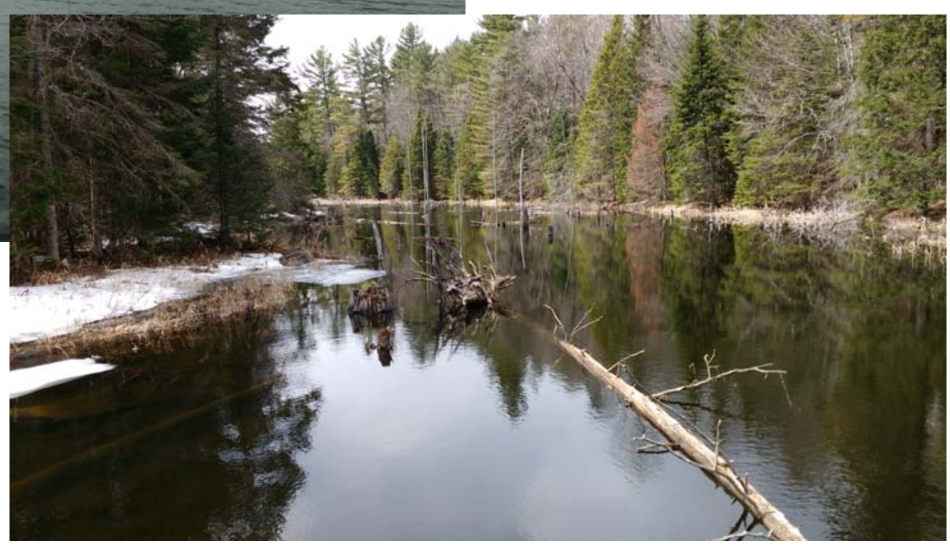
WHITE LAKE PRESERVATION PROJECT

REPORT

Water Quality Monitoring Program 2016



Late Summer Wild Rice on the White Lake Village Basin

Spring at Boundary Creek, Wabalac Road, North West Shore

ABSTRACT

White Lake waters were monitored for 10 different physical and chemical parameters. Nine sites representing all parts of the lake were sampled every two weeks from May through October. The results show that the presence of zebra mussels has altered the chemistry of the lake. Of particular interest is the significant increase in water clarity resulting from the filtering effect of zebra mussels. The total phosphorous levels measured in the lake water decreased by about 40 percent when compared to values obtained last year. There is no evidence that there was less phosphorous entering the lake in 2016 as compared to previous years. The much lower levels of total phosphorous found in the lake during the 2016 season is due to the explosion of zebra mussel populations throughout the lake. Lower phosphorous levels are entirely due to the transfer of phosphorous from the water column to the sediments by zebra mussels, a process which encourages green and blue-green algal blooms to occur. Although there were no significant algal blooms observed in 2016, the effects of zebra mussels as well as climate change are only two of the multiple stressors affecting White Lake which, taken together, make the lake more susceptible to algal blooms due to human activity.

Overview

Many people ask us to describe the condition of White Lake in a word. They ask if it is in good condition or in only fair condition. Although it would be expedient to do so, these terms are subjective, have little meaning, and cannot be used to paint a complete picture which is in reality much more complex. Our objective is to collect valid data in a systematic and scientific manner, to interpret these data and in turn inform you of changes taking place over time. We publish all of our raw data and invite anyone to suggest alternate interpretations. This is how science works. The word '*Preservation*' looms large in our organizational name because one of our main objectives is to work to keep the lake in as pristine a condition as possible.

The data collected during the 2015 ice-free season showed that the quality of White Lake waters progressed from Mesotrophic (moderately enriched, some nutrients) to Eutrophic (enriched, higher levels of nutrients) during the summer season. These observations were in general agreement with historical data collected over many years. However, the data we collected was more extensive and systematic than any data collected in the past. Recent toxic algal blooms spurred us to study the lake in more detail than ever so that we could gain insight into the cause and control of these algal blooms, which is are public health issue.

This year White Lake experienced an explosion in populations of zebra mussels, with numbers estimated to be up to one billion individuals. Zebra mussels have been found in every part of White Lake and are especially prevalent attached to aquatic plants.

The most obvious effect of the presence of zebra mussels is the greatly increased clarity of the lake. Looking back at 2015 and years previous, such a finding would have been welcomed as an improvement in water quality. However, attendant effects of zebra mussels are serious and transformative. Zebra mussels are filter feeders and in the numbers present in the lake, the entire volume of White Lake can be filtered by them in less than a week. The net effect is the virtually wholesale (~90%) transfer of nutrients from lake waters to the sediments. This has resulted in a significant change in water chemistry and biology and marks a new era in the life of White Lake. What is taking place is an irreversible change.

The report following this introduction details all of the changes we have measured and the interpretations we put forward. Not everyone will want to read and assimilate all of the information detailed in this report. In short; the water clarity has increased almost two-fold, the lake has become more acid, calcium levels have decreased, total phosphorous levels have decreased significantly, and the amount of chlorophyll-a present (a measure of phytoplankton populations) has crashed. White Lake is currently in the process of changing and will equilibrate to a new state over the next several years.

At present, we do not know what the final state of White Lake will be with respect to zebra mussels and their effect on water quality because every lake is unique with respect to available nutrients, physical and chemical conditions. However, there is ample scientific literature for us to use to predict some of the changes that will take place (see Bibliography at end of report). At best, we will have to become accustomed to the presence of zebra mussels as a common nuisance and at worst we will have to deal with more frequent toxic algal blooms. Only time will tell what the effects of zebra mussels will be on White Lake. For more information on the possible outcomes resulting from the presence of zebra mussels, please read section 13.0 of the full report. We may take some consolation in the fact that there are numerous water bodies in our area which have had zebra mussels for many years and this has not substantively diminished the enjoyment people derive from the Canadian 'cottage experience'.

The Science Committee and the WLPP value your opinions and suggestions and welcome any comments or questions you may have concerning this report, its contents or any of our other activities. There is an anonymous suggestions box setup for your convenience on the WLPP website main page at: www.WLPP.ca or you may contact us directly at WLPPmail@gmail.com.

Science Committee:
(*Conrad Grégoire, Stephanie Medwenitsch, Susan Munro, David Overholt, Adam Pugh, Peter Raaphorst*)
White Lake Preservation Project
January, 2017


Water Quality Monitoring Program Report
2016

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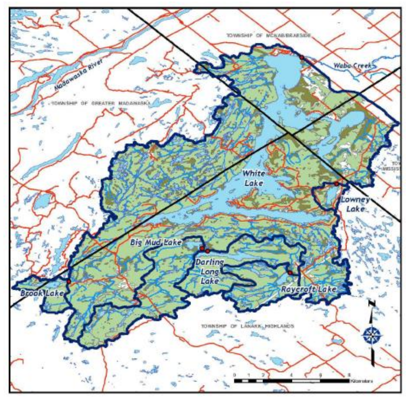
WHITE LAKE PRESERVATION PROJECT

Water Quality Monitoring Program
2016
Results and Discussion

Science Committee, WLPP



1.0 <u>Introduction and Summary of Results</u>: The quality of the water in White Lake is of great importance to anyone wishing to use the lake for recreational purposes and also for the maintenance of a healthy ecosystem including fisheries. The long term monitoring of water quality will provide a record of how the lake is changing with time. The effects of climate change, increasing use by humans and the influence of invading species on White Lake need to be recorded so that we can take whatever actions are required to ensure the long term health of the lake.

White Lake is characterized as a shallow warm water lake. The drainage basin (pictured in the map above) is relatively small compared with the total area of the lake. The North western and part of the Southern shores of the lake is comprised mainly of pre-Cambrian (acidic) rocks whereas the remainder of the shoreline and the rocks under the lake are calcium rich in nature (basic). It is the calcium rich rocks that give the lake its chemical signature with a basic pH and high calcium content. Both of these factors strongly favour the growth of zebra mussels, an invasive species which has now been observed in great numbers in all parts of White Lake.

An examination of the drainage basin map in concert with topographical maps reveals that the parts of the lake located near the pre-Cambrian rocks are fed by surface and ground waters emerging from heavily forested and hilly terrain. The remainder of the lake, including areas starting at Hayes Bay and stretching through the Canal, the Narrows and finally the White Lake Village Basin is surrounded by deforested landscape including some farms.

The forested areas, which include numerous beaver dams and ponds, serve as a buffer storing much of the water falling as rain or melting from snow. Trees also have a significant uptake of water during the growing season. On the other hand, the remainder of drainage basin comprising deforested landscape offers little or no storage of water above the natural water table. In parts of the lake which are surrounded by dense forest, and which also contains the deepest waters, rain and runoff reach the lake at a slower pace relative to the deforested areas. As a consequence of this, the shallowest parts of the lake including parts of the Canal and areas leading to and including parts of the White Lake Village Basin receive rain and snow melt surface waters as well as ground water infiltration (up through the bottom of the lake) at a much higher rate especially after a weather event such as heavy rains.

The net effect on lake water changeover is that waters located in Three Mile Bay, Sunset Bay and areas almost up to the Narrows are held back by the more rapid drainage of shallow areas of the lake. Very much like a car parked farthest away from the exit in an underground parking lot, the entire lot has to empty before that car can also exit. The waters contained in Three Mile Bay, especially, are like that car and thus likely have a higher residence time in the lake than most other parts of the lake. Since Three Mile Bay is one of the most populated and heavily used parts of the lake, special care must be taken by cottage owners and residents there to preserve water quality. The data presented below support these observations.

One of the more important findings reported last year was that no single part of the lake can be taken to represent the entire lake. Each sampling site (with the exception of the three shallow sites discussed below) exhibited similar but significantly different behaviour when comparing phosphorous concentrations and other factors. Taken together, the different sampling sites and their relative locations on the lake reveal a pattern showing that much of the phosphorous entering the lake stays in the lake and finds it way into the sediments. The accumulation of phosphorous in sediments increases as one travels on White Lake from North to South from The White Lake Village Basin towards Three Mile Bay. In theory, White Lake could be divided into as many as five separate zones with each zone exhibiting different chemical behaviours. These zones would be connected by areas where mixing takes place, for example, at the Jacobs Is. site just south of the narrows leading to the White Lake Village Basin. The data presented in this report support this finding. A map showing these zones is presented in this report. This means that when considering development options or other activities on the lake such as boating, we need to consider individual locations and their specific characteristics and cannot rely on generalized data or observations that relate more to other parts of the lake or no part of the lake at all.

An important source of information on White Lake which is currently in draft format is the State of the Lake report produced by the White Lake Steering Committee. We highly recommend reading this report in conjunction with this one in order to obtain a true picture of White Lake. The draft report is posted on the WLPP website at www.WLPP.ca

2.0 **Point Form Summary of Main Findings**:

1. Zebra mussel populations have greatly increased during the 2016 ice free season.

2. The clarity of the lake has nearly doubled compared to previous years.

3. When compared to previous years, the total phosphorous concentration in the water column has declined by over 30%.

4. As in previous years, the highest concentrations of total phosphorous were measured at Three Mile Bay and North Hardwood Island sites.

5. Chemical parameters such as calcium, pH, specific conductance, chlorophyll-a, dissolved oxygen, and total alkalinity have all dramatically changed (decreased) when compared to data from previous years.

6. All of the changes noted above are not indicative of improvements in lake water quality, but are the changes which have occurred as a result of the presence of zebra mussels.

7. Even though 2016 was significantly drier (less rain) than 2015, the warming and cooling patterns of the lake water are very similar and also agreed with the temperature profile obtained in 2014.

8. In terms of lake chemistry and physical conditions, the lake can be divided into 5 zones. The southern part of White Lake from Fisher's Point south to Sunset Bay (encompassing the main water body of the lake and about 80% of the volume of the lake) acts as a separate lake. The remaining zones of the lake, which include all of the shallow areas, cannot mix with the main water body since there is only a single outlet for waters leaving White Lake.

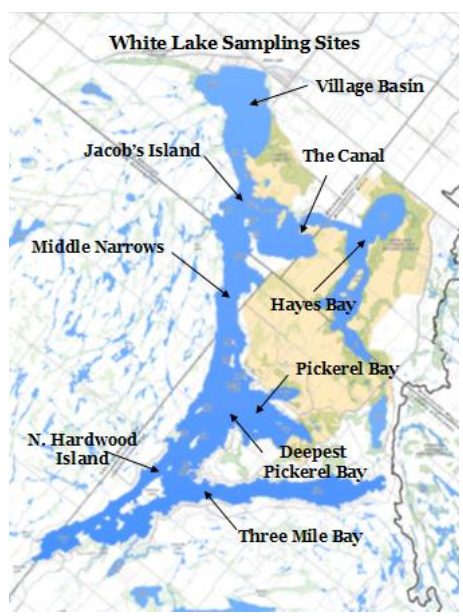
9. There were no dangerous or nuisance algal blooms observed in 2016.

10. The analysis of changes in water chemistry and water clarity resulting from the presence of zebra mussels in White Lake suggest that the popular 'Trophic Levels' suggested by the Ontario Handbook for Lake Capacity Studies no longer can be used to describe the condition of White Lake. A more scientific and studied approach is required.

3.0 Water Quality Monitoring Program:

The water quality monitoring program for 2016 consisted of two parts. The first part was carried out by WLPP volunteers and involved the collection of water samples mid-month for 6 months starting in May. Nine specific sampling sites were monitored covering all parts of White Lake. In addition to adding the Hayes Bay and Village Basin sites in 2016, we also added the Deepest Pickerel Bay site so that we would always have a site at which we can measure the Secchi depth, no matter how clear the water becomes as a result of the presence of zebra mussels. This site is located over the deepest spot on the lake at 9.0 m. Duplicate water samples were collected for phosphorous analysis and a single separate sample was collected for calcium analysis. Water samples were filtered through an 80 micron mesh to remove any suspended particles and biota. Note that the total phosphorous data obtained is for available and free phosphorous (there are several phases of phosphorous suspended and in solution) and does not reflect the phosphorous bound in suspended living or dead organisms, which is filtered out. Secchi depth readings as well as temperature at the Secchi depth were recorded at the same time. Additionally, Secchi depth and temperature readings were taken every two weeks during the summer season providing additional data for these parameters.

All water samples for the determination of phosphorous content were shipped to the Dorset Environmental Science Centre (Ontario Ministry of the Environment and Climate Change) for analysis under the auspices of the Lake Partners Program. The method used for the determination of phosphorous is described in the publication: B.J. Clark et al, *Assessing variability in total phosphorous measurements in Ontario lakes*, Lake and Reservoir Management, 26:63-72, 2010. The limit of detection for phosphorous using this method is 0.2 parts per billion (ppb).



The second sampling protocol was carried out under contract with the Mississippi Valley Conservation Authority (MVCA). Transportation to sampling sites on the lake was provided by WLPP volunteers. Sampling was carried out on three days mid-month in June, July and August. In addition to Secchi depth, readings were taken at metre or half-metre intervals for temperature, dissolved oxygen, specific conductance, and pH. Water samples were also taken for chlorophyll-a and alkalinity measurements. A separate report has been generated by the MVCA which is available on the WLPP website at www.WLPP.ca.

The results obtained from this study differed considerably from those obtained by the same program in 2015. Water clarity was very high with a maximum Secchi depth greater than 7 m being recorded. The pH of the lake indicated that waters were alkaline but decreased in pH as the season progressed. The alkalinity or hardness of the water and the electrical conductivity of the water also decreased with time. This trend was not observed in 2015 and these parameters were nearly constant throughout the ice-free season. Chlorophyll-a values essentially collapsed to levels which were at or near the limit of detection for the analytical method used. The scientific literature reports that when a zebra mussel infestation occurs, phytoplankton population in the water column can be reduced by more than 90%. Since White Lake is a relatively large but very shallow lake, the surface area on which zebra mussels can thrive is large when compared to the total volume of water contained in White Lake. For this reason, it is more likely that phytoplankton populations were almost totally removed as would not be the case for a much smaller and deeper lake. For all of the sampling sites, dissolved oxygen content was adequate to support the species of fish found in White Lake. However, dissolved oxygen values were lower in 2016 than during 2015 which may also be a consequence of the presence of zebra mussels using oxygen for respiration.

One important finding we highlighted in our 2015 report was that an important source of phosphorous entering White Lake during the summer months originates from sediments releasing previously bound phosphorous into the water column. In shallow areas, this could result from wind and wave mixing and boating activities. In deeper areas, anoxia in the upper sediment layers results in the dissolution of bound phosphorous and release via diffusion to the waters above. This phenomenon is common in lakes such as White Lake and is partly responsible for increasing phosphorous concentrations during the summer to levels above those considered eutrophic. This finding does not in any way diminish the importance of phosphorous coming from septic systems which is known to be a major source.

This year, the major changes occurring in White Lake are caused by the establishment of zebra mussels in all parts of the lake. White Lake is now in a period of transition lasting several years where the water chemistry is changing, phytoplankton concentrations are diminishing and aquatic plant growth is likely to increase. The renewed possibility of toxic algal blooms is present since zebra mussels favour the propagation of mycrocystis blue green algae which is one of the species of algae which produces toxins harmful to humans as well as all creatures living in the lake. Another change which we may notice over the summer months is the increased presence of Cladophora algae. This alga is green and hair-like and found in patches along the shoreline. Continued monitoring of the lake is required as is affirmative action by residents, cottagers, interested parties and the Councils for the four municipalities governing White Lake.

The changing climate tending towards warmer and longer summers (and ice-free periods) means that everyone using the lake, be they cottagers, permanent residents, campers, or casual users need to increase vigilance and care to ensure that their septic systems are working properly and that they use the lake in a sustainable manner. Protecting the shoreline and maintaining a healthy ‘zone of life’ are also very important factors in preserving White Lake.

