Water Quality Survey of Ten Lakes Located in the Carleton River Watershed Area of Digby and Yarmouth Counties, Nova Scotia

Prepared for

Nova Scotia Department of the Environment

By

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SUMMARY

In 2008, as a result of concerns that water quality was becoming seriously degraded within a number of lakes located within the Carleton, Meteghan, and Sissaboo River watersheds, the Nova Scotia Department of Environment initiated a program designed to evaluate the water quality status of nine lakes located within these watersheds. The results of this initial evaluation indicated that water quality was impaired in a number of the lakes surveyed, particularly with respect to high nutrient concentrations resulting in the development of high algal concentrations. In some instances the high algal concentrations contained species of blue-green alga known to produce microcystins, a toxin that, under certain conditions, may be harmful to humans, livestock and wildlife. As a result, further studies were carried out in 2009 and 2010 to better document the extent of the degradation in water quality and to determine its potential causes. This report summarizes the results obtained during the three survey years with a focus on water quality parameters that, when impaired, are potentially harmful to humans or can lead to the deterioration of conditions necessary to support aquatic life.

A total of ten lakes were surveyed over the three year survey period. Of the ten, seven were found to be severely impacted by nutrient over-enrichment in at least one of the three survey years, two were moderately impacted and only one was found not to be impacted in any of the three years. The lakes exhibiting the most serious symptoms of nutrient over-enrichment were located within the upper region of the study area and in close proximity to a high concentration of mink farming operations, the activities of which are most likely to be the major source of nutrients leading to nutrient over-enrichment of the lakes. There was considerable yearly variation in the extent to which an individual lake exhibited excessive algal growth which was found to be closely related to yearly variations in lake color. Despite the poor water quality, most of the surveyed lakes met the available established water quality guidelines for recreational use related to health issues, but many often failed the recreational aesthetic guidelines related to water transparency. All of the lakes surveyed were found to contain microcystin producing algal species in at least one of the survey years, but microcystin concentrations never exceeded established guidelines for recreational water use.

To more specifically define the magnitude and location of nutrient inputs to the lakes, rudimentary estimates of nutrient loading to each lake were carried out in 2009 and 2010. In addition, as an aid to categorize which lakes are most in need of remediation activities to decrease nutrient input, an assessment procedure was developed to estimate the relative assimilation capacity of each lake and its susceptibility to nutrient over-enrichment. Of the ten lakes surveyed, three were found to be highly susceptible to nutrient over-enrichment, four were moderately susceptible, two had low susceptibility and one lacked the necessary data for assessment.

Recommendations are made for future studies to elucidate the sources of nutrient inputs and to monitor the effect of any remediation actions that may be carried out.

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Water Quality Survey of Ten Lakes Located in the Carleton River Watershed Area of Digby and Yarmouth Counties, Nova Scotia

1. Background

In the summer of 2007, green turbid water conditions were observed in Lake Fanning, a large lake located within the Carleton River watershed. Water quality sampling subsequently found this to be caused by a blue green algal bloom and resulted in the posting of the lake as being unsafe for recreation and use as a drinking water supply. Similar conditions were again observed in Lake Fanning in 2008. As a result of these incidents, as well as public concerns of deteriorating water quality and similar conditions in a number of other lakes within the surrounding area, the Nova Scotia Department of Environment (NSDOE) established a water quality monitoring program designed to determine the nature and extent of the problem. The primary objective of the water quality monitoring program was to obtain information on the status of a number of lakes in the area suspected of having impaired water quality, with particular attention to obtaining information on those factors indicative of the degree of water quality deterioration and the causative factors responsible for any observed deterioration of water quality.

The first extensive water quality survey was carried out in 2008 (NSDOE 2009) and included nine lakes. The results revealed that a number of the lakes surveyed were being impacted by nutrient enrichment to levels that were well within the eutrophic category. Of particular concern was the presence in some lakes of the blue green alga *Microcystis* which, when present at high concentrations may produce microcystins, a hepatotoxin that is known to be carcinogenic if ingested by humans. This survey was repeated in 2009 (NSDOE 2010) to determine if the same conditions observed in 2008 persisted in 2009 and included an additional lake (Sloans) for which a development was being considered within its watershed. In addition, the water quality survey was extended to include the inlets and outlets of each lake. This survey was repeated in 2010 to further validate the results obtained in 2008 and 2009.

This report summarizes the results of all three survey years as well as additional relevant information obtained from earlier water quality surveys carried out by the Nova Scotia Department of Lands and Forests (NSDL&F) as part of their lake survey program, the Nova Scotia Department of Natural Resources (NSDNR) as part of an evaluation of the potential threat of nutrient over-enrichment to coastal plain plant species (Eaton and Boates 2003) and Nova Scotia Power Inc (NSPI) as part of their water quality monitoring program for lakes used in the generation of hydroelectric power.

2. Study Area

The Carleton River watershed is located northeast of Yarmouth and is a tributary of the Tusket River. It has a watershed area of approximately 200 km^2 and contains nearly 200 lakes of which eight were included in the surveys. These include, in order of drainage, Hourglass, Placides, Porcupine, Parr, Ogden, Fanning, Sloans and Vaughan. The two remaining lakes surveyed, Nowlans and Provost, lie within the Meteghan and Sissaboo watersheds, respectively. The location of each watershed and lakes surveyed are shown in Fig. 2.1.

Land use characteristics of these watersheds consist largely of forested land with sparsely populated residential areas and, in most cases, sparse development along the shorelines of the lakes surveyed. Traditional agricultural activity is limited but there are numerous mink farming activities in all three watersheds and these are considered by many to be responsible for the observed water quality problems.

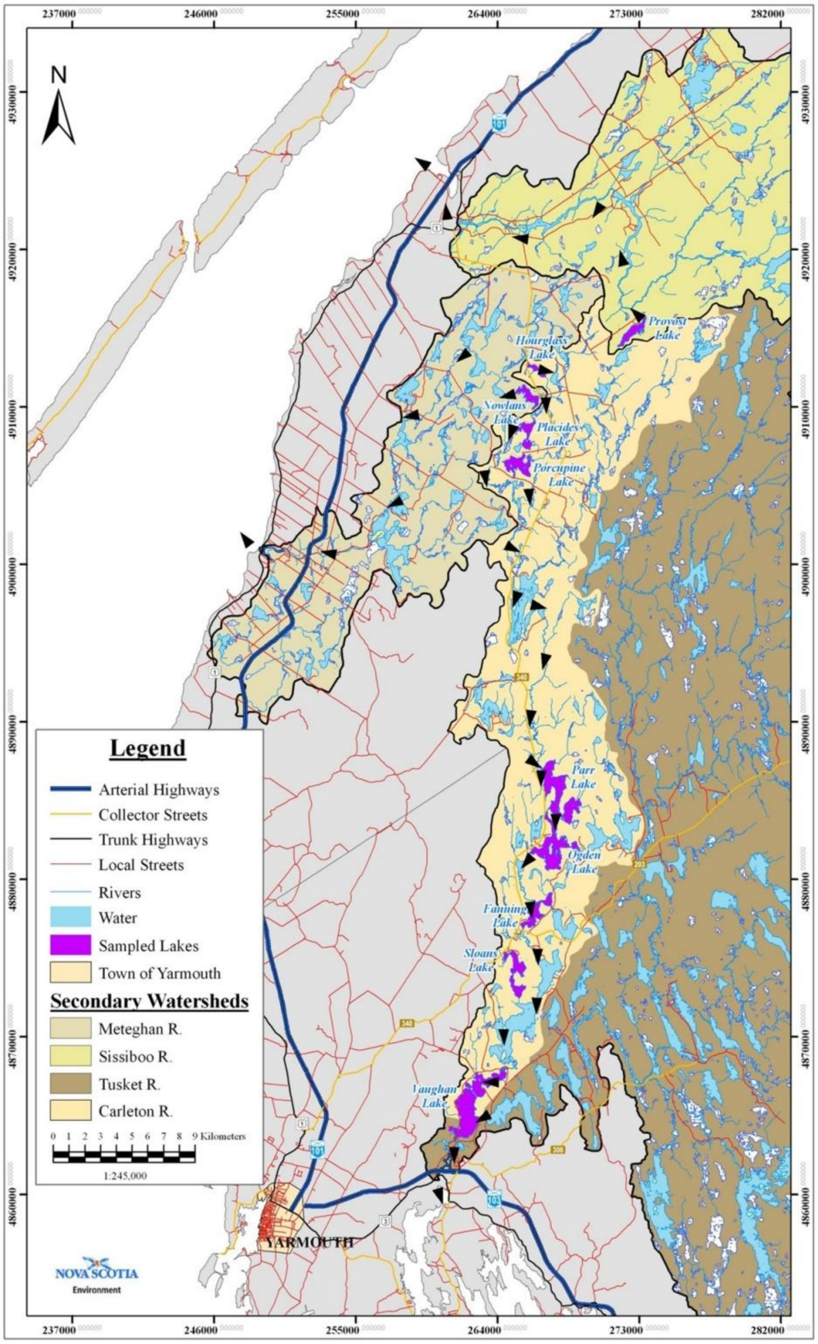

Fig. 2.1 Location of watersheds and lakes surveyed.

3. Approach

A large number of water quality parameters were measured during the water quality surveys. Those chosen for analysis are those most relevant to the assessment of the trophic status[1] of the surveyed lakes and, to a lesser extent, for safe recreational use. The water quality parameters chosen for analyses can be divided into three main categories: physical; chemical and; biological. The physical parameters include water temperature and water clarity. The chemical parameters include pH, alkalinity, nutrients (primarily phosphorus) and dissolved oxygen. The biological parameters include algal biomass measured as chlorophyll *a*, blue green algal species composition and numbers, algal toxin levels and fecal coliform bacteria numbers.

4. Methods

The water sampling methodologies and protocols used in this survey were the same as those used in the surveys carried out in 2008 and 2009 the details of which are described in NSDOE (2009; 2010).

Samples collected for assessing water quality were taken from the following four areas: (1) the deepest part of the lake; (2) each inlet to the lake; (3) each outlet from the lake and; (4) along the shoreline of the lake.

At the deepest part of the lake, in addition to the collection of water samples, depth profiles of water temperature, conductivity, pH, turbidity and dissolved oxygen were collected using a MS5 Hydrolab Sonde. If the lake exhibited water column temperature stratification, water samples were collected just below the surface (ca. 0.25 m), within the thermocline and one metre above the bottom of the lake. If not stratified, samples were collected only from just below the surface. Water transparency, measured as Secchi Disk depth, was also determined at this site. Water samples collected at this site were analyzed for algal biomass (as chlorophyll *a* concentration), nutrient concentrations, pH, alkalinity, color, and turbidity.

Water samples collected at the inlets and outlets were analyzed for the same parameters as for the deep water samples. The shoreline water samples were collected along the windward shoreline of the lake where blue green algae tend to be most concentrated and were analyzed for blue green algal species composition and numbers, algal toxin levels and fecal coliform bacteria numbers.

The deep station, inlet and outlet water quality samples were analyzed by the Environmental Services laboratory of the QE II Health Science Centre. Samples collected for blue green algal species composition and numbers were analyzed by ALS Laboratories in Winnipeg, MB, and fecal coliform samples were analyzed by either the Environment Laboratory of the Yarmouth Regional Hospital or the Environmental Services laboratory of the QE II Health Science Centre.

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[1] Trophic status refers to the level of biological productivity of a lake and is indicative of the degree to which a lake's water quality may be impacted by nutrient over-enrichment resulting from land use activities within the lake's watershed.

5. Morphological Characteristics of Surveyed Lakes

The ten lakes surveyed vary greatly in morphology (Table 5.1). Of particular note is the great variation in volume and flushing rate, important parameters in determining how susceptible a lake is to potentially harmful inputs.

Table 5.1 Morphological characteristics of surveyed lakes.

Lake	Drainage Basin Area (ha)	Surface Area (ha)	Mean Depth (m)	Maximum Depth (m)	Volume (m^3)	Flushing Rate (times/yr)
Hourglass*	55	31.4	2.1	7	666581	0.8
Placides	Data Unavailable					
Porcupine	972	146.9	9.6	13	14100410	0.7
Parr	24109	321.7	3.2	9	10529820	22.9
Ogden	25034	263.8	4.4	18	11674510	21.4
Fanning	28594	120.0	4.2	11	5010224	57.0
Sloans*	684	156.4	6.7	22	10469700	0.7
Vaughan	99999	467.4	5.1	18	23696802	42.2
Nowlans*	128	28.4	3.3	8	925834	1.4
Provost*	310	33.8	3.1	9	1057810	2.9
*Headwater lake						

Appendix I contains bathymetric maps of each lake with the exception of Placides Lake for which a bathymetric survey has not been completed.

6. Survey Results

In this section information obtained from the water quality surveys is evaluated with respect to established water quality guidelines for lake trophic status and recreational water use.

Trophic status refers to the level of productivity of a lake and is based primarily on nutrient concentration, algal biomass and water transparency. The nutrient most important in determining the productivity of freshwater aquatic systems is phosphorus which, in most freshwater ecosystems, is the limiting factor for algal growth. Algal biomass is typically measured as chlorophyll *a* concentration. Water transparency is a measure of the ability of light, a necessary requirement for algal photosynthesis, to penetrate into the water column and is influenced by the levels of both dissolved and particulate substances present. It is typically measured as Secchi Disk depth. The criteria most commonly used for each of these parameters in assessing the trophic status of a water body have been developed by the Organization for

Economic Cooperative Development (OECD 1982). Table 6.1 is a list of each parameter and the values considered to be representative of each trophic category. Phosphorous is the causal parameter and chlorophyll *a* and Secchi Disk depth are the response parameters. As phosphorus increases, chlorophyll *a* increases, which results in a decrease in Secchi Disk depth.

Table 6.1 OECD boundary conditions for trophic categories.

Trophic Category	**Parameter**		
	Total Phosphorus (mg/L)	Chlorophyll *a* (µg/L)	Secchi Depth (m)
Ultra-oligotrophic	< 0.004	< 1.0	≥ 6.0
Oligotrophic	≥ 0.004 - < 0.010	≥ 1.0 - < 2.5	≥ 3.0 - < 6.0
Mesotrophic	≥ 0.010 -.< 0.035	≥ 2.5 - < 8.0	≥ 1.5 - < 3.0
Eutrophic	≥ 0.035 - < 0.100	≥ 8.0 - < 25.0	≥ 0.7 - < 1.5
Hyper-eutrophic	≥ 0.100	≥ 25.0	< 0.7

There are a number of potential shortcomings in applying these criteria to the survey results obtained for this study. One is that the values listed in Table 6.1 are annual mean values, but the surveys for each lake were carried out on only one date in each year which precludes the calculation of annual values.

Another related shortcoming is that the 2008 survey was carried out during mid-summer when a number of the lakes exhibited water column stratification whereas the 2009 and 2010 surveys were carried out in the late summer or early fall when many of the same lakes were either unstratified or were undergoing destratification due to the fall overturn. The significance of this with respect to the above OECD criteria is that stratified lakes will tend to have much higher phosphorous concentrations within their bottom waters relative to the concentrations in surface waters, but after destratification the bottom waters will have mixed into the surface which will then have much higher phosphorus levels.

A third, and perhaps the most important shortcoming, is that a fourth tropic category, *dystrophic* (which literally means abnormal feeding) exists. Dystrophic lakes are characterized as being highly colored as a result of the run-off of humic and fluvic acid leachates originating from the decomposition of coniferous plants within a lakes watershed. These leachates impart a dark brown color to the water that can severely limit the penetration of light into the water column. As a result, dystrophic lakes often have very low Secchi Disk depths that are not indicative of high algal biomass and, if they are deep and unstratified, may be limited by light as opposed to phosphorous. The OECD criteria is based on the assumption that only phosphorus, and not light, is the factor limiting algal growth. In this case the only valid OECD criterion applicable for determination of trophic status is chlorophyll *a* concentration. This is discussed further in Section 7.

Water quality guidelines for recreation and protection of aquatic life have been established by Health Canada (2010). The available water quality guidelines relevant to this study are listed in

Table 6.2. Two of these parameters, Secchi Disk Depth and turbidity, are related to water clarity and are important mainly from an aesthetic viewpoint and are not actually harmful from a health perspective.

Table 6.2 Water quality guidelines for recreational use.*

Parameter	**Guideline Level**
E. coli (#/100 ml)	< 200
Secchi Disk Depth (m)	> 1.2
pH	5.0 – 9.0
Turbidity (NTUs)	< 50
Blue-green algae (#/ml)	< 100,000
Microcystin-LR (μg/L)	< 20

*Based on Health Canada (2010).

The databases used for analyses of the water quality survey results are contained in Appendix II and include the results of the surveys carried out by NSDOE in 2008, 2009 and 2010 as well as the results of historical surveys carried out by NSDL&F, NSDNR and NSPI.

6.1 Carleton River Watershed

6.1.1 Hourglass Lake

Hourglass Lake is a small, shallow headwater lake located within the northwest corner of the Carleton River watershed. Its only obvious input is from a small spring located a short distance above its southwestern shoreline. Its single outlet is located along its southern shoreline and drains into Placides Lake. Its mean depth is 2.1 meters and its flushing rate is 0.8 times/yr, the second lowest of all the lakes surveyed. A fish aquaculture operation is located along its northwestern shoreline. Fig. 6.1 shows the location of the water quality sampling stations.

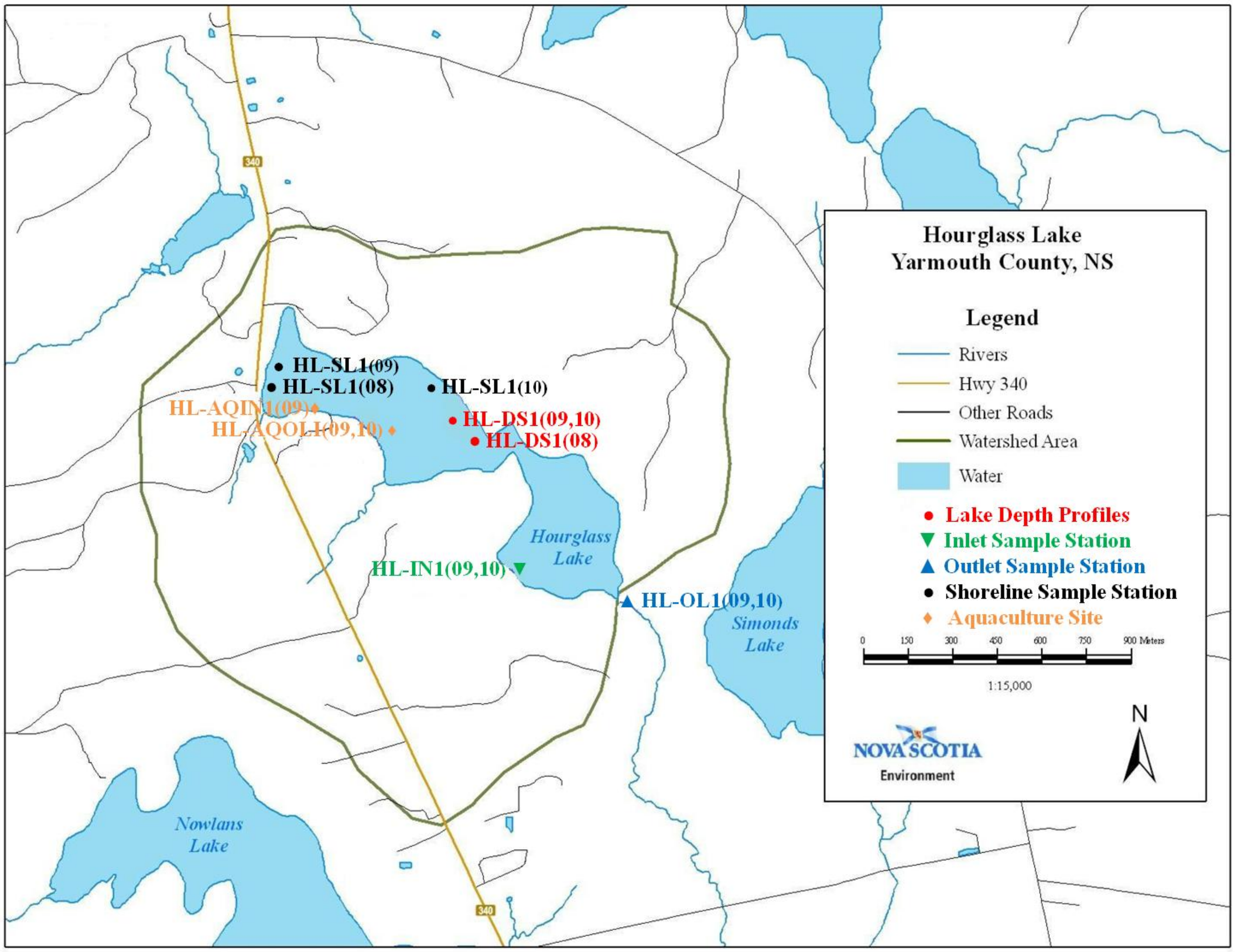

Fig. 6.1 Location of Hourglass Lake water quality sampling stations (numbers in parentheses represent years in which the station was sampled).

Despite its shallow depth, temperature and dissolved oxygen profiles taken during mid-summer in 2008 (Fig. 6.2) indicate that it undergoes water column thermal stratification with a weak thermocline beginning at a depth of about three meters, and the presence of hypoxic conditions within the hypolimnion which begins at about four meters depth. Because of its weakly developed thermocline, this lake is likely to undergo periods of summer destratification under strong wind conditions.

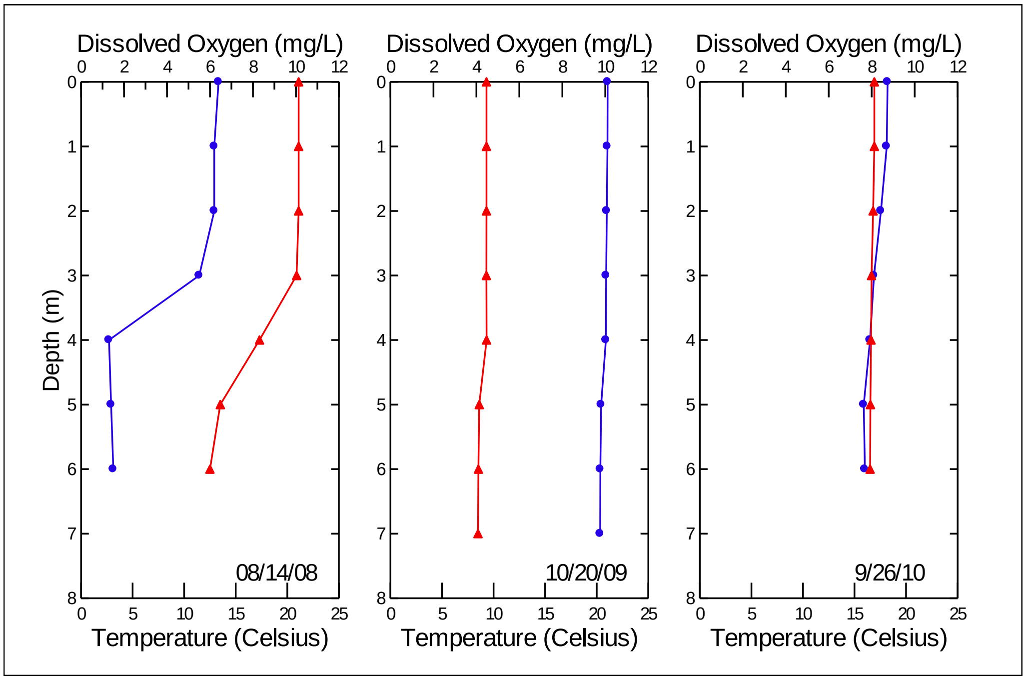

Fig. 6.2 Water column temperature (▲) and dissolved oxygen (●) profiles for Hourglass Lake during each survey year.

Total phosphorus levels measured at the deep lake sites in 2008 to 2010 (Fig. 6.3) were very high and indicative of eutrophic conditions. Although the levels were somewhat lower and confined to the hypolimnion, this was also true of a an earlier survey carried out in 1983 suggesting that this lake is likely to have been receiving high phosphorus inputs over a relatively prolonged period.

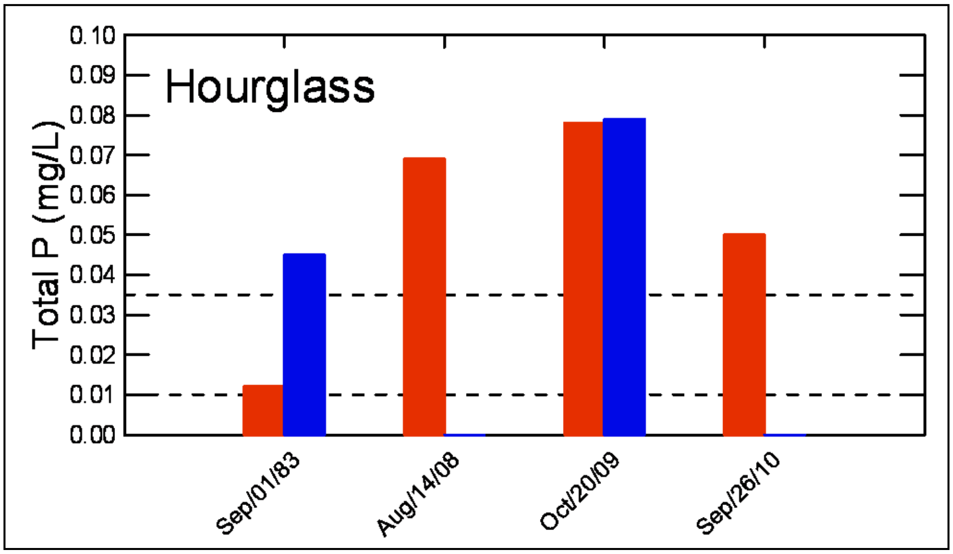

Fig. 6.3 Total phosphorous concentrations in surface (red) and bottom waters (blue) of Hourglass Lake (dashed lines represent divisions between trophic categories).

In 2009 and 2010 phosphorus concentrations were measured along the lake shoreline in close proximity to the inlet and outlet of the aquaculture site. In both years total phosphorus levels were slightly higher at the outlet than at the inlet (Fig. 6.4) suggesting that the high phosphorus levels within the lake to be most likely a result of effluents from the aquaculture operation which, because of the low flushing rate of the lake, have accumulated over time leading to the higher phosphorus levels evident since the 1983 survey.

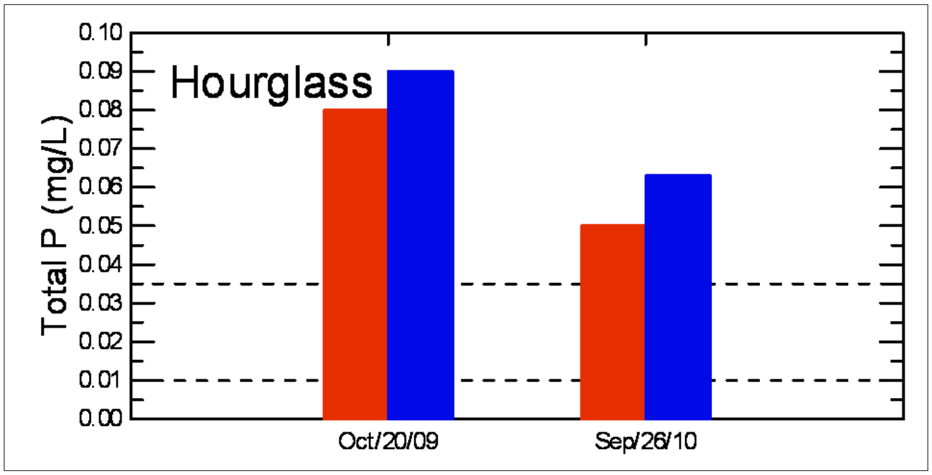

Fig. 6.4 Total phosphorous concentrations along the lake shoreline at the inlet (red) and outlet (blue) of the aquaculture site of Hourglass Lake (dashed lines represent divisions between trophic categories).

Total phosphorus concentrations at the outlet (Fig. 6.5) were considerably less than those measured within the lake which further supports the assertion that phosphorus entering this lake will tend to accumulate within the lake over time as opposed to being flushed out.

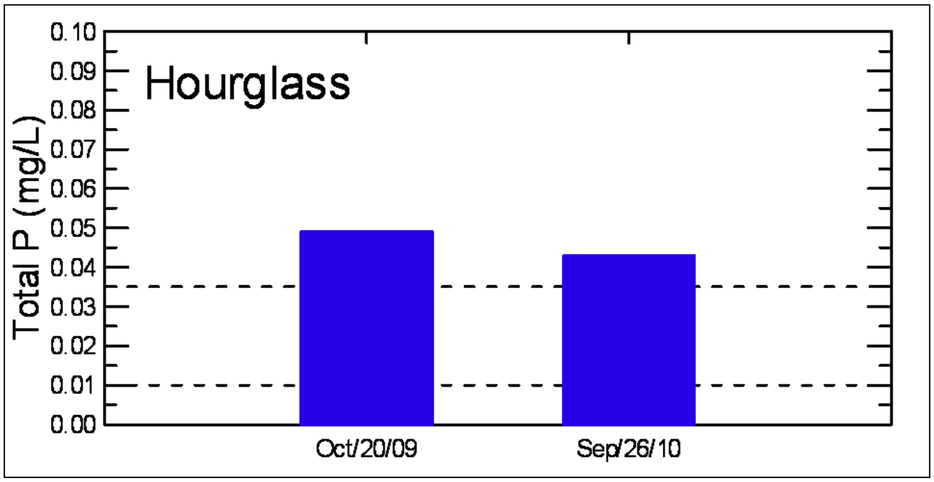

Fig. 6.5 Total phosphorous concentrations at the outlet of Hourglass Lake (dashed lines represent divisions between trophic categories).

Chlorophyll *a* levels fell well within the eutrophic category during 2008 and 2010, but were in the low mesotrophic category during 2009 (Fig. 6.6). This is likely a result of the high color of Hourglass Lake resulting from high precipitation events just prior to the 2009 survey which lowered water transparency and imposed a degree of light, as opposed to nutrient, limitation which respect to the development of high algal production. This is supported by the strong inverse relationship between Secchi Disk depth and color for this lake.

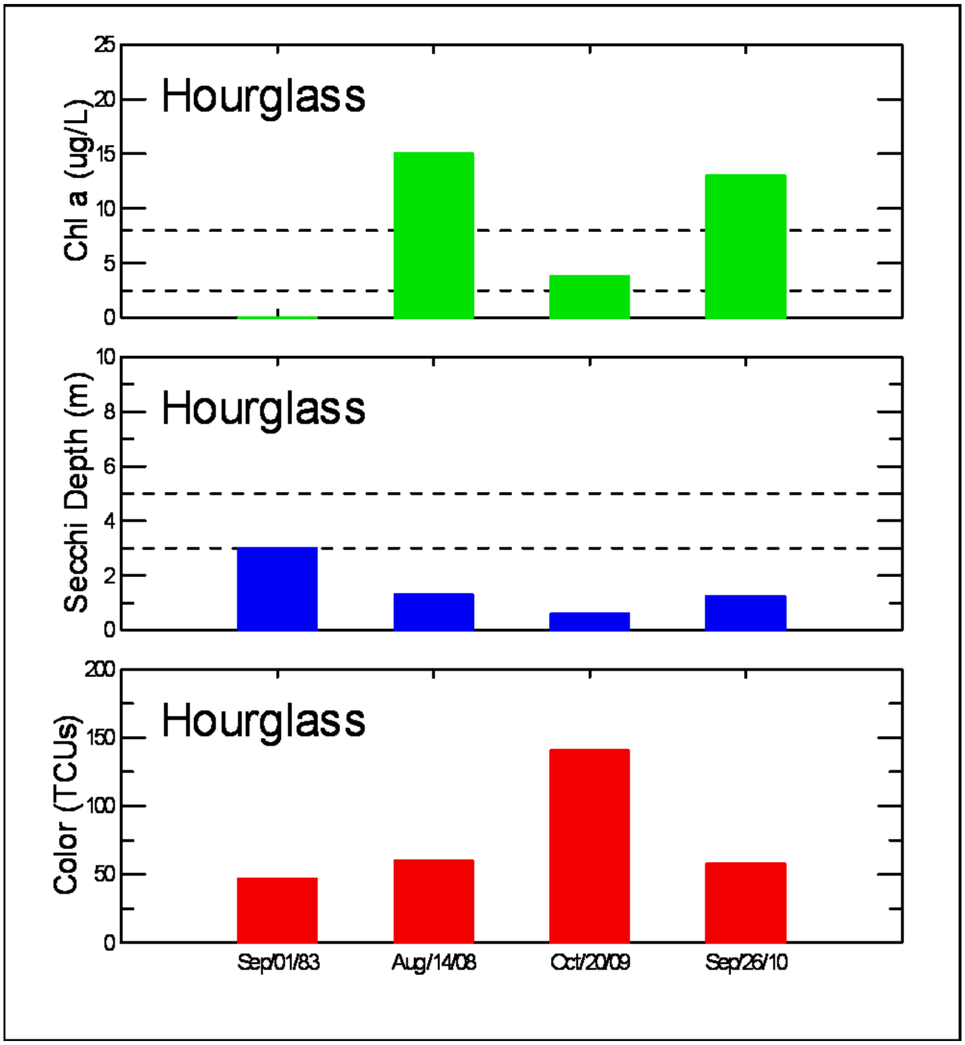

Fig. 6.6 Chlorophyll *a* concentration, Secchi Disk depth and color for Hourglass Lake (dashed lines represent divisions between trophic categories).

This lake would be classified as a moderately dystrophic lake in 2008 and 2009 and as a highly dystrophic lake in 2009.

The results of water quality samples collected along the shoreline of Hourglass Lake for each survey year (Table 6.3) showed very low levels of *E. coli*, blue green algae and microcystins and, as a result, no health concerns for recreational water use. Secchi depth, however, was below the guideline for water transparency in 2009.

Table 6.3 Summary of results for recreational use guidelines for Hourglass Lake.

Parameter	**Guideline**	**2008**	**2009**	**2010**
E. coli	< 200/100ml	-	0	7
Secchi Depth	> 1.2 m	1.3	0.6	1.25
pH	5.0 -9.0	6.2	6.2	6.8
Turbidity	< 50 NTUs	1.09	1.18	1.22
Blue-green algae	< 100,000 cells/ml	48	33	6
Microcystin-LR	< 20	< 0.20	< 0.20	< 0.20

6.1.2 Placides Lake

Placides Lake, like Hourglass Lake, is a small shallow lake. Its maximum depth is 6.9 meters[2]. It has a single inlet at its northern end which originates from a stream system fed by drainage from Hourglass and Simonds Lake. The outlet is located at its southern end which begins as a large stillwater. Fig. 6.7 shows the location of each water quality sampling station.

