UPPER RIDEAU LAKE

WATER QUALITY MONITORING REPORT

2004

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INTRODUCTION

This report presents the findings of water quality monitoring conducted on Upper Rideau Lake from June through October, 2004.

BACKGROUND

Water quality is an excellent diagnostic tool for evaluating the health of a lake. Nutrients and pathogens can enter our waterways from a number of sources. Monitoring water quality indicators can help identify these sources and also evaluate whether things are improving or not.

Lake Dynamics

Deeper lakes tend to stratify during the summer months based on temperature differences (Figure 1). As the sun heats up surface waters, the warmer water will remain on top, 'floating' on colder, denser waters below. The depth where the temperature change is greater than 1^{o}C per metre is called the thermocline. The epilimnion is the area found above the thermocline and the area found below is known as the hypolimnion.

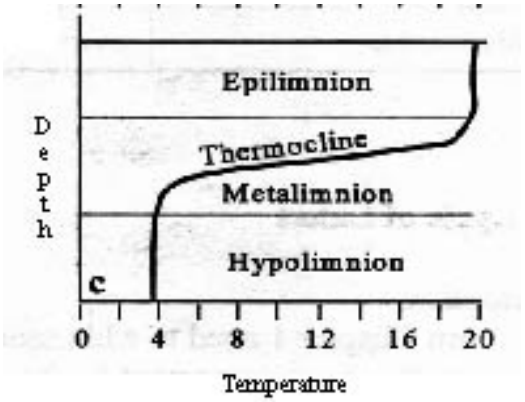


Figure 1: Thermal stratification (Mackie 1999)

Mixing only occurs twice a year in these lakes as air temperatures change in the spring and fall in what is called 'turn over'. In the fall, when the air cools, the surface of the lake will also cool. Water is at its most dense form at 4ºC, so as the surface temperature drops to 4ºC, it will sink. Surface water will continue sinking until the whole lake is uniform in density and temperature (4ºC). The lake turns over again in the spring as the ice melts and the surface warms to 4ºC creating a uniform temperature from top to bottom. This allows wind and wave action to mix the entire lake.

Trophic Status (Nutrients and the Effects of Nutrients)

Trophic status characterizes a lake as oligotrophic (low nutrient levels), mesotrophic (moderate levels of nutrients) or eutrophic (high levels of nutrients). This 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 can also be used to determine trophic status, as it provides a measure of the impact of plant growth associated with eutrophication. When the plants and algae die, they sink to the bottom and are decomposed by microorganisms, depleting the dissolved oxygen content of the hypolimnion.

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 nutrient controls (limits) plant growth. When the limiting nutrient is added to the system, accelerated algae and plant growth can occur.

Because phosphorus is often the limiting nutrient in freshwater systems, it is an excellent indicator of trophic status. Generally, the concentration of Total Phosphorus (TP) is taken to account for all chemical forms of phosphorus present. Oligotrophic lakes are characterized by an average TP level less than 10 µg/L, mesotrophic lakes have between 10 and 20 µg/L and eutrophic lakes have an average TP level greater than 20 µg/L. (1 mg/L = 1000 µg/L). Provincial water quality objectives are less than 20 µg/L.

The location of sampling is important. Samples taken close to shore are more likely to reflect processes that are happening on land (run-off from fertilizers, storm water runoff, erosion, agriculture). Samples taken in open water (mid lake) better represent the concentrations of phosphorus in the lake on a whole. Samples are taken at secchi depth to reflect the TP concentration just below the biologically productive area of the lake.

The phosphorus cycle is complex and while phosphorus is rapidly used by organisms in growth, it remains in the system (carbon and nitrogen are removed as gases by biological means). Phosphorus accumulates in the bottom of a waterbody as sediments with fertilizers and other contaminants adsorbed to them and as plants, algae, and other organisms that have phosphorus accumulated in their biomass. Sediments have a high capacity to store phosphorus, however it is not permanently removed. Low dissolved oxygen levels stimulate its release. This can be a problem, especially in high nutrient lakes, as decay of abundant plant growth depletes dissolved oxygen, further stimulating release.

Algae Growth

Algae growth is natural in lakes but with excessive nutrient concentrations, algae can become a nuisance. The monitoring of algae growth is carried out through chlorophyll sampling and secchi disc measurements. Because algae thrive on nutrients in the water, measures of algae growth can indicate nutrient availability in the water.

Chlorophyll

Chlorophyll is a pigment found in all aquatic plants and algae and therefore can be used to evaluate the algae content of a 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.

Certain chemical compounds fluoresce when exposed to sunlight. Chlorophyll is one such compound. Therefore an in-situ measurement of fluorescence can be used as an indicator of the presence of chlorophyll containing algae. Traditional lab methods of chlorophyll analysis are available but tend to be more costly and cumbersome. *In situ* analysis can provide a cost-effective measure, allowing more sites to be assessed, and can be correlated to lab measures. 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.

Secchi Depth

Secchi depth is a measure of water clarity, and in the past has been correlated to the amount of algae in the system. Secchi depth is measured by lowering a black and white 20cm radius disc into the water until it is no longer visible and then lifting it up until it reappears. Both depths are recorded and averaged for the overall secchi depth reading, a measure of how far light can penetrate the water column. A secchi depth greater then 5m indicates an oligotrophic lake, a measurement of 3-5 m is characteristic of a mesotrophic lake, and less then 3m signifies a eutrophic lake.

Secchi depth can be affected by a variety of factors including, suspended particles from shoreline

erosion, agricultural run-off, or tree pollen. Readings are subject to human interpretation and weather, such as sun and wind. 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 is improved, resulting in an increase in secchi depth reading. This can skew correlations of secchi depth to trophic status.

Dissolved Oxygen

Most aquatic life depends on sufficient quantities of dissolved oxygen (DO) for growth and reproduction. Microorganisms use DO in the process of decay. Lakes (or areas in lakes) with higher levels of nutrients and higher rates of growth are at greater risk for low DO. If levels become too low, aquatic life may be threatened. 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 turnover.

The Ontario water quality objectives for dissolved oxygen are shown in Table 1. 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.