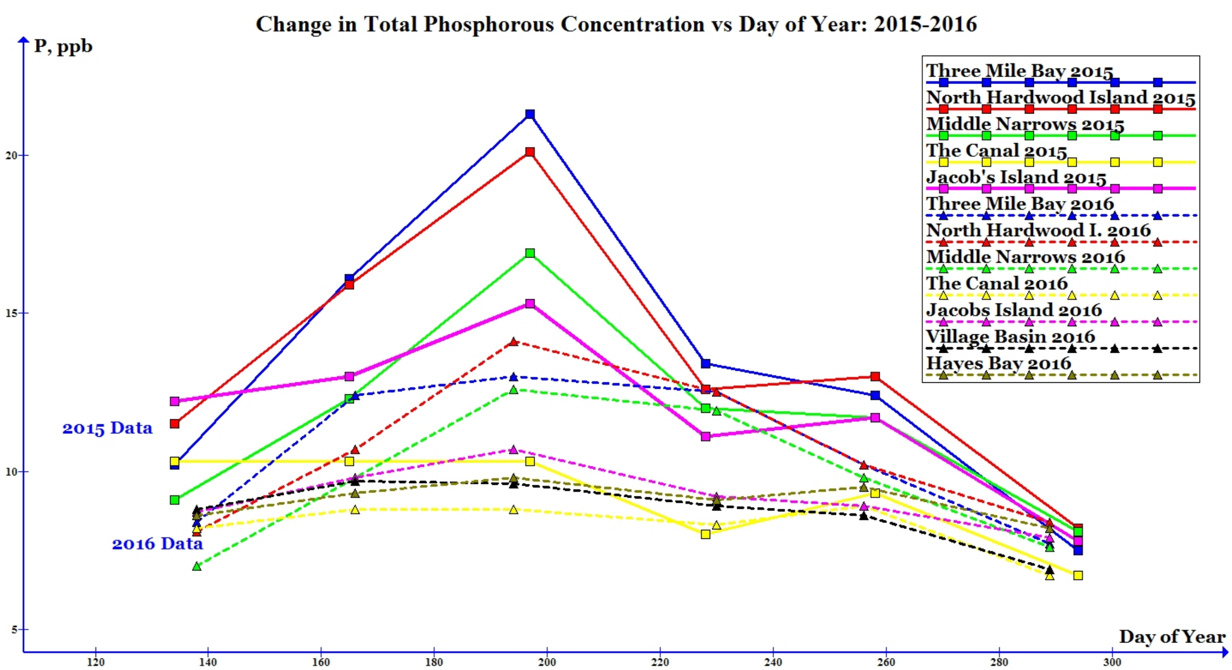
Note: The sections that follow below are more technical in nature and form the basis of the conclusions presented above.

4.0 **Phosphorous**

The graph below shows the change in total phosphorous concentrations during the ice-free season for 2015 and 2016. The 2016 data is shown as triangles connected with a dashed line.

The data for 2015 show an increase in the total phosphorous concentration over the summer months reaching a peak or highest value in mid-July. After this date, the total phosphorous concentration decreases significantly. These data also show that the highest total phosphorous values are obtained at the southern part of the lake nearest Three Mile Bay. These results and trends are in agreement with measurements made in previous years.

The data for 2016 show the same trend with waters increasing in total phosphorous concentrations as the sampling date approached mid-July. The main difference when comparing results from 2015 and 2016 is the marked decrease in total phosphorous concentrations. Total phosphorous concentrations are reduced by more than a third in 2016 as compared to 2015 results. Before explaining the root cause and meaning of this decrease, a discussion of the nature of total phosphorous concentration levels may be useful.



At any given time, phosphorous is entering the lake from a variety of sources including the atmosphere, surface runoff, ground water ingress, sediment back loading, septic systems, etc. At the same time, phosphorous is leaving the water column as it is taken up into living organisms, precipitated as part of an insoluble compound, etc. The total phosphorous concentration measured in lake water at any given time is the balance between the rates of phosphorous entering and leaving the water column. Starting in April and continuing until mid-July, the total phosphorous concentration in the lake steadily increases. This, in turn, means that the amount of phosphorous entering the water column *exceeds* the amount of phosphorous leaving the water column. In mid-July, the total phosphorous concentration reaches a maximum and at that point in time the rate of phosphorous entering the lake water is equal to and balanced by the rate of phosphorous leaving the water column. Beyond mid-July, the total phosphorous concentration in the lake water steadily decreases indicating that the rate of phosphorous input into the lake is *less* than the rate of loss of phosphorous from the water column.

Returning now to the results obtained for total phosphorous in 2016: One might be tempted to explain the sudden decrease in total phosphorous levels to lower levels (compared to previous years) of phosphorous input into the lake. Unfortunately, there is no evidence to support this assertion. More likely, however, is the introduction of a new pathway by which phosphorous is removed from the water column and it is this phenomenon which results in lower overall total phosphorous measurements.

The explosion of zebra mussel populations in White Lake during the 2016 season explains why total phosphorous levels have decreased significantly over previous years. Zebra mussels reportedly (see references) remove over 90% of the phytoplankton normally found in an unaffected lake. Zebra mussels are efficient at removing phosphorous from the water column and transferring it to sediments via feces and pseudo-feces. It is also reported that the concentration of soluble reactive phosphorous remains unchanged allowing for further phytoplankton production. The phosphorous transferred to sediments by zebra mussels eventually becomes available for algae growth and may result in an increase in both green and blue-green algal blooms in the future.

The shape of the phosphorous vs. day of year curves shown in the graph above can be explained by the effect of sediment or back loading of phosphorous formerly bound in sediments which are released back into the water column.

Although the concentration of phosphorous in lake water is measured in the low tens of parts per billion (ppb), the concentration of phosphorous in the sediments occurs in the parts per million (ppm) range. This means that the concentration of phosphorous in the sediments is literally thousands of times greater than that found in the waters above them. The waters of White Lake have a very low turnover, estimated to less than 0.9 times per year. Thus, phosphorous entering the lake by whatever means is efficiently sequestered by living organisms which in turn die and settle to the bottom of the lake. Lake sediments become the phosphorous reservoir for White Lake, with those sediments holding the accumulation of most of the phosphorous entering the lake over many centuries, or even thousands of years.

Oxygen levels in water and sediment contribute greatly to the availability of phosphorous for phytoplankton and algal growth. Phosphorous bound in sediments, organic sediment particles or chemically bonded to inorganic species such as iron only remain chemically bound if there is sufficient dissolved oxygen present. When oxygen becomes depleted due to consumption by rotting vegetation, for example, a change in redox (reduction/oxidation) potential in the sediment takes place which creates chemical conditions favouring the release of phosphorous (reducing conditions) back into the lake water above. When this happens, however, not all of the phosphorous is available for mixing with the water column above. Some of the phosphorous is tightly bound and remains that way. However, a significant portion of the phosphorous does become mobile. For White Lake, sediments will hold their phosphorous unless there is a mechanism in place by which it can be released. The scientific literature suggests that phosphorous in about the first 18 to 20 centimetres of sediment is available for reintroduction in to the water column under the right conditions.

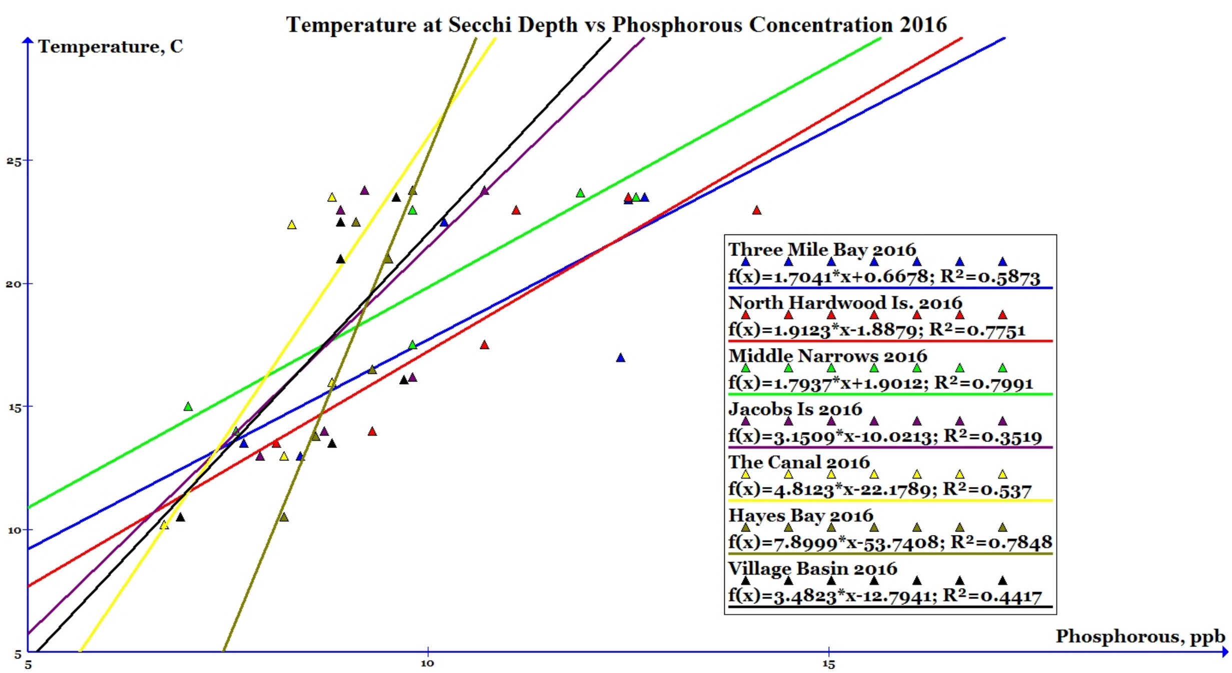
The interface between the bottom water of White Lake and the sediment is not as distinct or as sharp as one would imagine for a sandy-bottomed lake (White Lake has a muddy bottom). Organic matter settling out of the water column is generally in a very fine particulate form. When these particulates reach the bottom of the lake, they form an unconsolidated layer of what could be described as dense 'smoke' increasing in density as one moves further down the sediment column. Over time, and with the arrival of more material settling out of the water column, these sediments become more compacted and dense. The nature of White Lake bottom sediments, as described above, was verified by scuba diving during the summer of 2015.

Anoxic (no dissolved oxygen) conditions were not detected in White Lake waters during measurements taken during the ice-free months of 2016. However, during these measurements, if the oxygen measuring probe was lowered into the initial layers of sediment, the oxygen content did drop considerably, especially in Three Mile Bay. This observation may mean that in the unconsolidated layer of sediments, phosphorous could exist in a weakly bound or even free state. Movement of any free phosphorous out of this layer and into the water column could occur by such processes as diffusion within the sediment layers. Displacement of this phosphorous into the water column could also occur as a result of wind and waves and the disturbance of bottom water/sediment by the underwater wake created by outboard motors especially in shallow areas.

The data reported (below) for temperatures taken down the water column shows that after the first week of June, water temperatures are uniform from the surface of the lake to the bottom of the lake at all sampling sites. This efficient mixing of waters to produce uniform temperatures is due to conduction of heat through the water column and diffusion (convection) whereby water molecules can move to equalize temperatures. In short, the same mechanism(s) responsible for efficiently thermally mixing the water column could also be responsible for remobilizing loosely bound or free phosphorous from the unconsolidated lake sediment layer.

The release of phosphorous from sediments is also accelerated by an increase in water temperature over the summer season. During that time, bottom waters increase in temperature by about ten degrees. The rate of chemical reactions (such as those releasing phosphorous from sediments) roughly doubles for each 10 degree rise in ambient temperature. So we can expect that over the course of the summer, the rate of phosphorous released to the water column will also double further increasing the total amount of free phosphorous available to lake waters. The effects of diffusion and microbial action in sediments will also increase accordingly with increases in temperature.

Evidence for sediment or back loading of phosphorous is supported by the significant correlation between the water temperature (taken at the Secchi depth) and total phosphorous concentrations.

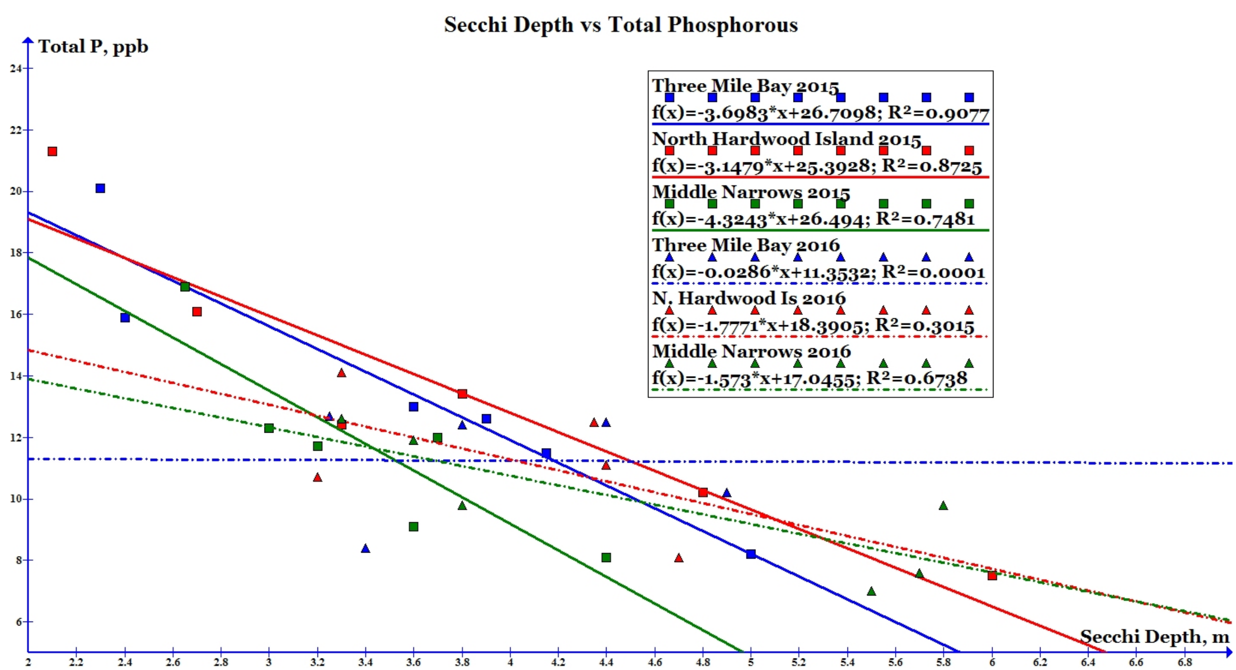


The graph above shows a high correlation between these two parameters as expressed by the **R^2** value, known as the correlation coefficient This value is calculated using the mathematical correlation equation shown in the legend (below each site name) of the above graph. Similar values were calculated for the corresponding 2015 data and are cited in our report posted on www.WLPP.ca.

Similar and high correlation coefficients are also obtained in 2015 for correlation plots of Secchi depth with total phosphorous. Below is a plot of this data plus data obtained during the 2016 field season. Whereas in 2015 these plots yielded correlation coefficients ranging from .75 to .91 (very high) for the deep water sites, similar values for these same locations in 2016 yielded correlation coefficients ranging from 0.0 to 0.7 (for the Middle Narrows Site). The collapse in the values for correlation coefficients is likely due to the presence of zebra mussels in White Lake.

In past years, the concentration of total phosphorous in the water column was directly related to the quantity of plankton produced which had the corresponding effect on the clarity of water in White Lake. At present, the clarity of White Lake is no longer closely related to total phosphorous concentration and is likely now more closely linked to the filtering capacity of the zebra mussel population at any given location on the lake.

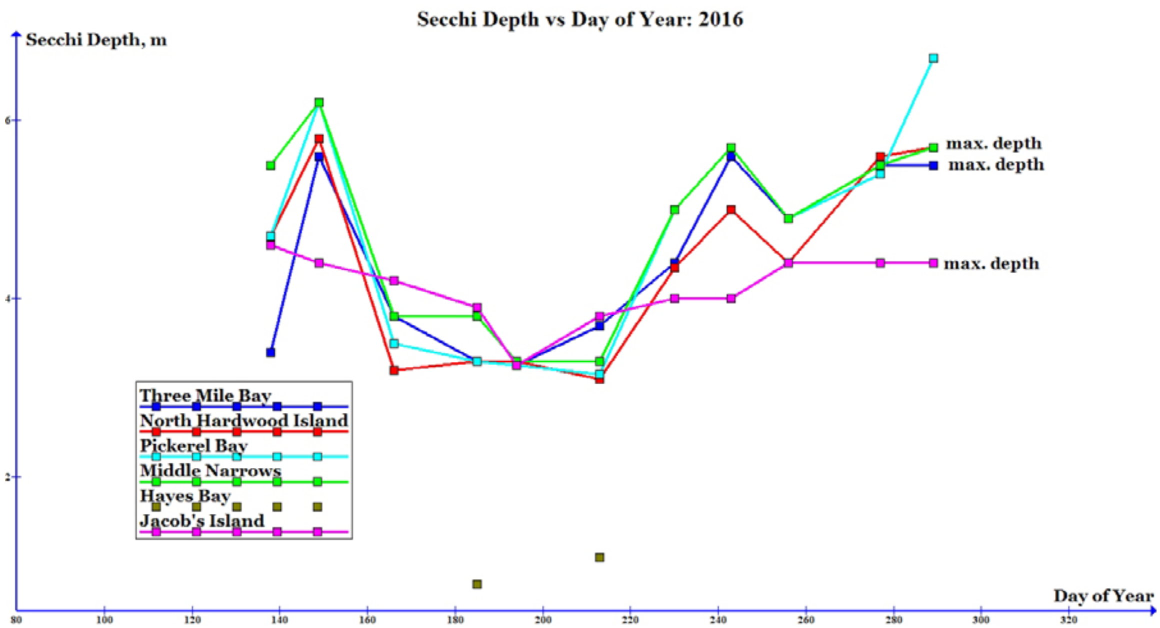
This development brings into question the value of continuing to use the 'Trophic Level Scale' as described in the Ontario Handbook for Lake Capacity Studies.



5.0 Secchi Depth

Secchi depth measurements provide a measure of the clarity of the water column. Measurements are taken with a disk approximately 12 inches in diameter sectioned off into two white and two black quadrants. The depth at which the disk disappears from view is the Secchi depth and is one half of the distance that sunlight is capable of penetrating into the water column.