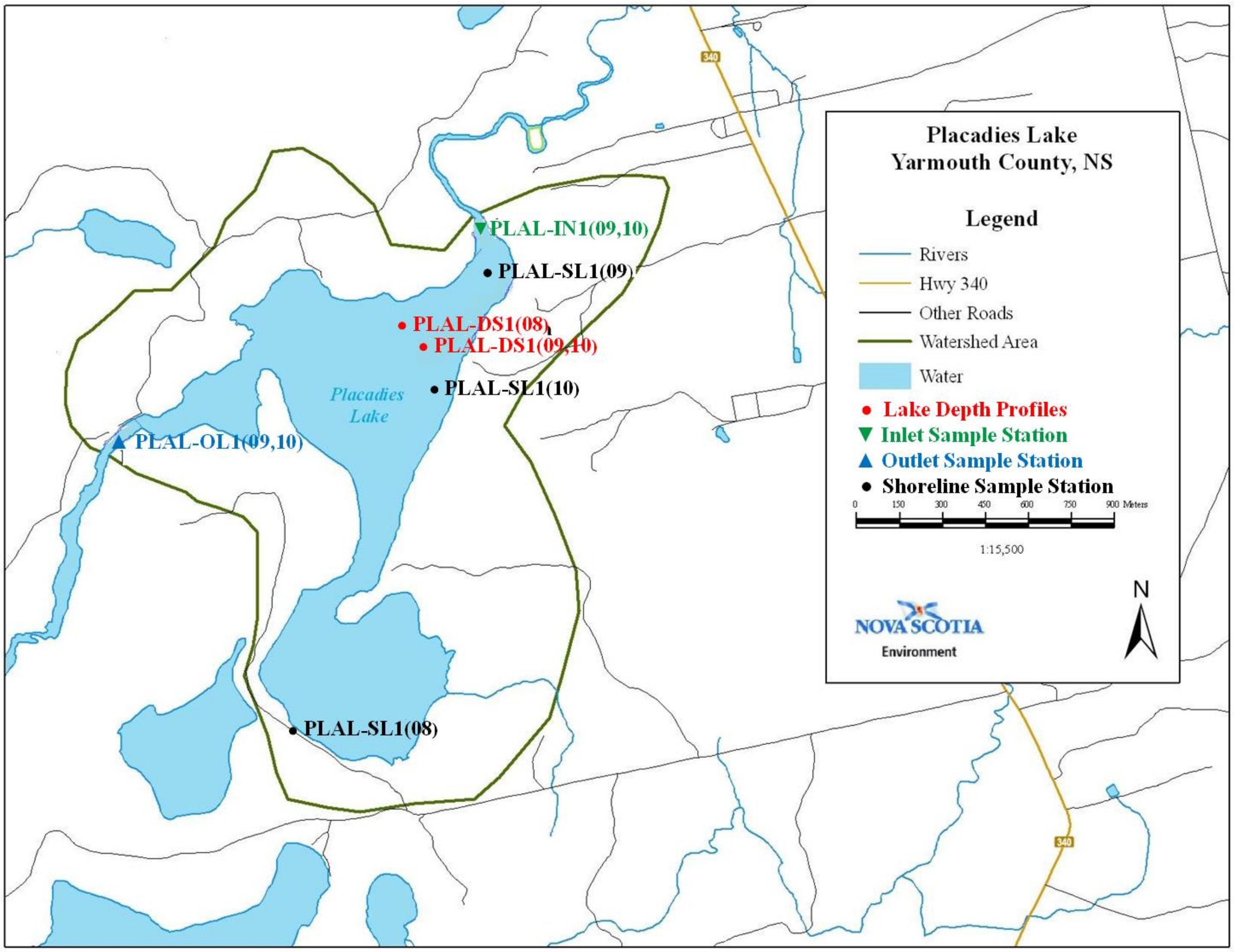

Fig. 6.7 Location of Placadies Lake water quality sampling stations (numbers in parentheses represent years in which the station was sampled).

The temperature and dissolved oxygen profiles taken during summer in 2008 (Fig. 6.8) illustrate that this lake stratifies weakly with a thermocline beginning at about four meters depth, and becomes hypoxic within the hypolimnion. Because of its weak thermocline, this lake is likely to periodically destratify during strong wind events.

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[2] Because a bathymetric map of Placides Lake is not available, it is not possible to determine its mean depth, volume or flushing rate.

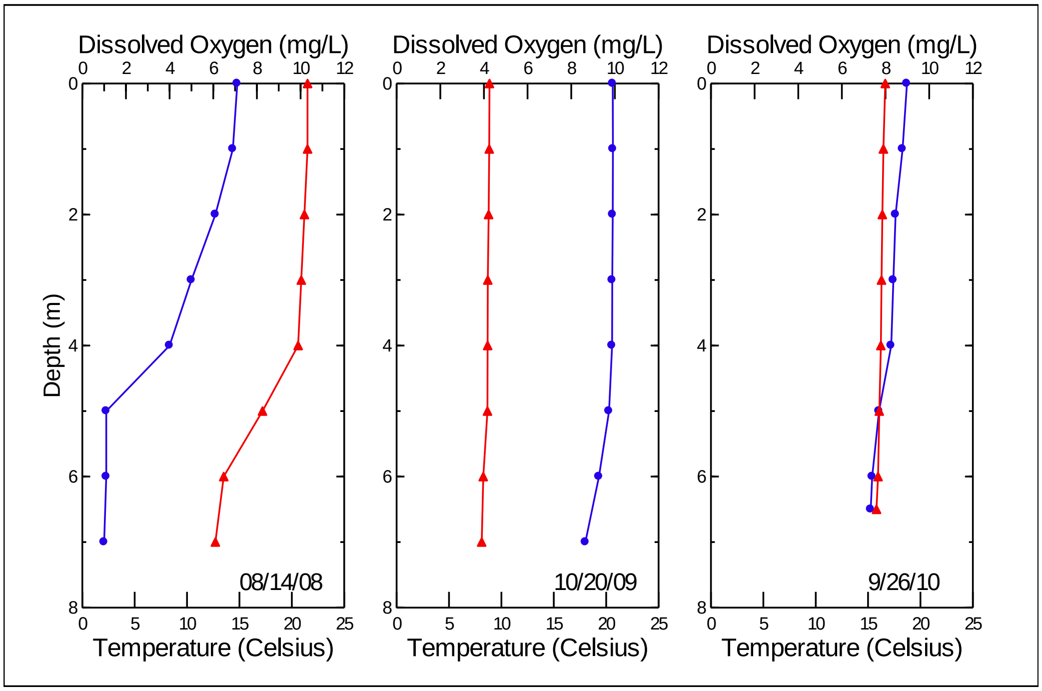

Fig. 6.8 Water column temperature (▲) and dissolved oxygen (●) profiles for Placides Lake during each survey year.

Total phosphorus values collected at the deep lake station place it well into the hyper-eutrophic category (Fig 6.9).

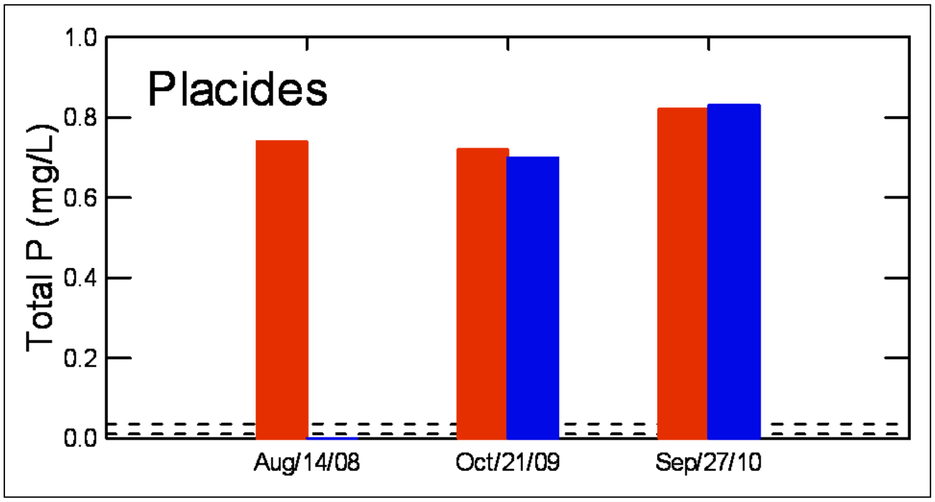

Fig. 6.9 Total phosphorous concentrations in surface (red) and bottom waters (blue) of Placides Lake (dashed lines represent divisions between trophic categories).

Total phosphorus values are also very high at both the inlet and outlet stations (Fig. 6.10). In 2009 phosphorus levels at the inlet were about equal to those at the outlet. In 2010, the inlet levels were higher than those of the outlet suggesting that phosphorus entering the lake is being entrained within the lake.

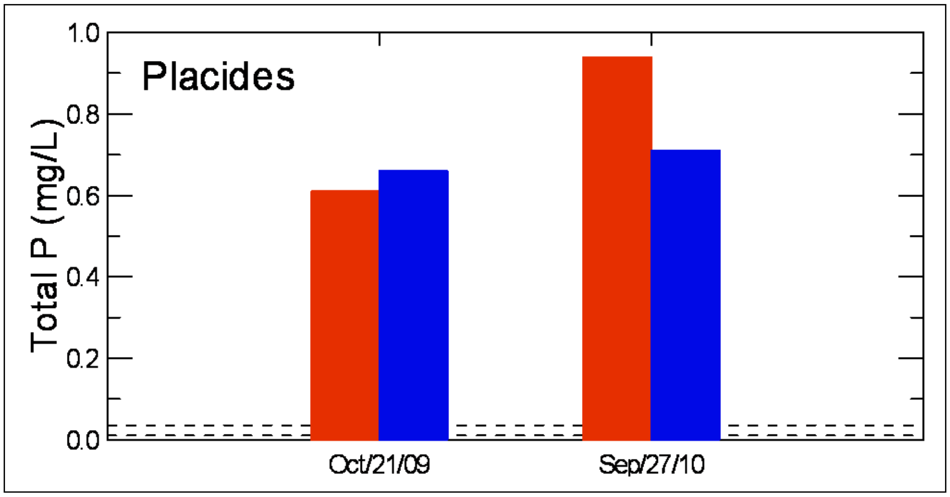

Fig. 6.10 Total phosphorous concentrations at the inlet (red) and outlet (blue) of Placides Lake (dashed lines represent divisions between trophic categories).

Like Hourglass Lake, chlorophyll *a* values were well within the eutrophic category during 2008 and 2010 (Fig. 6.11). In 2009 they were very low and within the ultra-oligotrophic category and, as was the case with Hourglass Lake, color was very high in that year. Secchi Disk depths fell within the hyper-eutrophic category in all years surveyed, but this also may be the result of very high color as opposed to high chlorophyll *a* levels. The low chlorophyll *a* values are in all probability a result of the fact that this lake may periodically destratify during summer and this, together with the lake's relatively high color, results in periodic light limitation of algal growth. This lake would be classified as a moderately dystrophic lake in 2008 and 2010 and as a highly dystrophic lake in 2009.

All of the health related guidelines (Table 6.4) were within acceptable limits. Secchi Disk depth, however, was slightly below the aesthetic guide for water clarity in 2008.

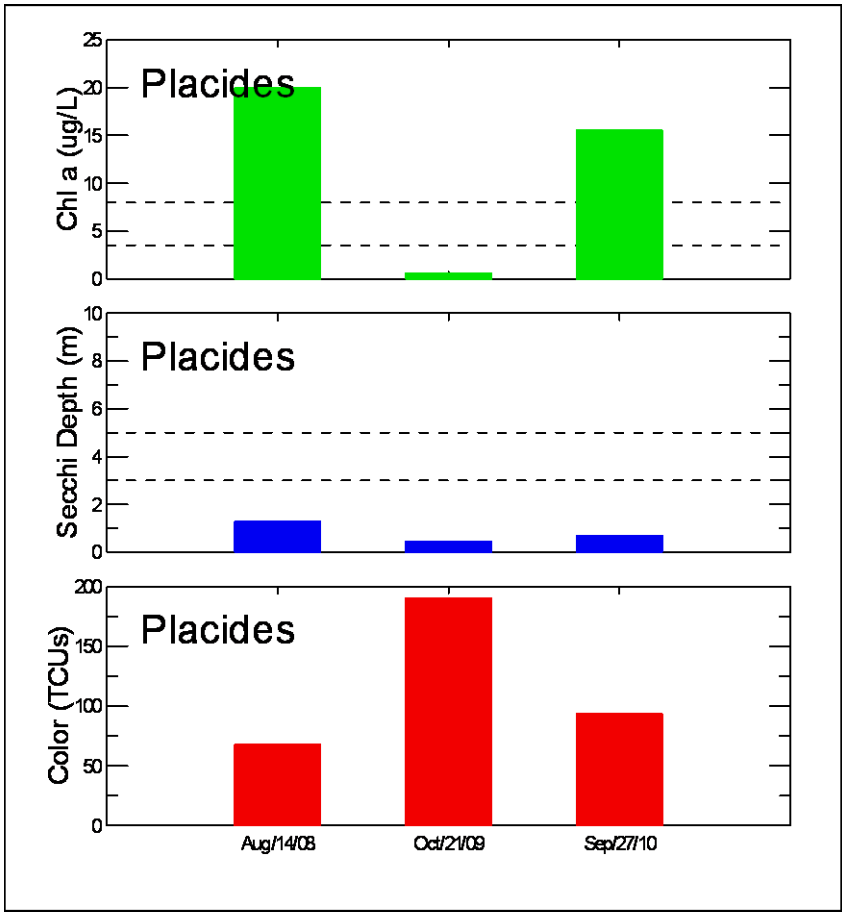

Fig. 6.11 Chlorophyll *a* concentration, Secchi Disk depth and color for Placides Lake (dashed lines represent divisions between trophic categories).

Table 6.4 Summary of results for recreational use guidelines for Placides Lake.

Parameter	Guideline	2008	2009	2010
E. coli	< 200/100ml	-	56	101
Secchi Depth	> 1.2 m	1.3	0.45	0.7
pH	5.0 -9.0	6.5	6.4	6.9
Turbidity	< 50 NTUs	2.0	5.4	10.0
Blue-green algae	< 100,000 cells/ml	64	424	0
Microcystin-LR	< 20	< 0.20	<0.20	< 0.20

6.1.3 Porcupine Lake

Porcupine Lake is a moderately sized but relatively deep lake. It has a small drainage basin area and that, combined with a relatively large volume, results in a low flushing rate of only 0.7 times per year. Its major input is a small stream that enters into its northeastern corner and receives drainage from three small lakes, Paul, Oliver and an unnamed lake, that lie to the northeast. Its output is located along its eastern shoreline and flows into the same river system that receives the outflow of Placides Lake. Fig. 6.12 shows the location of the water quality sampling stations.

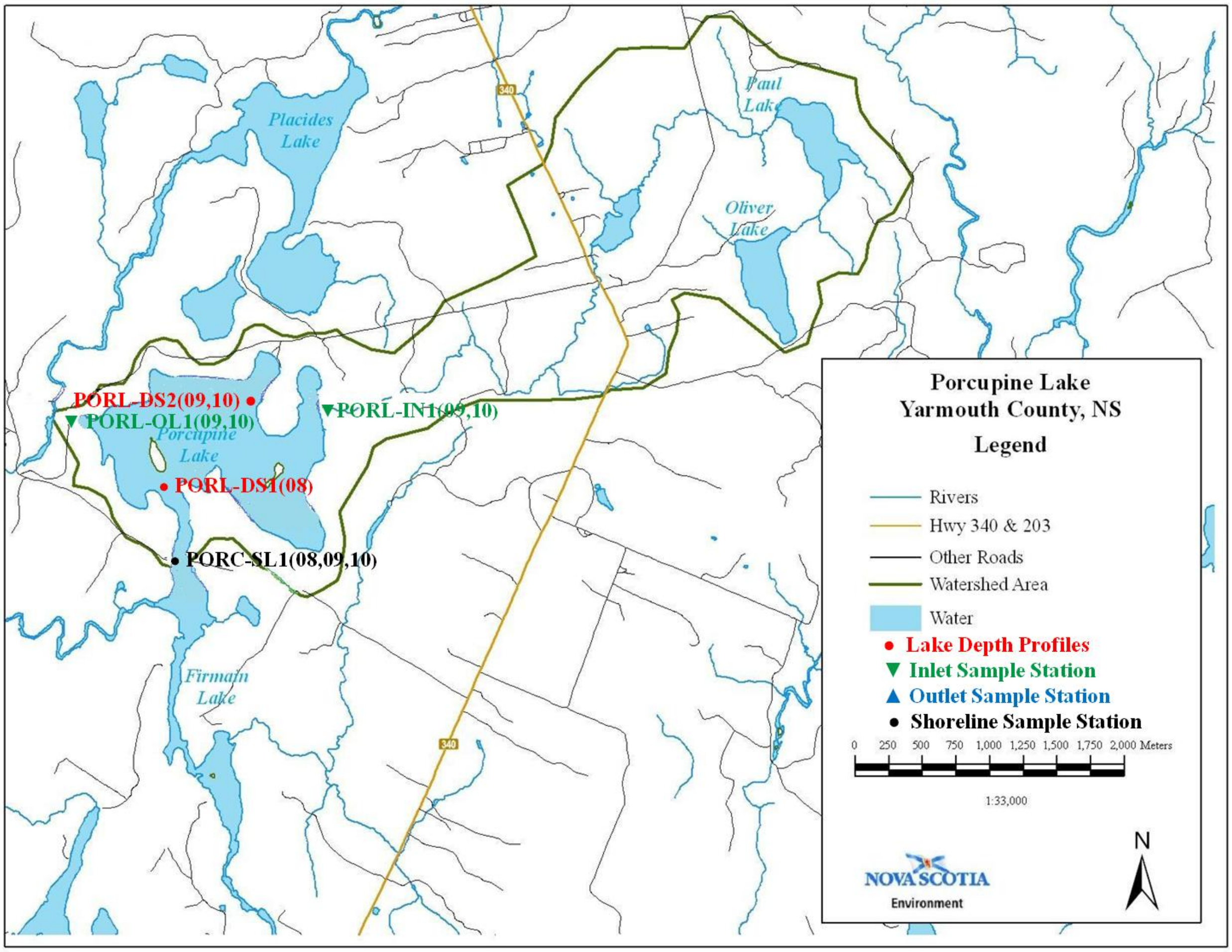

Fig. 6.12 Location of Porcupine Lake water quality sampling stations (numbers in parentheses represent years in which the station was sampled).

The temperature and dissolved oxygen profile taken in 2008 were at a different and much shallower station than the profiles taken in 2009 and 2010. However, it shows that the lake does stratify during the summer with a thermocline beginning at about five meters depth and a rapid decrease in dissolved oxygen beginning just below five meters depth. The one very low dissolved oxygen level at the very bottom of the lake observed in 2010 is the result of the profile having been taken at a time when the lake was very close to, but had not yet completed, the full stage of the fall overturn.

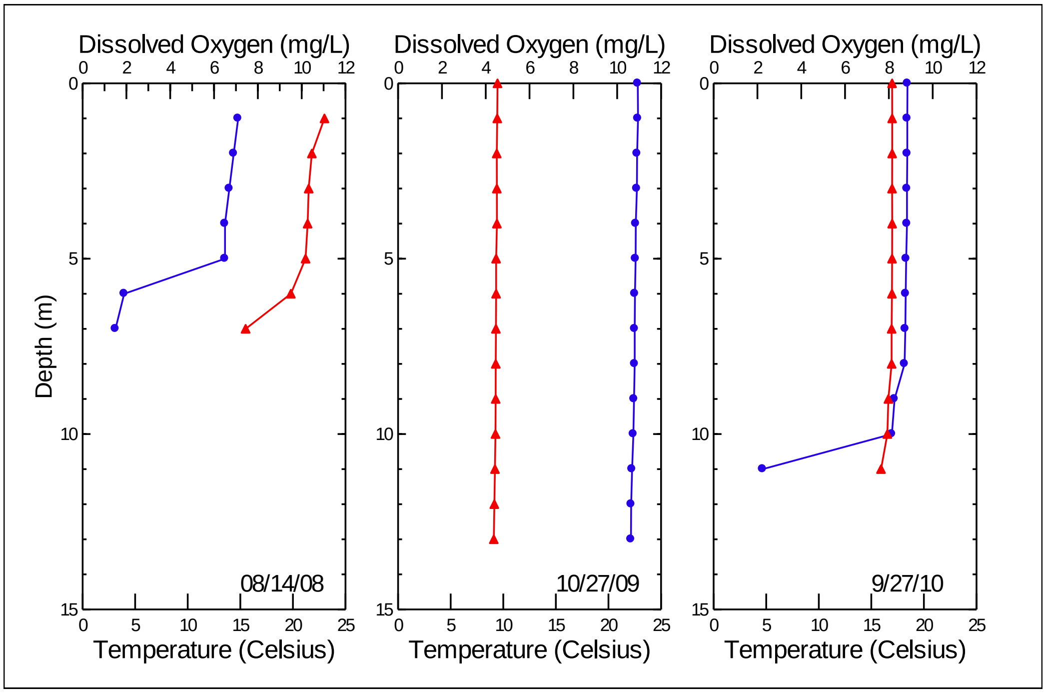

Fig. 6.13 Water column temperature (▲) and dissolved oxygen (●) profiles for Porcupine Lake during each survey year.

Total phosphorus values at the deep lake stations are mostly within the mesotrophic level with a trend over time to higher levels (Fig. 6.14). Surface water phosphorus levels were much lower than bottom water levels when the lake was stratified.

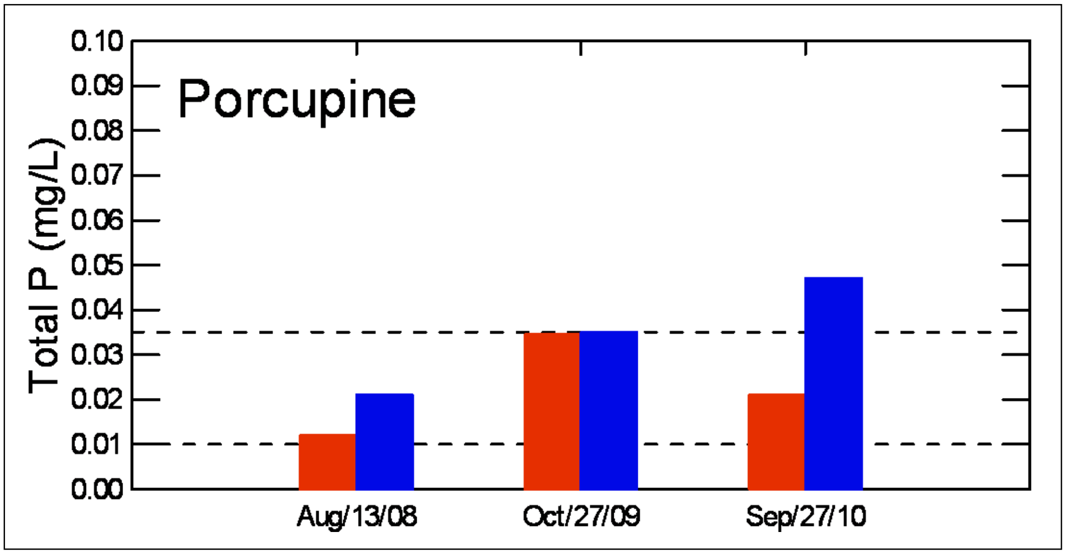

Fig. 6.14 Total phosphorous concentrations in surface (red) and bottom waters (blue) of Porcupine Lake (dashed lines represent divisions between trophic categories).

Total phosphorus levels at the input stream (Fig. 6.15) were nearly two times higher than within the lake, but were nearly half the level at the output. This indicates that this lake is likely to be accumulating phosphorus over time as would be expected due to its very low flushing rate.

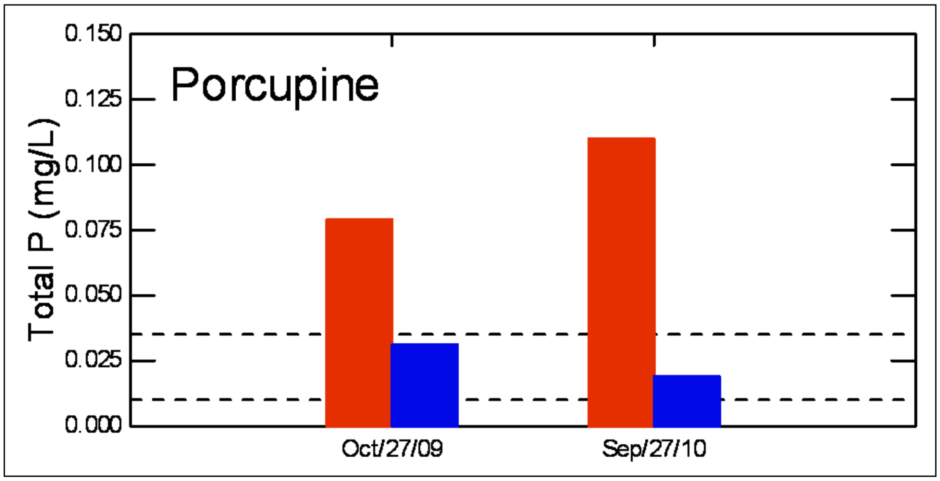

Fig. 6.15 Total phosphorous concentrations at the inlet (red) and outlet (blue) of Porcupine Lake (dashed lines represent divisions between trophic categories).

Chlorophyll *a* levels were highest in 2008 and 2010 (Fig.6.16) where they ranged from high to low mesotrophic levels, respectively. In 2009 they fell within the oligotrophic category. As with the other lakes previously discussed, they showed an inverse relationship to water color. This lake would fall into the moderately dystrophic category.

Porcupine Lake met all of the guidelines for recreational use (Table 6.5).

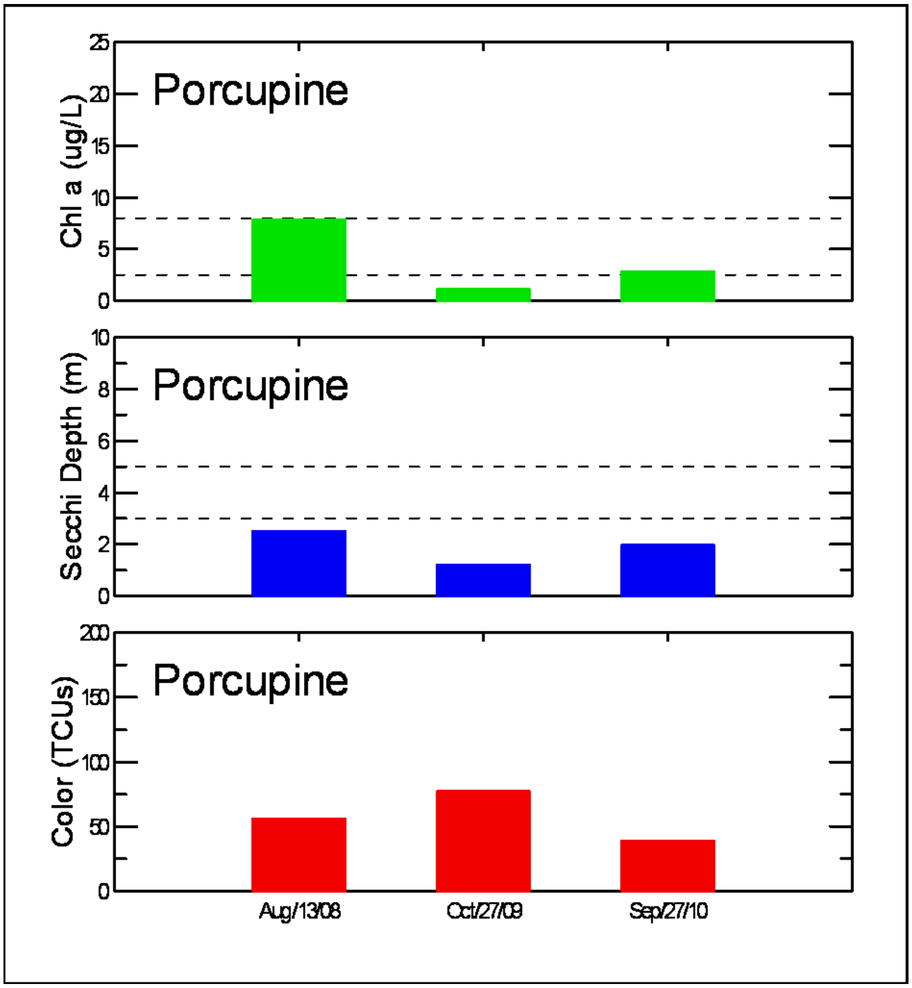

Fig. 6.16 Chlorophyll *a* concentration, Secchi Disk depth and color for Porcupine Lake (dashed lines represent divisions between trophic categories).

Table 6.5 Summary of results for recreational use guidelines for Porcupine Lake.

Parameter	Guideline	2008	2009	2010
E. coli	< 200/100ml	-	1	12
Secchi Depth	> 1.2 m	2.5	1.3	2.0
pH	5.0 -9.0	6.6	6.6	6.9
Turbidity	< 50 NTUs	0.95	1.15	0.65
Blue-green algae	< 100,000 cells/ml	56	2	20
Microcystin-LR	< 20	<0.20	<0.20	<0.20

6.1.4 Parr Lake

Parr Lake is a relatively large but shallow lake. It has a mean depth of 3.2 m and a flushing rate of about 23 times per year. Its major inlet, the Carleton River, is located in its northwestern corner. It also has two smaller inlets, Salmon Lake Brook located in its northeastern corner which drains Grass and Salmon Lakes lying to the northwest, and one small inlet stream located along the middle of its eastern shoreline. Its only outlet is located in the lake's southwest corner and discharges into nearby Ogden Lake via Robichauds Run. Fig. 6.17 shows the locations of the water quality stations surveyed.

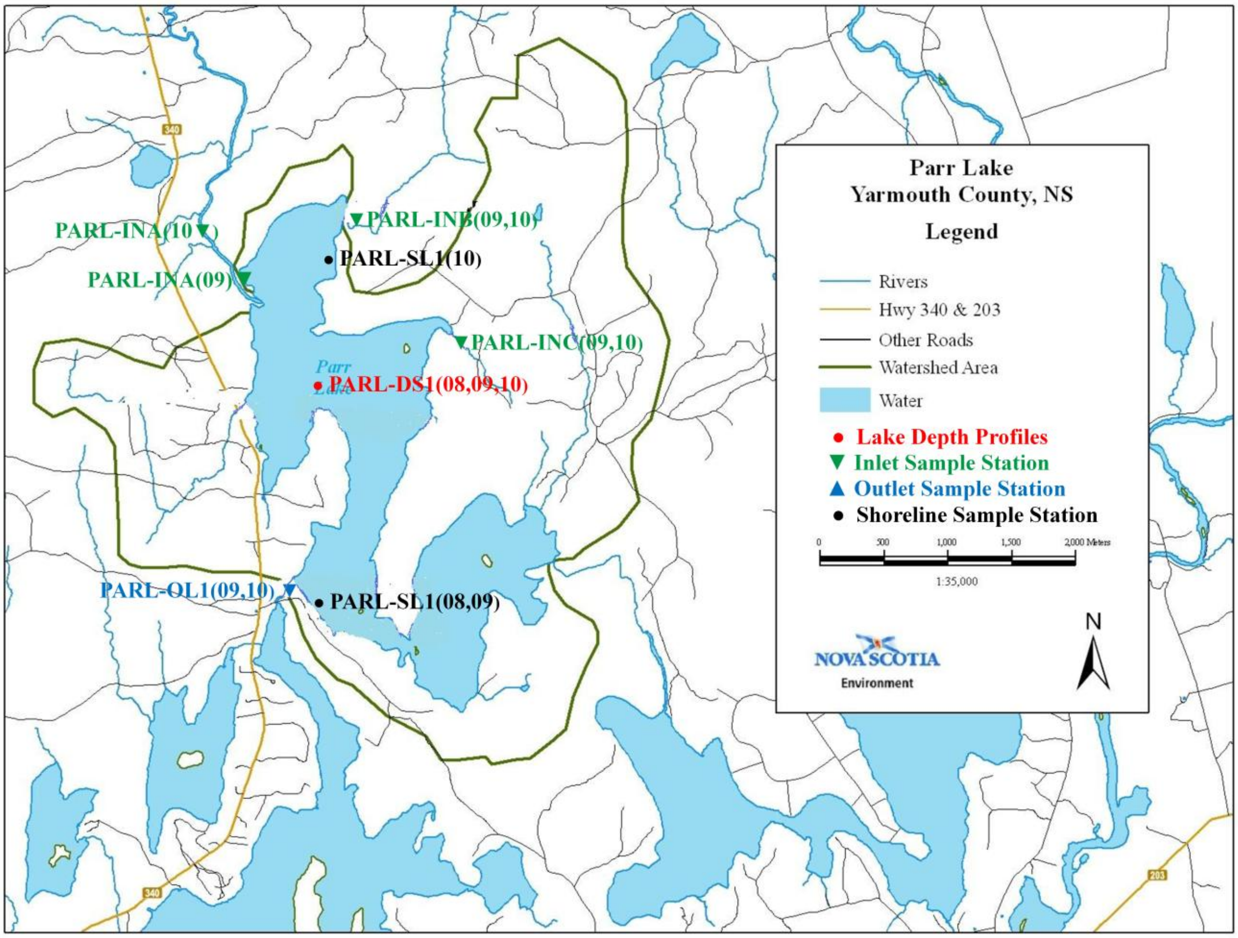

Fig. 6.17 Location of Parr Lake water quality sampling stations (numbers in parentheses represent years in which the station was sampled).

Temperature and dissolved oxygen profiles collected at the deep lake station show that it does not stratify (Fig. 6.18).

