Hutchinson
Environmental Sciences Ltd.

Lake of Bays Water Quality Report 2011

Prepared By: **Hutchinson Environmental Sciences Ltd.**
Prepared For: **Lake of Bays Association**

Project #: J100013
Date: March, 2012

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March 8, 2012 Project #: J100013

Deb Cumming
Environment Committee
Lake of Bays Association
PO Box 8
Baysville, ON P0B 1A0

Dear Ms. Cumming:

Re: HESL J100013 - Lake of Bays Water Quality Report 2011 – Draft Report

I am pleased to submit this final report to the Lake of Bays Association on behalf of Hutchinson Environmental Sciences Ltd. (HESL), which contains minor revisions to the draft report dated January 2012. The report summarizes the results of the 2011 monitoring program, and discusses long-term total phosphorus concentrations that have been observed since the onset of the program in 2002.

As in previous years, total phosphorus and bacteria concentrations in Lake of Bays were indicative of excellent water quality. Over the past 10 years, there has been a significant increasing trend in mean summer concentrations at the deepwater sites. The range of concentrations observed at the sites, however, are within the range that would be expected in Precambrian Shield lakes due to natural variability and the observed trend is not likely due to increased phosphorus loads from human activities.

It has been a pleasure to continue assisting the Association with their monitoring program and I look forward to working with you again to plan the 2012 field season.

Sincerely,

Tammy Karst-Riddoch, Ph.D.
Senior Aquatic Scientist
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1. Introduction

Since 2001, the Lake of Bays Association (LOBA) has championed a volunteer-based water quality monitoring program in Lake of Bays. The aim of the program is to characterize phosphorus and bacteria levels as an indication of general lake and watershed health while fostering community involvement and education.

Until the summer of 2000, monitoring in Lake of Bays was limited to tracking water clarity and spring phosphorus concentration under the Ontario Ministry of the Environment's Lake Partner Program. LOBA's monitoring program began with a pilot study in 2000 to monitor bacteria levels in the lake during summer. This project was successful and LOBA expanded the area of study in the summer 2001 to include near-shore areas adjacent to developed and undeveloped properties and areas influenced by wetlands and rivers. In 2004, the program was again expanded to monitor phosphorus concentrations in near-shore areas. Over the course of the program, site selection has changed reflecting changes in focus with an ever-increasing understanding of water quality conditions in Lake of Bays. Since 2009, sampling has focussed on deep water sites, with reduced sampling in enclosed bays (e.g., South Portage Bay, Rat Bay, Little Trading Bay) and river sites that were sampled in previous years (e.g., Narrows, Hollow River). The monitoring program, however, continues to monitor river-influenced sites. This approach continues to allow comparison with other water quality programs, such as the Lake Partner Program and the District Municipality of Muskoka (DMM) spring monitoring program, which collect data in central, deep areas of the lake. It also reflects experience collected through the years of the program, which showed that lake water quality is different from river water quality and that nearshore sites can show very local effects that are not representative for whole-lake water quality trends.

The LOBA monitoring program continues to focus on total phosphorus concentrations. For recreational lakes on the Precambrian Shield like Lake of Bays, water quality concerns are most often associated with nutrient enrichment due to increased human phosphorus sources. Phosphorus is a nutrient that limits growth of algae in most freshwater systems on the Canadian Shield. Phosphorus is a natural element in the environment and enters lakes from the atmosphere through precipitation, stream and overland flow, and to a lesser degree through groundwater. Increases in phosphorus loads to lakes from human sources can result in a deterioration of water clarity and decrease deep-water oxygen concentrations that affect coldwater fish habitat.

Bacteria in surface waters can also be a concern for recreational water quality. Coliform bacteria are a group of naturally occurring bacteria that are found in the intestines of warm-blooded animals. The presence of coliform bacteria in water potentially indicates the presence of disease-causing (pathogenic) micro-organisms. *Escherichia coli* (*E. coli*) is one of several types of coliform bacteria and is a more specific indicator of fecal contamination. Some strains of *E. coli* are capable of causing disease under certain conditions, for example, when the immune system is compromised. Most strains of *E. coli* will not cause disease symptoms, and coexist within us as part of our normal microbial population. Coliform bacteria are naturally occurring in surface waters originating from waterfowl and wildlife and therefore higher levels are often found in wetlands and along the shorelines of lakes and rivers. Human waste also contains coliform bacteria and so elevated coliform levels in areas of high human activity may represent the discharge of improperly treated sewage or grey water to the lake. Coliform

bacteria can remain active for a short period of time in surface water before they are degraded by ultraviolet light and temperature gradients. They may exist for longer periods in the sediments.

Bacteria (total coliform and *Escherichia coli*) continue to be monitored by the program, but sampling frequency for bacteria was reduced to every other year since 2009 because results have been very consistent over the course of the monitoring program. Biannual sampling will continue to allow assessment of long-term trends, while increasing resources to expand the program to include other parameters of interest to the Association.

Lake of Bays has so far been a clear lake with low phosphorus and bacteria levels and no obvious impact of development on water quality. In this report we present the results of the summer phosphorus and bacteria monitoring completed by the LOBA in 2011 and discuss them in the context of long-term water quality data collected by the LOBA, the MOE Lake Partner Program and the District Municipality of Muskoka.

2. Methods

Volunteers, coordinated by the LOBA Environment Committee, collected samples for analysis of total phosphorus concentrations on five occasions during the summer of 2011 (July 4 and 19, August 1 and 14/15, and September 2). The sampling and analytical methods in 2011 were consistent with those used in previous monitoring years and are summarized below. Detailed sampling instructions that are provided to the volunteers are presented in Appendix A.

2.1 Sample Collection

2.1.1 Total Phosphorus

Total phosphorus was sampled at 21 locations throughout Lake of Bays to include deep, open water locations ('deepwater' sites), nearshore sites adjacent to developed ('Disturbed' sites) and undeveloped shorelines ('Nearshore Undisturbed' sites), and other areas of interest, e.g., areas influenced by discharge from the Oxtongue and Hollow rivers ('River' sites). Sites monitored in 2011 are illustrated in Figure 1.

At each deep water site, a water sample was collected from the euphotic zone, at approximately two times the Secchi depth. At each nearshore site, a water sample was collected at a depth of ~30 cm. The samples were filtered using a mesh filter in order to remove zooplankton (microscopic animals living in the water, such as water fleas) that can contaminate the sample and result in non-representative, high phosphorus values.