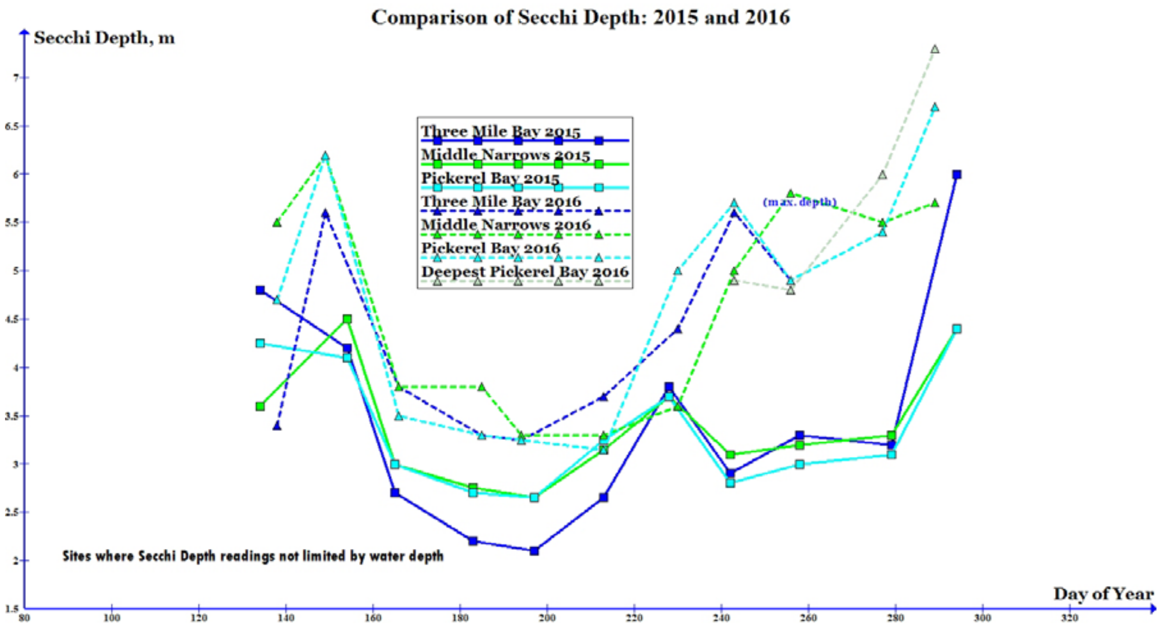
Below is a graph of the Secchi depth readings taken for White Lake during the 2016 field season. Note that there are no Secchi depth readings for shallow sites which only on two occasions had Secchi depths not exceeding actual water depth.



The annual Secchi depth profiles for 2016 followed a pattern similar to that of 2015. At the beginning of the summer, the Secchi depth increased sharply at the May 28 sampling date, a phenomenon observed also in 2015. This increase in Secchi depth may have been caused by the mixing of deeper cooler waters low in phytoplankton content with warmer surface waters. We know from temperature readings that this occurs on or about June 1 of each year.

As the summer progressed, the Secchi depth decreased as phytoplankton populations increased and then began to increase again after July 12. There was some loss in water clarity on September 12 followed by increasing clarity. There were also two Secchi depth readings for Hayes Bay where the water depth is only 1.6 m. These two very low readings are shown on the bottom of the graph as two isolated (brown) data points. On these two occasions, Hayes Bay waters were cloudy and murky. The Secchi depth reading of 0.8 m on July 3 was caused by a single motor boat we observed pulling an inflatable tube in circles within the bay. A minimum Secchi depth reading of 0.8 m and a maximum of 7.3 m were recorded during the 2016 field season.

Although the patterns of Secchi depth readings taken at each site over the summer were not unusual, the absolute values obtained as well as the timing of the marked increase during the summer months was very different than in previous years. The differences between 2016 and 2015 Secchi depth readings are clearly visible on the graph below. The dashed lined curves are for data obtained during 2016 and the solid lines for data obtained in 2015.



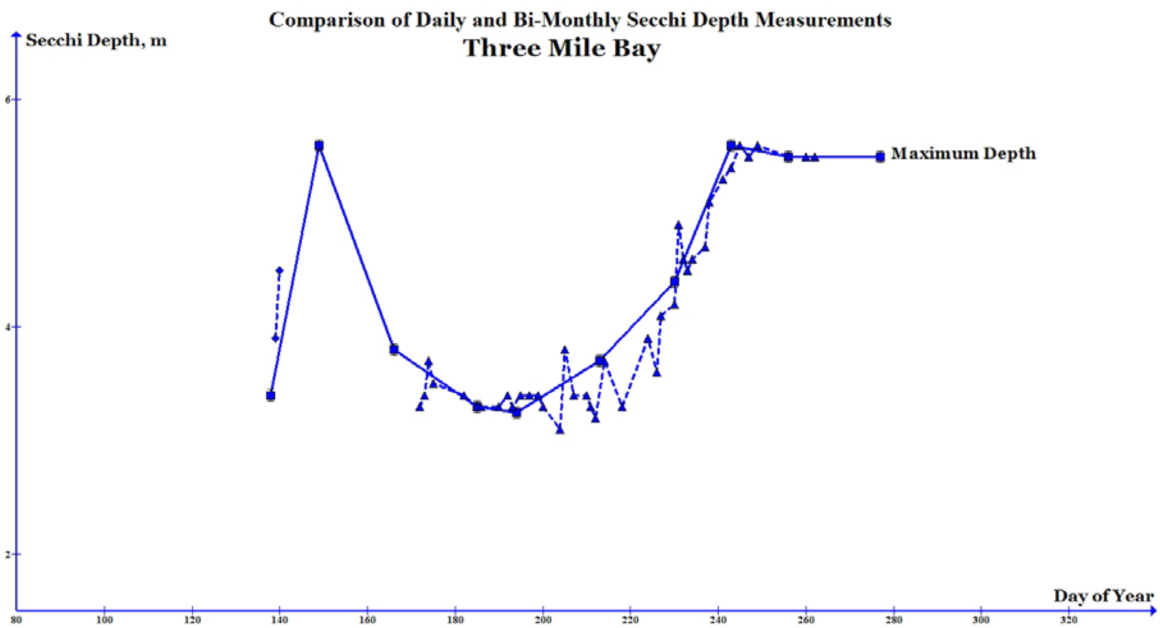
Although the general pattern formed by the graphs have the same shape, it is clear that throughout the year Secchi depths were much higher in 2016 than they were in 2015. Also, the rise towards much greater Secchi depths occurred much earlier in the year as compared to 2015. The increased clarity of White Lake was evident to most cottagers and boaters we spoke to and signalled a significant change in the character of White Lake. This increased clarity is attributed to the explosion in the numbers of zebra mussels (see section on zebra mussels) growing in White Lake. Whereas there were only a few zebra mussels detected in the lake during the fall of 2015, we calculate that there are now hundreds of millions present. Each one is capable of filtering from 1 to 1.5 L of water per day which means that the entire volume of White Lake could be filtered in only a matter of days. The WLPP found populations of zebra mussels occupying every part of White Lake. They were attached to the underside of docks, rocks or to the stems of all types of aquatic plants. We will continue to monitor the propagation of zebra mussels in the coming years and document changes resulting to the chemistry and biology of White Lake.

5.1 Comparison of Daily and Bi-Monthly Secchi Depth Measurements

Three Mile Bay

Dave Overholt and Conrad Grégoire

Daily measurements of Secchi depth were compared to those taken every two weeks during the summer months as part of our lake water quality monitoring program. The objective of this study was to determine if measurements taken every two weeks accurately reflected the Secchi Depth changes over time when compared to more detailed measurements taken at almost daily intervals.



The blue line with solid blue squares shows data collected separately and every two weeks during the ice-free season. The blue triangles indicated the daily readings taken over the same period of time. Both plots coincide well with each other indicating that the frequency of Secchi depth measurements taken during our regular sampling program were largely adequate to accurately reflect the change in Secchi depth of the lake over time. However, these data do show that the Secchi depth is variable on a daily basis and can change up to 0.3 metres depending on the day measurements are taken.

6.0 Chlorophyll-a

Water clarity is influenced by the amount of phytoplankton or microscopic algae present in the water. Chlorophyll-a is the green pigment in phytoplankton. The lower the chlorophyll-a concentration in the lake, the lower the phytoplankton population, and the clearer the lake becomes. The greater the phosphorous concentration in the water, the greater is the potential for phytoplankton growth to occur.

The evolution of chlorophyll-a levels in White Lake is shown in the series of three tables below. Historical reports (3rd table) show that the chlorophyll-a concentration in White Lake varied from about 3.5 to 5.5 parts per billion. In 2015, chrolophyll-a results were lower than historical results and ranged from about 1.5 to 4 parts per billion. These results are compatible with measurements taken from between 1975 and 2007.

Chlorophyll-a concentrations obtained for the 2016 season were a radical departure from historical values. Essentially, chlorophyll-a concentrations have been reduced to below or at the detection level of the analytical methodology used. The chart below would indicate that this result could be used to classify White Lake as oligotrophic or of very low productivity. This is not the case. The reason for the low chlorophyll-a concentration is the presence of an exploding population of zebra mussels. The published research on this subject indicates that populations of phytoplankton are reduced by 90% or more when zebra mussels invade a lake.

The much greater clarity of White Lake, the lower calcium (see below) and phosphorous concentrations measured during the 2016 season support this conclusion. Phytoplankton populations may rebound somewhat in coming years once the chemistry of White Lake reaches a new equilibrium imposed on it by the presence of larger numbers of zebra mussels.

Chlorophyll- a (ug/L or ppb) - 2015

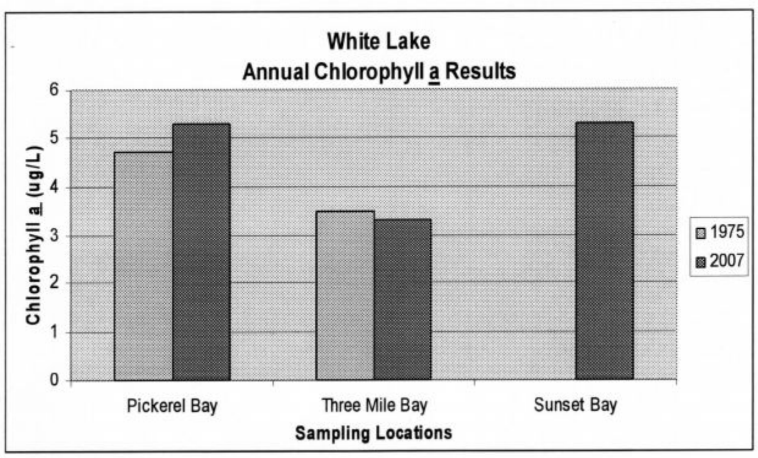
Sampling Site	May 14 (day 134)	July 16 (day 197)	Sept. 15 (day 258)
Three Mile Bay	<0.5	3.0	1.7
N. Hardwood Island	<0.5	2.9	1.7
Pickerel Bay	<0.5	2.3	1.4
Middle Narrows	<0.5	2.1	2.0
Jacob’s Island	<0.5	3.9	≤ 0.5
The Canal	<0.5	0.80	≤ 0.5

Chlorophyll- a (ug/L or ppb) - 2016

Sampling Site	June 14 (day 166)	July 12 (day 194)	August 17 (day 230)
Three Mile Bay	≤ 0.5	<0.5	<0.5
N. Hardwood Island	<0.5	<0.5	<0.5
Pickerel Bay	≤ 0.5	<0.5	<0.5
Middle Narrows	<0.5	<0.5	<0.5
Jacob's Island	<0.5	<0.5	<0.5
The Canal	<0.5	<0.5	<0.5
Hayes Bay	<0.5	<0.5	<0.5
Village Basin	<0.5	<0.5	-

The lower the Chlorophyll a density, the clearer your lake is!

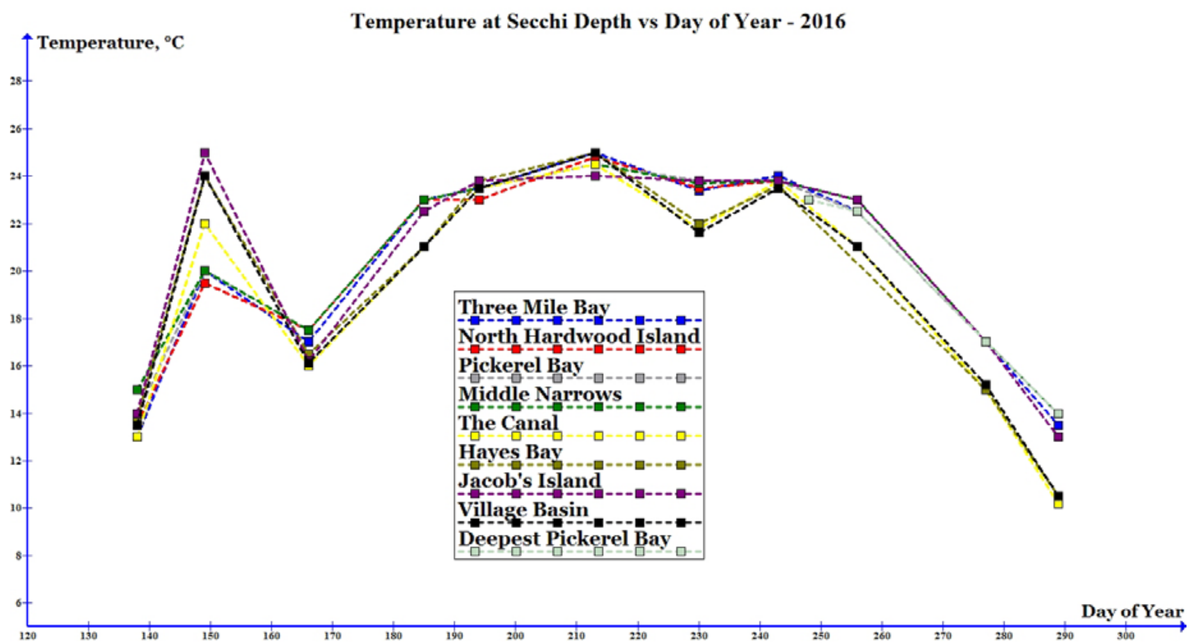
Nutrient Loading and How to Interpret the Water Quality Result : If the Chlorophyll a density is...	Your Lake is...
Up to 2 ug/L (low algal density)	Oligotrophic - unenriched, few nutrients
2 – 4 ug/L (moderate algal density)	Mesotrophic – moderately enriched, some nutrients
More than 4 ug/L (high algal density)	Eutrophic – enriched, higher levels of nutrients



7.0 Water Temperature

Temperature is one of the most important parameters when discussing water quality parameters. Changes in temperature affect the rates of chemical reactions, pH, and also the equilibrium concentrations of dissolved gases in the water column such as oxygen and carbon dioxide. Temperature also affects the solubility of many chemical compounds and can therefore influence the effect of pollutants in aquatic life. Increased temperatures elevate the metabolic oxygen demand, which in conjunction with reduced oxygen solubility, impacts many species. For White Lake, increased water temperatures would also increase the release of phosphorous (back loading) from sediments into the water column. All temperatures were taken at the Secchi depth using a thermometer calibrated against a secondary standard mercury glass thermometer.

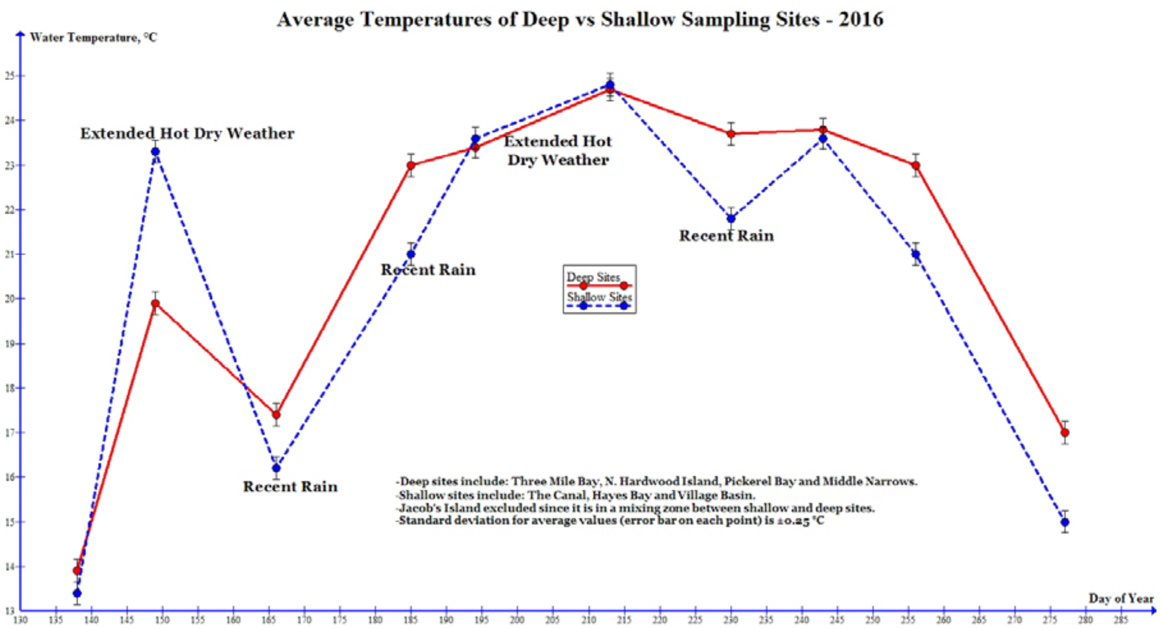
The graph below shows the temperature of White Lake water over the course of the ice-free season:



Although there are clearly some variation in measured temperatures depending on the location of the sampling site, the graphs follows a trajectory very similar to that observed last year. Temperatures measured on day 149 (May 28, 2016) show a spike in temperature when compared to values taken before and after that date. During the summer we also collected weather data and we know that the spike in temperature likely occurred as a result of a long period of hot dry weather during which the lake increased in temperature.