Table 1: Provincial Water Quality Objectives for dissolved oxygen

Temperature ^{0}C	Cold Water Fish DO mg/l	Warm Water Fish DO mg/l
0	8	7
5	7	6
10	6	5
15	6	5
20	5	4
25	5	4

pH

pH is used to determine whether a lake is acidic or alkaline. The pH of lakes is largely dependent on its bedrock composition. In an area that has a lot of granite bedrock, the lakes will tend to be somewhat acidic. Lakes with limestone bedrock or high levels of carbonates in their sediments will tend to have alkaline water chemistry and increase capacity to “buffer” against changes in pH from inputs such as acid rain. In a natural environment, pH of a lake can fluctuate daily and seasonally due to many factors such as plant photosynthesis and respiration. Bacterial decomposition and high nitrogen concentrations can also influence pH. The pH range of a healthy freshwater lake is between 6.5 and 8.5.

UPPER RIDEAU LAKE SAMPLING SCHEME

Sampling was carried out at two basin sites and 10 near-shore sites monthly in 2004 on June 16th, July 17th, August 16th, September 13th, and October 8th.

The basin sites (URLA 7, 8) are the deepest points of the lake, with minimal influence from any specific nearshore area. The nearshore sites were chosen to reflect potential sources of nutrient loading (hot spots) like villages, development, landscaped lawns, farms, golf courses, and so on.

Tables 2 and 3 outline sampling details for the basin and nearshore sites respectively.

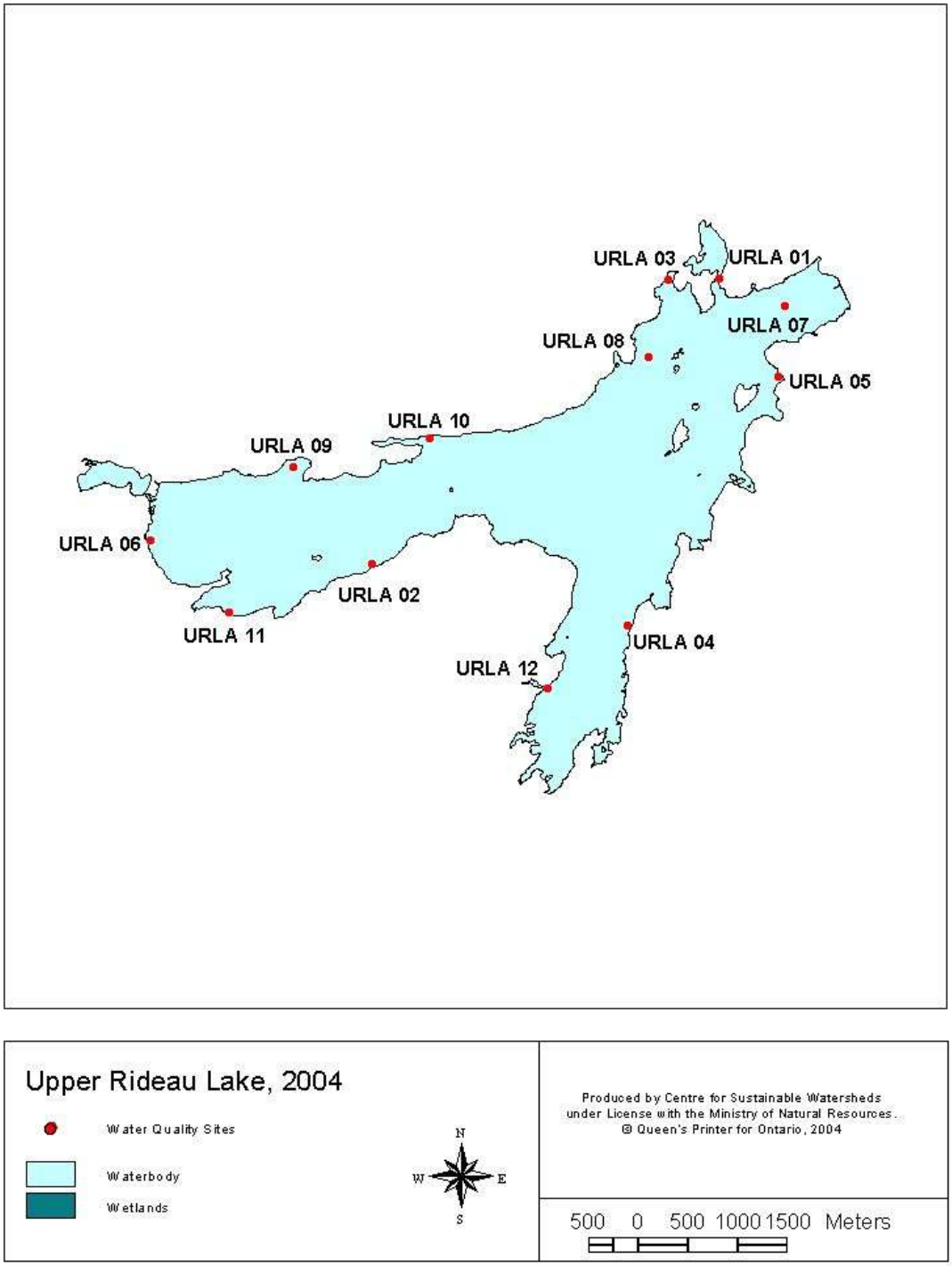
Table 2: Sampling procedures and site depths for basin sites

Site #	Location	Site Depth	Sampling Details
URLA7	Narrow's Lock	13m	-Total phosphorus (µg/L)samples taken at surface and secchi depth – samples analyzed at Caduceon Environmental Laboratories in Kingston -Full profiles taken in late August depicting DO and temperature - secchi depth observations
URLA8	Three Sisters	20m	-Monthly mini-profiles sampling pH, DO (mg/L), temperature (°C) and chlorophyll (µg/L) were taken at 1m intervals in top 10m of surface water

Table 3: Sampling procedures for nearshore sites

Site #	Location	Sampling Details
URLA1	Duck Bay	-Total phosphorus (µg/L) samples taken at 1m below surface - samples analyzed at Caduceon Environmental Laboratories in Kingston - Monthly samples of pH, D.O.(mg/L), temperature(°C) and chlorophyll (µg/L) taken 1m below surface of water (June – Oct.) with YSI multi-parameter sampling unit
URLA2	Golf Course	
URLA3	Kane's Bay	
URLA4	McNally's Bay	
URLA5	Mooney's Bay	
URLA6	Westport	
URLA9	Little Bay	
URLA10	Big Bay	
URLA11	Roes Bay	
URLA12	Adrian's Creek	

Figure 2: Map of Upper Rideau Lake indicating sample sites with GPS coordinates for the 2004 sampling season



RESULTS

Total Phosphorus – basin sites

Table 4 shows the Total Phosphorus (TP) results obtained at the two basin sites throughout the 2004 sampling season.

