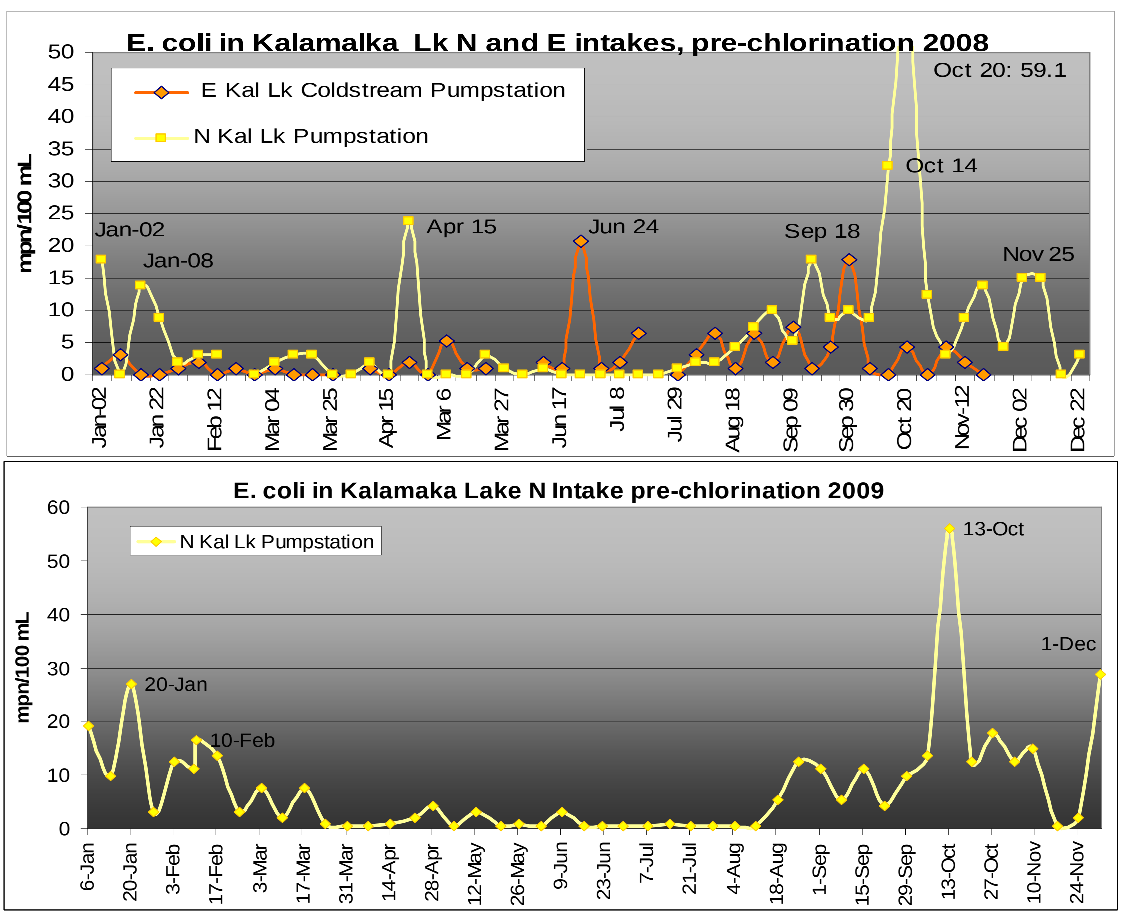


The spikes in Crypto reported in 1998 may be a function of the Coldstream Creek plume travel since flows from the creek are the primary driver of water quality in the North Arm. . Cyst/oocyst spikes may match up with *E. coli* spikes or other changes in water quality (e.g. turbidity, transmissivity, conductivity, flow rates in Coldstream Creek). More data will be assessed in the coming years.

Total coliforms are a broad category of bacteria that include soil bacteria and along with background colonies, they indicate the amount of bacterial loading in the water. Fecal coliforms are found in warm-blooded animal wastes and they serve as an indicator of recent fecal contamination (WSDH, N.D.). However, there are non-fecal bacteria that can give false positive fecal readings such as *Klebsiella*, *Enterobacter* and *Citrobacter,* leading to declining reliance on the fecal coliform assay (Doyle et al., 2006). *E. coli* (*Escherichia coli*) are the most common type of true fecal coliforms. Only a few of the thousands of *E. coli* strains are disease-causing, however, if *E. coli* are present, recent fecal contamination is probable. The presence of other pathogenic bacteria such as *Campylobacter* may be correlated, while *E. coli* counts do not correlate well with viruses or other pathogens (Carter et al. 1986; Keith et a, 1999).

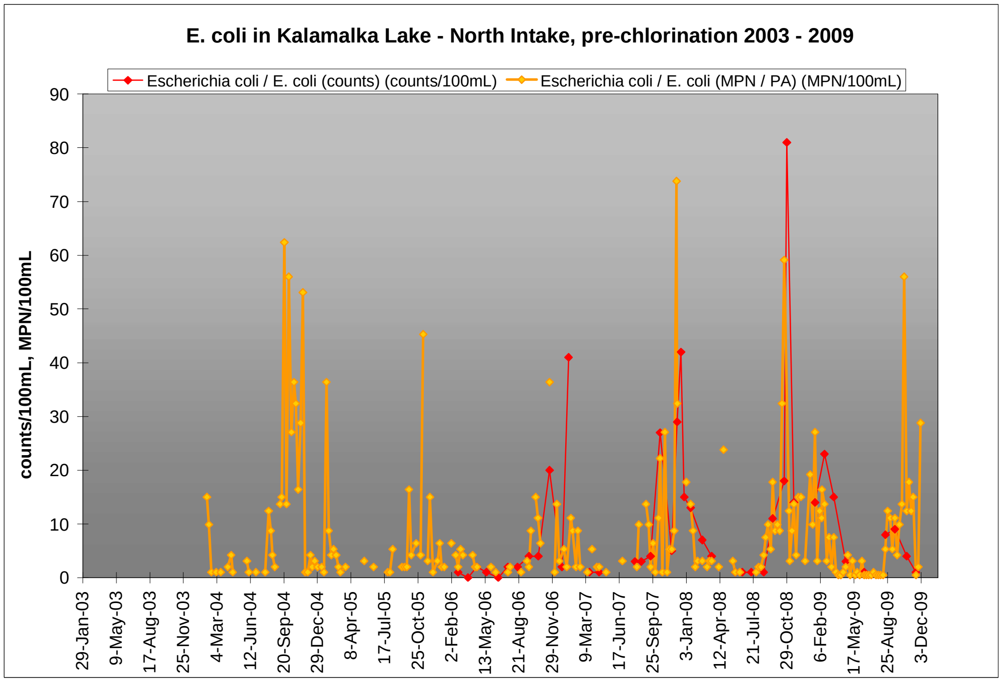
The criteria set by IHA for source/raw water is (1) No more than 10% of source/raw water *E. coli* samples exceed 20 cfu/100 mL *E. coli* within any 6 month period. (2) No more than 10% of source/raw water total coliform samples exceed 100 cfu/100 mL total coliform within any 6 month period (Health Canada, 2010; IHA, 2008). The highest peaks in *E. coli* counts in the 20 m deep N-Kal intake and 4 m deep E-Kal Intake (both located in the N Arm) were during the September to January period, not in spring freshet when they were expected (Figure 2.27). Only two peaks exceeding 20 mpn/100 mL occurred during the 2008 freshet compared to eight peaks in the fall/winter period. Similar results were obtained in 2007 (Clark, 2007).

FIGURE 2.27: *E. coli* at Kalamalka Lake Intakes (raw water) 2008, 2009



A similar pattern in *E. coli* events occurred at Lake Country, but the counts were much lower. Only 1 – 4 cfu/100mL *E. coli* were detected at the South DLC intake versus 8 – 76 cfu/100 mL *E. coli* at the N-Kal intake. The South intake counts were more in line with studies from 1973 – 1989 that gave fecal coliforms at 2.0 mpn/100 mL (Bryan, 1990), but the DLC counts may be biased low due to chlorination interference. Taking the data at face value, the high *E. coli* counts may be a North Arm problem rather than a lake-wide problem, however more accurate bacterial data is needed from DLC (Figures 2.27, 2.28).

Figure 2.28: Summary of *E. coli* in North Kalamalka Lake Intake 2003 - 2009



NOTE: MPN = Most probable number; PA= presence absence bacterial count

The fall/winter spikes in *E. coli* in North Kalamalka Lake may be the result of numerous factors:

- The cattle come off range and onto the Coldstream farms in the fall; in excess of 8000 animals.
- Rains flushing the Coldstream system cause storm water inflows and flows off agricultural properties.
- Rains may coincide with fall overturn seiches, creating a direct connection between contaminated creek inflows and domestic intakes.
- Sediment disturbance during rototilling for Eurasian milfoil control could cause brief *E. coli* spikes because viable bacteria can re-suspend from surface sediments.
- Waterfowl congregate in calm water areas near the shoreline; their feces are a direct source of *E. coli.*
- Finally, natural UV sunlight disinfection would be lowest during the winter months. Sunlight UV deactivation of bacteria is greatest near the surface in water with low turbidity and high transmissivity.

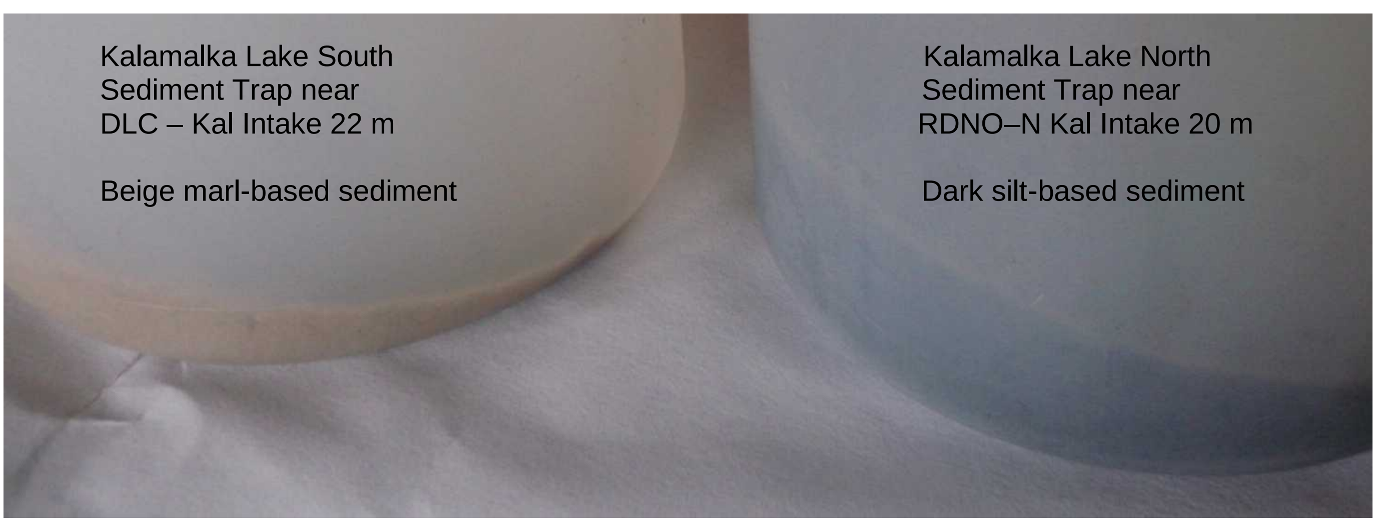
The total coliform samples in the GVW distribution system did not exceed the 10% guideline during any month of 2007 and therefore complied with the BC Drinking Water Protection Regulations (Clark, 2007). *E. coli* bacteria and protozoan cysts are very small and may be imported by Coldstream Creek inflows. Since these cysts have been detected in the North Arm of Kalamalka Lake (Figure 2.26), improved riparian protection against surface run-off and storm water management is indicated for the Coldstream Valley. *E. coli* spikes of >10 cfu/100mL occur in the North Arm, usually in the fall/early winter. The literature indicates that the majority of enteric bacteria in aquatic systems are associated with sediments. Streams can transport and deposit bacteria-laden bed sediments. Net settling velocities of fine sediments and associated bacteria were typically two orders of magnitude lower than those predicted from Stokes equation, due to re-entrainment of settled particles (Jamieson et al., 2005). Every effort should be made to prevent the loss of bacteria-rich fines from the Coldstream Valley to Kalamalka Lake.

Some bacterial source tracking was conducted by MoE and in 2010, GVW received an OBWB grant to conduct more extensive bacterial source tracking. This work is not yet complete. The annual Kalamalka Lake study performed by Larratt Aquatic shows very high bacterial numbers in Coldstream Creek. It likely represents a significant bacterial input to Kalamalka Lake. This suggests that riparian protection along the creek is needed.

On September 17, 2009 a remote sampler was repeatedly dropped into the sediment near the intake before retrieving a sample 1 m above the substrate. The intent was to mimic seiche turbulence to see if the sample would account for the turbidity spike that accompanies a seiche according to the N-Kal intake SCADA system (Figure 2.3). Unlike sediment samples from Okanagan Lake and South Kalamalka (Larratt, 2009c), the sediment that is easily stirred up near the N-Kal intake contained uncountable numbers of coliform bacteria, and 27 cfu/100 mL *E. coli* *(Table 2.7).* These results indicate that the risk of *E. coli* loading from North end sediments is significant and sediment re-suspension poses a pathogenic risk. Re-suspended sediment also increases turbidity, THM precursors and temporarily lowers UV transmissivity (LeChevallier and Au, 2004; Pettibone et al., 1999; Templeton et al., 2009). The high *E. coli* counts in the routine North intake water samples correlate to freshet and storms/seiches. Entrainment of bacteria-rich sediment is probable in both cases. The sediments below the intake did not contain benthic cyanobacteria (Table 2.5).

The sediment trap captured a high sediment accumulation rate because of the influence of Coldstream Creek (Figure 2.29; Table 2.4). The trapped material demonstrated a very high accumulation rate of 62 $g/m^2/yr$, of which 13.1% was volatile (organic). Silt and organics are always imported by streams but the instability and riparian damage along Coldstream Creek adds significantly to the sediment accumulations in the North Arm. For example, residents recall a deep area near the mouth of Coldstream Ck which has since filled in.

Figure 2.29: Sediment Trap Material from Kalamalka Lake Oct 2009–May 2010



The major source of *E. coli* in the North Arm can be linked to Coldstream Creek based on the sampling provided in Table 2.5 and other work (Sokal, 2009). *E. coli* come into the North Arm as free-floating particles and attached to sediment (Jamieson et al, 2005). The *E. coli* attached to sediment rapidly settle out and some remain viable for a period of years (Gerba and MacLeod, 1976; Fish and Pettibone, 1995; Meays, 2005).

Table 2.4: Sediment under North Kalamalka Intake and Sediment Trap Data

Sediment Sampling Under Intakes for Microflora - 2009

	14-Sep	14-Sep	17-Sep
frequency data	Ok Lk LC	Kal-GVW	Kal-LC
DIATOMS			
Asterionella formosa		L (dead)	L (dead)
Cocconeis		P	
Cyclotella		C	C-D
Cymbella sp	L (dead)	L (dead)	L (dead)
Fragilaria capucina		VL (dead)	
Fragilaria crotonensis	VL (dead)	M (dead)	L (dead)
Melosira italica	P (dead)	L	C (dead)
Navicula sp.	L	L (dead)	P
Stephanodiscus niagarae	VL (dead)	L (dead)	L (dead)
Synedra acus var radians			
Synedra ulna		P (dead)	
Siruriella elegans		L (dead)	
Tabellaria fenestrata	L (dead)		P (dead)
BLUE-GREEN ALGAE (toxins)			
Aphanocapsa sp.			**P**
Anacystis cyanea	**C-D**		
Aphanocapsa sp.	**C**		
Planktolyngbya limnetica	**M**		
Oscillatoria sp. smooth	**L**		
OTHER			
micro-flagellates	M	L	VL
Large flagellates	L	C	
bacteria	D	**D**	**C**
detritus	M	**L**	**L**
silt	L	C	D
SUM			

P=Present L= Low M=Moderate C=Common D=Dominant

Sediment Trap Samples 2009-2010

Deployed Sept 14/09 - Collected May 25/10

(15 cm dia; 175 cm^2 surface area)

	Ok Lk LC	Kal-GVW	Kal-LC
% solids	0.1	0.7	0.2
% volatile solids	19.6	13.1	15.2
dry weight (g)	0.222	7.250	2.503
volatile weight (g)	0.038	0.859	0.320
accum rate $g/m^2/yr$	1.9	62	21
volatile accum $g/m^2/yr$	0.33	7.4	2.7

Table 2.5: Lower Coldstream Creek Water Quality 2009

Coldstream Creek 2009

Parameter mg/L	16-Jun-09	16-Jul-09	11-Aug-09	29-Sep-09	20-Oct-09
pH	8.36	8.41	8.34	8.31	8.34
Alkalinity	218	260	285	299	289
Calcium	78.5	83.3	85.6	95.7	89
Conductivity uS/cm	521	653	708	755	732
chloride	9.59	15	17.9	20.5	17.1
Sodium	14	17.4	21.5	21.6	20
Total Coliforms CFU/100	DGT1400	DGT2000	4400	DGT1400	DGT1700
Background Colonies	DGT200	DGT200	DGT200	DGT200	DGT200
E.coli CFU/100	440	600	1500	360	110

DGT = detected, greater than or equal to: DGT is used when background colonies exceed 200 because they can reduce the growth of other bacteria on the plate

2.7.2 Sediment Contaminants

Sediment Contaminants - Metals

The estimated sediment accumulation rate for Kalamalka Lake is high at 2.9 mm/yr (1mm/yr in Okanagan Lake) but it is known to be higher still in the North Arm (OKBS, 1974). The sedimentation rate measured by a sediment trap near the N-Kal intake found a rate of 62 g/m^2/yr of dark-colored sediment, probably much of it from Coldstream Creek (Table 2.4).

At these sedimentation rates, it would only take a decade for 3 cm of new sediments to "seal over" contaminated sediments, assuming no sediment disturbance. This is fortunate because some pesticides used in the past are dangerous and persistent. For example, Walker et al. (1994) found a peak in arsenic and lead in Wood Lake sediments deposited in the 1940's that can be attributed to the use of lead arsenate as a pesticide to control coddling moth damage to fruit orchards. The use of these heavy metals as well as the use of DDT after World War II through to the 1960's may also explain the decimation of the benthic community of Wood Lake which went from "abundant" (Clemens et al., 1939) to non-existent by 1969 (Saether and McLean, 1972). There was similar tree fruit production around the South end of Kalamalka Lake during 1940 to present. Extensive agriculture was and is conducted throughout the Coldstream Valley, making it likely that some herbicide or pesticide contamination of Kalamalka Lake sediments occurred. Walker also found increased mercury in recent surface sediments in the Kalamalka -Wood Lake area (Walker et al., 1994). These contaminated sediments should be buried by more than 10 cm of recent sediment by 2010. Their contact with the water column should be minimal under normal circumstances. Burrowing fish (e.g. carp) and aquatic insects (e.g. *Mysis*) could disturb these sediments, as could wave and seiche turbulence in shallow areas. Having re-suspended sediment enter the intake is undesirable. It increases turbidity and possibly introduces small concentrations of sedimented contaminants.