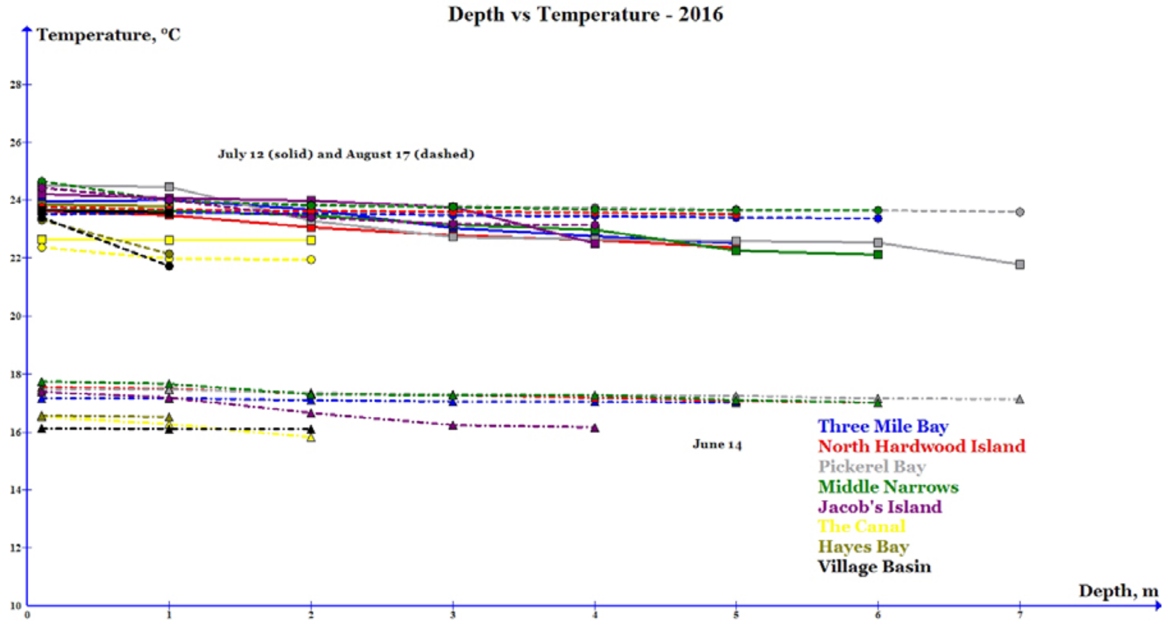
Although not evident in the figure above, there are also differences in temperatures taken at deeper sampling sites relative to those taken at the three very shallow ($\leq$ 2 m) sampling sites. This is illustrated in the following graph which shows the difference in averaged temperatures for the deep and shallow sites.

For the most part, water temperatures for all of the deeper sites were almost the same differing no more than 0.5 °C. However, the temperatures for the shallow sites were at times quite different from those of the deeper sites and were more influenced by recent or current weather conditions.

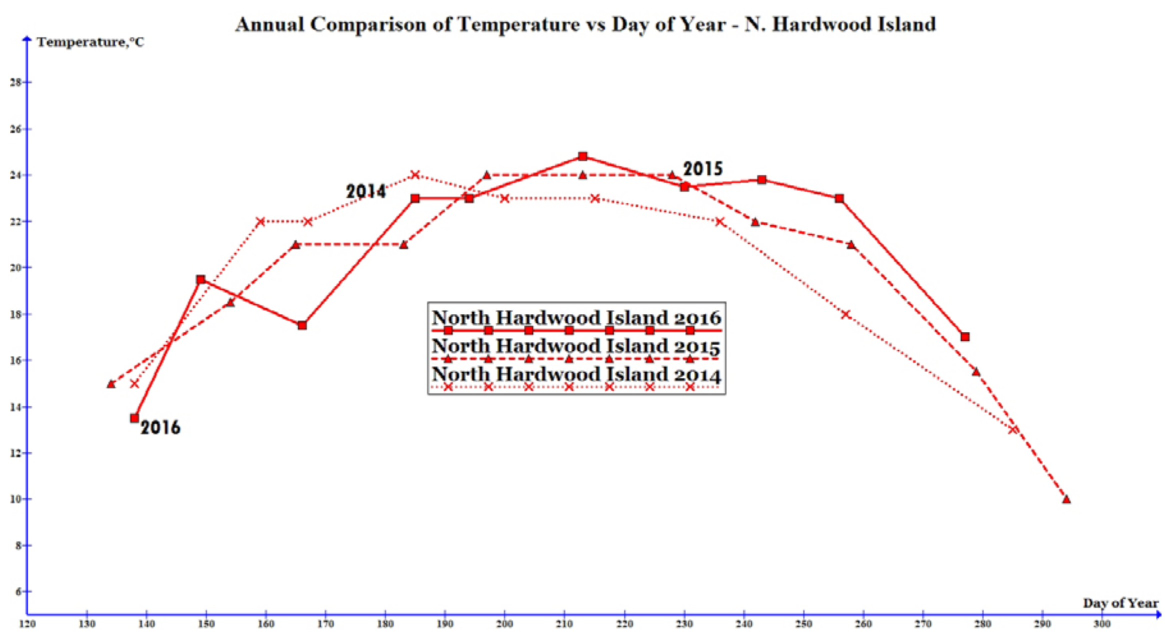


What can be said from this data and those reported for 2015 is: **a)** For the deep sites, temperatures are nearly the same everywhere at any given time and that these temperatures are not very susceptible to ongoing weather conditions; **b)** For shallow sites temperatures are very weather dependent. In the absence of a recent rain event, the shallow sites warm up faster than deep sites and attain a higher temperature by at least 1 °C. When the atmosphere is cooling, such as in the fall, the shallow sites cool at a faster rate than the deep sites and also attain lower temperatures by as much as several degrees Celsius; **c)** If there had been recent rains, the temperature of water at the bottom of the shallow site is about 1 °C cooler than water one metre directly above it. This indicates that cooler waters are entering these areas from ground water ingress up through the floor of the lake.

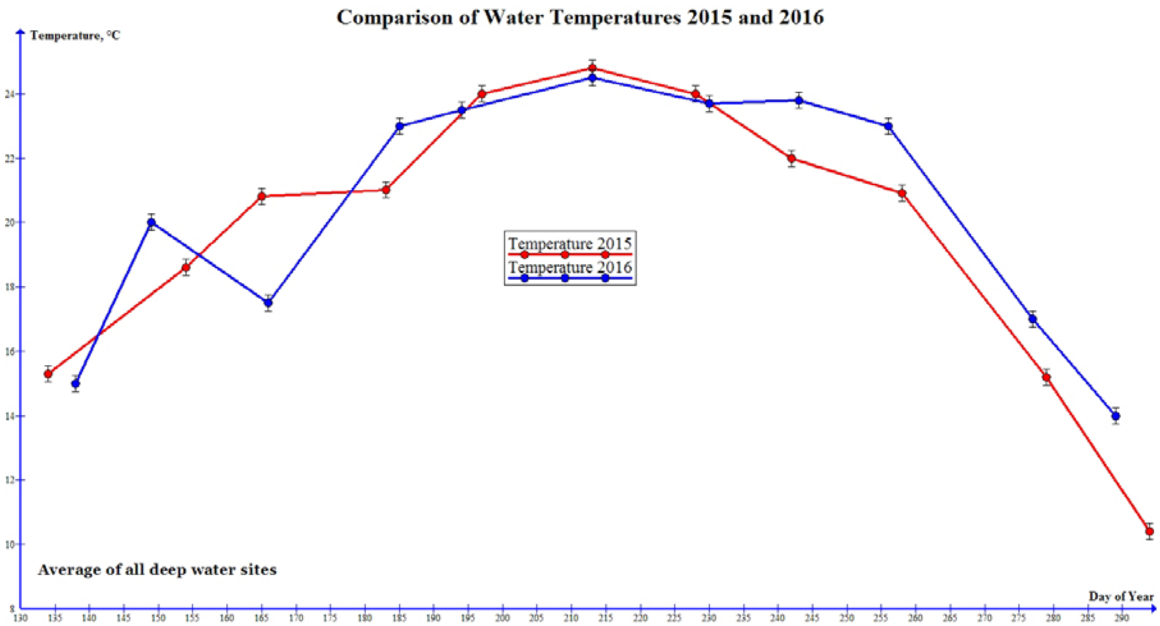
On three separate dates, measurements were also taken of the temperature profile with depth at eight locations on the lake. The graph below shows that for all three dates, the lake was at thermal equilibrium by June 14 and that the difference in temperature from the surface of the lake to the bottom was not more that 1.5 °C. During the 2015 season, we observed that on May 14, the waters of the lake were not yet at equilibrium with temperatures declining quickly at depths greater than 5 m. We can suggest that by about June 1, the lake has reached thermal equilibrium at all depths.



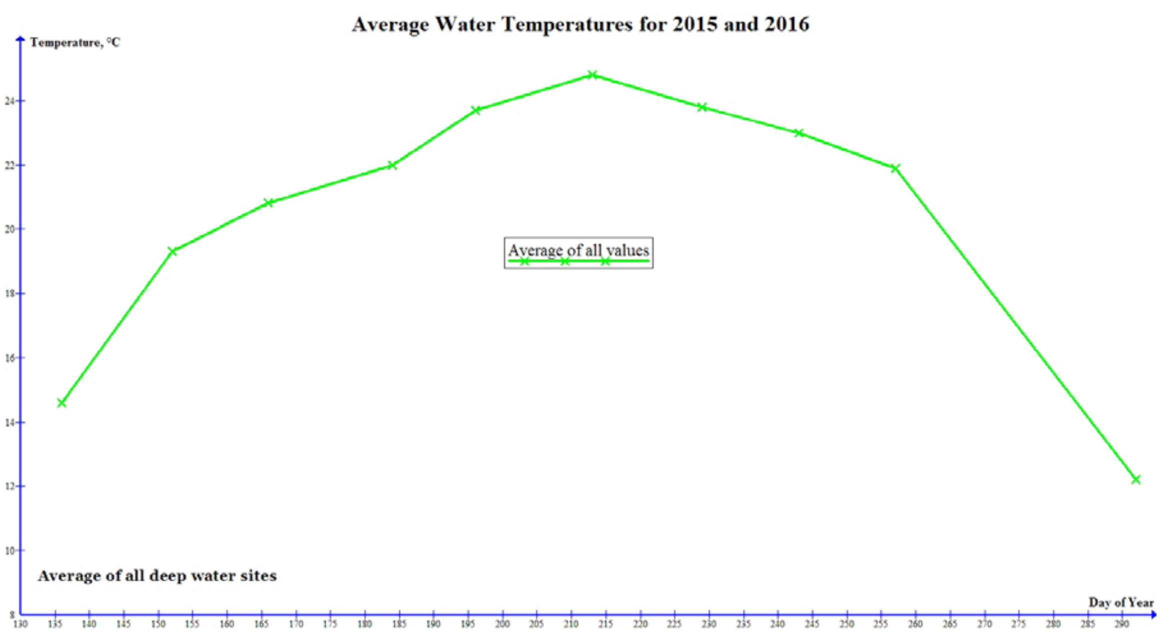
North Hardwood Island is the one site which we have been sampling for three consecutive years. Below is a plot of the water temperature data for all three years. Although there are some year to year differences for temperatures taken on a given date, the same general pattern in water temperatures with day of year is observed. This indicates, along with the other data in this section that the temperature regime of the lake is quite regular from year to year. Therefore, the heat content of the lake is not changing appreciably from year to year even if there are differences in weather conditions. This may indicate that the floor of the lake has a significant role in buffering or regulating the temperature of the lake itself.



If we average the temperature data measured at all of the deep sites for 2016 and compare this to the same data for 2015, we see (below) that the curves obtained are very similar, supporting the conclusions stated above.



If we take this process one step further, we obtain the graph below which shows the average of all temperatures taken during both the 2015 and 2016 field seasons. The resulting curve can, in general, be taken as the heating curve for White Lake during the ice-free season.

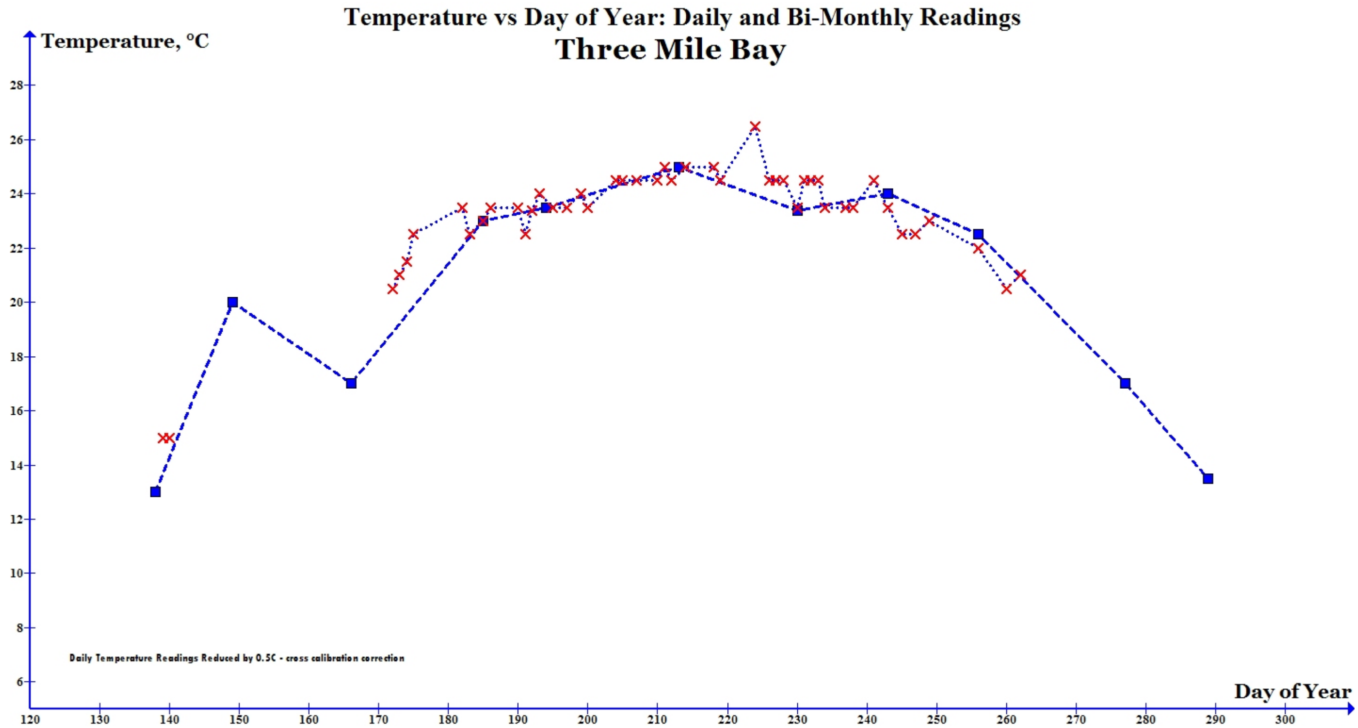


One additional point is worth mentioning. Since the temperature regime for both 2015 and 2016 were very similar, a change in lake temperatures cannot be used to explain the dramatic changes we also observed in water chemistry in 2016 as compared to values obtained in 2015. These parameters include pH, specific conductance, alkalinity and dissolved oxygen.

7.1 Comparison of daily and Bi-Monthly Temperature Measurements
Three Mile Bay

Dave Overholt and Conrad Grégoire

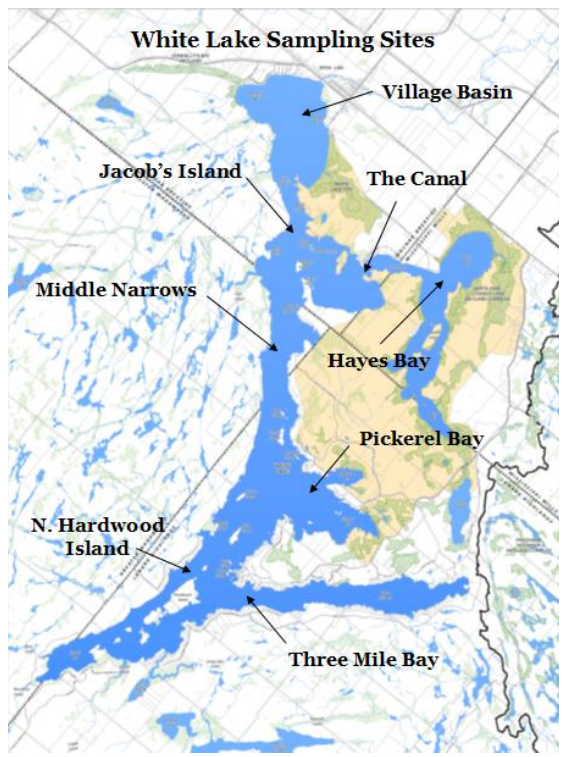
Daily measurements of lake water temperatures (taken at Secchi depth) were compared to those taken every two weeks during the summer months as part of our lake water quality monitoring program. The objective of this study was to determine if measurements taken every two weeks accurately reflected the temperature changes of lake water when compared to more detailed measurements taken nearly on a daily basis.



The blue line with solid blue squares shows data collected separately and every two weeks during the ice-free season. The red 'X's indicated the daily readings taken over the same period of time. Both plots coincide well with each other indicating that the frequency of temperature measurements taken during our regular sampling program were largely adequate to accurately reflect the change in temperature of the lake over time.

7.2 Evidence for Water Mixing Zone at Jacob's Island Sampling Site

Because of its size, location, geological setting and bathymetry coupled with the fact that there is a single outlet for water leaving the lake; there is data to show that White Lake can be considered to be divided into several interconnected but independent water bodies. Water flows to the outlet at Waba Creek in a northerly direction from the main body of the lake which includes the sampling site called Middle Narrows. Water also flows towards the outlet from the area which includes Hayes Bay and The Canal and surrounding areas. Before passing through the narrows, both of these sources of water must meet and mix. This occurs at the Jacob's Island site and surrounding areas which includes the Narrows and some of the adjacent Village Basin on the northern side of the narrows.

