Lake Windermere
2014 Water Quality Monitoring Results

Lake Windermere Ambassadors
625 4th St
Invermere, BC
V0A 1K0

Report prepared by: Kirsten Harma, MSc.

Final Report

December 23, 2014

Acknowledgements

The 2014 Lake Windermere water quality monitoring project has been made possible thanks to funding from the Columbia Valley Local Conservation Fund and the District of Invermere. In-kind support was also provided by the District of Invermere through the donation of a boat and fuel.

The project would not have been possible without the dedication and support of dozens of community volunteers. Acknowledgement is also due to Lake Windermere Ambassadors' Summer Student Ella Swan, who contributed her enthusiasm and good nature to on-water sampling and teaching volunteers about the Lake.

Executive Summary

The spring and summer of 2014 brought mild climatic conditions without the major flooding events which characterized 2012 and 2013. The measured lake depths in 2014 were comparable to those in 2012, and deeper than average levels between 2006-2008 and 2011. Lake Windermere met Objectives for temperature, dissolved oxygen, and turbidity throughout the summer. This means the water was clear, cool, and well oxygenated: all in line with historic levels. The beaches were clean in 2014. Measured beach bacteria levels did not exceed the recommended Guidelines for safe swimming on any of the public beaches over the summer.

Total phosphorus levels exceeded the Objective for the Lake at one sampling station in 2014. A slight increasing trend in this nutrient has been observed in the lake in recent years, warranting close monitoring of this critical nutrient and continued efforts on land to keep excess nutrients out of the lake.

Questions about this report?

Contact:
Lake Windermere Ambassadors
info@lakeambassadors.ca
(250) 341-6898

Introduction

People living around and recreating on Lake Windermere depend on having water that is clean enough to swim in, fish in and recreate on, as well as to draw from as a drinking water source. Lake Windermere is home to sixteen species of fish and is used by several hundred species of resident and migratory birds, all of which depend on the water being in a good condition. From 2006 to 2009, the Lake Windermere Project worked to assess the quality of the lake's waters for wildlife and human recreational uses. In 2010, the Ministry of Environment took those five years of data, as well as historic data, and determined water quality "Objectives" for Lake Windermere. These Objectives now serve as a benchmark against which we can compare present conditons. They are used to evaluate if the lake is in good condition for recreation as well as for fish and wildlife. By continuing to test lake water quality every summer, the Lake Windermere Ambassadors are now adding to a baseline of eight years of water quality data. Their continued efforts will allow for detection of any changes in water quality over time.

In 2014, Lake Windermere Ambassadors' volunteers and staff sampled lake water at three locations monitored historically by the Ministry of Environment and then by the Lake Windermere Project. The sites include a North, South and Mid (Windermere) section of the lake.

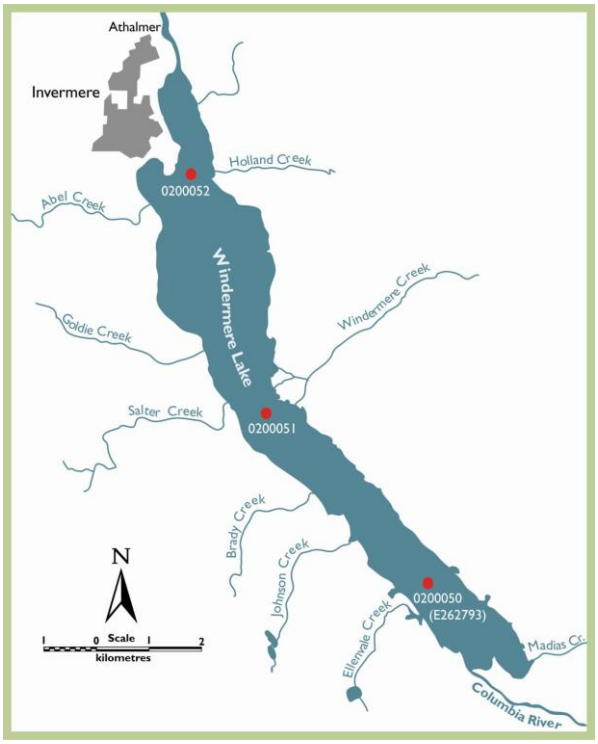
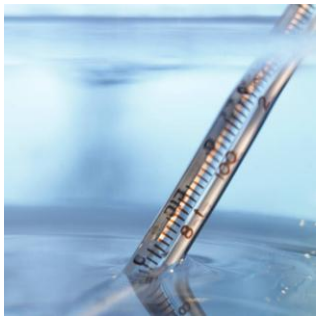


Figure 1: Lake Windermere and Sampling Sites: North Station, Mid Station, South Station

Temperature



Overview

Water temperature is of critical importance to aquatic life. Lower temperatures are generally more desirable. The Ministry of Environment determined how warm Lake Windermere can get during the summer before problems might start to occur. Those temperatures are the Water Quality Objectives for temperature.

Results

Lake Windermere's water temperature was within the limits to protect aquatic life in 2014. Temperatures at all three water monitoring stations remained consistently below the maximum recommended temperatures throughout the summer.