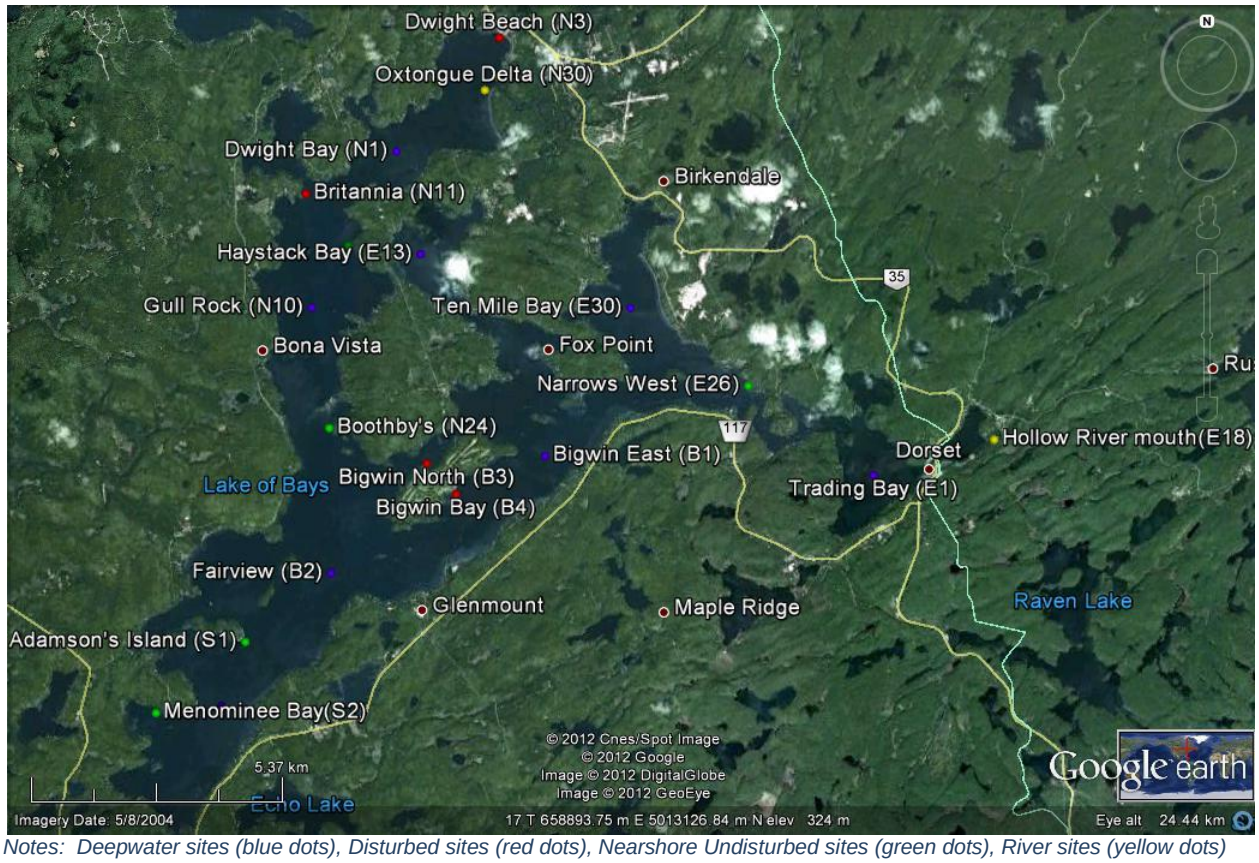
Samples were directly poured into the glass tubes used for phosphorus analysis, stored in a cool place and submitted for analysis to the Trent University laboratory at the Ministry of the Environment (MOE)'s Dorset Environmental Science Centre (DESC).

2.1.2 Bacteria

Bacteria samples were collected at the same sites as those visited for total phosphorus sampling. Bacteria were sampled at a depth of 22 – 30 cm at both near-shore and deep water locations and care was taken to prevent contamination (see detailed sampling procedure in Appendix B).

The bacteria counts were based on the use of "Coliplates" (EBPI). Coliplates are a manufactured product in which 96 cells are inoculated with sampled water, incubated for a 24-hour period and then assessed for both total coliform and *Escherichia coli* (*E. coli*) concentration based on comparison of the colorimetric response of each cell against a Most Probable Numbers chart. The detection limit for the Coliplate methodology is 3 colony forming units (cfu) in 100 mL of water. This means that if zero Coliplate cells turn colour after incubation, the lowest number of bacteria that can be reported is <3 cfu/100 mL. For the LOBA data, values of <3 cfu/100 mL are reported as 1 cfu/100 mL for statistical evaluation of the data, but note that the actual value can be 0 to 2 cfu/100 mL.

Figure 1. Map of Lake of Bays and Sites Sampled by the LOBA in 2011.



Notes: Deepwater sites (blue dots), Disturbed sites (red dots), Nearshore Undisturbed sites (green dots), River sites (yellow dots)

2.2 Quality Control

2.2.1 Total Phosphorus

2.2.1.1 Field Duplicates

In order to assess the variability of results related to sampling and analytical procedures, 8 field duplicates for total phosphorus were collected and analyzed in 2011.

Field duplicates analyzed at the DESC laboratory show excellent agreement between sample pairs with an absolute mean difference of 0.7 μg/L, but a consistent percentage of the samples (5%) have larger than expected differences between field duplicates (i.e., >4 μg/L). Much investigation has failed to identify the cause for these measured differences. Separate experiments have excluded sample container cleanliness, lab apparatus, variation in the sub 80μ-sample matrix, and external inputs of phosphorus as sources of contamination. It remains unclear how these samples are contaminated. In almost every case, however, when these samples are reanalyzed, the retested pair of samples agrees with the lower of the original two samples in the bad field split. After testing hundreds of such pairs with sample returns from the Lake Partner Program, sufficient confidence was gained to allow the elimination of the higher of the two samples in cases where there are bad splits (Bev Clark, HESL, pers. comm.) Following the DESC approach, bad splits were identified in the LOBA dataset (>4 μg/L difference between duplicates) and the higher value was removed from further analysis.

2.2.1.2 Outliers

In relatively small datasets like the LOBA data set, the calculation of average total phosphorus concentration is sensitive to outliers, that is, extreme values that are not representative of the site condition. In the past, outliers in the LOBA total phosphorus data were identified and removed from analysis based on professional judgement.

In this study, outliers are assessed statistically using the Grubb's Test (Grubbs 1969), which is a recommended procedure to screen the DMM's Lake System Health data set for outliers (Gartner Lee Limited, 2008). To perform the Grubb's Test, the ratio 'Z' is calculated as the difference between the suspect sample and the mean divided by the standard deviation (SD). Note that the mean and SD are calculated from all values, including the outlier. If Z is higher than the critical value of Z for a given sample size (N) (Table 1), the sample is considered to be an outlier at $p<0.05$.

For each sampling site, all total phosphorus values collected since 2002 were screened for outliers using the Grubb's test. Outliers were removed from the dataset for further analyses.