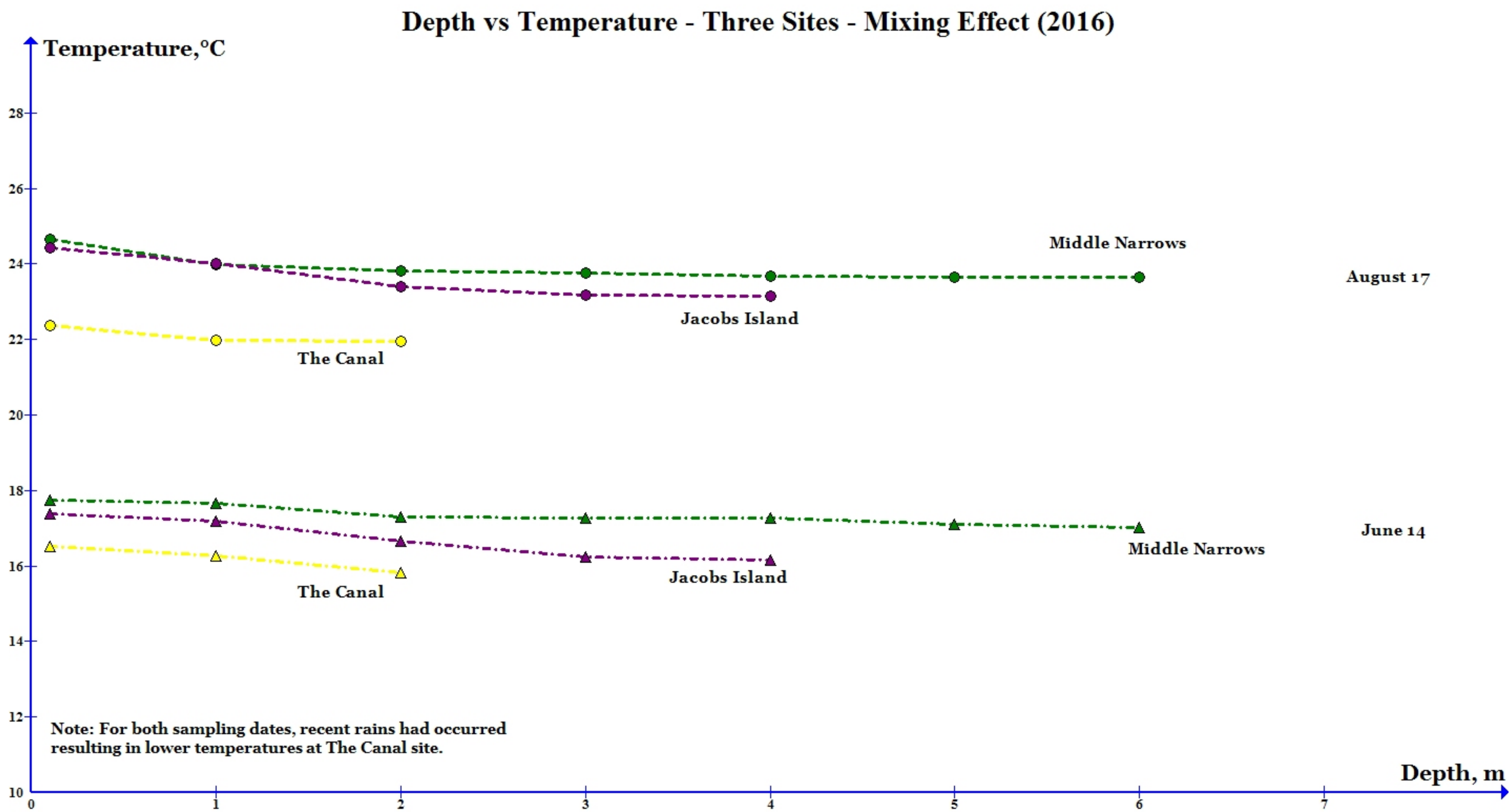


The evidence for this phenomenon includes data collected last year and reported in the WLPP 2015 Water Quality Monitoring Program Report. In this report, water temperatures in the shallow (2 m) waters of The Canal warmed and cooled faster than the deeper southern parts of the lake depending on air temperature when there were no recent rain events. If there were significant rains just prior to sampling the lake, The Canal was always cooler than the rest of the lake. This was attributed to the ingress of cold ground waters into The Canal area. The same phenomenon was observed during the 2016 sampling season.

The graph below shows water temperature data collected at different depths on June 14 and August 17, 2016 at three sites: The green line is temperature data for the Middle Narrows site representing bulk lake water entering the mixing zone; the purple line data is for temperatures at the Jacob's Island site where mixing occurs; and the yellow line is for water temperatures for samples collected at The Canal, the source of cooler water. The two sampling dates coincided with recent rains resulting in cooler water temperatures for The Canal when compared to the deeper parts of the lake.

It is clear from the graph that the waters entering the mixing zone from the south are about 1 degree warmer than water temperatures at Jacob's Island and several degrees warmer than water in The Canal. The resulting mix at Jacob's Island gives water temperatures which are intermediate between the two sources with cooler (and hence denser) waters found at greater depths. The larger volume of water originating from the main part of the lake (south) as compared to the shallow Canal waters results in waters originating from Middle Narrows being cooled by only about one degree whereas The Canal water was warmed by more than two degrees. If actual temperatures are considered it is possible to calculate the approximate mixing ratio of waters originating from Middle Narrows and The Canal. These calculations show that on August 17th, the ratio of the volume of water from Middle Narrows (or main body of the lake) mixing with waters from The Canal was about 4 to 1; whereas on June 14th, the ratio was 1.25 to 1.

From these data, we can also conclude that the volume of water leaving different parts of the lake varies depending or recent weather conditions, such as heavy or light rains. It is not possible to determine the mixing ratio if both sources of water reaching Jacob's Island are initially at the same or very close temperatures.


Depth vs Temperature - Three Sites - Mixing Effect (2016)
Temperature,°C
28
26
24
22
20
18
16
14
12
10
Middle Narrows
August 17
Jacobs Island
The Canal
June 14
Middle Narrows
Jacobs Island
The Canal
Note: For both sampling dates, recent rains had occurred
resulting in lower temperatures at The Canal site.
Depth, m
0
1
2
3
4
5
6
7

8.0 Calcium

Calcium (ppm) - 2015

Sampling Site	May 14 (day 134)	June 14 (day 165)	July 16 (day 197)
Three Mile Bay	36.2	37.3	36.7
N. Hardwood Island	37.3	37.2	36.7
Middle Narrows	35.3	33.2	35.8
Jacob's Island	36.2	33.3	35.2
The Canal	35.8	32.2	31.1
Average Values:	36.2 ± .7	34.6 ± 2.4	35.1 ± 2.3

Calcium (ppm) - 2016

Sampling Site	May 17 (day 138)	June 14 (day 166)	July 12 (day 194)
Three Mile Bay	36.4	30.7	30.7
N. Hardwood Island	31.8	32.0	31.7
Middle Narrows	31.1	32.1	32.0
Jacob's Island	31.4	33.0	29.1
The Canal	34.4	33.1	30.0
Hayes Bay	36.6	34.1	32.2
Village Basin	31.1	31.4	29.6
Average Values:	33.2 ± 2.5*	32.3 ± 1.1	30.8 ± 1.2
Removing Outliers:	31.9 ± 1.4		

An average of the calcium concentrations measured on each of the three dates for both 2015 and 2016 gives values of 35.3 ± .8 and 31.7 ± .8 parts per million, respectively. When compared to values for calcium obtained in 2015, the calcium concentration for White Lake in 2016 has diminished by about 10%. It is unclear if this reduction is related to the presence of zebra mussels especially when one takes into consideration that calcium values for 2014 were 33.4 ± .5 parts per million, intermediate between values obtained in 2015 and 2016. The average of all of the calcium values obtained for White Lake between 2008 and 2012 were 32.5 ± 1.6 parts per million. It is quite possible that the different calcium concentrations measured over the years and during the past two field seasons are natural difference caused by variances in water sources entering White Lake.

Certainly, zebra mussels require calcium in order to form their chitin shells (which also need phosphorous). However, White Lake contains over 3000 metric tons of calcium as metal and nearly 10,000 metric tons of the metal as carbonate. The propagation of zebra mussels in White Lake and their consumption of calcium in solution may be too small to impact on the total amount of calcium present in the lake. Future measurement of this metal in White Lake over the coming years may shed more light on the impact of zebra mussels versus natural annual variations.

9.0 pH, Alkalinity and Specific Conductance

pH

pH, alkalinity and conductivity are three parameters useful in the evaluation of lake water quality. All three parameters are interrelated in that a change in one can often result in a change in the other two. For this reason, we will be discussing these parameters as a group. Also, we will be comparing the results obtained during the 2015 sampling season with those obtained during the 2016 season and highlight any differences observed.

pH is a measure of the concentration of hydrogen ion in lake water and indicates the intensity of the acidic (pH<7) or basic characteristic (pH>7) of the system as a whole. The pH of lake water is controlled by dissolved chemical compounds in the water and some biochemical processes such as photosynthesis and respiration. In lake waters like those of White Lake, the pH is mainly controlled by the balance between carbon dioxide, carbonate and bicarbonate ions. Typical lake waters in Ontario have a pH in the range of from 6 to 9, where bicarbonate is the dominant chemical species in solution. pH readings were taken at the surface and at 1 m intervals with a multi-parameter probe and then averaged to give the results appearing in the tables below.

pH - 2016

Sampling Site	June 14 (day 166)	July 12 (day 194)	August 17 (day 230)
Three Mile Bay	7.92 ± .14	7.54 ± 1.6	7.04 ± .12
N. Hardwood Is.	8.10 ± .03	8.06 ± .08	7.15 ± .09
Pickerel Bay	8.14 ± .04	8.07 ± .11	7.24 ± .12
Middle Narrows	8.02 ± .05	8.05 ± .07	7.25 ± .09
Jacob’s Island	8.10 ± .06	8.09 ± .15	7.38 ± .14
The Canal	8.34 ± .03	8.26 ± .03	7.43 ± .03
Hayes Bay	8.23 ± .01	8.28 ± .13	7.55 ± .08
Village Basin	8.22 ± .03	8.41 ± .02	7.56 ± .06

Results: average ± standard deviation

Observations 2016: The shallow sites (last three in table) show anomalous (high) pH values when compared to those measured for the remaining deeper sites with the exception of Three Mile Bay which was slightly more acidic for each of the three sampling dates. The pH of the lake generally decreased (more acidic) with time over the summer.

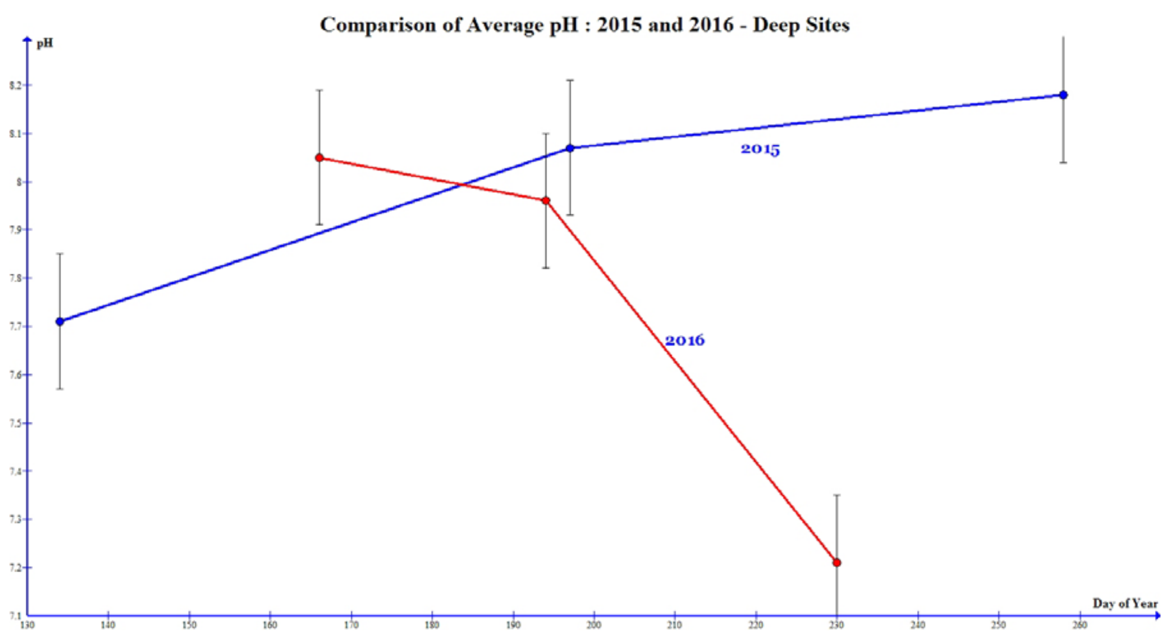
pH - 2015

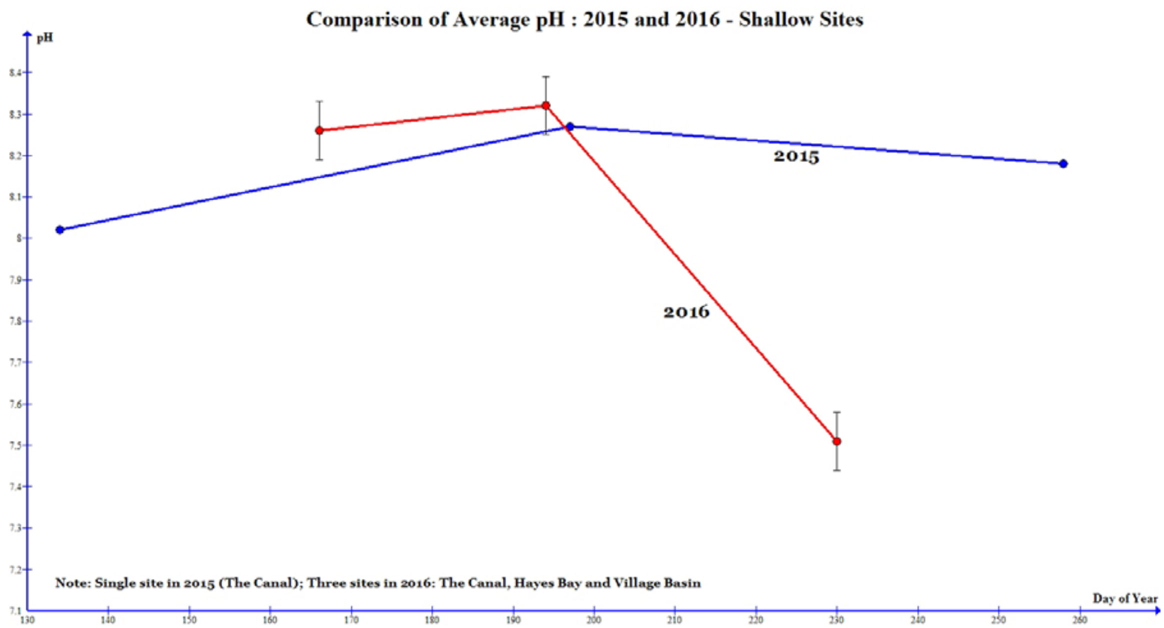
Sampling Site	May 14 (day 134)	July 16 (day 197)	September 15 (day 258)
Three Mile Bay	7.67 ± .17	8.01 ± .08	8.15 ± .03
N. Hardwood Is.	7.65 ± .15	8.01 ± .04	8.18 ± .02
Pickerel Bay	7.72 ± .13	8.03 ± .10	8.18 ± .03
Middle Narrows	7.42 ± .02	8.04 ± .09	8.28 ± .03
Jacob’s Island	7.78 ± .03	8.06 ± .17	8.19 ± .03
The Canal	8.02 ± .03	8.27 ± .04	8.18 ± .07

Results: average ± standard deviation

Observations 2015: The pH of White Lake increased with time over the summer. The Canal site (a shallow site) gave anomalously high (compared to the rest of the lake) pH values the May and July sampling dates.

Two-Year Observations: (a): For both the 2015 and 2016 data, the pH of lake waters from shallow sites was higher than the pH of waters sampled at the deeper sites located to the south of the Jacob’s Island sampling site; (b): For 2015, the pH of both shallow and deep sites increased with time; (c): For 2016, the pH of both shallow and deep sites exhibited a marked decrease with time. The two graphs below show the difference in lake water pH for deep and shallow sites for 2015 and 2016. Error bars are included for each data point.





As mentioned earlier, the pH of a body of water can change for a number of reasons; however, the change observed from 2015 to 2016 is very large and shows a reversal in trends from past years. These dramatic changes may be explained by the infestation of zebra mussels of White Lake. For the first time in 2016, White Lake became the home for many millions and as much as a billion zebra mussels. Most people reading this report would have observed the increased clarity of the lake when compared to previous years (see section on Secchi depth). The removal of calcium from the lake (see above) for the formation of zebra mussel shells may account for a loss of as much as 10% of the calcium in solution in the lake resulting in the observed changes in pH. Another mechanism which could be used to explain a decrease in pH involves increased bacterial activity on the lake bottom. The production of large quantities of zebra mussel feces and pseudo-feces would support increased activity by bacteria and the production of excess carbon dioxide, which reacts with water to produce carbonic acid. The analysis of other water quality parameters may shed further light on this discussion.

Total Alkalinity

Alkalinity is the base neutralizing or 'buffering' capacity of water or in other words the ability to neutralize acids and to resist changes in pH. Total alkalinity is a measure of the net buffering effect of all positively (such as Ca^+) and negatively (such as Cl^-) charged ions in solution in the lake water.

TOTAL ALKALINITY AS $CaCO_3$ (mg/L or ppm)

2016

Sampling Site	**June 14 (day 166)**	**July 12 (day 194)**	**August 17 (day 230)**
Three Mile Bay	100	100	100
N. Hardwood Island	100	100	100
Pickerel Bay	100	100	100
Middle Narrows	100	100	80
Jacob's Island	100	120	100
The Canal	100	100	80
Hayes Bay	100	120	100
Village Basin	100	100	100
Average Values:	110 ± 0	105 ± 9	95 ± 9

2015

Sampling Site	**May 14 (day 134)**	**July 16 (day 197)**	**Sept. 15 (day 258)**
Three Mile Bay	120	140	160
N. Hardwood Island	120	140	160
Pickerel Bay	120	140	160
Middle Narrows	120	120	140
Jacob's Island	110	120	140
The Canal	120	120	160
Average Values:	118 ± 4	130 ± 11	154 ± 10

Observations: The results for both 2015 and 2016 indicate that White Lake has a moderate buffering capacity. The very interesting contrast between the two years is the net decrease in alkalinity of about 30% in 2016 compared with results from 2015. This means that that the lake has experienced a loss in buffering capacity. Although we do not know this as a certainty, these results may be a direct consequence of the infestation of zebra mussels of White Lake during the 2016 ice-free season. The direct loss of dissolved calcium from the water column may have resulted in a decrease in total alkalinity.

Acid rain is no longer a threat to the environment since strict regulations were imposed decades ago on sulphur dioxide emissions from industrial sources. White Lake has always had, as it does now, adequate buffering capacity to handle acid inputs from natural sources.

Specific Conductance

Specific conductance is a measure of the ability of water to conduct an electric current. Specific conductance is also referred to as *conductivity*, *electrical conductivity* or *specific electrical conductance*. In general, the higher the concentration of dissolved salts in the water, the easier it is for electricity to pass through water. Conductivity is reported in *microSiemens* (µS) per centimeter (cm). Conductivity measurements can be converted to *total dissolved solids* measurements which are reported in parts per million (ppm). A rough approximation of the concentration of dissolved solids in a freshwater source in ppm (milligrams/litre) can be obtained by multiplying the µS/cm value by 0.66 (the actual conversion factor may range from 0.55 to 0.80 for water of different sources). Because they are temperature dependant, measurements are corrected and reported as if they were made at 25 ^{o}C.

