OTTER LAKE
WATER QUALITY MONITORING REPORT
2002

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INTRODUCTION

This report was written to present the findings of the water quality monitoring conducted on Otter Lake from July 8, 2002 to September 30, 2002, and to define and explain the overall condition of the lake at that time.

BACKGROUND

Lake Status and Eutrophication

Lake status is categorized as oligotrophic (low nutrient levels), mesotrophic (moderate levels of nutrients) and eutrophic (high levels of nutrients). Eutrophication is a natural aging process, whereby biological activity increases with the input of nutrients. Human inputs from lawn amendments or aging septic systems can accelerate this process. In the aquatic environment, nutrients act as fertilizers, promoting aquatic plant and algae growth. When the plants and algae die, they settle to the bottom of the water body, stimulating microbial breakdown processes that require oxygen. Decomposition of this biomass eventually depletes the dissolved oxygen, affecting habitat for fish and other aquatic life.

Trophic status is most commonly defined by chemical analysis of nutrients such as phosphorus and nitrogen that directly relate to a lake's ability to support biological growth. Secchi depth (measure of water clarity associated with algae growth) and chlorophyll (pigment in algae) indicate the presence of algae, and therefore the availability of nutrients for growth. Dissolved oxygen levels can also be used to determine trophic status, as they provide a measure of the impact of eutrophication (due to biological growth and decay as described above). Originating from leaking septic systems and stormwater run-off, pathogens can be introduced to the lake, limiting recreation potential and threatening human health. *Escherichia coli* (bacteria found in intestines of mammals) is commonly used as an indicator of fecal contamination. The following information provides more detail on these water quality parameters.

Lake Dynamics

Deeper lakes stratify into layers based on temperature during the summer months. The depth where the temperature changes very rapidly is called the thermocline. The epilimnion is found above the thermocline, the metalimnion is the area in which the thermocline occurs and the hypolimnion is the area bellow the thermocline (See Figure 1). It is important to note that once a lake becomes stratified, little or no mixing of the layers occurs.

Mixing does occur twice a year as air temperatures change in the spring and fall, during what is called ' turn over' . In the fall, when the air cools, the surface of the lake will also cool. Cooler water is denser than warmer water, so as the surface temperature drops, the cooler water at the surface sinks. This is known as the fall turn over. Surface water will continue cooling and sinking until the whole lake is uniform in density and temperature (at 4°C). The lake stops turning over and the surface continues cooling, eventually freezing. The lake turns over again in the spring, as the ice melts and the surface warms to 4°C becoming denser. Thermal stratification and stability occurs thorough the summer, as the surface layers become warmer and less dense, above the cooler denser water at depth.

Phosphorus

Phosphorus is generally recognized as the limiting nutrient in freshwater ecosystems, and the major contributing nutrient to eutrophication in these environments. Limiting nutrient means that all the other components necessary for growth are available, but a lack of a specific (limiting) nutrient controls (limits) plant growth. When the limiting nutrient is added to the system, algae and plant growth can occur.

Because phosphorus is often the limiting nutrient in freshwater systems, it is an excellent indicator of nutrient status. Oligotrophic lakes are characterized by an average total phosphorus (TP) level less then 10 micrograms per litre (µg/L), mesotrophic lakes have between 10 and 20 µg/L and eutrophic lakes have an average TP level greater than 20 µg/L.

Phosphorus is part of a complex cycle, which should be considered when choosing timing and location of sampling. Plants and algae incorporate phosphorus into their biomass as they grow, and when they (and other organisms) die, they settle to the bottom of the water body. As they decompose, the phosphorus that was incorporated into their biomass is released. In addition, sediments that have phosphorus adsorbed will settle, increasing phosphorus loading to the bottom. Phosphorus in the sediments can actually account for up to 90% of the total phosphorus in the system. Sediments have a high capacity to store phosphorus, however phosphorus in the sediments is not permanently removed. Low dissolved oxygen levels stimulate its release, and as described previously decay of plant growth decreases dissolved oxygen. This can be a problem, especially in high nutrient lakes, as once the lake becomes stratified, no mixing occurs, and dissolved oxygen available in the hypolimnion is depleted. Phosphorus being stored in the hypolimnion will also be mixed into the rest of the lake during spring and fall turnover. Therefore concentrations measured in surface waters can grossly underestimate the total amount of phosphorus that is actually available for plant and algae growth.

Nitrogen

Nitrogen is another important nutrient in an aquatic ecosystem. Fertilizers, agricultural waste and wastewater contribute to nitrogen in the water. In large amounts, ammonia and nitrates can be toxic to aquatic organisms. Total Kjeldahl Nitrogen (TKN) is a measure of ammonia + organic nitrogen. While there are currently no guidelines for TKN, waters not influenced by excessive organic inputs typically range from 0.1 to 0.5 mg/L (RVCA 2000).

Total nitrogen and phosphorus can be compared to determine the limiting nutrient. While total nitrogen is a measure of all forms of nitrogen – nitrate, nitrite, ammonia, ammonium and organic nitrogen, TKN (ammonia + organic N) is normally found in much larger quantities than the other forms, therefore it is possible to compare TKN to TP to determine the limiting nutrient. A TN:TP ratio greater than 25 indicates a phosphorus limited system.

Secchi Depth

Algae growth is natural in lakes but with excessive nutrient concentrations, algae can become a nuisance. Because algae thrive on nutrients in the water, measures of algal growth can indicate nutrient availability in the water. Secchi depth is a measure of water clarity, and has been correlated to the amount of algae in the system. A secchi disc is a black and white 20 cm disc that is lowered into the water until it is no longer visible and then lifted up until it reappears. Both depths are recorded and averaged for the overall secchi depth reading. A secchi depth greater then 5 metres indicates an oligotrophic lake, a measurement of 3-5 metres is characteristic of a mesotrophic lake, and less then 3 metres signifies an eutrophic lake.

Chlorophyll

Chlorophyll is a pigment found in all aquatic plants and algae and therefore is a measurement of the algae content of the water body. There are three different types of chlorophyll - *a*, *b*, and *c*. There are no federal or provincial guidelines for chlorophyll in freshwater, however, monitoring is useful to document changes in productivity of a water body.

Chlorophyll can be measured chemically in the lab or its activity can also be measured *in situ* (in the lake) by fluorescence meters (chlorophyll becomes activated as it obtains energy from the sun). *In situ* analysis can provide a cost-effective measure, allowing more sites to be assessed. Usually most of the fluorescence detected is due to the chlorophyll in the phytoplankton, however aquatic plants and other compounds present may fluoresce and contribute to the readings.