A remote core sediment sampler was used to collect triplicate cores from 20 m in front of the S-Kal and N-Kal intakes. Kalamalka Lake 20 m sediments are a fine silt/clay with moderate organic carbon contents. Recent 0-5 cm sediments throughout the lake contained more phosphorus and organic material than deeper sediments, suggesting increased algal productivity, probably as a response to increased nutrient loading (Table 2.6). All anthropogenic metals (zinc, aluminum, lead, arsenic) in North Arm sediments were 2 to 3 times the concentration in sediments near the south intake likely because of the greater urban development and agriculture through the Coldstream Valley. They also showed arsenic and lead enrichment, perhaps due to agriculture and the use of leaded gasoline. Zinc was also enriched in surface sediments and serves as a marker for storm water (galvanized pipe is zinc-coated) (Table 2.6). Because deeper sediments contain more calcium, marl precipitation events were probably more intense in the past and have become less intense in recent years, perhaps through the Coldstream Creek diversion.

Table 2.6:
Triplicate Sediment Cores from 20 m Near North Kalamalka Intake, 2001

Sample depth cm	Aluminum mg/kg	Arsenic mg/kg	Calcium mg/kg	Cadmium mg/kg	Iron mg/kg	Lead mg/kg	Strontium mg/kg	Zinc mg/kg	Phos. %	Nitrogen %	Sulphur %	Carbon %
Set 1 0-5 cm	16419	6.8	7.99	3.1	21838	9.5	224.2	86.8	0.08	0.30	0.27	4.48
Set 2 0-5 cm	13882	12.3	8.12	3.6	20789	7.7	205.9	81.4	0.09	0.32	0.21	4.65
Set 3 0-5 cm	20450	13.6	9.22	3.4	25978	9.3	284.6	86.5	0.09	0.33	0.47	4.92
Set 1 15-25	14359	6.3	9.99	5.0	20490	13.4	260.9	79.0	0.08	0.33	0.83	4.58
Set 2 15-25	17467	14.2	9.36	3.7	23555	15.6	275.9	81.0	0.09	0.28	0.50	4.39
Set 3 15-25	16055	11.3	10.06	3.1	22457	9.3	289.1	86.5	0.09	0.33	0.81	4.92
Set 1 >50 cm	11217	4.8	13.74	3.4	17677	3.6	291.3	59.1	0.06	0.40	1.12	4.65
Set 2 >50 cm	16168	9.0	10.24	2.8	21497	3.7	281.2	82.7	0.08	0.33	0.84	4.67
Set 3 >50 cm	12899	<1.0	12.68	2.5	19548	4.1	311.7	63.7	0.08	0.38	1.19	4.50

Sample Depth	Sand %	silt %	clay/marl %
0 - 5 cm	6	70	24
15 - 25 cm	6	74	20
> 50 cm	6	69.5	24.5

The following statistically significant trends occurred in the 2001 core data (Table 2.6):

- Recent 0-5 cm sediments contain more phosphorus than deeper sediments aided by the metals (iron, aluminum, manganese, calcium) that control phosphorus mobility, thus those sediments retain more phosphorus (P). A significant portion of that P would be donated by Coldstream Creek inflows
- Overall, deeper sediments contained more sulphur and calcium than recent sediments
- iron concentrations of north sediments were roughly 3 times those of south sediments
- Aluminum concentrations were roughly double those of south sediments; zinc is highest in recent sediments from the north end as a result of human activity
- Sr concentrations in the south sediments were roughly double those of the north sediments; calcium concentrations in south sediments were almost 3 times those of the north end
- Lead was highest in 15-25 cm sediments laid down during the era of leaded gas and lead arsenate pesticides, particularly in the north end

Sediment Contaminants – Bacterial

Sediments caught in a sediment trap suspended at 20 m adjacent to the N-Kal intake showed significant bacterial counts (Table 2.7). This data suggests that turbulence that re-suspends these sediments could increase bacterial concentrations in the raw water.

Table 2.7: Bacteria in Re-suspended Sediment beneath GVW North Kalamalka Intake

Sept. 14 2009	cfu/100 mL
Total Coliforms	Overgrown
Fecal Coliforms	27
E. coli	27

2.7.3 Trihalomethane Formation Potential

Trihalomethanes (THM's) are generated when combinations of total organic carbon, water temperature, contact time and chlorine dose are high (Larratt, 2007). There are many Okanagan water supplies that do not meet the THM criteria. THM's are higher during the summer months with high microflora production than they are in the winter months with low production. Almost all of the THM produced in the distribution system will be chloroform ($CHCl_3$).

Total THM's are monitored four times per year at the GVW North intake. The guideline for Canadian Drinking Water has an Interim Maximum Acceptable Concentration (IMAC) of 100 ug/L (0.100 mg/L). The IMAC has been met in all sampling to date (Clark, pers comm., 2010). For example, the IMAC was met in all four samples from chlorinated Kalamalka Lake water during 2007 with an average of 45 ug/L total THM (Clark, 2007).

2.7.4 Cyanobacteria

Blue-green algae are also called cyanobacteria and they are wide-spread and problematic. With climate change and eutrophication, the frequency and intensity of cyanobacteria growth is increasing in Canadian lakes. Many of these genera are known to produce toxins but were not present in Kalamalka Lake in amounts sufficient to cause a cyanotoxicity threat (Table 2.8). Like Okanagan Lake, the intake depths are often dominated by low light tolerant filamentous cyanobacteria of the *Lyngbya, Oscillatoria* and *Planktothrix* genera. At least one of the toxins produced by these cyanobacteria (Microcystin) can be degraded by chlorine under specific conditions. The risks from chronic low-dose exposure to cyanotoxins is the subject of much international and local study (Larratt, 2009). In general, Kalamalka Lake should be managed to minimize nutrient loading and intakes should be sited to minimize the quantities of cyanobacteria extracted in the raw water.

Since 2003, the site with the highest productivity as measured by chlorophyll-a is N-Kal 20 m. Over 2000 – 2009, chlorophyll-a at the surface averaged 1.2 ug/L but at the 20 m intake depth, it increased to average 2.0 ug/L due to the greater densities of cyanobacteria growing at depth and re-suspension of algal material from the sediments (Larratt, 2009). The algae count results were not as dramatic; they showed an increase of 16% to 732 cells/mL at 20 m over the surface in the North Arm.

Table 2.8: Toxins Produced by Blue-green Algae (Cyanobacteria)

Cyanobacteria	Lyngbyatoxin , plysia-toxin	Aplysia toxins	lipopoly saccharide	Cylindospermopsin	Microcystin	Nodularins	Anatoxins-a and/or -a(s)	Saxitoxins neosaxi-toxin	BMAA
Type of toxin	Dermal toxin	Dermal	Dernal	Liver toxin	Liver toxin carcinogenic	Liver toxin carcinogenic	Nerve toxin	Nerve toxin	Nerve toxin carcinogen
LD50 (ug/kg)				300	50–1000		20-5000		
Guideline					<1 ug/L		<1 ug/L		
Anabaena			Yes	Yes-?	Yes		Yes	Yes	Yes
Anabaenopsis			Yes		Yes				
Aphanizomenon			Yes	Yes			Yes	Yes	Yes
Aphanocapsa			Yes						
Cylindrospermopsis			Yes	Yes			Yes-?	Yes	Yes
Gloeotrichia					Yes				
Haplosiphon			Yes		Yes				Yes
Lyngbya/ Plectonema	Yes	Yes	Yes	Yes			Yes-?	Yes	Yes
Microcystis			Yes		Yes				Yes
Nostoc			Yes		Yes		Yes-?		Yes
Nodularia			Yes			Yes			Yes
Oscillatoria	Yes	Yes	Yes		Yes		Yes	Yes	Yes
Phormidium	Yes-?		Yes		Yes		Yes		Yes
Planktothrix	Yes	Yes	Yes		Yes		Yes	Yes	Yes
Pseudanabaena			Yes						
Raphidiopsis			Yes	Yes			Yes		
Schizothrix	Yes	Yes	Yes						
Synechococcus			Yes						Yes
Synechocycstis			Yes						Yes
Detection technique				HPLC	ELISA HPLC		HPLC+UV GC/MS		

NOTE: Yes-? = Not all authors list this toxin for the cyanobacteria

-Larratt 2009c

2.7.5 Sewage/Septage

Septage routinely carries pathogens, organic matter, nitrates, heavy metals, inorganic salts, pharmaceuticals & personal care products (PPCP's), cleaners, paints, auto wastes, petroleum hydrocarbons, PAH's and more, hence the need to isolate it from drinking water sources.

Caffeine can be used as a marker for human sewage and septage because no other animal excretes it. It is a durable molecule that is routinely found in rivers downstream from sewage treatment because caffiene's chemical structure resists extensive degradation by bacteria (Seiler, ND). This test is much more definitive if caffeine is detected than if it is below detection because caffeine is broken down by bacteria (Seiler et al., 1999). A caffeine sample was collected from the intake depth near the Kalamalka Lake intake on September 29, 2010 and shipped to ALS Labs, Edmonton. The results were below the detection limit of <0.20 ug/L caffeine and indicate that there is a low likelihood of threat from human sewage/septage in the vicinity of the intake under normal lake conditions. All known septic systems have been removed from service, and their impact on subsurface drainage will diminish. All of the subdivisions around the North Arm are currently on sewer, and the seasonal residences to the north are also now on sewer to the best of current knowledge.

Whenever sewer lift stations are required near lakes or streams, there is potential for a lift station failure and a sewage spill to the watercourse. Although sewer is a significant and necessary improvement in the North Arm, the unlikely but potentially catastrophic failure of a sewer main or a sewer lift station to the North Arm must be considered. Currently there are six sewer lift stations on or near Kalamalka Lake and all but two have received significant upgrades in 2004-2010. Upgrades included wet wells, pumps, alarms and back-up power supplies. Currently, plans are underway to upgrade the remaining two stations in close proximity to Kalamalka Lake and/or Coldstream Creek (M. Pethick, pers comm., 2010). These upgrades will minimize the risk of a repeat of the Feb. 11, 2009 lift station pump disruption that allowed a small spill to Kalamalka Lake, but will not eliminate the risk posed by sewer infrastructure that serves waterfront homes. The low risk of a spill from sewer lift stations is better than the steady feed of contaminants from the septic fields of near-shore homes prior to the sewer.

Flooding events are rare on Kalamalka Lake because the water level is regulated by the control structure in the North Arm. Flooding would be very unusual but could increase the impact from old septic fields or informal disposal sites at farms or residences.

Another potential source of septage is improper disposal from houseboats, yachts and cabin cruisers. Numerous complaints of improper houseboat sewage disposal have been reported, including human feces washing up on shore (J. Drought, pers. comm). These boats are currently rare on Kalamalka Lake but marina facilities constructed on Wood or Kalamalka Lake would increase their numbers.

2.7.6 Storm Water Locations

Storm water routinely carries petroleum hydrocarbons, PAH's, road surface contaminants, salt, pathogens, pesticides and nitrates. It may also carry other contaminants when people illegally dispose of materials down the storm drains. Outfall locations should be distant from the intake and preferably, they should be replaced with alternatives such as soak-away zones and rain water capture. Storm water washing pet and avian feces off adjacent streets and parking lots could elevate *E. coli* counts during storm events (Figure 2.27).

Ten storm drains are known to be located within the IPZ for the N-Kal intake. They include a large storm drain system from Okanagan College and subdivisions that discharges approximately 200 m south of the pumphouse and a smaller storm drain that runs along the N pumphouse wall. Storm water discharges within the IPZ increase the risk to the intake, particularly during storms and during the winter (Figure 3.4).

A serious storm water problem occurs when surface contaminants enter directly into storm water, including dairy lagoon overflow. For example, Kidston Road residents have reported that the storm drains have emitted a brown odorous plume into the lake and a localized filamentous algae bloom attests to storm water nutrient input (resident, pers. comm., 2010). Periodic pathogen introduction is also probable. Provincial agencies, residents, DoC and GVW have objected to this dangerous practise on several occasions and plans are underway for its correction.

The largest input of storm water near the N-Kal intake is via Coldstream Creek. Numerous storm drains empty into the creek without any storm water treatment (i.e. settling ponds, constructed wetland, stormseptor). Storm water probably accounts for a significant portion of the storm flows to the North Arm during the summer low base flow period.

2.7.7 Biofilm Development

Warm lake water rich in organic material will develop biofilm in a distribution system. Biofilms in distribution pipelines contain a build-up of precipitated minerals, organic material and microorganisms (bacteria, fungi, yeasts). Biofilms are dislodged from pipe walls during periods of high flow. Most Okanagan water supplies develop biofilms during the summer when the warmer water accelerates bacterial growth. It is virtually impossible to avoid biofilm entirely, and is one reason why water suppliers maintain chlorine residuals in their pipelines.

From 2004 to 2009, annual temperature averages within the N-Kal distribution system ranged from 6 - 8 ^{o}C while the maximum summer temperatures ranged from 11-15 ^{o}C. The temperatures within the distribution system meet the 15 ^{o}C CDWG guideline except in July. Although the averaged water temperatures peak in July, water temperatures rise in October because of autumn overturn and can spike briefly to19 ^{o}C. Overall, the N-Kal temperatures are moderate and although Kalamalka Lake water contains more than 4.0 mg/L TOC, biofilm is not a significant problem for the N-Kal system.

Moving to a deep intake would further reduce water temperatures. Figure 2.4 forecasts an average distribution system temperature range of 5 - 7 ^{o}C with a 30 m intake and 4.5 – 5.5 ^{o}C with a 40m intake. Deeper intakes should guarantee that maximum water temperatures in the N-Kal distribution system would remain below 12 ^{o}C, thereby limiting biofilm development. Currently, annual or biannual water main flushing reduces the biofilm development within the distribution system.

2.7.8 Water Infrastructure of the North Intake

Low water levels could theoretically strand the intake's wet well and disrupt service. Because Kalamalka Lake levels are regulated, this could only occur in an extreme drought. The N-Kal intake system is good to el 391.27 m. GVW can provide Duteau water to the Kalamalka Lk distribution system in the event of an emergency involving the N-Kal intake. At this time, water restrictions would be needed. Facilities are under construction to increase this capacity, however the expanded facilities would still have difficulty supplying peak flow demand.

2.7.9 Routine Monitoring and Emergency Planning

Routine sampling by GVW staff includes sampling for total and free chlorine, conductivity, hardness, pH, color temperature, turbidity, UV transmissivity as well as total coliforms and *E. coli.* Monthly monitoring reports are e-mailed to the Interior Health Drinking Water Officer.

GVW has procedures for releasing water quality advisories and boil water alerts in addition to their All Hazards Emergency Response Plan. The plan was prepared by: Public Safety Consultants Northwest LLC, Seattle, Washington. GVW's plan follows the guidelines of the BC Emergency Response Management System standards for response and incident management using the Incident Command System. The water quality manager is responsible to review the entire plan on an annual basis, co-ordinating the revision of the plan as needed, maintaining records of the revisions, and administering the overall plan. The emergency plan includes emergency contact numbers, steps to follow, agencies to notify, protocols to follow for public notice, etc. The ERP is required under the conditions to operate of the GVW's Operational Permit administered by IHA.

Table 2.8 contains the Module 1 Hazard and Contaminant Table recommended in the IHA Source Assessment process, for the North Kalamalka Intake. It summarizes the possible drinking water hazards that potentially may occur in the source water.

Table 2.8 MODULE 1: Hazard and Contaminant Table – North Kalamalka Intake

Report section	Drinking Water Hazard/Contaminant	Possible Effects	Existing Preventative Measures/Barriers
	Physical		
2.3	Coldstream Creek plume	Introduction of TSS, pathogens, nutrients, PPCP, petroleum hydrocarbons, sediment, pesticides	Some riparian protection through watershed, good farming practice
2.6 2.7	Sediment re-suspension from the Kalamalka Lake substrates	Increased turbidity can compromise disinfection treatment potentially causing illness if pathogens, heavy metals are present	0.67 m clearance of intake from Kalamalka Lake substrate (insufficient)
2.3 2.6	Seiche transport during storms	Intake is affected by surface water intrusions 7-12 times/year, increasing the risk of exposure to surface water chemical and biological contaminants	Intake depth at 22 m; 0.67 m above the substrate (insufficient)
2.3	Long-shore current transport	Long-shore currents transport can carry chemical and biological contaminants at speeds up to 364 m/hr at the surface (slower at the intake depth)	Intake location distant from urban centers
2.3	Drought low water levels or shoreline flooding	Wet well stranding or flooding of septic fields, yards, causing introduction of contaminants	Drought planning, outlet flow control, emergency alteration of works to lower wet well
	Chemical		
2.7.6 3.1.2	Storm water	Transport of nitrogen, pesticides road surface contaminants, dairy wastes, pathogens, salt	Plume can travel high in water column
3.1.3	Septage (sewage spill, septic fields, boat and RV disposal)	Exposure to: pathogens, organic matter, nitrates, heavy metals, inorganic salts, personal care products cleaners, paints, medications, auto wastes, PAHs	Community sewerage; Caffeine analysis was negative
3.1.4	Petroleum hydrocarbons	Deliberate or accidental spill or use of gas-powered boats, boat launch	Dilution, evaporation; depth of intake; location of intake
2.4	Turbidity	Interferes with disinfection; high during marl precipitation	Increased chlorine, UV dose, public notification
2.5	Taste/odor chemicals	Reduced aesthetic; periodic problem	Increase chlorination
2.4 2.7.2	Heavy metals	Bioaccumulation through chronic exposure	Contaminated sediments laid down before 1970 are buried non-detect in water
	Biological		
2.7.4 3.2.2	Cyanobacteria	Chronic low-dose exposure to cyanotoxin; health impacts vary with toxin type, can include hepatic cancer	Depth of intake; chlorination provides some protection; minimize nutrient loading
2.7.3	THM precursors (algae, organic material	Organic material (TOC) can react with chlorine to create THMs that are carcinogenic after long-term exposure	TOC load is moderate in Kalamalka Lake – never have exceeded 0.1 mg/L Total THM (IMAC) no excessive chlorine.
2.7	Viruses –pathogenic	Acute illness through water-borne exposure	Chlorination, UV disinfection
2.7	Bacteria (*E. coli*, fecal)	Illness through water-borne exposure	Chlorination UV
2.7	Protozoa -pathogenic	Illness through water-borne exposure	Chlorination UV
2.7.7	Biofilm	Shields pathogens from disinfection	Cl residual; pipeline flushing

3.0 Kalamalka Lake Intake Module 2 Contaminant Inventory

3.1 Anthropogenic Potential Water-Borne Hazards to GVW North Intake

A wide range of human activity occurs within the vicinity of the GVW North Intake on Kalamalka Lake, including boat-based recreation, lakeshore residential, orchards, a railway, a major highway and intensive agriculture along Coldstream Creek. The degree to which these activities affect the North intake is based on their proximity and their risk. The aerial photo in Figure 3.1 has important features marked.