Specific Conductance (µS/cm)
2016

Sampling Site	**June 14 (day 166)**	**July 12 (day 194)**	**August 17 (day 230)**
Three Mile Bay	236 ± 1	230 ± 2	214 ± 1
N. Hardwood Island	236 ± .5	233 ± 1	217 ± .8
Pickerel Bay	235 ± .5	234 ± 1	221 ± .7
Middle Narrows	235 ± .1	232 ± 1	217 ± 1
Jacob's Island	234 ± 1	231 ± 1	207 ± 4
The Canal	240 ± 2	223 ± 0	202 ± .3
Hayes Bay	266 ± .5	261 ± .5	242 ± 2
Village Basin	236 ± 0	233 ± 1	201 ± 1

Results: average ± standard deviation

Specific Conductance (µS/cm)
2015

Sampling Site	**May 14 (day 134)**	**July 16 (day 197)**	**September 15 (day 258)**
Three Mile Bay	251 ± 2	254 ± 0	251 ± .5
N. Hardwood Island	251 ± 2	254 ± 0	250 ± .4
Pickerel Bay	250 ± 1	254 ± .6	251 ± .5
Middle Narrows	247 ± 2	253 ± .8	249 ± 1
Jacob's Island	244 ± 1	249 ± 7	243 ± 1
The Canal	243 ± 1.0	236 ± 1	243 ± 2

Results: average ± standard deviation

Observations: For 2016, the shallow sites (last three in table) show anomalous conductivity values which are either much higher or lower than those measured for the remaining deeper sites. The one site which is consistently higher than any of the other sampling locations was Hayes Bay with specific conductance values 13% higher when compared to the average of other sites on a given date. This then means that the total dissolved solids in Hayes Bay waters were 13% higher than in the rest of the lake. This can occur as a result of surficial runoff from the surrounding countryside (road salt) or localized increased evaporation if the body of water is not being flushed out. Data on the concentration of chloride in Hayes Bay (discussed below) strongly suggests that the actual source of the increased conductivity is due to the presence of sodium chloride, probably from a subterranean salt spring seeping saline water or brine into Hayes Bay through bottom sediments.

The remaining shallow sites; The Canal and Village Basin, have lower conductivity values than other sites on the lake. This may be because these sites are regularly being flushed with ground waters lower in total dissolved solids when compared to the other (deeper) areas of the lake where turnover is much less.

For 2015, and for all three sampling dates, the water conductivity decreased as one sampled sites starting with Three Mile Bay and proceeding north; i.e. the farther away from Three Mile Bay, the lower the conductivity. The Canal reading for July 16 is highlighted in yellow because it is much lower than deeper sites possibly owing to an influx of infiltrating ground waters on or near the sampling date. On average, the conductivity of White Lake waters remained the same over the 2015 ice free season.

When comparing 2016 and 2015 data for specific conductance, it is clear that values were much lower during 2016 than during 2015. The average specific conductance for the deeper sampling sites was 228 ± 10 μS/cm for 2016 and 250 ± 3 μS/cm for 2016. When converted to total dissolved solids as described above, this represents a decrease of about 15 ppm in dissolved solids for 2016 as compared to 2015. Differences are even greater when individual sampling dates are considered.

As was the case for the water quality parameters discussed above in earlier sections, the loss in total dissolved solids may be due to the growing presence of zebra mussels in White Lake. This year was a very hot and primarily dry summer when compared to 2015, and so the effects of evaporation, if there were any, were totally cancelled by whatever mechanism was depleting dissolved solids from the water column. (Please see section below on weather).

10.0 Chloride

Chloride data for 2015 and 2016 are given in the tables below. The data collected in 2015 shows that a concentration of about 3.5 ppm chloride is found at all sampling sites with the exception of The Canal, where chloride values are slightly elevated. The 2016 data shows the same pattern with the new sampling site of Hayes Bay giving a chloride concentration of 10 ppm (not sampled in 2015), which is about three times the concentration measured at all other sites on the lake with the exception of The Canal, which gave a value of 5.35 ppm. For all of the sites (except The Canal and Hayes Bay) the average values for both 2015 and 2016 are all the same within error.

In the sections above, the specific conductance for the Hayes Bay site was anomalously high for all three sampling dates which spanned the summer months. This indicates that the high conductance value is due to the presence of higher concentrations of sodium chloride, especially since Ca values are only slightly elevated compared to Ca concentrations at other sites.

The source of the additional chloride is not likely to be from road salt since if this were the case, values for conductance would decline over the course of the summer months. Therefore, it is more likely to originate from subterranean brines reaching this area of the lake through the sediment layer. The elevated values for chloride found at the Canal are likely due to the mixing of waters from Hayes bay with those of the Canal or its own weaker source of subterranean brine. This is the only part of the lake where this phenomenon has been observed.

Chloride (ppm) - 2015

Sampling Site	**May 14 (day 134)**	**June 14 (day 165)**	**July 16 (day 197)**
Three Mile Bay	3.49	3.42	3.30
N. Hardwood Island	3.34	3.41	3.14
Middle Narrows	3.48	3.51	3.44
Jacob’s Island	3.43	3.58	3.38
The Canal	3.93	3.87	4.20
Average Values*:	3.44 ± .07	3.48 ± .08	3.32 ± .13

*excluding The Canal

Chloride (ppm) - 2016

Sampling Site	May 17 (day 138)	June 14 (day 166)	July 12 (day 194)
Three Mile Bay	3.4	3.5	3.7
N. Hardwood Island	3.4	3.5	3.6
Middle Narrows	3.5	3.8	3.7
Jacob's Island	3.7	4.1	3.8
The Canal	5.4	5.5	5.1
Hayes Bay	10.00	10.1	10.3
Village Basin	3.7	4.4	4.6
Average Values*:	3.53 ± .16	3.86 ± .39	3.88 ± .41

*excluding The Canal and Hayes Bay

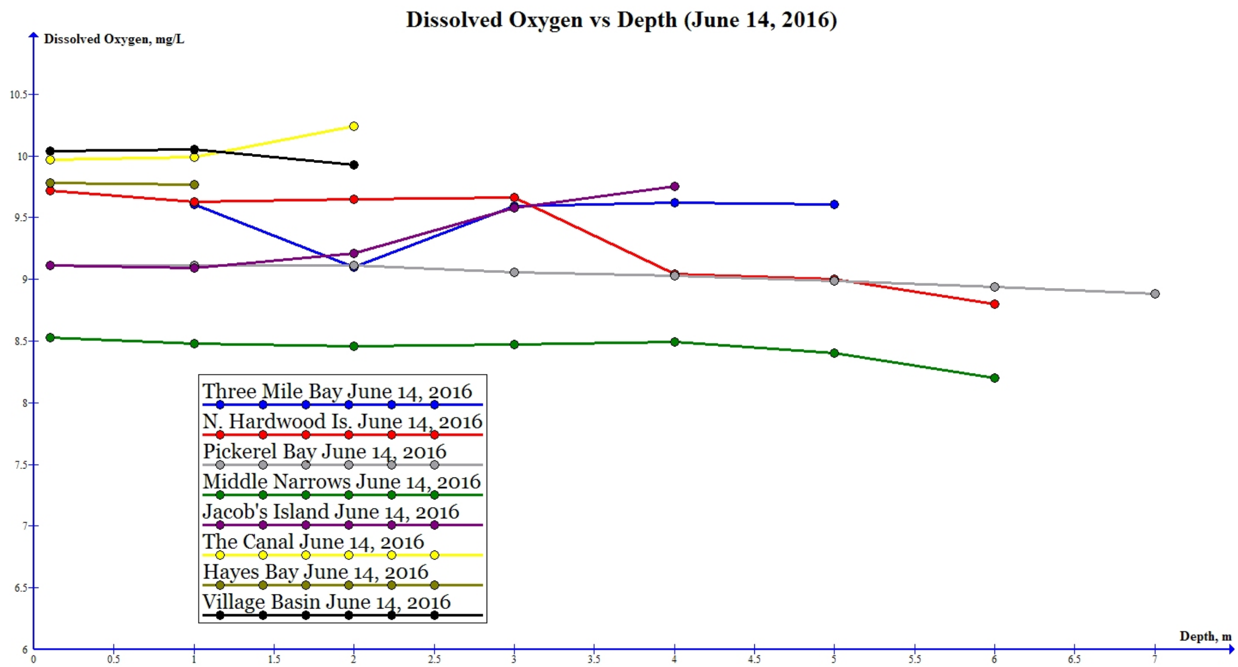
11.0 Dissolved Oxygen

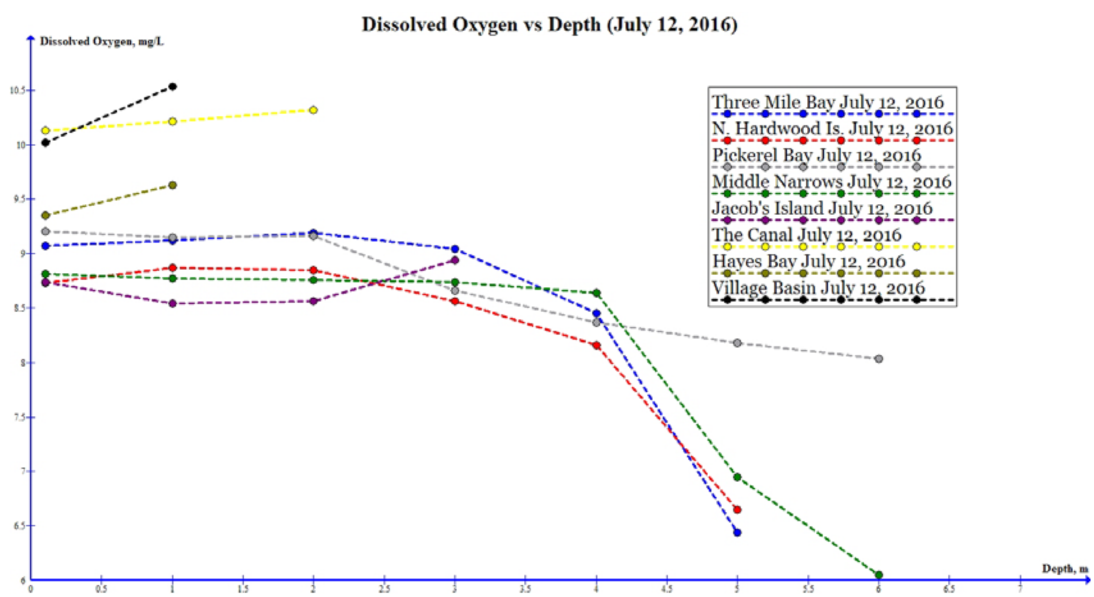
Oxygen is an essential element in any aquatic system. Oxygen is needed by all organisms to sustain life. The amount of oxygen dissolved in lake water, for example, varies from day to day and even during the day. Most of the dissolved oxygen in lake water comes from the atmosphere and becomes dissolved into the water column by diffusion and the action of wind and waves. Oxygen concentration varies significantly with water temperature with colder waters able to contain more oxygen in solution than warmer waters. Oxygen is also produced during sunlight hours as a result of photosynthesis in phytoplankton and aquatic plants. Oxygen is consumed by these same plants during the night, when no photosynthesis can occur, and also by fish, plankton and the decay of organic materials at the bottom of the lake.

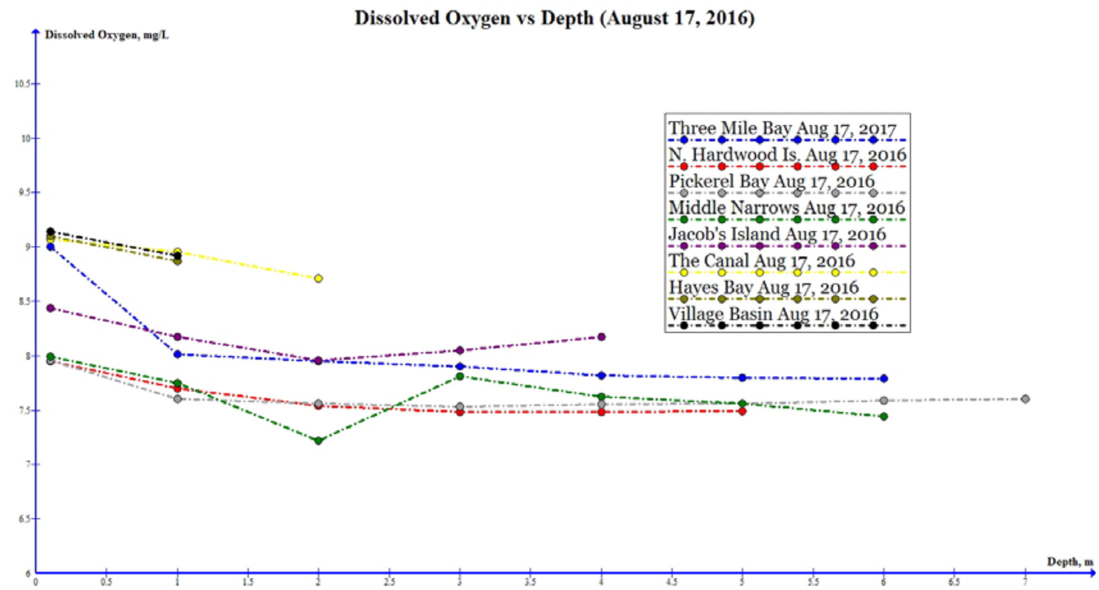
Because of the dependence of oxygen levels on many environmental factors, it is easy to see that the concentration of oxygen in lake water can vary greatly during the ice-free months and can certainly change from year to year.

The concentration of oxygen in the water column can seriously affect fish populations and if dissolved oxygen concentrations dip below about 5 mg/L, fish stocks can be severely stressed or even die. Oxygen levels of from 7 to 11 mg/L are very good for most fish and other aquatic organisms.

The three graphs shown below are plots of dissolved oxygen as a function of depth taken for each of 8 sites representing every part of White Lake. Samplings were taken on June 14, July 12 and August 17, 2016.

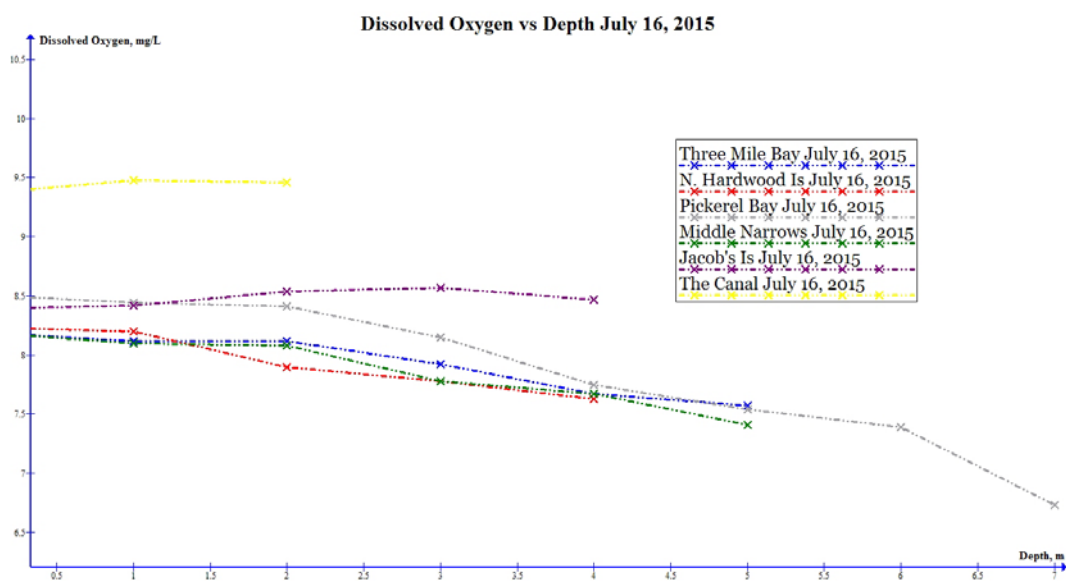

Dissolved Oxygen vs Depth (June 14, 2016)
Dissolved Oxygen, mg/L
Depth, m
Three Mile Bay June 14, 2016
N. Hardwood Is. June 14, 2016
Pickerel Bay June 14, 2016
Middle Narrows June 14, 2016
Jacob's Island June 14, 2016
The Canal June 14, 2016
Hayes Bay June 14, 2016
Village Basin June 14, 2016


Dissolved Oxygen vs Depth (July 12, 2016)
Dissolved Oxygen, mg/L
Depth, m
Three Mile Bay July 12, 2016
N. Hardwood Is. July 12, 2016
Pickerel Bay July 12, 2016
Middle Narrows July 12, 2016
Jacob's Island July 12, 2016
The Canal July 12, 2016
Hayes Bay July 12, 2016
Village Basin July 12, 2016



The results show that from June to August, 2016, the oxygen concentration varied from a low of 6 mg/L to a high of 10.5 mg/L. Generally, the concentration of oxygen was lower for the deeper sites, especially Three Mile Bay than for the much shallower sites such as The Canal, Hayes Bay and the Village Basin where concentrations were uniformly higher. This may be due to the fact that at the shallow sites, there are no aquatic plants on the central part of the lake bed and that the effect of wind and wave would be more pronounced than for deeper sites where oxygen could only reach greater depths by diffusion and convection.

For the July 12 sampling date, oxygen concentrations decreased precipitously at depths greater than 3 m. This may be the result of the hot, dry and windless weather we experienced during the summer of 2016. Another explanation could be increased microbial activity in sediment due to increasing water temperatures at mid-season. By August, oxygen concentrations had bounced back to more acceptable levels everywhere on the lake.