Dissolved Oxygen and Temperature

Most aquatic life depends on sufficient quantities of dissolved oxygen (DO) for growth and reproduction. As the life cycle of many fish and other aquatic organisms is dictated by temperature, the relationship between DO and temperature is important. Also, as temperature affects the ability of water to hold DO, DO and temperature are often measured together (see Table 1).

Table 1: Provincial Water Quality Objectives for Dissolved Oxygen
Dissolved oxygen concentrations should not be less than the values specified below for cold water biota (e.g. salmonid fish communities) and warm water biota (e.g. centrarchid fish communities)

Temperature	**Cold Water Biota**		**Warm Water Biota**	
°C	*% Saturation*	*DO mg/L*	*% Saturation*	*DO mg/L*
0	54	8	47	7
5	54	7	47	6
10	54	6	47	5
15	54	6	47	5
20	57	5	47	4
25	63	5	48	4

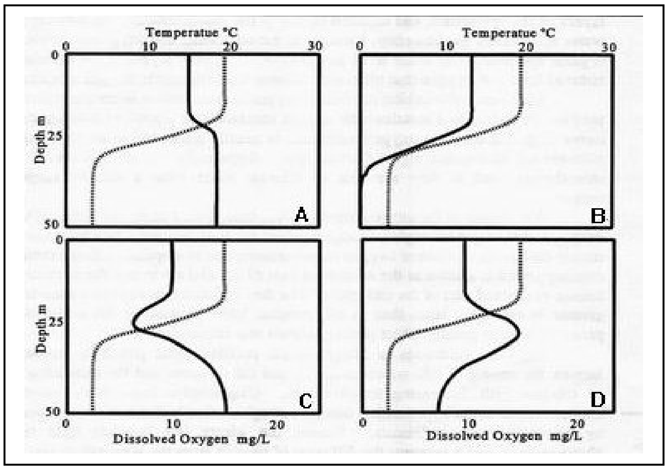
More stringent objectives may be required for waters with sensitive biological communities, lake trout for example, or in situations where additional stressors occur. Ontario Ministry of the Environment and Ministry of Natural Resources suggest that optimal habitat for lake trout requires greater than 6 mg/L oxygen at less than 10°C, while they can exist in waters with dissolved oxygen concentrations as low as 4 mg/L at less than 15°C (MOE and MNR 1986). The optimal habitat for splake requires temperatures between 10 to 16°C with a minimum dissolved oxygen concentration greater than 5 mg/L (Kerr, S.J. and R.E. Grant 2000).

When plants and other organisms die, the process of decay uses up dissolved oxygen. Since lakes (or areas in lakes) with higher levels of nutrients have greater organic growth, they will have higher rates of breakdown and are at greater risk for low dissolved oxygen. Dissolved oxygen can be replenished on the surface by wind and wave action, as well as some aquatic plants, but because there is no mixing between thermally stratified layers in the summer, dissolved oxygen used up in the hypolimnion will not be replenished until fall turn over. Cold water fisheries therefore are extremely sensitive to high nutrient loading due to the threat of oxygen depletion in the hypolimnion.

The amount of dissolved oxygen is also be used to characterize a lake's nutrient status. Figure 1 shows dissolved oxygen-temperature profiles that are typical of different types of lakes. Oligotrophic lakes tend to have a dissolved oxygen profile pattern similar to "A" and "C", showing an increase in the amount of oxygen in the hypolimnion (bottom). Mesotrophic and eutrophic lakes tend to follow the pattern of "B" and "D", showing a decrease in oxygen in the hypolimnion.

The % oxygen saturation in the hypolimnion is also helpful to characterize the lake. The % oxygen saturation is the ability of the water to retain dissolved oxygen and is dependent on temperature and pressure. The % oxygen saturation commonly found in mesotrophic lakes is between 25-90% in the hypolimnion and in eutrophic lakes it falls between 0-25%.

Figure 1: **Example Dissolved Oxygen-Temperature Profiles**
The dark line represents dissolved oxygen and the light line represents temperature.



(Mackie, 1999)

Escherichia coli (E. Coli)

Pathogens (bacteria, viruses, protozoa) in freshwater can impact human use of water resources by contaminating drinking water or affecting recreational activities, such as swimming. Storm water runoff is one of the biggest sources of contamination. When rainwater runs into lakes and streams, it can carry with it fecal matter from cats, dogs, cows, water fowl and other animals living in the area. Birds, in particular gulls, domesticated ducks and geese have become a serious contamination source. Several beaches in the region are routinely fouled in this manner. Contamination can also occur through inadequately treated wastewater (municipal sewage, leaky sewage lines or malfunctioning septic systems).

Coliforms are bacteria found in the large intestine of humans and other animals. While a few strains of coliforms produce serious toxins, most are not harmful. *Escherichia coli* (*E. coli*) and fecal coliform are often used as indicators of possible contamination by fecal matter, and the *potential* for contamination of other pathogens. The recommended safety level of *E. coli* in a lake for aquatic life and recreational safety is 100 colony-forming units (CFU) per 100ml of water.

OTTER LAKE SAMPLING SITES

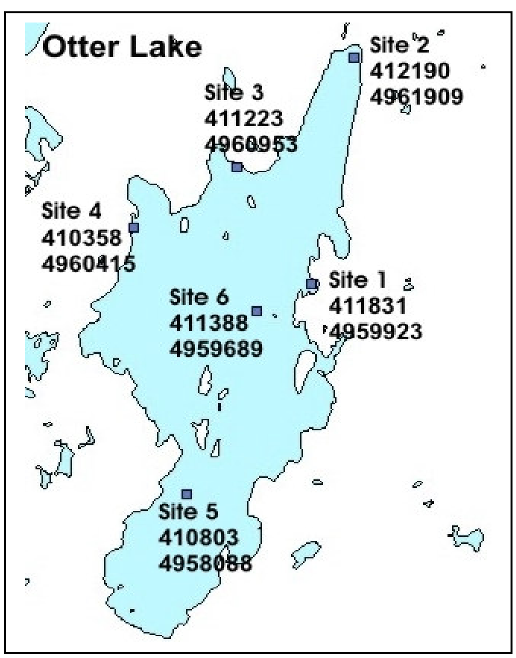
Sampling detail for Otter Lake is described in Table 2. Location and GPS co-ordinates of sampling sites are shown in Figure 2.