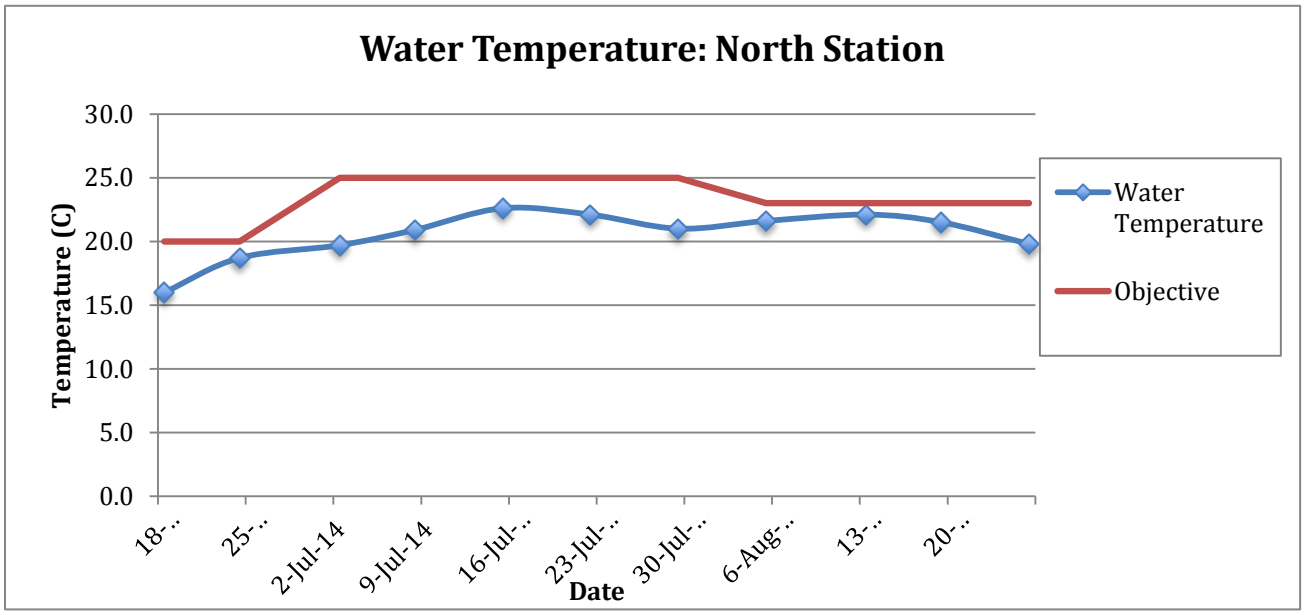


Figure 2: Example of water temperature data: North station surface, 2014. Blue dots represent weekly samples – the blue line is added to improve interpretation and does not represent continuous data. Red line represents the monthly Objectives.

Dissolved Oxygen

Overview

Dissolved oxygen is a measure of the amount of oxygen dissolved in water. Fish and other aquatic life need oxygen. The Ministry of Environment determined levels of oxygen necessary to protect aquatic life in Lake Windermere (Water Quality Objectives).

How much oxygen is enough? The Ministry of Environment determined that oxygen should never drop to or below 5 milligrams per liter (instantaneous minimum), and the average of five samples taken over 30 days should be at or above 8 milligrams per liter (mg/L) to support aquatic life.

Results

Oxygen levels were always sufficient for aquatic life during the 2014 sampling season.

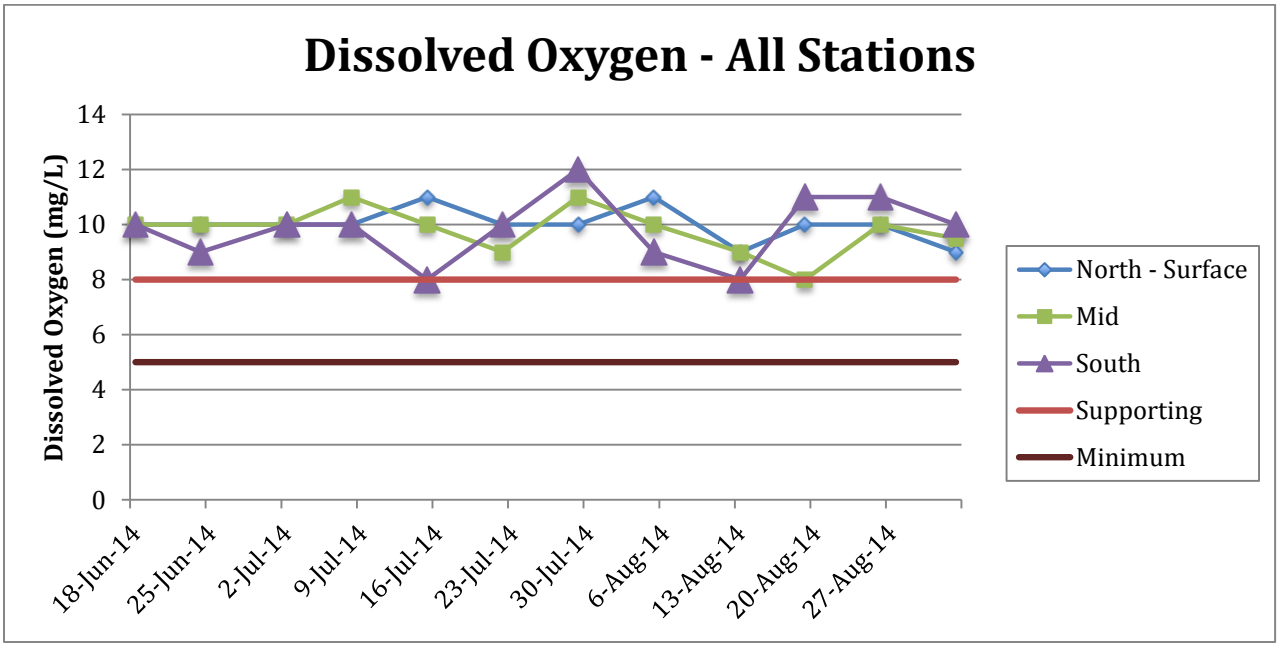


Figure 3: Green, Blue and Purple Lines = Measured Oxygen levels; Red lines = Minimum for instantaneous readings (5.0) and Objective for average oxygen measured over a 30-day period (8.0) to support aquatic life.

Noteworthy in the 2014 data are the values for oxygen found in the lake. 2006-2013 average values for oxygen in July and August were 9 mg/L and the 2014 average was a point higher at 10 mg/L.

Despite the higher average, having some high values is consistant with historic data. Maximum values of 11 and 12 were observed both in the 1971-1983 time period (Neufeld, 2010), and of 13 and 14 in the 2006-2013 period,.

Table 1: Comparison of 2014 Dissolved Oxygen levels to previously measured values. Number of sample (n) for 2006-2013 is 36; and for 2014 is 12.

	North Station		South Station	
	2006-2013	2014	2006-2013	2014
Average	9	10	9	10
Standard Deviation	1.2	0.6	1.1	1.1
Min	6	9	7	8
Max	14	11	13	12

Dissolved oxygen levels above 10 mg/L are usually found in colder water, which can hold more oxygen. Freshwater at 20°C is considered *saturated* with 9 mg/L of dissolved oxygen[1] . For any value above that, the water is considered *supersaturated*. This supersaturated state is likely caused by the plant life rapidly photosynthesizing in the lake during the day[2].