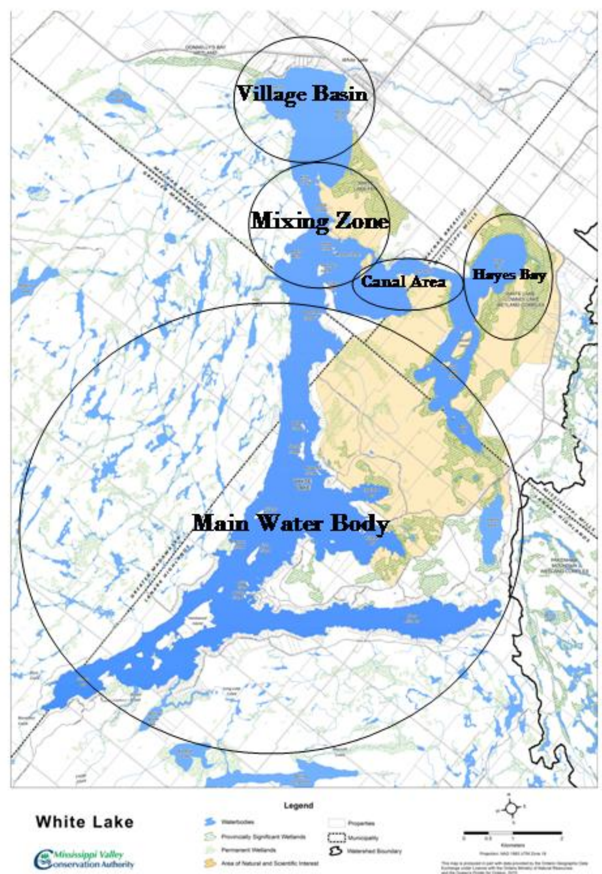
When comparing the results of July 2016 with those obtained in July of 2015 (above) we can see a similar but not as precipitous a decrease in oxygen concentrations with depth in 2015 with the lowest concentrations reaching levels similar to those of 2016. The presence of zebra mussels is known to decrease oxygen levels in affected lakes and this also may be a factor for White Lake in 2016.

Since weather patterns were quite different when comparing 2015 with 2016, this may indicate that the loss of oxygen at depth is more likely due to changes in lake water and lake sediment temperatures. In the section of this report discussing temperatures, it was shown that the temperature profiles of the lake over the ice-free months during 2015 and 2016 were nearly the same and relatively independent of weather conditions. This observation may indicate that the temperature of the lake bottom has a strong influence on the temperature regime of the water column above it.

12.0 Zone Map of White Lake

In previous reports, we have suggested that White Lake could be thought of as a collection of almost independent interconnected water bodies rather than a unitary lake.

There are a number of criteria which could be used to divide the lake into different zones based on population density, geology, shoreline coverage, etc. Each of these criteria would produce a different zone map than the one we present here. The zone map we provide here is based on the physical and chemical measurements we have been making over several years. The map essentially describes how the lake works and gives the minimum number of areas which should be separately monitored in the future. While all zones have some characteristics in common, there are enough differences between each zone (shown on the map) to justify its classification.



The ***Main Water Body*** is the part of White Lake which takes in virtually all of the water with a depth greater than four metres. This zone contains Sunset Bay, Three Mile Bay Pickerel Bay and surrounding areas. This zone existed as a lake before any dam was constructed which raised the level of the lake by about 1.5 metres. Here one finds very deep layers of sediments (up to 6 metres) and very similar water chemistry throughout the zone. The temperature regime, the pH, conductivity, oxygen content, alkalinity and Secchi depths are very nearly the same everywhere. Although the total phosphorous concentrations differ somewhat (with higher levels further South on the lake), the change in phosphorous concentrations over the summer months follows the same pattern with maximum concentrations reached in mid-July.

Hayes Bay is only 1.6 m in depth at high water in the spring. It is characterized by thin sediments of black marl and is free of aquatic plants. Note that shoreline areas are densely populated with aquatic plants with many marshes and some fens. Only the central basin lake bed is free of aquatic plants. The waters there have a slightly higher pH than the rest of the lake and also a higher conductivity. The concentration of salt is higher by a factor of three compared to the rest of the lake probably from saline ground water entering through the sediment layer. Because of its dark sediments and shallow depth, this part of the lake heats up the fastest and to the highest temperatures if there had not been a recent rain event. The concentration if total phosphorous is lower here than in the rest of the lake, but slightly higher than concentrations in the Canal area. The waters from Hayes Bay flow into the Canal Area.

The ***Canal Area*** on White Lake is characterized by white marl sediments and a depth of 2.4 metres. For both 2015 and 2016, the lowest concentrations of total phosphorous are found here with levels less than half of those found in the Main water Body. The temperature data indicates that in this zone, large quantities of subterranean ground waters are infiltrating into the lake and also leaving the lake relatively more quickly than waters from Hayes Bay or the Main Water Body. This is especially evident immediately after a significant rain event. There are no aquatic plants on the lake bed. Note that shoreline areas are densely populated with aquatic plants with many marshes. Only the basin lake bed is free of aquatic plants. These waters have a slightly higher salt content than the rest of the lake due to the mixing of waters originating from Hayes Bay.

The ***Village Basin*** zone is characterized by white marl sediments and an almost uniform depth of 1.65 m at high water. The floor of the lake is largely free of aquatic plants save some bulrush and patches of wild rice. Note that shoreline areas are densely populated with aquatic plants with many marshes and some fens. Only the central basin lake bed is free of aquatic plants. Total Phosphorous levels are about 30% lower than found in the Main Water Body. The water sampled here is representative of the water which is leaving White Lake over the dam and into the creek. Temperature data from this area also shows, as in the case of The Canal and Hayes Bay that there is significant ingress of subterranean ground waters mixing in with lake water.

Hayes Bay, The Canal and the Village Basin have several things common. Prior to the building of the dam, these areas existed as open water only during the spring freshet and then quickly turned into marshes or wetlands with water depths of perhaps half a metre or less. Another commonality is the lack of aquatic plants in the central basins of these areas. It could be that since each of these areas is partially flushed by ground water ingress that plants do not have a chance to take hold. Certainly the white marl of the Canal and the Village Basin would provide a poor source of nutrients to plant root systems. For Hayes Bay, the sediment there is organic but made up of a very fine particulate not offering much of a foothold for aquatic plants. For all three areas, the effect of wind and waves would also contribute to low plant growth.

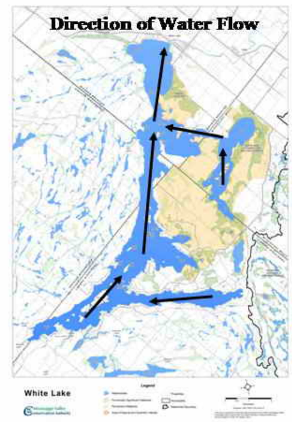
The ***Mixing Zone*** encompasses both sides of the narrows including Rocky Island and extends some distance towards the Village Basin. This area is characterized by shallow dark sediments and ranges from 2.5 m to 4 m in depth at high water. In this area, the lake floor is covered with dense mats of aquatic plants. The temperature of the water in this area is intermediate between the waters coming from The Canal and the Main Water Body. The simple reason for this is that this is where waters from both of these zones mix to give water with special characteristics relative to other parts of the lake. Generally speaking, the water in the Mixing Zone is clearer than would be observed in other parts of the lake for a given total phosphorous concentration. Water leaving this area and entering the Village Basin has lost a significant fraction of it phosphorous content to sedimentation and aquatic plants.

Waters originating from the upper four zones have no opportunity to mix with the much deeper waters of the Main Water Basin which contains by far the greatest share of the volume of White Lake. It could be argued that one the most vulnerable parts of White Lake is Hayes Bay because there is little opportunity for any nutrients entering this bay to be flushed out at a reasonable rate. With the exception of Three Mile Bay whose waters have access to the remainder of the deeper Main Water Body, the shallow areas at the top of the lake contain the densest populated areas with the likely greatest human impact possible.

By using a graphical technique (printing a copy of the map of White Lake onto a graph paper and counting squares), it is possible to determined both the surface area and volume of the Main Water Body and the sum of the four remaining zones which includes Hayes Bay, Canal Area, Mixing Zone and Village Basin. For this calculation, we are using the known volume of White Lake (74.74 million m^3) and the published surface area of 22.7 km^2. From our research, it is reasonable to also estimate that the average depth of the Main Water Body to be 4.45 m and that of the rest of the zones combined to be 1.5 m. The table below lists the results obtained from these calculations.

Parameter	Main Water Body	Sum of Four Shallow Zones
Surface Area, $10^6 m^2$	13.74	8.37
Percent Total Area	60.5	39.5
Volume, $10^6 m^3$	61.14	13.5
Percent Volume of Total	81.9	18.1

The results given in the table above show that the shallow zones together only account for about 18% of the volume of water contained in White Lake. Essentially separated from the rest of the lake (Main Water Body) by direction of water flow towards the outlet at Waba Creek, this part of the lake is clearly less able to absorb incoming contaminants than the deeper part of the lake, which itself is not very deep in absolute terms when compared to many other lakes in the area.



Although we have divided the lake into five distinct zones based on water chemistry, it is also reasonable to consider White Lake as actually two separate lakes connected by the Mixing Zone. The larger and deeper Main Water Body forming one lake, and the remaining shallow zones forming the second lake. Note that the water entering the Mixing Zone from the Main Water Body on towards the Village Basin is reduced in nutrients by sedimentation, filtering and the action of aquatic plants within the Mixing Zone.

13.0 Zebra Mussels - Peter Raaphorst

Zebra mussels are native to Southern Russia and were first documented in 1769. They were believed to have been introduced into the Great Lakes in the late 1980's in ballast water from transoceanic ships carrying veligers (larvae), juvenile or adult mussels. Since then they have spread into the Eastern US and up into Canada through interconnected waterways and by hitchhiking on boat surfaces or in engine cooling systems. Note that they can live up to 7 to 9 days out of the water. Adults average 2 to 3 cm in length, but can grow up to 5 cm. Now they have arrived in White Lake! Last fall, the White Lake Preservation Project's Science committee first documented their presence.

Note the zebra stripes giving it the name

Zebra mussels live for about 4 to 5 years. One female can produce 20 to 40 thousand eggs each reproductive cycle which can be repeated 30 to 40 times a year. During the five-year lifetime, a single zebra mussel will produce about five million eggs, and about 50,000 of these will reach adulthood. The offspring of a single mussel can in turn produce a total of half a billion adult offspring. It's easy to see why we calculate that there may be over a billion of them right now in White Lake.

Zebra mussels feed on small organisms called plankton (which includes algae) that drifts in the water. The zebra mussels blanketing the bottom of our lakes filter water as they eat plankton. White Lake is very rich in plankton and provides an ideal feeding ground for zebra mussels. An adult mussel can filter 1 to 1.5 litres of water a day so just imagine how quickly they may filter the water in White Lake if there are a billion in the lake.

Zebra mussels covering milfoil stems.

In 2016 the WLPP Science Committee did an extensive assessment of zebra mussel distribution. Samplings were done in all parts of the lake from White Lake Village to Sunset Bay. All sites had zebra mussels. Most were found to be attached to the smooth surfaces of docks, boats, etc., and on all aquatic-plant species. So far few if any were found on rocks but some were found on the exposed underside of rocks. On one 4-ft long milfoil (common aquatic plant in White Lake), 172 zebra mussels were counted. Using average numbers for such counts, a very crude estimate of zebra mussel numbers was done assuming that they are attached on all water plant species. The calculation showed that about one billion mussels are now in the lake. Most of them are small indicating that these are mostly the new generation of 2016.

What we can expect for the coming year:

•Clearer water caused by the filtration of the lake. Note, this has already been observed using Secchi disk water clarity measurements.
•Zebra mussels will be more visible on shoreline substrates such as rocks logs etc.
•Larger sized zebra mussels will become common and some will be over 5 cm in length.
•There will be a reduction or loss of our native clam population. These may become extinct within a couple of years. Otters that feed on clams may also be reduced in numbers.
•There is going to be pressure on larval insects like dragonflies by restricting their emergence.
•There will be direct competition for algal resources that microscopic aquatic crustaceans require, which in turn support species of fish that eat plankton.
•Faster and thicker weed growth will occur which is the result of the greater penetration of sunlight in the water column. This was already observed in 2016.
•There will be increased decomposition of organic matter forming oxygen depleted zones in the lake which can affect fish and also change water chemistry.
•Certain types of blue green algae (a cyanobacteria) blooms may occur which could also produce microcystin (toxic to the liver). These blooms could appear in

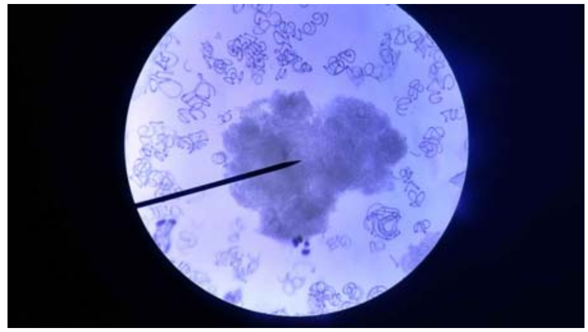
greater frequency and intensity than at present. ***Note that we cannot be certain of the extent of the above effects and must wait and measure these over time as the zebra mussel population in White Lake reaches an equilibrium state.***

The presence of zebra mussels in lakes inevitably and irreversibly changes the chemistry of the lake. For example, the pH of the lake is lower (more acid), the conductivity is lower as is the alkalinity when compared to data collected in 2015. All of these parameters decreased sharply on the graphs at about the same time that the Secchi depth shot up by meters as lake water was being filtered and clarified by the zebra mussels. The scientific literature on the effect of zebra mussel infestations on lakes like White Lake report that their presence essentially transfers key nutrients from the water column to the sediments. They increase markedly the production of ammonia and oxidative products like nitrite and nitrate. Zebra mussels convert more of the phosphorous present in the water column to a bio-available form which is as serious as increasing the overall concentration of phosphorous. The effects on the sediments could also be problematic since, via feces, nutrients will be transferred there at a rapid rate. The stems of aquatic plants in White Lake are now covered with zebra mussels which will provide in-situ fertilization of these plants and promote further growth.

White Lake right now is in a transition period with rapid changes taking place likely over the next several years. The published literature on the effects of zebra mussels in lakes indicate that although their effects will increase dramatically over the short term, the situation may improve somewhat over the longer term as White Lake reaches a new equilibrium. Only time will tell what the actual effects of the presence of zebra mussels will be on White Lake, in particular the occurrence of blue-green algae and the associated presence of toxins. Climate change may be a factor in producing algal blooms, but for White Lake, this is only one of the multiple stressors on the lake which taken together make the lake more susceptible to algal blooms due to human activity.

The White Lake Preservation Project will continue to monitor White Lake water quality and document the changes taking place. We will also be making an effort to update and inform all individuals on this and other invasive species. Please check our website at www.WLPP.ca for updates.

14.0 Algal Blooms – 2016



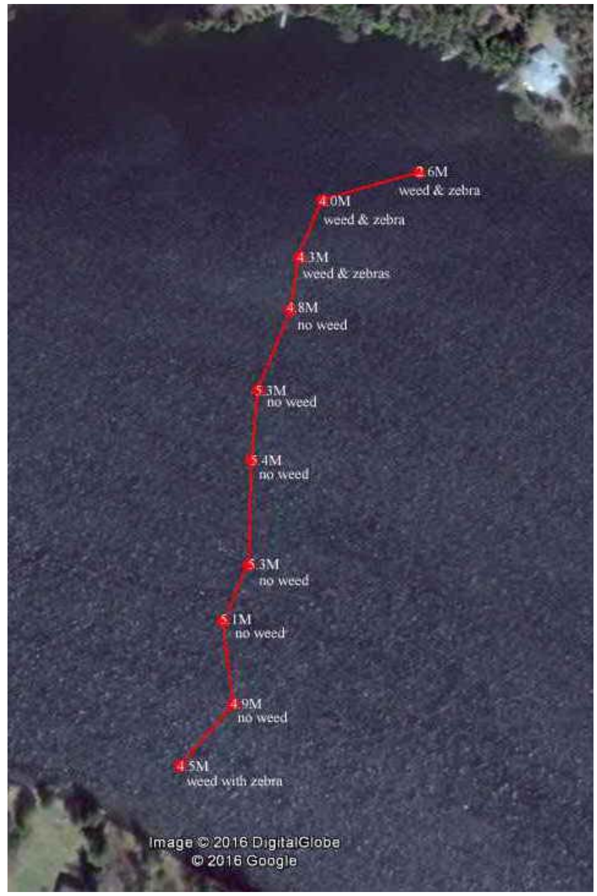
During the 2016 ice-free season there were no significant algal blooms observed on White Lake. Algal blooms of anabaena blue green algae were observed during each of the 2013, 2014 and 2015 seasons. One season (2013) produced significant levels of mycrocystin toxins whereas the other blooms produced lower levels. Some of the toxin analysis results were at or below the detection levels of the analytical chemistry methods used to measure these. In all cases, the algal blooms were found in all parts of White Lake.

According to the literature (see bibliography below) the presence of zebra mussels favours the growth of microcystis (a variety of blue green algae) over the growth of the species of blue green algae (anabaena) we have been troubled with in the recent past on White Lake. It is possible that since White Lake is transitioning to a chemical state resulting from the presence of zebra mussels, that this year's conditions were not right for the production of an algal bloom of either of these species of blue green algae. The photo micrograph above shows the algae present in White Lake on October 7, 2016. The water sample was taken on the NW shore of the lake. The squiggly-looking alga is anabaena and the relatively large blob in the middle of the photo is a species of microcystis. Clearly, both species are present in White Lake. We will continue to monitor algal populations in the lake.

15.0 <u>Aquatic Plant Propagation Study – Three Mile Bay Transect</u>

David Overholt

One of the expected side effects of clearer lake water is the increased growth of aquatic plants at depths where they do not now exist. In an effort to monitor any changes in plant growth taking place over the next several years, we are monitoring the presence or absence of aquatic plants at specific locations across Three Mile Bay. We are using a GPS device to monitor exact locations. A special weed grapple device was constructed and used to collect weeds at depth and to bring them to the surface. By monitoring the locations where the lake floor is covered with aquatic plants and whether or not zebra mussels are present, we will be able to determine if the bottom plant cover is increasing with time. The photo to the right shows the transect currently being monitored and the data collected at each indicated site.



The data show that depending on the location, the presence of weeds currently extends to depths approaching 5 m. At depths greater than 5 m, the lake bottom is free of weeds. Also, zebra mussels were found attached to all weeds found on the transect showing that they have infiltrated all areas where they could find a surface on which to attach. In coming years, the study area will be expanded to include areas on either side of the current transect.

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17.0 Acknowledgements

We are grateful to the Lake Partner Program of the Ontario Ministry of the Environment and Climate Change for providing us with sampling equipment and the analysis of water samples for total phosphorous, calcium and chloride. The Gottlieb Foundation is gratefully acknowledged for providing the WLPP with a grant supporting the contract with the Mississippi Valley Conservation Authority. Costs and time related to lake sampling activities were self-funded by the Science Committee of the White Lake Preservation Project.