Table 2: Sampling detail for the five sites sampled by CSW on Otter Lake in 2002

Near Shore Sites	
Site #	**Sampling Detail**
1	**Bi-weekly:** dissolved oxygen (mg/L), pH, temperature (º C), and chlorophyll (µg/L) using YSI multi-parameter field unit at one metre from the surface. Sampling dates: July 8, July 22, August 6, August 19, September 4, and September 30, 2002.
2	
3	
4	

Pelagic (Open Water) Sites		
Site #	**Depth**	**Sampling Detail**
5	20 m	**Monthly:** TP at one metre from the surface and one metre from bottom of each site and TKN at one metre from the surface. 2002 sampling dates: July 8, August 6, Sept 4 and Sept 30. **Bi-weekly** profiling (samples taken from bottom to surface at one metre intervals) using a YSI multi-parameter field unit: dissolved oxygen, % oxygen saturation, pH and temperature (º C). 2002 sampling dates: July 8, July 22, August 6, August 19, Sept 4, and Sept 30.
6	35 m	

Figure 2: Location and GPS co-ordinates of Otter Lake sites sampled in 2002



FINDINGS

Total Phosphorus (TP)

Table 3 shows results of TP measurements taken at two depths (surface and one metre from the bottom) at the open water sites in the 2002 sampling season. Oligotrophic lakes are characterized by average TP values less then 10 micrograms per litre (µg/L), mesotrophic lakes have between 10 and 20 µg/L and eutrophic lakes have an average TP level greater than 20 µg/L (M = mesotrophic, O = oligotrophic, E = eutrophic).

Table 3: Surface and bottom TP (µg/L) for two basin sites on Otter Lake in 2002

	Surface		**Bottom**	
Date	**Site 5** (µg/L)	**Site 6** (µg/L)	**Site 5** (µg/L)	**Site 6** (µg/L)
July 8	40	30	40	40
August 6	15	11	13	12
September 4	6	10	8	11
September 30	8	9	11	9
Average	*17.25*	*15*	*18*	*18*
Average excluding July 8	*9.7*	*10*	*10.7*	*10.7*

TP concentrations were below 15 µg/L at both sites throughout most of the summer. July 8th results were all considerably higher than other dates and should not be included in trophic assessment. The average surface TP value at Site 5 indicated oligotrophic conditions and at Site 6 suggested oligo-mesotrophic conditions. There was no considerable difference between surface and bottom tests.

Nitrogen

Table 4 shows TKN values for the open water sites, and also reports the TKN:TP ratio.

Table 4: TKN, and TKN:TP ratio for Otter Lake offshore sites sampled in 2002

	Site 5			**Site 6**		
Date	**TKN** (µg/L)	**TP** (µg/L)	**TKN:TP**	**TKN** (µg/L)	**TP** (µg/L)	**TKN:TP**
July 8	600	40	**15**	500	30	**16**
August 6	590	15	**40**	520	11	**47**
September 4	480	6	**80**	690	10	**69**
September 30	450	8	**56**	540	9	**60**
Average	**530**			**562**		

The average TKN values for Sites 5 and 6 were 530 and 562 (µg/L) respectively. While there are no Ontario guidelines, these values do suggest that there may be some organic loading (RVCA 2000). The value is below Alberta guidelines of 1 mg/L (Government of Alberta 1999).

Except for the July 8th sampling date (discussed above), the TKN:TP ratio was well over 25, suggesting that the lake is phosphorus limited.

Secchi Depth

Table 5 shows the secchi depth and associated trophic status throughout the season for Sites 5 and 6 respectively. A reading greater then 5 m indicates an oligotrophic lake, from 3-5 m indicates a mesotrophic lake and a reading less then 3 m indicates a eutrophic lake. The average for Site 5 was 3.15 m, indicating mesotrophic status. The readings for Site 6 were more variable, however the average was 3.34 m, also indicating mesotrophic status.

Table 5: Secchi depth (m) for Site 5 and Site 6.

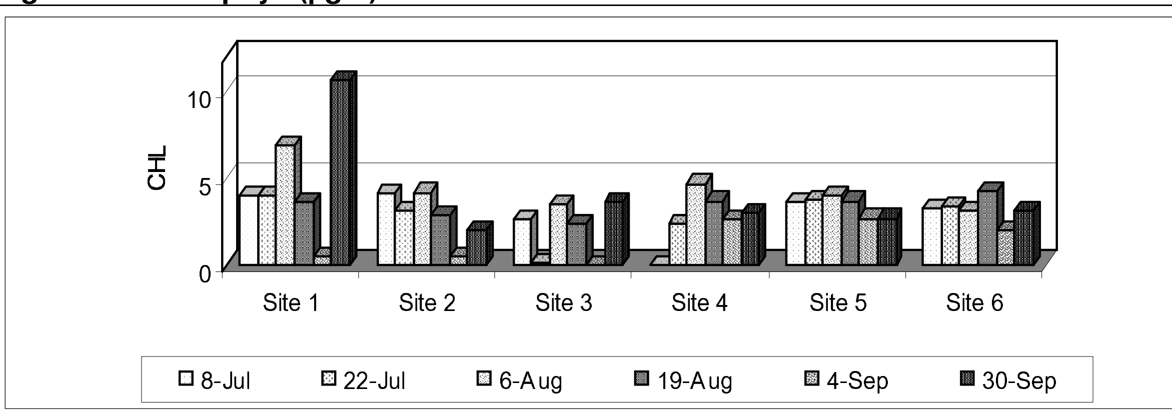
Site 5			Site 6		
Date	**Secchi Depth (m)**	**Trophic Indication**	**Date**	**Secchi Depth (m)**	**Trophic Indication**
July 8	3.4	***Mesotrophic***	July 8	3.1	***Mesotrophic***
July 22	3.0		July 22	2.5	
August 6	3.5		August 6	2.0	
August 19	4.5		August 19	3.6	
September 4	4.5		September 4	5.5	
Site Average	***3.15***		***Site Average***	***3.34***	

Secchi depth can be affected by suspended particles from shoreline erosion, agricultural run-off, or tree pollen. As well, because this reading is subject to human interpretation, it is subjective. Weather, such as sun and wind can also influence readings. For these reasons water clarity should not be used alone when assessing water quality. The presence of zebra mussels can also affect secchi readings. Because they filter water to feed on algae, the clarity of the water they infest is improved, resulting in an increase in secchi depth reading. This can skew correlation of secchi depth to trophic status.

Chlorophyll

Figure 4 shows YSI chlorophyll readings (µg/L) at the six sites sampled on Otter Lake. Each of these samples was taken at one meter from the surface. Site 1 shows higher values on August 6 and September 30, but the other sites are more consistent throughout the season. High readings can indicate high amounts of algae, but also be affected by aquatic plants. Follow up testing for TP and/or *E. coli* (depending on potential source) may be useful to determine if there is a potential area of concern near this site.