Table 1. Grubb's Critical Values of Z (p <0.05)

N	Critical Z	N	Critical Z
3	1.15	27	2.86
4	1.48	28	2.88
5	1.71	29	2.89
6	1.89	30	2.91
7	2.02	31	2.92
8	2.13	32	2.94
9	2.21	33	2.95
10	2.29	34	2.97
11	2.34	35	2.98
12	2.41	36	2.99
13	2.46	37	3.00
14	2.51	38	3.01
15	2.55	39	3.03
16	2.59	40	3.04
17	2.62	50	3.13
18	2.65	60	3.2
19	2.68	70	3.26
20	2.71	80	3.31
21	2.73	90	3.35
22	2.76	100	3.38
23	2.78	110	3.42
24	2.8	120	3.44
25	2.82	130	3.47
26	2.84	140	3.49

2.2.2 Bacteria

Quality control measures for bacteria included:

1. The inclusion of a sample of distilled water by one volunteer sampler at one selected site for each sample date for bacterial analysis as a field blank;
2. The inclusion of a field duplicate on at least one sampling date for each site; and
3. Submission of water samples to the Central Ontario Analytical Laboratory (COAL), an accredited laboratory in Orillia, Ontario, for membrane filtration analysis of total coliform and *E. coli* for comparison with the Coliplate method. COAL has a reportable range from 0 to >80 cfu/100 mL for potable water samples and <4 to >8 cfu/100 mL for recreational water samples.

2.3 Data Analysis

2.3.1 Total Phosphorus

Total phosphorus concentrations were compared by site and site type for the 2011 monitoring period and long term annual trends were evaluated by site type and compared to DMM spring monitoring data.

Mean total phosphorus concentrations in Lake of Bays were evaluated against a) the MOE's interim Provincial Water Quality Objectives (PWQO; MOE 1994), and b) thresholds set for Lake of Bays by the District Municipality of Muskoka (DDM). The PWQO for the protection of aquatic life states that:

1. Average total phosphorus concentrations for the ice-free period should not exceed 20 µg/L to avoid nuisance concentrations of algae in lakes.
2. A high level of protection against aesthetic deterioration will be provided by a total phosphorus concentration for the ice-free-period of 10 µg/L or less. This should apply to all lakes naturally below this value.
3. Excessive plant growth in rivers and streams should be eliminated at a total phosphorus concentration below 30 µg/L.

In addition to the interim PWQO, the MOE suggests that for recreational lakes on the Canadian Precambrian Shield, phosphorus should only be increased by 50% over background concentration (i.e., the concentration of phosphorus that would occur if all human development was removed from the watershed) to a maximum cap of 20 µg/L to protect water quality (MOE, 2011). Background +50% thresholds have been set for individual basins of Lake of Bays by the DMM for the Lake System Health Program using a whole watershed scale water quality model that can predict phosphorus concentrations in Muskoka lakes (Table 2; Gartner Lee Ltd., 2005). Thresholds range from 5.9 µg/L in Trading Bay to 8.0 µg/L in Ten Mile Bay.

Table 2. Background Total Phosphorus Concentration +50% Thresholds for Individual Basins of Lake of Bays (Gartner Lee Ltd., 2005)

Basin	Background TP +50% (µg/L)
Dwight Bay	7.5
Haystack Bay	6.8
Rat Bay	7.7
South Muskoka River Bay	7.9
South Portage Bay	6.3
Ten Mile Bay	8.0
Trading Bay	5.9

2.3.2 Bacteria

Bacteria (*E. coli* and total coliform) levels were compared to the Provincial Water Quality Objectives (PWQO) for recreational water use (Ministry of the Environment and Energy 1994).

For total coliform, the PWQO is 1,000 colony forming units (cfu) per 100 mL, based on a geometric mean for a series of water samples. The MOE recommends that this objective be used as a guideline only, and that bacterial assessment of water quality should be based on more specific fecal bacteria indicators such as *E. coli*. The PWQO for *E. coli* is 100 cfu per 100 mL, based on a geometric mean of at least five samples taken from one site within one month. This objective is intended to protect swimming and bathing beaches for recreational use. Where testing indicates sewage or fecal contamination, a site-specific judgment must be made as to the severity of the problem and the appropriate course of action.

Although the five sampling visits to Lake of Bays did not occur within one, but two months, we calculated geometric means from the five dates as a reasonable approximation of the degree of bacterial contamination over the summer season.

3. 2011 Monitoring Results

3.1 Quality Control

3.1.1 Total Phosphorus

3.1.1.1 Field Duplicates

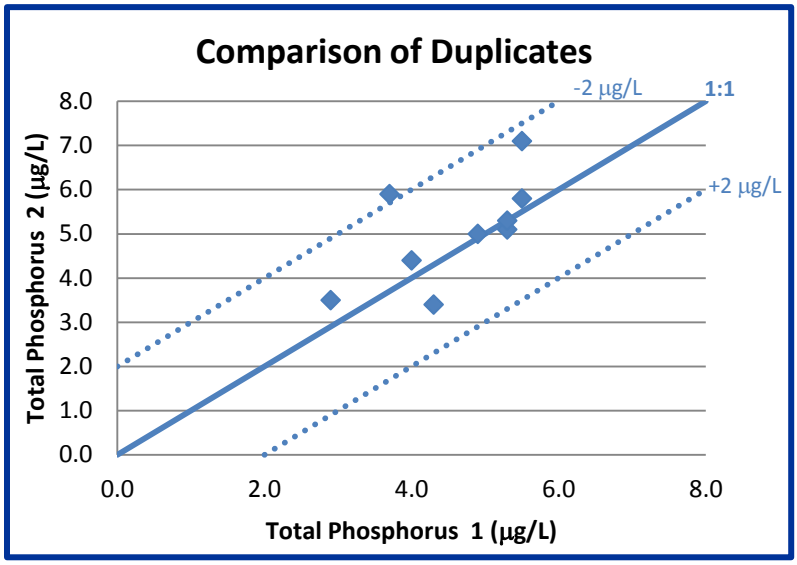
The quality control program continues to provide a high degree of confidence in the sampling protocols and analyses for total phosphorus with no bad splits (i.e., >0.4 μg/L difference between sample pairs) between field duplicates in 2011. Since 2002, bad splits occurred in 4 of 55 (7.3%) field duplicate samples (Figure 2, Table 3). The mean difference between field duplicates was 0.7 μg/L in 2011 and 0.9 μg/L in all years (2002-2011) after removing the bad splits, which is comparable to the DESC dataset that has a mean difference of 0.7 μg/L between thousands of field duplicate samples.

Table 3. Summary of Bad Splits between Total Phosphorus Field Duplicates in Lake of Bays, 2002-2011

Date	Site	TP1 (μg/L)	TP2 (μg/L)	Difference (μg/L)
01-Sep-06	Dwight Bay	9.2	*31.9*	22.7
01-Sep-06	Menominee Bay	*15.9*	8.1	7.8
23-Jul-07	Narrows West	*8.2*	4.1	4.1
7-Sep-10	Ten Mile Bay	6.1	*12.9*	6.8

Note: Sample values in italics are considered to be contaminated and are removed from the dataset for further analysis.

