LAKES ASSOCIATIONS WATER QUALITY STUDY: MARY LAKE

August 9, 2013

Dear John:

The attached document includes data collected on Mary Lake through the University of Waterloo's Water Quality Monitoring project in the month of July 2013.

As this is part of a long-term monitoring program, detailed analysis of results could lead to misinterpretation of the water quality of Mary Lake. It is important to analyze the trend of water quality over time, and more data is needed to accurately interpret the state of the lake. We have provided helpful summaries, websites, and provincial/ federal standards for the parameters measured within this study. If you would like to understand the results in greater depth, a professional environmental consultant should be contacted.

Please do not hesitate to contact us with any questions, or if you would like a copy of the sampling and lab protocol followed within this study.

Cheers,

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TABLE OF CONTENTS

1 METHODOLOGICAL SUMMARY

All field sampling followed the Canadian Council of Ministers of the Environment, Protocols Manual for Water Quality Sampling in Canada (CCME, 2011), which can be accessed online. All lab procedures followed the protocols and instructions listed by the HACH company (2013), Canada, for the following parameters: dissolved oxygen, pH, conductivity, nitrate, nitrite, orthophosphate (reactive phosphorus) and total phosphorus. (HACH company, 2013). The primary objectives and variations that should be noted regarding sampling are found in the remainder of this section

Two sample days were selected for each lake in the month of July. Mary Lake was sampled on July 11 and July 23, 2013. Although this was not a large enough time frame to be representative of the changes in seasonal water conditions, water nutrient level-- particularly phosphorus-- is best evaluated in the months of July, August, and September (because of sunlight intensities) (Chen *et al,* 2009).

Samples were taken below the thermocline where possible for two main reasons: firstly, the Muskoka area contains cold water lakes, which in turn contain cold water biota. To evaluate these biota, cold water samples are required to determine health and the presence of stressors. Secondly, with the sampling period being situated in the month of July, surface waters reach high temperatures that are not representative of a lake's average annual temperature. The layer of warm water is essentially unstable and constantly in motion, while below the thermocline nutrient levels and temperatures remain stagnant and contain the lakes nutrient allotment for the year (until the annual turnover in spring). Measuring water quality at this depth can indicate stressors on aquatic life such as low dissolved oxygen levels or abnormal nutrient levels, or ample water contaminants (Forsburg, C. 1989).

Data from this year's analysis was, and will be, pooled with previous and future years results to provide a long-term water quality assessment of each lake (Hirsch *et al,* 1982). For the purpose of a long-term study, the sites sampled this July 2013 were selected from the sample sites of the July 2012 study, or determined in co-operation with Lake Association partners. These selected sites will continue to be used in future years to ensure the consistency and quality needed to detect changes in water quality overtime. All of the results were compared to the values from last year's study conducted by University of Waterloo students. Additionally, total phosphorus data has been compared to the Ministry of Environment data from previous years which can be accessed online on the MOE Lake Partnership Program website: http://www.ene.gov.on.ca/ /en/local/lake_partner_program/STDPROD_078989.html.

2 SITE MAP, COORDINATES AND DESCRIPTIONS

Figure 1 below is an aerial photo of Mary Lake. The red markers represent the sample sites selected. Each site was sampled twice throughout the month of July. Sites were selected based on even distribution throughout lake, a desire to sample near outflow and inflow points, and community partner opinions.