Figure 4: Chlorophyll (µg/L) at six sites in Otter Lake in 2002



Dissolved Oxygen – Temperature

Appendix A shows the dissolved oxygen and temperature profiles taken throughout the season at Sites 5 and 6. From these profiles, it could be determined that both sites followed a pattern indicative of some nutrient enrichment (see "B" Figure 1). Table 6 shows the levels of dissolved oxygen at the two deep sites at 10, 15.5 and 18°C, showing the range of optimal habitat (10°C) to tolerance (15.5°C) for lake trout and the range of conditions for rainbow trout (18°C).

Table 6: Dissolved Oxygen Concentrations (mg/L) at 10 and 15.5°C

Date (2003)	Site 5			Site 6		
	10 °C	*15.5 °C*	*18°C*	*10 °C*	*15.5°C*	*18°C*
July 08	5.75	8.01	8.18	6.59	7.63	7.83
July 22	4.84	6.32	7.04	5.77	5.80	6.33
Aug 06	2.78	3.17	3.01*	4.39	3.84	4.01
Aug 19	2.06	2.95	3.73	3.26	3.63	4.37
Sept 4	0.91	2.37	3.46	1.77	2.25	3.10
Sept 30	0.12	1.12	4.06	0.61	0.45	2.64

* at 11.5°C, DO was 3.95

According to the MNR, Otter Lake has supported lake trout in the past. The lake is currently stocked with rainbow trout and has been stocked with splake. Dissolved oxygen-temperature analysis near the end of the summer, before fall turn-over, provides an indication of the 'worst case' scenario. While lake trout prefer 8-15°C, splake prefer 12-16°C and rainbow trout can thrive in warmer temperatures 13-18°C. Lake trout require 6 mg/L of dissolved oxygen for optimal habitat while splake and rainbow trout require 5 mg/L (MNR 2002). These fish can tolerate levels as low as 4 mg/L. There are other factors that influence the suitability of a water body for specific fisheries.

Northern pike are normally found in weedy bays throughout the spring and fall, and move to cooler depths (about 4.5 m) during the peak of the summer. For survival, they require at least 3 mg/L of dissolved oxygen (Scott & Crossman 1973). During the warmer summer months of 2002, Otter Lake had sufficient amounts of oxygen at that depth.

Both smallmouth and largemouth bass prefer water within the epilimnion. Smallmouth desire temperatures from 20.3°C to 21.3°C whereas largemouth prefer warmer temperatures from 26.6°C to 27.7°C. Both species require a minimum of 5 mg/L of dissolved oxygen for normal activity however smallmouth can tolerate levels to 2.5 mg/L and largemouth can tolerate levels of 2 mg/L (The Content Well). These criteria were met in Otter Lake in 2002 (see Appendices B and C). It should be noted that dissolved oxygen can vary diurnally, due to plant and algae/photosynthesis (producing DO) during the day and respiration (consuming DO) at night. Diurnal testing would show whether levels decreased significantly at night.

pH

The pH range of a healthy freshwater lake is between 6.5 and 8.5. pH in Otter Lake's hovered above 8.5 at all sites throughout the season, indicating that it is somewhat alkaline (see Appendix C). This is not uncommon for Eastern Ontario, as lakes with limestone bedrock or high levels of carbonates in their sediments will tend to have alkaline water. This chemistry will help the lake to "buffer" against changes in pH from inputs such as acid rain.

2002 SUMMARY

- Most findings suggested that Otter Lake had oligo-mesotrophic nutrient status in 2002.
- Average TP from the two off-shore sites (representing minimal point source influence) throughout the season indicated oligotrophic or oligo-mesotrophic status.
- Average TKN values suggest some organic loading but are below guidelines for Alberta (no guidelines available for Ontario).
- The TKN:TP ratio at both off-shore sites indicated that phosphorus was the limiting nutrient. This means that any added phosphorus can contribute to plant and algae growth.
- Chlorophyll levels were occasionally elevated at Site 1. Follow up testing for TP and/or *E. coli* (depending on potential source) may be useful.
- The secchi depth readings suggested that this lake exhibits mesotrophic conditions.
- Dissolved oxygen at the optimal temperatures for cold water fisheries became low by August, and could cause stress to these fisheries.
- Dissolved oxygen in the epilimnion is sufficient for warm water fisheries (northern pike, largemouth bass, smallmouth bass, etc.)
- pH was slightly high, likely due to limestone/carbonate geology.

RECOMMENDATIONS

Although the information gathered during the summer 2002 sampling season indicated that Otter Lake was healthy, further testing should be completed on an annual basis to ensure that this is the case from year to year. An annual monitoring strategy will help track changes in water quality over time and identify hot spots (problem areas). It has been estimated that three to five years of data should be recorded at the same sites in order to determine trophic status and yearly trends. The following recommendations are offered:

- Because it is the limiting nutrient, TP is one of the most important nutrients to monitor. Increases in phosphorus concentrations will necessarily contribute to algae and plant growth. Testing in the pelagic zones helps assess overall status of the lake, while near-shore testing will help identify hot spots. Testing at depth is required less frequently. The Lake Partner Program (MOE) offers some free analysis.
- Secchi readings should be continued. It should be noted, however, that the presence of zebra mussels can affect its effectiveness as a trophic status indicator.
- It is important to continue to monitor dissolved oxygen levels. While comprehensive profiling is not required on a yearly basis, at least one profile per site would be recommended on an annual basis (mid August to mid September) to evaluate fish habitat.
- A field unit, such as the YSI, is a cost-effective tool to assess chlorophyll *in situ*. While it may enable more locations and more frequent sampling, *E. coli* and TP testing is more conclusive. Indications of high chlorophyll from the YSI should be verified with TP and/or *E. coli* testing (depending on potential source).
- Potential nutrient sources may include aging or malfunctioning septic systems, domestic lawn care & golf courses, stormwater run-off, agriculture, and boating. Continued near-shore testing is recommended to determine if any of these hot spots or potential sources exist. Sites should be close to shore, or inflow areas such as storm drains, farms or streams. Sampling dates geared to rain events will maximize opportunity to observe contamination (precipitation data should be recorded).
- Streams assessments could also help identify any upland hot spots. Benthic invertebrates are useful indicators of water quality and environmental health. Incorporated into a volunteer monitoring program, benthic assessment can be a cost-effective method for evaluating several sites, including streams.

While more sampling will provide a clearer picture of the nutrient status at a site, frequency of sampling is always dictated by resources available. Nevertheless, sampling times should be evenly timed – preferably starting as soon after ice out as possible, before the spring turn-over and continue through to the fall turn-over. One winter sampling should also be considered. Algae blooms can occur in the winter under the ice and as with the summer, when it dies off, decomposition will cause a decrease in the amount of dissolved oxygen. Since there is no wind or cycling of the water in the winter because of the ice, oxygen is not replenished. This can result in what is known as a winter fish kill.