Table 4: TP results for basin sites

Location	Total Phosphorus (µg/L) Upper Rideau Lake, 2004						
	Depth	June	July	August	September	October	Average
Narrow's Lock	Surface	16	15	15	22	35	21
	Secchi	15	16	16	24	29	20
Three Sisters	Surface	15	13	16	25	32	20
	Secchi	14	15	21	22	32	21

The average seasonal TP concentration at secchi depth and surface for both basin sites was at or above 20µg/L, indicating high nutrient (eutrophic) conditions. Results in June and July for both sites showed moderate nutrient concentrations but higher values in September and October brought up the seasonal average. Although phosphorus concentrations can vary through the water column, in 2004 there were no significant differences between phosphorus levels at the surface and at secchi depth. Overall averages were consistent with those from 2003.

Total Phosphorus – nearshore sites

Table 5 shows the Total Phosphorus (TP) results observed at the nearshore sites throughout the 2004 sampling season.

Table 5: TP results for nearshore sites

Location	Total Phosphorus (µg/L) Upper Rideau Lake, 2004					
	June	July	August	September	October	Average
Duck Bay	20	17	18	18	22	19
Golf Course	20	13	15	25	29	20
Kane's Bay	17	13	19	17	27	19
McNally's Bay	14	14	17	18	30	19
Mooney's Bay	16	18	20	19	31	18
Westport	24	54	24	22	25	31
Little Bay	16	25	16	30	26	22
Big Bay	14	17	18	29	29	20
Roes Bay	19	25	19	20	26	21
Adrians Creek	20	20	26	24	29	23

The average seasonal TP concentrations for 4 of the 10 sites were above 18µg/L indicating meso-eutrophic status or moderate to high nutrient conditions. 6 of the 10 nearshore sites had averages of 20µg/L or above indicating high nutrient conditions (eutrophic).

Secchi Depth

Table 6 shows the average secchi depth and associated trophic status throughout the season for the basin sites. A reading greater then 5 metres indicates an oligotrophic lake, from 3-5m indicates a mesotrophic lake, and a reading less then 3m indicates a eutrophic lake.

Table 6: Secchi depth and related trophic status for basin sites

Narrows Lock		
Date	Secchi Depth (m)	Trophic Status
June 16	4.5	Mesotrophic
July 17	3.2	Mesotrophic
August 16	4.6	Mesotrophic
September 13	2.7	Eutrophic
October 7	6.1	Oligotrophic
Average	**4.2**	**Mesotrophic**

Three Sisters		
Date	Secchi Depth (m)	Trophic Status
June 16	4.7	Mesotrophic
July 17	2.6	Eutrophic
August 16	4.1	Mesotrophic
September 13	3.7	Mesotrophic
October 7	6.2	Oligotrophic
Average	**4.3**	**Mesotrophic**

Seasonal secchi averages for both basin sites indicated mesotrophic status. Higher clarity was observed at both sites in October, which may be attributed to die off of plants and algae late in the season. As mentioned earlier, secchi depth can be affected by suspended particles from shoreline erosion, agricultural run-off, or tree pollen as well as weather conditions, and should not be used alone when evaluating lake condition.

Chlorophyll

Figure 3 provides the chlorophyll values (µg/L) observed with the YSI multi-parameter field unit at the twelve sites at one metre below the surface. Refer to Appendix B for chlorophyll data for all sites.

Figure 3: Chlorophyll results for all sites at surface.