Figure 3.1 Features of the North Arm, North Kalamalka Lake

3.1.1 Inflows

Coldstream Creek travels as a plume that is still “intact” several kilometres into Kalamalka Lake from the creek mouth. The distance from Coldstream Creek mouth and the N-Kal intake is 850 m and allows some dilution. It is capable of strongly impacting the entire North Arm during freshet and storms. Whole-lake effects such as nutrient loading and non-settling particulates such as viruses and bacteria from Coldstream Creek theoretically have the potential to affect the entire lake. The behaviour of the Coldstream Creek plume is complex and it is covered in Section 2.3.

The full gamut of agricultural and urban contaminants can be transported by Coldstream Creek and local surface runoff. Examples include:

- Agriculture (liquid manure) applied to agriculture land but not contained on site
- Feed lot or liquid manure lagoon overflow (For example, since 1994, Coldstream Ranch has increased production from 813 cow/calf pairs and 1800 head feedlot to 2400 cow/calf pairs and a 5000 head feedlot by converting some ranch land to feed production (Coldstream Ranch website, 2011))
- Fertilizer/ pesticide application from adjacent lands
- Hobby Farms - livestock (cows/ horses) access to creek and overland flow of manure
- Urban storm water run-off (pet feces, hydrocarbons)
- Nutrient-rich ground water inflows (from activities in watershed including animal husbandry and septic systems (Dill, 1972))

After nutrients from this agricultural valley diffuse into the lake water, algae and cyanobacteria can accelerate their growth, creating a secondary problem.

Figure 3.2 Coldstream Creek Storm Plume Deflecting NW Toward Public Beach

Contaminant transport from Wood Lake, the other major surface input, will be very dilute by the time it reached the north end of Kalamalka Lake and is far less likely to impact water quality in the North Arm than contaminants from Coldstream Creek.

Another method of water-borne contaminant introduction to Kalamalka Lake is via overland flow and subsurface drainage directly to the lake. Land use within several hundred meters of Kalamalka Lake has the highest potential to impact water quality and is covered in Section 3.1.5. Contaminants such as heavy metals, pesticides, petroleum hydrocarbons, nutrients and accidental spills can impact the intake area. Lakeshore modification is extensive in the North Arm and places further pressure on the ecology of this section of the lake.

Canada geese and gulls frequent the public beach area (Figure 3.3). Gulls are drawn by the predator-free beach and gulls by food scraps. Geese also feed on agricultural properties that may use antibiotics, creating the potential for antibiotic-resistant *E. coli*, while the gulls frequent the municipal land fill where a wide range of contaminants are available. Canada geese can excrete more than 460 grams (1 pound) of waste per bird per day, and gull feces have more *E.coli* per gram than any other avian species (Dept. of Natural Science, 2003). These birds represent a potentially significant *E. coli* load to the North Arm. Signage discouraging waterfowl feeding, and regular garbage pick-up will help limit the gull problem. A planned compost diversion of food wastes at the dump should reduce gull feeding.

Figure 3.3: Canada Geese and Gulls on Main Beach, September 2009.

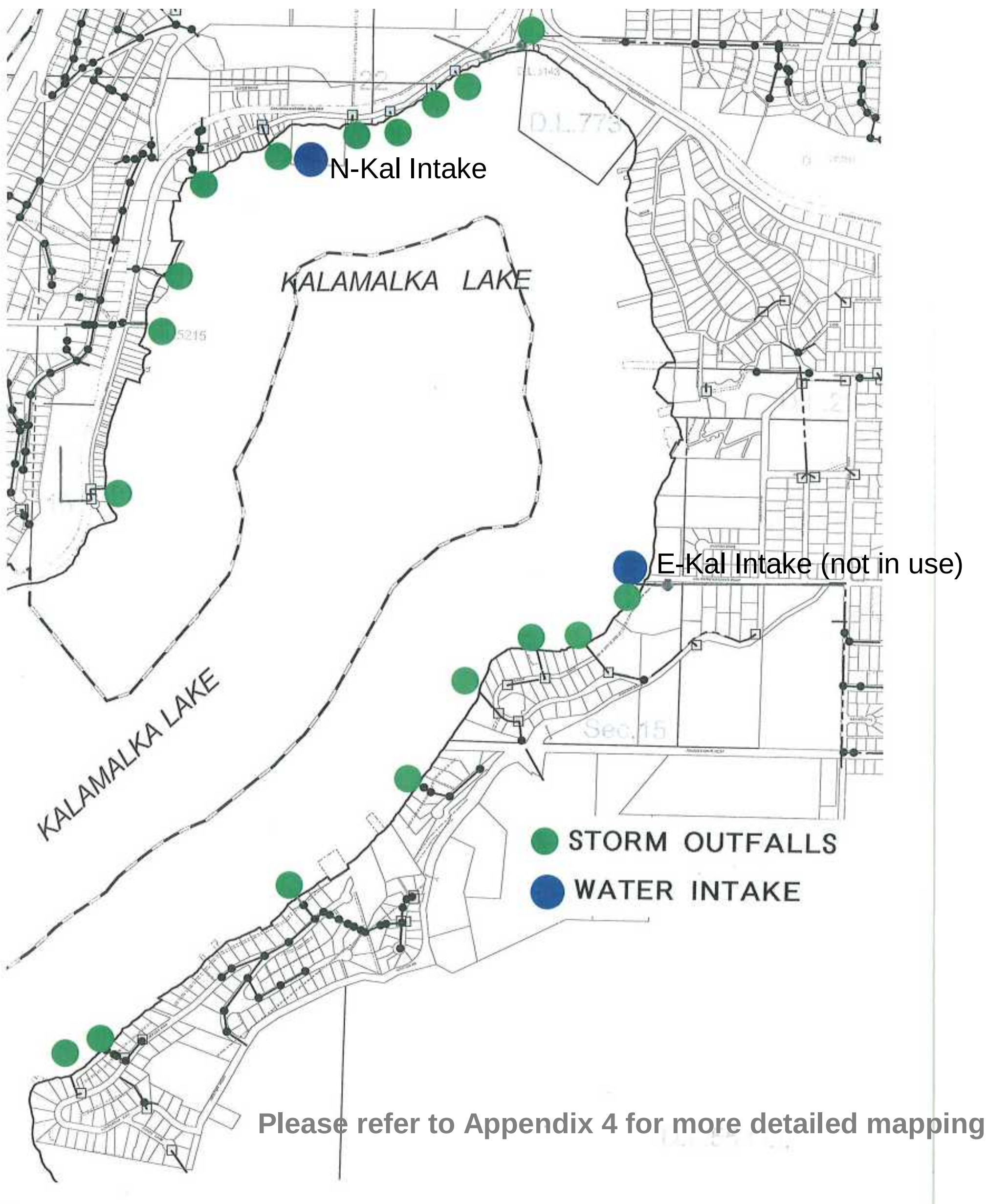
3.1.2 Storm Water Outfalls

Transport for distributed shoreline sources such as local runoff or storm water outfalls would behave similarly to a creek input (Hayco, 2000). Inflows can pool as a water parcel and travel as a discrete packet of water, diffusing as it travels. For example, an inflow of storm water can pool near the outfall and be transported by currents. It is therefore not wise to count on dilution with the full volume of the North Arm when water-borne contaminants are considered.

Storm water in the Okanagan region routinely carries hydrocarbons and materials released from the paving materials, road salt, pathogens as indicated by *E. coli* and landscaping chemicals including fertilizer and pesticides. Additionally, some people may dispose of hazardous materials into a storm drain. In Canada, these have included solvents, paint, detergents, waste automotive products, and drug products. Education on the hazards of illegal disposal, landscaping run-off, washing down driveways and not picking up after pets has improved storm water quality in the Kelowna area (M. Toma, pers. comm.).

There are several storm outfalls in the vicinity of the N-Kal intake, marked with green circles (Figure 3.4). They include the storm water outfall for the college that enters Kalamalka Lake approximately 200 m north of the pumphouse and a smaller very shallow outfall located adjacent to the pump house. Ideally, no new outfalls should discharge into the intake protection zone.

Figure 3.4: Location of Storm water Outfalls and GVW Kal Lake Intakes



Surface contaminants, including manure, have a history of discharge to the Kidston Rd–Kinloch Rd storm drain system which discharges directly to the North Arm adjacent to the E-Kal intake. The risk of pathogen contamination posed by this discharge includes the introduction of antibiotic-resistant bacteria that can become endemic in the exposed wildlife populations (Nijsten et al., 1996; Saleha, 2009). Fortunately, the E-Kal intake is no longer in use. The connection between improperly stored/disposed dairy waste and water-borne disease is significant. For example, the 1993 Milwaukee outbreak of *Cryptosporidiosis* was caused by a rain-on-snow event that washed dairy waste into watercourses (Mackenzie et al., 1994), and it bears similarities to the one that impacted Coldstream Creek in January 2010.

Very little storm water treatment has been developed in the Vernon and Coldstream municipalities. As in most of the Okanagan to date, most storm water discharges to the nearest watercourse without treatment. Localized on-site soak-away disposal could be considered for street run-off as well as rainwater gardens for roof drain runoff to lower the total amount of storm water. Where on-site stormwater disposal is appropriate, developers are required under the Subdivision Development and Servicing Bylaw to retain 50% of the mean annual rainfall volume. For minor conveyance systems, they are required to design for the 1 : 10 year storm. If there is a storage facility such as a storm pond, post-development flow rates must be kept below the pre-development storm rates for up to the 1 : 10 year event unless the downstream flow is inadequate in which case, the flow rate used is the 1 : 100 year storm event.

Storm Water Run-off and Potential Spills

Storm water runoff will flow directly from the rail line to Kalamalka Lake (Figure 3.1). The railway is still active and is currently leased to Knighthawk Rail Ltd. It connects with the CN Kamloops Yard. Knighthawk Rail stores railcars on sidings immediately adjacent to Kalamalka Lake, sometimes for a period of years, depending on rail demand. The line carries primarily wood products but chemicals and grain are also hauled. Locomotive fuels, oils and lubricants would also be a risk in the event of a derailment on areas of the track that are within 10 meters of Kalamalka Lake along the North Arm. Unpreserved wood products and grain present no threat to water quality, but chemicals could. Depending on the density of the chemical spilled, it could be carried into water deeper than the intake and be diluted before it reached the intake via water currents. The exact behavior of the material would depend on its density relative to lake water temperature, winds, recent seiches, etc. and would be impossible to predict the threat it could present to the N-Kal intake and on what time-frame. Ideally, no hazardous chemicals should be transported on this rail line. A containment boom/cleanup kit suitable for dangerous products hauled by train could be purchased by the Railway and the appropriate planning put in place.

The rail line itself is within 10 m of the water's edge in several places along the North Arm of Kalamalka Lake. The entire line is within the riparian area of Kalamalka Lake, usually within 50 m of the shoreline. Direct runoff from the rail bed is probable and may include creosote. Although a measurable impact on intake water quality is unlikely, it should be noted that positioning a rail bed within 10 m of a lake would not meet current environmental standards. The rail line passes within 20 m of the North Kalamalka pumphouse and a spill near this facility would be serious.

Highway 97 represents a large impervious surface and the storm water from it will carry the same contaminants as municipal storm water, with additional salt and turbidity from winter abrasive. It is located within 300 – 700 m of the North Arm lakeshore and therefore, spills are possible. Runoff from the highway is managed by unlined ditches that allow infiltration. Seepage to ground from ditches will allow pathogen deactivation and can remove some PAH's but chloride and spilled contaminants may persist.

3.1.3 Sewer Infrastructure and Septic Fields

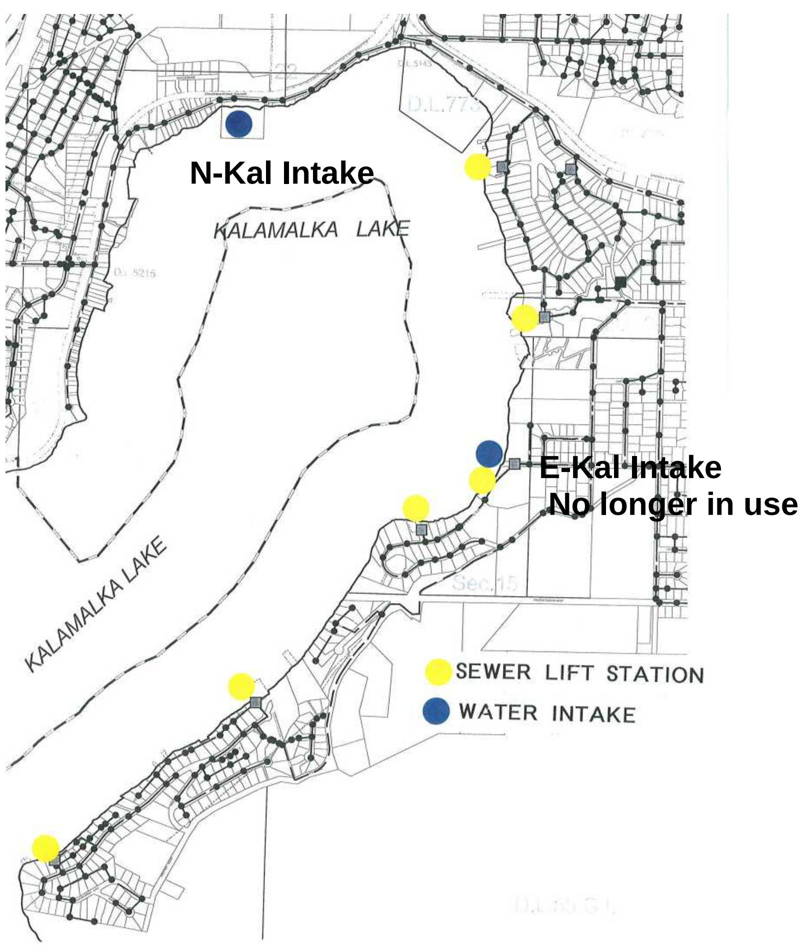
The sewer system around the lake was installed in the 1970's. District of Coldstream has an extensive sewer system that replaced individual residential septic systems over the past 25 years. Over the past five years, the sewer system has received extensive upgrades. Most of the North Arm area is on sewer. Secondary-treated sewage is pumped to McKay Reservoir and distributed from there to the spray irrigation system. The DoC has an agreement with the CoV to receive sewer in the City of Vernon Water Reclamation Centre.

Sewer infrastructure

Although sewer is a significant and necessary improvement to the North Arm, the unlikely but failure of a sewer main or lift station to the an intake has occurred and must be considered. The closest lift station to an intake is the Coldstream Creek Sewage Lift Station located immediately beside the E-Kal intake (Figure 3.5); the E-Kal intake was removed from domestic service in 2010. Fortunately, there are no sewer lift stations in the vicinity of the N-Kal intake and they should not be built in the shoreline area within the IPZ whenever it can be avoided.

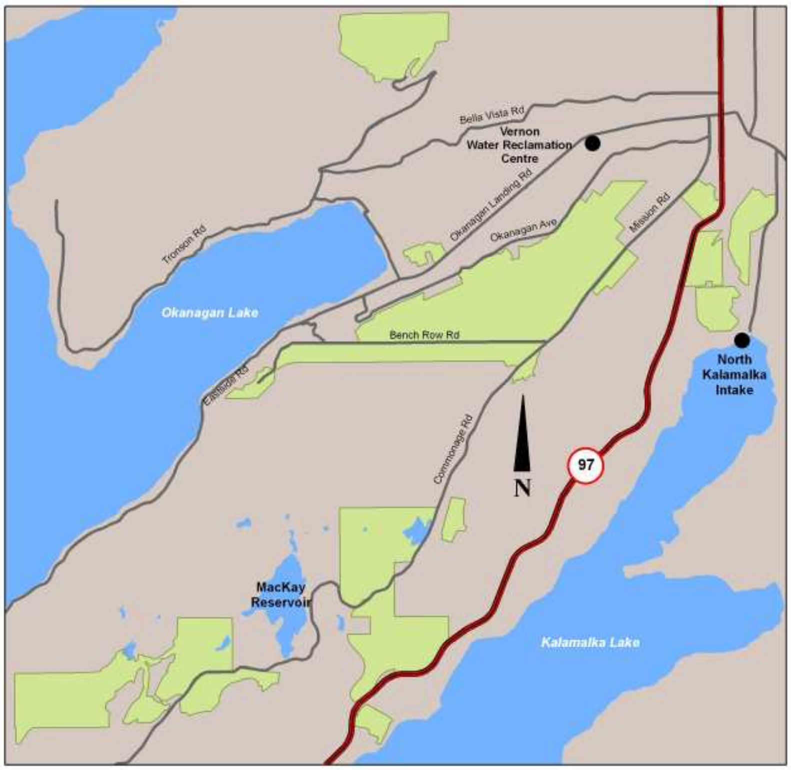
Flooding could increase the impact from old septic fields or informal disposal sites at farms or residences but flooding events are rare on Kalamalka Lake because the water level is regulated.

Figure 3.5: Location of Near-shore Sewer Lift Stations and GVW Kalamalka Lake Intakes



Effluent Spray Irrigation Runoff / Subsurface Flow from McKay Reservoir
Coldstream and Vernon wastewater undergoes primary, secondary and tertiary treatment, including fine screening, grit removal, primary clarification, biological nutrient removal, secondary clarification, filtration and ultraviolet disinfection. The 13,000 m^3 treated water is then pumped 7 km to the MacKay Reservoir on Commonage Road. From late April to early October, reclaimed water is drawn out of MacKay Reservoir, chlorinated and used as irrigation water on approximately 970 ha of hay as well as Predator Ridge Golf Resort, Vernon Golf & Country Club, Vernon Seed Orchard, Kalamalka Forestry Centre and Pacific Regeneration's Vernon Nursery (Figure 3.6) (Vernon, 2010).

Figure 3.6: Approximate Effluent Spray Irrigation Area for City of Vernon



There may be subsurface flows from the McKay Reservoir which is 200 m above Kalamalka Lake, and from the irrigated lands. Samples collected by Larratt Aquatic on April 6, 2010 from Bailey Creek in Kekuli Park that receives drainage from the spray effluent program, and possibly McKay Reservoir, measured 4.16 mg/L nitrate and 182 mg/L chloride. Another sample collected from seepage that emerges at the Kekuli Park boat launch measured 11.9 mg/L nitrate and 236 mg/L chloride. Both samples indicate significant loading and are well above concentrations found in local natural drainage systems. This area is under hydrogeological investigation by O'Connell and Assoc. and a ground water monitoring program is currently under development by Summit Environmental, set to commence in 2011(T. Brett, pers. comm.). The risk of treated effluent impacting the N-Kal intake is very low, however increasing the nutrient status of the lake can increase algae density. Although there may be impacts of the spray effluent disposal program, this system should have less impact on Kalamalka Lake than the alternative, a direct discharge of treated effluent into the lake.