An educational campaign may also be a consideration - to help teach shoreline residents about the impacts of shoreline living and small steps they can take to help protect/improve water quality. This may include workshops on healthy shoreline living, information on your website, articles/tips in your newsletters, shoreline home visits, and/or an appeal at your AGM.

REFERENCES

Government of Alberta. 1999. Surface Water Quality Guidelines for Use in Alberta. www.gov.ab.ca/env/protenf/publications/SurfWtrQual-Nov99.pdf

Horne, A.J., & Goldman. 1994. Limnology. 2nd Ed. McGraw Hill Inc. NY: 576p.

Mackie, G. L. 1999. Chapter 5: Knowing a Lake's Healthy Signs. Applied Aquatic Ecosystems. University of Guelph. ON: 5.1-5.39.

Ministry of Natural Resources (MNR). 2002. Guidelines for Stocking Fish in Inland Waters of Ontario. Fisheries Section, Fish and Wildlife Branch. August 2002.

Raven, P.H., Evert, R.F., and Eichhorn, S.E. 1992. Biology of Plants. 5th Ed. Worth Publishers. NY: 791p

Rideau River Round Table. 2001. State of the River Report: A report on the environmental Health of the Rideau River.

Rideau Valley Conservation Authority (RVCA). 2000. Existing Conditions and Trends in the Tay River Watershed.

Scott, W.B., & E.J Crossman. 1973. Freshwater Fishes of Canada. Fisheries Research Board of Canada. ON: 966p.

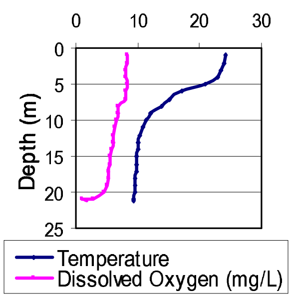
The Content Well. . Fish & Game Information. www.thecontentwell.com/Fish_Game/index.html Creative Publishing International

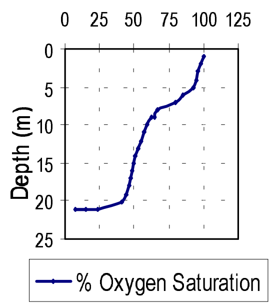
APPENDIX A
Dissolved oxygen-temperature and % oxygen saturation profiles

Dissolved oxygen (mg/L), temperature (ºC) and oxygen saturation (%)
DO - temperature profiles are on the left and % oxygen saturation profiles are on the right

Site 5

July 8, 2002





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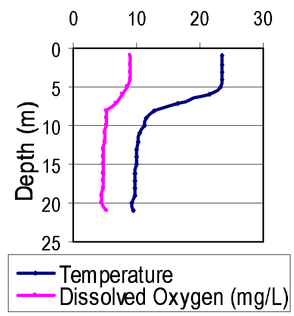

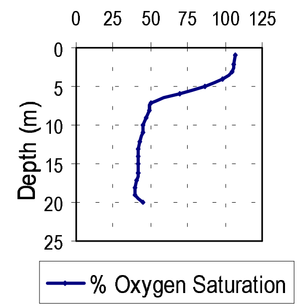

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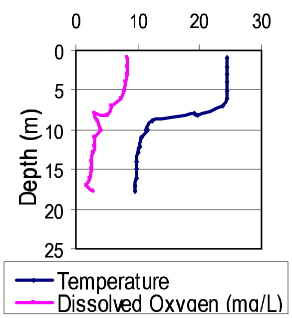

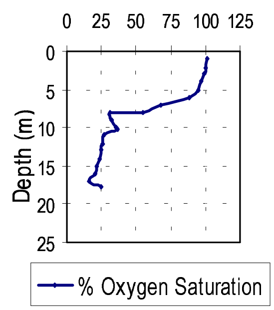

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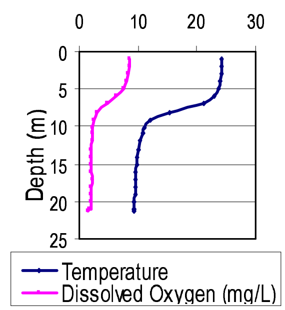

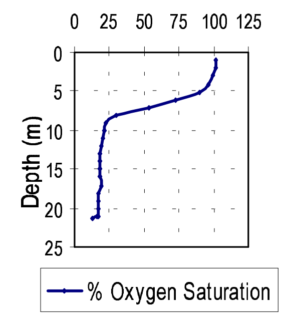

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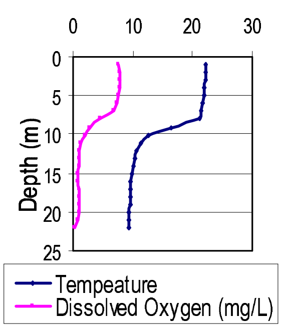

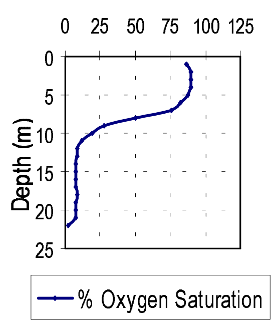

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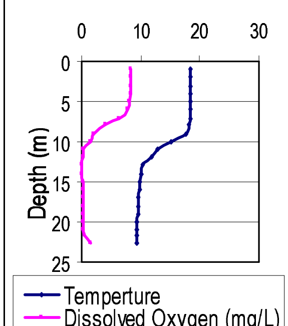
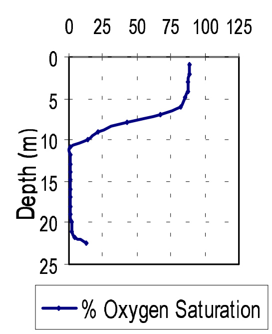
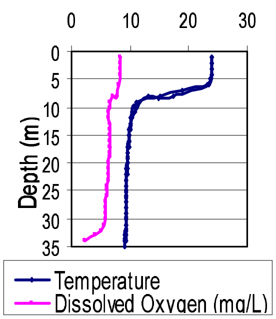
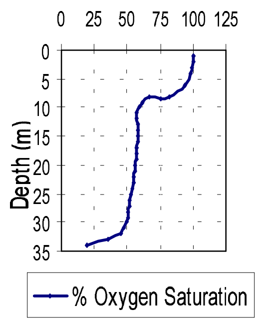