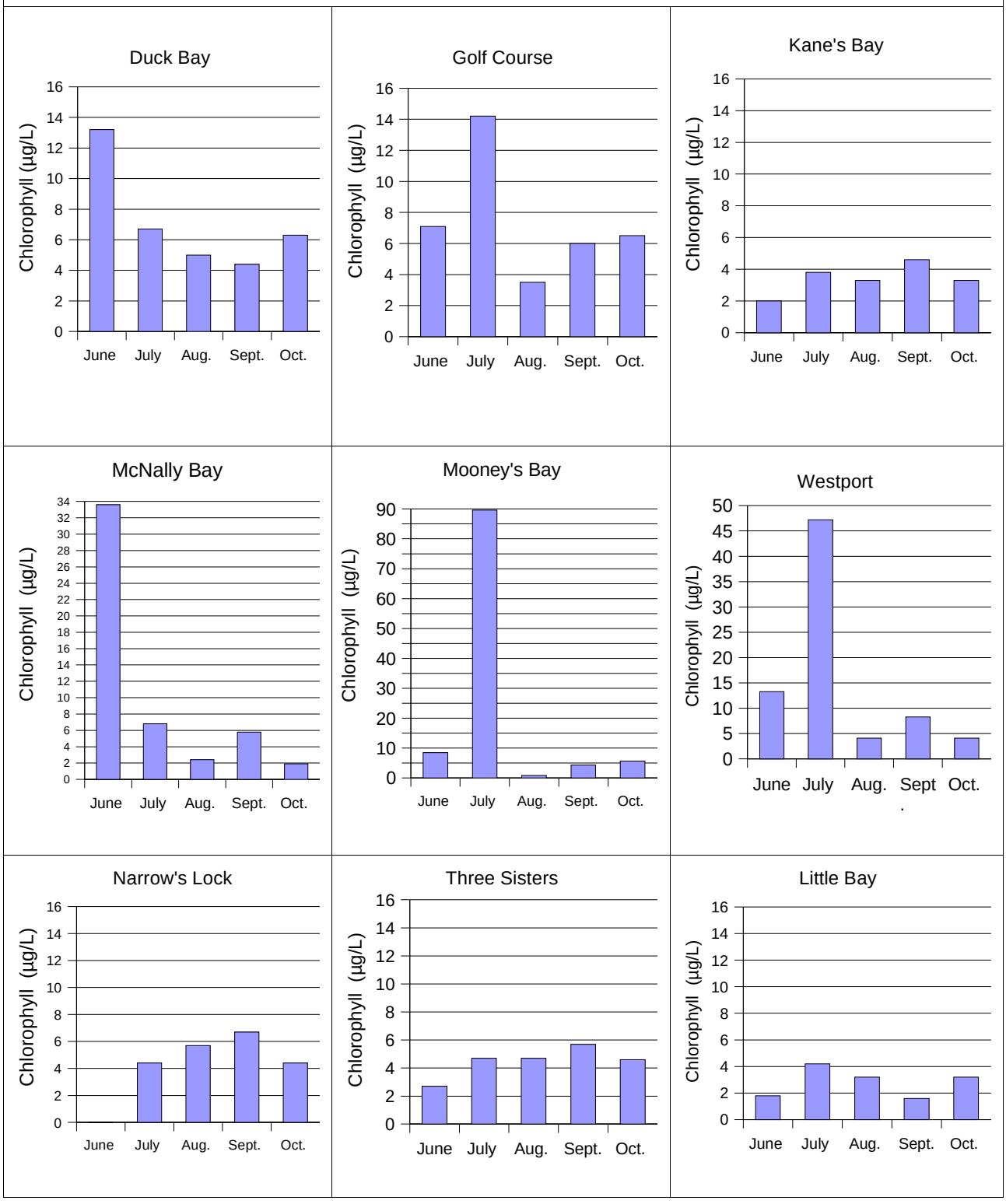
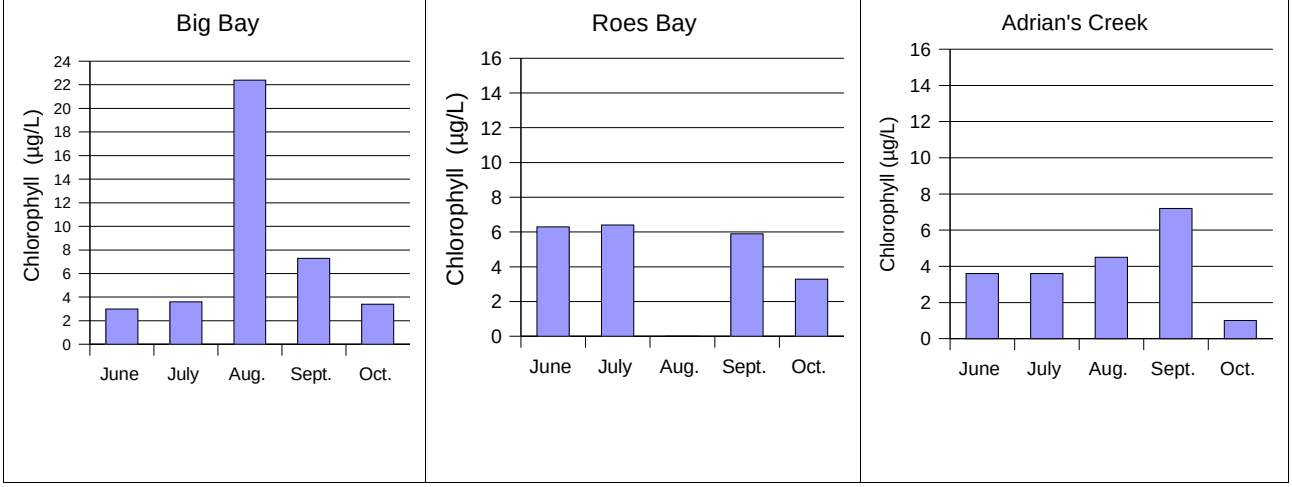


Figure 3: Chlorophyll results for all sites at surface.



These chlorophyll measurements represent a total value for all three types of chlorophyll pigment. There are currently no provincial water quality objectives for chlorophyll, however consistently higher values can be used to identify areas of concern that should perhaps be studied further. Westport, Mooney's Bay, McNally's Bay, Big Bay, Duck Bay and Golf Course all showed at least one high value at some point during the sampling season. Elevated readings may be a result of increased levels of nutrient enrichment from fertilization, erosion, or agricultural processes.

Temperature

Temperature readings taken at one metre below the surface are shown in Figure 4 below.