To date, the Ministry of Environment does not recognize supersaturation as a water quality concern so there is no set Objective for maximum dissolved oxygen considered safe for aquatic life. The US

[1] http://www.env.gov.bc.ca/wat/wq/BCguidelines/do/do-01.htm
[2] http://www.fondriest.com/environmental-measurements/parameters/water-quality/dissolved-oxygen/

EPA considers 110% of total gas pressure (of oxygen and other gases) a benchmark for protecting aquatic life[3]. The BC Ministry of Environment recognizes that some waters in British Columbia have naturally occuring high levels of dissolved gases and aquatic life have adapted to these conditions.

Turbidity

Overview

Turbidity is a measure of the light scattered by particles suspended in water, and indicates the cloudiness or clarity of the water. When waters are highly turbid, light cannot penetrate to reach aquatic plants, which reduces photosynthesis, and fish become stressed due to reduced ability to navigate, clogging of gills, and other factors. Since aquatic life in Lake Windermere have adapted to seasonal flushes of sediment into the lake, how much turbidity should be in the water (Water Quality Objective) depends on time of year.

The Objectives for Lake Windermere for turbidity are set to protect recreational water quality and aquatic life. During spring runoff (May 1 – August 15), in what is known as "turbid flow", the 95th percentile of turbidity measurements taken in five days over a 30-day period should not exceed 5 NTU (turbidity units). During "clear flow" (August 16 – April 30), the maximum turbidity at any time should be less than or equal to 5 NTU. Additionally, the objectives for "clear flow" is that the average of 5 samples over 30 days should not exceed 1 NTU.

Results

Turbidity levels in the lake in 2014 met the Objectives throughout most of the summer. This is in contrast to the 2012 and 2013 seasons which saw some of the highest turbidity levels on record.

The Objectives for turbidity during the turbid flow period (95 percentile below 5 NTU) were not exceeded at the North or Windermere Station. At the South end of the lake, the turbid flow Objective was exceeded due to high turbidity on June 18th and 24th.

During "clear flow" after August 15th, the maximum turbidity Objective value was never exceeded at any station.

[3] http://www.env.gov.bc.ca/wat/wq/BCguidelines/tgp/tgptextonly.htm

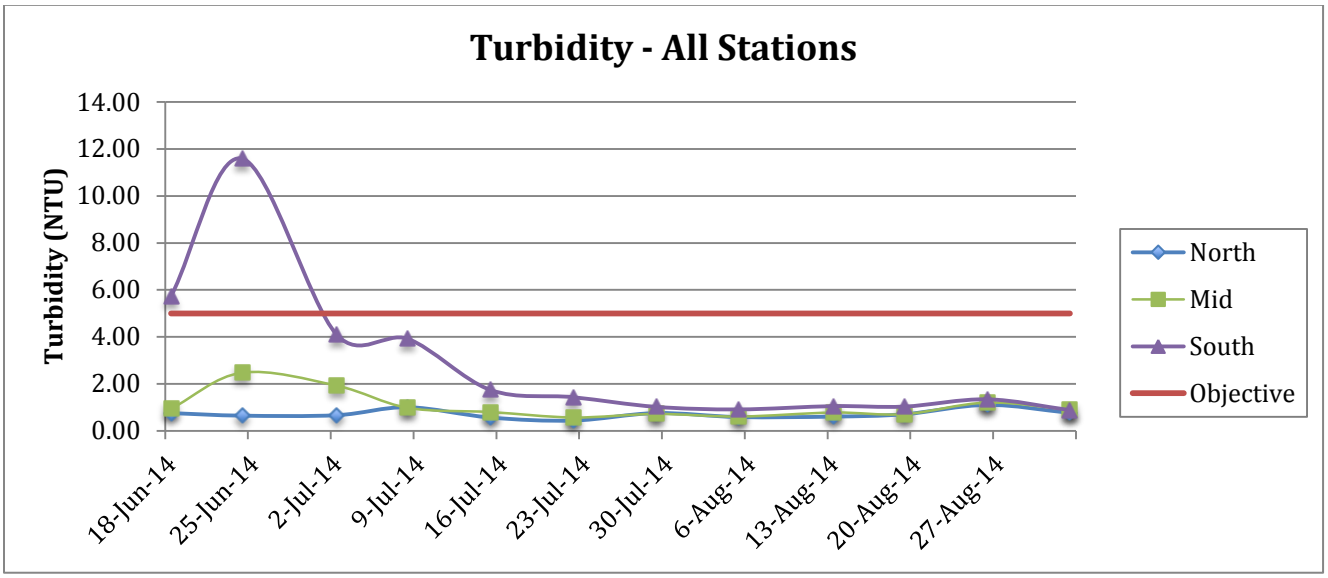


Figure 4: Turbidity, all stations. Coloured points are turbidity values. Lines added to ease interpretation only - no continuous data were taken. Red line is the Objective for a 30-day period during the Turbid Flow period, and for any one point during the Clear Flow period.
Note: Values in early June caused the 95th percentile over a 30-day period to exceed the 5 NTU objective at the South Station.

Secchi Depth

Overview

A Secchi disk gives us a reading of water transparency according to the depth of the measurement. Secchi depth, like turbidity, is a measure of the suspended particles in the water. These suspended particles can be a combination of things such as zooplankton, algae, pollutants, and silt. Secchi data collected year after year can provide valuable information on trends in transparency in monitored lakes.

Results

The average Secchi depth for Lake Windermere in 2014 was 6.12 m +/- 0.55 m.

The average from 2006, 2007, 2008 and 2011 was 4.51 m +/- 0.84 m. In 2012, average Secchi depth was much lower, at 2.92 m. These results correspond with the results for turbidity, indicating that in 2014 lake clarity was closer to historic conditions than to the previous two summers.

The graph below shows that Secchi depths were relatively consistent throughout the whole summer, with only a slight decrease in visibility in late April.