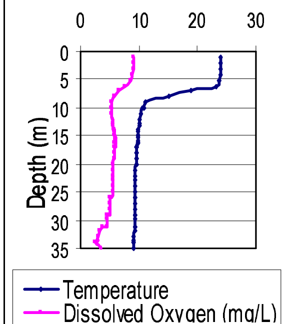
Site 6

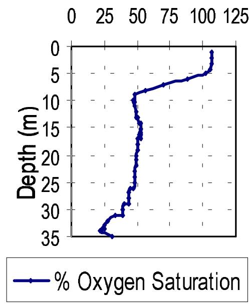
July 8, 2002



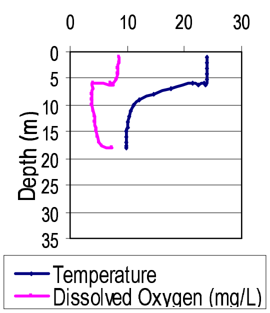


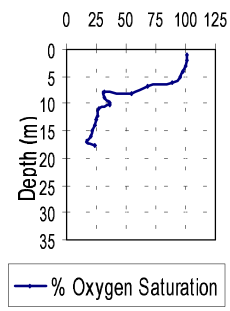
July 22, 2002



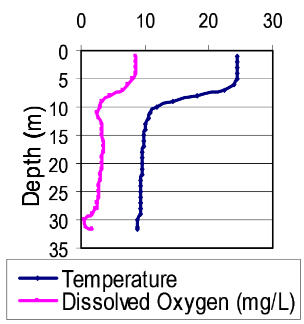


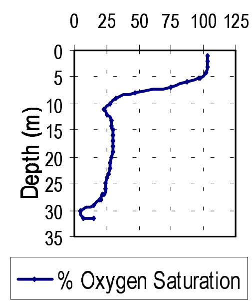
August 6, 2002



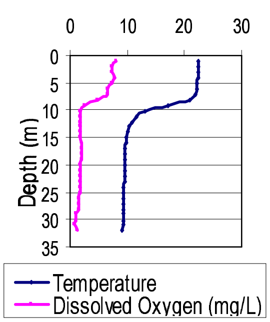


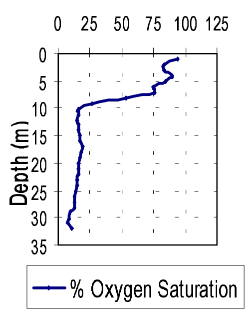
August 19, 2002



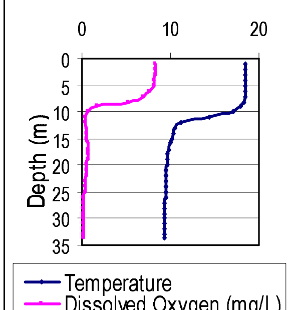


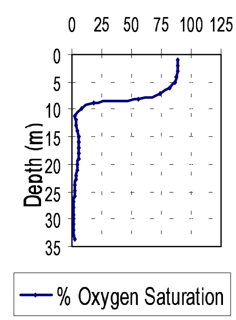
September 4, 2002





September 30, 2002





APPENDIX B

Profile data

Depth (m), temperature (°C), and dissolved oxygen (mg/L)

Site 5

8-Jul-02				22-Jul-02				6-Aug-02			
Temp ºC	DO % %	DO mg/L	Depth m	Temp ºC	DO % %	DO mg/L	Depth m	Temp ºC	DO % %	DO mg/L	Depth m
24.25	99.70	8.35	1.0	23.47	106.30	9.03	1.0	24.46	101.00	8.43	1.0
24.04	98.10	8.25	2.0	23.48	106.40	9.04	2.1	24.47	100.60	8.39	2.1
23.51	96.20	8.16	3.0	23.46	106.20	9.03	3.0	24.47	99.50	8.30	3.0
22.96	94.70	8.13	4.0	23.45	105.10	8.93	4.1	24.47	97.50	8.13	4.0
20.96	92.30	8.22	5.0	23.13	98.40	8.41	5.1	24.46	95.10	7.93	5.1
17.24	84.90	8.16	6.1	16.60	69.30	6.75	7.0	24.40	88.40	7.39	6.1
15.24	79.60	7.98	7.0	21.39	87.00	7.69	6.1	23.80	67.90	5.74	6.9
13.86	66.70	6.89	8.0	12.75	50.50	5.34	8.0	19.11	31.70	2.93	7.9
12.17	62.80	6.73	9.0	11.48	48.80	5.32	9.1	19.57	54.70	5.01	8.1
12.22	64.60	6.92	9.0	11.25	47.30	5.18	10.1	12.25	31.80	3.41	9.0
11.36	59.30	6.48	10.0	10.58	45.30	5.04	11.1	11.40	35.80	3.91	10.0
10.74	57.20	6.34	11.0	10.31	44.40	4.97	12.1	11.57	36.30	3.95	10.1
10.45	54.60	6.10	12.0	10.10	43.00	4.84	13.0	10.49	27.20	3.03	11.0
10.20	52.80	5.93	13.1	9.96	41.70	4.71	14.1	10.30	26.30	2.94	12.1
10.04	51.10	5.75	14.0	9.93	41.60	4.70	15.0	10.04	24.60	2.78	12.9
9.83	49.90	5.66	15.0	9.85	41.20	4.66	16.1	9.93	23.40	2.64	14.0
9.76	48.90	5.55	16.1	9.84	41.20	4.67	16.1	9.82	21.50	2.43	15.0
9.72	47.60	5.40	17.1	9.69	41.20	4.68	17.1	9.63	16.60	1.88	17.0
9.64	45.90	5.22	18.0	9.67	40.90	4.65	18.0	9.77	21.00	2.38	16.1
9.58	44.40	5.06	19.1	9.26	39.40	4.53	20.0	9.50	24.40	2.79	17.8
9.52	40.60	4.63	20.1	9.63	39.30	4.47	19.1				
9.34	8.00	0.92	21.0	9.39	44.90	5.14	20.8				
9.34	23.70	2.72	21.0								
9.43	15.50	1.77	21.2								

Site 5 (cont)