Figure 4: Seasonal changes in temperature at one metre below the surface

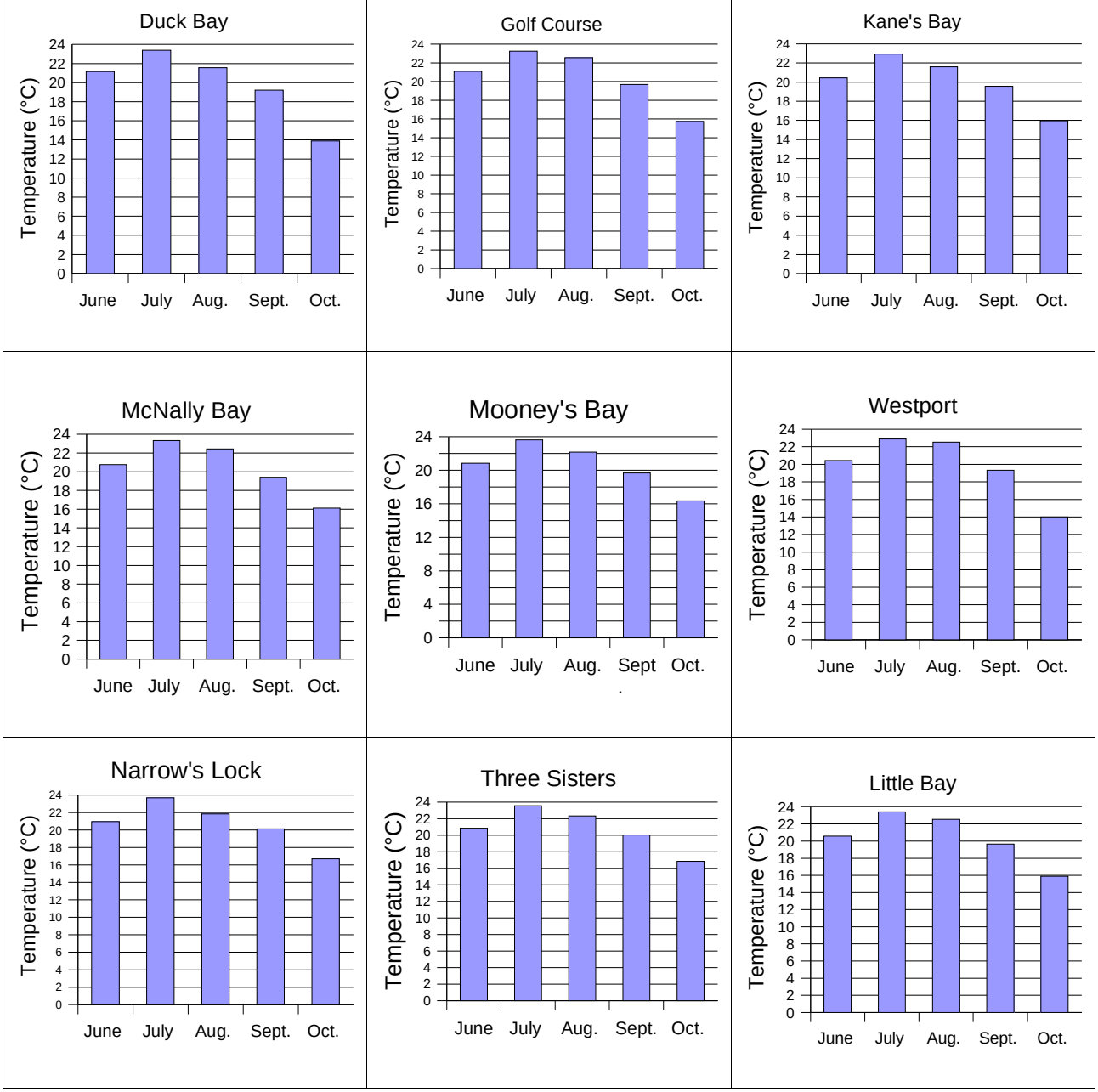
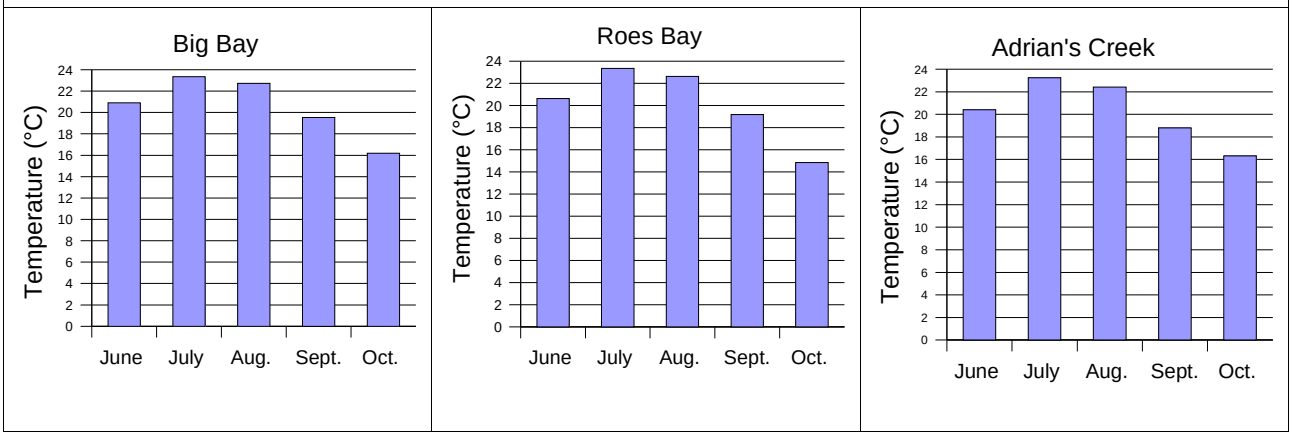


Figure 4: Seasonal changes in temperature at one metre below the surface



The surface temperature for all sites followed seasonal changes peaking in July. While the temperatures peaked in August in 2003, the 2004 sampling season saw heavy rainfall and high winds which may have contributed to this change.

When complete temperature profiles were taken in August the three sisters site was fully stratified. The Narrows Lock site was not stratified as the thermocline extended to the lake bottom. Thermoclines are visible in profiles shown in Figure 5. Refer to Appendix A for full temperature profile data.

Dissolved Oxygen At Surface

Table 7 shows the dissolved oxygen and temperature levels taken at one metre below the surface for all sites.

Table 7: Temperature (°C) and dissolved oxygen (mg/L) data for all sites at surface