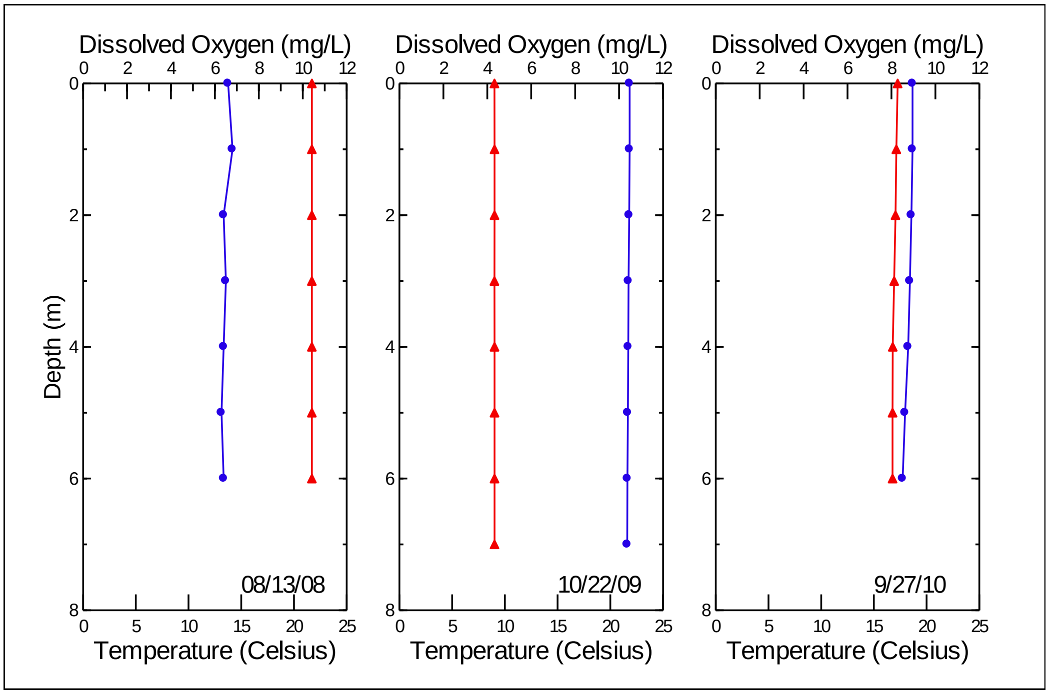

Fig. 6.18 Water column temperature (▲) and dissolved oxygen (●) profiles for Parr Lake during each survey year.

Total phosphorus concentrations (Fig. 6.19) at the deep lake station were within the upper oligotropic level during a survey carried out in 1986. In 2008 and 2010 they were withn the mesotrophic level. In 2009, however, they were near the the hyper-eutropic category.

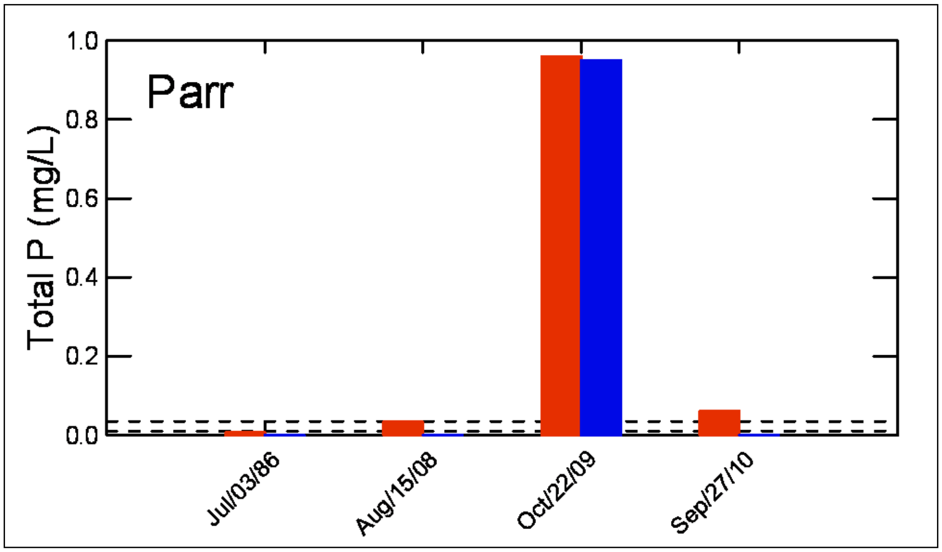

Fig. 6.19 Total phosphorous concentrations in surface (red) and bottom waters (blue) of Parr Lake (dashed lines represent divisions between trophic categories).

Total phosphorus levels at the main inlet from the Carleton River (PARL-INA) were very high during 2010 (Fig. 6.20). They were also high at one of the smaller inputs (PARL-INC) during 2010. The remaining inlets had relatively low total phosphorus levels.

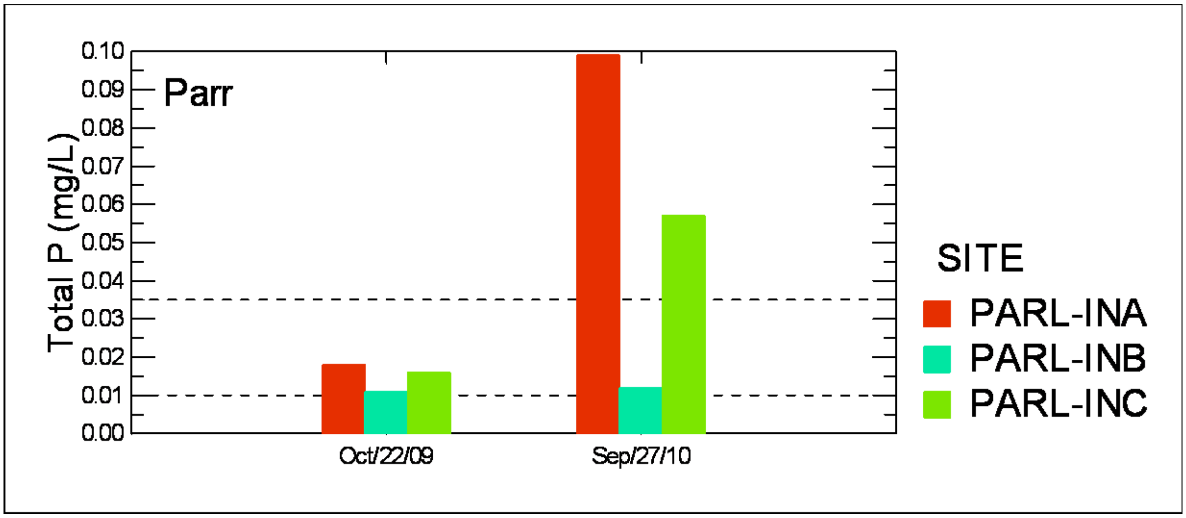

Fig. 6.20 Total phosphorous concentrations at the inlets of Parr Lake (dashed lines represent divisions between trophic categories).

Total phosphorus levels at the outlet of Parr Lake (Fig. 6.21), which drains into Ogden Lake, were well within the eutrophic range during both 2009 and 2010.

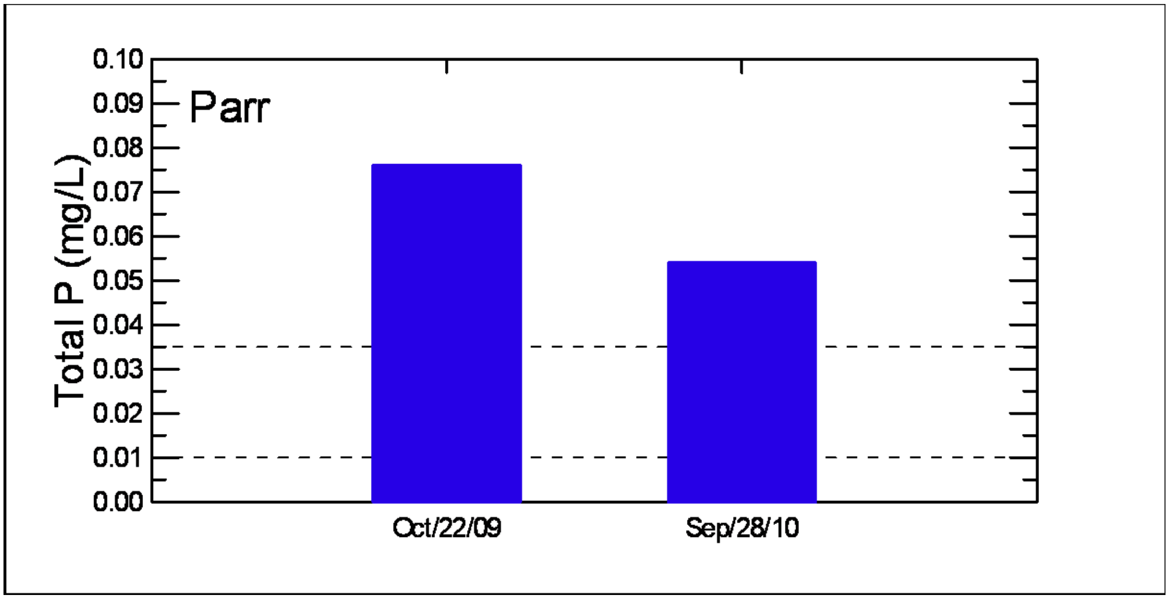

Fig. 6.21 Total phosphorous concentrations at the outlet of Parr Lake (dashed lines represent divisions between trophic categories).

Since phosphorus input levels were much lower in 2009 than 2010, it is difficult to explain the higher lake and output phosphorus levels observed in 2009.

Chlorophyll *a* levels in Parr Lake were within the low eutrophic range in 2008 and 2010 and within the ultra-oligotrophic range in 2009 (Fig. 6.22) despite the extremely high phosphorus concentrations observed in that year. The low levels observed during 2009 may be a result of the low Secchi Disk depth resulting from the particularly high color observed in that year. A survey carried out in 1983 also recorded very high chlorophyll *a* levels, but this is difficult to explain as total phosphorus were very low.

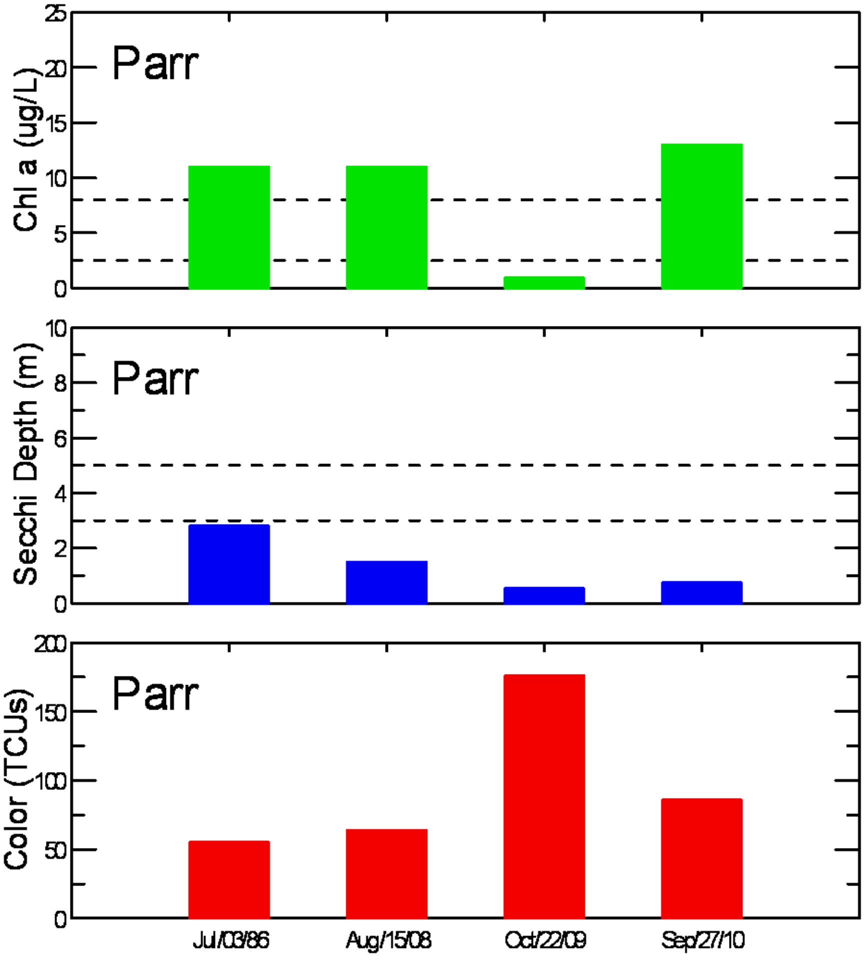

Fig. 6.22 Chlorophyll *a* concentration, Secchi Disk depth and color for Parr Lake (dashed lines represent divisions between trophic categories).

The results of the shoreline water quality samples (Table 6.6) for Parr Lake indicate that all health related guidelines parameters were within acceptable limits. The Secchi Disk depth guideline for water clarity, however, was below the guideline in 2009 and 2010.

Table 6.6 Summary of results for recreational use guidelines for Parr Lake.

Parameter	Guideline	2008	2009	2010
E. coli	< 200/100ml	-	1	2
Secchi Depth	> 1.2 m	1.5	0.53	0.75
pH	5.0 -9.0	6.2	5.4	6.2
Turbidity	< 50 NTUs	1.38	1.19	1.88
Blue-green algae	< 100,000 cells/ml	2220	267	102
Microcystin-LR	< 20	<0.20	<0.20	<0.20

6.1.5 Ogden Lake

Ogden Lake is a relatively large deep lake. Its mean depth is 4.4 meters and its flushing rate is 21.4 times per year. It has one major inlet and one major outlet. The inlet is located at its northern tip and receives its input from Ogden Lake to which it is connected by a narrow channel. Its outlet is located along its western shoreline and flows into a small pond prior to entering Rounding Lake. The water quality sampling stations are shown in Fig. 6.23.

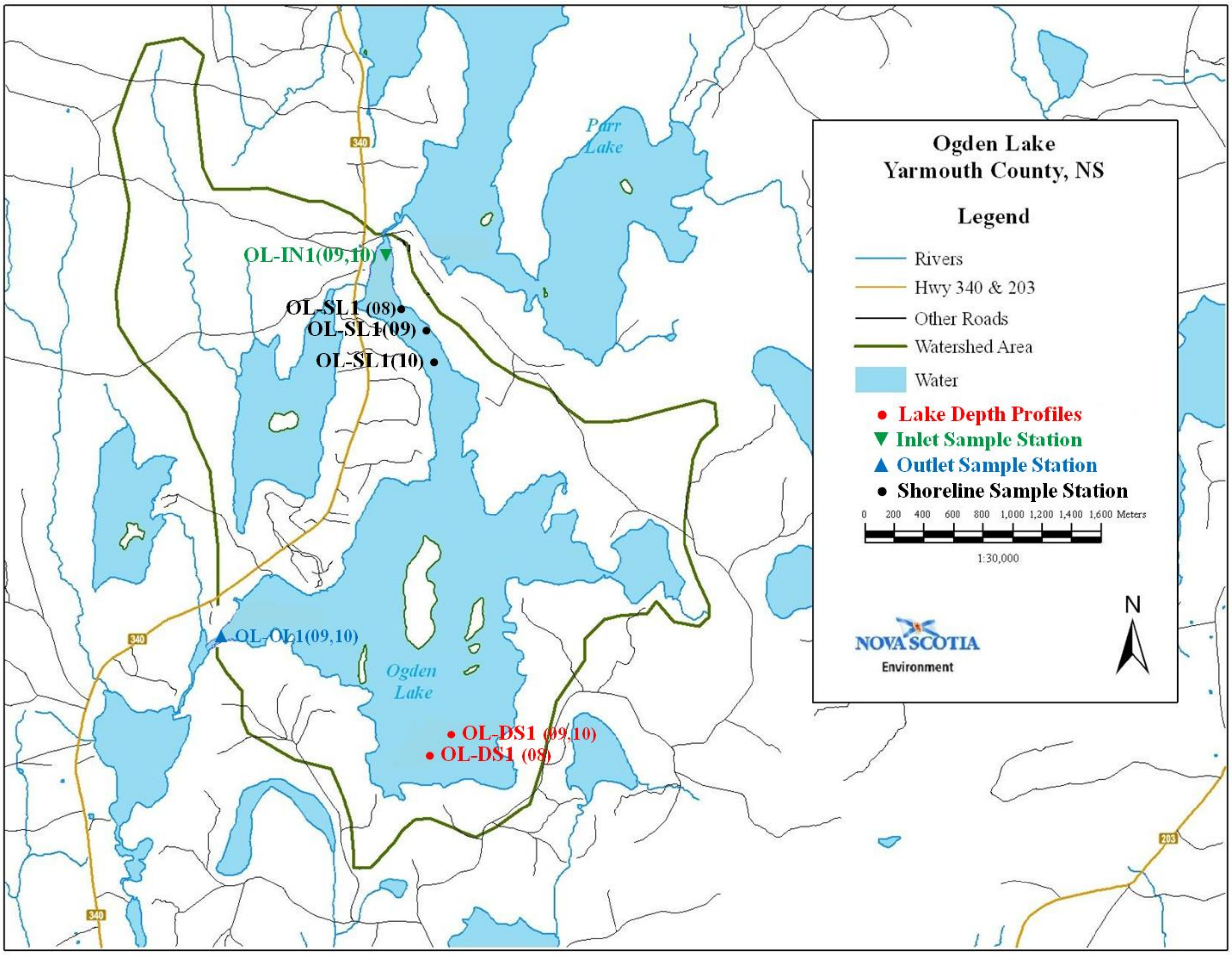

Fig. 6.23 Location of Ogden Lake water quality sampling stations (numbers in parentheses represent years in which the station was sampled).

Temperature and dissolved oxygen profiles taken during the summer (Fig. 6.24) show that the lake stratifies with a thermocline beginning at about 6 meters depth and the development of hypoxic conditions just below the surface of the thermocline.

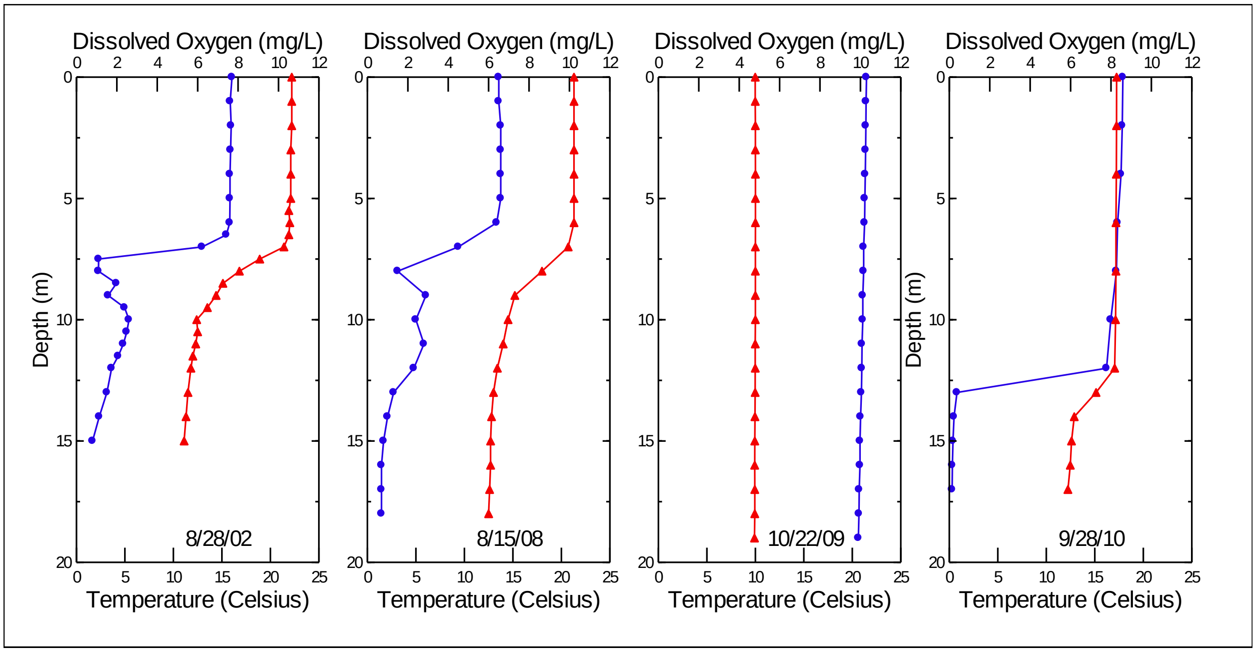

Fig. 6.24 Water column temperature (▲) and dissolved oxygen (●) profiles for Ogden Lake during each survey year.

Total phosphorus levels within surface waters during the summer (Fig. 6.25) were mostly within the mesotrophic range, but levels within the hypolimnion were very high and well into the eutrophic level. The highest concentrations were observed in the fall of 2010 and are most likely the result the mixing of surface and bottom water as a result of the fall overturn. Earlier surveys carried out in 1986 and 2002 show that this lake was not receiving very high phosphorus inputs at that time.

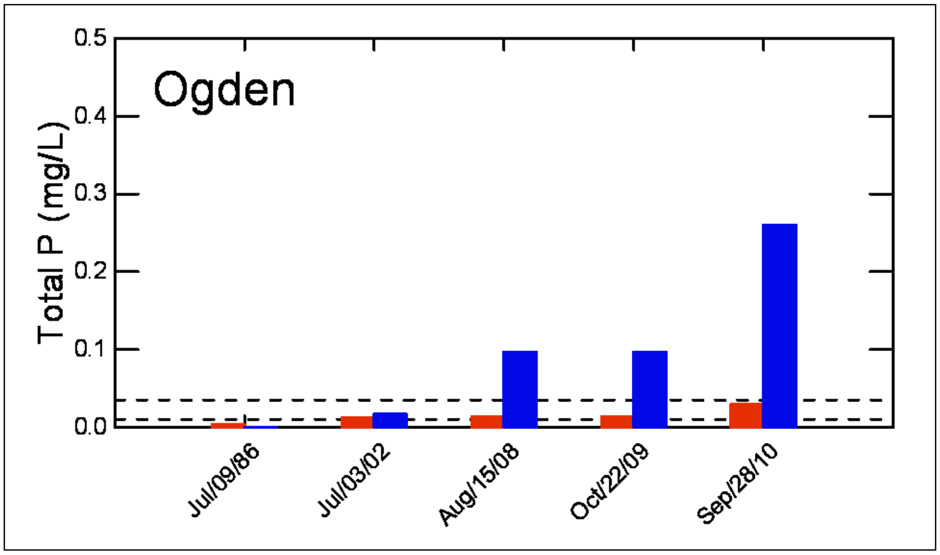

Fig. 6.25 Total phosphorous concentrations in surface (red) and bottom waters (blue) of Ogden Lake (dashed lines represent divisions between trophic categories).

Total phosphorus concentrations measured at the inlet and outlet in 2009 and 2010 (Fig 6.26) were also high. Inlet concentrations were higher than at the outlet indicating that phosphorus is likely to be accumulating within the lake.

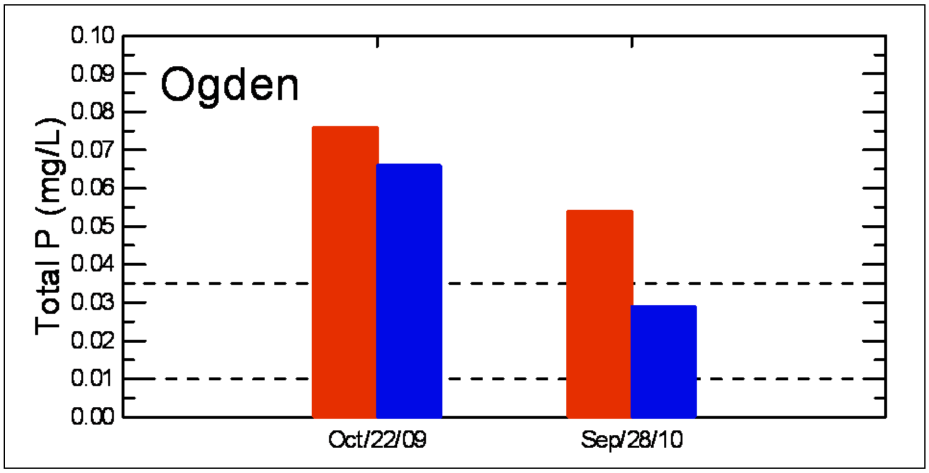

Fig. 6.26 Total phosphorous concentrations at the inlet (red) and (outlet) of Ogden Lake (dashed lines represent divisions between trophic categories).

Chlorophyll *a* levels for Ogden Lake followed the same pattern as for most other lakes with eutrophic levels in 2008 and 2010 and a lower level in 2009. In this case 2009 levels fell within the low oligotrophic level. Earlier surveys carried out in 1986 and 2002 had chlorophyll *a* levels within the oligotrophic range. Secchi Disk depths fall mostly within the eutrophic category, but this is a result of the high color of this lake.

The results of the shoreline water quality samples (Table 6.7) for Ogden Lake indicate that all health related parameters were within acceptable limits. Secchi Disk depth, however, was below the aesthetic guideline for water quality in 2009 and 2010.

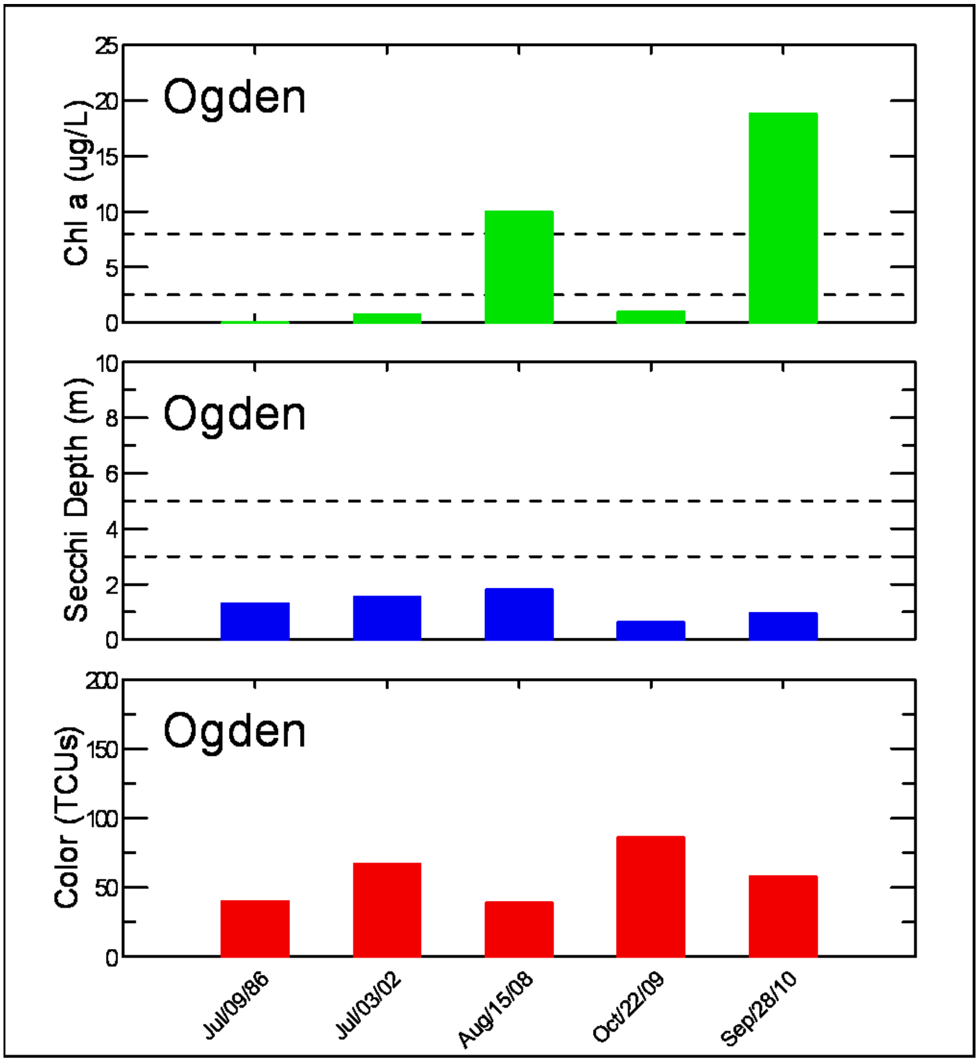

Fig. 6.27 Chlorophyll *a* concentration, Secchi Disk depth and color for Ogden Lake (dashed lines represent divisions between trophic categories).

Table 6.7 Summary of results for recreational use guidelines for Ogden Lake.

Parameter	Guideline	2008	2009	2010
E. coli	< 200/100ml	-	3	2
Secchi Depth	> 1.2 m	1.8	0.63	0.95
pH	5.0 -9.0	6.1	5.8	6.3
Turbidity	< 50 NTUs	1.28	1.11	4.2
Blue-green algae	< 100,000 cells/ml	1210	195	2480
Microcystin-LR	< 20	<0.20	<0.20	<0.20

6.1.6 Fanning Lake

Fanning Lake is a large lake with a mean depth of 4.4 meters and a flushing rate of 57 times per year, the highest of all the lakes surveyed. Its major inlet is the Carleton River. Two smaller inlets enter along its northeastern shoreline, the most northern of which drains Lower Cranberry Lake and the other drains Mink Lake. Its only outlet is located in the lake's southwest corner where it re-enters the Carleton River system. Fig. 6.28 shows the location of each water quality sampling station.

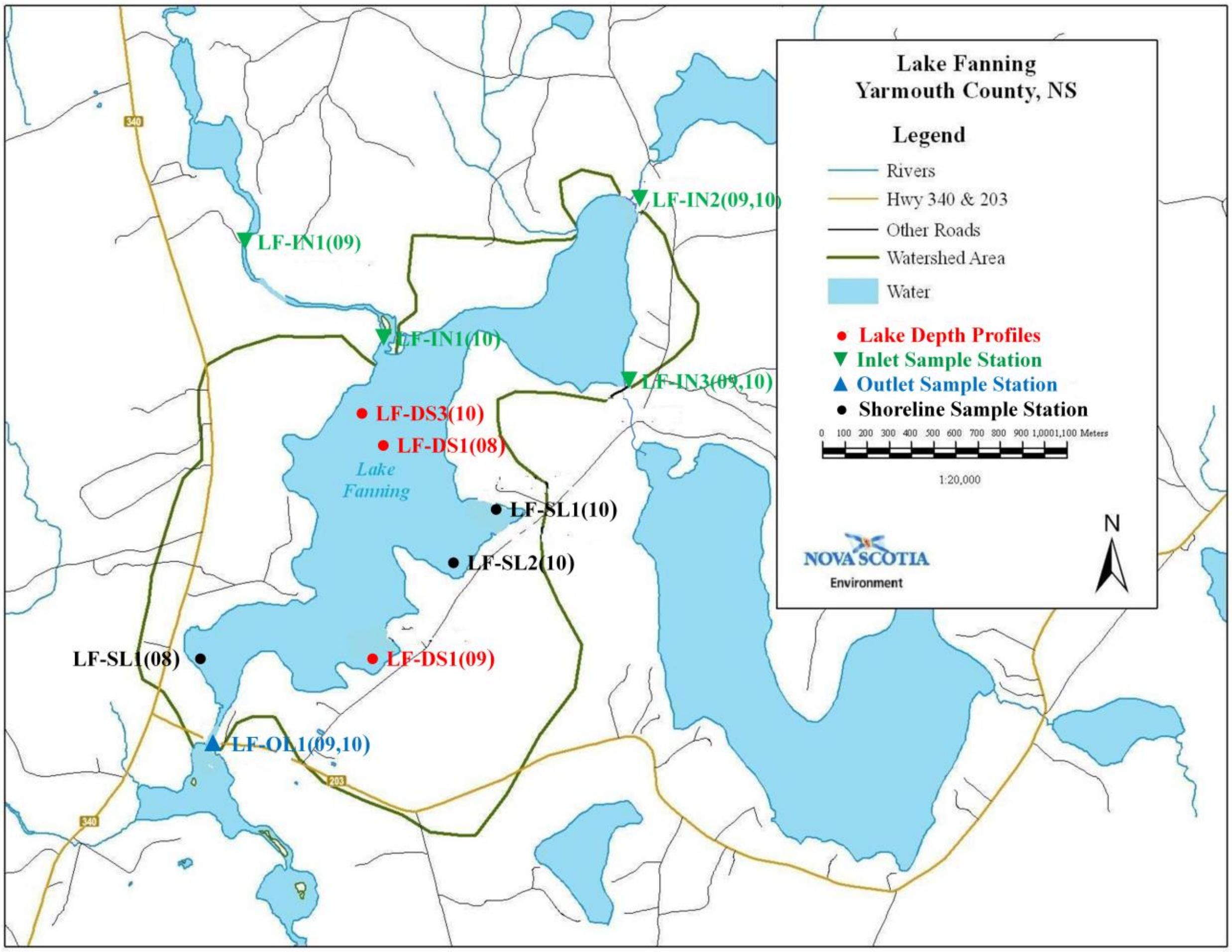

Fig. 6.28 Location of Lake Fanning water quality sampling stations (numbers in parentheses represent years in which the station was sampled).

Water temperature and dissolved oxygen profiles taken during summer show that Fanning Lake stratifies with a relatively weak thermocline beginning at about six meters and that, despite the weak thermocline, its bottom waters become anoxic a short distance below the beginning of the thermocline (Fig. 6.29).

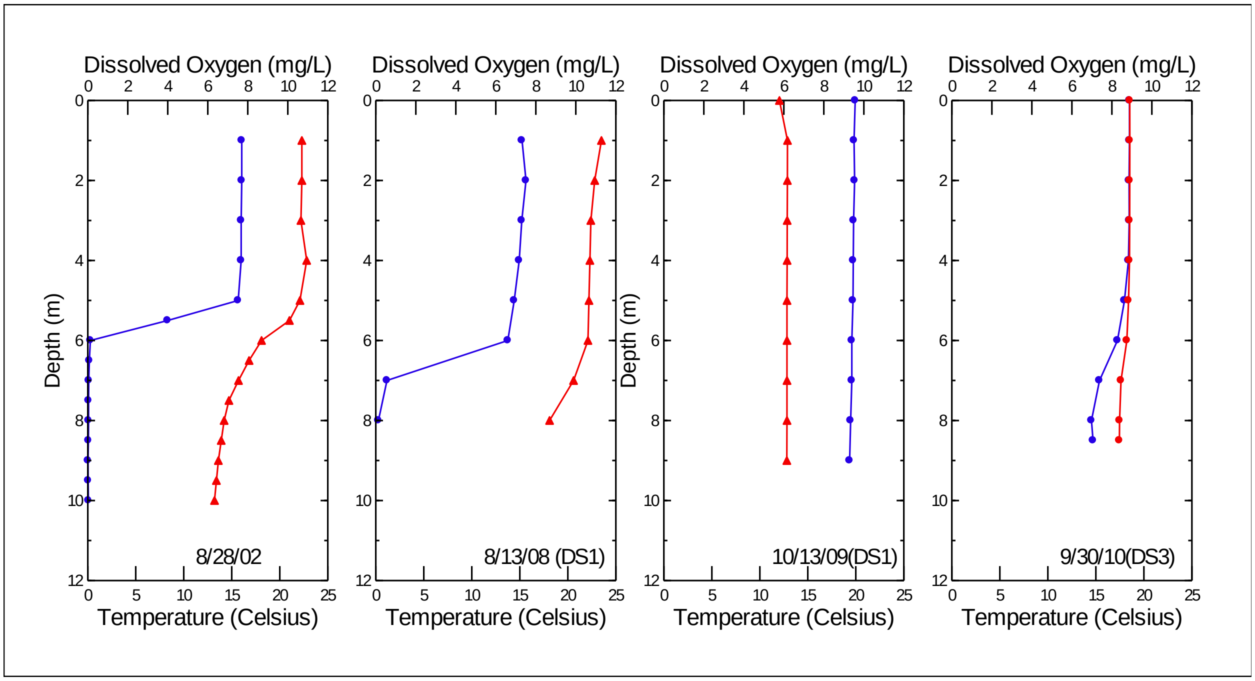

Fig. 6.29 Water column temperature (▲) and dissolved oxygen (●) profiles for Fanning Lake during each survey year.