19-Aug-02				4-Sep-02				30-Sep-02			
Temp ºC	DO % %	DO mg/L	Depth m	Temp ºC	DO % %	DO mg/L	Depth m	Temp ºC	DO % %	DO mg/L	Depth m
24.25	101.8	8.52	1.0	22.18	86.7	7.55	1.0	18.33	88.8	8.34	1.0
24.25	101.3	8.48	2.1	22.13	89.8	7.83	2.0	18.33	88.5	8.32	2.0
24.18	99.1	8.31	3.0	22.08	89.8	7.83	3.0	18.32	88.1	8.28	3.0
23.92	96.2	8.10	4.0	22.02	89.8	7.84	4.0	18.32	87.4	8.21	4.1
23.76	89.7	7.58	5.0	21.83	87.3	7.66	5.0	18.33	85.9	8.08	4.9
23.02	72.4	6.20	6.0	21.74	82.3	7.23	6.0	18.32	82.1	7.72	6.1
21.27	53.4	4.73	7.0	21.55	76.3	6.73	7.0	18.29	67.1	6.31	7.0
15.47	29.6	2.95	8.1	21.1	49.8	4.42	8.0	18.11	43.0	4.06	7.9
11.99	22.9	2.47	9.0	16.37	28.1	2.75	9.1	17.66	21.2	2.02	9.0
11.06	21.7	2.39	10.0	12.67	18.7	1.99	10.0	15.25	14.3	1.44	10.0
10.76	20.1	2.23	11.0	11.33	11.8	1.30	11.0	12.97	1.5	0.15	11.0
10.36	19.2	2.15	12.0	10.58	9.0	1.01	12.1	11.95	1.2	0.13	11.9
10.1	18.3	2.06	13.1	10.31	8.5	0.95	13.0	10.4	1.0	0.12	12.9
9.88	17.7	2.00	14.0	10.09	8.0	0.91	14.0	10.09	1.1	0.12	14.0
9.73	17.9	2.03	15.0	9.84	7.4	0.83	15.0	9.87	1.1	0.13	14.9
9.69	18.0	2.05	16.0	9.69	7.8	0.88	16.0	9.71	1.2	0.14	16.0
9.6	18.9	2.15	17.1	9.56	7.9	0.9	17.0	9.58	1.3	0.14	16.9
9.54	17.6	2.01	18.0	9.51	8.1	0.92	18.0	9.57	1.3	0.15	18.0
9.52	17.1	1.95	19.0	9.47	7.8	0.89	19.1	9.47	1.4	0.16	19.0
9.45	16.8	1.92	20.0	9.43	7.8	0.89	20.1	9.44	1.8	0.21	20.0
9.4	15.7	1.80	21.0	9.41	7.6	0.86	21.1	9.41	2.6	0.3	21.0
9.4	16.8	1.92	21.1	9.38	2.5	0.28	22.0	9.43	4.8	0.55	21.7
9.25	12.5	1.44	21.4					9.36	13.3	1.52	22.5

Site 6

8-Jul-02				22-Jul-02				6-Aug-02			
Temp ºC	DO % %	DO mg/L	Depth m	Temp ºC	DO % %	DO mg/L	Depth m	Temp ºC	DO % %	DO mg/L	Depth m
24.06	100.2	8.42	1.0	23.9	107.1	9.02	1.0	24.03	101.1	8.5	1.0
24.07	100.2	8.42	1.0	23.89	106.7	9	2.0	24.02	100.8	8.48	2.0
24	100	8.41	2.1	23.87	106.3	8.96	3.0	24.02	100.1	8.42	3.0
23.93	99.5	8.38	3.1	23.86	105.3	8.88	4.1	24.01	98.5	8.29	4.1
23.88	97.9	8.25	4.1	23.82	102.1	8.62	5.1	23.38	81.9	6.97	5.0
23.36	93.4	7.95	6.0	23.18	88.3	7.54	6.1	23.98	96.2	8.09	5.0
13	66.4	6.99	8.0	18.89	70.4	6.54	7.0	21.54	44.9	3.96	5.9
17.46	81.8	7.82	8.0	15	56.4	5.69	8.1	23.68	85	7.19	6.1
14.8	75.2	7.61	8.5	11.01	48.3	5.32	8.9	22.39	87.6	7.59	6.4
11.68	61.6	6.68	9.0	10.9	48.3	5.34	10.1	17.7	43	4.09	7.0
11.17	59	6.47	10.0	10.32	47.9	5.36	11.0	14.74	37	3.75	8.1
10.75	57.2	6.34	11.0	10.18	49.1	5.51	12.0	11.98	35.4	3.81	9.0
10.43	57.3	6.4	12.0	10.1	49.3	5.55	13.0	11	34.4	3.79	10.0
10.18	58	6.52	13.0	10.13	50	5.63	13.2	10.58	35.7	3.98	11.0
10.04	58.4	6.59	14.0	9.92	52.2	5.9	14.0	10.32	37.7	4.22	12.0
9.9	58.3	6.59	15.0	9.8	52.2	5.92	15.1	10.16	38.6	4.34	13.0
9.8	57.8	6.55	16.1	9.75	51.7	5.87	16.1	9.98	39.4	4.44	14.1
9.72	57.5	6.53	17.1	9.67	52.9	6.01	17.1	9.87	40.1	4.54	15.0
9.72	57.5	6.53	17.1	9.68	50.5	5.74	17.1	9.82	42.3	4.79	16.0
9.68	57.5	6.53	18.0	9.6	50.6	5.76	18.1	9.78	43.7	4.95	17.0
9.61	57	6.49	19.1	9.5	50.2	5.73	19.1	9.8	49.2	5.58	17.8
9.56	56.3	6.42	20.0	9.49	49.4	5.64	20.0	9.95	64.8	7.31	17.9
9.53	55.6	6.34	21.0	9.45	49	5.6	21.0				
9.46	55.1	6.3	22.0	9.44	48.9	5.58	22.0				
9.44	54.7	6.25	23.0	9.44	48.5	5.54	23.0				
9.42	53.7	6.14	24.0	9.42	48.1	5.5	24.0				
9.39	52.6	6.02	25.0	9.42	47.9	5.48	25.0				
9.37	52.2	5.98	26.0	9.37	47.1	5.39	26.0				
9.34	51.5	5.9	27.0	9.35	45	5.15	26.1				
9.33	50.9	5.84	28.0	9.32	44	5.04	27.0				
9.31	50.3	5.77	29.1	9.3	43.5	4.99	28.0				
9.3	49.7	5.69	30.0	9.29	43.9	5.04	29.0				
9.29	47.5	5.45	31.1	9.28	39.9	4.58	29.0				
9.27	44.8	5.14	32.0	9.26	38.6	4.43	29.9				
9.26	35.9	4.13	33.0	9.24	38.6	4.43	31.0				
9.24	19.6	2.25	34.0	9.27	33.7	3.86	31.1				
				9.22	27.8	3.19	32.0				
				9.18	25.6	2.95	33.0				
				9	22.1	2.55	34.0				
				9.07	31.4	3.62	34.8				

Site 6 (cont)