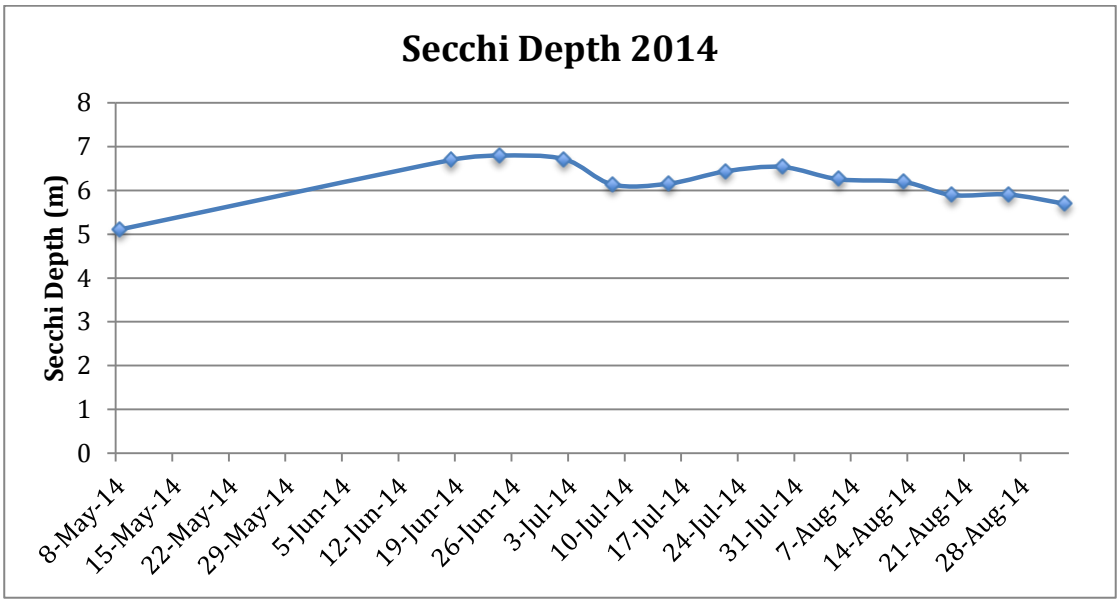


Figure 5: Secchi Depth

Compared to other lakes throughout BC measured during the BC Lake Stewardship Society's annual "Secchi Dip-in" in July, Lake Windermere's clarity was close to the median (BCLSS newsletter, October 2014). The clearest lake in BC had a Secchi depth of 22 m. The majority of BC lakes had clarity between 4 and 8 meters.

Phosphorus

Overview

Phosphorus is a nutrient that is usually found in limited quantities in natural lakes. In high quantities it leads to algae blooms. Unnatural inputs of phosphorus into lakes are one of the main contributors to algae blooms. Past results from sampling for phosphorus indicate that Lake Windermere is "oligotrophic." This means that low nutrient levels and clear waters have been the norm in this lake.

The Ministry of Environment (MOE) determined that the most total phosphorus that should be present in Lake Windermere (Objective) is a concentration of 0.01 milligrams per liter (mg/L), collected at spring ice-off, to protect drinking water sources and aquatic life.

After noting increasing trends in phosphorus in the lake, the Lake Windermere Ambassadors' staff consulted Rick Nordin, PhD Aquatic Ecologist and advisor at the BC Lake Stewardship Society. He recommended reinstituting the sampling methodology taken prior to release of the MOE protocols. Prior to 2011, discrete samples were analyzed from one metre below the surface and one metre above the bottom. MOE protocols called for composite samples consisting of a single mixed sample of top and bottom water. This recommendation is presumably due to Province-wide cost reduction

policies. Given that Lake Windermere only has one site where discrete "top" and "bottom" samples can reasonably be taken, it was considered worthwhile to evaluate lower and upper strata in the lake.

Results

After ice-off, Total Phosphorus levels exceeded the Objective at the North station. The average value of the samples taken one metre from the bottom and one metre from the top was 0.03 mg/L, exceeding the 0.01 mg/l Objective.

Dissolved Phosphorus was also analyzed with these samples. In the lower sample, Total Phosphorus was 0.043 mg/L and Dissolved was 0.041 mg/L. This indicates that the Total Phosphorus contains a high fraction of the biologically available Dissolved Phosphorus, and the high reading is therefore not due to particulate matter.

After the data were received from the lab, the project team decided to take an additional sample at the North station in the ice-off time period. The subsequent sample were taken May 8th. At that time, values exceeding the 0.01 mg/L Objective were also noted, though to a lesser degree (surface = 0.019; bottom = 0.015; average = 0.017 mg/L).

Although summer phosphorous levels were not set by the MOE for Lake Windermere, these levels have been monitored annually to increase understanding of nutrient dynamics in the lake. June and July phosphorus levels were well below 0.01 mg/L throughout the lake. In August, phosphorus levels were higher than 0.01 mg/L at the Mid and South station. In 2013, levels at the Mid station in August were 0.067 mg/L, higher than had been found from 2006-2009. The 2014 value of only 0.022 is not as alarmingly high as the previous year.

Figure 7 and 8 below show an increasing trend in both Total and Dissolved Phosphorus in the lake over time. The North station graph represents a mix of methods: composite and discrete surface and bottom samples. The South station graph includes only surface samples, yet still shows an increasing trend, verifying that a trend occurs even when method is consistent.

The "Water Quality Objectives for Lake Windermere" (Neufeld, 2010) report notes, "*phosphorus concentrations have remained quite similar, if not declined, since the 1970s*." Any deviation from that strong trend deserves attention. Given the fact that this important nutrient was found to exceed the Objective for Lake Windermere for the first time, and an increasing trend in phosphorus levels throughout the year continues, increased vigilence in watching nutrient levels in the lake is warranted.