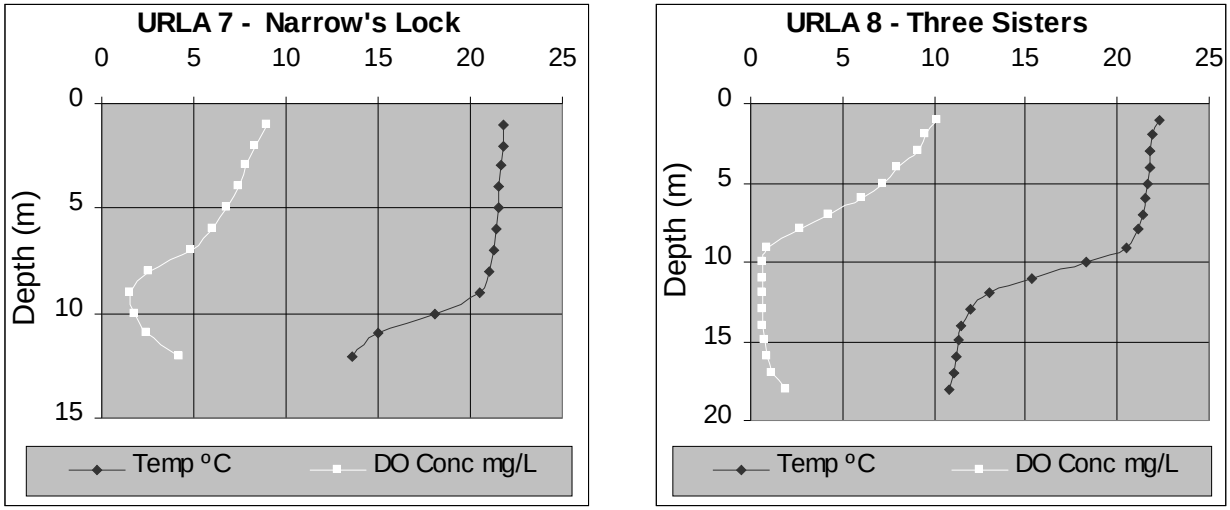
Location	Dissolved Oxygen and Temperature Data – Upper Rideau Lake, 2004					
	Parameter	June 16	July 17	August 16	Sept. 13	Oct. 7
Duck Bay	DO (mg/L)	10.38	9.15	10.62	10.31	10.74
	Temp (°C)	21.17	23.40	21.57	19.22	13.90
Golf Course	DO (mg/L)	9.82	9.74	11.73	11.43	11.05
	Temp (°C)	21.10	23.26	22.56	19.71	15.75
Kane's Bay	DO (mg/L)	9.39	9.83	9.91	9.98	9.30
	Temp (°C)	20.44	22.93	21.60	19.57	15.97
McNally's Bay	DO (mg/L)	10.02	9.36	11.95	10.18	10.51
	Temp (°C)	20.76	23.33	22.43	19.40	16.11
Mooney's Bay	DO (mg/L)	9.41	9.76	10.76	10.25	9.43
	Temp (°C)	20.85	23.62	22.16	19.69	16.35
Westport	DO (mg/L)	10.86	8.57	12.01	11.53	10.63
	Temp (°C)	20.43	22.88	22.51	19.31	14.01
Narrows Lock	DO (mg/L)	9.80	10.07	9.03	9.82	9.17
	Temp (°C)	20.97	23.70	21.84	20.13	16.70
Three Sisters	DO (mg/L)	9.81	10.02	10.15	10.20	8.97
	Temp (°C)	20.85	23.57	22.33	20.01	16.84
Little Bay	DO (mg/L)	9.87	9.50	11.78	10.11	10.07
	Temp (°C)	20.57	23.40	22.54	19.64	15.91
Big Bay	DO (mg/L)	10.21	9.13	11.22	10.97	9.98
	Temp (°C)	20.90	23.36	22.72	19.54	16.19
Roes Bay	DO (mg/L)	10.29	9.11	11.81	11.63	9.96
	Temp (°C)	20.63	23.36	22.64	19.19	14.85
Adrians Creek	DO (mg/L)	9.87	9.35	11.76	9.60	9.36
	Temp (°C)	20.40	22.95	22.42	18.80	16.32

DO remains relatively constant in surface waters through the summer as wind and wave action allows it to be continually replenished from the atmosphere. The DO conditions observed in the surface waters of Upper Rideau Lake (Table 7) are sufficient to support warm water fish populations such as smallmouth and largemouth bass, which for normal activity, require a minimum of 4 mg/L dissolved oxygen when surface temperatures are above 20°C (refer to Table 1).

Dissolved Oxygen - Temperature Profiles

Figure 5 shows the dissolved oxygen - temperature profiles taken at the basin sites. Appendix A provides complete temperature and dissolved oxygen profile data.

Figure 5: Dissolved oxygen and temperature profile data for both the basin sites - August 16th , 2004



Testing near the end of summer, before fall turn-over provides an indication of the worst case scenario as demand for dissolved oxygen is at its highest. In August, anoxic conditions (less than 1mg/L of dissolved oxygen) occurred in the hypolimnion of the Three Sisters site. The Narrows Lock site, which is shallower, was not completely stratified as the thermocline extended to the lake bottom. DO concentrations at the thermocline for this site were approaching low concentrations.

pH

Table 8 shows the pH levels obtained at all sites one metre below the surface.

Table 8: pH data for all sites at surface

Location	pH – Upper Rideau Lake, 2004					
	June	July	Aug.	Sept.	Oct.	Average
Duck Bay	8.34	8.08	8.14	8.03	7.71	8.06
Golf Course	7.93	8.01	8.06	7.94	7.91	7.97
Kane's Bay	7.77	7.93	8.12	8.02	7.43	7.85
McNally's Bay	7.98	8.07	8.05	7.70	7.63	7.89
Mooney's Bay	7.83	8.15	8.04	7.79	7.46	7.85
Westport	8.43	7.55	8.37	7.92	7.71	8.00
Narrows Lock	8.00	8.21	7.85	7.84	7.46	7.87
Three Sisters	8.03	8.14	7.99	7.65	7.44	7.85
Little Bay	7.97	7.97	8.27	7.64	7.64	7.90
Big Bay	8.04	7.75	8.20	7.75	7.52	7.85
Roes Bay	8.19	7.92	8.04	8.22	7.63	8.00
Adrians Creek	7.88	7.95	7.98	7.43	7.55	7.76

Results indicate acceptable pH levels for Upper Rideau Lake. The lake is slightly alkaline, common for lakes with limestone bedrock or high levels of carbonates in their sediments. This chemistry will help the lake to “buffer” against changes in pH from inputs such as acid rain.

SUMMARY

- Average seasonal TP values at both Narrows Lock and Three Sister's basins were approximately 20µg/L, indicating high nutrient (eutrophic) conditions which is consistent with the 2003 results.

- Average TP values at Golf Course, Westport, Little Bay, Big Bay, Roe's Bay and Adrian's Creek were indicative of high nutrient conditions, while concentrations at the other near shore sites showed moderate to high nutrient levels.

- The average secchi depth readings obtained at both the Narrows Lock and the Three Sisters sites indicated mesotrophic conditions.