Septic Fields and Private Septic Treatment Facilities
The subdivisions around the North Arm are all connected to sewer. According to real estate information, numerous residences around Coldstream Creek are still on septic fields. Properly functioning fields should not release pathogens but they will release nutrients and pharmaceuticals and personal care produc*ts* (PPCP's) to the ground water or subsurface flow. Recent research has shown that wastewater treatment plants and septic systems only partially remove pharmaceuticals*,* so these chemicals end up in ground water and have been measured in adjacent rivers and lakes (Knox County, ND). Improperly functioning septic systems will allow even greater concentrations of PPCP's to pass as well as microbial contaminants. Septic system contamination can severely impact surface and ground water (USEPA, 2007).

The potential human health risks associated with minute levels of PPCP's in drinking water is still being determined. Until more is known, there is much the public health and environmental protection community can do to educate the public about the best practices concerning the use and disposal of PPCP's, thus protecting drinking water sources (Ground Water Foundation N.D.; Reemtsma et al., 2003).

Ascertaining the risk from septic/sewer systems to the N-Kal intake will be addressed in part with the GVW 2010 Bacterial Tracking Study currently underway with OBWB funding, but is beyond the scope of this report.

3.1.4 Moorage, Docks and Powerboat Recreation
Boat traffic on Kalamalka Lake increases the contribution of petroleum hydrocarbons including PAH's, motor oil, gasoline and lubricants via exhaust emissions. The boat traffic near the intake can be intense during July and August. Boating traffic may increase after the Kekuli Bay Launch reconstruction and expansion is completed.

A liter of gasoline can contaminate 750,000 to 1,000,000 liters of water (Envi. Canada, 2010). Accidental spills during refueling are a key source of petroleum hydrocarbons to lakes and they can accumulate in the sediments near docks, moorage, boat launches and marinas. Because Kalamalka Lake has no large marinas (there are 9 "marinas" with more than 6 boat slips on Kalamalka Lake), the potential problem presented by petroleum hydrocarbons to the N-Kal intake is currently low. Howeverr, there is the large Kalavista boat launch located 750 m from the intake and accidental spills at that location are possible. Current estimates of power boats launched at Kalavista each summer is about 3,500 and this number is expected to increase (GDH et al., 2010). Low viscosity fuels such as gasoline can spread rapidly and dispersion is dependent upon temperature and turbulence. Evaporation is less effective on heavier petroleum hydrocarbons but remains the single most important weathering process in the first few days following a spill that is not cleaned up appropriately (Wang and Stout, 2007).

Another potential source of boat contamination is waste water. Although this type of boat is currently rare on Kalamalka Lake, they are not prohibited. Improper "black water" (sewage) disposal from houseboats, yachts and cabin cruisers can occur. In BC, grey water is routinely discharged from these boats. Grey water contains detergents, dyes, personal care products and can contain heavy bacterial loads comparable to domestic sewage (MoE, 2010). A 2008-09 study funded by MOE and Interior Health on Shuswap Lake, "…indicated that the presence of houseboats is correlated to the chance of detecting fecal coliforms, that grey water discharges contribute endocrine disruptors to the lake and houseboat discharges are a consistent source of fecal bacteria." These problems led the BC Ministry of Environment to implement a phased-in compliance with the provincial Environmental Management Act Sec. 13 which prohibits the discharge of both black and grey water from any vessel into any inland or coastal marine water.

The Greater Vernon Parks and Recreation Master Plan (2004) stated that regulators should be, “discouraging more motor boats on Kalamalka Lake near the drinking water supply at the north end.” Limiting the number of boat storage at marinas, slips and docks can indirectly assist in lowering the motorized boat use on lakes (MoE, 2009). There are no commercial marinas in the North Arm at present.

In addition to posing a potential threat to water quality at the N-Kal intake, motorized boating has led to unauthorized camping, dumping of refuse and establishment of “party sites” which have left permanent scars on sensitive landscapes, damaged fragile archaeological sites and displaced species at risk in Kalamalka Lake Provincial Park (MoE, 2009). Clearly there are numerous issues caused by irresponsible power boating that can have long-term ramifications to Kalamalka Lake in addition to immediate water quality concerns.

Commercial marinas are significant sources of pollution caused by discharges of sewage, food waste, fish cleanings, bilge water release, and materials associated with boat maintenance. Vessel traffic and dredging activity in marinas and in shallow navigation channels such as Oyama Canal can churn up sediments, reintroducing metals, nutrients, organic matter and toxins into the water (MoE, ND).

No additional marinas, boat launches or multi-slip dock facilities should be contemplated within the North Intake Protection Zone (IPZ) in particular and in the North Arm generally. The concerns presented by a marina on Wood or Kalamalka Lake must be weighed carefully against the benefits of such a project and include:

- Increased introduction of petroleum hydrocarbons during normal motor operation and potentially by accidental spills;
- Increased use of the lakes with boats equipped with on-board septic holding tanks that do not retain grey water;
- Seasonal pump-out stations at marinas can fail – for example the August 14, 2009 spill of raw sewage from the Westbank Yacht Club into Gellatly Bay, Okanagan Lake. Storm water deluged a manhole and overflow of storm water and raw sewage flowed into the lake for 45 minutes (Appendix 1).

A clean-up kit for a petroleum hydrocarbons spill into Kalamalka Lake should be stored with the local Hazmat Team and at the major boat launches. RDNO may wish to consider encouraging non-motorized recreation by planning facilities that promote sailing, kayaking, canoeing, all of which have far less potential to impact intake water quality.

3.1.5 Adjacent Land Use

Land use within several hundred meters of Kalamalka Lake and land use directly connected by storm sewer have a greater potential to impact water quality than land use not directly connected to the lake. Fortunately, there is no industrial land use and limited commercial land use on the periphery of the North Arm of Kalamalka Lake. Near-shore land use is dominated by: residential, tree culture, parks, beaches, dairies and orchards (Figure 3.1).

RDNO considers Swan Lake, Goose Lake and Kalamalka Lake and all local watercourses to be environmentally sensitive, and these areas have been identified as Development Permit Areas and restrictions are placed on the use of land within these areas. Land within 15 meters of the natural boundary of a watercourse should remain free of development with the exception of fencing, works and plantings to control erosion, protect banks, protect fisheries or waterfowl habitat or otherwise preserve and enhance the creek and associated habitats (Rural Vernon Bylaw 1708, 2001Official Community Plan). A similar bylaw could protect DoC lands adjacent to Kalamalka Lake.

Shoreline Properties Shoreline properties have the highest potential to impact the lake. Of the 6.6 km of shoreline around the North Arm, 5 km (76%) is developed as shoreline residential. A further 0.9 km has the rail way immediately adjacent (within 30 m) of the water's edge and 0.7 km is developed as beach. All of the shoreline near the North intake is either residential or swimming beach (Figure 3.1). The 220 ha of residential properties also increase the amount of impervious surface with roads and roofs, generating storm water. Like the storm water generated from residential properties, overland flow and seepage to ground can carry fertilizers, pesticides, pathogens, detergents and solvents from residential properties bordering the lake. The impact would be determined by the type, volume and the location of the contaminant introduction. Lakeshore owners should be encouraged to preserve a shrub greenbelt between their properties and the lake to intercept drainage. It is illegal to modify the natural shoreline without a permit because of its protective value and fisheries value, but unfortunately, this is a frequent occurrence in the North Arm. Best practices management of properties within the Intake Protection Zone is more important to the N-Kal intake than management of properties remote from the intake, but all are important.

Overland flow from these properties is the most serious, followed by subsurface drainage which is slower and offers in-situ treatment and attenuation. Both of these routes for contaminant travel are non-point source and are unlikely to measurably impact the intake water quality. However, overland flow and ground water contamination both contribute incrementally to the contaminant and nutrient loads reaching the lake. Although shoreline flooding is rare on this regulated lake, it is not wise to store toxic or high nutrient materials near or below the high water mark.

Kalavista "Lost" Lagoon was originally a wetland that was dredged for a land development and diversion ditches were created from Coldstream Creek into this constructed facility. It measures 160 m by 36 m and is 717 m from the N-Kal intake. The creek flows have since been restored to their original channel and the lagoon functions as a disturbed wetland ringed by residential use. It receives storm water from a portion of Kalavista Drive and the back of some lots on Postill Drive and Tebo Drive. The residents complain about odor and currently are petitioning DoC to dredge it and/or flush it. Flushing or dredging Kalavista Lagoon would represent localized nutrient enrichment to Kalamalka Lake. The potential for contaminants or pathogens from Kalavista to travel to the N Arm and the N-Kal intake should be assessed before these modifications are permitted. Pathogenic bacteria from near-shore wetlands can impact a water intake (Hospital et al., 2011).

Modified shoreline wetlands surrounded by developments are problematic in the Okanagan. Complaints of odor, plant growth impeding boats and insect issues are common. Residents often feel strongly about dredging or flushing, but a case-by-case assessment is needed. Suction dredging can be helpful but adequate isolation of the dredged area is essential during dredging and initial re-filling to prevent a plume that will likely travel towards the N-Kal intake. Flushing requires determination of the volumes to be flushed and the water quality of the lagoon, the flushing water and the receiving lake water. The travel of the flushed water will probably be towards the intake under most wind conditions, based on available water current data for the North Arm. Flushing with storm water may not provide adequate treatment, particularly during a large storm.

Playing Fields Parks and Beaches Parks and schools with playing fields can also release fertilizers and pesticides to the lake via storm water or through seepage to ground water (Envi Canada, 2010). The largest developed park in the vicinity of the North intake is 2.0 ha Kalamalka Beach Park. It is 750 m from the intake making proper septage management imperative and it is already on sewer. A second smaller beach adjoins the pumphouse and it is equipped with porta-potties in the summer months. The main boat launch also has a porta-potti and is gated to prevent overnight camping.

Forestry Experimental Vernon Seed Orchard The Forestry Experimental Seed Orchard covers 66 ha and is 185 m from Kalamalka Lake at the closest point. Fertilizer use and reclaimed water use would be lower than what is used for conventional tree fruit culture, but the possibility of increased nutrients in subsurface flow cannot be discounted. The majority of the flow leaving this site would report to Vernon Creek and not the North Arm.

Orchards 18 hectares of orchard are located along the NE shore and they come within 130 m of the shoreline (Figure 3.1). Tree fruit culture is dependent on a number of sprays and in the past, these have included some very dangerous and currently banned substances including lead arsenate and DDT. Again, the risk posed by this agriculture is proportional to the amount of overland flow, drift or seepage of applied chemicals that reaches the lake and their fate there. Some agricultural chemicals are photo-degraded in lake water, others are persistent. Fertilizer and soil amendments may also be required by growers periodically. Excess irrigation will increase the subsurface flow reporting to the lake from these orchards. A green belt of riparian trees between the lake and the orchards would be an asset to Kalamalka Lake.

Dairy/Grazing Grazing/pasture account for a further 1.45 ha and donates nutrients from dairy manure spread on the fields to the lake, but the greatest problem is the dairy waste holding facilities that have a history of discharge to the Kidston Rd–Kinloch Rd storm drain system and from there, directly to the North Arm, adjacent to the East Kal Intake. The threat posed by this situation is high, particularly because diaries often use antibiotics and the *E. coli* and other bacteria released can be antibiotic-resistant.

Municipal Landfill The Greater Vernon Recycling and Disposal Facility (GVRDF) leachate storage pond is located 975 m from the North Arm shoreline, about 200 m in elevation above Kalamalka Lake. The road salt storage area beside the GVRDF was decommissioned in 2007, and the salt plus 10 cm of salinized soil was removed. Ground water samples to monitor the plume from this site are collected three times per year. No Maximum Allowable Concentrations for drinking water were exceeded in 2009 at the

GVRDF property boundary downstream from the leachate storage pond. Ground water impact attributable to recycling and disposal activities downstream from the pond are difficult to assess due to overlapping plumes from the leachate pond and from the old salt storage site (N. Kohnert, pers. comm.).

Highways Chloride is an urban storm water contaminant that is contributed primarily by winter road salting and salt storage (Baker, 2007). The cations of sodium and magnesium are also contributed. Further downstream from the GVRDF, the chloride concentration in the surface spring above Hwy 97 averaged 600 mg/L (Aquatic Life Guideline for surface water = 600 mg/L) (N. Kohnert, pers. comm.). Grab samples collected at the rail line culvert in winter 2010 exceeded 1300 mg/L Cl. By this point, there are at least three sources of road salt impacting the area in addition to the GVRDF contribution. They are:

- Saline subsurface plume from the decommissioned (2007) salt storage area
- the on-going use of salt for winter traction on Hwy 97 and the old Hwy 97
- used winter abrasive stored near the head of the draw beside the old highway

RDNO consultants determined that the chloride from the old road salt storage area will diminish within approximately ten more years. If it is not done already, contaminated soil removal and capping/revegetation of the salt storage site should be considered, and storage of snow with its used winter abrasive load should not be stored in the draw. On-going ground water monitoring will continue to capture these influences and direct remedial action.

Parks Kalamalka Provincial Park protects 2.7 km of the NE area of the North Arm. The majority of the park land is undeveloped – a huge asset to the lake and the North Arm in particular.

3.1.6 Vandalism and Accidental Introductions

Deliberate spills into Okanagan lakes through ignorance or spite have occurred in Kelowna (Appendix 1). For example, 20 gallon pails of hydraulic oil and motor oil were deliberately spilled into Okanagan Lake near the Poplar Point intake in 2009, necessitating an expensive clean-up. While vandalism can be difficult to predict and control, obvious hazardous targets such as fuel storage or portable outhouses should be protected. The impact of human activity to Kalamalka Lake is dependent upon the behavior of all Kalamalka Lake residents and users.

Accidental introductions of invasive aquatic species is increasing in BC with the trailored boat and boating/fishing equipment as the most common transmission vector from region to region (O'Neil, 1993; Larratt, 2011). Of these, the species with the most potential to harm Kalamalka Lake source water is the *Dreissena* zebra and quagga mussels. They have rapidly spread throughout N America from the initial infestation in the Great Lakes during 1986-8. Several boats infested with these mussels have been detected and turned back at the BC-Washington border in 2011. Some authorities feel it is a question of when they arrive, not if.

The microscopic mussel larvae or "veligers" are easily transported from infested waters through ballast water discharge and on boats and gear (Mills et al., 1996). They are notorious for their tendency to colonize water intake pipelines, boat hulls and docks in layers up to 15-60 cm thick (O'Neil, 1993). Zebra mussels can attach to intake pipes at water flow velocities of up to 2 m/second (O'Neil, 1993). The *Dreissena* invasion has resulted in drastic changes to the ecology of infested lakes and rivers. In North America, it is causing annual multi-million losses to the economy (USGS, 2002), estimated at 140 million per year in the Great Lakes region during 2007 (Pennsylvania Sea Grant).

Pre-chlorination has been the most common treatment for control, but if this method is used to control both zebra and quagga mussels, the amount of chlorine used may reach hazardous levels to sensitive lake organisms (Grime, 1995). Mussel larvae can be killed in the laboratory after just a few hours using copper exposures of 0.02 mg/L copper ion while killing most of the adults with the algaecide required 96 hours of continuous exposure to 2 mg/L and that copper dose would likely have unintended ecological impacts (Kennedy, 2002). Potassium ions and hot water are two other effective controls in use in North America.

Since these mussels have not yet reached Kalamalka Lake, no action is currently required, however, intake upgrades should bear *Dreisenna* in mind, and the public should be educated on decontaminating their boat and equipment when moving from one lake to another. Decontaminating boats is smart maintenance and can be invaluable in protecting Kalamalka Lake.

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

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

3.2.1 Kalamalka Lake Marling

The annual marl events in Kalamalka Lake each summer curb algae production but they also increase turbidity. Turbidity attributable to marl exceeds 1 NTU for more than a month every summer and can exceed 2 NTU (Larratt, 2009 a,b). Even though this turbidity source is "clean" in the sense that marl does not include pathogens, it can still interfere with disinfection.

3.2.2 Cyanobacteria in Kalamalka Lake

While cyanobacteria densities in the N-Kal intake water never exceed the WHO and AWWA recommended guidelines, they still allow a chronic low dose exposure to cyanotoxins. For example the Panorama Farms liquid dairy manure that washed into Coldstream Creek and Kalamalka Lake in January 2010 caused a cyanobacteria bloom. The bloom did not exceed 2000 cells/mL at the N-Kal intake but filters on that system accumulated the cyanobacteria filaments and backwash water exceeded 7000 cells/mL. This bloom forced the temporary closure of a local brewery using that water. They detected unusually high ATP concentrations in North Kalamalka Lake water. Fortunately, one of the most likely cyanotoxins that can be produced by cyanobacteria in Kalamalka Lake is degraded by chlorine but at twice the dose required for disinfection and pH must be near neutral (Hudnell, 2007). UV disinfection is also helpful but again, the UV dose to deactivate microcystins is greater than the dose for water disinfection (Larratt, 2009).