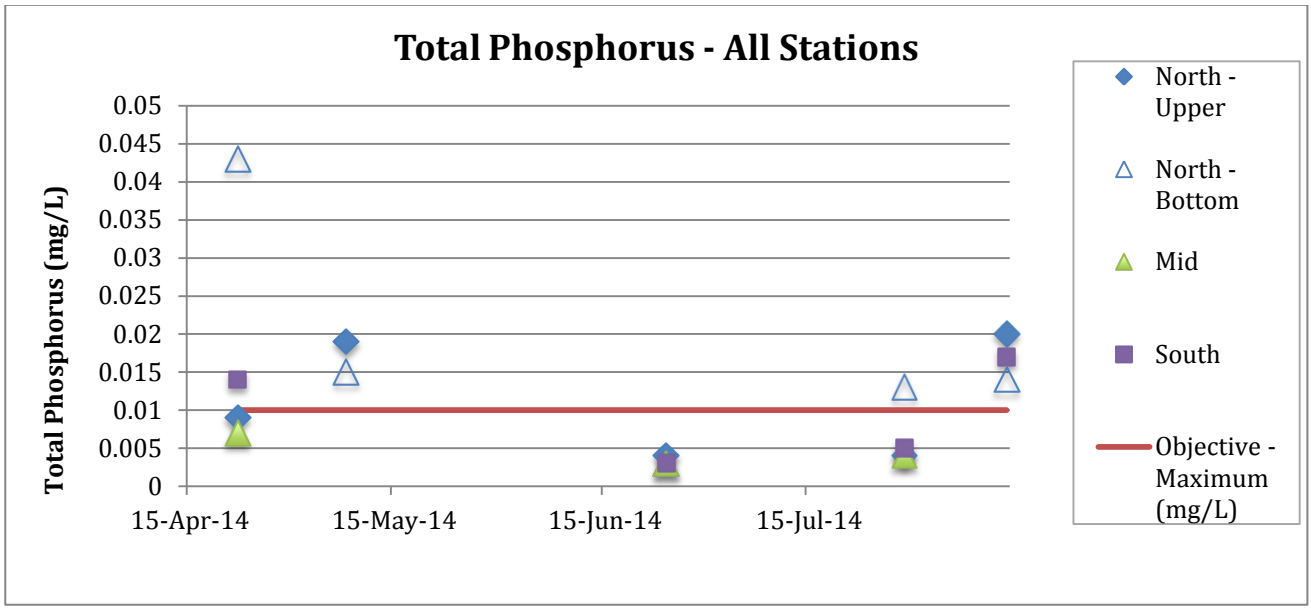


Figure 6: Total Phosphorus 2014 – All Stations

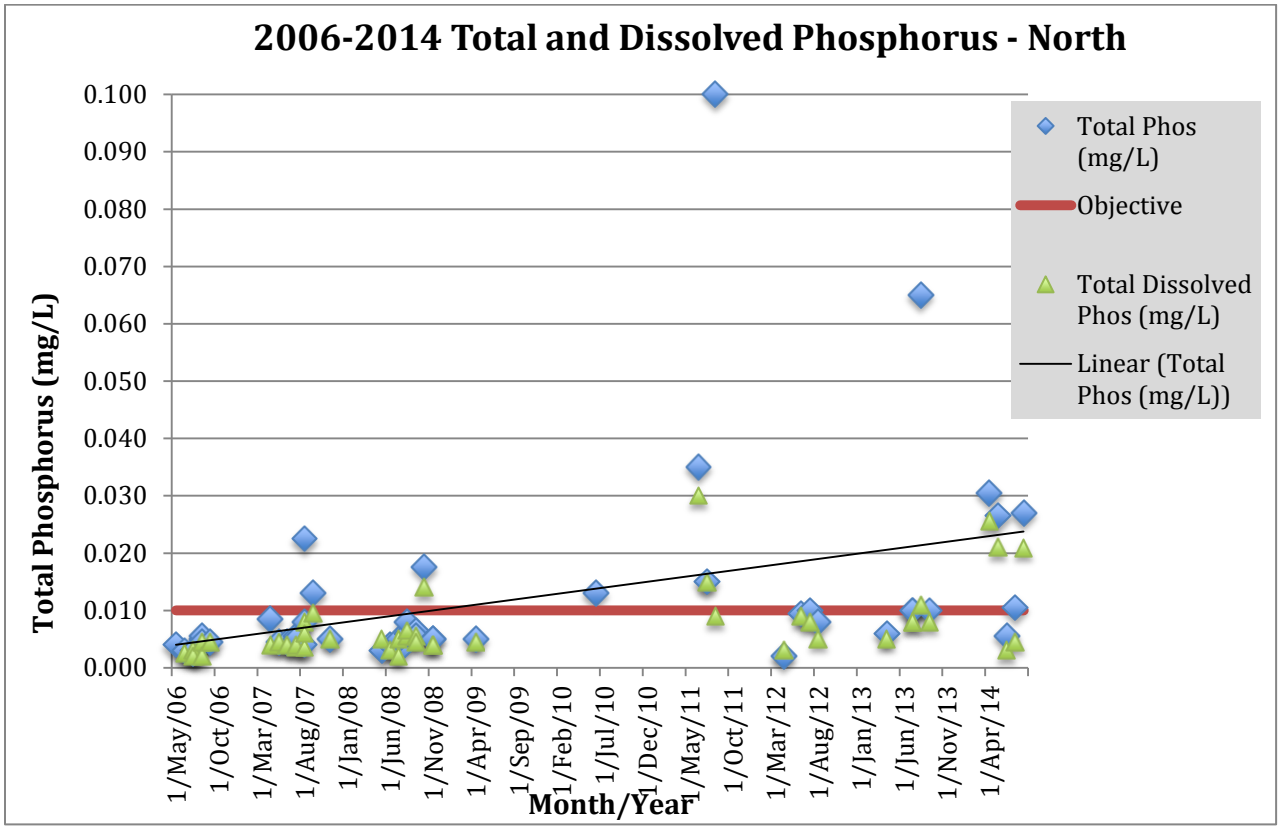


Figure 7: Total and Dissolve Phosphorus readings from May 2006 through August 2014. Note that since the North station was sampled using two separate methods, this chart represents a composite of upper and lower strata in the lake. The black linear trend line delineates an increase in Total Phosphorus in the lake over time.