Figure 2. Total Phosphorus Field Duplicates in Lake of Bays, 2011.



3.1.1.2 Outliers

A total of 25 samples were identified as outliers in the LOBA dataset using the Grubb's test, two of which occurred in the 2011 data (Table 4). These outlier samples were removed from all analyses in this report, but should be reassessed each year as additional data are added to the dataset. Several samples from the River sites are statistical outliers based on the Grubb's test, however, these samples were not removed from the analysis as river-influenced sites are expected to be highly variable between sampling events and the high measured TP values likely reflect this variability.

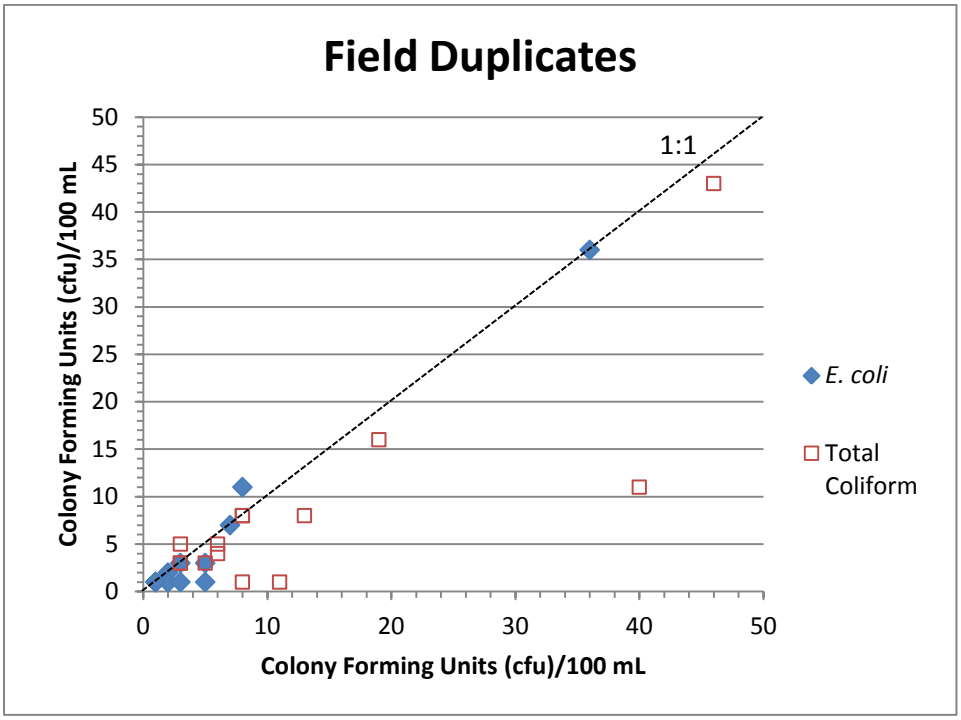
3.1.2 Bacteria

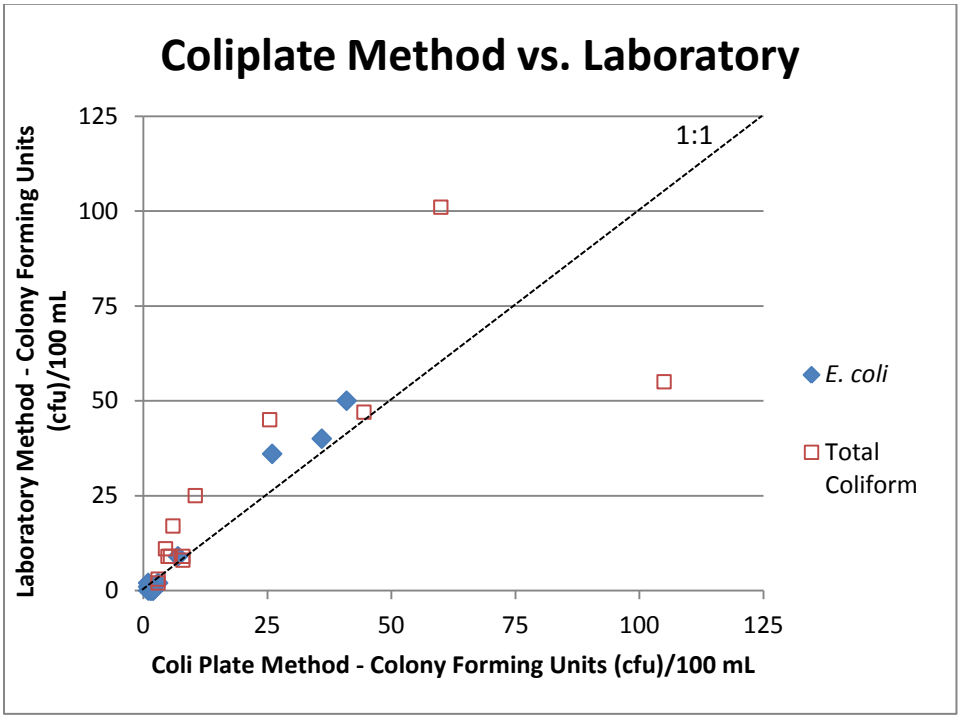
The quality control program in 2011 again yielded positive results that provide a high degree of confidence in the sampling protocols and analyses for bacteria (Figure 3). The maximum differences between bacteria duplicates using the Coliplate method ranged was 4 cfu/100 mL for *E. coli* and 29 cfu/100 mL for total coliform. Similarly, differences between the coliplate and laboratory results were low with a maximum difference of 10 cfu/100 mL for *E. coli* and 50 cfu/100 mL for total coliform. Laboratory results tended to provide higher bacteria concentrations than the coliplate method, but the absolute results of the two methods are still very similar and would provide for the same overall conclusion regarding bacterial contamination.

Table 4. Summary of Outliers in the LOBA 2002-2011 Dataset Based on Grubb's Test (p <0.5) Excluding River Sites.

Site	Date of Outlier	Outlier TP (µg/L)	Mean TP (02-11) Excluding Outliers (µg/L)
Adamson's Island	18-Jul-11	15.1	4.0
Bigwin Bay	15-Jul-02	9.6	4.4
Bigwin North	23-Aug-04	27.7	5.2
	6-Aug-07	97.7	
Britannia	1-Sep-03	12.6	4.1
	1-Sep-05	9.4	
	4-Aug-08	8.4	
Dwight Bay	14-Jul-03	0.7	5.2
	19-Jul-10	11.7	
Fairview	31-Aug-07	12.5	4.6
	17-Jul-09	12.3	
Gull Rock	14-Jul-03	16.9	4.8
Haystack Bay	6-Sep-04	74.0	5.3
	7-Aug-06	40.3	
	1-Sep-06	14.1	
	6-Aug-07	11.8	
	17-Jul-09	57.7	
Menominee Bay	4-Jul-05	11.0	4.1
Moffat's	5-Aug-02	36.7	4.3
	6-Aug-07	15.1	
Narrows West	4-Jul-11	11.4	4.9
Ten Mile Bay	21-Aug-06	10.2	5.3
Trading Bay	19-Aug-02	17.7	4.9
	19-Jul-04	12.3	
	21-Aug-06	11.0	

Figure 3. Comparison of *E. coli* and total coliform results between a) field duplicates and b) laboratory and Coliplate methods.