3.2.3 Kalamalka Lake Provincial Park – Shoreline Wildlife

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

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

3.3 SUMMARY MODULE 2: Contaminant Source Inventory Table

Contaminant Source and Type	Owner/ Jurisdiction	Location	Distance to intake	Possible Contaminants	Contaminant Transport Mechanism	Comments
Inflows						
Coldstream Creek plume	n/a	N 50.2243 W119.2636	Max 890 m	nutrients bacteria pathogens PAHs	currents seiches	Plume diluted at intake
Lost Lagoon Kalavista Drive	n/a	N 50.2285 W119.2626	717 m	Nutrients bacteria pathogens	Long shore currents	Res. request to pump or dredge
Overland flow with flooding	n/a	Many locations	diffuse	sediment pathogens fertilizers pesticides	currents	Only in storms or freshet
Sewage						
Lift station, sewer mains	DoC	Several, see Fig. 3.5	>500 m	sewage*	overland flow	Rare, serious event
Septic fields active or old	Various	Various	Not known	septage*	Subsurface seepage	Serious, but all known on sewer
McKay Res.	Vernon	N 50.1221 W119.2016	5000 m	2^o treated effluent	seepage	high nutrients monitored by MoE, C of V
Storm Water						
Hwy 97	MoH	W of intake	780 m	PAH salt pathogens accidental spills;	infiltration seepage	Cl-, some PAH travel in seepage
Kelowna Pacific Railway	Knight Hawk Rail	Passes within 35 m of wet well	127 m	PAH creosote accidental spills	overland flow subsurface	Within riparian on W shore; 20 m from pump-house
Municipal storm water	DoC	Several, see Fig 3.4	<100 m	PAH salt bacteria nutrients pesticides	Outfall(s) ditch seepage	Outfalls should not occur in IPZ
Panorama Dairy	private	N 50.213 W119.266	1570 m	Antibiotic-resistant bacteria, pathogens	Pond overflow to storm drain	Very serious if public contact outfall plume
Municipal Landfill	GVW	N 50.1310 W119.1359	2088 m	Salt, metals, PAHs pesticide residue etc.	Leachate pond seepage	Flows monitored by GVW
Motorboat						
Motorboats	various			PAHs	currents	Increasing use
Kalavista; other boat launches	DoC	N 50.1342 W119.1553	715 m	PAHs porta-pottie septage	Currents seiches	Currents transport towards beach
Land Use						
Main Beach; other beaches	DoC RDNO	N 50.2309 W119.2662	700 m	Garbage, PAHs	Currents seiches	Currents travel around bay
Pump-House Park	DoC	N 50.2299 W119.2748	91 m	Garbage, pet feces	Currents seiche	Close to intake
Shoreline residential	DoC		115 m+	Pesticides fertilizers	Long-shore currents	76% of shoreline in North Arm
Residential	DoC		150 m+	fertilizers pesticides PAHs spills	Currents	220 ha around North Arm
Orchards	Various DoC	W of intake	1.5km+	fertilizers pesticides PAHs fuels	Sub and surface drainage	Historic pesticides may still be in subsurface
Natural						
Kal Lake marl	BC	throughout lake	n/a	turbidity particulates	vertical transport	Can exceed 1 NTU
Cyanobacteria	BC	throughout	n/a	Cyanotoxins	seiches	May, Nov/Dec
Kal Lk Prov Park	BC	E of intake	1.5 km+	wildlife pathogens	currents	Low concern

3.4 Summary MODULE 2: Hazard from Contaminants Identification Table

Contaminant Source / Type	Possible Contaminants	Existing Preventative Measures and Barriers	Possible Preventative Measures and Barriers
Inflows			
Coldstream Creek plume	nutrients bacteria pathogens PAHs	Studies to guide riparian restoration are underway	Riparian restoration; storm water treatment and rainwater infiltration
Kalavista Lagoon	Nutrients pathogens	confined flow,chlorine UV	Perimeter wetland restoration
Overland flow flooding	sediment pathogens fertilizers pesticides	Chlorine + UV diinfection, SCADA	Restrict pesticide use on near shore properties; discourage over-watering
Sewage			
Lift Station sewer mains	Sewage	Lift stations have alarms, gen-sets	Need spill contingency plan and spill containment equipment; alarms
Septic fields active or old	Septage	Most houses connected to sewer	Educate septic field users contaminants that can reach lake
McKay Res.	nutrients	Monitoring program, used for irrigation	Intercept flow with vegetation
Storm Water			
Hwy 97	PAH salt pathogens accidental spills;	Ditches	Storm water pond(s) re-use for road-side plantings
Kelowna Pacific Railway	PAH creosote accidental spills	Communication with rail line has been established and on stakeholder list	Add greenbelt where possible between rail line and shore; restrict transport of hazardous chemicals
Municipal storm water	PAH salt bacteria nutrients pesticides	Water system has SCADA chorine/UV	storm water treatment and use for irrigation
Dairy	Antibiotic-resistant pathogens	None	Storm water retention/treatment pond on the dairy property; zero discharge
Municipal Landfill	Salt, metals, PAHs pesticide residue etc.	Monitoring wells; recycling of hazardous waste, leachate collection	Phased soil capping, hybrid poplar planting near spring, monitoring wells
Motorboat			
Motorboats	PAHs	None	Encourage non-motorized use; prohibit lake-side re-fuelling
Boat launch	PAHs septage holding tank	Restrictions on launch use; chlorine and UV	Have spill kit on hand; enforce proper fueling handling; education
Land Use			
Main Beach Pump Hs Park	Garbage, PAHs stored septage	Beach management GVW has chlorine/UV	Discourage feeding birds with signs; manage garbage septage well
Shoreline residential	Pesticides fertilizers PAHs with docks	None	Limit docks, foreshore alterations; restrict pesticide use or ban
Near-shore Subdivisions	fertilizers pesticides PAHs spills	None	Consider pesticide ban on all lakeshore properties and subdivisions
Orchards	fertilizers pesticides PAHs fuels	Distant from shore	Restrict pesticides to biodegradable ones; secure chemical storage
Natural			
Kal Lake marl	turbidity particulates	Particulate monitoring; auto UV adjustment	None possible, may require micro-filtration
Cyanobacteria	Cyanotoxins	Monthly and emergency monitoring in place	Limit nutrient sources; riparian restoration on Coldstream Creek
Kalamalka Prov Park	wildlife pathogens	Riparian preservation	Continued riparian preservation

Pesticides include: herbicides, insecticides, fungicides, rodenticides, and avicides; Many pesticides are highly toxic and are battery acid): **Petroleum hydrocarbons** include PAHs, fuels, oils, grease **Septage/sewage** includes: pathogens, organic matter, THM precursors, nitrates, nutrients, heavy metals, inorganic salts, pharmaceuticals, personal care products, cleaners, paints, medications, auto wastes: **Pathogens** includes: bacteria, viruses, fungi, protozoan parasites

4.0 Kalamalka Lake Intake Module 7: Risk Characterization and Analysis

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

Table 4.1: Module 7 Hazard and Risk Tables

Qualitative Measures of Hazard

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

Qualitative Measures of Consequence

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

Qualitative Risk Analysis Matrix

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

Risk Characterization and Analysis

The location of the Kalamalka intake makes it more vulnerable to urban contamination than an intake in the upland watershed reservoir lakes. The risks within the intake protection zone (IPZ) are generally higher than the risks presented by the same hazard occurring outside the IPZ. Tables 4.2 and 4.3 summarize the hazards and assign a risk level based on likelihood and consequence of each hazard, along with existing and proposed improvements to the barrier(s) guarding the GVW North Kalamalka Intake system. For ease of assessment, the hazards have been grouped by typical source.

Seasonal Variation in Hazard and Risk Analysis

The largest variation in the risk of hazards presented to the N-Kal intake is caused by the thermal conditions within Kalamalka Lake. The possible contaminant distribution will be very different during each stratified season (May – October) versus the freely mixing season (Nov – Apr). Please refer to section 2.2 for more information.

If contaminants are suspended in the surface water during the stratified season, the intake is protected because the surface water layer is buoyant and does not mix with the deeper cold water at the depth of the intake. However, even in the summer, a wind storm can tip the water layers and deliver surface water to the intake (a seiche). The deeper the intake, the more protected it will be from seiches. The N-Kal intake at 20 m is never completely immune to a contaminant found in the surface water layer.

If contaminants are heavier than the density of the surface water layer, they will drop until they reach the depth that matches their density or they settle at a rate determined by their density, particle size, water temperature, etc. If a contaminant enters Kalamalka Lake that plunges to the deep water layer, it will be confined there and the potential dilution of the surface water layer volume is not available.

During the late fall, winter and early spring, Kalamalka Lake is freely mixing. No thermal barrier protects the intake from buoyant contaminants, but more dilution is potentially available.

Currents in Kalamalka Lake are primarily wind-driven. Windy weather develops most often in March to June, with average wind speeds of 9 – 13 km/hr (WindFinder, 2011). Average water travel will be fastest during these months, however severe wind storms can develop in most months. Potential transport of surface contaminants via water currents will be fastest in March to April, prior to lake stratification. Faster transport can theoretically minimize dilution. For example, modeling in Okanagan Lake forecasted dilutions as low as 480:1 for a creek plume travelling 8 kilometers in 2 days (Hospital et al., 2011).

Recommendations for mitigation of “high and moderate” risks found in the matrix tables below are presented in Section 5.1

Risk Characterization Table: MODULE 7 Part 1: Risks Within Intake Protection Zone

Table 4.2: Risks Inside Intake Protection Zone (IPZ) with the Potential to Impact the North Kalamalka Intake

Drinking Water Hazard	Likelihood Level	Consequence Level	Risk Level	Comments/ Assumptions
Inflows				
1 Coldstream Creek Plume	**A**	**2**	High	Coldstream Creek has single biggest impact on N-Kal intake inc pathogens
2 Long-shore current transport	**A**	**2**	High	Transport contaminants quickly over short distances; IPZ needs vigilance
3 Sediment re-suspension	**A**	**1**	Mod	Common during seiches; *E. coli* were found in sediment under intake
4 Lost Lagoon Kalavista Dr	**A**	**1**	Mod	Risk increases with dredging or increased stormwater through-put
5 Flood, overland, subsurface	**D**	**3**	Mod	Kal Lk controls prevents flooding; subsurface flow to IPZ is important
Sewage				
6 Lift stations, sewer mains spill	**E**	**4**	High	Unlikely event but major impact expected when spill occurs within IPZ
7 Septic fields active/old seepage	**D**	**3**	Mod	Some seepage can be expected, most likely from decommissioned fields
8 McKay Reservoir spill to intake	**E**	**4**	High	Unlikely event but major impact expected when spill is transported to IPZ
Stormwater				
9 Stormwater plume to intake	**B**	**3**	High	Storm water carries many contaminants, outfalls currently in IPZ
10 Stormwater pathogens	**C**	**2**	Mod	Large bacterial introductions possible from pet/avian/dairy feces
Motorboats				
11 Chemical, septic, garbage spill	**E**	**3**	High	Depending on spill location and type, emergency response may be needed
12 Launch hydrocarbon PAH spill	**D**	**3**	Mod	Unlikely event with moderate impact expected when spill occurs within IPZ
Land Use				
13 Shoreline Residential	**A**	**2**	High	Building/storing materials below high water line should be corrected
14 Hwy 97, railway spill	**D**	**4**	High	Chemical spill emergency possible, depends on density, toxicity, currents
15 Adjacent subdivisions	**C**	**2**	Mod	Subsurface drainage can carry pesticides, inappropriately stored chemicals
16 Effluent spray irrigation	**C**	**2**	Mod	Diluted, attenuated effluent may travel towards the intake
17 Beaches	**D**	**3**	Mod	Disease carrier swims at beach or beach-goer releases contaminant
18 Agriculture: tree fruit, dairy,etc.	**D**	**3**	Mod	Toxicity and persistence of pesticides varies; nutrients can stimulate algae
Natural				
19 Geese and gulls	**A**	**2**	High	These birds can carry difficult to treat medically pathogens
20 Cyanobacteria blooms	**C**	**3**	High	Chronic low-dose exposure to cyanotoxins >2000 cells/mL undesirable
21 Algae blooms	**A**	**1**	Mod	Algae increase TOC, THM precursors, odor, chlorine consumption
22 Natural marl event in summer	**A**	**1**	Mod	Turbidity will exceed 1 NTU at intake after summer marl event
23 Sediment loading	**A**	**1**	Mod	Sedimentation is high in the N Arm with damaged riparian areas

(Recommendations for mitigation of "high" risks are presented in Section 5.1)

Table 4.3: Risks Outside Intake Protection Zone (IPZ) with the Potential to Impact the North Kalamalka Intake

Drinking Water Hazard	Likelihood Level	Consequence Level	Risk Level	Comments/ Assumptions
Inflows				
24 Sediment re-suspension	**C**	**1**	Low	Sediment re-suspension is common but exerts minor impact
25 Long-shore current transport	**C**	**2**	Mod	Transport contaminants over long distances, can remain concentrated
26 Flood, overland, subsurface	**D**	**3**	Mod	Flooding along Coldstream valley can increase contaminant load in plume
Sewage				
27 McKay Reservoir spill	**E**	**4**	High	Unlikely event but impact expected when spill transported by currents
28 Lift stations, sewer mains spill	**E**	**3**	Mod	Unlikely event but impact expected when spill occurs outside the IPZ
29 Septic field (active or old)	**C**	**2**	Mod	Seepage from cottages possible, will be diluted before reaching IPZ
Stormwater				
30 Storm water plumes	**D**	**3**	Mod	Storm water contaminants may reach IPZ
31 Stormwater pathogens	**D**	**2**	Low	Large bacterial introductions possible, may reach IPZ when lake is mixed
Motorboats				
32 Launch hydrocarbon PAH spill	**D**	**2**	Low	Unlikely event with minor impact expected when spill occurs outside IPZ
33 Boat chemical, garbage spill	**E**	**2**	Low	Depending on spill location and type, monitoring may be needed
Land Use				
34 Shoreline Residential	**A**	**2**	High	Building/storing materials below high water line should be corrected
35 Hwy 97, railway spill	**D**	**3**	Mod	Chemical spill could be serious, depending on density, toxicity, currents
36 Residential subdivisions	**C**	**2**	Low	All Okanagan residents must protect the watershed; drainage would dilute
37 Effluent spray irrigation	**C**	**2**	Mod	Diluted, attenuated effluent may travel towards the intake
38 Beaches	**D**	**2**	Low	Any pathogen introduction would be diluted and have a chance to settle
39 Agriculture: eg tree fruit, dairy	**D**	**2**	Low	Large nutrient inflows could increase the algae production of Kal Lake
Natural				
40 Algae blooms	**A**	**1**	Mod	Algae blooms can be transported around North Arm by currents
41 Cyanobacteria blooms	**C**	**2**	Mod	Concentrated cyanobacteria may travel in "water packet" or disperse
42 Natural marl event in summer	**A**	**1**	Mod	Turbidity will exceed 1 NTU at intake after summer marl event
43 Geese and gulls	**C**	**2**	Mod	Bacteria can be deactivated/consumed in the lake; cysts settle
44 Sediment loading	**A**	**1**	Mod	Sediment transport from Coldstream Valley is high

(Recommendations for mitigation of "high and moderate" risks are presented in Section 5.1)

4.1 Condition of Source

Kalamalka Lake provides excellent quality drinking water with no color, moderate hardness, and rare taste and odor events. It currently meets GCDWQ guidelines for raw source water. Kalamalka Lake is not under the control of GVW and neither is the Coldstream Creek Valley. Water quality relies on every resident and user of the resource. Moderate population densities and the absence of industrial uses helps water quality in the region while dairy, cattle ranching, horse ranching and residential use have degraded the resource. While slow degradation of the resource is far more likely, a sudden water quality disaster could occur and GVW can respond by pumping Duteau Creek water to this area for emergency flows only.

4.2 Physical Integrity of Intake, Treatment and Distribution System

The new Mission Hill UV water treatment plant was completed in 2006 and is designed for 60 ML/day. Chlorination is achieved with sodium hypochlorite that is manufactured on-site. All of these processes are monitored with an array of on-line analyzers and routine sample collection. Upgrades to the system are performed based on priority in the Master Water Plan (KWL 2002). Like any water system, the distribution system is subject to aging, settling of suspended materials, accidental line breaks and cross-connections. On-going maintenance, repairs and monitoring are vital to any water distribution system. An emergency response plan aids in providing an appropriate and swift response to an emergency. Operation and maintenance are scheduled as part of the Capital Replacement Plan.

Maintenance involves routine reservoir cleaning, proactive line flushing and valve exercising. GVW contracts full-time operators with Level I, II, III and IV EOCP certification. Operators must maintain certifications with annual accredited educational units (Clark, pers comm., 2011).

4.3 Risk Assessment for Healthy and Health-compromised Individuals

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

4.4 Intake Extension

In most years of an 11 year study, a 30 m intake would be superior to the current 20 m intake, but in a large freshet year, the 30 m location would provide inferior water quality because of its proximity to the Coldstream inflow plume. For example, the surface water at the 30 m site had turbidity reaching 15 NTU while the 30 m depth at that site ranged from 0.8 – 3.0 NTU during freshet with an average of 2.0 NTU, which is inferior to the 1.5 NTU average at the N-Kal 20 m intake. The surface water turbidity spikes at the 30 m site were double those at the 20 m site during freshet – a vulnerable time when contaminants (cysts, bacteria adhered to solids) drop out of the plume and settling to the intake zone below. This situation can persist for up to three weeks. Additionally, monitoring in 2010 found an elevated *E. coli* count of 24 CFU/100 mL at the 30 m site/depth following a large storm while the 20 m and 40 m sample sites were apparently unaffected. It is also apparent that Coldstream Creek inflows are a significant source of *E. coli* to the North Arm (Table 4.4). Additional monitoring will be conducted in 2011.

The largest disadvantage to extended intakes is their cost of installation. The distance to a 40 m depth is large and would require a new pipeline. Extending the existing intake to 30 m would also be expensive. Modifying the current intake by flexing the sclair pipe up to gain more clearance would be less expensive (Al Cotsworth, pers comm; Arnie Badke, pers. comm.). RDNO Engineering staff are preparing a cost-benefit options analysis that will be informed by the 2011 additional monitoring program.