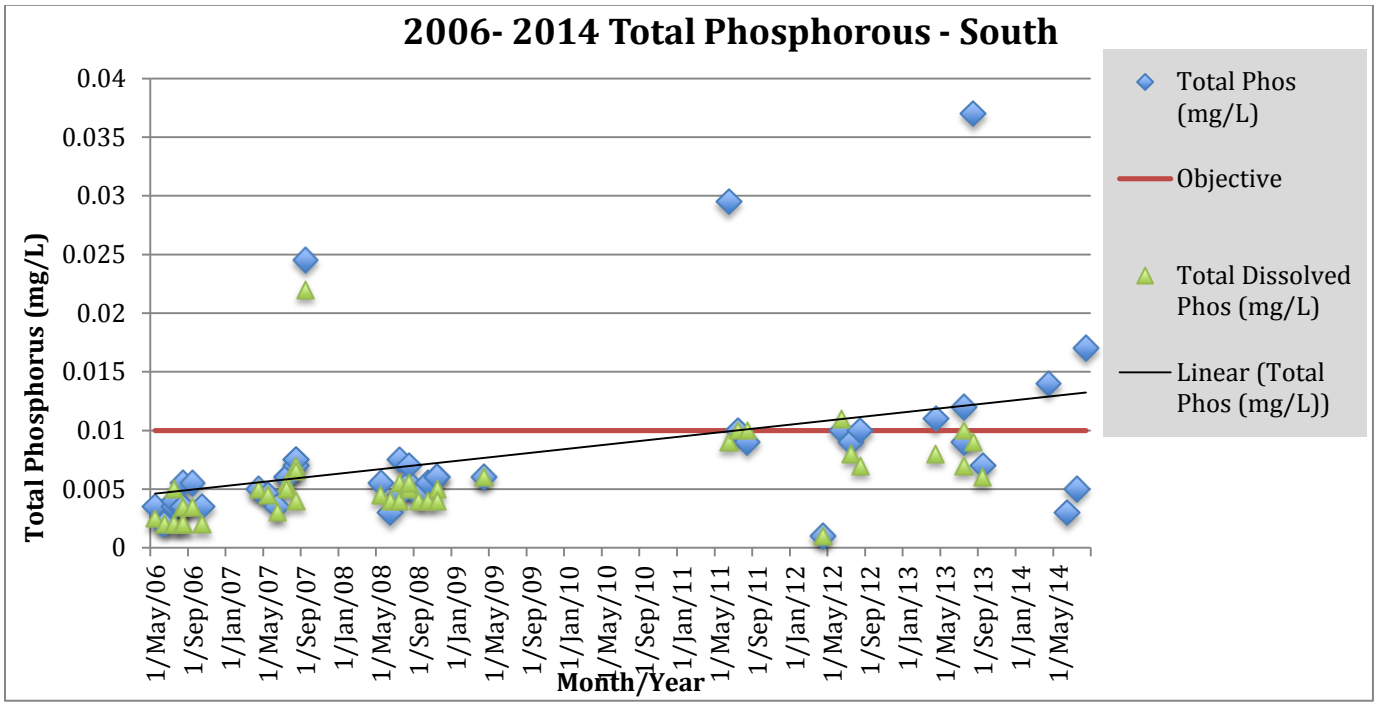
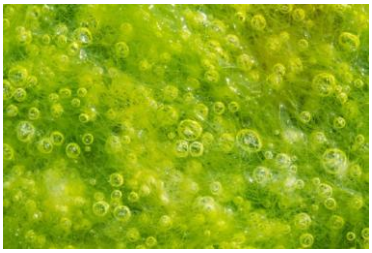


Figure 8: South Station Total and Dissolve Phosphorus readings from May 2006 through August 2014. The black linear trend line delineates an increase in Total Phosphorus in the lake over time.

Chlorophyll "a"



Overview

Chlorophyll is the green pigment in plants that allows them to create energy from light. By measuring Chlorophyll a, you are indirectly measuring the amount of living plant matter found in a water sample. The increase in nutrients in a lake usually leads to increased production of algae, so a measure of Chlorophyll a is another way to understand potential nutrient pollution in a lake.

The Ministry of Environment has not set objectives for Chlorophyll a in lakes for the Province nor for Lake Windermere. Along with a study of phosphorus, chlorophyll levels can be used to get an overall understanding of lake productivity. The Ministry of Environment categorizes lakes with cholorophyll a levels between 1 to 10 ug/L as "oligotrophic", meaning that they are low in nutrients. The Lake Windermere Project monitored Chlorophyll a from 2006 to 2008 over a period of three weeks in late summer of each year. The mean value from that time period at the North station was 1.6 ug/L. Thus, at that time, Lake Windermere was deemed oligotrophic.

McKean and Nordin (1984) looked at Chlorophyll a and phosphorus sampled in Lake Windermere in 1976 and 1982. They developed a model which suggested that conditions were oligotrophic (low nutrient) tending on mesotrophic (medium nutrient). They noted that the actual productivity found was lower than predicted by the model, likely given the flushing rate of the lake.

Given the observed trend of increasing phosphorus in Lake Windermere, measuring Chlorophyll a levels in the lake in 2014 was deemed an appropriate test to see if the lake's productivity might be changing.

Results:

Chlorophyll a was tested on August 13, 2014 following Ministry of Environment sampling protocols. Samples were taken at the North and South stations, yielding values of 0.7 ug/L and 0.6 ug/L, respectively.

Since these results are still within the "oligotrophic" range, they suggest that the increase in the nutrient phosphorus in the lake has not led to an increase in algal productivity.

It is important to note that these results only portray a snapshot of conditions on one day. Previous monitoring took place over three weeks in the growing season. If funding is available, further samples of chlorophyll a should be taken in future summer seasons to allow for a more complete comparison.

---

pH

Overview

Water is neutral at a level of 7 and alkaline (basic) at higher values. The water in Lake Windermere has historically been basic. This is characteristic of lakes fed by water flowing over limestone materials such as those present in the Canadian Rockies.

Results

As per historic conditions, the pH in the lake tended towards basic in 2014. The South end of the lake was closer to neutral than the downstream sections of the lake throughout the summer. That difference was particularly apparent during the spring snowmelt season.