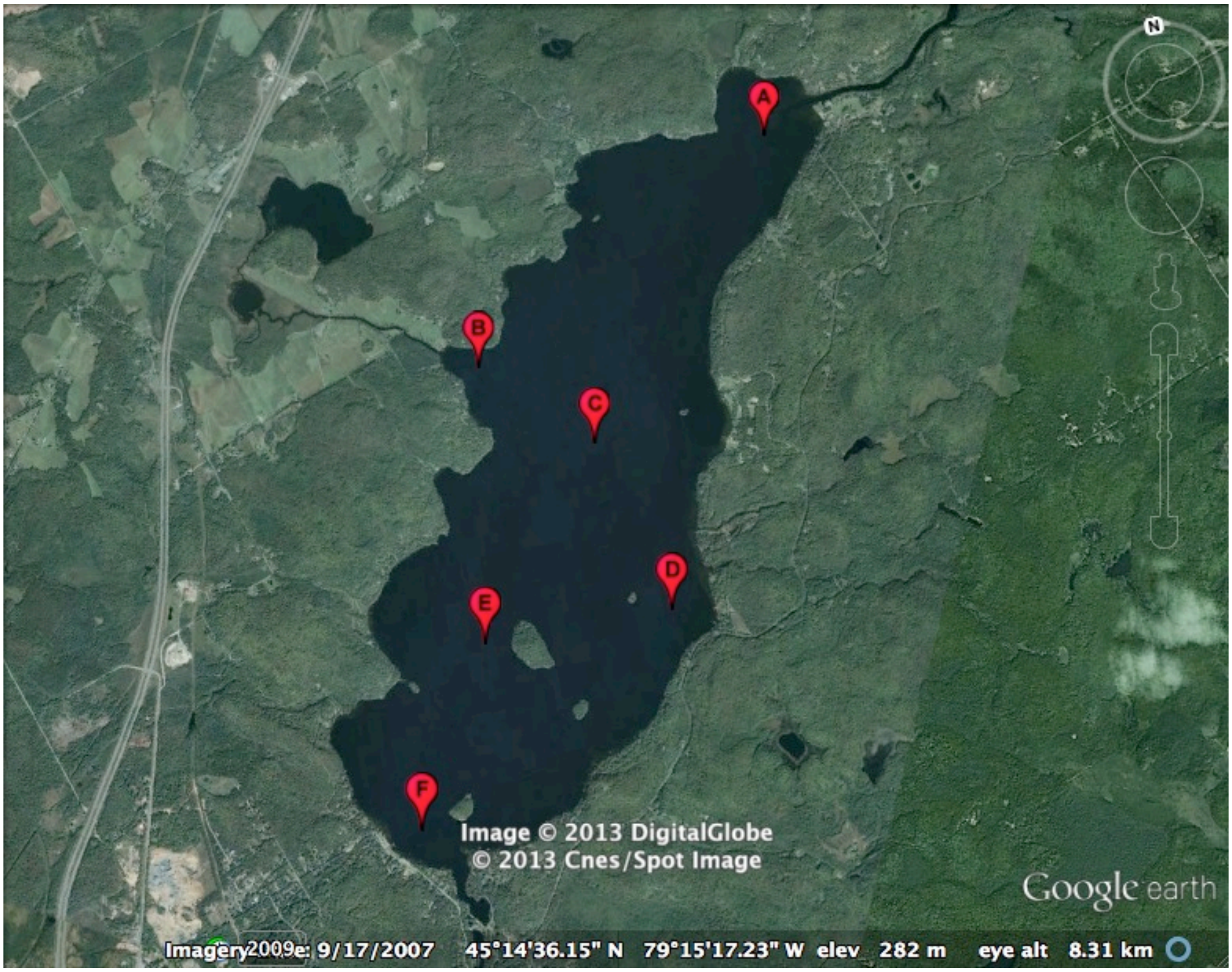

Figure 1: Aerial photo of sample locations.

Table 1: Site description and coordinates.

Site	GPS Coordinates	Description
A	N 45.265942, W 079.234206	At mouth of Muskoka River, flowing from Fairy Lake.
B	N 45.253169, W 079.266176	In Bay; cottages line shoreline; mud creek enters at this point, flowing from 2 smaller lakes
C	N 45.246551, W 079.256336	Middle of Mary Lake
D	N 45.234496, W 079.251893	Near shore with several cottages; in between shore and small island; Jackson's creek flows in nearby.
E	N 45.234510, W 079.269980	Channel flows right through lake at this point, in between two islands
F	N 45.223204, W 079.278687	Outflow point of Mary Lake; located SE of small island and large granite cliff. Current pulled sampler and temperature probe horizontally.

3 RESULTS

Field notes and lab data collected throughout sampling period.

3.1 FIELD DATA

Table 2: Field notes for sample day one and two.