- Elevated chlorophyll readings were observed at points during the season at Westport, Mooney's Bay, McNally's Bay, Big Bay, Duck Bay and Golf Course.

- Dissolved oxygen at both basin sites as well as the nearshore sites was sufficient to support warm water fisheries such as large and smallmouth bass.

- pH results for all sites stayed within healthy lake limits of 6.5-8.5.

REFERENCES

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

RECOMMENDATIONS

Annual water quality testing is useful to track changes in water quality over time and identify hot spots (problem areas).

- Because it is the limiting nutrient for plant and algae growth in an aquatic environment, TP is one of the most important nutrients to monitor. Testing in the open water areas (the basins) helps assess overall status of the lake, while near-shore testing may help identify potential on-shore impacts.
- While more sampling will provide a clearer picture of the nutrient status at a site, frequency of sampling is always dictated by resources available. In any event, sampling events should be evenly spaced – preferably starting as soon after ice out as possible, before the spring turn-over and continuing through to the fall turn-over. The Rideau Valley Conservation Authority is carrying out a comprehensive testing of nearshore sites on Upper Rideau Lake in 2005 as part of their Watershed Watch program. The Upper Rideau Lake Association should also continue with Lake Partner Program sampling.
- A field unit, such as the YSI, is a cost-effective tool used to assess chlorophyll *in situ* at *m*ore locations and more frequently. This type of data is most useful to compare sites, for example to take measurements at numerous sites a few times over the summer. Any identified hotspots could be verified by taking a TP or *E.coli* sample at the same time.
- Benthic macroinvertebrates are excellent and inexpensive indicators of long term water quality in lakes and streams. The Ministry of the Environment has developed a program to help volunteers participate in monitoring benthics in their waterways. Contact CSW or RVCA to learn about how to get involved.
- Other projects that could complement water quality monitoring are bathymetry surveys. Bathymetry can provide a detailed georeferenced description of the lake bottom. This type of data provides the detail necessary to accurately assess the volume of the hypolimnion (therefore the amount of dissolved oxygen available in the hypolimnion).
- Keep up the good work with your efforts in raising awareness about potential impacts on water quality!

APPENDIX A: Profile data collected using the YSI multi-parameter sampling unit measuring temperature (°C), depth (m) and dissolved oxygen (mg/L).

URLA 7: Narrow's Lake		
Depth	16 August 2004	
(m)	DO (mg/L)	Temp (ºC)
1	9.03	21.84
2	8.32	21.76
3	7.84	21.68
4	7.41	21.59
5	6.85	21.52
6	6.01	21.44
7	4.91	21.32
8	2.59	21.02
9	1.48	20.54
10	1.82	18.12
11	2.46	15.04
12	4.23	13.56

URLA 8: Three Sisters		
Depth	16 August 2004	
(m)	DO (mg/L)	Temp (ºC)
1	10.15	22.33
2	9.58	21.94
3	9.10	21.82
4	7.99	21.74
5	7.21	21.65
6	6.00	21.51
7	4.21	21.35
8	2.69	21.11
9	0.86	20.49
10	0.63	18.34
11	0.61	15.34
12	0.60	13.05
13	0.61	11.93
14	0.69	11.46
15	0.76	11.31
16	0.87	11.19
17	1.12	11.07

Thermoclines

APPENDIX B: Profile data including temperature, dissolved oxygen, pH and chlorophyll for all sites measured at surface.

Location	Parameter Sampled	June	July	August	September	October
URLA1 Duck's Bay	DO(mg/L)	10.38	9.15	10.62	10.31	10.74
	Temp (°C)	21.17	23.40	21.57	19.22	13.90
	pH	8.34	8.08	8.14	8.03	7.71
	Chlorophyll(µg/L)	13.20	6.70	5.00	4.40	6.30
URLA2 Golf Course	DO(mg/L)	9.82	9.74	11.73	11.43	11.05
	Temp (°C)	21.10	23.26	22.56	19.71	15.75
	pH	7.93	8.01	8.06	7.94	7.91
	Chlorophyll(µg/L)	7.10	14.20	3.50	6.00	6.50
URAL3 Kane's Bay	DO(mg/L)	9.39	9.83	9.91	9.98	9.30
	Temp (°C)	20.44	22.93	21.60	19.57	15.97
	pH	7.77	7.93	8.12	8.02	7.43
	Chlorophyll(µg/L)	2.00	3.80	3.30	4.60	3.30
URLA4 McNally's Bay	DO(mg/L)	10.02	9.36	11.95	10.18	10.51
	Temp (°C)	20.76	23.33	22.43	19.40	16.11
	pH	7.98	8.07	8.05	7.70	7.63
	Chlorophyll(µg/L)	33.60	6.80	2.40	5.80	1.90
URLA5 Mooney's Bay	DO(mg/L)	9.41	9.76	10.76	10.25	9.43
	Temp (°C)	20.85	23.62	22.16	19.69	16.35
	pH	7.83	8.15	8.04	7.79	7.46
	Chlorophyll(µg/L)	8.50	89.60	0.80	4.30	5.60
URLA6 Westport	DO(mg/L)	10.86	8.57	12.01	11.53	10.63
	Temp (°C)	20.43	22.88	22.51	19.31	14.01
	pH	8.43	7.55	8.37	7.92	7.71
	Chlorophyll(µg/L)	13.30	47.20	4.10	8.30	4.10
URLA7 Narrows Lock	DO(mg/L)	9.80	10.07	9.03	9.82	9.17
	Temp (°C)	20.97	23.70	21.84	20.13	16.70
	pH	8.00	8.21	7.85	7.84	7.46
	Chlorophyll(µg/L)	0.00	4.40	5.70	6.70	4.40
URLA8 Three Sisters	DO(mg/L)	9.81	10.02	10.15	10.20	8.97
	Temp (°C)	20.85	23.57	22.33	20.01	16.84
	pH	8.03	8.14	7.99	7.65	7.44
	Chlorophyll(µg/L)	2.70	4.70	4.70	5.70	4.60
URLA9 Little Bay	DO(mg/L)	9.87	9.50	11.78	10.11	10.07
	Temp (°C)	20.57	23.40	22.54	19.64	15.91
	pH	7.97	7.97	8.27	7.64	7.64
	Chlorophyll(µg/L)	1.80	4.20	3.20	1.60	3.20
URLA10 Big Bay	DO(mg/L)	10.21	9.13	11.22	10.97	9.98
	Temp (°C)	20.90	23.36	22.72	19.54	16.19
	pH	8.04	7.75	8.20	7.75	7.52
	Chlorophyll(µg/L)	3.00	3.60	22.40	7.30	3.40
URLA11 Roes Bay	DO(mg/L)	10.29	9.11	11.81	11.63	9.96
	Temp (°C)	20.63	23.36	22.64	19.19	14.85
	pH	8.19	7.92	8.04	8.22	7.63
	Chlorophyll(µg/L)	6.30	6.40	-0.30	5.90	3.30
URLA12 Adrian's Creek	DO(mg/L)	9.87	9.35	11.76	9.60	9.36
	Temp (°C)	20.40	22.95	22.42	18.80	16.32
	pH	7.88	7.95	7.98	7.43	7.55
	Chlorophyll(µg/L)	3.60	3.10	4.50	7.20	1.00