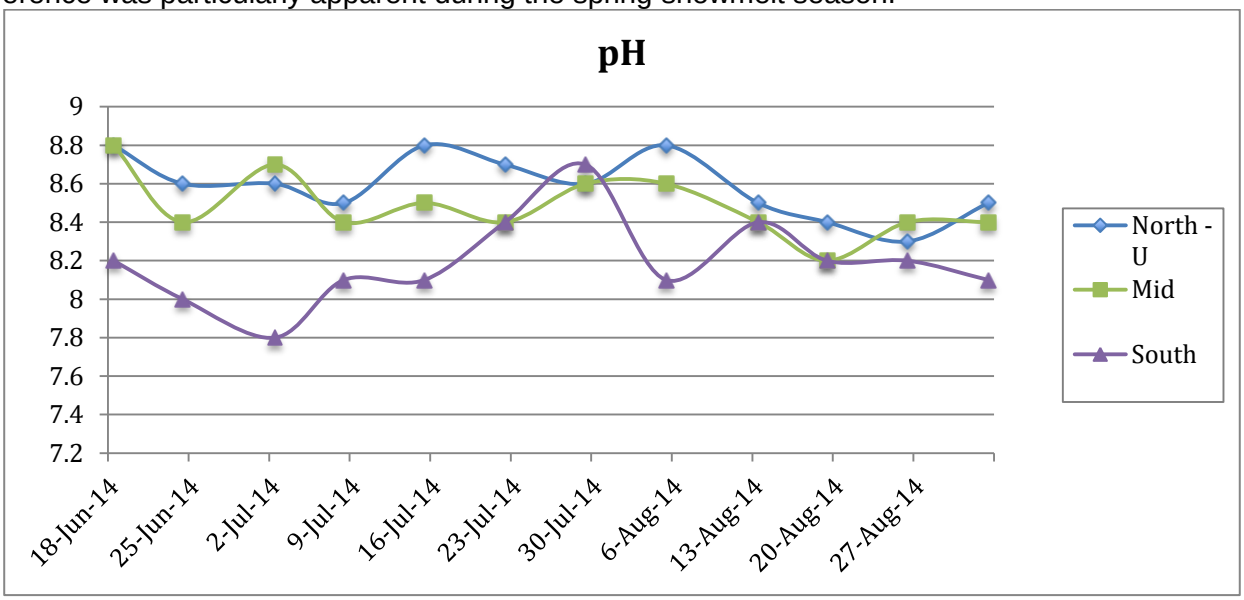


Figure 9: pH of Lake Windermere, all stations measured in 2014

Conductivity

Overview

Conductivity is a measure of the ability of water to pass an electrical current. Conductivity in water is affected by the presence of inorganic dissolved solids such as chloride, nitrate, sulfate, sodium, magnesium, calcium, iron, and aluminum cations. Conductivity is affected by temperature: the warmer the water, the higher the conductivity.

Conductivity levels offer a clue to the nature of the kind of water flowing into the lake. A failing sewage system on the lakeshore raises the lake's conductivity because of the addition of chloride, phosphate, and nitrate; an oil spill lowers the conductivity.

The Ministry of Environment has not set Objectives for conductivity in Lake Windermere. These values should be monitored regularly to detect any sudden changes that might be due to an unwanted discharge of pollution into the lake.

Results

Conductivity at all three stations remained relatively consistent over the summer, with only a slight increase over the summer notable at the South station. Since water temperature peaked in July and then decreased, the influence of temperature on conductivity appears to be minimal, unless cancelled out by some other factor.

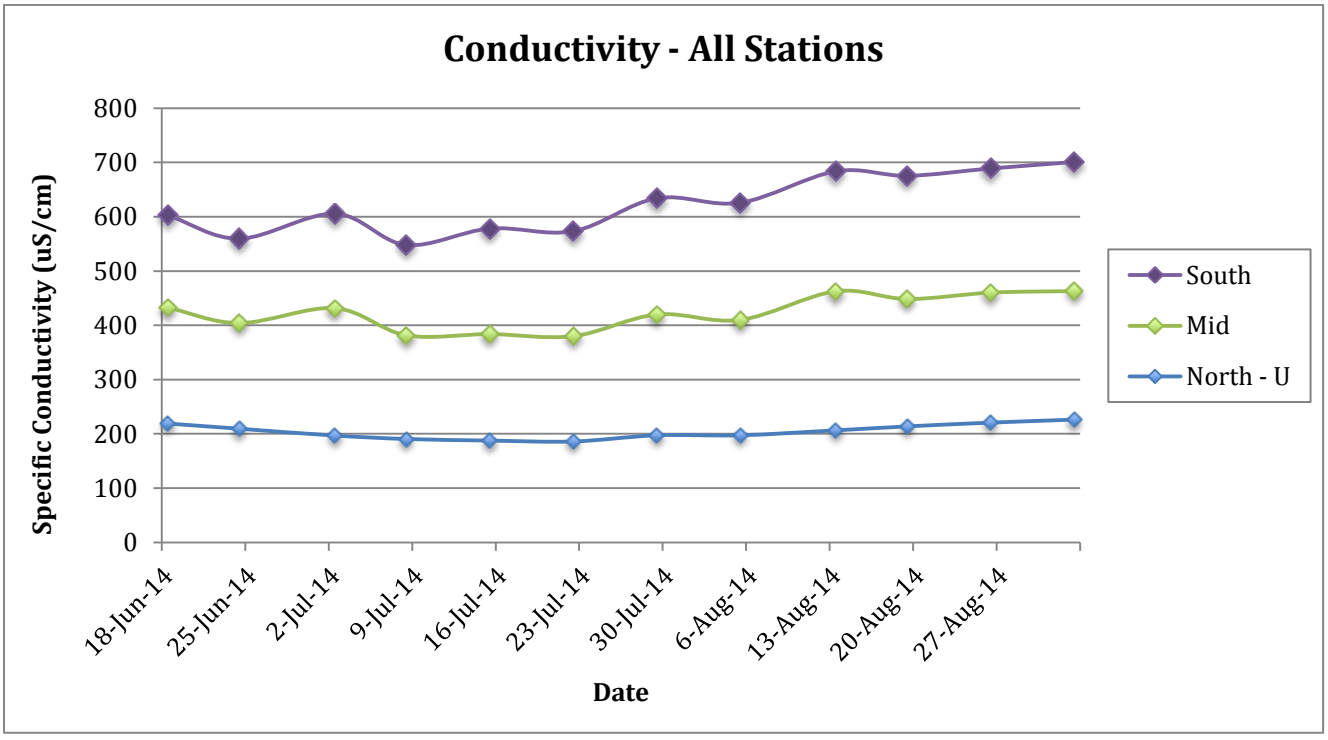


Figure 10: Conductivity at all stations – 2014. Lines are for interpretation and do not represent continuous measurements.

There was a distinct difference in conductivity between the different sampling stations. The South end of the lake had the highest conductivity, and the North had the lowest conductivity, indicating that the water is diluted as it flows through the lake.