Appendix 1: Weather Conditions for 2015 and 2016

Weather conditions can have a significant effect on water chemistry and it is important to note annual weather conditions as an aid in interpreting chemical and physical parameter data. For the months of June/July/August: a) the average mean temperature was 1.1°C cooler during 2016 when compared to 2015; b) the total precipitation was 33.8 mm less for 2016 than for 2015, a reduction of 13.6%; c) there were 11 fewer rainfalls of 1 mm or more for 2016 when compared to 2015, a reduction of 40%.

Monthly Meteorological Values – Environment Canada: *2015*

Ottawa Intl. Airport	Mean Temp., °C	Highest Monthly Max. Temp.	Total Precip., mm	Number of Days with Precip. of 1mm or More
April	6.2	23.7	64.2	10
May	15.8	30.7	62.2	9
June	17.8	27.8	108.0	12
July	20.9	34.3	40.8	5
August	20.0	31.5	100.0	10
September	17.9	32.1	69.4	6
October	7.1	23.4	73.6	9
Total			**518.2**	**61**

Monthly Meteorological Values – Environment Canada: *2016*

Ottawa Intl. Airport	Mean Temp., °C	Highest Monthly Max. Temp.	Total Precip., mm	Number of Days with Precip. of 1mm or More
April	3.5	23.1	43.8	5
May	14.2	33.2	26.2	5
June	18.5	23.3	66.2	5
July	21.5	34.0	57.2	6
August	22.0	34.6	91.6	5
September	16.3	29.8	38.8	7
October	8.6	24.5	107	11
Total			**430.8**	**44**

Monthly Meteorological Values – Environment Canada: Comparison of 2016 with 2015

Ottawa Intl. Airport	Mean Tem., °C	Highest Monthly Max. Temp.	Total Precip., mm	Number of Days with Precip. of 1mm or More
April	- 2.7	- 0.6	- 20.4	- 5
May	- 1.6	+ 2.5	- 36.0	- 4
June	+ 0.7	- 4.5	- 41.8	- 7
July	+ 0.6	- 0.3	+ 16.4	+ 1
August	+ 2.0	+ 3.1	- 8.4	- 5
September	- 1.6	- 2.6	- 30.6	+ 1
October	+ 1.1	+ 1.1	+ 33.4	+ 2
Total	**- 1.5**	**- 1.3**	**- 81.4**	**- 17**

For the months of June/July/August: a) the average mean temperature was 1.1°C cooler during 2016 when compared to 2015; b) the total precipitation was 33.8 mm less for 2016 than for 2015, a reduction of 13.6%; c) there were 11 fewer rainfalls of 1 mm or more for 2016 when compared to 2015, a reduction of 40%.

Appendix 2: Studies on the Precision of Secchi Depth Measurements

David Overholt

Secchi depth measurements provide a gauge of the clarity of the water column. Measurements are taken with a disk approximately 12 inches in diameter sectioned off into two white and two black quadrants. The depth at which the disk disappears from view is the Secchi depth and is one half of the distance that sunlight is capable of penetrating into the water column.

When taking Secchi depth readings, it is recommended that measurement be taken on full sun days and from the side of the boat shaded from the sun. To test this assertion, Secchi depth readings were taken at different times during a single day from both the shaded and sunny side of the boat. The results are presented in the table below:

Time	Secchi D., m - shaded side	Secchi D., m - sunny side
9:25	3.3	3.2
10:36	3.3	3.2
12:11	3.3	3.1
2:30	3.4	3.1
3:50	3.3	3.0
Average ± standard deviation	3.32 ± 0.50	3.12 ± 0.08

Site: Three Mile Bay, July 5, 2016

Results:

The results show that the shaded Secchi depth readings are more precise by nearly a factor of two and about 0.2 m greater than readings taken from the sunny side of the boat. Clearly, the reflection of sunlight on the water's surface makes the measurement of Secchi depth less precise and more prone to error.

In a separate experiment, a periscope type viewer was constructed and used to measure the Secchi depth. This technique, although not used in our data collection program, gave Secchi depths which were 0.3 m greater than those obtained using conventional means.

Appendix 3: <u>Water Depth Reduction During Summer 2016</u>

The water level draw down from April to October 2016 was determined by measuring the actual depth of water at the three shallow sampling sites listed below. A calibrated weighted sounding line was used to make measurements. The results show that the Madawaska River Management Plan target levels for White Lake water depth were respected.

This data, however, cannot be used to measure target levels set during the summer months and only indicates the initial and final lake water levels. We plan to take more routine measurements during the hotter summer months in 2017 in order to make this determination. Target levels and the water management plan are posted on the WLPP website at www.WLPP.ca Note that these measurements are not comparable to the gauge measurements at the dam and assume that the depth of White Lake is at its maximum level on April 15.

Site	**High Water Depth April 15, 2016**	**Low Water Depth October 15, 2016**
Village Basin	1.65 m	1.20 m
The Canal	2.40 m	1.95 m
Hayes Bay	1.60 m	1.20 m

Difference in Depth over Season:

Village Basin	0.45 m
The Canal	0.45 m
Hayes Bay	0.40 m

Average: 0.43 ± .03 m

Madawaska River Management Plan target level drawdown for same period: 0.52 m

On October 15, 2016, the White Lake water level was 0.09 m (3.5 in.) ABOVE Madawaska River Management Plan target levels.

Appendix 4: Chemical and Physical Data - 2016

Three Mile Bay N. 45° 15.767'; W. 076° 32.521 Depth: 6.0 M

Date	Time	Day of Year	Secchi Depth, M	Temp, °C	Ca, ppm	Total P, ppb	Comments
May 17	10:04	138	3.40	13.0	36.4	8.2, 8.6 (8.4)	**Alkalinity = ppm**
May 28	10:56	149	5.60	20.0		-	
June 14	10:15	166	3.80	17.0	30.7	12.0, 12.8 (12.4)	Alk: 100 pH= 7.92
July 3	9:57	185	3.30	23.0		-	
July 12	9:57	194	3.25	23.5	30.7	12.4, 13.0 (12.7)	Alk: 100 pH= 7.54
July 31	10:15	213	3.70	25.0		-	
August 17	10:08	230	4.40	23.4		12.8, 12,2 (12.5)	Alk: 100 pH= 7.04
August 30	10:02	243	5.60	24.0		-	
September 12	10:05	256	4.90	22.5		10.4, 10.0 (10.2)	
October 3	10:31	277	5.50 (bottom)	17.0		-	Nov. 4, 2016: Temp. 7.75 °C
October 15	10:07	289	5.50 (bottom)	13.5		7.4, 8.0 (7.7)	Nov. 4, 2016: Secchi Depth 5.45 m

North Hardwood Island N. 45° 16.162'; W. 076° 33.203' Depth: 5.0 M

Date	Time	Day of Year	Secchi Depth, M	Temp, °C	Ca, ppm	Total P, ppb	Comments
May 17	10:24	138	4.70	13.5	31.8	8.0, 8,2 (8.1)	
May 28	11:07	149	5.80	19.5		-	
June 14	10:33	166	3.20	17.5	32.0	10.4, 11.0 (10.7)	Alk: 100 pH= 8.10
July 3	10:08	185	3.30	23.0		-	
July 12	10:18	194	3.30	23.0	31.7	14.4, 13.8 (14.1)	Alk: 100 pH= 8.06
July 31	10:26	213	3.10	24.8		-	
August 17	10:29	230	4.35	23.5		12.4, 12.6 (12.5)	Alk: 100 pH= 7.15
August 30	10:26	243	5.0+ (bottom)	23.8		-	
September 12	10:17	256	4.40	23.0		12.0, 10.2 (11.1)*	
October 3	10:42	277	5.60 (bottom)	17.0		-	
October 15	10:23	289	5.70 (bottom)	14.0		8.4, 10.2 (9.3)*	

*higher value discarded as outlier

Pickerel Bay N. 45º 16.33'; W. 076º 31.03 Depth: 7.5 M

Date	Time	Day of Year	Secchi Depth, M	Temp, °C	Ca, ppm	Total P, ppb	Comments
May 17	10:53	138	4.70	14.0	-	-	
May 28	11:23	149	6.20	20.0	-	-	
June 14	10:49	166	3.50	17.5	-	-	Alk: 100 pH= 8.14
July 3	10:24	185	3.30	23.0	-	-	
July 12	10:50	194	3.25	23.5	-	-	Alk: 100 pH= 8.07
July 31	10:37	213	3.15	24.5	-	-	
August 17	10:54	230	5.00	23.8	-	-	Alk: 100 pH= 7.24
August 30	10:43	243	5.70	23.8	-	-	Sept 4 (day 248) readings: SD: 4.6M, temp: 22.5 °C, time: 12:05 clear sunny day
September 12	10:40	256	4.90	22.5	-	-	
October 3	11:00	277	5.40	17.0	-	-	
October 15	10:45	289	6.70	14.0	-	-	

Deepest Pickerel Bay N. 45º 16.81'; W. 076º 31.63 Depth: 9.0 M

Date	Time	Day of Year	Secchi Depth, M	Temp, °C	Ca, ppm	Total P, ppb	Comments
May 17		138	-		-	-	
May 28		149	-		-	-	
June 14		166	-		-	-	
July 3		185	-		-	-	
July 12		194	-		-	-	
July 31		213	-		-	-	
August 17		230	-		-	-	
August 30		243			-	-	Sept 4 (day 248) readings: SD: 4.9M, temp: 23.0 °C, time: 11:49 clear sunny day
September 12	10:32	256	4.80	22.5	-	-	
October 3	10:52	277	6.0	17.0	-	-	
October 15	10:35	289	7.3	14.0	-	-	

Middle Narrows N. 45º 18.548'; W. 076º 31.271' Depth: 6.0 M

Date	Time	Day of Year	Secchi Depth, M	Temp, °C	Ca, ppm	Total P, ppb	Comments
May 17	11:09	138	5.50	15.0	31.1	6.6, 7.4 (7.0)	
May 28	11:36	149	6.20 (bottom)	20.0		-	
June 14	11:12	166	3.80	17.5	32.1	9.8, 11.6 (9.8)*	Alk: 100 pH= 8.02
July 3	10.46	185	3.80	23.0		-	
July 12	11.04	194	3.30	23.5	32.0	12.6, 12,6 (12.6)	Alk: 100 pH= 8.05
July 31	10:57	213	3.20	24.5		-	
August 17	11:09	230	3.60	23.7		12.2, 11.6 (11.9)	Alk: 90 pH= 7.25
August 30	10:55	243	5.00	23.8		-	
September 12	10:55	256	5.80	23.0		9.4, 10.2 (9.8)	
October 3	11:09	277	5.50	17.0		-	
October 15	10:58	289	5.70	14.0		7.4, 7.8 (7.6)	

*higher value rejected

The Canal N. 45º 19.267'; W. 076º 30.013' Depth: 2.4 M

Date	Time	Day of Year	Secchi Depth, M	Temp, °C	Ca, ppm	Total P, ppb	Comments
May 17	11:22	138	> depth	13.0 B=13	34.4	8.2, 8.2 (8.2)	
May 28	11:47	149	> depth	22.0 B=22		-	
June 14	11:35	166	> depth	16.0 B=16	33.1	8.8, 8.8 (8.8)	Alk: 100 pH= 8.34
July 3	11:01	185	> depth	21.0 B=21		-	
July 12	11:19	194	> depth	23.5 B=?	30.0	8.2, 9.4 (8.8)	Alk: 100 pH= 8.26
July 31	11:08	213	> depth	24.5 B=24.5		-	
August 17	11:25	230	> depth	22.4 B=21.9*		8.2. 8.4 (8.3)	Alk: 80 pH= 7.43
August 30	11:07	243	> depth	23.8 B=24		-	
September 12	11:01	256	> depth	21.0 B=21		8.8, 9.0 (8.9)	
October 3	11:21	277	> depth	15.0 B=15.0		-	
October 15	11:10	289	> depth	10.2 B=10.0		6.8, 6.6 (6.7)	

Temperatures taken 1 m from botton. B= bottom temperature

Hayes Bay N. 45º 19.037'; W. 076º 28.424' Depth: 1.6 M

Date	Time	Day of Year	Secchi Depth, M	Temp, °C	Ca, ppm	Total P, ppb	Comments
May 17	11:55	138	> depth	13.8 B=13.8	36.6	8.2, 9.0 (8.6)	
May 28	12:02	149	> depth	24.0 B=24.0		-	
June 14	11:56	166	> depth	16.5	34.1	9.4, 9.2 (9.3)	Alk: 100 pH= 8.23
July 3	11:15	185	0.8	21.0 B=21.0		-	Water murky ;Single boat tubing on bay
July 12	11:41	194	> depth	23.8	32.2	9.6, 10.0 (9.8)	Alk: 120 pH= 8.28
July 31	11:22	213	1.1	25.0 B=25.0		-	No boats when sampling
August 17	11:41	230	> depth	22.5 B=21.9*		9.0, 9.2 (9.1)	Alk: 100 pH= 7.55
August 30	11:24	243	> depth	23.6 B=23.6		-	
September 12	11:31	256	> depth	21.0 B=21.0		9.2, 9.8 (9.5)	
October 3	11:32	277	> depth	15.0 B=15.0		-	
October 15	11:20	289	> depth	10.5 B=10.5		8.6, 7.8 (8.2)	

Temperatures taken 1 m from botton. B= bottom temperature

Jacob's Island N. 45º 19.989; W. 076º 30.622' Depth: 4.0 M

Date	Time	Day of Year	Secchi Depth, M	Temp, °C	Ca, ppm	Total P, ppb	Comments
May 17	12:12	138	4.60 (bottom)	14.0	31.4	9.0, 8.4 (8.7)	
May 28	12:14	149	4.40 (bottom)	25.0		-	
June 14	12:20	166	4.20 (bottom)	16.2	33.0	9.8, 12.0 (9.8)	Alk: 100 pH= 8.10
July 3	11:32	185	3.90	22.5		-	
July 12	12:00	194	3.25	23.8	29.1	10.4, 11.0 (10.7)	Alk: 120 pH= 8.09
July 31	11:35	213	3.80	24.0		-	
August 17	11:58	230	4.00 (bottom)	23.8		9.2, 9.2 (9.2)	Alk: 100 pH= 7.38
August 30	11:39	243	4.00 (bottom)	23.8		-	
September 12	12:15	256	> 4.4 (bottom)	23.0		9.0, 8.8 (8.9)	
October 3	11:57	277	> 4.4 (bottom)	16.3		-	
October 15	11:40	289	> 4.0 (bottom)	13.0		8.2, 7.6 (7.9)	

Village Basin N. 45º 21.233'; W. 076º 30.303' Depth: 1.65 M

Date	Time	Day of Year	Secchi Depth, M	Temp, °C	Ca, ppm	Total P, ppb	Comments
May 17	12:26	138	> depth	13.5	31.1	8.8, 8.8 (8.8)	
May 28	12:24	149	> depth	24.0		-	
June 14	12:39	166	> depth	16.1	31.4	9.8, 9.6 (9.7)	Alk: 100 pH= 8.22
July 3	11:46	185	> depth	21.0 B=21.0		-	
July 12	12:25	194	> depth	23.5	29.6	9.6, 9.6 (9.6)	Alk: 100 pH= 8.41
July 31	11:50	213	> depth	25.0 B=25.0		-	
August 17	12:20	230	> depth	22.5 B=21.6*		9.0, 8.8 (8.9)	Alk: 100 pH= 7.56
August 30	11:57	243	> depth	23.5 B=23.5		-	
September 12	12:35	256	> depth	21.0 B=21.0		8.6, 9.2 (8.9)	
October 3	12:13	277	> depth	15.2 B=15.2		-	
October 15	12:00	289	> depth	10.5 B=10.5		7.0, 6.8 (6.9)	

Temperatures taken 1 m from botton. B= bottom temperature

Weather Conditions 2016

Date	Day of Year	Weather Conditions
May 17	138	Clear sunny day, 2-3 previous days wind 15 to 30 km/hr, 15 km/hr day before sampling. Air temp. ~15 °C
May 28	149	Hot, sunny, no wind – hot and dry for two weeks previous to sampling Air temp. ~27 °C; significant pollen in water
June 14	166	Full sun, air temp. 17 °C. Jun 11 – 10 hours of steady rain, not heavy; very high pollen in water; Jun 12 to 13 – winds of 25 to 40 easing to < 10 km/hr
July 3	185	Clear sunny day, Air tem. 24 °C. three days prior good but not heavy rain broke 3 weeks of drought. Winds ~ 10 km/hr
July 12	194	Sunny, very few clouds;, wind ~10 km/hr; Air temp. 25 °C; July 9 some rain/July 10 heavy rain (~2" lake depth increased) July 11 sunny and calm
July 31	213	Partially cloudy, air temp. 23 °C; winds ~10 km/hr. Hot and dry previous ten days, lake level down due to evaporation
August 17	230	Bright, clear sunny no wind. Air temp. 23°C. Following 2 weeks of ~30 °C Air temps, significant rain Aug 13/14/16 (day before sampling)
August 30	243	Bright sunny day, no wind, Air temp. 23 °C. No rain for 14 days, max day temps 27 °C; streams are not running at all.
September 12	256	Sunny day no clouds winds ~5 km/hr. Last significant rains 5 days prior to sampling. Very windy 1.5 days before sampling.
October 3	277	Moderate rain day before sampling. Boundary and Paris Creeks not flowing. Bright overcast day. Winds from 0 to 5 km/hr.
October 15	289	Moderate rain 2 days prior to sampling (not enough to run streams) Mostly sunny day with winds ranging from 0 to 15 km/hr.

Notes:

1. Temperatures were taken at Secchi Depth. When sampling site depth was less than Secchi depth, temperatures were taken 1 M from bottom.

2. Water samples for total phosphorous were taken at Secchi Depth or when sampling site depth was less than Secchi depth, samples were taken 1 M from bottom.

3. All water samples were filtered through 80 micron filter prior to determination of total phosphorous.

4. Sampling dates were ideally the first of the month for temperature and Secchi depth and the 15^{th} of the month for Secchi depth, temperature and total phosphorus. Some adjustments in timing had to be done to accommodate inclement weather and availability of personnel.

5. Total phosphorous water samples were not taken at the Pickerel Bay or Deepest Pickerel Bay locations as these locations were not part of the Lake Partners Program for 2016.