<table>
<tr><th colspan="4">Mary Lake</th></tr>
<tr><td colspan="2">Day 1: 2013/07/11</td><td colspan="2">Day 2: 2013/07/23</td></tr>
<tr><td colspan="2">Weather</td><td colspan="2">Weather</td></tr>
<tr><td colspan="2">Start @ 11:21AM: Mostly cloudy, Humidity: 64.3%, Temperature: 21.6^{o}C, Wind: 1.2 m/s</td><td colspan="2">Start @ 9:31AM: Overcast, windy, scattered showers, Temp: 22.5^{o}C, Wind: 2.1 m/s, Humidity: 81.8%</td></tr>
<tr><td colspan="2">End @ 12:23AM: Sunny, Humidity: 42.8%, Temperature: 26.1^{o}C, Wind: 0.7 m/s</td><td colspan="2">End @ 10:30AM: Overcast, 22.5^{o}C, Wind: 0.2 m/s, Humidity: 81.8%</td></tr>
<tr><td colspan="2">Lake Condition</td><td colspan="2">Lake Condition</td></tr>
<tr><td colspan="2">Waves made it difficult to see Secchi disk. Sampler and temperature/depth probe would sometimes be dragged horizontally due to current. Heavy rain yesterday may influence lab and field results</td><td colspan="2">Waves, not as rough as first sampling day. Had difficulty descending temperature probe, so depths sampled on previous sample day were referenced.</td></tr>
<tr><td>Site</td><td>Sample Depth (m)</td><td>Sample Temperature (^{o}C)</td><td>Below Thermocline? (Y/N)</td></tr>
<tr><td>A1</td><td>7.0</td><td>14.0</td><td>Y</td></tr>
<tr><td>A2</td><td>7.0</td><td>23.6</td><td>N</td></tr>
<tr><td>B1</td><td>6.0</td><td>14.3</td><td>Y</td></tr>
<tr><td>B2</td><td>7.0</td><td>13.0</td><td>Y</td></tr>
<tr><td>C1</td><td>8.0</td><td>15.2</td><td>Y</td></tr>
<tr><td>C2</td><td>8.0</td><td>13.2</td><td>Y</td></tr>
<tr><td>D1</td><td>8.0</td><td>15.8</td><td>Y</td></tr>
<tr><td>D2</td><td>8.0</td><td>14.5</td><td>Y</td></tr>
<tr><td>E1</td><td>8.0</td><td>12.4</td><td>Y</td></tr>
<tr><td>E2</td><td>8.0</td><td>16.4</td><td>Y</td></tr>
<tr><td>F1</td><td>6.5</td><td>20.4</td><td>N</td></tr>
<tr><td>F2</td><td>7.0</td><td>13.0</td><td>Y</td></tr>
</table>

3.2 LAB DATA

Table 3 below outlines the results obtained during lab testing. Averages and standard deviations were calculated to provide a summary of each parameter, and are probably the most important to consider when determining whether results lie within provincial standards of water quality. T-tests were conducted between the two data sets to determine whether any significant difference exists between the two samples. If values are >0.05, the samples are related. If <0.05, it is indicative of a significant difference between the two sample sets. This difference exists between a couple of the parameters tested, but this should not be cause for concern. It is more important to look at the actual concentrations found at these sites.

Table 3: Lab data from both sample days. Averages, standard deviations, and t-tests comparing set 1 and 2 are found at bottom of table.

Mary Lake								
Site	**Secchi Depth (m)**	**DO (mg/L)**	**pH**	**Conduct-ivity (µS/cm)**	**TP (µg/L)**	**PO_4 (mg/L)**	**NO_3 (mg/L)**	**NO_2 (mg/L)**
A1	1.75	9.13	6.94	47.1	9	0.13	0.3	0.003
A2	2.0	8.59	7.06	49	14	0.11	0.3	0.003
B1	3.0	8.91	7.05	46.9	8	0.14	0.4	0.003
B2	2.5	8.98	7.01	47.4	8	0.14	0.4	0.001
C1	2.75	8.89	6.88	46.4	9	0.14	0.3	0.002
C2	2.5	9.04	6.98	47.8	7	0.13	0.4	0.002
D1	2.5	8.65	6.85	46.6	9	0.09	0.4	0.002
D2	2.5	8.84	7.04	47.1	9	0.14	0.2	0.003
E1	2.5	9.3	6.82	46.9	10	0.11	0.3	0.001
E2	2.75	8.44	7.02	47.5	7	0.2	0.3	0.003
F1	2.5	8.51	6.85	47.2	9	0.13	0.3	0.002
F2	2.5	9.01	7.13	47.6	9	0.13	0.4	0.002
Average	2.48	8.86	6.97	47.29	9.00	0.13	0.33	0.00
Standard Deviation	0.328	0.262	0.100	0.673	1.809	0.026	0.065	0.001
T-Test	0.838	0.613	0.00577	0.0140	1.000	0.245	1.000	0.721

* Asterix indicates lake bottom was reached with Secchi disk.