When all measured physical, chemical and biological parameters are considered, from 2000 to present, the advantages of an intake extension from the current 20 m intake are considerable. Either extending the GVW North Kalamalka Lake intake to 40 m or adding a valve on the current 20 m intake to an extension to 30 m, is recommended. A valve would allow closure of the extension during a large freshet. The 40 m extension requires larger diameter pipe so could not simply be bolted onto a 30 m intake in a future extension. In summary, extending the current intake to 40 m would allow:

- Theoretically lower risk of contaminants from land-based activities, Coldstream Creek plume and waterfowl habitat
- Greater distance from Coldstream Creek mouth, allows plume dilution
- Most seiches would be evaded (Table 5.3), therefore reduced seiche impact and reduced transport of surface contaminants or contaminants re-suspended by seiche turbulence
- Maximum temperature deviation during a seiche would be lowered to 1-3^{o}C
- Lower overall water temperature (range 3.5–19^{o}C at 20 m vs 4.0–9.0^{o}C at 40 m)
- Lower distribution system water temperatures – would no longer exceed 15 ^{O}C
- Lower turbidity (range in 2008: 0.3 – 0.5 NTU at 40 m vs 0.4 – 1.2 NTU at 20 m
- Better UV transmissivity during fall overturn
- Lower algae density (avg. range of chlor-a 1.7 ug/L at 40 m vs 2.7 ug/L at 20 m)
- Lower total coliforms and possibly pathogens
- Non-detectable *E. coli* at 40 m versus <1 – 8 CFU/100mL at 20 m in 2008
- Opportunity to give intake better clearance from substrate (minimum 3 m vertically above substrate recommended vs current 0.6 m)

Table 4.4 Bacterial Results for North Kalamalka Lake 2010

North Kalamlka Lake 2010			26-May-10 Wet month					23-Jun-10 End of freshet					23-Jul-10				
Bacterial parameter	Units	RDL	N-Kal 0	N-Kal 20	N-Kal 30	N-Kal 40	Cold Ck	N-Kal 0	N-Kal 20	N-Kal 30	N-Kal 40	Cold Ck	N-Kal 0	N-Kal 20	N-Kal 30	N-Kal 40	Cold Ck
Coliforms, Total	CFU/100mL	1	1	21	7	<1	DGT1200	<1	1	<1	<1		19	<1	<1	DGT1	
Background Colonies	CFU/100mL	200		> 200		> 200	> 200	<1	<1	<1	<1		> 200	> 200	> 200	> 200	
E. coli	CFU/100mL	1	<1	3	1	<1	180					46000	3	<1	<1	<1	
Coliforms, Total (MPN)	MPN/100ml	3										11000					11000
E. coli (MPN)	MPN/100ml	3															2400

North Kalamlka Lake 2010			19-Aug-10					23-Sep-10 Rain				
Bacterial parameter	Units	RDL	N-Kal 0	N-Kal 20	N-Kal 30	N-Kal 40	Cold Ck	N-Kal 0	N-Kal 20	N-Kal 30	N-Kal 40	Cold Ck
Coliforms, Total	CFU/100mL	1	14	7	1	1	DGT1600	56	DGT20	DGT58	OGW	4600
Background Colonies	CFU/100mL	200	> 200				> 200	> 200	> 200	> 200		> 200
E. coli	CFU/100mL	1	<1	<1	1	<1	480	4	1	24	1	300
Coliforms, Total (MPN)	MPN/100ml	3										
E. coli (MPN)	MPN/100ml	3										

DGT = Detected at greater than
OG = overgrown
OGW = overgrown with

Table 4.5: Average Water Quality Change with Current, 30 m and 40 m Intake Depths – typical data

Kalamalka Lake	North 20m	North 30m	North 40m
Distance to pumphouse* m	275	828	1785
# of seiches exceeding 2 °C/yr	10	4	1
Max seiche temp. fluctuation °C	11.7	9.9	4.0
Avg temp range in distribution system °C	6-9	5-7	4-6
Est peak temp in distribution system °C	17	12	9
Total organic carbon mg/L	5.8	5.9	5.5
Chlorophyll-a ug/L	2.7	2.2	1.7
Turbidity NTU (IHA limit =1)	0.75	0.5	0.5
UV Transmissivity %	90.8	90.6	90.9
Avg algae counts (cells/mL)	1972	1717	1259
E. coli counts (2008 LRG FRESHET cfu/100 mL)	16	3	1
E. coli counts (2010 REG FRESHET cfu/100 mL)	3	2	0
E. coli counts (2011 LATE FRESHET cfu/100 mL; n=6)	4	6.5	1.3

* Actual engineered site and distance may vary

Quantifiable water quality changes are summarized in Table 4.5. It remains the task of water planners to determine the benefits of intake extension versus other capital improvements such as filtration. Extending the intake may support GVW's deferral of filtration application. Deferring filtration allows GVW to take advantage of on-going technological advances while still improving water quality in the interim under IHA's guidance.

Figure 4.1: Possible Intake Locations, North Arm Kalamalka Lake

4.5 Strength/Weakness Opportunities/Threats SWOT Analysis

A SWOT analysis provides a summary overview of the balance between the major positive and negative aspects of the GVW North Kalamalka Lake Intake. Only those aspects with the greatest potential to influence GVW water quality at present and into the future are considered in Table 4.6.

Table 4.6: Strength/Weakness Opportunities/Threats Analysis Summary of the GVW North Kalamalka Lake Intake

Strengths	Weaknesses
▪ The large size and depth of oligotrophic Kalamalka Lake helps maintains constant water quality in the main lake volume ▪ Low concentrations of cyanobacteria most of the year ▪ Dense urban areas are not close to the intake; land use near IPZ is mainly low-density residential ▪ SCADA system including temperature, turbidity chlorine ▪ Chlorination and UV disinfection operating ▪ Water operators have appropriate training levels and training is on-going ▪ Appropriate IHA directed water quality monitoring is reported; pro-active study of Kal Lk and research is funded by RDNO ▪ 30+ years of water quality and limnology records ▪ Trained, full-time staff at RDNO ▪ Co-ordination of Kal Lk study between DLC GVW and MoE, IHA, OBWB, DoC ▪ FIM and SHIM mapping are underway for Kal Lk and Coldstream Ck ▪ GVW has a WQ deviation response plan and a emergency response plan	▪ Rapid contamination of North Arm by dairy effluent spills on Coldstream Creek ▪ Intake is 0.6 m from substrate ▪ The 20 m depth of the intake provides some protection from surface contaminants but seiches regularly deliver surface water to the intake depth in the spring and fall ▪ Natural turbidity caused by the marl precipitation increases deposition in water mains, requiring increased cleaning (marling is also a strength because it reduces algae growth) ▪ Rapid changes in water quality occur in the North Arm via storm water inflows ▪ Lack of DoC and GVW control over Kalamalka Lake and adjacent land use ▪ Lack of NORD control over materials hauled on rail line and Hwy 97 ▪ Recreational and land development pressures on Wood-Kalamalka Lakes are increasing ▪ Back-up water supply available from Duteau but cannot meet peak demand

Opportunities	Threats
▪ Apply for License of Occupation over Intake Protection Zone from ILMB ▪ Encourage riparian restoration along Coldstream Creek and study ground water issues on the creek ▪ Extending the GVW intake to 40 m would provide better water quality and be more remote from sources of contamination but is expensive (extension to 30 m less effective) ▪ Establish and enforce no-build, no-disturb “Foreshore Zone” bylaw for foreshore protection that is currently in draft by DoC ▪ Increase intake clearance to 3 m ▪ Increase treatment of storm water directed to IPZ and encourage infiltration and rainwater capture ▪ Enter into discussions with rail line on chemicals hauled – exchange contact info ▪ Public Education about Kal Lk as a water source (get help from NGO’s) ▪ Encourage on-site storm water retention e.g. rain gardens, swales, detention tanks	▪ Cyanobacteria counts can exceed 2000 cells/mL in the spring and may be increasing with climate change ▪ Unusual winter cyanobacteria bloom occurred in Jan 2010 after manure incident on Coldstream Creek – Coldstream Creek and its watershed are not adequately protected ▪ Increasing population pressures for lake recreation, particularly motorized craft ▪ Several large outfalls are within 300 m of the intake ▪ Impact of remaining septic systems is not known ▪ Inadequate enforcement of recreation polluters and foreshore development violations

FIM-Foreshore Inventory Mapping
SHIM – Sensitive Habitat Inventory Mapping

5.0 Kalamalka Lake Intake Module 8: Recommendations

The summation of Modules 1, 2 and 7 lead to the recommendations to protect source water quality at the GVW North Kalamalka Lake Intake presented here as Module 8. All identified high-risk potential impacts to the N-Kal intake are addressed in these recommendations. The numbered hazards from Table 4.2 and 4.3 addressed by each recommendation are shown in the Risk box attached to each recommendation below.

.

5.1 Source Protection Action Plan

The only items worth placing into a source protection action plan are those that can be realistically achieved both from a financial and practical standpoint. Improvements that provide the best cost-benefit for risk reduction are itemized below. Implementation of these recommendations will help support the deferral of filtration application to IHA. Additional protection measures intended to protect unimpaired areas are also provided. All of these recommendations require the co-operation of residents, recreators and developers. Most of the watershed lies outside of the jurisdiction of GVW or DoC, restricting their ability to protect their source water. Similarly, lack of DoC and GVW control over Kalamalka Lake limits the protection these municipalities can provide.

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

5.2 High Priority Recommendations Based on Risk Rating

The following recommendations address at least one "high" risk rating as identified in Table 4.2 and 4.3.

5.2.1 Improve current 20 m N-Kal intake

Risk	Timeframe	Outcome
2 3 22 24 25 42	2012-3	Greater protection from sediment and pathogen re-suspension
Action 1	Options to improve the clearance could be examined. RDNO could initiate a study to examine options and provide preliminary costs to increase the intake clearance from the lake bottom to 3 m. These options may include extending the current intake 100 m out and raising it 3 m or flexing the current pipe to achieve the recommended clearance (R. Hrasko pers comm. 2010; Arnie Badke pers comm., 2010).	
Action 2	After the options study, the cost-effectiveness can be determined, and capital planning initiated.	
Action 3	Approximately every second year, when divers clear the intake screens, they could recover some of the material they clean off the screens for testing, measure the clearance and photograph the intake.	

5.2.2 Cost benefit analysis of extending intake

Risk	Timeframe	Outcome
1 2 3 6 7 8 9 10 13 18	2011 onward	Selection of best possible gain in water quality for the expenditure between intake extension and expanding the Water Treatment Plant
Action 1	Under GVW's guidance, one full year of detailed sampling twice monthly at 0, 20m, 30m, 40m, and 47m commenced in spring 2011	
Action 2	GVW could complete a cost benefit analysis on intake extension to 30 m or to 40 m based on all available studies	

5.2.3 Investigate options for the Intake Protection Zone (IPZ)

Risk	Timeframe	Outcome
1 3 4 7 9 10 12 13 15	immediate	Increased source protection by pre-empting or placing limits on future developments (e.g. marinas, house boat moorage) and also public education, spill prevention.
Action 1	DoC and GVW investigate applying to Front Counter BC for either a License of Occupation (or head-lease) or a License for Community Purposes over the Intake Protection Zone. NOTE: Staff at Front Counter BC indicated that, “ILMB would not be prepared to consider issuing tenures over large areas of Crown land foreshore or otherwise, to provide protection to water intakes or water quality” – Bernadette Aura, Natural Resource Officer, July 26, 2010, however, precedents exist for environmental reasons and houseboat exclusion (Peachland, City of Kelowna, District of West Kelowna, Westbank First Nation)	
Action 2	A letter outlining the IPZ area and its purpose/importance could be submitted to Front Counter BC with a formal request that any application to Front Counter BC within the IPZ be forwarded to RDNO and DoC for comment, regardless of the license application outcome.	

5.2.4 Storm water outfall improvements

Risk	Timeframe	Outcome
9 10 14 15 18	2011-onward	Prevent contaminants from reaching IPZ
Action 1	RDNO to assist DoC to develop BMP’s for the 1/100 year flood at new developments. The volume carried by new storm water outfalls that would discharge within the intake protection zone to be minimized or eliminated by on-site storm water management. BMPs may include soak-away zones, detention ponds, rain gardens etc. Localized on-site soak-away disposal could be considered for street run-off as well as rainwater gardens for roof drain runoff to lower the total amount of storm water in areas where the geology permits to-ground disposal.	
Action 2	RDNO with co-operation of DoC could implement a monitoring plan for existing storm water outfalls to include first flush, mid, and late sampling of storm events for at least one year for at least: Cl to monitor for salt; nitrate to monitor for nutrients and *E. coli* to monitor for fecal contamination. The data can be used to rank the threat posed to the intake.	

5.2.5 Bylaw to prohibit multi-slip marinas within the IPZ

Risk	Timeframe	Outcome
11 12	2011-12	Increased source protection by pre-empting future marina development and also spill prevention and development community education.
Action 1	RDNO should encourage and assist DoC and CoV to draft a bylaw to specifically prohibit multi-slip marinas within the IPZ, particularly those designed for power boats and houseboats, that could be incorporated into the DoC or CoV bylaws.	
Action 2	RDNO should encourage and assist DoC and CoV in notifying the development community so they can devise alternates such as boat storage warehouses and valet service.	

5.2.6 Watershed control program

Risk	Timeframe	Outcome
1 3 5 7 18 39	Long-term commitment	Significantly improved water quality entering North Arm; supports deferral of filtration
Action 1	RDNO to continue to work with DoC to review the recommendations of the Ecoscape SHIM report on Coldstream Creek. The report recommendations are aimed at enhancing natural habitats which assist the goal of the IHA directed watershed control program. This will require long term political will and buy-in from adjacent residents. Initial restoration projects that are now underway should be used as demo projects with before/after documentation.	
Action 2	RDNO and DoC could mount a storm water monitoring program that includes agricultural land runoff that reaches the Coldstream storm drain system and the stormwater ditches in Lavington.	
Action 3	RDNO and DoC could request assistance from the Regional Drinking Water Team on watershed issues on Crown land where they have no formal jurisdiction.	
Action 4	A ground water monitoring program using existing wells and monitoring wells would answer several outstanding questions on nutrient sources to Coldstream Creek.	
Action 5	DoC and RDNO could develop specific objectives and deliverables for managing fecal contamination from Coldstream Creek with guidance from IHA. This should probably focus on establishing/maintaining functional riparian buffers and minimizing direct inputs (e.g. storm water; animal access points). MoE has a monitoring project underway and valuable information will come from it.	

5.2.7 Bylaw to protect Kalamalka Lake foreshore

Risk	Timeframe	Outcome
12 13 14	immediate	Increased source protection
Action 1	DoC has approved a W1 water zone to define the use of foreshore. The DoC land use planning department could use other foreshore policies and BMP's to draft enforceable (no-build, no-disturb) set-backs from the high water mark, recognizing the limitations of DoC's jurisdiction, perhaps modeled after Rural Vernon Bylaw 1708.	

5.2.8 Public education

Risk	Timeframe	Outcome
12 13 15 17	On-going	Better voluntary control of contaminants to Kalamalka Lake Prevent contaminants from reaching IPZ
Action 1	RDNO to provide public education through boat launch signage of the IPZ, including encouraging off-water refuelling and providing who-to-call after a spill would be beneficial at boat launches	
Action 2	Public education through open houses, targeted mailings and other initiatives encourage responsible public behaviour. For example, a directed mailer to shoreline owners could highlight their rights, ownership and responsibility, and explain best practises to protect the lake. Mailers to subdivisions with storm water entering the North Arm could explain where their storm water goes in relation to the intake and how to improve storm water quality.	
Action 3	RDNO should ensure that dog feces collection bags continue to be provided, and continue education for dog-owners regarding the costs of not collecting dog feces in RDNO parks. This initiative can improve storm water quality and could be implemented here (Appendix 3).	

5.2.9 Annual overview of changes to North Arm, Kalamalka Lake

Risk	Timeframe	Outcome
13 15 17 23 44	Every two years	Knowledge of changes to aid planning, processing applications and compliance
Action 1	RDNO with DoC assistance and/or a FIM consultant could prepare a date-stamped video survey of the North Arm from a boat to provide a permanent record of shoreline change. This recommendation will capture any modifications made without permits and identify those with the potential to incrementally degrade water quality in the North Arm.	

5.2.10 Clean-up preparedness for a petroleum hydrocarbon or sewage spill

Risk	Timeframe	Outcome
6 11 12 14 18	Long-term commitment	Preventing pathogen contamination within IPZ
Action 1	GVW with assistance from DoC and Parks co-operate to provide a clean-up kit for a petroleum hydrocarbon (gas/oil etc.) spill into Kalamalka Lake could be stored with the CoV Fire Department or Search and Rescues, and at the major boat launches (Kekuli Bay, Kalavista). Spills should be reported and cleaned up in accordance with the Spill Reporting Regulation (B.C. Reg.263/90).	
Action 2	RDNO could outline their concerns about risks to drinking water quality identified in this report and ensure that the local HAZMAT team are equipped and trained to handle lake spills from all possible sources, particularly within the IPZ.	
Action 3	RDNO may wish to consider encouraging non-motorized recreation by planning facilities that promote sailing, kayaking, canoeing, all of which have far less potential to impact intake water quality than motorized watercraft.	

5.2.11 Study effects of Kalavista (Lost) Lagoon on North Arm, Kalamalka Lake

Risk	Timeframe	Outcome
4 7 9 10 13	On-going	Provides basis for decision on lagoon modifications
Action 1	RDNO with help from proponents could hire a consultant to study impacts on lake/intake from flushing or dredging of Kalavista Lagoon. Pathogen assessment will be essential prior to flushing. The impacts of additional stormwater inflows could also be determined.	

5.2.12 Discourage waterfowl and gulls on public beaches

Risk	Timeframe	Outcome
2 4 17 18 19 43	Long-term commitment	Preventing pathogen contamination within IPZ
Action 1	RDCO with assistance from CoV could erect signage discouraging waterfowl feeding and daily garbage pick-up from the beach and parking lots will help limit waterfowl feces contamination of the public beaches adjacent to the intake	
Action 2	Daily garbage pick-up from the beach and parking lots will help limit waterfowl feces contamination of the public beaches adjacent to the intake. A program of beach grooming and daily garbage pick-up has resulted in a substantial reduction of avian *E. coli* for the City of Kelowna and could be implemented here (Appendix 3)	
Action 3	Providing barriers to prevent walk-on goose access to docks is important.	
Action 4	RDNO could continue to support the Okanagan Goose Management Program that successfully implements an addling program.	

5.2.13 Discussions with railway on potentially hazardous goods they transport

Risk	Timeframe	Outcome
14 35	On-going	Better risk abatement with knowledge of goods hauled and cars sided along the North Arm
Action 1	GVW and DoC could open discussions with Knighthawk Rail concerning what they carry on the line paralleling Kalamalka Lake shoreline within 30 m. Currently, their emergency response plan is to call the local Hazmat Team.	
Action 2	GVW and DoC can question the practice of siding chemical cars for extended periods beside Kalamalka Lake should be reviewed. RDNO and DoC could formally request that no chemical cars be stored (sided) near the lake, particularly along the North Arm (All of rail line visible on Figure 3.1).	

5.2.14 Collaboration with City of Vernon reclaimed water and RDNO landfill

Risk	Timeframe	Outcome
5 16 19 27 37 43	Commence in 2011	Better understanding of source protection and supports deferral application
Action 1	GVW water quality manager could meet annually with the manager of the reclaimed water program and the solid waste manager to review on-going environmental programs, protection measures and monitoring results. Data collected from monitoring wells on both the landfill and the MacKay Reservoir subsurface drainage could be reported annually to the GVW water manager. Spills (if any) should be reported.	
Action 2	Recommendations regarding further protection work (if required) and bringing in MoTH can be discussed and developed at an annual meeting.	

5.3 Moderate Priority Recommendations Based on Risk Rating

The following recommendations address predominately “moderate” risk ratings as identified in Table 4.2 and 4.3.

5.3.1 Basin-wide issue partners

Risk	Timeframe	Outcome
28 29 36 39	Long-term commitment	Maintaining and improving Kalamalka Lk water quality through agency co-ordination
Action 1	Reports and possibly meetings/presentations could be co-ordinated by the OBWB whose mandate includes facilitating integrated management of the Kalamalka Lake watershed. These meetings should improve communication and reduce duplication of effort.	

5.3.2 Timing of rototilling for milfoil control

Risk	Timeframe	Outcome
2 3 25	Long-term commitment	Minimize the frequency of water quality advisories in the winter, possibly by roto-tilling during freshet
Action 1	The impact of the milfoil roto-tilling on the N-Kal intake turbidity and UV transmissivity is under investigation and OBWB and GVW could co-ordinate the monitoring.	
Action 2	The milfoil roto-tilling will be targeted in the Bacterial Source Tracking study, currently underway with funding assistance from OBWB.	