3.2 Total Phosphorus

The 2011 summer total phosphorus concentration of sites monitored in Lake of Bays ranged from 2.6 to 12.8 µg/L, with a mean concentration of 5.2 µg/L (Table 5). Mean summer total phosphorus concentrations at all sites were <10 µg/L and are indicative of oligotrophic conditions with low algal productivity, and provide a "high level of protection against aesthetic deterioration" due to nuisance aquatic plant growth (MOE, 1994). Moreover, the mean 2011 summer total phosphorus concentrations were below the DMM's threshold values (background total phosphorus concentration +50%) in Dwight (7.5 µg/L), Haystack (6.8 µg/L), Ten Mile (8.0 µg/L) and Trading (5.9 µg/L) bays and all other sites without DDM thresholds were below the lowest Lake of Bays threshold of 5.9 µg/L, further indicating excellent water quality with respect to phosphorus.

Table 5. Total Phosphorus Concentrations in Lake of Bays, 2011

Site ID	Site	4-Jul	18-Jul	1-Aug	15-Aug[1]	2-Sep	Mean
Deepwater (mean TP = 5.6 µg/L)							
B1	Bigwin East	5.2	3.1	6.7	4.8	4.7	4.9
B2	Fairview	4.9	4.0	6.1	4.8	4.8	4.9
E1	Trading Bay	5.1	4.2	6.9	7.1	5.7	5.8
E13	Haystack Bay	6.9	6.1	5.6	5.3	7.1	6.2
E30	Ten Mile Bay	5.7	4.5	5.2	5.1	4.9	5.1
N1	Dwight Bay	5.3	5.2	5.3	6.2	4.6	5.3
N10	Gull Rock	7.4	5.0	5.0	6.0		5.8
S3	Price's Point	4.2	12.8	5.6	4.7	7.6	7.0
Disturbed (mean TP = 4.7 µg/L)							
B3	Bigwin North	6.2	2.6	5.2	5.4	4.8	4.8
B4	Bigwin Bay	3.9	3.7	5.0	6.2	3.9	4.5
N11	Britannia	4.9	2.9	4.6	4.5	3.9	4.2
N3	Dwight Beach	9.5	7.4	5.7	4.9	3.9	6.3
B6	Port Cunnington	5.1	2.6	4.0	3.8	3.5	3.8
Nearshore Undisturbed (mean TP = 4.7 µg/L)							
E26	Narrows West		3.4	8.5	4.1	4.6	5.2
N13	Moffat's	5.6	3.6	4.4	6.2	3.1	4.6
N24	Boothby's	4.9	2.8	5.5	5.8	5.1	4.8
S1	Adamson's Island	4.9		4.9	3.2	3.6	4.2
S2	Menominee Bay	5.1	3.9	4.4	5.0	6.3	4.9
River (mean TP = 6.0 µg/L)							
E18	Hollow River mouth	4.6	4.5	6.7			5.3
N2	Oxtongue mouth	9.3	7.9	7.1	6.9		7.8
N30	Oxtongue Delta	8.2	4.5	5.2	3.7	3.1	4.9

Note: [1]sites B1-B3, E13 and N30 were sampled on August 14th, 2011.

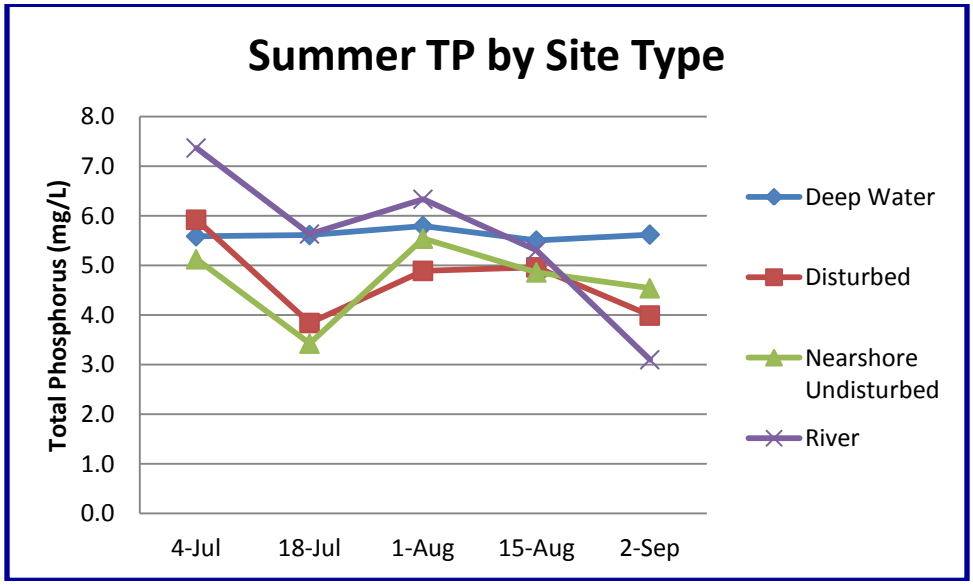
Overall, total phosphorus concentrations were similar between site types that are not influenced by river inputs. As expected, nearshore sites (i.e., Disturbed and Nearshore Undisturbed) were more variable over the summer season as they are shallow, more greatly influenced by nearshore mixing, nutrient uptake by aquatic plants and nutrient inputs from runoff (Figure 3). 'Disturbed' and 'Undisturbed Nearshore' sites displayed very similar trends, again suggesting

that there is little impact of shoreline disturbance on phosphorus concentrations. On average, these sites had lower phosphorus concentrations than the deepwater sites likely due to uptake by aquatic plants and attached algae that are more abundant in shallower water. Sites influenced by rivers that transport phosphorus-bound particulate matter, by contrast, displayed a decreasing trend over the summer of 2011. This is consistent with decreasing flows in the rivers that typically occur as summer progresses.

Of all the sites monitored in 2011, only 3 sites differed notably from other sites of the same type, including Price's Point (Deepwater), Narrows West (Nearshore Undisturbed) and Dwight Beach (Disturbed) (Figures 4 to 7).