Surveys carried out prior to 2008 showed total phosphorus concentrations to be within the oligotrophic to lower mesotrophic range (Fig. 6.30). The surveys carried in 2008 and 2009 show much higher concentrations. In 2008 the survey was carried out while the lake was stratified and most of the phosphorus is within the bottom waters. During 2009 the survey was carried after fall overturn and surface water had about the same level of phosphorus as the bottom water. In 2010 the survey was also carried out after fall overturn, but phosphorus levels were much lower than in the two previous years. The very low phosphorus level reported in a survey carried out in 1986 indicates that phosphorus input to Lake Fanning was likely much lower in the past.

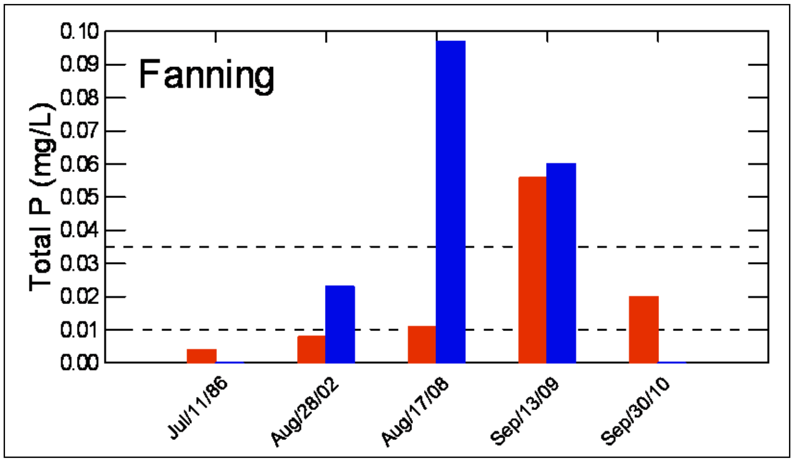

Fig. 6.30 Total phosphorous concentrations in surface (red) and bottom waters (blue) of Fanning Lake (dashed lines represent divisions between trophic categories).

Of the three inlets, the Carleton River inlet (FL-IN1) had the highest phosphorus levels (Fig. 6.31) which were notably less in 2009 than in 2010 making it difficult to explain the lower lake phosphorus levels in 2010.

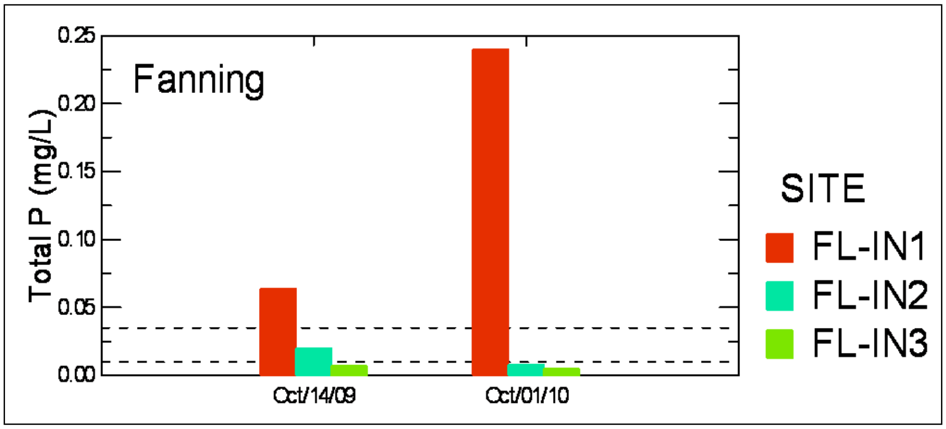

Fig. 6.31 Total phosphorous concentrations at the inlets of Fanning Lake (dashed lines represent divisions between trophic categories).

Total phosphorus levels at the output (Fig. 6.32) of Fanning Lake were much greater in 2009 than in 2010.

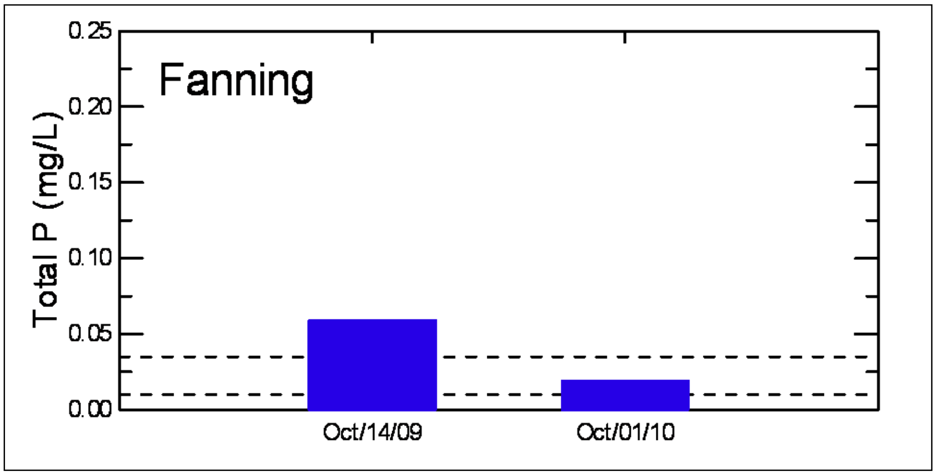

Fig. 6.32 Total phosphorous concentrations at the outlet of Fanning Lake (dashed lines represent divisions between trophic categories).

Chlorophyll *a* concentrations fell within the mesotrophic category in 2008, the oligotrophic category in 2009 and the eutrophic category in 2010 (Fig.6.33). An earlier survey in 1986 recorded very low levels that were in the ultra-oligotrophic category. Another survey in 2002 showed levels in the high oligotrophic and lower mesotrophic categories. Overall, there appears to be a distinct trend of increasing chlorophyll *a* levels with time. Secchi Disk depths were mostly within the eutrophic category, but are closely correlated with color as opposed to chlorophyll *a*.

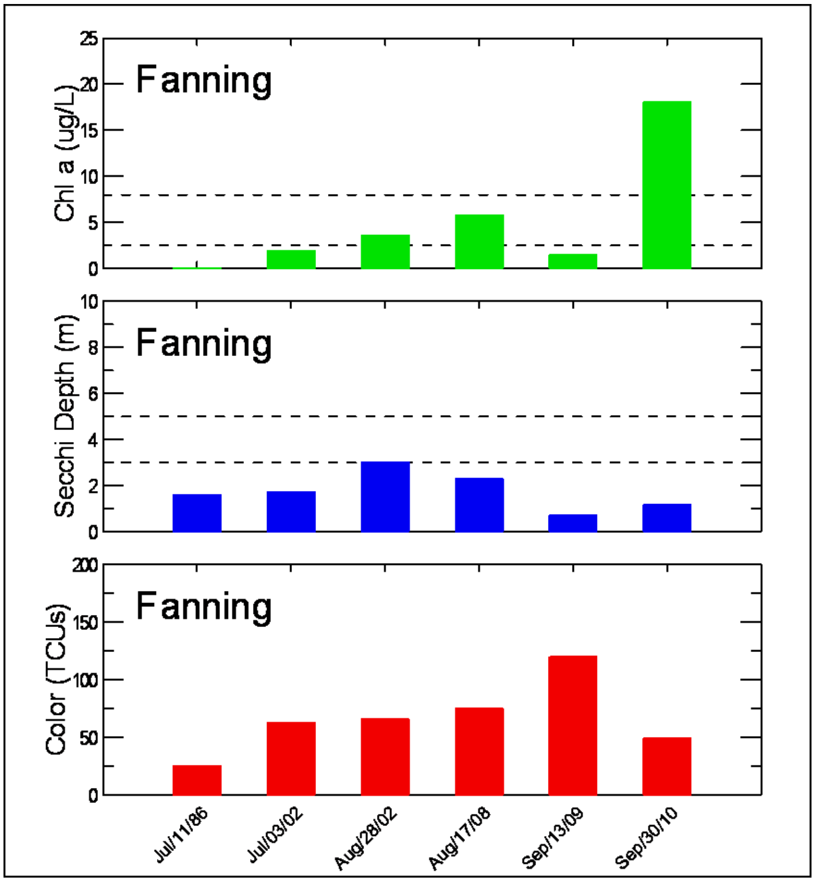

Fig. 6.33 Chlorophyll *a* concentration, Secchi Disk depth and color for Fanning Lake (dashed lines represent divisions between trophic categories).

The results of the shoreline water quality samples (Table 6.8) indicate all parameters were within acceptable limits except for low a Secchi Disk depth in 2009.

Table 6.8 Summary of results for recreational use guidelines for Fanning Lake.

Parameter	Guideline	2008	2009	2010
E. coli	< 200/100ml	-	3	2
Secchi Depth	> 1.2 m	2.3	0.7	1.2
pH	5.0 -9.0	6.4	5.9	6.4
Turbidity	< 50 NTUs	0.85	1.23	2.82
Blue-green algae	< 100,000 cells/ml	128, 5160	5	7340, 1400
Microcystin-LR	< 20	<0.20, <0.20	<0.20	<0.20

6.1.7 Sloans Lake

Sloans Lake is an intermediate sized, deep lake that lies below Fanning Lake and to the east of Raynards Lake. Its mean depth is 6.7 meters and its flushing rate is 0.7 times per year, the lowest of all the lakes surveyed. It contains two basins separated by a narrow channel. The northern basin has a maximum depth of 22 meters and the southern basin has a maximum depth of 15 meters. It has no distinct input. Its output lies along its southern shoreline and drains into Raynards Lake. This lake was not surveyed in 2008, but was surveyed three times during 2009 in order to obtain a comprehensive database on its water quality prior to a proposed development within its watershed. Fig. 6.34 shows the location of each water quality sampling station.

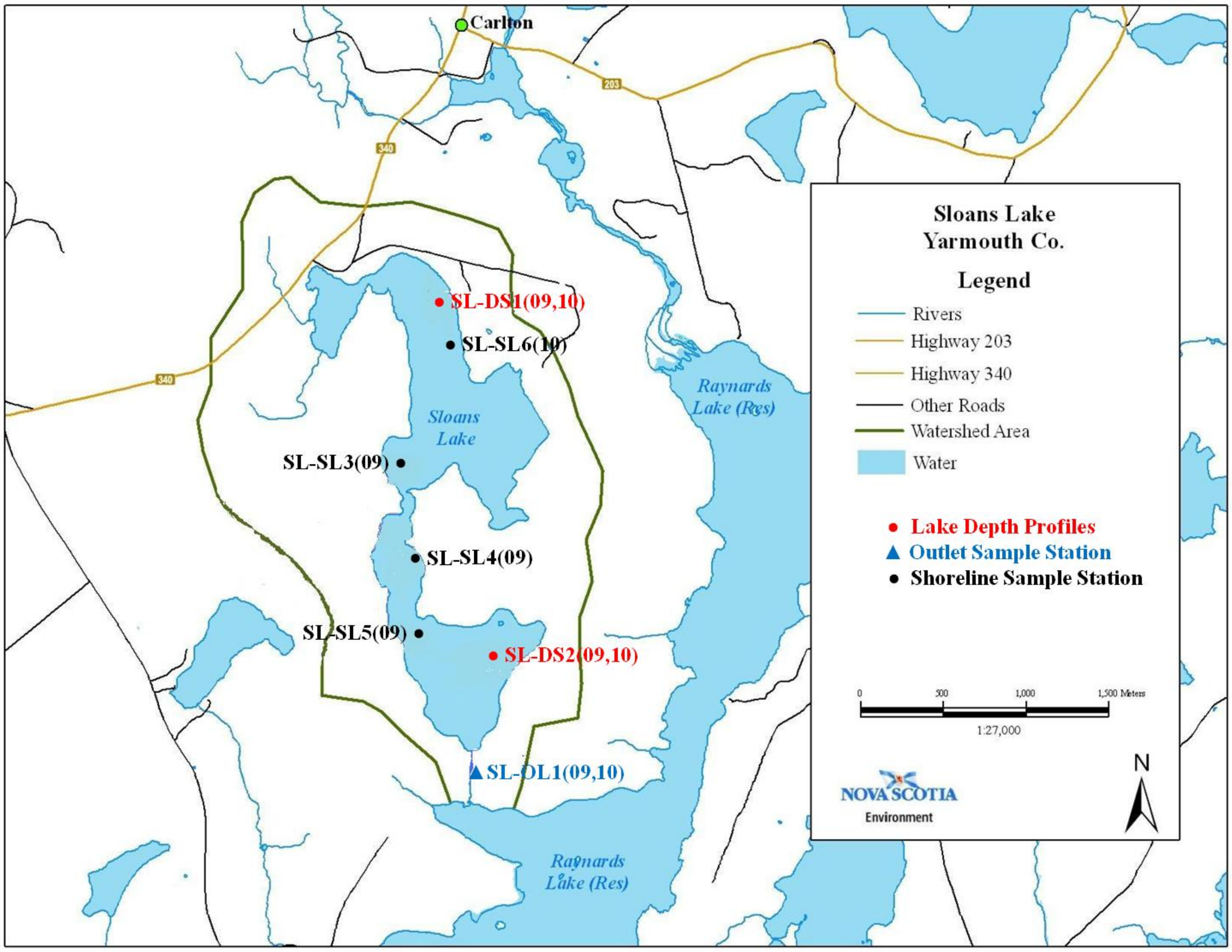

Fig. 6.34 Location of Sloans Lake water quality sampling stations (numbers in parentheses represent years in which the station was sampled).

Water temperature and dissolved oxygen depth profiles (Fig 6.35) show that this lake stratifies during the summer with a thermocline beginning at about 6 meters depth and hypoxic conditions beginning shortly below the top of the thermocline.

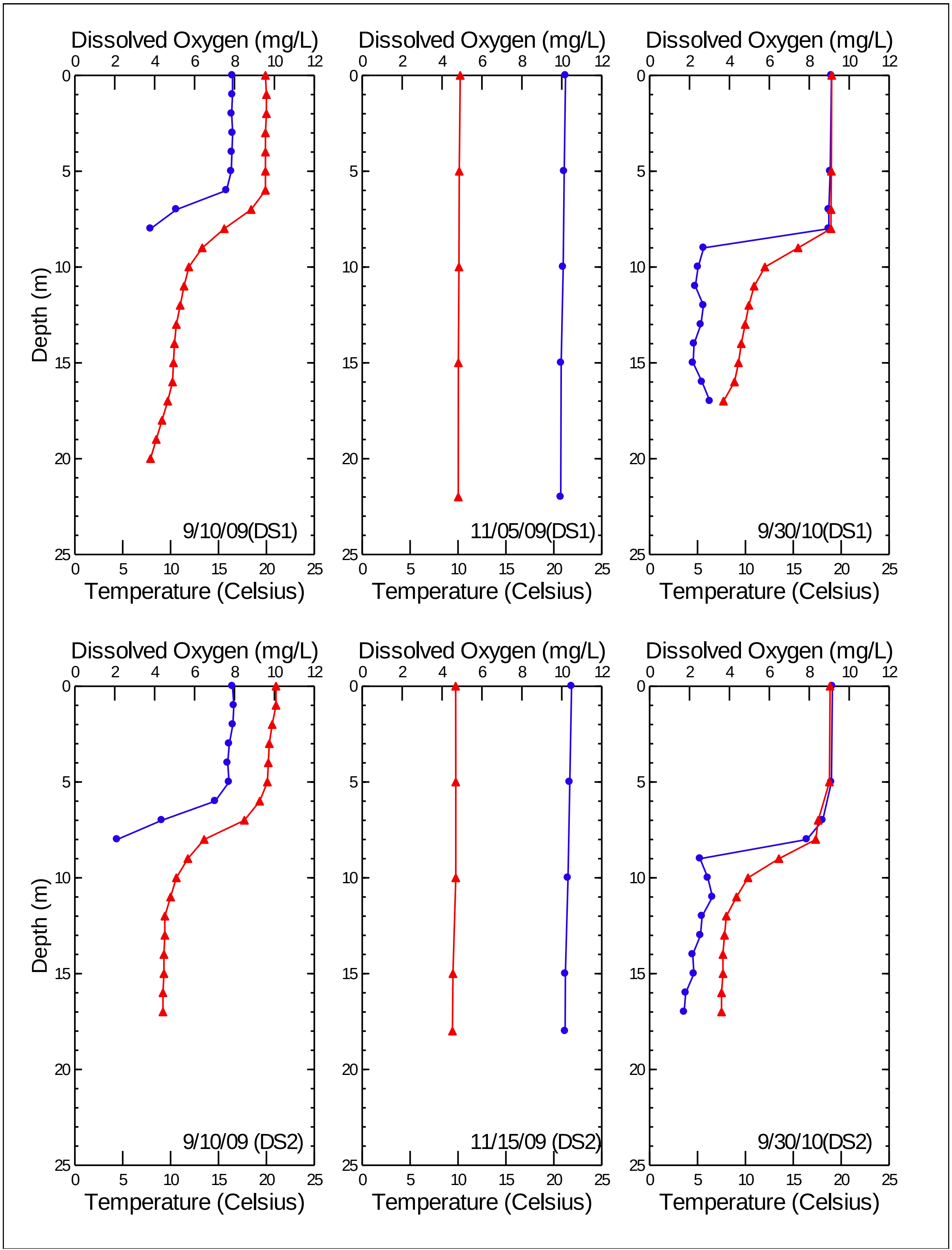

Fig. 6.35 Water column temperature (▲) and dissolved oxygen (●) profiles for Sloans Lake during each survey year.

Both surface and bottom water total phosphorus concentrations at the deep lake stations within the northern basin were mostly within the oligotrophic category (Fig. 6.36). Within the southern basin total phosphorus levels were even lower and all were within the oligotrophic category. Total phosphorus levels were also very low at the outlet (Fig. 6.37).

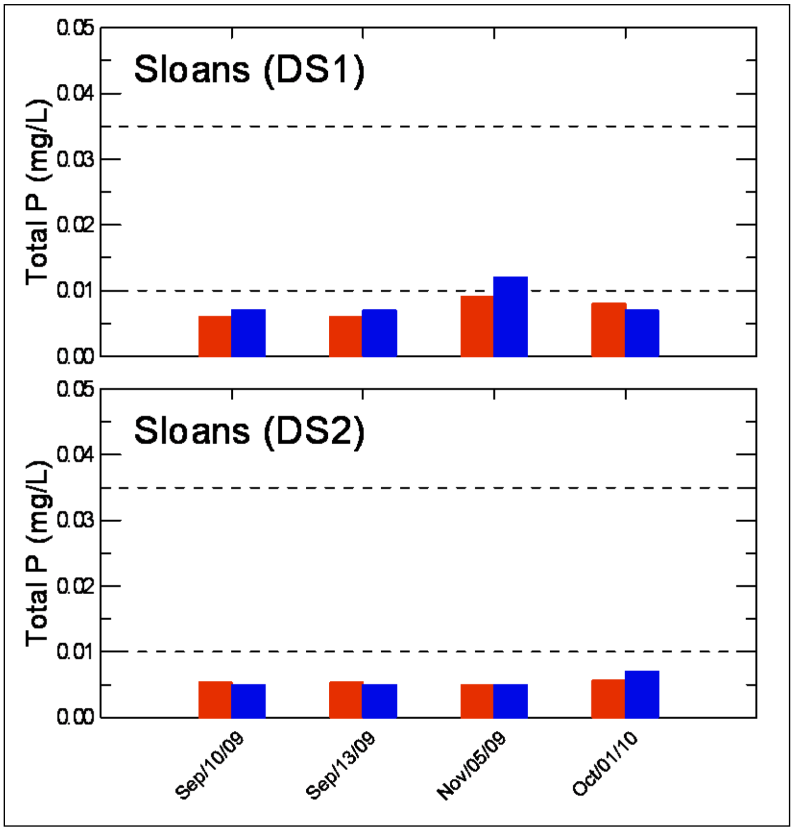

Fig. 6.36 Total phosphorous concentrations in surface (red) and bottom waters (blue) of Sloans Lake (dashed lines represent divisions between trophic categories).

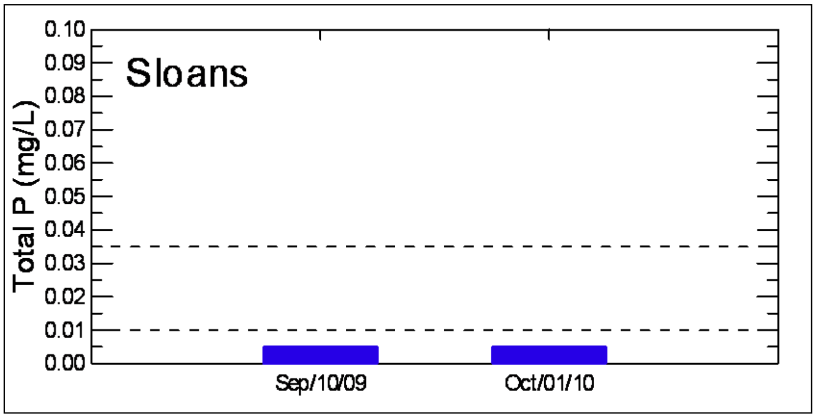

Fig.6.37 Total phosphorous concentrations at the outlet of Sloans Lake (dashed lines represent divisions between trophic categories).

Chlorophyll *a* levels were very low and well within oligotrophic levels (Fig. 6.38). Secchi Disk depths, however, were mostly within the mesotrophic category or lower oligotrophic category. The results of earlier surveys by NSDL&F and NSDNR (Eaton and Boates 2003) show that Sloans Lake's water quality has changed very little since 1986.

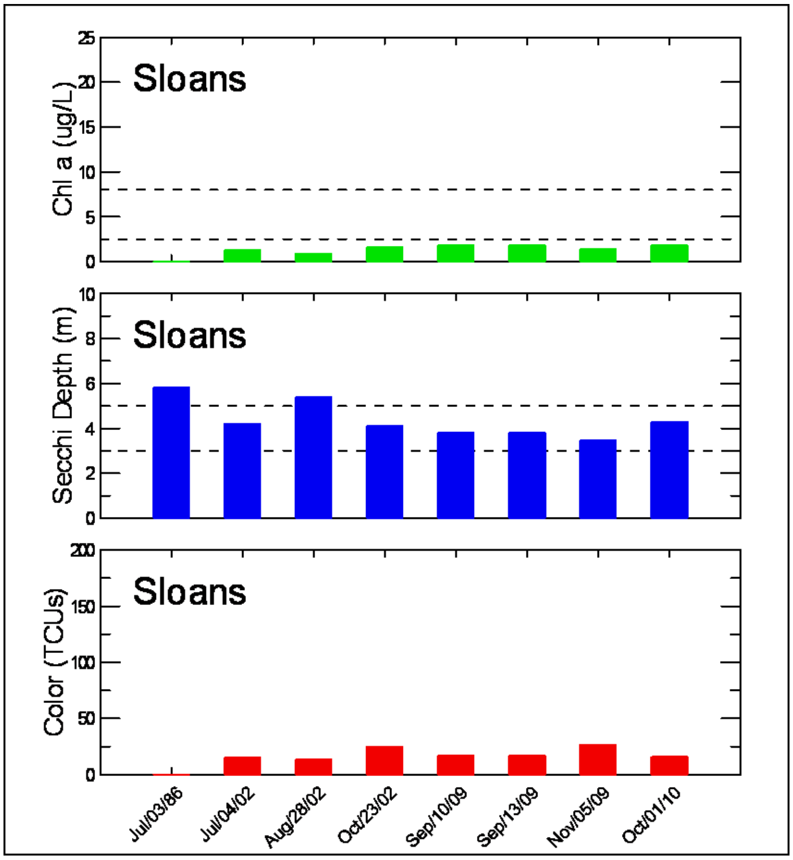

Fig. 6.38 Chlorophyll *a* concentration, Secchi Disk depth and color for Sloans Lake (dashed lines represent divisions between trophic categories).

The results of the water quality assessments of Sloans Lake for recreational use (Table 6.9) indicate that all guidelines were met. This lake is the most pristine of all the lakes surveyed.

Table 6.9 Summary of results for recreational use guidelines for Sloans Lake.

Parameter	Guideline	2009	2010
E. coli	< 200/100ml	6	2
Secchi Depth	> 1.2 m	3.8	4.3
pH	5.0 -9.0	6.9	7.0
Turbidity	< 50 NTUs	0.42	0.32
Blue-green algae	< 100,000 cells/ml	3880, 5110, 2070, 30, 100, 216	24800, 57600, 16200, 12300
Microcystin-LR	< 20	<0.20, <0.20, <0.20 <0.20, <0.20, <0.20	<0.20, 0.34, <0.20, 0.66

6.1.8 Vaughan Lake

Lake Vaughan is a large moderately deep lake which is used as a reservoir for hydropower generation. Its mean depth is 5.1 meters and its flushing rate is 42.2 times per year, the second highest of all lakes surveyed. It has two inputs, one located in its northeastern corner which receives inputs from Raynards Lake, and another located along its mid-eastern shoreline which receives inputs from Gavels Lake. Its one outlet is located along its most southern shoreline where it flows into the Tusket River. Fig. 6.39 shows the location of each sampling station.

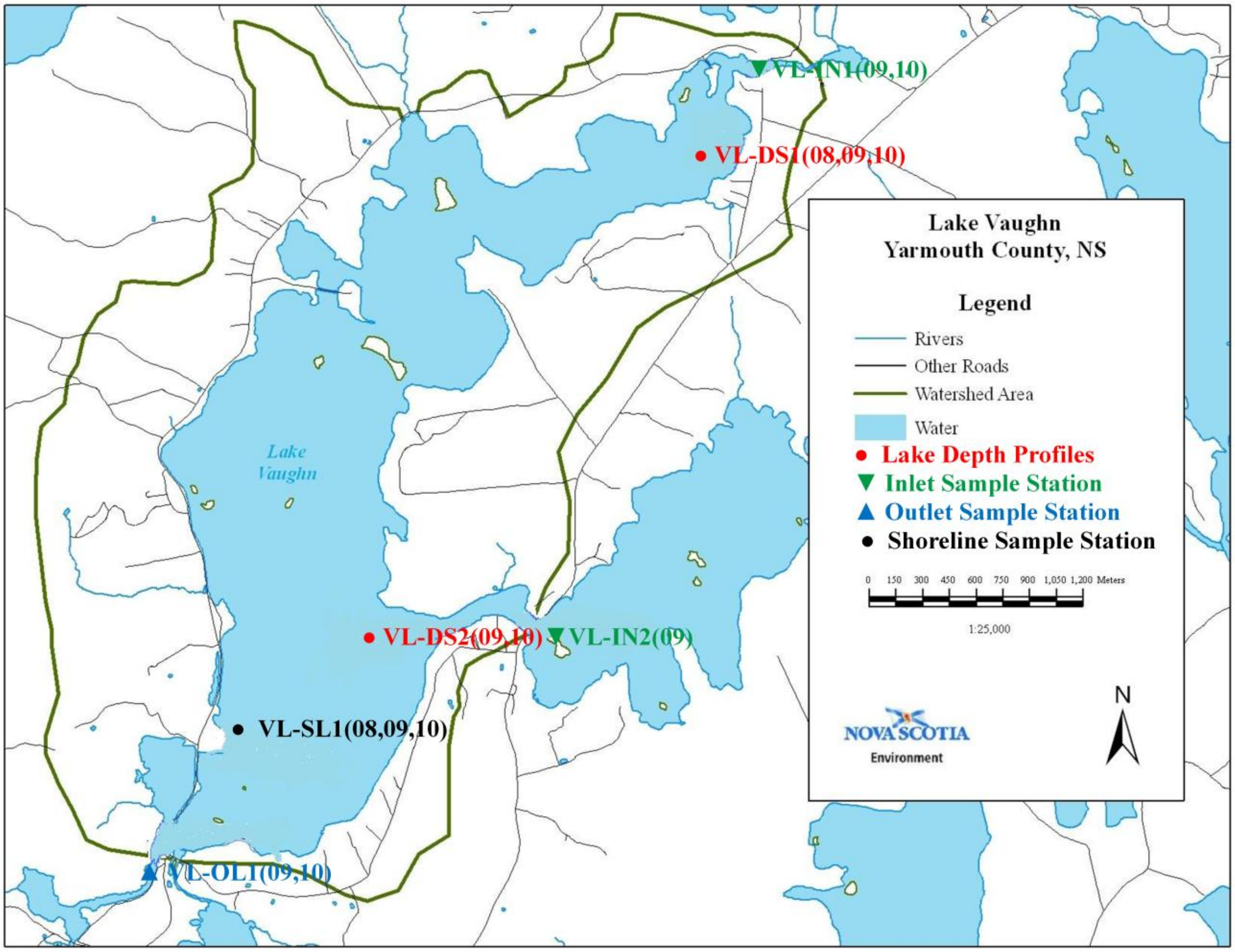

Fig. 6.39 Location of location of Vaughan Lake water quality sampling stations (numbers in parenthesis indicate year of sampling).

Water temperature and dissolved oxygen profiles (Fig.6.40) show that it stratifies during summer with a deep thermocline beginning at a depth of about nine meters. Dissolved oxygen levels decreased rapidly within one meter of the upper part of the thermocline to almost anoxic conditions.

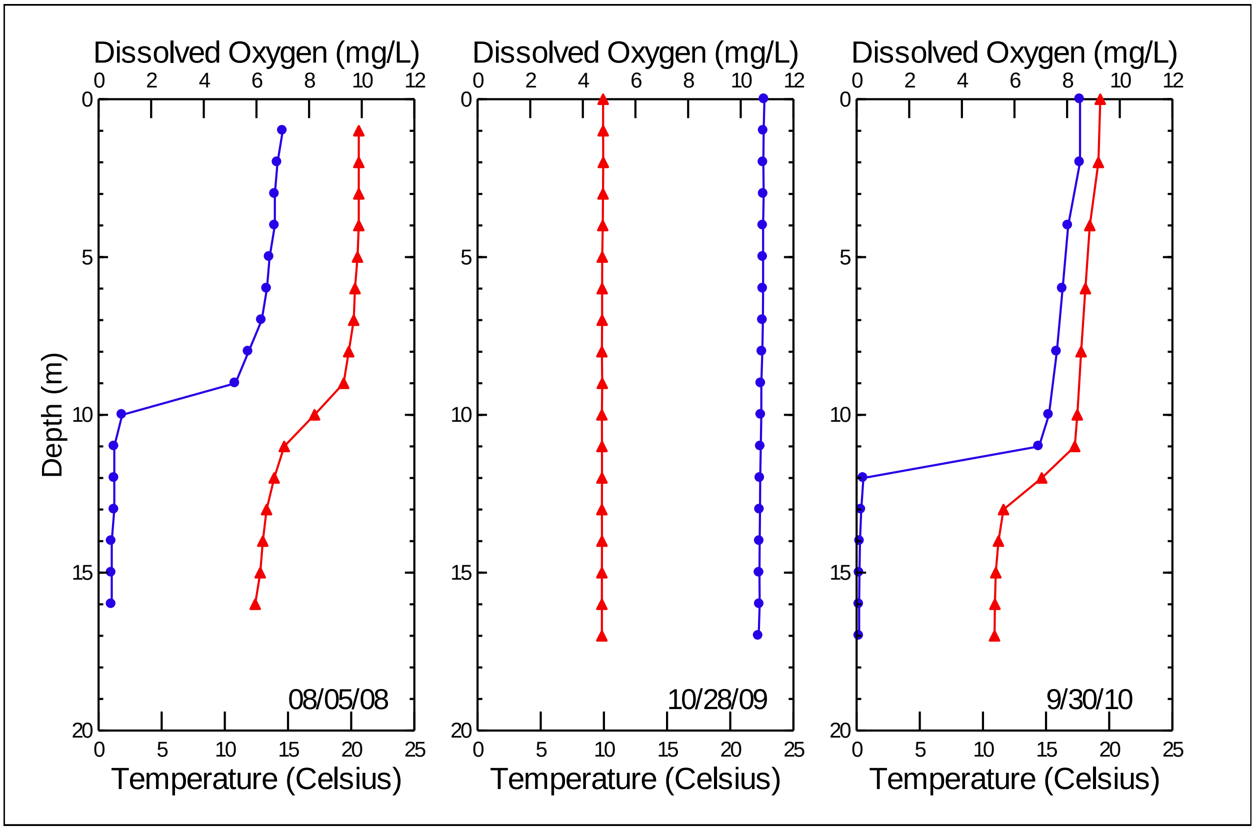

Fig. 6.40 Water column temperature (▲) and dissolved oxygen (●) profiles for Vaughan Lake during each survey year.

Total phosphorus concentration within the surface waters (Fig. 6.41) were in the oligotrophic range in 2008 and the mesotrophic range in 2009 and 2010. During all times surveyed, bottom water total phosphorus concentrations were higher than in surface waters, but less so in 2009 when the lake had completed its fall overturn. Overall there appears to be a trend of increasing phosphorus levels over the three years of the survey.

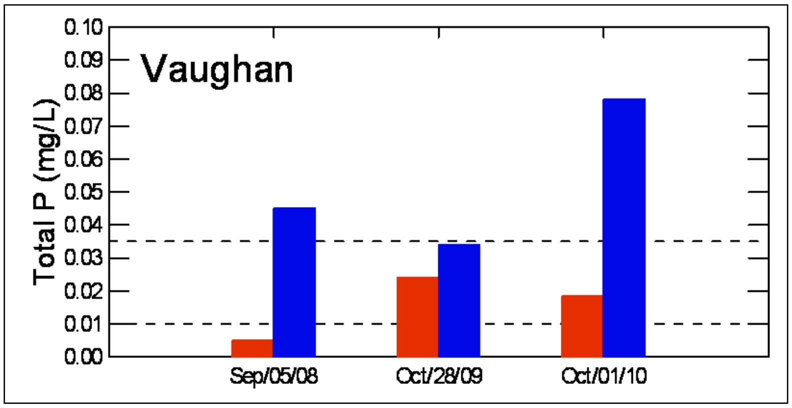

Fig. 6.41 Total phosphorous concentrations in surface (red) and bottom waters (blue) of Vaughan Lake (dashed lines represent divisions between trophic categories).

In 2009, total phosphorus concentrations at the input from Raynards Lake (VL-IN1) were within the upper mesotrophic level and about two times greater than levels at the input from Gavels Lake (Fig. 6.42). Phosphorus levels at the input from Raynards Lake were much less in 2010 and were within the lower mesotrophic level.