Appendix C: Mini-profile data collected throughout the season including dissolved oxygen (mg/L), temperature (°C), pH and chlorophyll (µg/L).

Narrow's Lock - URLA 7- Upper Rideau Lake, 2004								
Depth (m)	June				July			
	DO	Temp.	pH	Chl.	DO	Temp.	pH	Chl.
1	9.80	20.97	8.00	0.00	10.07	23.70	8.21	4.40
2	9.79	20.91	8.00	1.00	9.69	23.60	8.18	4.80
3	9.73	20.86	7.98	2.70	8.99	23.42	8.09	5.10
4	9.62	20.79	7.96	3.10	7.87	22.66	7.71	3.70
5	9.33	20.68	7.93	2.90	7.21	22.39	7.41	3.60
6	8.97	20.44	7.86	2.50	6.33	21.49	7.25	2.50
7	8.52	19.61	7.71	2.20	5.86	21.00	7.22	1.90
8	8.59	17.54	7.55	2.70	5.79	20.36	7.22	2.00
9	8.66	15.15	7.47	3.20	6.11	18.30	7.27	2.90
10	9.68	13.47	7.50	1.70	8.06	16.33	7.36	4.10

Narrow's Lock - URLA 7- Upper Rideau Lake, 2004								
Depth (m)	September				October			
	DO	Temp.	pH	Chl.	DO	Temp.	pH	Chl.
1	9.82	20.13	7.84	6.70	9.17	16.70	7.46	4.40
2	9.63	20.16	7.85	4.70	9.14	16.69	7.46	2.80
3	9.31	20.15	7.82	6.70	9.12	16.67	7.45	3.00
4	8.79	20.07	7.73	6.00	9.07	16.67	7.45	3.00
5	8.09	19.76	7.52	3.90	9.05	16.65	7.45	3.30
6	7.64	19.51	7.43	3.60	9.02	16.64	7.43	3.40
7	7.30	19.27	7.39	3.50	8.99	16.64	7.41	2.80
8	7.17	19.14	7.37	3.30	8.97	16.63	7.42	2.80
9	7.09	19.04	7.37	3.20	8.92	16.61	7.41	3.00
10	7.23	18.83	7.35	3.40	8.96	16.58	7.39	3.10

Three Sisters - URLA 8- Upper Rideau Lake, 2004								
Depth (m)	June				July			
	DO	Temp.	pH	Chl.	DO	Temp.	pH	Chl.
1	9.81	20.85	8.03	2.70	10.02	23.57	8.14	4.70
2	9.71	20.71	8.01	3.10	9.61	23.32	8.10	4.10
3	9.61	20.67	7.97	3.40	8.94	23.25	8.04	5.10
4	9.53	20.63	7.97	3.50	7.72	22.94	7.81	4.60
5	9.39	20.58	7.94	3.20	7.00	22.20	7.38	2.70
6	9.14	20.42	7.91	3.20	6.48	21.38	7.19	2.30
7	9.06	19.65	7.84	2.60	6.20	21.02	7.16	2.20
8	9.08	18.62	7.75	2.60	5.96	20.26	7.15	2.00
9	9.80	14.57	7.64	3.30	6.08	19.12	7.17	1.90
10	11.17	14.77	7.77	6.20	7.82	16.31	7.27	2.30

Three Sisters - URLA 8- Upper Rideau Lake, 2004								
Depth (m)	September				October			
	DO	Temp.	pH	Chl.	DO	Temp.	pH	Chl.
1	10.20	20.01	7.65	5.70	8.97	16.84	7.44	4.60
2	10.22	20.01	7.64	5.70	8.96	16.69	7.42	4.90
3	10.25	20.00	7.63	5.90	8.97	16.67	7.42	4.30
4	10.31	20.00	7.65	6.00	8.96	16.67	7.41	4.30
5	10.52	19.99	7.67	5.10	8.93	16.65	7.42	3.40
6	**	**	**	**	8.91	16.64	7.41	2.70
7	**	**	**	**	8.78	16.58	7.39	3.10
8	**	**	**	**	8.84	16.57	7.41	2.90
9	**	**	**	**	8.90	16.54	7.41	3.30
10	**	**	**	**	8.98	16.53	7.42	3.50

note: ** data from field meter was not recoverable

Appendix D: Site information

Site Name	Site ID	Site Depth (m)	GPS Co-ordinates	
			Northing	Easting
Duck's Bay	URLA 1	2.5	4950821	395950
Golf Course	URLA 2	2.1	4947585	392061
Kanes Bay	URLA 3	2.1	4950840	395407
McNally's Bay	URLA 4	2	4946858	394929
Mooney's Bay	URLA 5	2.1	4949702	396643
Westport	URLA 6	1.3	4947868	389605
Narrows Lock	URLA 7	13	4950491	396835
Three Sisters	URLA 8	18.3	4949960	395199
Little Bay	URLA 9	3.6	4948685	391159
Big Bay	URLA 10	3.3	4949015	392703
Roes Bay	URLA 11	1.5	4947070	390431
Adrians Creek	URLA 12	2.3	4946186	394039