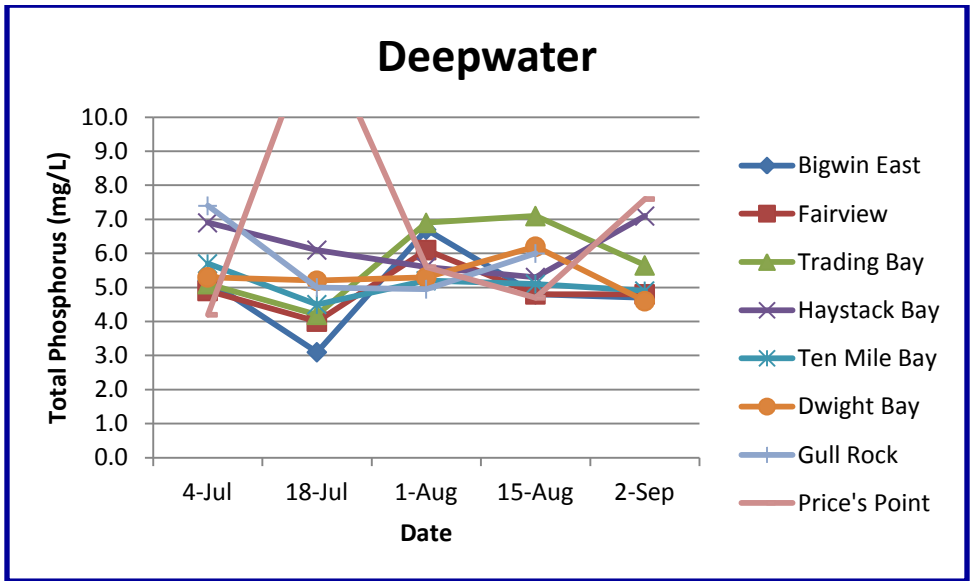
Price's Point differed from other Deepwater sites on July 18th when total phosphorus concentration at this site increased substantially to 12.8 mg/L from a mean of 5.5 on the other sampling dates (Figure 4). Since monitoring at Price's Point began in 2005, total phosphorus concentrations at this site have been highly variable (mean TP = 5.5 μg/L, standard deviation (stdev) = 2.5 μg/L) in comparison to the other Deepwater sites over the same period (stdev ranging from 1.2 to 1.9 μg/L). The higher variability observed at Price's Point cannot be explained at this time considering its location in the narrows near the outflow of the lake, variability could result from turbulent mixing as water flows past this site.

Figure 4. Total Phosphorus Concentrations in Lake of Bays 2011 by Site Type



Note: Data points for each date represent mean values of all sites of one type.

Figure 5. Total phosphorus concentrations in Lake of Bays 2011, Deepwater sites.



Narrows West differed from other Nearshore Undisturbed sites on August 1st with a higher total phosphorus concentration of 8.5 µg/L (Figure 5). This increase is not likely the result of shoreline disturbance, but is more consistent with the influence of phosphorus loading from the Hollow River. The Hollow River discharges to Trading Bay, and water flows from the bay through the narrows past the Narrows West site, then towards the outlet past Bigwin Bay. All of the sampling sites along this flow path displayed an increase in total phosphorus concentration on August 1st.

At Dwight Beach, total phosphorus concentration was elevated in July relative to the other Disturbed sites and concentrations displayed a sharp decreasing trend over the course of the summer (Figure 6). As with the Narrows West site, it is likely that river inputs strongly influenced the changes in phosphorus concentration at Dwight Beach, which is located in proximity to the Boyne River and Oxtongue River inlets. This is supported by the similar pattern of decreasing total phosphorus concentration observed at the Oxtongue Mouth and Delta sites (Figure 7). The Boyne River discharges just west of Dwight Beach and would have likely had similar flow regimes to the Oxtongue River.

Figure 6. Total phosphorus concentrations in Lake of Bays 2011, Nearshore Undisturbed sites.

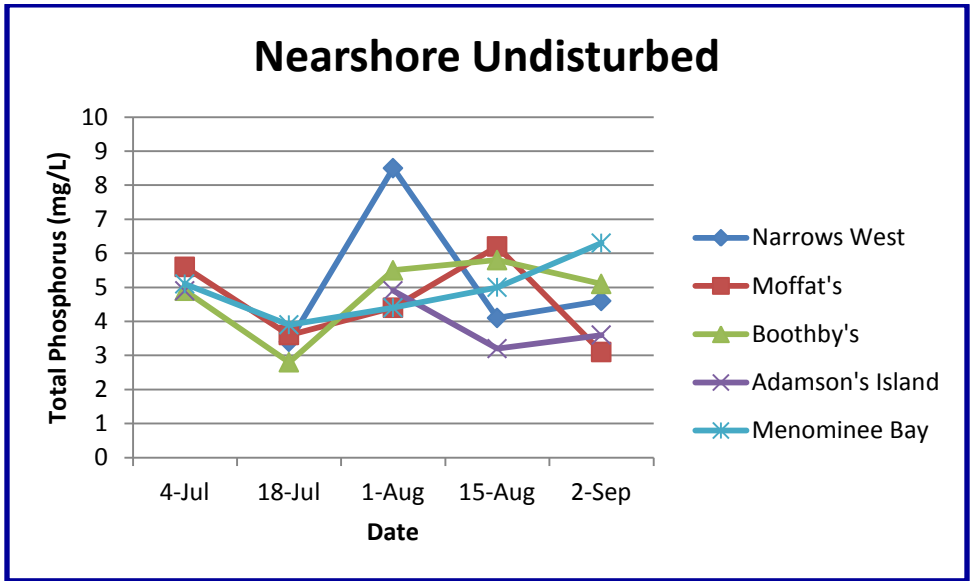


Figure 7. Total phosphorus concentrations in Lake of Bays 2011, Disturbed sites.