5.3.3 Maintain Kalamalka Protected Area

Risk	Timeframe	Outcome
29 30 34 36 37	2011	Kalamalka Protected Area has a key role in the preservation of surface and ground water input quality into Kalamalka Lake along its length.
Action 1	RDNO, DoC and Vernon could petition the Province to maintain its status as a natural park in perpetuity and to encourage a zero-tolerance policy to recreational or land development activities within its boundaries that have the potential to adversely impact water quality.	
Action 2	All Park regulations pertaining to aquatic protection should be vigorously enforced by Park's staff.	

5.3.4 GIS Mapping of Kalamalka Lake

Risk	Timeframe	Outcome
10 13 14 151618	Annual updates	Determines intake-land use conflicts; faster emergency responses
Action 1	RDNO could incorporate source water protection objectives into their current GIS systems and continue to update the GIS system as studies and information becomes available. Discussions with GIS staff could be initiated to determine what types of information should be entered into GIS, identify data gaps and enter data relevant to regional emergency response.	

.

5.3.5 Information exchange

Risk	Timeframe	Outcome
20 21 40 41	On-going	Faster warning of algae blooms and turbidity spikes
Action 1	Exchange GVW turbidity data for Okanagan Springs Brewery ATP data on Kal Lk water. GVWs SCADA turbidity would provide the Brewery with useful information at no charge and their ATP data would likewise provide data on the amount of algae in the water at no cost to GVW.	

Report Prepared By:

Mrs. Heather Larratt
Aquatic Biologist, R.P.Bio.

Literature Cited or Consulted

Anderson, Des, 2009. 2009 Water Supply Outlook and Okanagan Lake Operation. Water Stewardship Division BC Ministry of Environment

Ashley, K., MacGregor, B., Shepard, B., Sebastian, D., Matthews, S., Vidmanic, L., Ward, P., Yassien, H., McEachern, L., Andrusak, H., Lasenby, D., Quirt, J., Whall, J., Taylor, E., Kuiper, P., Troffe, M., Wong, C., Scholten, G., Zimmerman, M., Epp, P., Jensen, V., and Finnegan, R. Okanagan Lake Action Plan Year 3 (1998) Plan. B.C. Fisheries Report Number RD 78 1999.

Baker, Lawerence, A., 2007. Storm water Pollution: Getting at the Source of the problem with the end-of-pipe approach for storm water pollution. On-line Journal Storm water http://www.stormh2o.com/index.aspx

BC Ministry of Environment, 1975. Synopsis of Kalamalka –Wood Lake Study.

BC Ministry of Environment, No Date. Water Quality: Boating and Marine Activities. Accessed Sept 20 2010. http://www.env.gov.bc.ca/wat/wq/nps/NPS_Pollution/boating/Boating_Main.htm

Bitto, Adenike and Abdalla Aldras, 2009. Prevalence of *Giardia* and *Cryptosporidium* in Muskrats in Northeastern Pennsylvania and New York, Journal of Environmental Health, April 2009.

Bryan, J.E., 1990. Water Quality of Okanagan, Kalamalka and Wood Lakes. B.C. Ministry of Environment.

Bryan, J. and Jensen, V. 1996. Review of Okanagan Lake Physical and Chemical Limnology. Pp 44-56 In Andrusak, H. S. Matthews, I McGregor, K Ashley, R. Rae, A. Wilson, J. Webster, G Andrusak, L. Vidmanic, J Stockner, D. Sebastian, G. Scholten, P. Woodruff, B. Jantz, D. Bennett, H. Wright, R. Withler, S. Harris. 2005. Okanagan Lake Action Plan Year 9 (2004) Report

Carter, A.M., R. E. Pacha, G. W. Clark, and E. A. Williams, 1987. Seasonal Occurrence of Campylobacter spp. in Surface Waters and Their Correlation with Standard Indicator Bacteria. Applied and Environmental Microbiology, Mar. 1987, p. 523-526 Vol. 53, No. 3

City of Kelowna, 1998. Okanagan Lake Water Quality Intake Study June – August, 1998. City of Kelowna Water Operations 951 Raymer Ave., Kelowna, B.C.

Clark, Renee 2007. 2007 Annual Overview of Greater Vernon's Drinking Water Quality. Greater Vernon Water, 3rd Floor 3105 33rd Street, Vernon BC

Clark, Renee 2008. Greater Vernon Water Quality Report 2008. Greater Vernon Water, 3rd Floor 3105 33rd Street, Vernon BC

Clements, W.A. Rawson D.S. McHugh, J.L. 1939. A Biological Survey of Okanagan Lake. B.C. Fisheries Research Board of Canada Bulletin No. LVI

Coldstream Creek Restoration Project, 2000. Coldstream Creek Restoration Project Phase 1: Summary Report and Recommendations for Future Restoration Efforts in the Coldstream Creek Watershed (Pg 11 and 26)

Cooke G.D. and Kennedy, R.H. 2001. Managing Drinking Water Supplies. Lake and Res. Management Vol 17, No3, September 2001.

Cox, Peter, Merran Griffith, Mark Angles, Daniel Deere, and Christobel Ferguson, 2005. Concentrations of Pathogens and Indicators in Animal Feces in the Sydney Watershed Applied and Environmental Microbiology, October 2005, p. 5929-5934, Vol. 71, No. 10 0099-2240/05/$08.00+0 doi:10.1128/AEM.71.10.5929-5934.200508).

Dai, X. and J. Boll, 2006. Settling Velocity of Cryptosporidium parvum and Giardia lamblia. Water Research, Vol 40 Issue 6 pp 1321 – 1325.

Department of Natural Science, 2003, Density of Goose Feces in Vilas Park http://natsci.edgewood.edu/wingra/wingra_goosefeces.htm (Accessed January 11, 2008).

Daniel P. Deregnier, Larry Cole, Daniel G. Schupp,And Stanley L. Erlandsen, 1989. Viability of Giardia Cysts Suspended in Lake, River, and Tap Water. Applied and Environmental Microbiology, May 1989, p. 1223-1229 Vol. 55, No. 5
Copyright © 1989, American Society for Microbiology.

Dill, Peter, 1972. Geology of the Main Okanagan Lakes (chpt 4).

Donskow, K., A. Bajer, M. Bednarska, and E. Sinski. 2005. Experimental transmission of *Cryptosporidium parvum* isolates from wild rodents and calves to laboratory bred common voles (*Microtus arvalis*). Acta Parasitologica 50: 19–24.

Doyle, Michael P. and Marilyn C, Erickson, 2006. Closing the Door on the Fecal Coliform Assay. Microbe, Volume 1, Number 4.

Drieschner, Dannielle and Kyle Hawes, 2009. Sensitive Habitat Inventory and Mapping (SHIM) – 2009 Survey Period for Coldstream Creek, Brewer Creek and Craster Creek.

Dougherty, Jennifer A. 2005. Septic System Effluent, an Unconstrained Source for Pharmaceuticals and Personal Care Products (PPCPs) in Ground and Surface Water US EPA Grant Number: F5B20266

Dechesne, Magali and Emmanuel Soyeux, 2005. Assessment of source water pathogen contamination*Journal of Water and Health, 2007Q* IWA Publishing 2007

Elmund, G. Keith; Allen, Martin J.; Rice, Eugene W., 1999. Comparison of Escherichia coli, Total Coliform, and Fecal Coliform Populations as Indicators of Wastewater Treatment Efficiency Water Environment Research, Volume 71, Number 3, May/June 1999 , pp. 332-339(8).

Environment Canada, 2010. Ground water Contamination. Accessed Aug 30 2010.http://www.ec.gc.ca/eau-water/default.asp?lang=En&n=6A7FB7B2-1

Fish, J.T. and G.W. Pettibone, 1995. Influence of freshwater sediment on the survival of *Escherichia coli* and *Salmonella* sp. as measured by three methods of enumeration. Letters in Applied Microbiology. Volume 20, Issue 5, pages 277–281, May 1995.

Fisher, M.M., R.R. Reddy and R.T. James, 2001. Long-Term Changes in the Sediment Chemistry of a Large Shallow Subtropical Lake. Lake and Res. Management Vol 17, No3, September 2001.

GDH Solutions, Summit Environmental and Ipsos-Reid, 2010. Boat Launch Study ofKaamalka Lake and Okanagan Lake Draft Report Sept 4, 2010. Prepared for Regional District od North Okanagan

Gerba, C.P. and J.S. MacLeod, 1976. Effect of Sediments on the Survival of Fish in Marine Waters, Appl. Environ. Micrbiol., 1976. Jy 32(1) 114 – 120.

Godshalk, G.L. and R.G. Wetzel, 1977 Decomposition of macrophytes and the metabolism of organic matter in sediments p. 258-265 IN Interactions between sediments and freshwaters Proc. Int. Symp. Junk.

Government of Canada, 2004 Guidelines for Canadian Drinking Water Quality: Supporting Documentation Protozoa: Giardia and Cryptosporidium
Prepared by the Federal-Provincial-Territorial Committee on Drinking Water of the Federal-Provincial-Territorial Committee on Health and the Environment
http://www.hc-sc.gc.ca/ewh-semt/pubs/water-eau/giardia_cryptosporidium-eng.php

Ground Water Foundation, The, No Date. Accessed Sept 19 2010. http://www.groundwater.org/gi/ppcp_about.html

Grigorovich, I. A., J. R. Kelly, J. A. Darling, and C. W. West. 2008. The quagga mussel invades the Lake Superior Basin. Journal of Great Lakes Research 34(2): 342-350.

Hansen, Patti and Jack Allingham, 2006. District of Lake Country's Water Systems 2006 Water Operations Report. D of LC 10150 Bottom Wood Lake Road Lake Country BC V4V 2M1 www.lakecountry.bc.ca

Hayco (Hay and Company Consultants Inc.) 2002. Okanagan Lake Limnology Study - Helping to Improve Water Quality and Safety IN Innovation November 2002.

Hay and Company, 2009. Kelowna Old Floating Bridge Pontoon Sinking – Technical Memo January 12, 2009 File V13201134 and February 13, 2009 File V13201184
Hayco (Hay and Company Consultants Inc.) 2000. Okanagan Lake Limnology Study.

Health Canada, 2010. Criteria for Exclusion of Filtration in Waterworks Systems. http://www.hc-sc.gc.ca/ewh-semt/pubs/water-eau/turbidity/chap_3-eng.php

Health and Welfare Canada 1992. Guidelines for Canadian Recreational Water Quality Canada. Prepared by the Federal-Provincial Working Group on Recreational Water Quality of the Federal-Provincial Advisory Committee on Environmental and Occupational Health

Hilton, J., J.P. Lishman and P.V. Allen, 1986. The Dominant processes of sediment distribution and focusing in a small eutrophic, monomictic lake

Hospital, Aurelien, Edwin Wang and James Stronach, 2011. City of Kelowna Drinking Water Source Protection Report. EBA File V13201297.

Howard, T.E., 1971. Report on Okanagan Lake Nutrient, Dissolved Oxygen and Transparency in Spring, 1970. B.C. Research, Division of Applied Biology

Hudnell H. Kenneth, 2007. US EPA International Symposium on Cyanobacterial Harmful Algal Blooms (ISOC-HAB), Chapter 13.

Interior Health Authority (IHA) 2008. Issue Paper: Planning for Drinking Water Filtration, Appendix C.

Jamieson, Rob, Doug M. Joy, Hung Lee, Ray Kostaschuk and Robert Gordon, 2005. Transport and deposition of sediment-associated *Escherichia coli* in natural streams Water Research Volume 39, Issue 12, Pages 2665-2675

Kerr Wood Leidal and Dobson Engineering, 2008. Duteau Creek Watershed Assesment and Recommendations for Source Protection. KWL File 773.052

Knox County Website ND, www.knoxcounty.org/health/**pharmaceutical**_waste.php *Accessed on Feb 14, 2010.*

Larratt, H.M., 2007. Biological Enhancement of Mine Ponds and Assessment of Adjacent Natural Lakes – Highland Valley Copper 2006 Annual Report

Larratt H.M., 2009a Kalamalka Lake Water Quality Study: Microflora, Water Chemistry & Thermal Profiles 2008.

Larratt, H.M., 2009b. Kalamalka Lake Water Quality Study: Microflora, Water Chemistry & Thermal Profiles 2009.

Larratt, H.M., 2009c. Deep Okanagan Lake Biology Report. For: Okanagan Basin Water Board, grant-funded publication.

Larratt, H.M., 2011. Zebra Mussel and Quagga Mussels: Information, detection and decontamination strategies for aquatic invasive species. Available from heather@larratt.net

Larratt, H.M., Mark Freberg and Bob Hamaguchi, 2008. Developing Tailings Ponds and Pit Lakes as Bioreactors and Habitat Cost - Effective Successes at Highland Valley Copper. available through HVC Highland Valley Copper Box 1500 Logan Lake, BC V0K 1W0

LeChevallier, Mark, W., and Kwok-Keung Au, 2004. Water Treatment and Pathogen Control – Process Efficiency on Achieving Safe Drinking Water, World Health Organization, IWA Publishers, London. Pp 53-55.

McNamara, Christopher J., Michael J. Lemkk, and Laura G. Leff, 1997. Characterization of Hydrophobic Stream Bacteria Based on Adhesion to n-Octane OHIO J. SCI. 97 (3): 59-61, 1997 Department of Biological Sciences, Kent State University, Kent, OH 44242

MacKenzie, W. R., N. J. Hoxie, M. E. Proctor, M. S. Gradus, K. A. Blair, D. E. Petersen, J. J. Kazmierczak, D. G. Addiss, K. R. Fox, J. B. Rose, and J. P. Davis. 1994. A massive outbreak in Milwaukee of Cryptosporidium infection transmitted through the public water supply. New England J. Med. 331:161-167.

Mallevaille, J., and Suffet, I.H., 1987. Identification and Treatment of Tastes and Odours in Drinking Water, AWWA.
Meger, Patti, 2007 Annual Water Report for District of Lake Country.

Meays, Cynthia, L. 2005. Bacterial Source Tracking of *E. coli*. http://dspace.library.uvic.ca:8080/handle/1828/57

Mills et al., 1999). Mills, E.L., J. R. Chrisman, B. Baldwin, R. W. Owens, R. O'Gorman, T. Howell, E. F. Roseman, and M. K. Raths. 1999. Changes in the Dressenid Community in the Lower Great Lakes with Emphasis on Southern Lake Ontario. J. Great Lakes Res. 25(1):187-197.

(MoE) Baric, Keith and Robertson, Brian 2009. Re: Ponderosa Enterprises Ltd. Marina – Wood Lake. Comments from the Ecosystems Section of Environmental Stewardship Division February 5, 2009 File 58000-20/89052 to ILMB

Nijsten, R., N. London, A. van den Bogaard and L. Stobberingh, 1996. Antibiotic resistance among Escherichia coli isolated from faecal samples of pig farmers and pigs Journal of Antimicrobial Chemotherapy (1996) 37, 1131-1140

Nordin, R.N., 1985. Water Quality Criteria for Nutrients and Algae Technical Appendix. B.C. Ministry of Environment, Water Management Branch, 104 p.

Nordin, R.N., Swain, L., Nyman, R., Rocchini, R., and Wetter, D. 1988. Phosphorus in the Okanagan Valley Lakes; Sources, Water Quality Objectives and Control Possibilities.

O'Neill, Charles, R. Jr., 1993. Control of Zebra Mussels in Residential Water Systems, New York Sea Grant Extension Specialist [From: *Sea Grant: Coastal Resources Fact Sheet*, July 1993. *Reformatted for Web.*]

OKBS, Okanagan Basin Water Study, 1974. Summary Report of the Consultative Board, March 1974. Chapter 4, Geology of the Main Valley Lakes.

Ontario Ministry of Environment N.D. Accessed Sept 1, 2010. Understanding Storm water Management; An Introduction to Storm water Management Planning and Design http://www.ene.gov.on.ca/cons/4328.htm

Palmer, M.C., 1980. Algae in Water Supplies. U.S. Dept. of Health, Education and Welfare.

Pettibone, Gary W. Kim N. Irvine and Kelly M. Monahan, 1999. Impact of a Ship Passage on Bacterial Levels and Suspended Sediment Characteristics in the Buffalo River, New York. Water Research,Volume 30 Issue 10 Oct 1996 pp 2517 – 2521.

Reemtsma, Helge, Deborah A. Grimm and Siddhartha Mitra, 2003. Pharmaceuticals and personal care products (PPCPs) in surface and treated waters of Louisiana, USA and Ontario, Canada IN The Science of The Total Environment Volume 311, Issues 1-3, 20 July 2003, Pages 135-149

Seiler, Ralph L., Steven D. Zaugg, James M. Thomas and Darcy L. Houcroft, 1999. Caffeine and Pharmaceuticals as Indicators of Wastewater Contamination in Wells. USGS Vol 37 No3 GROUND WATER May/June 1999. pg 405 – 410.

Saleha, A.A., Tin Tin Myaing, K.K. Ganapathy, I. Zulkifli, R. Raha and K. Arifah, 2009. Possible Effect of Antibiotic-Supplemented Feed and Environment on the Occurrence of Multiple Antibiotic Resistant Escherichia coli in Chickens International Journal of Poultry Science 8 (1): 28-31, 2009

Seiler, R.L., ND. Chemicals from Consumers, Retrieved May 30 2011. http://www.waterencyclopedia.com/Ce-Cr/Chemicals-from-Consumers.html

Sokal, Michael, (MoE), 2009. Coldstream Creek Water Quality Monitoring 2008 – 2009. Project Summary – June 27, 2009. BC Ministry of Environment Protection Division, Penticton.

Stantec, 2007. Lake Ontario Intake Assessments. PowerPoint prepared by John Langan of Stantec

Templeton, Michael, R., Raymond E. Cantwell, Claire Quinn, Ron Hofmann and Robert C. Andrews, 2009. Pilot-scale assessment of the impacts of transient particulate water quality events on the UV disinfection of indigenous total coliform bacteria in drinking water treatment. Journal of Water Supply: Research and Technology—AQUA | 58.1 | 2009.

U.S. EPA, 1998. Giardia: Human Health Criteria Document United States Office of Water EPA-823-R-002 Environmental Protection 4304 August 1998.

U.S. Geological Survey, 2007.Modeling Hydrodynamics, Water Temperature and Suspended Sediment. http://pubs.usgs.gov/sir/2007/5008/section5.html

Van Gemert, L.J. and Nettenbreijer, A.H. 1977. Compilation of Odour Theshold Values in Air and Water. Natl. Inst. for Wtr. Supply, Voorburg, Netherlands.

Vernon, City of 2010. City of Vernon Website, Water Reclamation and Spray Irrigation http://www.vernon.ca/services/utilities/reclamation/index.html

Walker, I.R., E.D. Reavie, S. Palmer and R.N. Nordin, 1994. A Palaeoenvironmental Assessment of Human Impact on Wood Lake, Okanagan Valley, British Columbia, Canada. Quarternary International Vol.14 pp 58 – 70.