4 INTERPRETATION & DISCUSSION

This section provides a summary table of the parameters tested within this study. As mentioned previously, the data collected is part of a long term monitoring program and the interpretation of these results are meant to give general insight on potential sources, impacts and solutions to water quality issues. It should be noted that this is not a professional analysis of the data. An environmental consultant should be contacted for in-depth interpretation.

4.1 WATER QUALITY STANDARDS

The table below provides standards set by various water quality agencies. Our main source for these objectives is the Ministry of Environment and Energy's "Policy, Guidelines, Provincial Water Quality Objectives," (MOEE, 1999). In some instances, such as for phosphate, nitrate and nitrite, no standards have been set. For these reasons, other recognized sources (CCME, 2012b; USEPA, 2013) have been accessed to suggest acceptable levels of these contaminants.

Table 4: Standards set for parameters tested as outlined by three established water quality agencies.

Parameter	MOEE (1999)	CCME (2012b)	USEPA (2013)
Dissolved Oxygen	For Cold Water Biota: @ 0^{o}C, DO: 8 mg/L @ 5^{o}C, DO: 7 mg/L @ 10-15^{o}C, DO: 6 mg/L @ 20-25^{o}C, DO: 5 mg/L	Lowest acceptable dissolved oxygen concentration: for warm water biota: early life stages = 6000 µg/L for warm water biota: other life stages = 5500 µg/L for cold water biota: early life stages = 9500 µg/L for cold water biota: other life stages = 6500 µg/L	-
		-	-
pH	6.5 - 8.5	6.5 - 9.0	6.5 - 9.0
Clarity, Secchi depth	1.2m	1.2m	1.4m
Conductivity (µS/cm)	-	-	150-500 µS/cm
Nitrate (NO_3)	-	13 mg/L	10 mg/L
NO_2 (mg/L)	-	0.06 mg/L	5 mg/L

Parameter	MOEE (1999)	CCME (2012b)	USEPA (2013)
PO_4 (mg/L)	-	0.02 mg/L (summer)	-
Total Phosphorus (µg/L)	20 µg/L	-	-

4.2 CONTAMINANT SOURCES, IMPACTS, & SOLUTIONS

DISSOLVED OXYGEN

Dissolved Oxygen (DO) is an important lake parameter to measure when determining water quality as it is connected to the abundance and health of aquatic life (WHO, 2011). DO is influenced by water temperature, flow, and algal/plant growth. Cold water is able to hold a greater amount of dissolved oxygen than warm water (USEPA, 2012). Fast flowing water, as a result of its continual movement, dissolves more oxygen than standing water (USEPA, 2012). A certain amount plant growth is necessary to produce oxygen and food for fish and other aquatic life (USEPA, 2012). However, excessive growth of aquatic plants and algae can result in low DO. The living vegetation eventually becomes dead organic material, which requires oxygen to break down (USEPA, 2012). This depletes the amount of oxygen available for other organisms, and can lead to species decline (Anderson, Burkholder & Glibert, 2002; USEPA, 2012). Algal blooms and plant growth are caused by high nutrient levels (such as phosphorus and nitrogen) in the water (Anderson, Burkholder & Glibert, 2002; Audet et al, 2012; Bonari et al, 2012).