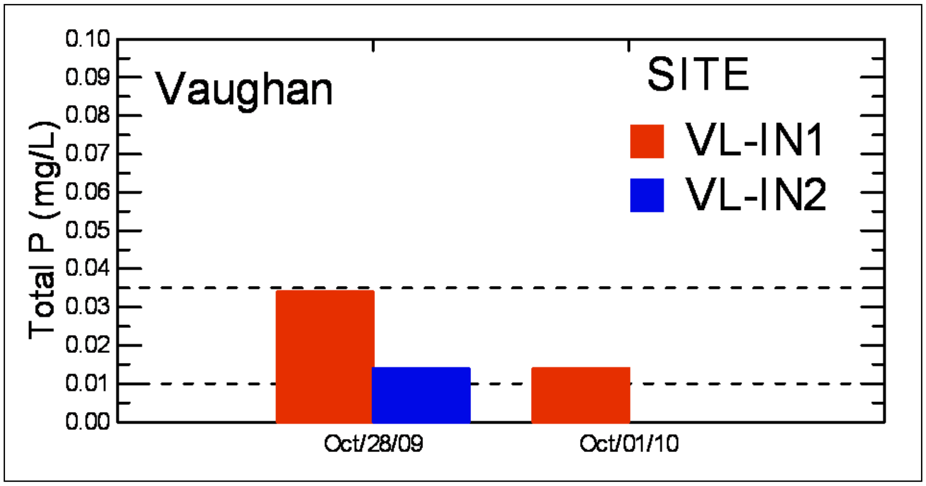

Fig. 6.42 Total phosphorous concentrations at the inlets of Vaughan Lake; the inlet from Gavels Lake was not sampled in 2010 (dashed lines represent divisions between trophic categories).

Phosphorus levels at the outlet (Fig. 6.43) were within the mid-mesotrophic range.

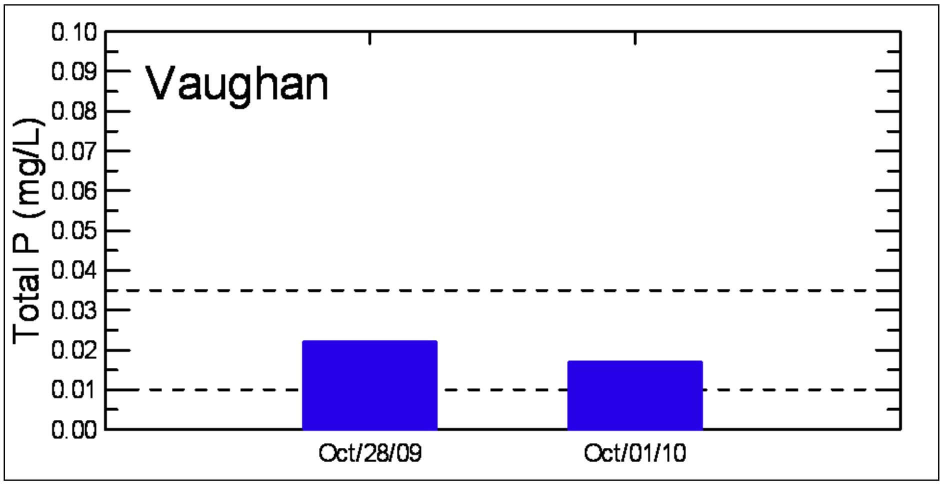

Fig. 6.43 Total phosphorous concentrations at the outlet of Vaughan Lake (dashed lines represent divisions between trophic categories).

Between 2008 and 2010 chlorophyll *a* levels in Vaughan Lake went from mesotrophic to ultra-oligotrophic then to oligotrophic (Fig. 6.44). An earlier study carried out in 1979 found chlorophyll *a* levels well within the ultra-oligotrophic range.

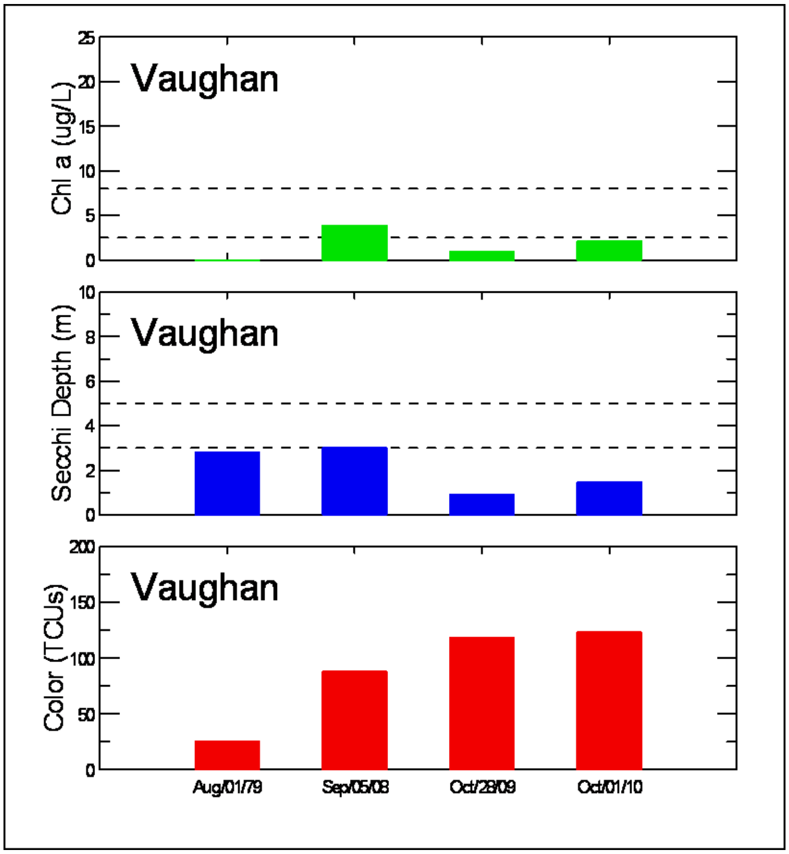

Fig. 6.44 Chlorophyll *a* concentration, Secchi Disk depth and color for Vaughan Lake (dashed lines represent divisions between trophic categories).

With the exception of a low Secchi Depth in 2009, Vaughan Lake met all of the guidelines for recreational water use in all years surveyed (Table 6.10).

Table 6.10 Summary of results for recreational use guidelines for Vaughan Lake.

Parameter	Guideline	2008	2009	2010
E. coli	< 200/100ml	-	5	122
Secchi Depth	> 1.2 m	3.0	0.9	1.2
pH	5.0 -9.0	6.3	6.2	6.2
Turbidity	< 50 NTUs	0.71	0.93	1.13
Blue-green algae	< 100,000 cells/ml	408	0	0, 26
Microcystin-LR	< 20	<0.20	<0.20	<0.20, <0.20

6.2 Sissaboo River Watershed

6.2.1 Provost Lake

Provost Lake is a small shallow headwater lake located within the southern area of the Sissaboo Watershed. It has a mean depth of 3.1 meters and a flushing rate of 3.9 times per year. It has no distinct inputs. Its outlet is located within its northeastern corner and drains into the Sissaboo River. Fig. 6.45 shows the location of each water quality sampling station.

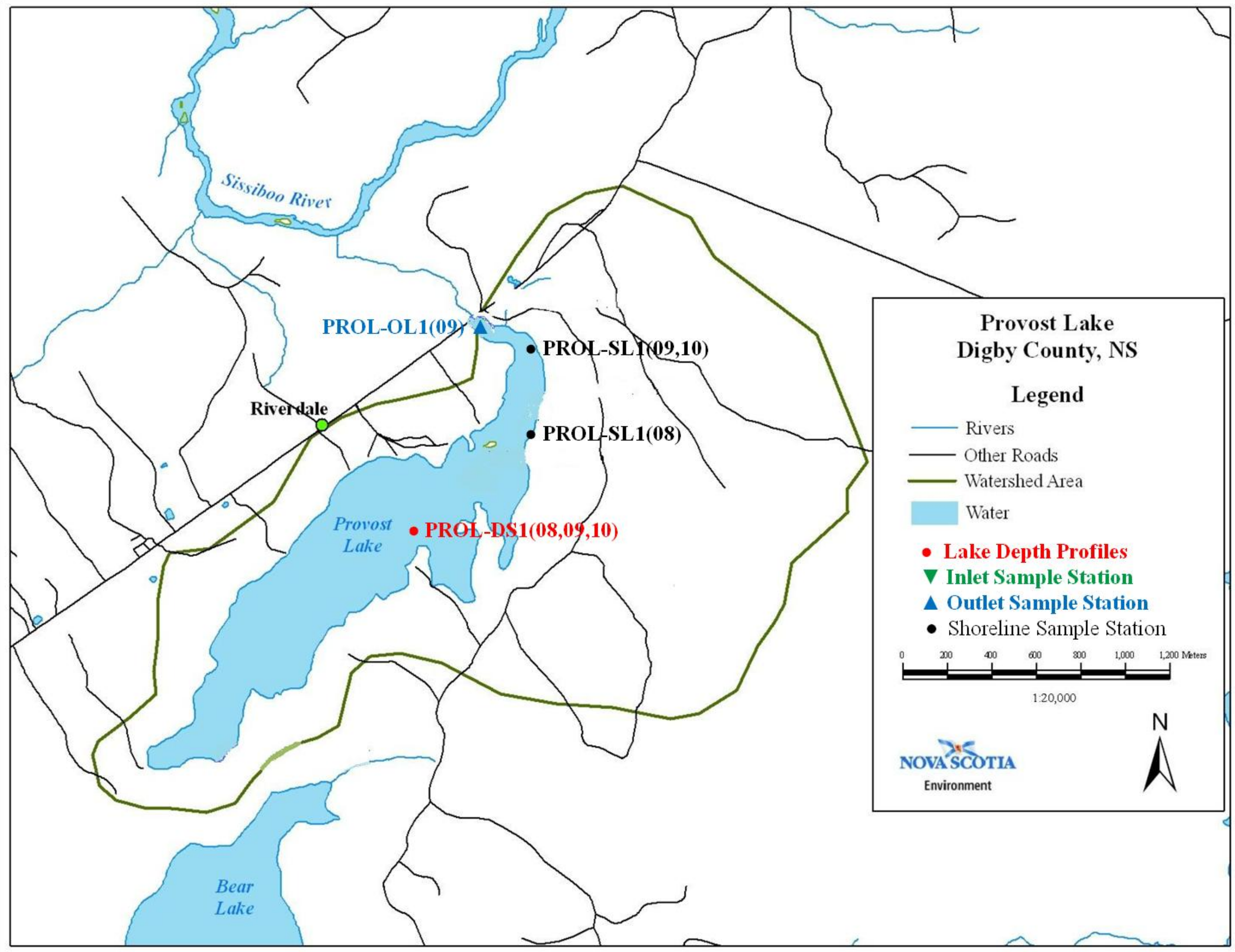

Fig. 6.45 Location of Provost Lake water quality sampling stations (numbers in parentheses represent years in which the station was sampled).

Provost Lake does not appear to undergo water column stratification (Fig. 6.46). The lower dissolved oxygen levels measured during the summer survey carried out in 2008 are a result of the warmer water temperatures during the summer.

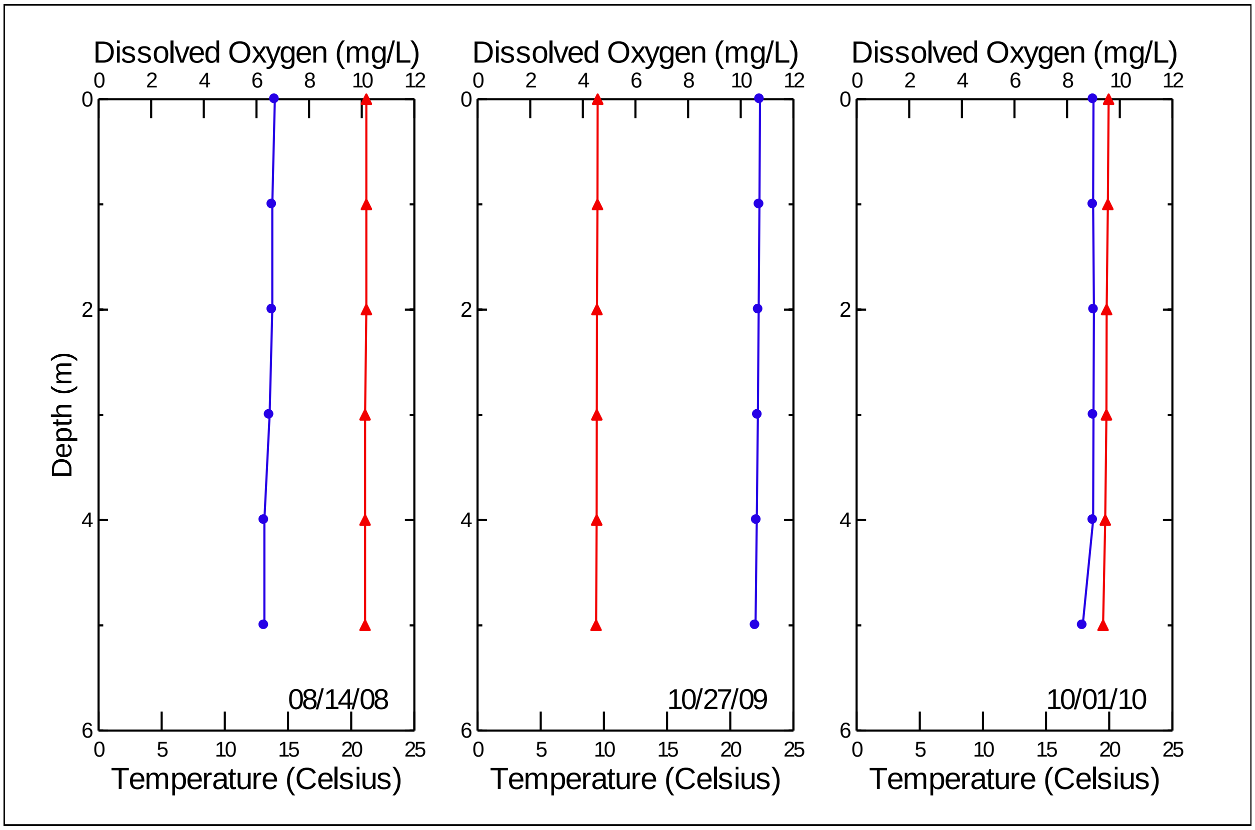

Fig. 6.46 Water column temperature (▲) and dissolved oxygen (●) profiles for Provost Lake during each survey year.

Total phosphorus concentrations were in the oligotrophic or lower mesotrophic range Fig. (6.47). These levels are considerably higher than those found in a survey carried out in 1983 and there appears to be a trend for increasing levels since 2008.

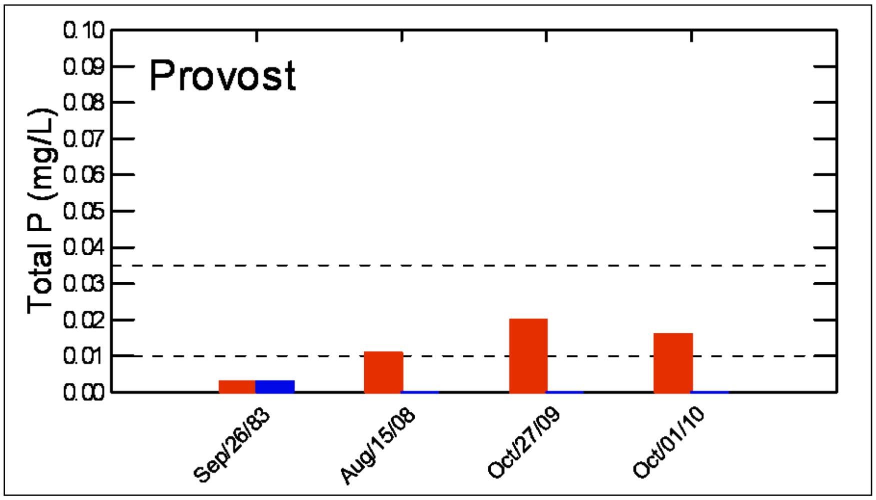

Fig. 6.47 Total phosphorous concentrations in surface (red) and bottom waters (blue) of Provost Lake (dashed lines represent divisions between trophic categories).

Total phosphorus concentrations at the outlet (Fig. 6.48) are within the low mesotrophic range and slightly lower than concentrations within the lake.

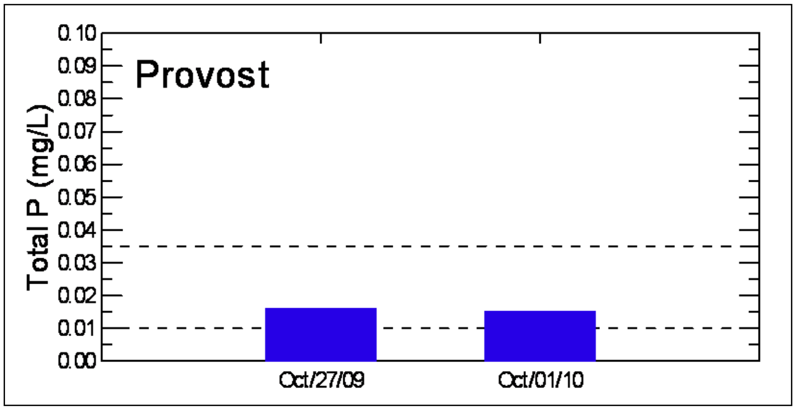

Fig. 6.48 Total phosphorous concentrations at the outlet of Provost Lake (dashed lines represent divisions between trophic categories).

Chlorophyll *a* levels (Fig 6.49) were within the eutrophic range in 2008 and 2010, but within the low mesotrophic range in 2009.

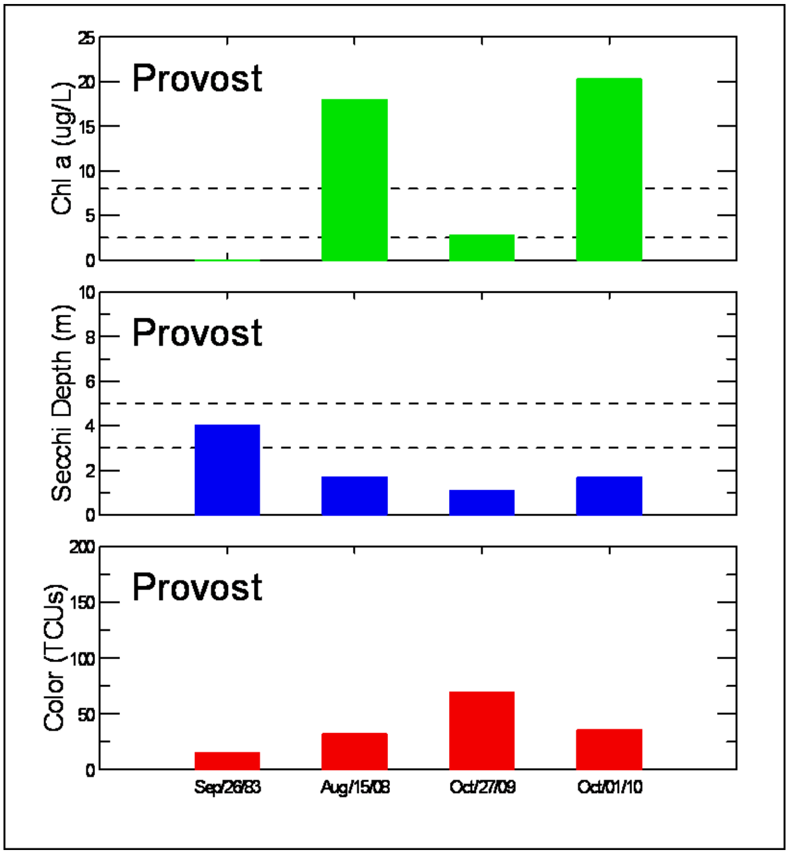

Fig. 6.49 Chlorophyll *a* concentration, Secchi Disk depth and color for Provost Lake (dashed lines represent divisions between trophic categories).

The low chlorophyll *a* level in 2009 is most likely a result of the high color in that year. An earlier survey carried out in 1983 showed chlorophyll *a* levels to be within the ultra-oligotrophic range. Secchi Disk depths were in the eutrophic or mesotrophic category and are well correlated with color as opposed to chlorophyll *a* levels.

Water quality guidelines (Table 6.11) for recreational use were met in all years with the exception of a low Secchi Disk depth in 2009.

Table 6.11 Summary of results for recreational use guidelines for Provost Lake.

Parameter	**Guideline**	**2008**	**2009**	**2010**
E. coli	< 200/100ml	-	4	2
Secchi Depth	> 1.2 m	1.7	1.1	1.7
pH	5.0 -9.0	6.1	5.9	6.0
Turbidity	< 50 NTUs	2.6	1.19	1.57
Blue-green algae	< 100,000 cells/ml	492	10	38
Microcystin-LR	< 20	<0.20	<0.20	<0.20

6.3 Meteghan River Watershed

6.3.1 Nowlans Lake

Nowlans Lake is a small shallow headwater lake located within the mid-eastern region of the Meteghan River watershed. Its mean depth is 3.3 meters and its flushing rate is 1.4 times per year. It has a small inlet located along its eastern shoreline and a single outlet that flows into Prime Lake. Fig. 6.50 shows the location of the water quality sampling stations.

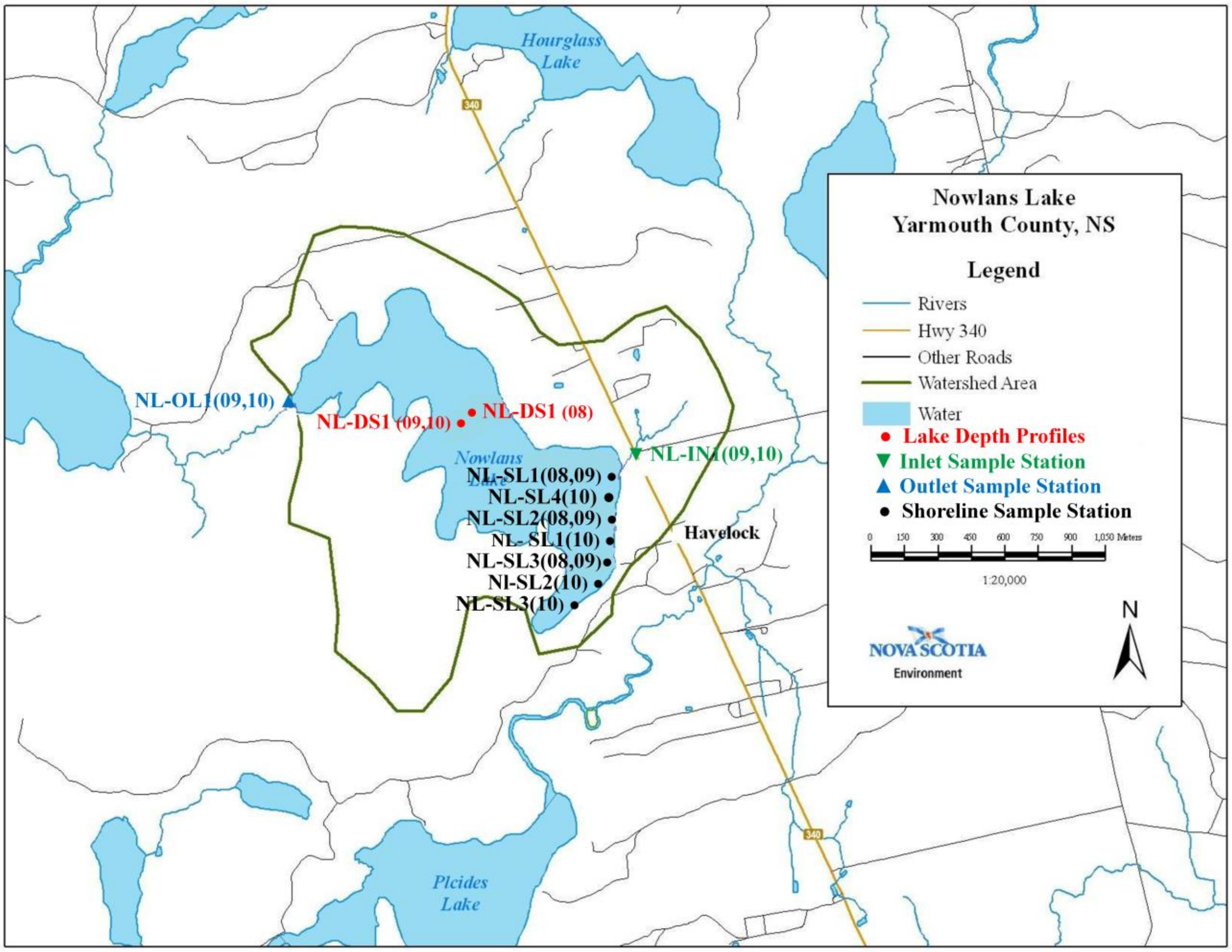

Fig. 6.50 Location of Nowlans Lake water quality sampling stations (numbers in parentheses represent years in which the station was sampled).

Water temperature and dissolved oxygen depth profiles collected in 2008 during summer show that Nowlans Lake exhibits a very weak thermal stratification with the top of the thermocline beginning at about five meters depth (Fig.6.51). Dissolved oxygen concentrations begin to decrease at about three meters, well above the top of the thermocline which is rarely seen to occur, and the lake becomes very close to being anoxic at about six meters depth. This lake is likely to undergo periodic destratification under strong wind conditions.

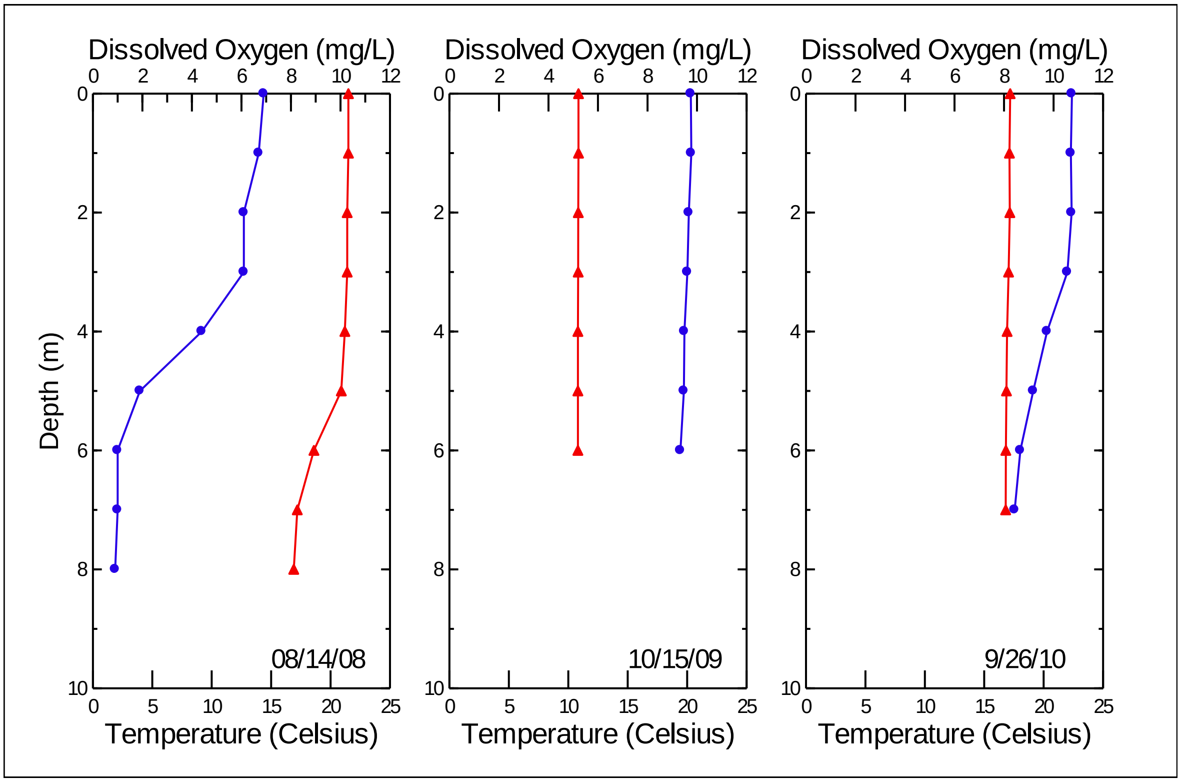

Fig. 6.51 Water column temperature (▲) and dissolved oxygen (●) profiles for Nowlans Lake during each survey year.

Total phosphorus levels measured between 2008 and 2009 are extremely high and well into the hyper-eutrophic range (Fig. 6.52). In contrast, levels measured during an earlier survey carried in 1983 were within the oligotrophic range for surface waters and the low mesotrophic range for bottom waters.

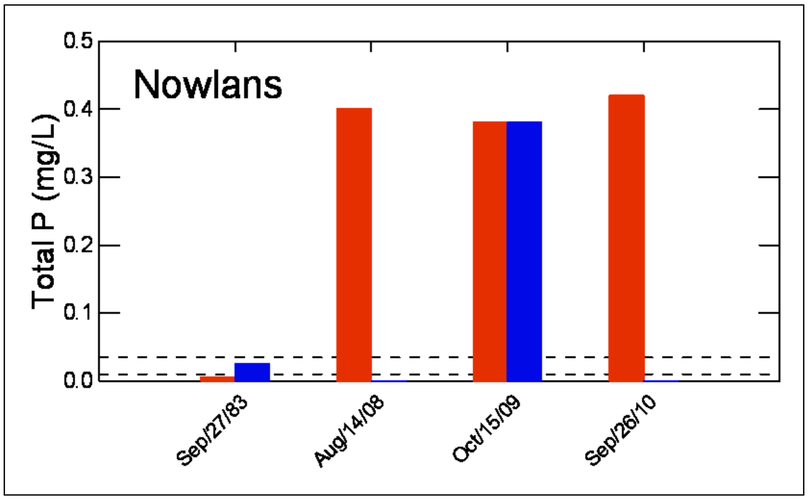

Fig. 6.52 Total phosphorous concentrations in surface (red) and bottom waters (blue) of Nowlans Lake (dashed lines represent divisions between trophic categories).

Total phosphorus levels at the inlet are extremely high and considerably less at the outlet (Fig. 6.53) indicating that this lake has a high capacity to entrain incoming nutrients.

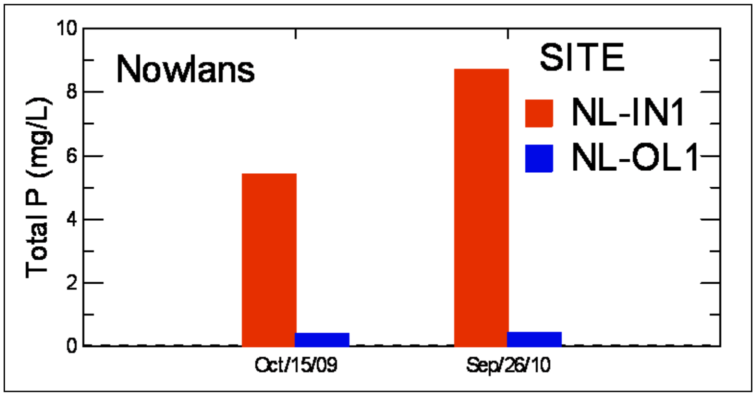

Fig. 6.53 Total phosphorous concentrations at the inlet (red) and outlet (blue) of Nowlans Lake (dashed lines represent divisions between trophic categories).

Chlorophyll *a* levels are also very high (Fig. 6.54) and Secchi Disk depths are very low. A survey carried out in 1983 reported very low chlorophyll *a* levels.

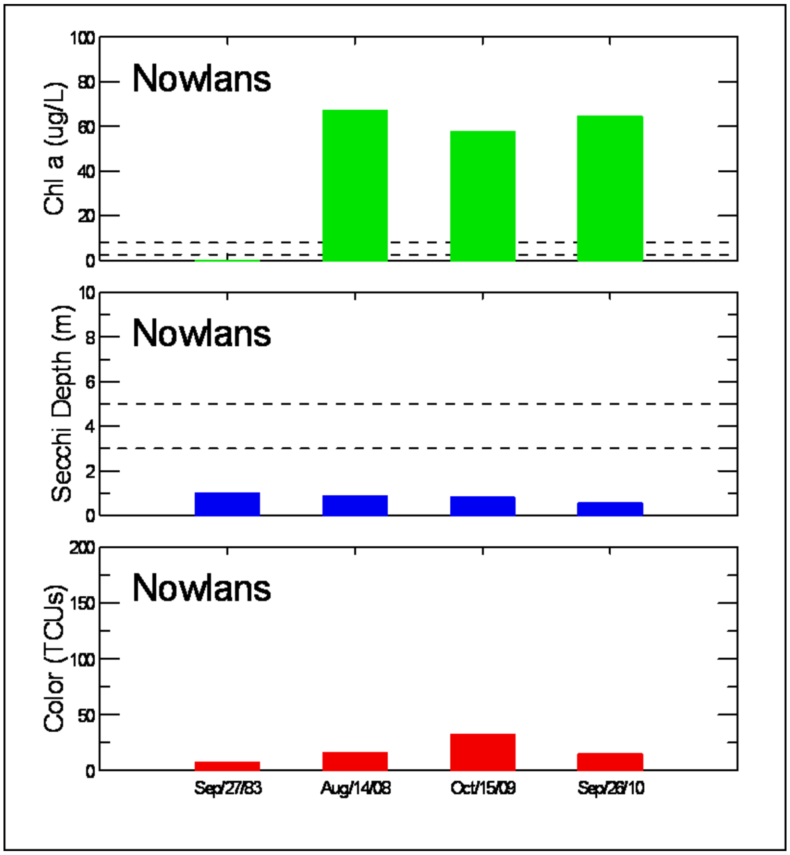

Fig. 6.54 Chlorophyll *a* concentration, Secchi Disk depth and color for Nowlans Lake (dashed lines represent divisions between trophic categories).

Unlike many of the other lakes surveyed, Nowlans Lake has very low color which results in a more normal response to nutrient over-enrichment.

Of all the lakes surveyed, Nowlans Lake is the most seriously impacted by nutrient over-enrichment. It is also the only lake to have exceeded the recreational guideline for blue green alga numbers which occurred in 2008 and 2009 (Table 6.12). Although it never contained microcystin concentrations greater than the guideline, it is the only lake in which concentrations were high enough to be detected. In addition, despite its low color, it failed the guideline for Secchi Disk depth in all years surveyed.

Table 6.12 Summary of results for recreational use guidelines for Nowlans Lake.