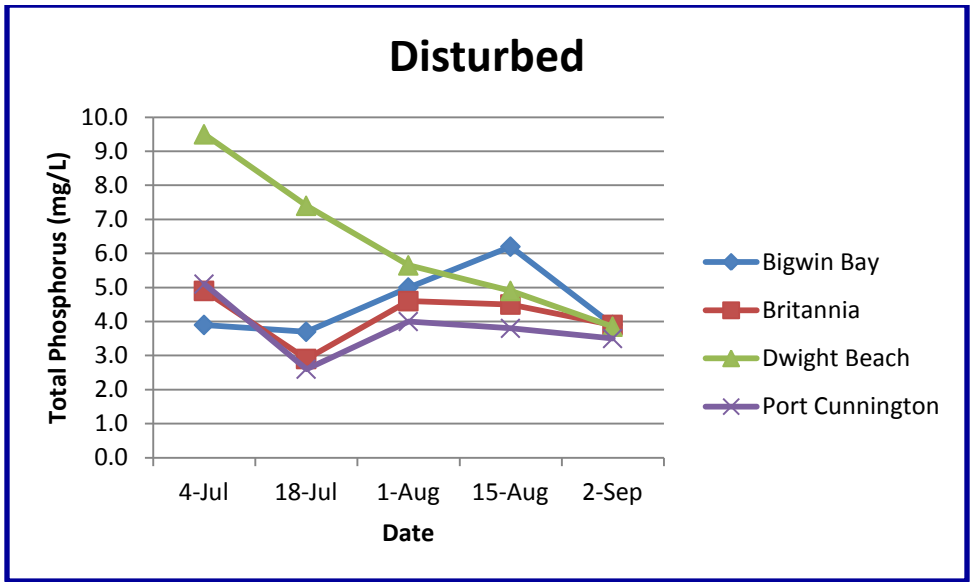
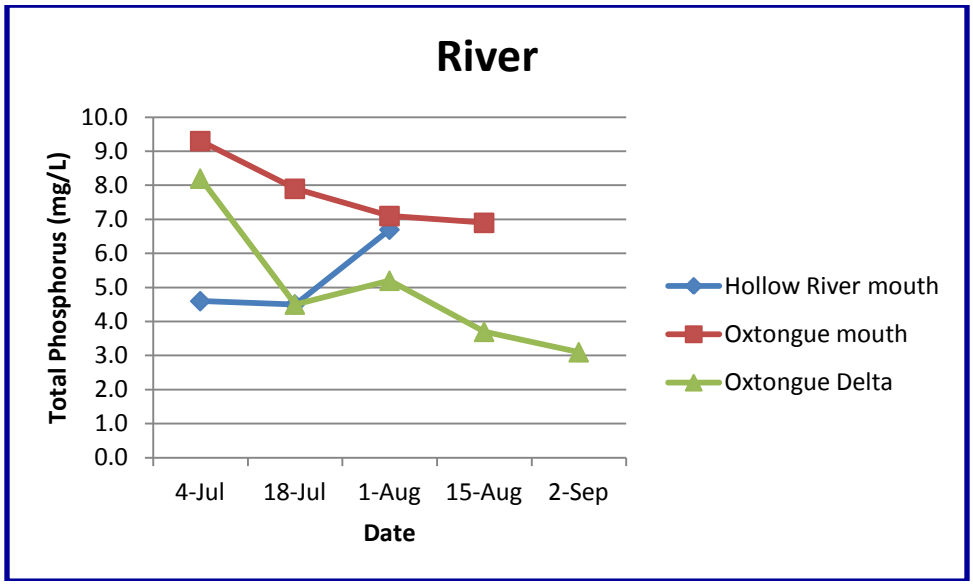


Figure 8. Total phosphorus concentrations in Lake of Bays 2011, River sites.



3.3 Bacteria

Overall, the bacteria levels in Lake of Bays did not pose any human health risk with respect to exposure from recreational activity in the summer of 2011. Absolute and geomean ($n_{sampling\ events}$=6) bacteria counts were well below the PWQO of 100 cfu/100 mL for *E. coli* and 1,000 cfu/100 mL for total coliform at all sampling sites (Table 6). The highest bacteria counts were observed in the river-influenced and nearshore sites, a pattern that has been observed in previous years in Lake of Bays and that is expected as rivers and nearshore areas are more exposed to bacteria sources from wildlife and riverside development in comparison to the offshore deepwater sites.

Table 6. Summer Geomean E.coli and Total Coliform Concentration in Surface Water, 2011

Site	E. coli (cfu/100 mL)	Total Coliform (cfu/100 mL)
Deepwater		
Bigwin East	1	4
Dwight Bay	1	4
Fairview	1	2
Gull Rock	1	3
Haystack Bay	2	5
Price's Point	1	3
Ten Mile Bay	2	3
Trading Bay	2	4
Disturbed		
Bigwin Bay	9	26
Bigwin North	2	5
Britannia	2	5
Dwight Beach	22	29
Port Cunnington	4	12
Nearshore Undisturbed		
Adamson's Island	2	3
Boothby's	3	7
Menominee Bay	4	7
Moffat's	3	12
Narrows West	12	21
River Influenced		
Hollow River mouth	9	26
Oxtongue Delta	4	7
Oxtongue mouth	5	9

4. Long-term Phosphorus Trends

The Lake of Bays Water Quality Monitoring Program has been consistently collecting data over the summer season for ten years at numerous locations throughout the lake (Table 7). The yearly number of collected samples including QA/QC samples ranged from 50 in 2002 to 113 in 2011, with a total number of 841 samples collected at the end of the 2011 program. This data set provides an excellent opportunity to assess long-term trends and variability in Lake of Bays total phosphorus over the years. All data collected by the LOBA monitoring program since 2002 are provided in Appendix B.

Table 7. Number of Total Phosphorus Samples Collected by the Lake of Bays Monitoring Program (2002-2011)

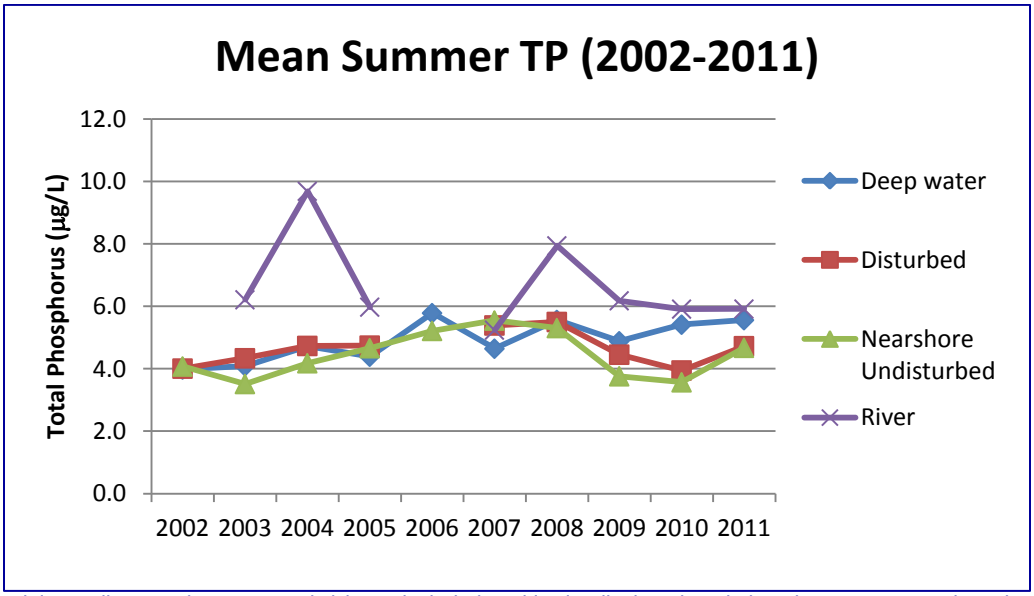
Site Type	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2002 to 2011
Deepwater	30	39	28	29	53	49	48	47	46	44	413
Disturbed	15	22	13	8		10	13	15	15	28	139
Nearshore Undisturbed	5	7	5	14	21	32	32	20	29	26	194
River Influenced		16	7	8		10	15	10	16	13	95
All Site Types	**50**	**84**	**53**	**59**	**74**	**101**	**108**	**92**	**106**	**113**	**841**

To summarize trends over the years, we calculated mean phosphorus concentrations per site type and per year using all of the LOBA data with the exception of data from Little Trading Bay. As described in the 2010 monitoring report, the Little Trading Bay (E20) deepwater site was removed from the Deepwater class for analysis of long term trends because total phosphorus concentrations (2005-2008) at this site were significantly higher than at other deepwater sites and do not reflect the overall conditions of deepwater areas in the lake. Little Trading Bay is a relatively small distinct basin located at the far east end of Lake of Bays and is likely influenced by inputs from the Hollow River which discharges at the east end of the bay and the bay likely receives little water from the main body of the lake (i.e., little mixing).