In order to control nutrient levels, point source pollution from wastewater plants and non-point source pollution caused by surface run off from agricultural land, lawns, and beaches, should be assessed (Han et al, 2010). It is also be valuable to understand the flow of water through the watershed, and to consider the water chemistry and the shoreline uses of lakes upstream (Han et al, 2010). Standard levels of dissolved oxygen vary depending on water temperature and for cold versus warm water species. The lakes sampled in this study were 10-15^{o}C below the thermocline, and therefore have an objective of 6 mg/L. In instances where thermocline was not found, temperature ranged from 20-25^{o}C, and therefore should have a DO of at least 5 mg/L (MOEE, 1999).

pH

There can be various effects on lake ecosystem health from high or low pH levels. A pH value of 6.5-9 is considered a healthy range for freshwater lakes (Suter II, *et al*, 2012). pH is linked with most chemical and biological processes in lakes and can be a limiting factor for many species. Distinctive species flourish in various pH levels, but a fluctuating level can reduce biodiversity and result in negative effects on the biological community (Jeffries, *et al,* 2000).

A low pH level would be considered high in acidity and have a value lower than 6.5. A low pH can result in a reduction of biodiversity and have impacts on fish community health such as mucus on gills or reproductive failure. Other biological effects can include a transition of lake species from acid-sensitive to acid tolerant species (Driscoll, *et al,* 2001). Causes of low pH can include wetland or floodplain draining, acid rain, landfill leachate, industrial effluent, inflow oxidation, or reduction processes. Evidence of low pH in a lake can include tea coloured water (Jeffries, *et al,* 2000), geology or soil type, yellow iron precipitates on rocks or filamentous algae (Suter II, *et al*, 2012).

A high pH level that is very basic would be considered a value of 9 or higher on the pH scale. Adverse effects of a highly basic lake are far less common than those of an overly acidic lake. Anthropogenic sources of acidic pollutants are generally more common. Causes of a high pH level can include limestone gravel roads, alkaline geology and soils, agriculture, or asphalt production and disposal. Lake symptoms of high pH involve an abundance of macrophytes, filamentous algae, or algal mats (Vestergaard, O. & Sand-Jensen, K., 2000), and low dusk and dawn dissolved oxygen levels. Negative biological effects that can occur are a reduction in biodiversity and detrimental effects to fish communities (Suter II, *et al*, 2012). How ever it should be noted that lakes with a higher alkalinity generally have greater species diversity and larger populations (Rachel, 2011).

CONDUCTIVITY

The measurement of waters conductivity is used as an indicator of total dissolved solids and the ionic strength of the water. Conductivity levels are most sensitive to variations of dissolved solids, predominantly mineral salts (Hayashi, M. 2004). Freshwater conductivities span a wide range, from 10 to 1,000/µS cm; 1,000 µS/cm representing cases of heavily polluted waters (Chapman, D.V.1996). Common pollutant sources causing abnormally high conductivity levels include: road salts, land irrigation, land cover alteration (runoff), sewage or industrial effluent, or combustion wastes. Evidence of high ionic content can be loss of vegetation, presence of salt tolerant vegetation, mineral precipitates, or crystalline deposits (Ziegler, *et al.* 2012).

WATER CLARITY

The Secchi disk was used to measure water clarity/turbidity within our study. Turbidity is an important parameter to assess because it indicates the amount of suspended solids, and therefore the amount of light penetration, in the water (Neuhausser & Steel, 2002; USEPA, 2012b). Suspended materials can include sediment, plankton, microbes, and algae (USEPA, 2012b). In large amounts, suspended solids can cause water quality to decline, as these particles increase water temperature by absorbing more heat (Neuhausser & Steel, 2002; USEPA, 2012b). If light penetration is significantly reduced, photosynthesis of aquatic plants will decline, impacting their productivity and lowering the dissolved oxygen levels (Neuhausser & Steel, 2002; USEPA, 2012b). These impacts can create a snowball effect, causing a decline in fish populations, as well as other organisms (Neuhausser & Steel, 2002).

Turbidity is increased as a result of human impact and natural events such as urban runoff, soil erosion, and point-source pollution (USEPA, 2012b). The parameters tested within this study are connected and influenced by one another. High phosphate and nitrate/nitrite levels will increase algal blooms, therefore reducing sunlight penetrance, DO, and survival rates of other species.