Parameter	Guideline	2008	2009	2010
E. coli	< 200/100ml	-	38	36
Secchi Depth	> 1.2 m	0.85	0.8	0.55
pH	5.0 -9.0	6.5	7.3	8.0
Turbidity	< 50 NTUs	19.6	10.6	34.3
Blue-green algae	< 100,000 cells/ml	104000,78800, 95600,98100	120000,120000 175000	24800,57600, 16200,12300
Microcystin-LR	< 20	0.3,0.3, 0.3, <0.20	<0.20, <0.20 <0.20	<0.20,0.34 0.66,<0.20

7. Trophic Status

7.1 Development of Appropriate Trophic State Criteria

Based on the results of the water quality surveys carried out between 2008 and 2010 it is obvious that many of the lakes surveyed are currently receiving inputs containing very high levels of total phosphorus. It is also obvious that that the response to these high inputs varies greatly among the lakes and that trophic status, as indicated by both chlorophyll *a* and Secchi Disk depth, does not correlate particularly well with total phosphorus concentrations within the lake. The relationship between surface water total phosphorus concentrations and chlorophyll *a* is very poor (Fig. 7.1a), as is the relationship between Secchi Depth and chlorophyll *a* (Fig.7.1b). Secchi Disk depth, one of the primary response parameters used in assessing trophic status, in particular, is determined for most of these lakes by color as opposed to algal biomass (Fig. 7.1c). There is also a strong relationship between total phosphorus and color (Fig. 7.1d). Most of the lakes surveyed are clearly dystrophic and, with the exception of chlorophyll *a* concentration, the OECD criteria previously described in Section 6 and listed in Table 6.1 are not appropriate for establishing their trophic status.

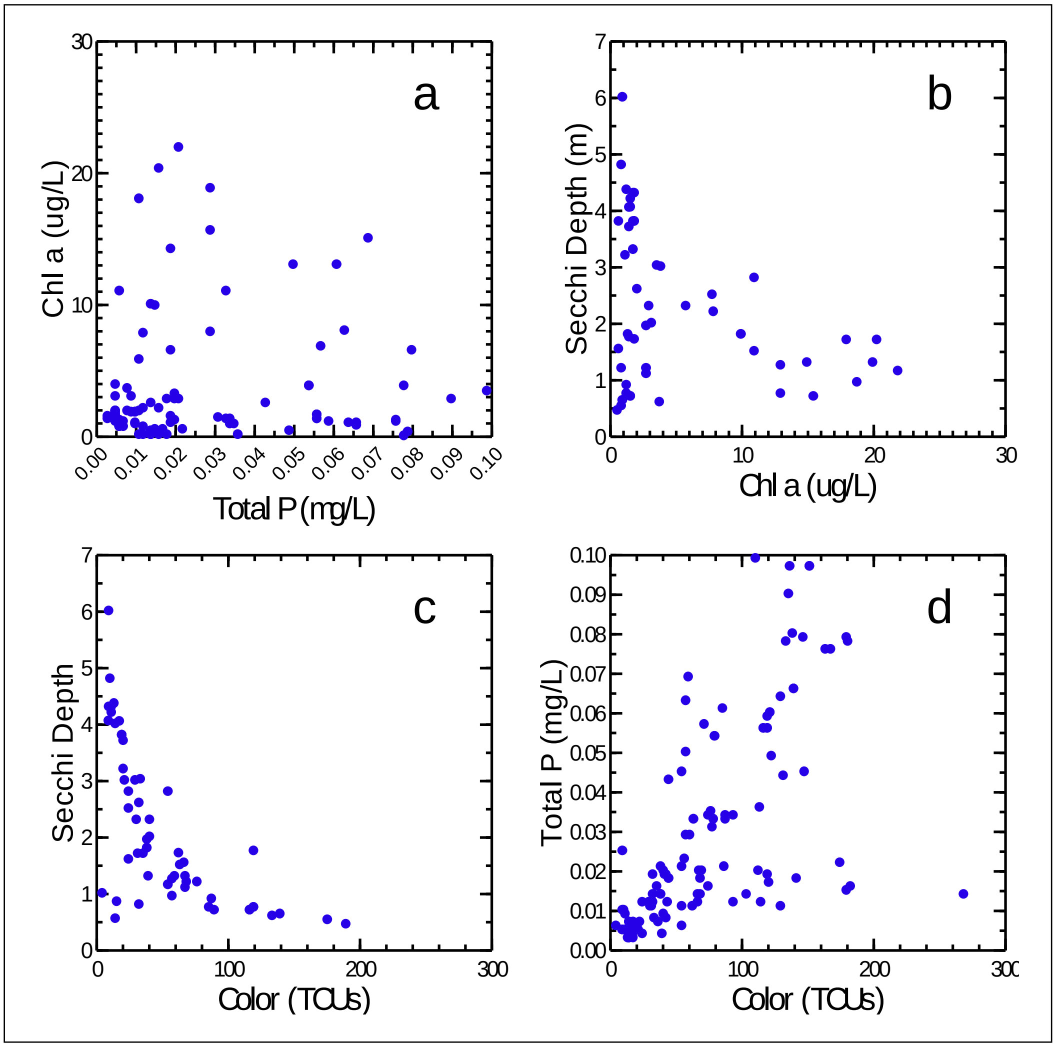

Fig. 7.1 Relationships between trophic state parameters and water color.

The only trophic parameter suitable for evaluating the trophic status of dystrophic lakes is chlorophyll *a* concentration as this is the most important and most direct indication of the extent to which a lake has responded to nutrient inputs.

7.2 Trophic State Evaluation

The level of chlorophyll *a* for each lake in each survey year is listed in Table 7.1 along with its OECD trophic status based solely on chlorophyll *a* concentration. In addition, the degree to which each lake exhibits dystrophic characterises is also indicated, based on the value of color measured as True Color Units (TCUs) and the boundary conditions listed at the bottom of Table 7.1.

Table 7.1 Yearly variation in trophic status based on OECD criteria for chlorophyll *a* concentration and color.

Lake	**Year**	**Chl a** (μg/L)	**Trophic Status**	**Color** (TCUs)
Hourglass	2008	15.0	Eutrophic/*	60
	2009	3.8	Mesotrophic/***	134
	2010	13.0	Eutrophic/**	58
Placides	2008	20.0	Eutrophic/**	68
	2009	0.6	Ultra-oligotrophic/***	190
	2010	15.5	Eutrophic/**	90
Porcupine	2008	7.8	Mesotrophic/*	25
	2009	1.1	Oligotrophic/**	76
	2010	2.8	Mesotrophic/*	39
Parr	2008	11.0	Eutrophic/**	64
	2009	0.9	Ultra-oligotrophic/***	176
	2010	13.0	Eutrophic/**	86
Ogden	2008	10.0	Eutrophic/*	39
	2009	5.5	Mesotrophic/**	86
	2010	18.8	Eutrophic/**	58
Fanning	2008	5.8	Mesotrophic/*	31
	2009	1.5	Oligotrophic/***	118
	2010	18.1	Eutrophic/*	49
Sloans	2009	1.7	Oligotrophic/*	20
	2010	1.9	Oligotrophic/*	11
Vaughan	2008	3.9	Mesotrophic/*	22
	2009	0.9	Ultra-oligotrophic/***	134
	2010	2.2	Oligotrophic/**	95
Nowlans	2008	67.0	Hyper-eutrophic/*	16
	2009	58.0	Hyper-eutrophic/*	33
	2010	64.5	Hyper-eutrophic/*	15
Provost	2008	18.0	Eutrophic/*	32
	2009	2.8	Mesotrophic/**	68
	2010	20.3	Eutrophic/*	36

* < 50 – Oligo-dystrophic ** ≥ 50 - < 100 – Meso-dystrophic *** ≥ 100 – Eu-dystrophic

It is obvious that there has been considerable yearly variation in the trophic status of the surveyed lakes, and that this is largely a result of the yearly variations in lake color. Of particular note is that, without exception, for all the lakes surveyed the lowest chlorophyll *a* concentrations were observed in 2009 and this corresponded to the year when color values were highest. All of the lakes falling into the ultra-oligotrophic category have color values greater than 100 TCUs. In most cases, the high color in 2009 resulted in a shift of one trophic level lower, but for two of the lakes, Placides and Parr where color levels increased by more than 100 percent, the shift was to two trophic levels lower.

The inverse relationship between chlorophyll *a* level and color is evident in Fig. 7.2.

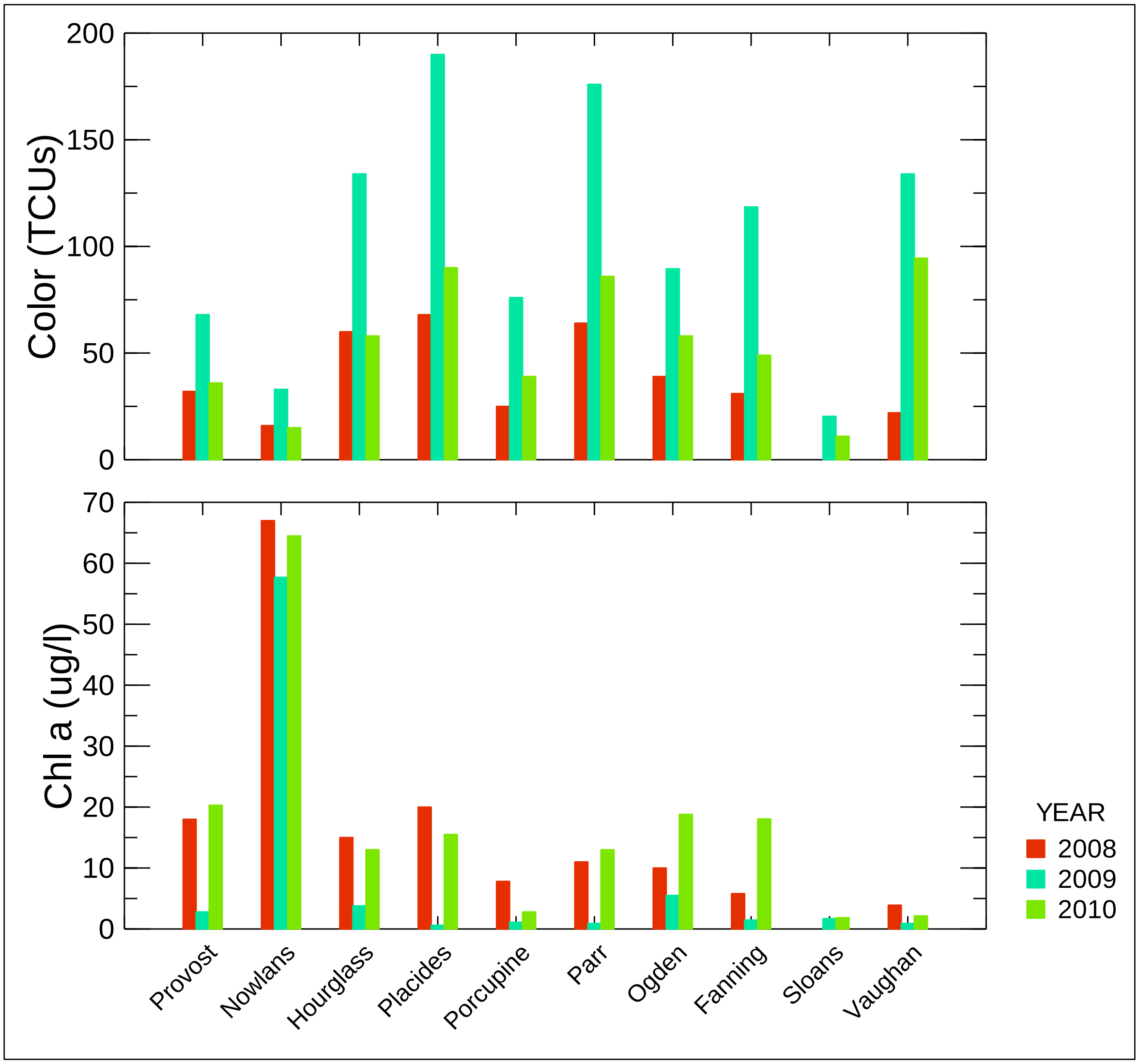

Fig. 7.2 Yearly variation in water color and chlorophyll *a* levels.

With one exception, total phosphorus levels changed relatively little between years compared to the changes observed for color and chlorophyll (Fig. 7.3). The one exception was Parr Lake in which total phosphorus increased dramatically 2009.

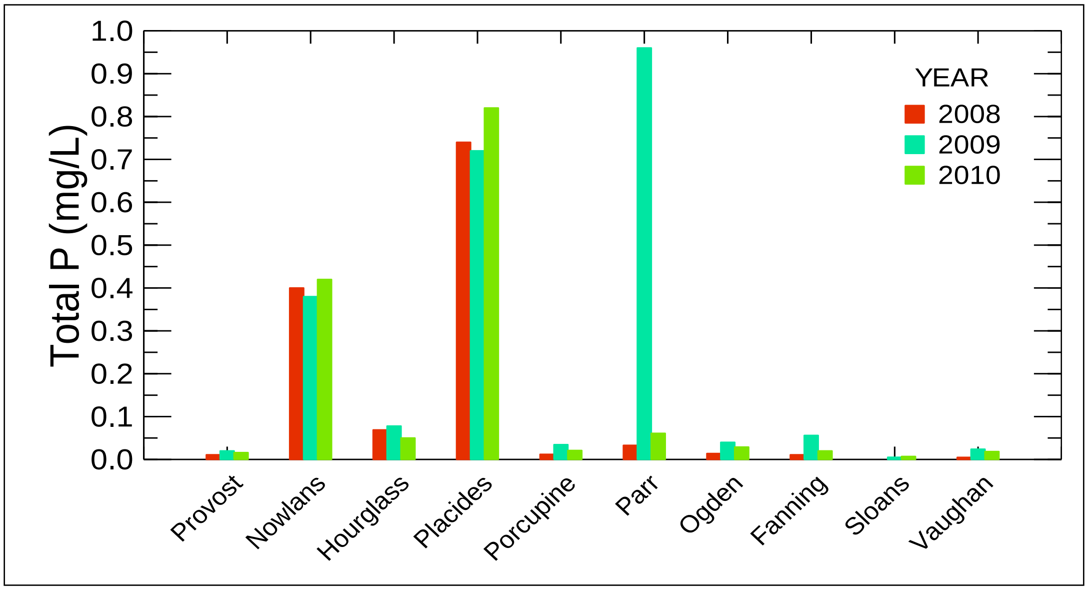

Fig. 7.3 Yearly variation in total phosphorus concentrations.

7.3. Precipitation and Water Color

Because of the large variation in chlorophyll *a* levels between the survey years, and its strong relationship to lake color, the variation in color between years was examined to determine if it is related to variations in precipitation. Since color in dystrophic lakes is most often the result of surface water run-off containing leachates from coniferous vegetation, a strong relationship would be expected between color and the amount of precipitation.

Daily precipitation data collected at Yarmouth by Environment Canada was tabulated for the five day period prior to each survey period, and for the period over which the survey was carried out. Fig. 7.4 illustrates the relationship between lake color and daily precipitation and shows the strong relationship between the two. Total precipitation during the three survey periods amounted to 50, 99 and 7 mm for 2008, 2009 and 2010, respectively.

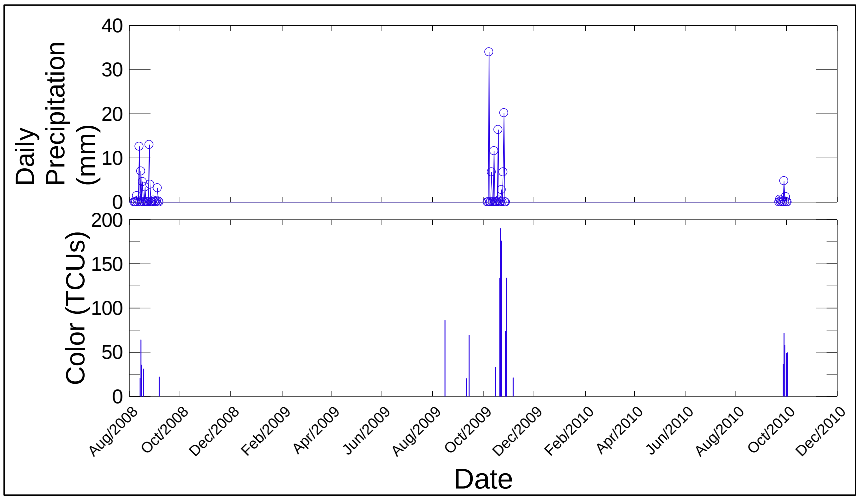

Fig 7.4 Relationship between precipitation and lake water color.

7.4 Nitrogen Phosphorus Ratios

The ratio of nitrogen to phosphorus is often evaluated to determine if the productivity of a lake is limited by either nitrogen or phosphorus. TN:TP ratios greater than 17:1 are considered to indicate phosphorus limitation and, conversely, ratios less than 17:1 are considered indicative of nitrogen limitation. Fig. 7.5 illustrates the yearly variation in N:P ratios of the surveyed lakes.

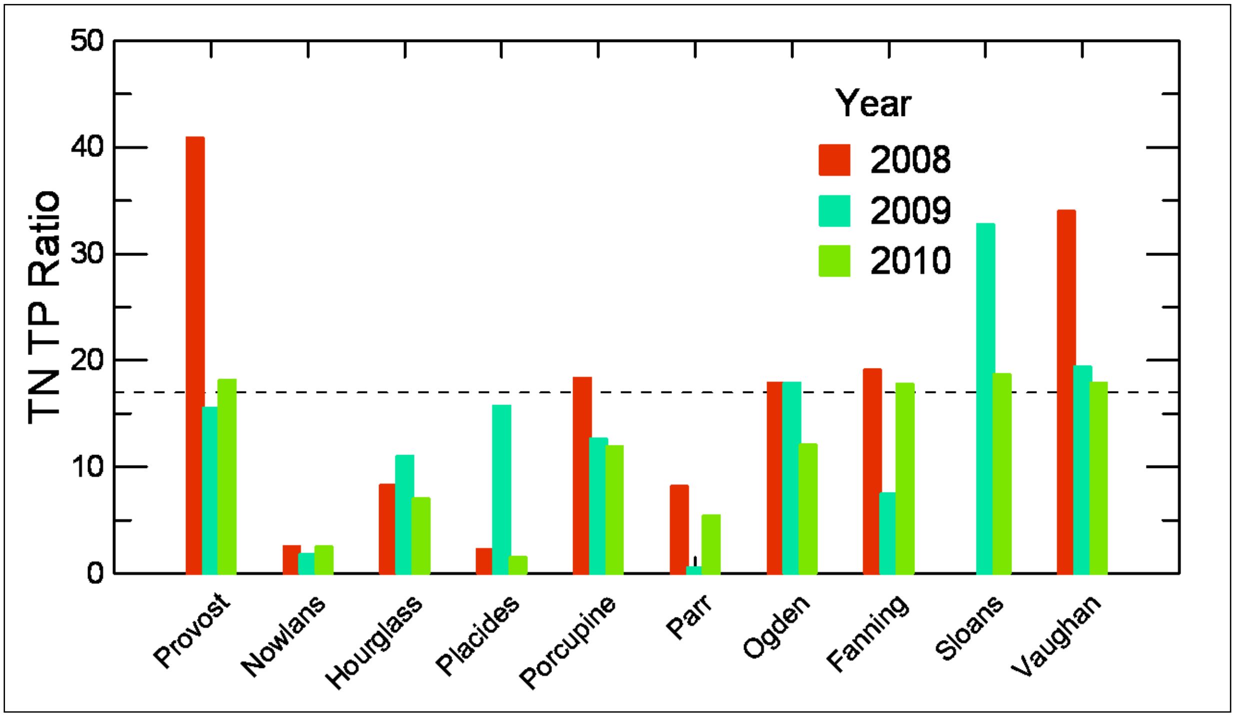

Fig. 7.5 Yearly variation in N:P ratios.

In most years and for most lakes, N:P ratios were either very close to or below 17:1 indicating that nitrogen and phosphorus are both limiting (ratios close to 17:1), or that nitrogen is the limiting nutrient (ratios significantly below 17:1) Exceptions when phosphorus may be most limiting were Provost and Vaughan Lakes in 2008, and Sloans Lake in 2009.

7.5 Nutrient Input Comparisons

Table 7.2 and Fig. 7.6 show the relative differences between the total phosphorus levels at the inlets to each of the surveyed lakes. This information should prove useful in the design of any future monitoring programs to identify the specific location of activities leading to high nutrient loadings. It is obvious that the highest inputs for lakes located within the Carton River watershed are mainly within the upper region of the watershed. With a few exceptions, there was not a great deal of variation in input total phosphorous concentrations between the two years in which they were monitored.

Table 7.2 Yearly variation in total phosphorus concentration at lake inputs.

Lake	Station	Year	Total P (mg/L)	Description of Input
Hourglass	HL-IN1	2009	0.170	Headwater lake with small spring input
		2010	0.037	
Placides	PLAL-IN1	2009	0.610	Stream entering form Hourglass and Simonds Lakes
		2010	0.940	
Porcupine	PORL-IN1	2009	0.079	Stream entering from Paul, Oliver and an Unnamed lake
		2010	0.110	
Parr	PARL-INA	2009	0.018	Input from Carleton River
		2010	0.099	
	PARL-INB	2009	0.011	Stream input from Salmon and Grass Lakes
		2010	0.012	
	PARL-INC	2009	0.016	Small stream
		2010	0.057	
Ogden	OL-IN1	2009	0.076	Channel input from Parr Lake
		2010	0.054	
Fanning	FL-IN1	2009	0.064	Input from Carleton River
		2010	0.024	
	FL-IN2	2009	0.020	Small stream input from Cranberry Lake
		2010	0.008	
	FL-IN3	2009	0.007	Small stream input from Mink Lake
		2010	0.005	
Sloans	-	-	-	Headwater lake with no distinct water inputs
Vaughan	VL-IN1	2009	0.034	Stream input from Raynards Lake
		2010	0.014	
	VL-IN2	2010	0.014	Channel input from Gavels Lake
Nowlans	NL-IN1	2009	5.400	Headwater lake with distinct input from a drainage ditch
		2010	8.700	
Provost	-	-	-	Headwater lake with no distinct water inputs

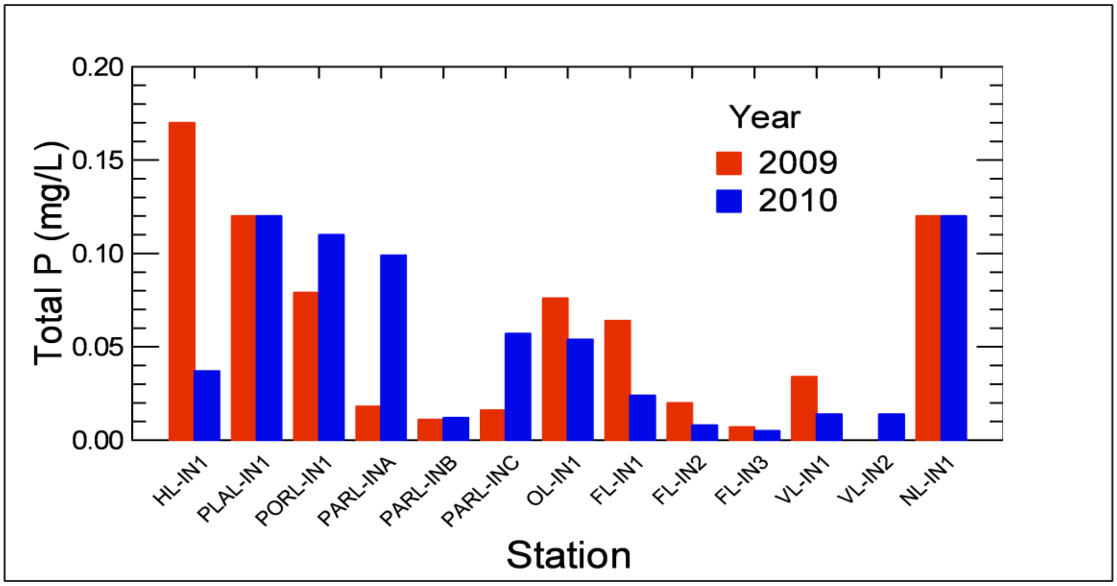

Fig 7.6 Total phosphorus levels within the inputs to each lake.

7.6 Nutrient Loading Comparisons

In order to determine the major sources of nutrient inputs to each lake, rudimentary estimates of daily phosphorus loadings were made at the inlets and outlets of each lake in 2009 and 2010. In 2009 these estimates were made at 25 sites. In 2010, however, due to low water levels and flows as a result of the extremely dry conditions prior to and during the survey period (see Fig.7.4), it was only possible to make these estimates at four sites. The results are summarized in Table 7.3.

Table 7.3 Summary of daily nutrient loading estimates.

Lake	Station	Year	Width (m)	Depth (m)	Velocity (m/sec)	Flow (m^3/day)	Total P (mg/L)	TP Loading (kg/day)
Hourglass	HL-IN1	2009	Springfed			0.0001	0.170	0.002
	HL-OL1	2009	1.53	0.20	0.24	0.08	0.050	0.32
		2010	1.00	0.20	0.07	0.01	0.043	0.05
Placides	PLAL-IN1	2009	7.62	1.22	0.46	4.25	0.610	223.86
	PLAL-OL1	2009	4.57	1.22	0.37	2.04	0.660	116.26
Porcupine	PORL-IN1	2009	3.05	0.91	0.24	0.68	0.080	4.64
	PORL-IN1	2009	1.83	0.46	1.02	0.85	0.030	2.28
Parr	PARL-INA	2009	0.91	0.30	0.46	0.13	0.020	0.20
	PARL-INB	2009	3.05	0.91	0.28	0.77	0.010	0.73
		2010	2.00	0.50	0.20	0.20	0.012	0.21
	PARL-INC	2009	1.22	0.20	0.30	0.08	0.020	0.10
	PARL-OL1	2009	7.62	2.44	0.76	14.16	0.080	92.97
Ogden	OL-IN1	2009	6.10	2.20	0.91	12.26	0.080	80.53
		2010	5.00	0.50	2.00	5.00	0.054	23.33
	OL-OL1	2009	7.62	1.22	1.52	14.16	0.070	80.74
Fanning	FL-IN1	2009	5.49	1.22	1.00	6.69	0.060	36.99
	FL-IN2	2009	1.22	0.30	0.30	0.11	0.020	0.20
	FL-IN3	2009	1.22	0.61	0.30	0.23	0.010	0.14
	FL-OL1	2009	7.62	2.44	1.83	33.98	0.060	173.22
Sloans	SL-IN1	2009	0.61	1.52	0.05	0.05	0.038	0.15
	SL-OL6	2009	1.83	0.15	0.05	0.01	0.005	0.01
Vaughan	VL-IN1	2009	14.63	2.44	0.46	16.31	0.030	47.91
	VL-IN2	2009	24.38	2.20	0.30	16.35	0.010	19.78
	VL-OL1	2009	20.00	3.08	0.61	37.55	0.020	71.36
Provost	PROL-IN1	2009	1.22	0.30	0.17	0.06	0.010	0.08
	PROL-OL1	2009	1.52	0.61	0.24	0.23	0.020	0.35
Nowlans	NL-IN1	2009	1.52	0.30	0.02	0.01	5.400	4.40
		2010	0.50	0.10	0.50	0.03	8.700	18.79
	NL-OL1	2009	2.44	1.22	0.08	0.24	0.400	8.35

It should be noted that the relative magnitude of the loading estimates alone do not necessarily determine the trophic status of the receiving lakes. Other factors besides nutrient loading that are related to the nutrient assimilation capacity, discussed in Section 7.7, are important in determining the extent to which nutrient inputs result in the development of algal biomass.

7.7 Nutrient Assimilation Capacities

The survey results clearly indicate that phosphorus inputs to a lake, when considered alone, do not necessarily correlate well with the degree to which a lake exhibits eutrophic symptoms. The ability of a lake to assimilate nutrients without becoming eutrophic, i.e., it's susceptibly to eutrophication, depends on a number of complex and interrelated factors. Lake algal productivity is dependent on two main factors: the availability of nutrients and the availability of light. The degree to which a lake will develop eutrophic characteristics, however, depends on a number of other factors as well. Of major importance is a lake's flushing rate. Lakes having high flushing rates will continuously remove both nutrients and algae from a lake and prevent the build up of high levels of both nutrients and algal biomass. Flushing rate is in turn dependent on the relationship between a lakes depth and surface area, which determines its volume, and the area of the lakes drainage basin, which determines the volume of its water inputs. Also important are a lakes transparency and whether or not it exhibits thermal stratification of its water column. These latter two factors taken together are important in determining the nutrient assimilation capacity of a lake in that for an unstratified lake having high color and low transparency, algae are more likely to be limited in growth by light than by nutrient availability.

Based on these factors, it is possible to develop a rudimentary assessment of the degree to which each of the surveyed lakes is susceptible to development of high algal biomass and eutrophication if subjected to high nutrient inputs. This information is important in determining the effort which should be placed to ensure that a particular lakes watershed is protected from activities that may result in high levels of nutrient run-off.

The basis of the ranking developed involves evaluation of three parameters: (1) the degree to which the lake exhibits thermal water column stratification; (2) the lake's flushing rate and; (3) the lake's water transparency based on color. Using this set of parameters, a lake that exhibits stratification, has a low flushing rate and low color would be considered to be highly susceptible to eutrophication and, conversely, a lake that does not stratify, has a high flushing rate and high color would be considered relatively resistant to eutrophication. The criteria developed for each of the three parameters are listed in Table 7.4.

Table 7.4 Eutrophication susceptibility criteria.

Parameter	**Low**	**Moderate**	**High**
Flushing Rate (times/yr)	>25	≤25 - <1	≤1
Color (TCUs)	>100	≤100 - >50	≤50
Stratification	No	Periodic	Yes

Using these criteria a numerical ranking was developed using the values of one, two and three to represent low, moderate and high, respectively, for each of the criteria, and these were then summed for each of the survey lakes to develop the total ranking score. The results are listed in Table 7.5.

Although very basic, this scheme does appear to explain some of the variations observed in the trophic status of the surveyed lakes. Nowlans Lake, for example, is both highly susceptible and its water input has a very high nutrient level which explains its hyper-eutrophic status. In contrast, Sloans Lake, which is also highly susceptible but being a headwater lake with no distinct water inputs or significant nutrient loading from overland runoff, has a very low nutrient input, is only within the oligotrophic category. If Sloans were to be subjected to high nutrient inputs, it would in all likelihood become hyper-eutrophic.

Table. 7.5 Relative susceptibility of surveyed lakes to eutrophication.*

Lake	**Stratification**	**Flushing Rate** (times/yr)	**Color**** (TCUs)	**Total Score**	**Relative Susceptibility**
Sloans	Yes (3)	0.7 (3)	16 (3)	9	High
Porcupine	Yes (3)	0.7 (3)	47 (3)	9	High
Nowlans	Periodic (2)	1.4 (2)	21 (3)	8	High
Hourglass	Periodic (2)	0.8 (3)	84 (2)	7	Moderate
Ogden	Yes (3)	21.4 (2)	61 (2)	7	Moderate
Vaughan	Yes (3)	42.2 (1)	84 (2)	6	Moderate
Fanning	Yes (3)	57 (1)	66 (2)	6	Moderate
Provost	No (1)	3.9 (2)	44 (3)	5	Low
Parr	No (1)	23 (2)	108 (1)	4	Low
Placides	Insufficient data to evaluate				

*Numbers in parenthesis represent score for that category.
** Based on the mean value of color over the three survey years.

8. Fecal Coliform Bacteria, Blue-green Algae and Microcystins

Table 8.1 summarizes the results of water quality samples collected at the shoreline stations and analyzed for fecal coliform numbers, blue-green algal composition and numbers, and Microcystin-LR concentration. Appendix IIB contains information on the species of blue-green algae contained in each sample.

Table 8.1 Summary of fecal coliform numbers, blue-green algal numbers and Microcystin-LR concentrations.

Lake	Station	Year	Fecal Coliforms (#/100 ml)	Blue-green algae (cells/ml)	Blue-green Genera (#)	Microcystin-LR (μg/L)
Hourglass	HL-SL1	2008	-	48	1*	<0.20
		2009	<2	33	1	<0.20
		2010	7	6	1*	<0.20
Placides	PLAL-SL1	2008	-	64	1*	
		2009	56	424	2	<0.20
		2010	101	0	-	<0.20
Porcupine	PORL-SL1	2008	-	56	1*	<0.20
		2009	1	2	1	<0.20
		2010	12	20	1	<0.20
Parr	PARL-SL1	2008	-	2220	2*	<0.20
		2009	1	267	3*	<0.20
		2010	<2	102	2*	<0.20
Ogden	OL-SL1	2008	-	1210	3*	<0.20
		2009	3	195	2	<0.20
		2010	2	2480	1*	<0.20
Fanning	FL-SL1	2008	-	128	3*	<0.20
		2009	-	5	2*	<0.20
		2010	3	7340	3	<0.20
	FL-SL2	2009	2	1400	1*	<0.20
Sloans	SL-SL3	2009	6	100	1	<0.20
	SL-SL4	2009	6	2070	2	<0.20
	SL-SL5	2009	4	216	3	<0.20
	SL-SL6	2010	2	278	4*	<0.20
Vaughan	VL-SL1	2008	-	408	1	<0.20
		2009	3	5	2*	<0.20
		2010	3	7340	3*	<0.20
	VL-SL2	2010	12	26	2	<0.20
Provost	PROL-SL1	2008	-	492	2*	<0.20
		2009	4	10	1*	<0.20
		2010	<2	38	2*	<0.20
Nowlans	NL-SL1	2008	-	104000	4*	0.30
		2009	38	120000	3*	<0.20
		2010	57	24800	3*	<0.20
	NL-SL2	2008	-	78800	3*	0.30
		2009	15	127000	2*	0.30
		2010	40	57600	2*	0.34
	NL-SL3	2008	-	95600	4*	0.30
		2009	9	175000	1*	<0.20
		2010	36	16200	3*	0.66
	NL-SL4	2010	86	12300	3*	<0.20

*Contains genera known to produce microcystins (see Appendix IIB for details).

Fecal coliform numbers never exceeded the recreational guideline of 200/ml within any of the lakes. The highest numbers observed were at Nowlans and Placides Lake.

Although there was considerable variability both among lakes and between years, with the exception of Nowlans Lake, the recreational guidelines for blue-green algal numbers or Microcystin-LR concentration were also never exceeded. Nowlans Lake exceeded the guideline of 100,000 cells/ml for blue-green algal numbers in at least one shoreline sampling station in both 2008 and 2009, and was the only lake found to contain high numbers of *Microcystis* (Appendix IIB), the blue-green alga that is most often responsible for producing Microcystin-LR. Although *Microcystis* is a blue-green alga, unlike most other species of blue-green algae, it lacks the ability to fix nitrogen and in fact has a high requirement for nitrogen. Relative to the other lakes surveyed, Nowlans Lake had very high total nitrogen levels and TN:TP ratios which may explain the high *Microcystis* numbers observed.