Wang, Zhendi and Scott A. Stout, 2007. Oil Spill Environmental Forensics; Finger-printing and Source Identification. Academic Press San Diego, pg 384.

Washington State Department of Health, N.D. Coliform Bacteria and Drinking Water. http://www.doh.wa.gov/ehp/dw/programs/coliform.htm

Wetzel, Robert, G., 2001 Limnology, Lake and River Systems, Third Edition. Academic Press, San Diego.

*www.inspecSourceedia.com/**septic**/Drugs_in_**Septic**_Tanks.htm* - Cache ND Accessed Feb 15, 2010.

http://www.windfinder.com/windstats/windstatistic_kelowna_airport_okanagan_lake.htm ND Accessed July 11, 2011.

Ziegler, Peter E., Susan E. Wade, Stephanie L. Schaaf, Yung-Fu Chang and Hussni O. Mohammed, 2007. *Cryptosporidium* Spp. From Small Mammals In The New York City Watershed Department of Population Medicine and Diagnostic Sciences, College of Veterinary Medicine, Cornell University, Ithaca, New York 14853, USA

Water Bucket No Date, Accessed Sept 19, 2010. http://www.waterbucket.ca/okw/sites/wbcokw/documents/media/150.pd

Other Resources:

(USGS, 2002), USGS Zebra and Quagga Mussel Distribution Maps USGS (2002) *Dreissena polymorpha*. http://nas.er.usgs.gov/zebra.mussel/docs/sp_account.html. Cited 2 Nov 2002

SeaGrantPennsylvania
http://pserie.psu.edu/seagrant/publications/fs/Quagga_Mussel_12-2003.pdf

Personal Communications:

Arnie Badke General Manager of Engineering

Al Cotsworth P. Eng., Ultility Manager, RDNO

Nicole Kohnert, P.Eng., FEC Manager of Regional Engineering Services

Renee Clark, Certified Water Quality Technologist, RDNO Water Quality Manager

Tricia Brett, M.Sc., RDNO, part-time employee

Appendix 1: Supporting Documentation

www.kelownacapnews.com
NEWS

▼ POPLAR POINT JULY 15 2009

Waste oil dumped into Okanagan Lake

The Kelowna Fire Department was called early Monday morning to respond to an apparent oil spill in the city's north end.

The oil spill was first spotted at 7:30 a.m. at the Poplar Point area of Okanagan Lake.

On arrival of the initial response crew, the fire department discovered that vandals had taken oil containers and spilled the contents on a barge and in the water around the barge.

With the assistance of the fire department and the Marine Rescue spill response trailer, oil booms and spill pads were distributed along the 200-foot area of the shoreline.

The provincial ministry of environment and the RCMP were also alerted.

Assistant fire chief Bryan Collier said it appears that 20 litre pails of hydraulic oil and motor oil were taken to the area and dumped.

AUG 15 2009

Sewage leaks into lake

Raw sewage has leaked into Okanagan Lake at the Westbank Yacht Club boat launch on Gellatly Road in West Kelowna.

The leak occurred Friday morning during a downpour. 1407

CORD spokesman Chris Radford said that surface water deluged a manhole, causing it to overflow at 9 a.m. Aug. 14. Runoff into Okanagan Lake continued for approximately 45 minutes. "It was a combination of raw sewage and storm water," said Radford.

As a result the boat launch at Gellatly Bay is closed indefinitely. Water samples from the Gellatly Bay boat launch were being taken Friday. As of press deadline Interior Health and the B.C. Ministry of Environment were working to determine when it would be safe to reopen the launch.

For more information, visit www.districtofwestkelowna.ca.

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

▼ KELOWNA

Authorities quick to control gasoline leak into lake

SEAN CONNOR/CAPITAL NEWS

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

JENNIFER SMITH
STAFF REPORTER

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

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

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

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

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

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

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

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

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

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

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

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

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

jsmith@kelownacapnews.com

Fire-Fighting Storm water Contaminates Mill Creek and City Beach, Kelowna

Fire's toxic chemical trail leaves questions

Aug 4, 2010

KATHY MICHAELS
CONTRIBUTOR

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

SEE TOXIC A4

SEAN CONNOR/CAPITAL NEWS

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

Appendix 2:
Activities Impacting the Intake Protection Zone Checklist

Municipal

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

Residential Yard Maintenance, Landscaping & Gardening

- Minimize the disturbance of shoreline areas by maintaining natural vegetation cover.
- Minimize high-maintenance grassed areas.
- Replant lakeside grassed areas with native vegetation.
- Do not import fine fill or sand for beaches.
- Use paving stones instead of pavement.
- Stop or limit the use of fertilizers, pesticides.
- Don't use fertilizers in areas where the potential for water contamination is high, such as sandy soils, steep slopes, or compacted soils.

Agriculture

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

Onsite Sewage Systems

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

Auto Maintenance

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

Boating

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

-After BC Lake Stewardship Society 2008

Appendix 3: *E. coli* Source Tracking in City of Kelowna Creeks Receiving Storm Water and at Beaches

City of Kelowna Creeks with Storm Water 2006
E. coli Bacterial Source Tracking

Probable Source	Count	Percent
Human	3	13
Canine	6	25
Bovine		0
Horse		0
Song birds		0
Gulls	1	4
Duck	7	29
Canada Goose	1	4
Racoon		0
Deer	4	17
Unknown	2	8
SUM	24	100

City of Kelowna Creeks and Beaches 2006
E. coli Bacterial Source Tracking

Probable Source	Count	Percent
Human	8	8
Canine	15	14
Bovine	1	1
Horse		0
Song birds	14	13
Gulls	18	17
Duck	20	19
Canada Goose	16	15
Racoon	4	4
Deer	5	5
Unknown	4	4
SUM	105	100

City of Kelowna Creeks with Storm Water 2008
E. coli Bacterial Source Tracking

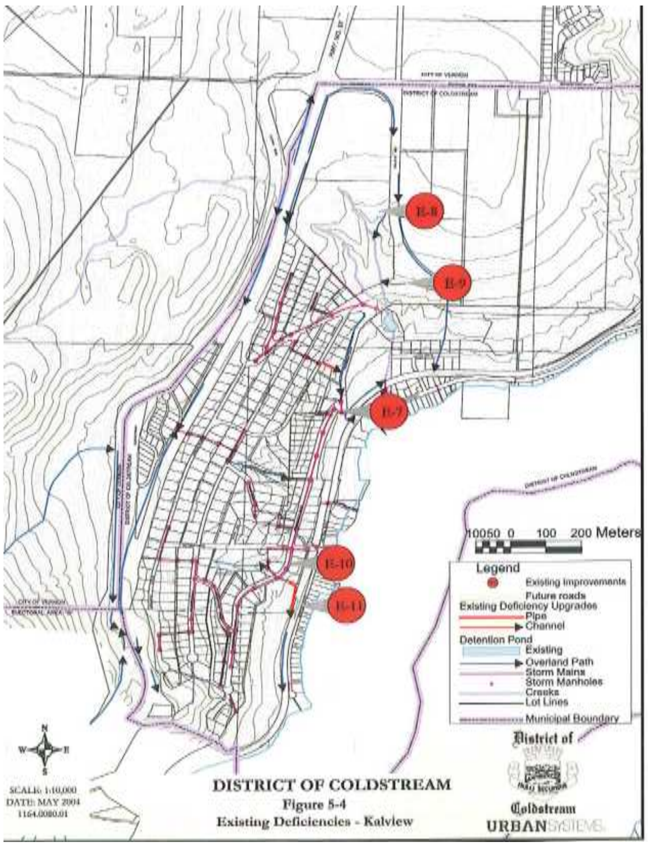
Probable Source	Count	Percent
Human	3	5
Canine	2	3
Bovine	6	9
Horse	2	3
Song birds	14	21
Gulls	5	8
Duck	7	11
Canada Goose	12	18
Racoon	1	1
Deer	6	9
Unknown	8	12
SUM	66	100

City of Kelowna Creeks and Beaches 2008
E. coli Bacterial Source Tracking

Probable Source	Count	Percent
Human	10	5
Canine	13	6
Bovine	21	10
Horse	11	5
Song birds	44	21
Gulls	18	8
Duck	18	8
Canada Goose	26	12
Racoon	6	3
Deer	19	9
Unknown	28	13
SUM	214	100

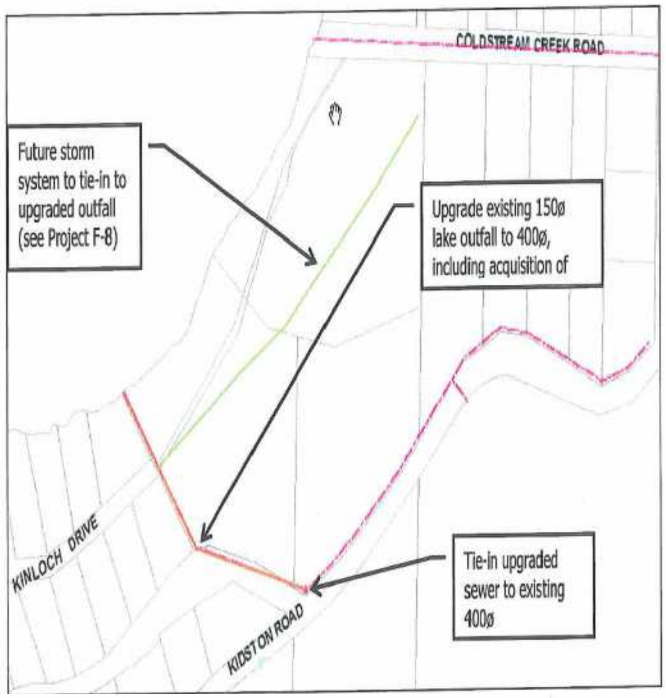
Courtesy of City of Kelowna, Analyses performed at UVic

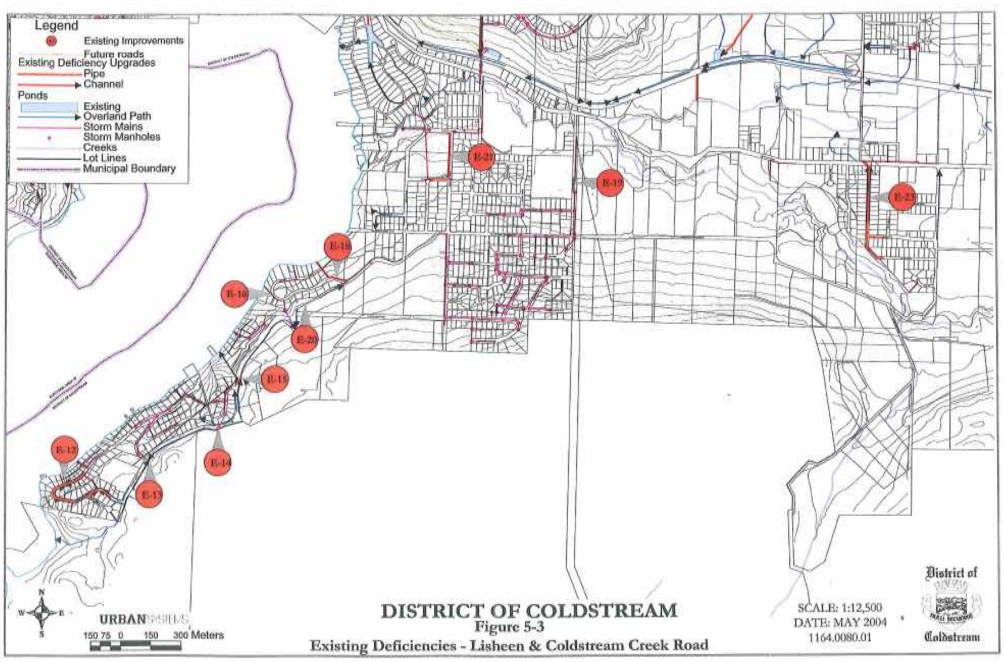
Appendix 4: Locations of Proposed DoC Storm Sewer / Sewer Upgrades



Description: According to as-built data, the storm sewer servicing the Cunliffe Road area outlets on Coldstream Creek Road.

If an outlet is required, an extension of the existing system is proposed to tie-in to a storm pipe on Kidston Road. The interconnection will also allow the opportunity to upgrade the existing undersized lake outfall from 150ø to 450ø.





Supplied by: Alanna Dean, P.Eng, M.Eng.
Director of Engineering, District of Coldstream

Appendix 5:
North Kal Intake Assessment Open House Summary

Department: RDNO Engineering
Focus Area: Public Input
Project: North Kalamalka Intake Assessment and recommendations for Protection
Process: Public consultation
Submitted by: Renee Clark, Water Quality Manager

Purpose and objectives

The North Kal Intake Assessment was developed in 2009 – 2010. An important part of the assessment is the collaboration with all technical stakeholders in the watersheds especially the District of Coldstream as the surrounding area is within its municipal boundaries. Due to the limnological complexity of this assessment IHA has requested that stakeholder involvement be limited to a 'technical advisory committee'. A public Open House was held prior to completion of the assessment to gather information and support from the community in establishing a protection zone for the North Kalamalka Lake Intake.

The open house consisted of a survey to define who and why people participated, posters that allowed participants to voice what recommendations outlined in the assessment that they would support, and two presentations that informed the participants about the process of the assessment and building a protection plan.

Input received from the public Open House will be reviewed by the consultant and included in the Assessment where it is felt consistent with existing science and drinking water protection objectives.

Public Open House Survey Questions and Results

- **Is Kalamalka Lake your Drinking Water Source?**
  Yes = 21
  No = 6
  Not Sure = 1
- **Where do you live?**
  Coldstream = 14
  Vernon = 11
  Electoral Areas A/B = 1
  Other = 3 (all Area C)
- **Do you own land next to Kalamalka Lake?**
  Yes = 4
  No = 24
- **Do you own land within 200 metres of Kalamalka Lake?**
  Yes = 8
  No = 19
- **Do you own land within 200 metres of Kalamalka Lake?**
  Yes = 8
  No = 19
  One person didn't know the answer

- **Do you own land in the proposed intake protection zone?**
  Yes = 2
  No = 24
  Not Sure = 2
- **Do you own land next to Coldstream Creek?**
  Yes = 2
  No = 26
- **Do you own land within 200 metres Coldstream Creek?**
  Yes = 2
  No = 26
- **What is your primary water use?**
  Indoor Only = 2
  Indoor and Yard = 31
- **How did you hear about this open house?**
  Newspaper = 20
  Internet = 9
  Friends and Family = 7
- **Do you feel that any of the recommendations from the assessment will impact you personally?**
  Yes = 22
  No = 4
  One person didn't know the answer
- **Would you like to be kept informed on actions from this?**
  Yes = 23
  No = 4

Other Comments:

1. Well done presentation. Would like to see a timetable of completion and implementation. We have seen plenty of bioscience, perhaps some environ-economics at Kal Lake is in order.
2. Please don't drain the storm water from Middleton Mountain into the lagoon. Put a slow zone for motorized boats around lake and put buoys out into the lake from boat launch that boats need to take so they are not in shallow water.
3. I thought the consultant's report was thorough and fairly well presented (but too long to digest adequately). My biggest challenge is to establish a sense of priorities for the list of recommendations without the ability to understand for each recommendation:
   - The cost of implementation
   - The likely benefit
   - The probability of successful implementation
     - Note: I did not put red stickers on recommendations 5, 10, 12, 13 and 14 because all these should happen automatically as a matter of course
4. Reduce polycyclic aromatic hydrocarbons (PAHs) follow examples from Lake Tahoe and Whatcom Lake. Re: eventual ban on 2 stroke (less efficient) engines. Require: Measure PAHs, Education, Ban 2 stroke and reduce all boat traffic (1 to 5 year plan).
5. a. Municipalities could ban cosmetic use of pesticides
   b. A 2 hour travel time in 80% of wind events is only a minimum level of protection. Other communities in North America are willing to implement a greater level of

protection of their drinking water. While it is necessary to implement at least a minimum level of protection we should aim for a higher level, and not assume that our water is actually “protected”.
   c. Is it possible to design an education program on this issue for school age kids that could be apart of a science class for example?
   d. Restrict development of any more lots on Kal Lake
   e. Compost collection municipally sounds like a good idea
   f. Very grateful this study was initiated, very good recommendations
6. A very good presentation
7. Glad to have ongoing studies/monitoring of Kal need good baseline data to understand benefits of any actions to improve quality. Is the rail company using pesticides on the tracks? Is this a water quality issue?
8. An excellent presentation! Thank you for the opportunity to comment!
9. Thanks

Recommendation Ranking Results – Public Input

Top 3 Recommendations

Number	Recommendation	Support
4.	Storm Water Outfall Improvements	24
11.	Watershed Control Program	22
15.	Maintain Kalamalka Protected Area	21

Other Notable Recommendations

Number	Recommendation	Support
3	Bylaw to Protect Kalamalka Lake Foreshore	17
2	Bylaw to Prohibit multi-slip marinas within IPZ	16
1	Protect Intake Protection Zone (IPZ) – Licence of Occupation	15
12	Basin Wide Issue Partnership	15
9	Discourage waterfowl and Gulls on Public Beaches	14
13	Collaboration with RDNO Landfill and City of Vernon Wastewater	14
5	Public Education	13
8	Study Effects of Kalavista Lagoon on North Arm Kal Lake	13
7	Clean- up and preparedness for Hydrocarbon Spill	12

The 4 Least Supported Recommendations

Number	Recommendation	Support
10	Discussion with Railway on Goods Transported	10
14	Winter Abrasive (Salt) Storage and Disposal	9
6	Annual overview of Changes in the North Arm of Kalamalka Lake	8
16	GIS Mapping of Kalamalka Lake	8

The following are Issues/ concerns identified by public house participants of which they felt were not addressed in the assessment.

Issue/concern	Recommendation
Development	Restrict development of any more properties on Kal Lake
Bylaw	Municipality should ban cosmetic pesticides
Livestock Management	Owners within Kal Lake drainage should manage livestock from accessing watercourses
Enforcement	Do not allow 2 stroke boat engines – enforce 4 cycle only
Study and Monitor	Intense recreational motor boat use should be further studied and its impacts on the lake ecology. Users present a false economy.
Education	Provide more information and education regarding Kalamalka Lake
Livestock Management and Education	Prince George area ranchers along the Fraser River have a program called Salmon and Fish that improves riparian areas – this should be a program provided along Coldstream Creek. (Coldstream area)
Land use	Buy back properties along riparian areas and create a public use park – trail system along lake
Enforcement/ foreshore protection	Institute a No Wake Zone at the North End
Enforcement	Boating Permits should be required for power boats on Kal Lake – mechanical inspection
Study and Monitor	Dye test study of Silver Star Lagoons
Study and Monitor	Dye test study of Coldstream Ranch Lagoons (Manure)
Study and Monitor	Is a 2 hour travel time in 80% of wind events is only a minimum a level of protection.

___________end of report_____________