For the protection of aquatic life and recreational purposes, the standard objective of water clarity is a Secchi disk visibility of 1.2m (MOEE, 1999). Highly turbid waters will appear cloudy, and may have an objectionable smell, taste and colour, depending on the suspended materials (USEPA, 2012b). In order to normalize turbidity levels, pollution sources should be assessed, land development should be reduced, and shoreline stabilization should be implemented (Neuhausser & Steel, 2002). With all of this in mind, it is important to note that turbidity fluctuates greatly in the event of a storm, when surface runoff and erosion increase. Measurements taken after rainfall will likely not be representative of the lake (USEPA, 2012b). Overcast and rough waves can also impact the accuracy of measurement, as these conditions make it difficult to see the Secchi disk.

NITRATE & NITRITE

Nitrate is an important nutrient used by plants, but can become a contaminant as a result of waste water effluent, and surface run off from fertilized agricultural land, and mown lawns (Bonari et al, 2012; Llopis-Gonzalez et al, 1994; WHO, 2011). Nitrogen becomes nitrate when oxidized by plants, substrate, or water (CCME, 2012). Nitrite is also found within water bodies, but typically in much lower concentrations (CCME, 2012). It is considered more toxic than nitrate and often results when nitrate is reduced by microbial action (CCME, 2012; Llopis-Gonzalez et al, 1994; WHO, 2011). Although not tested in our study, ammonia is another influential form of nitrogen of aquatic environments. When oxygen levels are low in water bodies, there will be a higher concentration of ammonia, and a lower concentration of the oxidized nitrate and nitrite (Buyle et al, 1993).

Together with high concentrations of phosphorus, these forms of nitrogen can result in increased plant and algal growth, leading to eutrophication if contaminants are not controlled (Anderson, Burkholder & Glibert, 2002). Eutrophication is the increased presence of plant and algae caused by nutrient loading. The accumulation of dead plant material requires a large amount of oxygen to decompose, depriving aquatic life and resulting in species decline.

There is no standard objective outlined by the MOEE for nitrate or nitrite at this time. However, the CCME has suggested values of 13 mg/L for nitrate and 0.06 mg/L for nitrite. If lab results indicate values above this standard, it is recommended that wastewater sources be identified, and treatment be reevaluated and improved. Ideally, lawns lining the shore should grow naturally without fertilizer, pesticides or herbicides, and mowing should be avoided to reduce surface runoff (Bonari et al, 2012). Upstream water sources should be identified and assessed to determine whether sources in other areas of the watershed could be the result of high nitrate and/or nitrite values.

ORTHOPHOSPHATE (REACTIVE PHOSPHORUS) & TOTAL PHOSPHORUS

Water quality and biological communities in lakes can be adversely effected by high or increasing concentrations of phosphorus, and generally reflect degraded habitats (Miltner &

Rankin, 1998). Phosphorus is considered to the most deterministic factor in water quality. High levels can lead to an increase in phytoplankton (algae) biomass, turbid waters, and the eutrophication of lakes (Søndergaard, M. *et al.* 2003). Primary sources of excess phosphorus in lake systems can include septic systems, runoff from impervious (paved) surfaces, residential lawns, storm water inputs, fertilizers, and atmospheric deposition. Natural phosphorus sources are influenced by rock and soil type in the surrounding area (Kurtz, *et al.* 2012). Orthophosphates and Total phosphorus differ in forms of phosphorus. The measurement of orthophosphate measures both dissolved and suspended orthophosphate (Kurtz, *et al.* 2012); it is the soluble and inorganic forms of phosphorus taken up by plant cells that can be directly taken up by algae. (Murphy, S. 2007). Total phosphorus is the measure of all forms of phosphorus; orthophosphate, condensed phosphate, and organic phosphate (Kurtz, *et al.* 2012).
Total Phosphorus levels in lakes can be classified at the following levels:

- 0-12µg/L, Oligotrophic (nutrients poor)
- 12-24µg/L, Mesotrophic (nutrients optimal)
- 24-96µg/L, Eutrophic (nutrients excessive)
- 96-384+ µg/L, Hypereutrophic (nutrients highly excessive and detrimental)

(Carlson, R.E. & Simpson, J. 1996) (Carlson, R.E. 1997)
Natural orthophosphate levels generally range 0.005 – 0.05 mg/L. In ideal conditions orthophosphate levels between 0.08 and 0.10 mg/L can trigger small periodic algal blooms, however this will not cause eutrophication if total phosphorus and orthophosphate levels are below 0.5 mg/L and 0.05 mg/L (Dunne and Leopold, 1978).

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