Although Nowlans Lake never exceeded the guideline for LR concentration, it was the only lake to have had Microcystin-LR concentrations above the analytical detection limit. The lack of high Microcystin-LR concentrations, despite high blue-green algal numbers, is not an unusual observation. Although the environmental conditions under which microcystin producing algae produce microcystins are not well understood, there is considerable evidence that this occurs mainly at the end of the logarithmetic growth phase when the algal population begins to decline. If samples were collected at this growth phase, higher Microcystin-LR concentrations may have been observed.

All of the other lakes surveyed had relatively low numbers of blue-green algae which suggests that those found to have high levels of chlorophyll *a* contain algal populations composed of algae species other than blue-green species.

9. pH and Alkalinity

Although not directly related to trophic status, pH and alkalinity are important water quality parameters with respect to the ability of a lake to support healthy aquatic communities. Many Nova Scotia lakes and rivers, particularly those located within the southwestern region of the province, have low alkalinities and have become acidified to the point where pH values are at times as low as four as a result of acid precipitation originating from industrial areas located in western Canada and the northeastern United States. The CCME (2001) guideline for pH for the protection of aquatic life is 6.5 to 9.0. There is no guideline for alkalinity. Fig. 9.1 illustrates the pH and alkalinity levels observed in the surveyed lakes during each survey year.

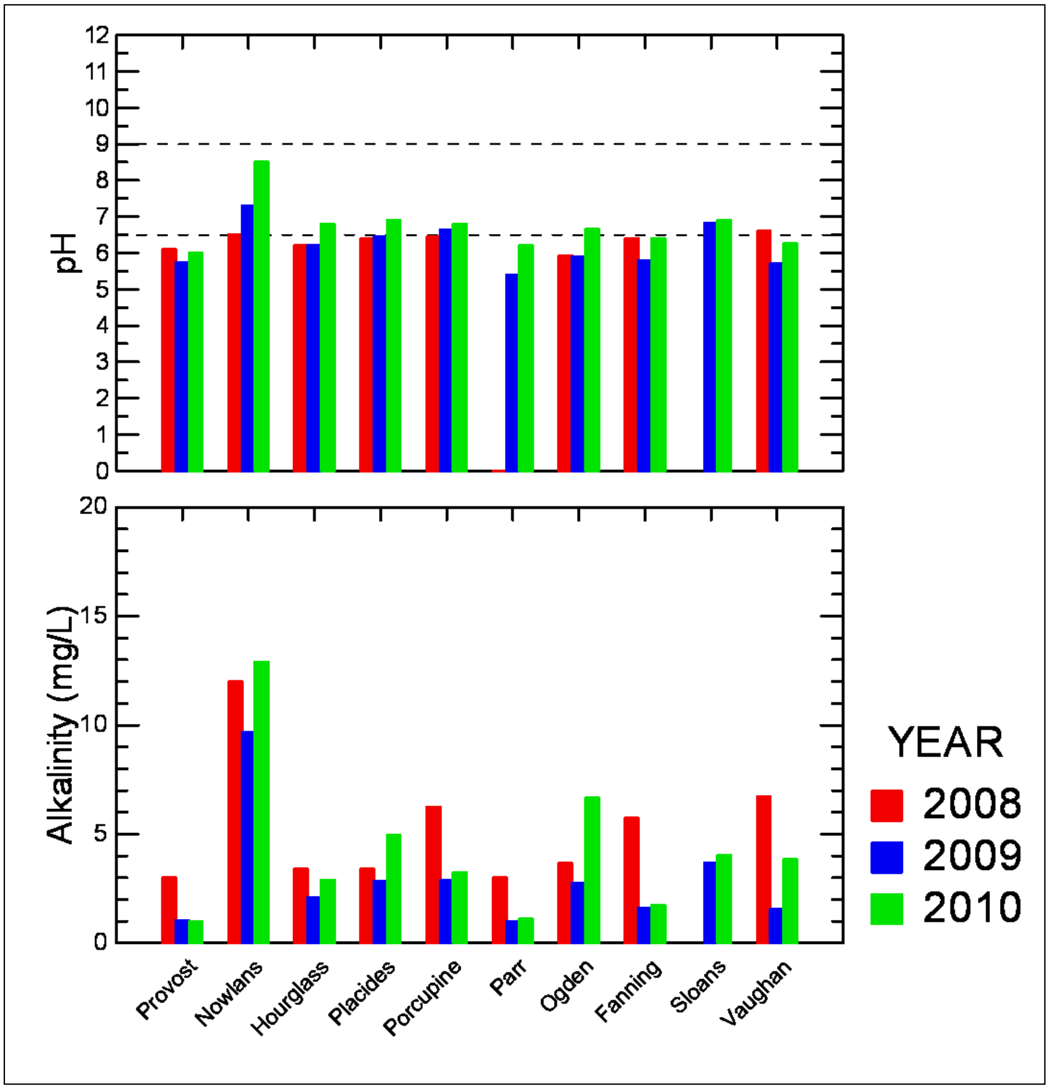

Fig. 9.1 pH and alkalinity of surveyed lakes during each survey year (dashed lines represent upper and lower limits of guideline for pH).

Although most of the surveyed lakes are below the lower pH guideline, the deviation is very small and acidification is not likely to be of any real concern with respect to impacting aquatic life in any of the lakes. Alkalinity exhibited greater yearly variation than pH, but was always relatively low in most cases and if further reductions were to occur significant changes to lower pH values may result. Of note is the relatively high pH and alkalinity of Nowlans Lake. The cause of this requires further investigation, but may be related to the drainage inputs originating from a nearby mink farm. The alkalinity value of that input in 2010 was 82.8 mg/L.

10. Discussion and Conclusions

Based on the results of the water quality surveys carried out between 2008 and 2010, it is obvious that most of the surveyed lakes have been impacted to some degree by nutrient-overenrichment. Water quality surveys carried out in the late 1970s and early 1980s suggest most of these lakes to have been relatively pristine at that time. The most severely impacted lakes are those located within the upper regions of the study area. Although the surveys were not intended or designed to provide evidence of a direct link to any particular nutrient source, the most probable source of nutrients leading to the decline in water quality are those originating from the activities of the mink farms highly concentrated in that area. The low fecal coliform numbers present in shoreline water quality samples suggests that residential development along lake shorelines is not a serious contributor to nutrient over-enrichment.

In all cases nutrient levels within input streams were greater than levels within output streams indicating that the lakes are likely to be retaining nutrients, most likely within bottom sediments as algae die and settle to the bottom. In addition, the lower values at the outlets indicate that there are likely to be no significant point sources of nutrients located near the shorelines. An exception to this may be Hourglass Lake, where shoreline samples collected in close proximity to the input and output of an aquaculture operation indicated higher phosphorus levels in the area of the outlet.

Despite the high nutrient levels all lakes but one met the health related guidelines for recreational use. The only recreational guidelines that were commonly exceeded were the aesthetic guidelines related to water clarity, which was mainly a result of the high levels of water color observed in 2009. Nowlans Lake exceeded the guidelines for blue-green algal numbers in two of the three survey years, and was the only lake in which microcystins were detected, but microcystins were present at levels far below those considered to be a health risk. Many of the lakes, however, were found to contain algal species known to produce microcystins, and because this is thought to occur only under certain environmental conditions and particularly near the end stage of an algal bloom, surveys carried out during that period may have revealed higher microcystin levels.

The importance of water color in terms of its influence on nutrient assimilation capacity and, as a result, the trophic status of a lake within any particular year is significant. Because water color can vary greatly on a seasonal and annual basis due to variations in precipitation, evaluations of the efficacy of any proposed remediation activities to reduce nutrient over-enrichment can be challenging and will require monitoring water quality on a much more frequent basis than once a year.

11. Recommendations for Future Studies

Any further studies should focus on the design and implementation of an investigative water quality monitoring program to provide an extensive assessment of the exact sources and magnitudes of the nutrient inputs responsible for the degradation in water quality and, once identified, the design and implementation of a remediation program.

A program for assessment of nutrient sources could be carried out for each lake on a sub-watershed basis and involve nutrient sampling beginning at all inlets to the lake, and then extending upstream into the tributaries of each inlet. Because this approach is likely to involve a great deal of sampling, it could initially be carried out using one of the many field kits available for spot sampling of water chemistry. The primary advantage of using a field kit, aside from the considerably lower cost of analysis, is that it provides instant feedback of nutrient levels at a site which allows a decision to be made as to whether additional sampling should be carried out further upstream. The only disadvantage to using a field kit is that the methodologies employed are less sensitive than traditional laboratory methods. This, however, should not be a problem because of the very high nutrient levels involved.

In order to determine the success of any remediation activities, a long-term monitoring program could be designed and implemented. To reduce costs and minimize the resources required this program could be volunteer based using local residents for the required field work. Laboratory analysis of water samples and interpretation of data, however, would be best carried out through technically qualified personnel with expertise in this area. An excellent model for this type of program is the very successful volunteer based water quality monitoring program being coordinated and funded by the Municipality of Kings County for a series of lakes located in the Gaspereau River watershed.

12. References

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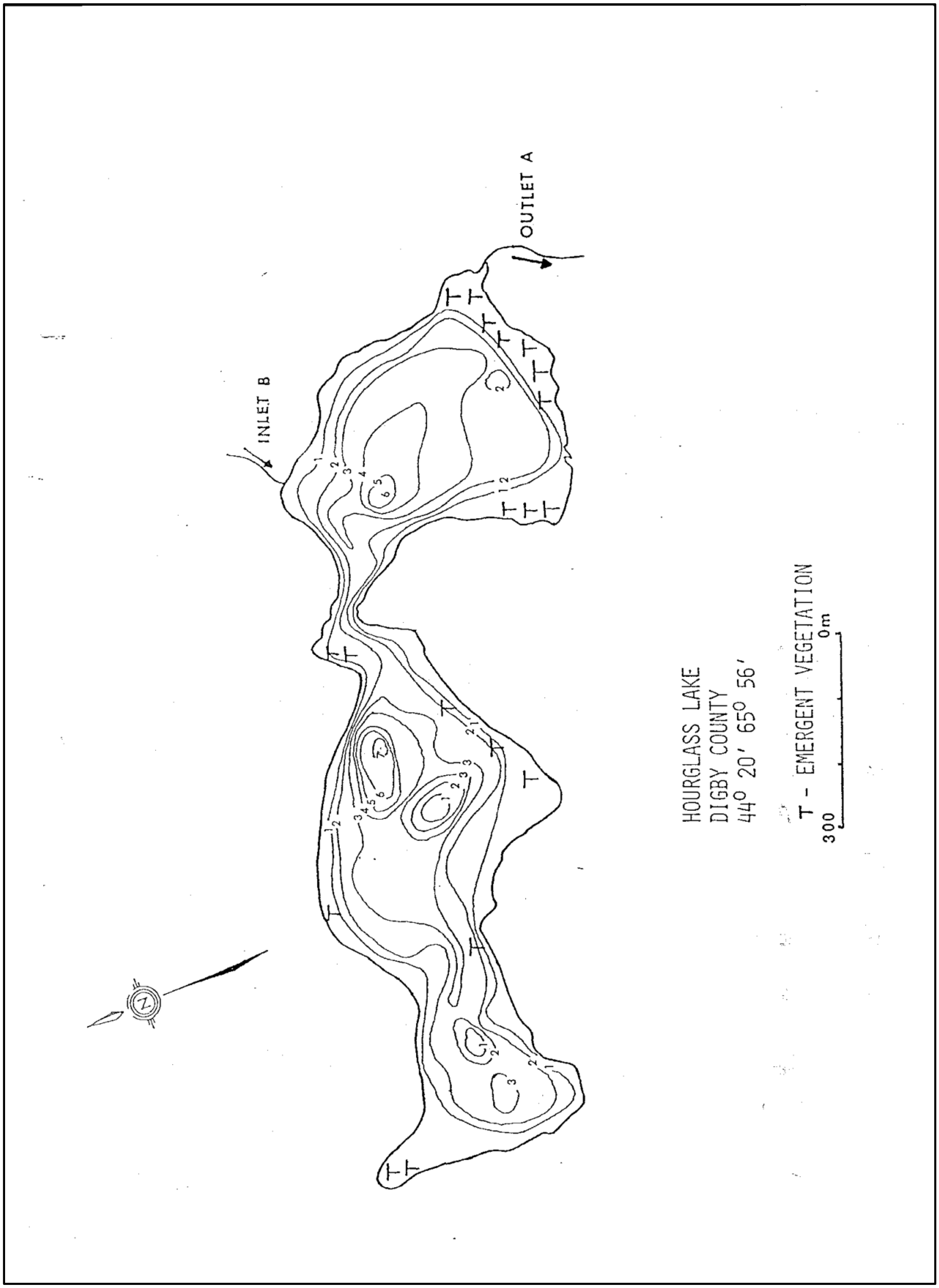
APPENDIX I

Bathymetric Maps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DIGBY COUNTY
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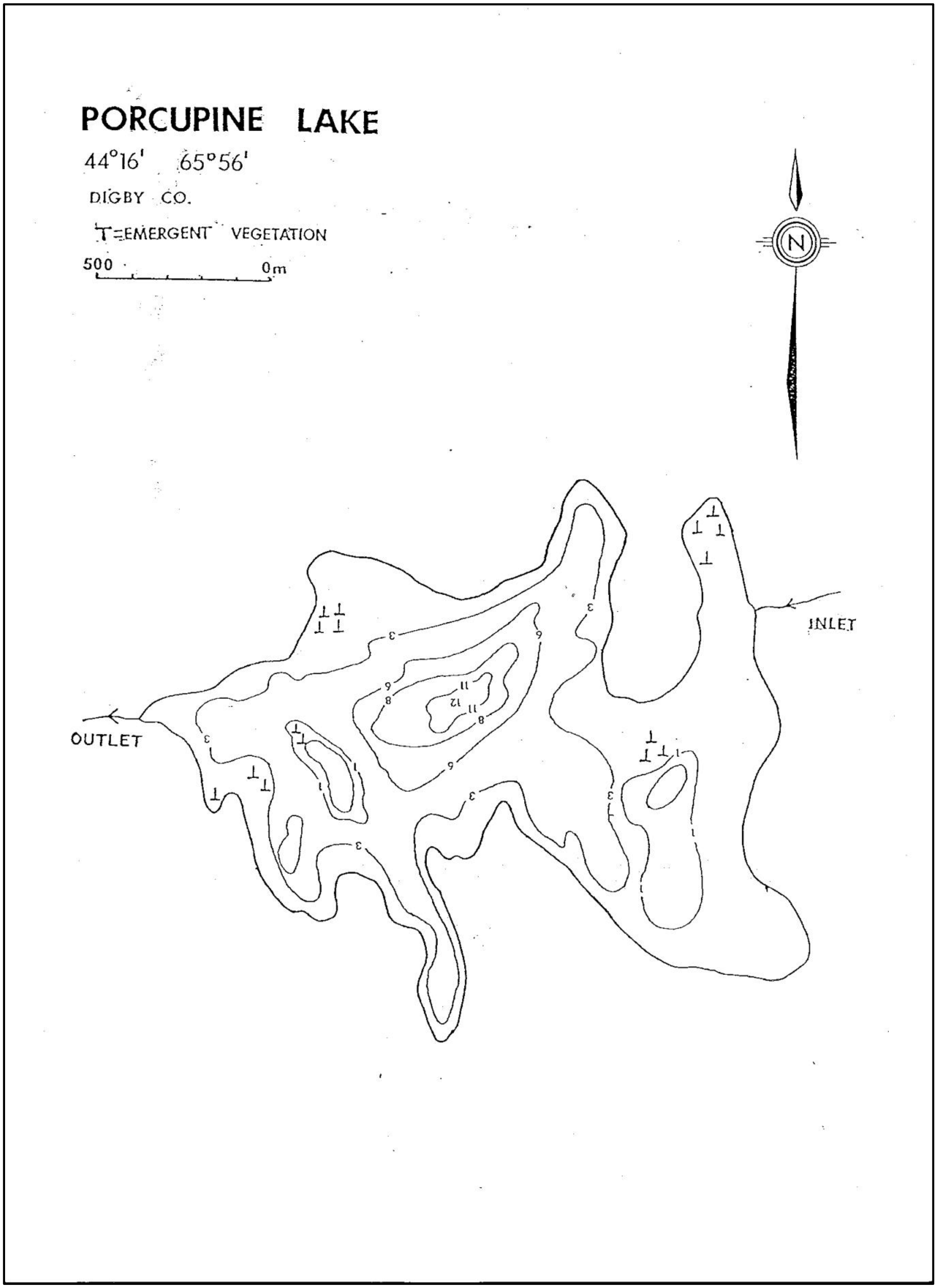
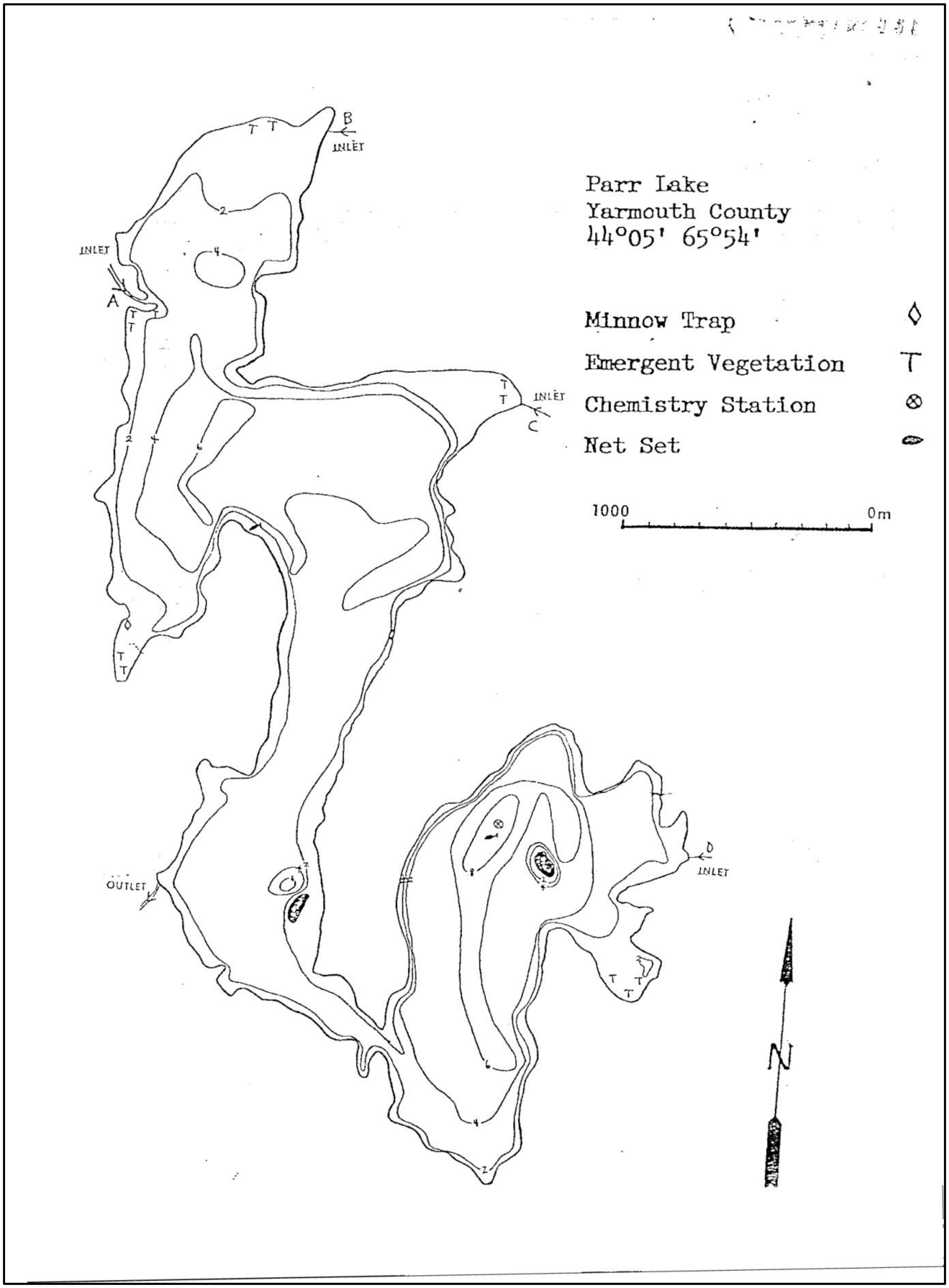
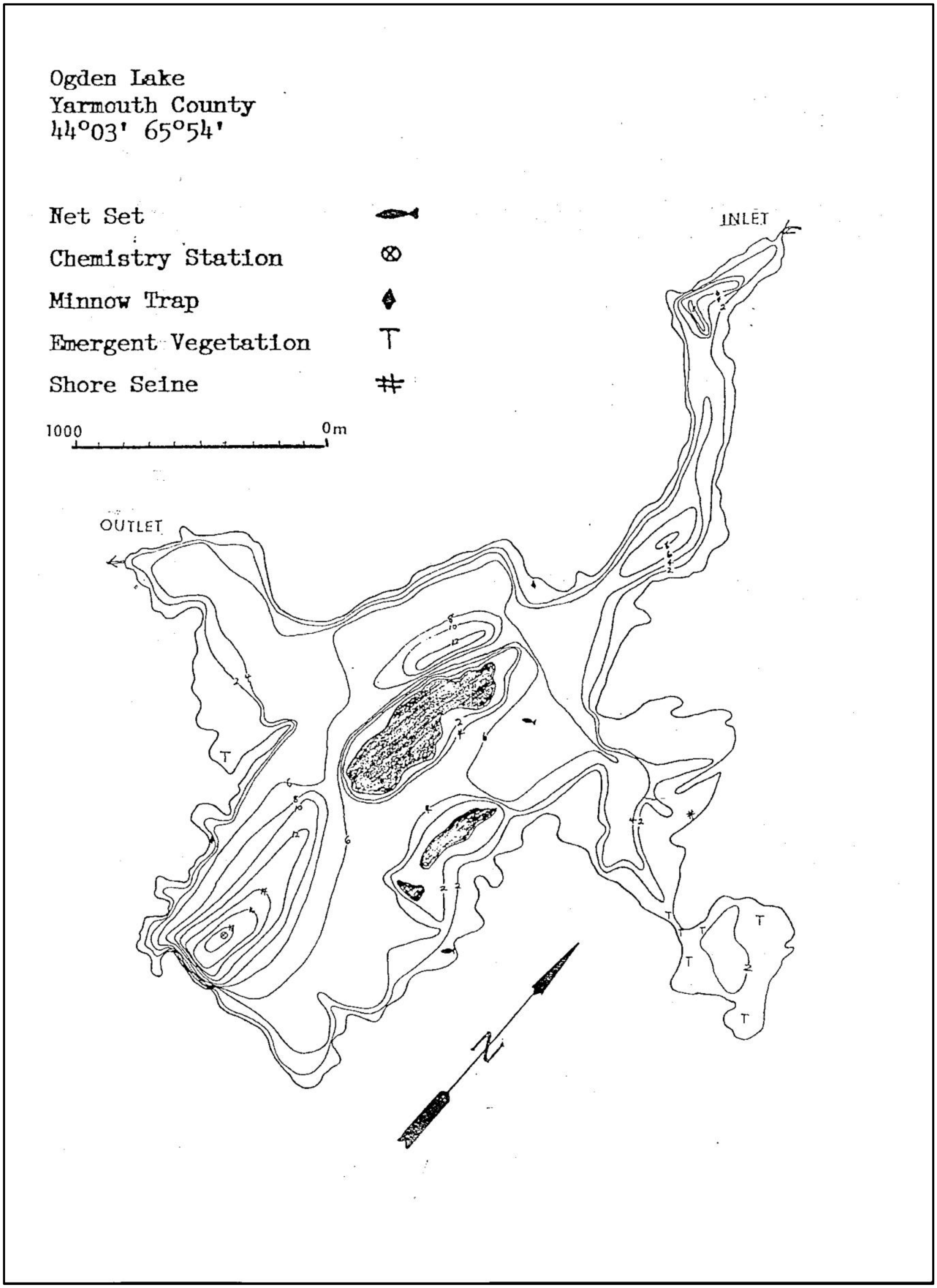
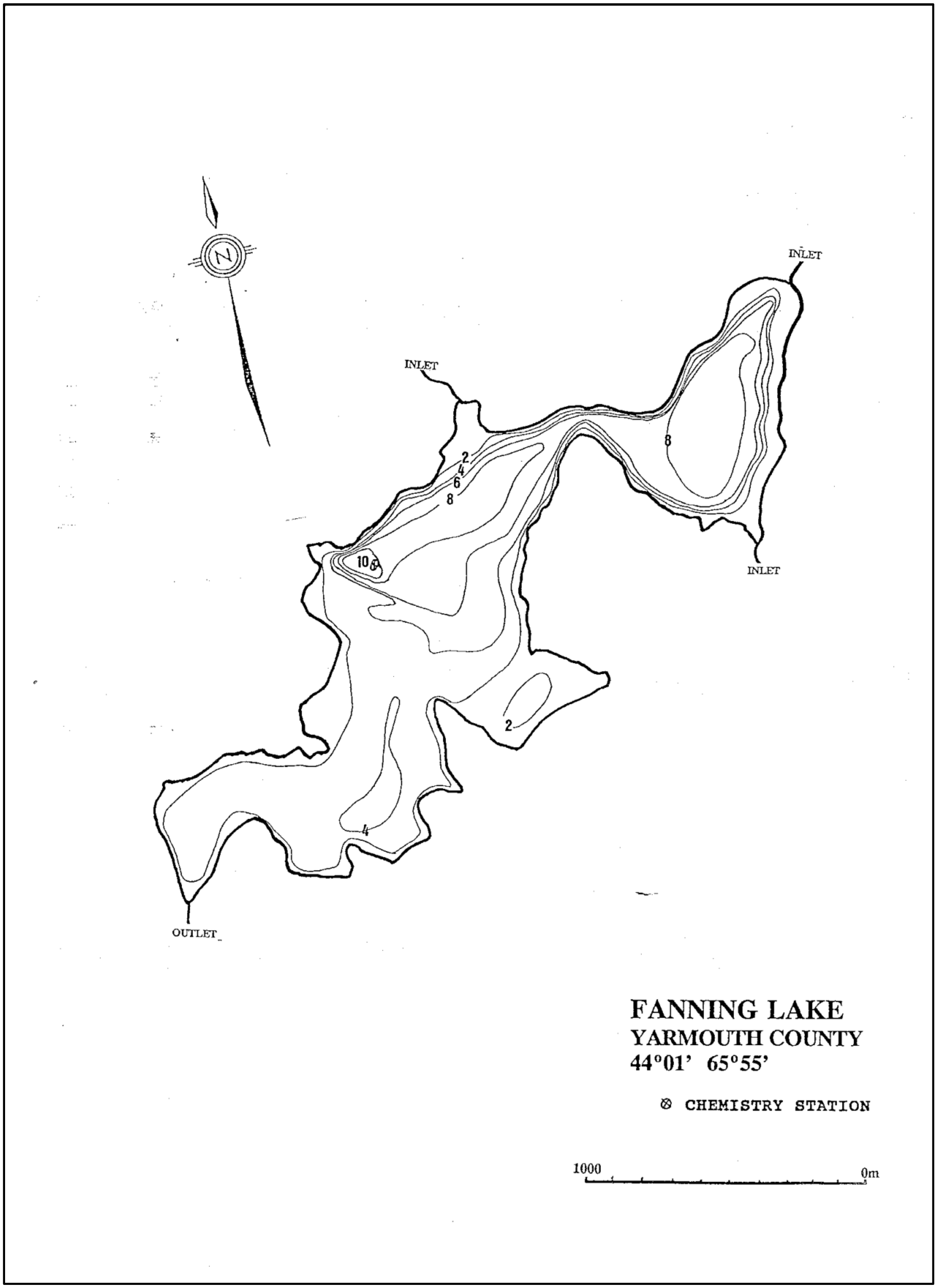
0m
INLET B
OUTLET A

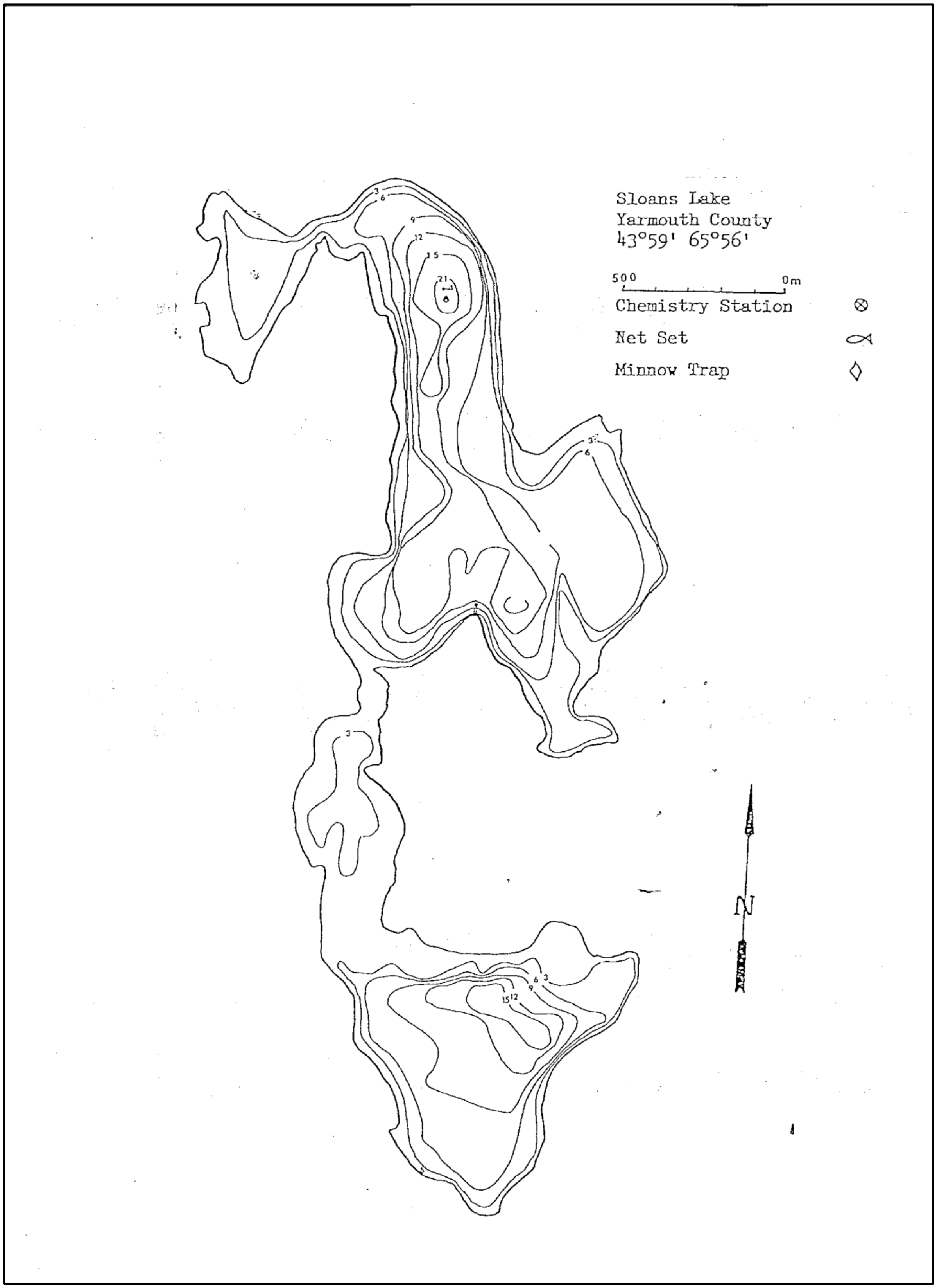

PORCUPINE LAKE
44°16' 65°56'
DIGBY CO.
⊥=EMERGENT VEGETATION
500
0m
N
INLET
OUTLET
3
6
8
9
11
12
1

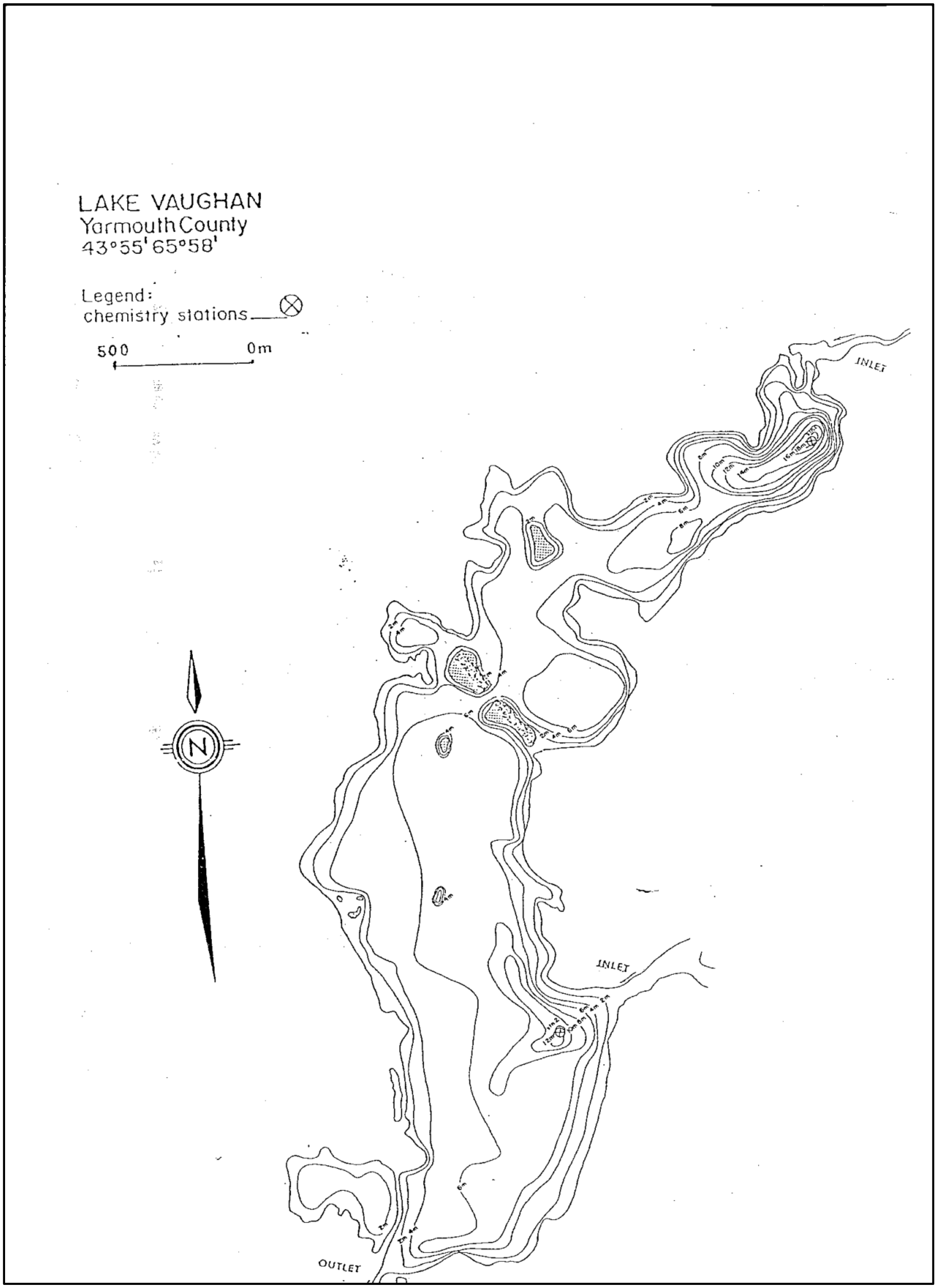

Parr Lake
Yarmouth County
44°05' 65°54'
Minnow Trap ◊
Emergent Vegetation T
Chemistry Station ⊗
Net Set
1000
0m
N
INLET
A
B
INLET
C
INLET
D
INLET
OUTLET
2
4
6
8