Notable is the fact that water quality sampling in Windermere Creek shows higher levels of conductivity than in Lake Windermere. A summary of 2006 to 2012 creek water quality data (Lotic, 2014) showed average creek conductivity levels near the creek mouth ranged from 700 to 1,000 uS/cm. Conductivity at the Windermere station in the lake average close to 400 uS/cm. This indicates that the creek has a minimal influence on lake conductivity. Whatever factors are decreasing conductivity over the course of the lake override the highly conductive water from Windermere's second largest tributary.

Depth

The measured lake depths in 2014 were comparable to those in 2012, and deeper than average levels between 2006-2008 and 2011. Lake depth slowly increased during the June and July freshet, and slowly decreased over the summer.

Note that sampling conditions occasionally make it difficult to measure lake depth given that the instrument used is the Secchi disc. Field notes for July 8th say that depth was difficult to measure due to wind and drift. The actual depth, in this case, is likely lower than measured, meaning that the peak seen in Figure 11 below is likely not a representation of actual conditions.

Below is a graph showing lake depth in 2014 compared to 2012 and 2011 and the average between 2006 and 2008.

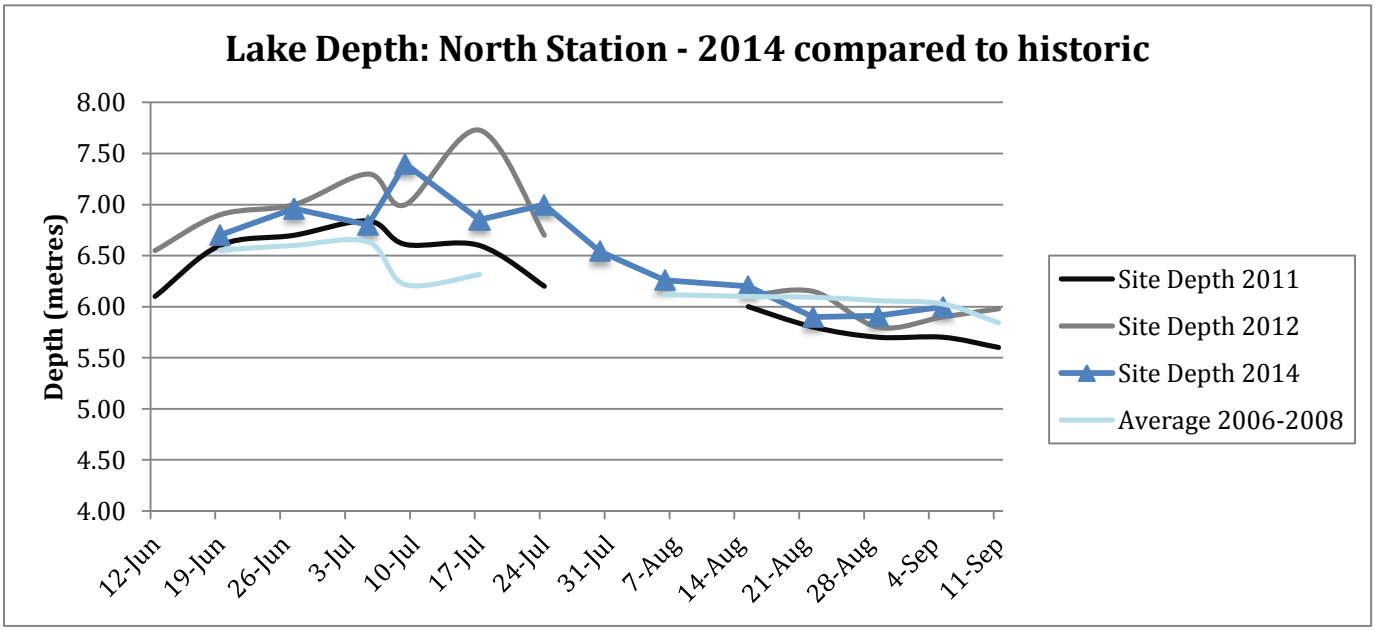


Figure 11: Water depth in Lake Windermere.
*Note – data were not collected on all sampling days – some data points interpolated to smooth the line

Swim Beach Water Quality

In 2014, Interior Health updated its protocols to analyze beach water samples for the *E-coli* bacteria, in compliance with Health Canada Guidelines. This new analysis method allowed the program to gain a better assessment of whether swim beach water quality met recognized standards than in previous years, when the water was tested for fecal coliform bacteria.

Health Canada – Guidelines for Canadian Recreational Quality

For fresh recreational waters used for primary contact activities, the guideline values are as follows:

- Geometric mean concentration (minimum of five samples taken over 30 days): ≤ 200 *E. coli*/100 mL
- Single-sample maximum concentration: ≤ 400 *E. coli*/100 mL

The 2014 beach monitoring program assessed two sample locations on James Chabot Beach, two on Kinsmen Beach, and one on Windermere Beach.

The geometric mean did not exceed the 200 colonies/ 100 mL recommended for contact recreation on any of the public beaches, nor did any single sample exceed 400. The highest single sample was 135 colonies, on August 11, 2014 at Kinsmen Beach.

The highest geomean values over a 30-day period were as follows:

James Chabot = 7.3 *E. coli*/100 mL
Kinsmen Beach = 7.1 *E. coli*/100 mL
Windermere = 1.8 *E. coli*/100 mL

~ ~ ~

References

BC Lake Stewardship Society. 2014. Events: 2014 Secchi Dip-In. Accessed 11/21/2014. http://www.bclss.org/newsevents/events/144-2014-secchi-dip-in.html

McPherson, S. K. Kuchapski, and R. MacDonald. 2014. Windermere Creek 2009-2012, Water Quality Monitoring Report. A Columbia Basin Water Quality Monitoring Project. Prepared by Lotic Environment. Ltd.

Ministry of Environment. 2014. Water Quality Guidelines Reports. Environmental Protection Division. Accessed online 12/10/14 at: http://www.env.gov.bc.ca/wat/wq/BCguidelines/tgp/tgptextonly.htm

Neufeld, A., Swain, L. and K. Reiberg. 2010. Water Quality Assessment and Objectives for Windermere Lake. Technical Report. First Update. November, 2010.