Since 2002, the mean summer total phosphorus concentrations have ranged between ~3 and 6 µg/L in the Deepwater and nearshore (both Disturbed and Nearshore Undisturbed) sites (Figure 9). The river-influenced sites have been more variable with generally higher concentrations that have ranged from ~5 to 10 µg/L. Overall, these concentrations are low and continue to reflect the low primary productivity or oligotrophic conditions in Lake of Bays. It is noted, however, that with the inclusion of the 2011 sampling data, there is a significant increasing trend in mean summer total phosphorus concentration at the Deepwater sites since 2002 (linear regression, n=10, p=0.01).

A trend towards increasing total phosphorus concentrations at the Deepwater sites was noted in previous LOBA monitoring reports, which was coincident with a decrease in water clarity (as Secchi depth, Lake Partner Program data[1]). It is likely that this observed trend in phosphorus is within the range of natural variability for the lake and not the result of increased phosphorus loads over that time period. Interannual variability in total phosphorus concentrations occurs due to many factors including differences in weather patterns, shoreline activities, localized nutrient uptake by plants and changes in the food chain, etc. Based on long-term monitoring records from Precambrian Shield lakes, the natural variability in total phosphorus concentration is approximately 20% (Bev Clark, pers. comm., former coordinator of MOE's Lake Partner Program), that is, annual total phosphorus concentrations can deviate by +/-20% from the long term mean.

Figure 9. Long-term Trends in Mean Summer Total Phosphorus by Site Type



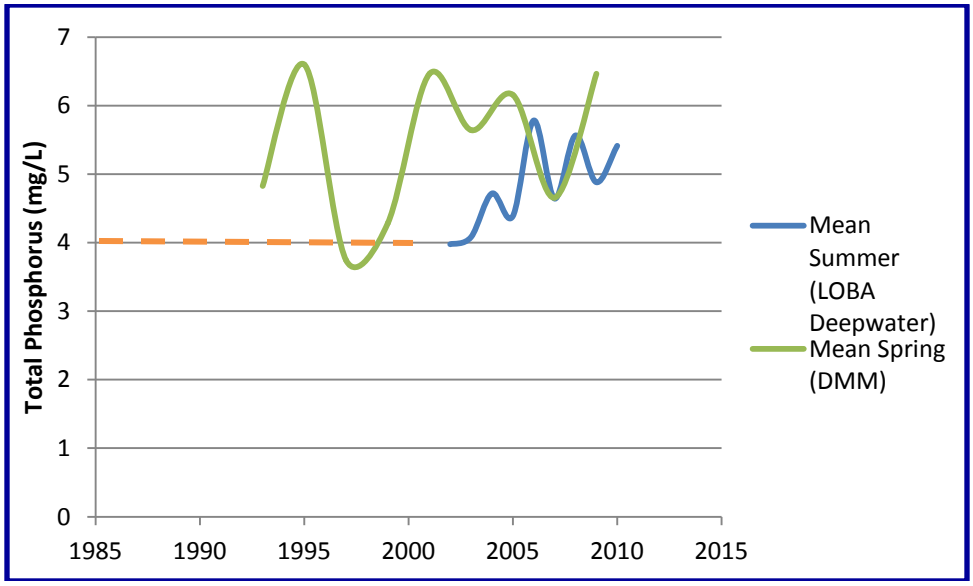
Note: Little Trading Bay (Deepwater site) is not included as this site displayed total phosphorus concentrations that were significantly higher than other deepwater sites and is not representative of deepwater sites in Lake of Bays

For Lake of Bays, mean total phosphorus concentration at the Deepwater sites has ranged from 4.0 to 5.8 µg/L, which is within 20% of the 10-year long term mean of 5.0 µg/L. Further support for natural variability is provided by spring total phosphorus monitoring data collected by the DMM, which has been highly variable between sample years, but without evidence of trends (Figure 10). The main cause for greater interannual changes in spring total phosphorus concentrations (DDM data) than summer concentrations (LOBA) is most probably related to the varying intensity of spring snowmelt, which would result in varying amounts of phosphorus in the lake during spring that would settle out with stratification and have no effect on summer concentrations. Despite annual differences in the two monitoring programs, they provide similar

[1] *The LPP Secchi depth data collected after 2002 were only available from Little Trading Bay and south of Britania Bay. The Little Trading Bay site is not representative of Lake of Bays as described in this report and the exact location of the monitoring site south of Britania Bay is not known. The LPP Secchi Depth data is therefore not readily comparable to the LOBA data.*

long term mean phosphorus concentrations for the open deepwater sites from (TP spring$_{02\text{-}09}$ = 5.7 µg/L, TP summer$_{02\text{-}11}$ = 5.0 µg/L).

Figure 10. Long-term Trends Spring and Summer Total Phosphorus in Deep Areas of Lake of Bays.



Note: The DMM 2011 monitoring data was not available at the time of report production.

5. Summary

The total phosphorus and bacteria data collected by the Lake of Bays Association over the summer of 2011 were of high quality and indicated continued excellent water quality at all sampling sites in the Lake of Bays. The main results of data analyses from 2011 and from previous years are as follows:

1) Total phosphorus concentrations are characteristic of lakes with low primary productivity and meet the highest Provincial standards for protection from algae bloom development and were below applicable DMM thresholds for phosphorus (background phosphorus concentration +50%);

2) The Grubb's test provides a statistical means to identify extreme values for total phosphorus that could influence the evaluation of trends in the data. Evaluation of outliers should be repeated each year with the entire data set;

3) Total phosphorus concentrations were highest in river sites compared to lake sites, as expected due to natural processes;

4) There is a significant increasing trend in mean summer total phosphorus concentration in deepwater sites of Lake of Bays from 2002 to 2011. Phosphorus concentrations over

that time period are, however, within 20% of the mean which is considered as the range of natural variability for Precambrian Shield lakes in Ontario. This fact and the lack of a similar observed trend in spring overturn phosphorus concentrations collected by the DDM suggest that the trend is due to natural fluctuations and not the result of an increase in total phosphorus inputs from human sources, and

5) Bacteria levels in Lake of Bays did not pose any human health risk with respect to exposure from recreational activity in the summer of 2011.

6. References

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Appendix A. Sampling Protocol of the Lake of Bays Association Water Quality Program

Appendix B. LOBA Monitoring Data, 2002-2011