19-Aug-02				4-Sep-02				30-Sep-02			
Temp *ºC*	**DO %** %	**DO** *mg/L*	**Depth** *m*	**Temp** *ºC*	**DO %** %	**DO** *mg/L*	**Depth** *m*	**Temp** *ºC*	**DO %** %	**DO** *mg/L*	**Depth** *m*
24.45	103.7	8.65	1.0	22.35	93.7	8.13	1.0	18.42	89	8.35	1.0
24.45	103.5	8.63	2.0	22.34	83.3	7.24	2.0	18.42	88.6	8.31	2.1
24.45	102.8	8.57	3.0	22.33	83	7.2	3.0	18.42	88.1	8.26	3.0
24.45	102	8.51	4.0	22.32	89.3	7.75	4.0	18.41	86.3	8.1	5.0
24.39	96.5	8.06	5.0	22.3	84.7	7.36	5.0	18.41	87.4	8.2	4.0
24.4	97.8	8.17	5.0	22.24	75	6.52	6.0	18.41	81.6	7.66	6.0
24.04	87.6	7.37	6.0	21.98	75.5	6.6	7.0	18.39	73.5	6.9	7.1
22.32	74.1	6.44	7.0	20.96	53	4.72	8.0	18.29	55.9	5.25	8.2
18.22	47.2	4.44	8.0	17.03	26.5	2.56	9.0	17.92	18.6	1.76	8.9
14.3	31.7	3.25	9.1	13.07	16.3	1.71	10.0	17.16	7.8	0.75	9.9
11.81	27.8	3	10.0	11.56	16.1	1.75	11.0	14.37	2.6	0.27	11.1
10.85	23	2.54	11.0	10.85	14.8	1.64	12.1	11.2	3.1	0.34	12.0
10.48	24.8	2.76	12.1	10.32	15.9	1.78	13.1	10.57	3.8	0.43	13.0
10.15	28.3	3.18	13.0	10.08	15.8	1.77	14.0	10.3	4.7	0.53	14.0
10.01	28.9	3.26	14.0	9.95	16.7	1.89	15.1	10.12	5.3	0.59	15.0
9.93	29.8	3.37	15.0	9.76	16.9	1.91	16.0	9.94	5.5	0.62	15.9
9.79	30	3.41	16.0	9.67	18.7	2.13	17.1	9.79	5.7	0.64	17.0
9.75	30.1	3.41	17.0	9.61	18.5	2.11	18.0	9.71	5.6	0.63	18.0
9.7	30.1	3.42	18.1	9.55	17	1.93	19.1	9.66	5.4	0.61	19.0
9.61	29.5	3.36	19.0	9.53	16.5	1.88	20.0	9.59	4.9	0.56	20.0
9.55	28.7	3.28	20.0	9.48	15.7	1.79	21.0	9.55	4.6	0.53	21.0
9.48	28	3.2	21.0	9.48	16.3	1.87	22.0	9.51	3.8	0.44	22.0
9.46	27.4	3.13	22.0	9.46	15.4	1.76	23.0	9.48	3.1	0.35	22.9
9.44	26.7	3.05	23.1	9.41	14.4	1.64	25.0	9.45	2.5	0.28	23.9
9.41	25.1	2.87	24.0	9.45	14.6	1.67	24.0	9.43	2.3	0.26	25.0
9.39	24.5	2.8	25.1	9.36	12.5	1.43	28.1	9.42	1.9	0.22	25.9
9.38	23.7	2.72	26.0	9.39	12.6	1.45	26.1	9.39	1.6	0.18	28.0
9.35	21.9	2.51	27.0	9.32	9.5	1.09	29.0	9.4	1.7	0.19	27.0
9.35	22.4	2.57	27.1	9.29	8.6	0.99	30.1	9.36	1.1	0.13	29.9
9.34	19.4	2.22	28.0	9.27	7.5	0.86	31.0	9.38	1.3	0.15	29.1
9.34	21.2	2.43	28.0	9.2	10.2	1.17	32.0	9.35	1.2	0.14	31.0
9.3	14.5	1.66	29.0					9.34	1.3	0.15	32.1
8.81	4.3	0.5	30.1					9.33	1.3	0.15	33.0
8.74	6.9	0.8	31.4					9.31	1.9	0.22	33.6
8.75	14.4	1.67	31.6								

APPENDIX C
Surface Data

Temperature (°C), dissolved oxygen (mg/L), % oxygen saturation, pH, and chlorophyll (µg/L) data collected at surface on Otter Lake in 2002.

All sites were measured at 1 m in depth.

Temperature (°C)						
	8-Jul	**22-Jul**	**6-Aug**	**19-Aug**	**4-Sep**	**30-Sep**
Site 1	24.17	24.09	22.94	24.68	22.58	18.34
Site 2	23.75	24.15	22.52	24.71	22.97	18.39
Site 3	23.97	24.11	23.19	24.92	NA	18.41
Site 4	24.05	24.48	23.49	24.77	22.69	18.33
Site 5	24.25	23.47	24.46	24.25	22.18	18.33
Site 6	24.07	23.9	24.03	24.45	22.35	18.42
Dissolved Oxygen (mg/L)						
	8-Jul	**22-Jul**	**6-Aug**	**19-Aug**	**4-Sep**	**30-Sep**
Site 1	8.79	8.88	8.63	9.45	7.86	9.39
Site 2	8.76	9.19	8.63	9.26	7.86	8.28
Site 3	8.77	9.1	8.8	10.3	NA	9.23
Site 4	9	8.26	9.46	8.85	8.7	8.39
Site 5	8.35	9.03	8.43	8.52	7.55	8.34
Site 6	8.42	9.02	8.5	8.65	8.13	8.35
pH						
	8-Jul	**22-Jul**	**6-Aug**	**19-Aug**	**4-Sep**	**30-Sep**
Site 1	8.67	8.77	8.7	8.81	8.84	8.34
Site 2	8.68	8.76	8.62	8.68	8.83	8.29
Site 3	8.68	8.75	8.67	8.77	NA	8.33
Site 4	8.65	8.57	8.86	8.72	8.94	8.36
Site 5	8.67	8.74	8.75	8.71	8.77	8.39
Site 6	8.7	8.78	8.76	8.75	8.8	8.4
Chlorophyll (µg/L)						
	8-Jul	**22-Jul**	**6-Aug**	**19-Aug**	**4-Sep**	**30-Sep**
Site 1	4	4	6.9	3.6	0.5	10.6
Site 2	4.1	3.1	4.2	2.9	0.5	2
Site 3	2.6	0.1	3.5	2.4	NA	3.6
Site 4	NA	2.4	4.7	3.7	2.6	3
Site 5	3.6	3.8	4	3.7	2.7	2.7
Site 6	3.3	3.4	3.1	4.3	2	3.1