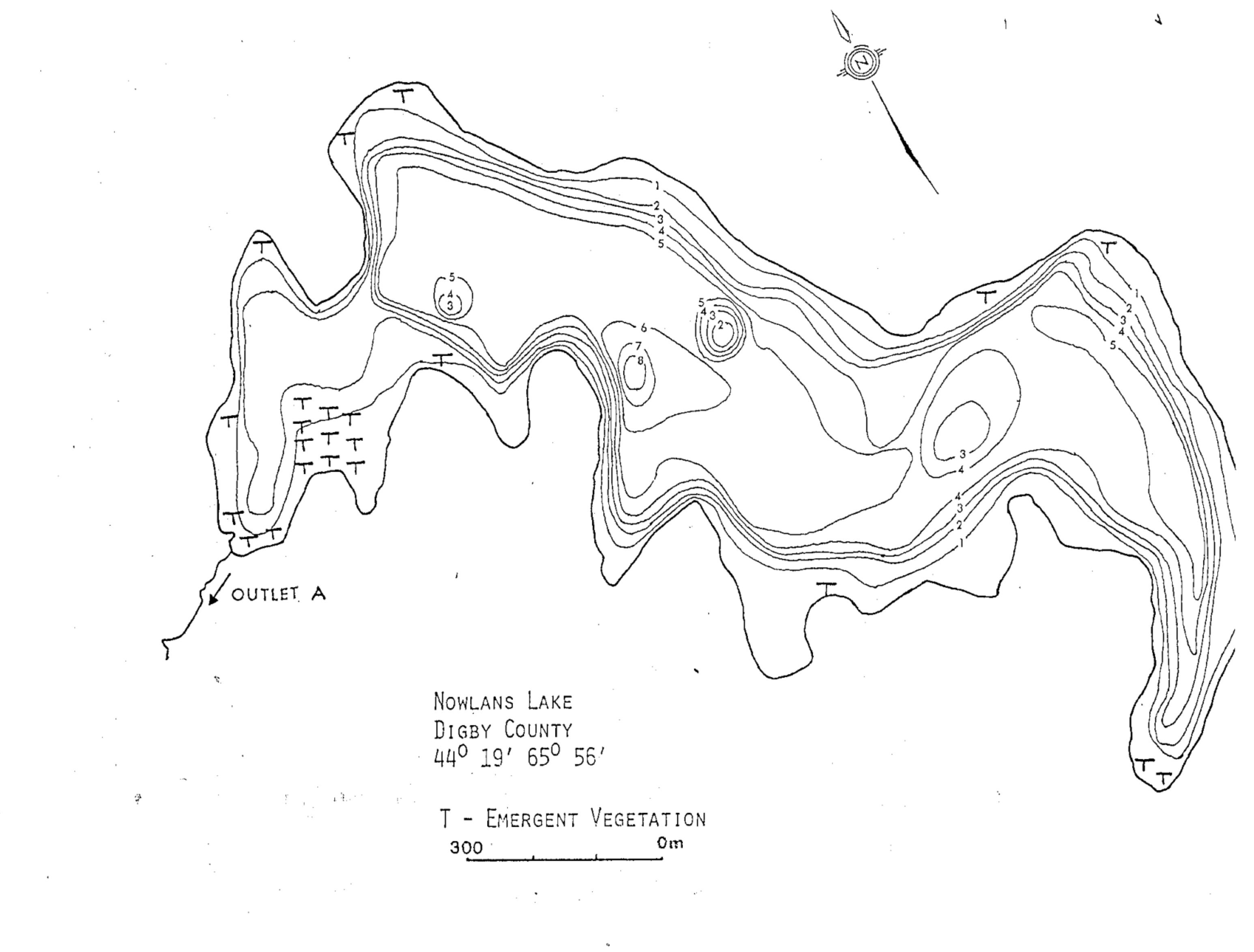

Ogden Lake
Yarmouth County
44°03' 65°54'
Net Set
Chemistry Station
Minnow Trap
Emergent Vegetation
Shore Seine
1000
0m
INLET
OUTLET
T
N



FANNING LAKE
YARMOUTH COUNTY
44°01’ 65°55’


Sloans Lake
Yarmouth County
43°59' 65°56'
500
0m
Chemistry Station ⊗
Net Set
Minnow Trap ◇
3
6
9
12
15
21
3
6
3
6
3
9
12
15
N


LAKE VAUGHAN
Yarmouth County
43°55' 65°58'
Legend:
chemistry stations
500
0m
INLET
INLET
OUTLET
2m
4m
6m
8m
10m
12m
14m
16m
18m


N
1
2
3
4
5
6
7
8
OUTLET A
NOWLANS LAKE
DIGBY COUNTY
44° 19' 65° 56'
T - EMERGENT VEGETATION
300
0m


OUTLET
PROVOST LAKE
DIGBY COUNTY
44° 21' 65° 51'
T - EMERGENT VEGETATION
500
0m
N
1 2 3 4 5 6 7 8

Appendix II

Databases

Appendix IIA - Physical and Chemical Parameters

Lake	Watershed	Date	Station	Depth (m)	Secchi Depth (m)	Chlorophyll *a* (ug/L)	Color (TCUs)	Turbidity (NTUs)	Ortho -Phosphate-P (mg/L)	Total Phosphorus (mg/L)	Alkalinity (mg/L)	pH	Data Source
Provost	Sissaboo	9/25/1983		0.0	4.0				0.001	0.003	1.8	5.9	NSDL&F
Provost	Sissaboo	9/25/1983		8.0			15		0.001	0.003		5.6	NSDL&F
Provost	Sissaboo	8/14/2008	PROL-DS1	0.0	1.7	18.0	32		0.005	0.011	3.0	6.1	NSDOE
Provost	Sissaboo	10/26/2009	PROL-DS1	0.0	1.1	2.8	68		0.006	0.020	1.1	5.9	NSDOE
Provost	Sissaboo	10/26/2009	PROL-DS1	4.1			70		0.006	0.020	1.0	5.6	NSDOE
Provost	Sissaboo	10/26/2009	PROL-IN1			0.1	269		0.005	0.014	1.0	4.3	NSDOE
Provost	Sissaboo	10/26/2009	PROL-OL1			2.1	75		0.005	0.016	1.0	5.4	NSDOE
Provost	Sissaboo	10/26/2009	PROL-SL1										NSDOE
Provost	Sissaboo	9/30/2010	PROL-DS1	0.0	1.7	20.3	36	1.57	0.005	0.016	1.0	6.0	NSDOE
Provost	Sissaboo	9/30/2010	PROL-OL1			9.9		1.37	0.005	0.015	3.2	6.6	NSDOE
Provost	Sissaboo	9/30/2010	PROL-SL1										NSDOE
Nowlans	Meteghan	9/26/1983		0.0	1.0		5		0.002	0.006	7.7	6.2	NSDL&F
Nowlans	Meteghan	9/26/1983		7.5			10		0.020	0.025		6.0	NSDL&F
Nowlans	Meteghan	8/13/2008	NL-DS1	0.0	0.9	67.0	16		0.300	0.400	12.0	6.5	NSDOE
Nowlans	Meteghan	10/13/2009	NL-SL1										NSDOE
Nowlans	Meteghan	10/14/2009	NL-DS1	0.0	0.8	57.7	33		0.029	0.380	9.5	7.3	NSDOE
Nowlans	Meteghan	10/14/2009	NL-DS1	5.7			31		0.026	0.380	9.8	7.3	NSDOE
Nowlans	Meteghan	10/14/2009	NL-IN1			0.1	86		5.100	5.400	67.4	7.5	NSDOE
Nowlans	Meteghan	10/14/2009	NL-OL1			38.4	45		0.360	0.400	9.5	7.2	NSDOE
Nowlans	Meteghan	10/14/2009	NL-SL1										NSDOE
Nowlans	Meteghan	10/14/2009	NL-SL2										NSDOE
Nowlans	Meteghan	10/14/2009	NL-SL3										NSDOE
Nowlans	Meteghan	9/25/2010	NL-DS1	0.0	0.6	64.5	15	28	0.287	0.420	12.9	8.5	NSDOE
Nowlans	Meteghan	9/25/2010	NL-IN1			0.5	50	3.1	8.440	8.700	82.8	7.5	NSDOE
Nowlans	Meteghan	9/25/2010	NL-OL1			88.0	35	34.34	0.247	0.420	10.7	7.6	NSDOE
Nowlans	Meteghan	9/25/2010	NL-SL1										NSDOE
Nowlans	Meteghan	9/25/2010	NL-SL2										NSDOE
Nowlans	Meteghan	9/25/2010	NL-SL3										NSDOE
Nowlans	Meteghan	9/25/2010	NL-SL4										NSDOE
Hourglass	Carleton	8/31/1983		0.0	3.0		30		0.002	0.012	2.5	5.8	NSDL&F
Hourglass	Carleton	8/31/1983		5.0			55		0.001	0.011	7.2	6.1	NSDL&F
Hourglass	Carleton	8/31/1983		7.0			55		0.001	0.045	8.7	6.1	NSDL&F
Hourglass	Carleton	8/13/2008	HL-DS1	0.0	1.3	15.0	60		0.034	0.069	3.4	6.2	NSDOE
Hourglass	Carleton	10/19/2009	HL-AQIN1			6.5	139		0.056	0.080	2.0	6.1	NSDOE
Hourglass	Carleton	10/19/2009	HL-AQOL1			2.8	136		0.062	0.090	2.4	6.2	NSDOE
Hourglass	Carleton	10/19/2009	HL-DS1	0.0	0.6	3.8	134		0.057	0.078	2.1	6.2	NSDOE
Hourglass	Carleton	10/19/2009	HL-DS1	6.3			147		0.050	0.079	2.1	6.2	NSDOE
Hourglass	Carleton	10/19/2009	HL-IN1			11.1	224		0.115	0.170	2.8	5.7	NSDOE
Hourglass	Carleton	10/19/2009	HL-OL1	0.0		0.4	123		0.027	0.049	2.9	6.4	NSDOE
Hourglass	Carleton	10/19/2009	HL-SL1										NSDOE
Hourglass	Carleton	9/25/2010	HL-AQIN1							0.050			NSDOE
Hourglass	Carleton	9/25/2010	HL-AQOL1			8.0	58	1.56	0.030	0.063	3.0	6.8	NSDOE
Hourglass	Carleton	9/25/2010	HL-DS1	0.0	1.3	13.0	58	1.22	0.022	0.050	2.9	6.8	NSDOE
Hourglass	Carleton	9/25/2010	HL-IN1			0.2	9.8	1.8	0.006	0.370	21.3	7.6	NSDOE
Hourglass	Carleton	9/25/2010	HL-OL1			2.5	45	1.06	0.006	0.043	3.9	6.9	NSDOE
Hourglass	Carleton	9/25/2010	HL-SL1										NSDOE
Placides	Carleton	8/13/2008	PLAL-DS1	0.0	1.3	20.0	68		0.580	0.740	3.4	6.5	NSDOE
Placides	Carleton	8/13/2008	PLAL-DS1	7.0			202		3.440	5.200	24.0	6.3	NSDOE
Placides	Carleton	10/20/2009	PLAL-1N1-A			0.2	187		0.580	0.630	2.2	6.0	NSDOE
Placides	Carleton	10/20/2009	PLAL-1N1-B			0.2	184		0.580	0.610	2.6	6.1	NSDOE
Placides	Carleton	10/20/2009	PLAL-DS1	0.0	0.5	0.6	190		0.661	0.720	2.8	6.5	NSDOE
Placides	Carleton	10/20/2009	PLAL-DS1	5.8			207		0.680	0.700	2.9	6.4	NSDOE
Placides	Carleton	10/20/2009	PLAL-IN1			0.2	187		0.580	0.610	3.0	6.2	NSDOE
Placides	Carleton	10/20/2009	PLAL-OL1			1.0	187		0.620	0.660	2.9	6.3	NSDOE
Placides	Carleton	10/20/2009	PLAL-SL1										NSDOE
Placides	Carleton	9/26/2010	PLAL-DS1	0.0	0.7	15.5	90	7.98	0.705	0.820	4.7	6.9	NSDOE
Placides	Carleton	9/26/2010	PLAL-DS1	6.0			97	10	0.652	0.830	5.2	6.9	NSDOE

Placides	Carleton	9/26/2010	PLAL-IN1			0.5	105	3.02	0.078	0.940	5.0	6.8	NSDOE
Placides	Carleton	9/26/2010	PLAL-OL1			7.8	84	5.75	0.348	0.710	4.6	6.9	NSDOE
Placides	Carleton	9/26/2010	PLAL-SL1										NSDOE
Porcupine	Carleton	8/12/2008	PORL-DS1	0.0	2.5	7.8	25		0.005	0.012	3.0	6.6	NSDOE
Porcupine	Carleton	8/12/2008	PORL-DS1	6.0			87		0.005	0.021	9.5	6.3	NSDOE
Porcupine	Carleton	10/26/2009	PORL-DS1	0.0		1.3	75		0.011	0.034	3.0	6.6	NSDOE
Porcupine	Carleton	10/26/2009	PORL-DS1	12.7			79		0.017	0.033	3.0	6.7	NSDOE
Porcupine	Carleton	10/26/2009	PORL-DS2	0.0	1.2	0.9	77		0.017	0.035	2.6	6.6	NSDOE
Porcupine	Carleton	10/26/2009	PORL-IN1			0.3	180		0.055	0.079	2.2	6.0	NSDOE
Porcupine	Carleton	10/26/2009	PORL-OL1			1.4	78		0.015	0.031	2.6	6.6	NSDOE
Porcupine	Carleton	10/26/2009	PORL-SL1										NSDOE
Porcupine	Carleton	9/26/2010	PORL-DS2	0.0	2.0	2.8	39	1.31	0.005	0.021	3.1	6.8	NSDOE
Porcupine	Carleton	9/26/2010	PORL-DS2	10.5		0.5		8.3	0.013		3.4	6.8	NSDOE
Porcupine	Carleton	9/26/2010	PORL-IN1			0.9	176	5.91	0.110	0.110	5.4	6.9	NSDOE
Porcupine	Carleton	9/26/2010	PORL-OL1			1.0	33	0.65	0.005	0.019	3.3	6.9	NSDOE
Porcupine	Carleton	9/26/2010	PORL-SL1										NSDOE
Parr	Carleton	7/2/1986		0.0	2.8	11.0	55		0.001	0.006	1.0	5.8	NSDL&F
Parr	Carleton	8/14/2008	PARL-DS1	0.0	1.5	11.0	64		0.012	0.033	3.0		NSDOE
Parr	Carleton	10/21/2009	PARL-DS1	0.0	0.5	0.9	176		0.075	0.960	1.0	5.4	NSDOE
Parr	Carleton	10/21/2009	PARL-DS1	6.2			178		0.075	0.950	1.0	5.4	NSDOE
Parr	Carleton	10/21/2009	PARL-INA			0.1	142		0.006	0.018	2.2	6.2	NSDOE
Parr	Carleton	10/21/2009	PARL-INB			0.1	130		0.005	0.011	1.0	5.1	NSDOE
Parr	Carleton	10/21/2009	PARL-INC			0.1	183		0.005	0.016	1.0	5.0	NSDOE
Parr	Carleton	10/21/2009	PARL-OL1			1.1	168		0.059	0.076	1.0	5.5	NSDOE
Parr	Carleton	10/21/2009	PARL-SL1										NSDOE
Parr	Carleton	9/26/2010	PARL-DS1	0.0	0.8	13.0	86	1.88	0.031	0.061	1.1	6.2	NSDOE
Parr	Carleton	9/26/2010	PARL-INA			3.4	111	1.66	0.069	0.099	1.7	6.1	NSDOE
Parr	Carleton	9/26/2010	PARL-INB			0.1	115	0.23	0.005	0.012	1.5	5.9	NSDOE
Parr	Carleton	9/26/2010	PARL-INC			6.8	72	2.65	0.028	0.057	3.9	6.6	NSDOE
Parr	Carleton	9/26/2010	PARL-OL1	0.0		3.8	80	1.58	0.029	0.054	1.6	6.2	NSDOE
Parr	Carleton	9/26/2010	PARL-SL1										NSDOE
Ogden	Carleton	7/8/1986		0.0	1.3		40		0.001	0.004	1.2	6.2	NSDL&F
Ogden	Carleton	7/2/2002		0.0	1.5	0.7	67		0.007	0.012	2.5	5.9	Eaton
Ogden	Carleton	7/2/2002		12.0			64				2.3	5.6	Eaton
Ogden	Carleton	8/27/2002		13.0			97				2.0	5.6	Eaton
Ogden	Carleton	8/14/2008	OL-DS1	0.0	1.8	10.0	39		0.005	0.014	3.0	6.1	NSDOE
Ogden	Carleton	8/14/2008	OL-DS1	9.0			45		0.008	0.018	3.0	5.8	NSDOE
Ogden	Carleton	8/14/2008	OL-DS1	18.0			152		0.051	0.097	5.0	5.9	NSDOE
Ogden	Carleton	10/21/2009	OL-IN1			1.2	164		0.043	0.076	1.1	5.5	NSDOE
Ogden	Carleton	10/21/2009	OL-OL1			0.8	140	1.14	0.047	0.066	1.6	5.8	NSDOE
Ogden	Carleton	10/21/2009	OL-SL1										NSDOE
Ogden	Carleton	9/27/2010	OL-DS1	0.0	1.0	18.8	58	4.2	0.008	0.029	1.5	6.3	NSDOE
Ogden	Carleton	9/27/2010	OL-DS1	16.0		1.8	206	5.35	0.194	0.260	11.8	7.0	NSDOE
Ogden	Carleton	9/27/2010	OL-IN1	0.0		3.8	80	1.58	0.029	0.054	1.6	6.2	NSDOE
Ogden	Carleton	9/27/2010	OL-OL1			15.6	61	4	0.006	0.029	1.5	6.2	NSDOE
Ogden	Carleton	9/27/2010	OL-SL1										NSDOE
Ogden	Carleton		OL-DS1	0.0	0.6	1.0	86		0.005	0.014	3.0	6.1	NSDOE
Ogden	Carleton		OL-DS1	9.0			45		0.008	0.018	3.0	5.8	NSDOE
Ogden	Carleton		OL-DS1	18.0			152		0.051	0.097	5.0	5.9	NSDOE
Fanning	Carleton	7/10/1986		0.0	1.6	0.0	25		0.001	0.004	1.3	5.5	NSDL&F
Fanning	Carleton	7/2/2002		0.0	1.7	1.9	63		0.007	0.011	1.0	5.9	Eaton
Fanning	Carleton	7/2/2002		9.0			62				1.8	5.7	Eaton
Fanning	Carleton	8/27/2002		0.0	3.0	3.6	34		0.001	0.008	2.1	6.2	Eaton
Fanning	Carleton	8/27/2002		9.0			97				4.8	6.0	Eaton
Fanning	Carleton	10/22/2002		5.0	2.6	2.1	33		0.001	0.012	2.0	6.1	Eaton
Fanning	Carleton	8/16/2008	FL-DS1	0.0	2.3	5.8	31		0.005	0.011	3.0	6.4	NSDOE
Fanning	Carleton	8/16/2008	FL-DS1	7.0			57		0.005	0.023	4.2	6.3	NSDOE
Fanning	Carleton	8/16/2008	FL-DS1	9.0			137		0.055	0.097	10.0	6.5	NSDOE
Fanning	Carleton	9/12/2009	FL-DS1	0.0	0.8	1.3	120		0.037	0.056	1.6	5.9	NSDOE
Fanning	Carleton	9/12/2009	FL-DS1	7.9			122		0.037	0.060	1.5	5.9	NSDOE
Fanning	Carleton	9/12/2009	FL-DS2	0.0	0.7	1.6	117		0.035	0.056	1.7	5.6	NSDOE
Fanning	Carleton	10/12/2009	FL-DS1	0.0	0.8	1.3	120		0.037	0.056	1.6	5.9	NSDOE
Fanning	Carleton	10/12/2009	FL-DS1	7.9			122		0.037	0.060	1.5	5.9	NSDOE
Fanning	Carleton	10/12/2009	FL-DS2	0.0	0.7	1.6	117		0.035	0.056	1.7	6.0	NSDOE
Fanning	Carleton	10/13/2009	FL-IN1			1.0	130		0.043	0.064	1.6	5.9	NSDOE
Fanning	Carleton	10/13/2009	FL-IN2			1.2	113		0.005	0.020	2.5	6.3	NSDOE
Fanning	Carleton	10/13/2009	FL-IN3			0.7	37		0.005	0.007	1.6	6.4	NSDOE
Fanning	Carleton	10/13/2009	FL-OL1			1.1	120		0.030	0.059	1.8	6.0	NSDOE
Fanning	Carleton	9/29/2010	FL-DS2	0.0		14.2	43	2.93	0.005	0.019	1.7	6.4	
Fanning	Carleton	9/29/2010	FL-DS3	0.0	1.2	21.9	55	2.82	0.005	0.021	1.8	6.4	NSDOE
Fanning	Carleton	9/29/2010	FL-SL1										NSDOE
Fanning	Carleton	9/29/2010	FL-SL2										NSDOE
Fanning	Carleton	9/30/2010	FL-IN1			1.9	50	1.15	0.005	0.240	1.4	6.6	NSDOE
Fanning	Carleton	9/30/2010	FL-IN2			1.9	43	0.54	0.005	0.008	2.8	6.7	NSDOE
Fanning	Carleton	9/30/2010	FL-IN3			1.1	21	0.35	0.005	0.005	1.8	6.6	NSDOE

Fanning	Carleton	9/30/2010	FL-OL1			6.5	42	2.17	0.005	0.019	1.7	6.5	NSDOE
Fanning	Carleton	9/30/2010	FL-SL1										NSDOE
Fanning	Carleton	9/30/2010	FL-SL2										NSDOE
Sloans	Carleton	7/2/1986		0.0	5.8				0.001	0.003	2.9	5.8	NSDL&F
Sloans	Carleton	7/3/2002		0.0	4.4	1.3	14		0.001	0.003	3.8	6.9	Eaton
Sloans	Carleton	7/3/2002		3.0	4.0	1.5	18		0.001	0.003	3.6	6.8	Eaton
Sloans	Carleton	7/3/2002		10.0			14				3.6	6.2	Eaton
Sloans	Carleton	7/3/2002		10.5			14				3.8	6.2	Eaton
Sloans	Carleton	8/27/2002		0.0	4.8	0.9	11		0.001	0.010	4.0	6.8	Eaton
Sloans	Carleton	8/27/2002		3.0	6.0	1.0	10		0.001	0.010	4.0	6.8	Eaton
Sloans	Carleton	8/27/2002		15.0			14				4.3	6.0	Eaton
Sloans	Carleton	8/27/2002		15.0			18				4.0	5.9	Eaton
Sloans	Carleton	10/22/2002		0.0	4.2	1.6	12		0.001	0.005	3.8	6.6	Eaton
Sloans	Carleton	10/22/2002		6.0	4.1	1.6	9.8		0.001	0.005	3.8	6.6	Eaton
Sloans	Carleton	10/22/2002		15.0			18				6.0	6.2	Eaton
Sloans	Carleton	10/22/2002		15.0			60				8.0	6.2	Eaton
Sloans	Carleton	9/9/2009	SL-DS1	0.0	3.8	1.9	20		0.005	0.005	3.2	6.9	NSDOE
Sloans	Carleton	9/9/2009	SL-DS1	8.0		0.7			0.005	0.006			NSDOE
Sloans	Carleton	9/9/2009	SL-DS1	19.0			15		0.005	0.007	3.7	6.8	NSDOE
Sloans	Carleton	9/9/2009	SL-DS2	0.0		1.8	20		0.005	0.005	3.1	6.8	NSDOE
Sloans	Carleton	9/9/2009	SL-DS2	8.0	3.8	0.7			0.005	0.006			NSDOE
Sloans	Carleton	9/9/2009	SL-DS2	16.0			14		0.005	0.005	3.4	6.7	NSDOE
Sloans	Carleton	9/9/2009	SL-IN1-200m				132			0.044	14.1	7.2	NSDOE
Sloans	Carleton	9/9/2009	SL-IN1-50m			0.1	114		0.005	0.036	12.5	7.1	NSDOE
Sloans	Carleton	9/9/2009	SL-IN6			1.2	20		0.005	0.005	3.1	6.8	NSDOE
Sloans	Carleton	9/9/2009	SL-OL6			1.2	20		0.005	0.005	3.1	6.8	
Sloans	Carleton	9/9/2009	SL-SL3										NSDOE
Sloans	Carleton	9/9/2009	SL-SL4										NSDOE
Sloans	Carleton	9/9/2009	SL-SL5										NSDOE
Sloans	Carleton	9/12/2009	SL-DS1	0.0	3.8	1.9	20			0.005	3.2	6.9	NSDOE
Sloans	Carleton	9/12/2009	SL-DS1	8.0		0.7				0.006			NSDOE
Sloans	Carleton	9/12/2009	SL-DS1	19.0			15			0.007	3.7	6.8	NSDOE
Sloans	Carleton	9/12/2009	SL-DS2	0.0	3.8	1.8	20			0.005	3.1	6.8	NSDOE
Sloans	Carleton	9/12/2009	SL-DS2	8.0		0.7				0.006			NSDOE
Sloans	Carleton	9/12/2009	SL-DS2	16.0			14			0.005	3.4	6.7	NSDOE
Sloans	Carleton	11/4/2009	SL-DS1	0.0	3.2	1.2	21			0.006	4.1	6.9	NSDOE
Sloans	Carleton	11/4/2009	SL-DS1	22.0			44			0.012	6.7	7.0	NSDOE
Sloans	Carleton	11/4/2009	SL-DS2	0.0	3.7	1.5	21			0.005	3.5	6.8	NSDOE
Sloans	Carleton	11/4/2009	SL-DS2	17.6			21			0.005	3.0	6.8	NSDOE
Sloans	Carleton	11/4/2009	SL-IN1-200m			0.1	69		0.005	0.014	4.1	6.7	NSDOE
Sloans	Carleton	11/4/2009	SL-IN1-50m			0.1	67		0.005	0.014	3.4	6.7	NSDOE
Sloans	Carleton	11/4/2009	SL-IN6			1.6	22		0.005	0.005	3.5	6.8	NSDOE
Sloans	Carleton	11/5/2009	SL-SL3										NSDOE
Sloans	Carleton	11/5/2009	SL-SL5										NSDOE
Sloans	Carleton	9/30/2010	SL-DS1	0.0	4.3	1.8	12	0.32	0.005	0.009	3.7	7.0	NSDOE
Sloans	Carleton	9/30/2010	SL-DS1	14.0		0.7	18	0.35	0.005	0.007	4.7	6.9	NSDOE
Sloans	Carleton	9/30/2010	SL-DS2	0.0	4.3	1.9	10	0.27	0.005	0.005	3.6	7.0	NSDOE
Sloans	Carleton	9/30/2010	SL-DS2	9.0		1.4	15	0.32	0.005	0.005	4.0	6.8	NSDOE
Sloans	Carleton	9/30/2010	SL-DS2	15.0		1.1	23	0.89	0.005	0.007	4.2	6.8	NSDOE
Sloans	Carleton	9/30/2010	SL-OL6			3.0	12	1.2	0.005	0.005	3.9	7.0	NSDOE
Sloans	Carleton	9/30/2010	SL-SL6										NSDOE
Vaughan	Carleton	7/31/1979		0.0	2.8		25				2.0	6.0	NSDL&F
Vaughan	Carleton	9/4/2008	VL-DS1	0.0	3.0	3.9	22		0.005	0.005	3.0	7.2	NSDOE
Vaughan	Carleton	9/4/2008	VL-DS1	9.5			94		0.005	0.012	8.1	6.3	NSDOE
Vaughan	Carleton	9/4/2008	VL-DS1	14.0			148		0.005	0.045	9.1	6.3	NSDOE
Vaughan	Carleton	10/27/2009	VL-DS1	0.0	0.9	1.3	88		0.014	0.033	1.8	6.2	NSDOE
Vaughan	Carleton	10/27/2009	VL-DS1	18.5			88		0.016	0.034	1.9	6.2	NSDOE
Vaughan	Carleton	10/27/2009	VL-DS2	0.0		0.5	180		0.005	0.015	1.0	4.7	NSDOE
Vaughan	Carleton	10/27/2009	VL-IN1			0.9	94		0.014	0.034	1.8	6.2	NSDOE
Vaughan	Carleton	10/27/2009	VL-IN2			0.4	104		0.005	0.014	1.0	4.6	NSDOE
Vaughan	Carleton	10/27/2009	VL-OL1			0.5	175		0.006	0.022	1.0	4.8	NSDOE
Vaughan	Carleton	9/29/2010	VL-SL1										NSDOE
Vaughan	Carleton	9/29/2010	VL-SL2										NSDOE
Vaughan	Carleton	9/30/2010	VL-DS1	0.0	1.2	2.8	69	1.13	0.018	0.018	1.6	6.2	NSDOE
Vaughan	Carleton	9/30/2010	VL-DS1	12.0		0.0	181	14.9	0.043	0.078	8.9	7.1	NSDOE
Vaughan	Carleton	9/30/2010	VL-DS2	0.0	1.8	1.5	120		0.005	0.019	1.0	5.5	NSDOE
Vaughan	Carleton	9/30/2010	VL-IN1			2.5	33	0.86	0.005	0.014	1.9	6.5	NSDOE
Vaughan	Carleton	9/30/2010	VL-OL1			0.5	121	0.75	0.005	0.017	1.0	5.2	NSDOE

Appendix IIB - Biological Parameters

Lake	Date	Station	Total Coliforms (#/100ml)	Fecal Coliforms (#/100 ml)	Microcystins (ug/ml)	BGA (cells/ml)	Microcystis*	Anabaena*	Aphanocapsa	Oscillatoria*	Pseudoanabaena	Aphanothece	Gomphosphaeria	Spirulina	Aphanizomeneon*	Planktolyngbya	Aphanocapsa	Gomphosphaeris
Provost	08/27/08	PROL-SL1			<0.02	492		484							8			
Provost	10/27/09	PROL-SL1	>200	4	<0.20	10					10							
Provost	10/01/10	PROL-SL1	1095	<2	<0.20	38		8			30							
Nowlans	08/28/08	NL-SL			<0.20	98100	840	1620							608	2		
Nowlans	08/28/08	NL-SL1			0.30	104000	28600	1230							272			73500
Nowlans	10/15/09	NL-SL1	1040	38	<0.20	120000					30				120000	20		
Nowlans	09/26/10	NL-SL1	300	57	<0.20	24800	21600				74				3200			
Nowlans	08/28/08	NL-SL2			0.30	78800	16200	704							638			
Nowlans	10/15/09	NL-SL2	613	15	<0.20	127000									122000		5000	
Nowlans	09/26/10	NL-SL2	1553	40	0.34	57600	54100								3570			
Nowlans	08/28/08	NL-SL3			0.30	95600	17600	2000							640			75400
Nowlans	10/15/09	NL-SL3	411	9	<0.20	175000									175000			
Nowlans	09/26/10	NL-SL3	1414	36	0.66	16200	12400	20							3750			
Nowlans	09/26/10	NL-SL4	>2419	86	<0.20	12300	9670	32			124				2460			
Hourglass	08/27/08	HL-SL1			<0.20	48									48			
Hourglass	10/20/09	HL-SL1	120	<2	<0.20	33										33		
Hourglass	09/26/10	HL-SL1	488	7	<0.20	6				6								
Placides	08/27/08	PLAL-SL1			<0.20	64									64			
Placides	10/21/09	PLAL-SL1	1414	56	<0.20	424					65					359		
Placides	09/27/10	PLAL-SL1	517	101	<0.20	0												
Porcupine	08/28/08	PORL-SL1			<0.20	56				56								
Porcupine	10/27/09	PORL-SL1	>200	1	<0.20	2										2		
Porcupine	09/27/10	PORL-SL1	>200	12	<0.20	20					20							
Parr	09/04/08	PARL-SL1			<0.20	2220			824						1390			
Parr	10/22/09	PARL-SL1	146	1	<0.20	267					98				6	163		
Parr	09/27/10	PARL-SL1	731	<2	<0.20	102		22						80				
Ogden	08/15/08	OL-SL1			<0.20	1210		940		16					256			
Ogden	10/22/09	OL-SL1	187	3	<0.20	195					130					65		
Ogden	09/28/10	OL-SL1	182	2	<0.20	2480		2480										
Fanning	08/28.08	FL-SL1			<0.20	128		24		32					72			
Fanning	10/15/08	FL-SL			<0.20	5160		5140								17		
Fanning	10/13/09	FL-SL1	291	3	<0.20	5									1	4		
Fanning	09/30/10	FL-SL1	461	3	<0.20	7340		6940	20	372								
Fanning	10/12/10	FL-SL2	462	2	<0.20	14000		14000										
Sloans	09/09/09	SL-NB			<0.20	3880					125	1250						2500
Sloans	09/09/09	SL-SB			<0.20	5110					16	2500				97		2500
Sloans	11/05/09	SL-SL3	115	6	<0.20	100						100						
Sloans	09/09/09	SL-SL4	139	6	<0.20	2070						1250				500		324
Sloans	11/05/09	SL-SL4			<0.20	100												30
Sloans	09/10/09	SL-SL5	117	4	<0.20													
Sloans	11/05/09	SL-SL5	30	0	<0.20	216			50						4			162
Sloans	10/01/10	SL-SL6	977	2	<0.20	278			80		108	20	70					
Vaughan	09/05/08	VL-SL1			<0.02	408									408			
Vaughan	10/28/09	VL-SL1	>200	5	<0.20	0												
Vaughan	09/30/10	VL-SL2	>2419	12	<0.20	26				8	18							
Vaughan	09/30/10	VL-SL1	597	122	<0,20	0												

*Genera known to contain microcystin producing species.