## 1.0 INTRODUCTION

The following report examines the water quality record of Buck Lake, both north and south basins with the intent to provide a compendium of data and information for the present and future use of the Buck Lake Association. The aim is make available under one cover as much of the water quality record as can be attained in order to inform the reader regarding the efforts of government agencies and volunteers for the Buck Lake Association to document water quality conditions over the period of record.

The parameters used to qualify and quantify water quality are discussed in the context of the Ontario Provincial Water Quality Objectives, where objectives are available. A further goal is to examine those parameters that are affected by human activity within the watershed for possible trends in water quality over the period of record if the dataset permits.

What follows is an examination of the majority of water quality parameters for which there was enough data to develop either descriptive statistics and or a trend through time analysis. A few parameters may be found on the accompanying CD that are not discussed herein. These parameters either do not have much relevance to characterizing the water quality of the lakes or have insufficient data available.

**Appendix 1-A and Appendix 1-B** contain the edited raw data in tabular form. Most of this data was acquired in electronic format from the Ministry of Environment. The un-edited raw data can be viewed on the CD that accompanies the report. The report, tables and graphs and appendices are also included on the CD.

The tables in **Appendix 1-A and Appendix 1-B** are arranged in order by station description file (SDF) code. The Ministry of the Environment assigns station description file numbers for sampling locations. The 12-0004 section of the SDF number refers to the Cataraqui River watershed; the 700 series numbers refer to sample locations under a formal survey such as the Recreational Lakes Program or the Acid Precipitation in Ontario Study.

12-0004-707 72,75,79,87, BUCK LAKE – South Basin – Deepest Sounding
12-0004-708 75,79,87, BUCK LAKE - North Basin, South end – Deepest Sounding
12-0004-727 72,
12-0004-728 72,
12-0004-729 72,

<u>**Within each one of the station description file numbers, the parameters for that station are listed alphabetically**</u> and descriptive statistics are calculated and tabulated where applicable. The number of samples, maximum, minimum, mean and standard deviation are provided. The extraneous data, for example weather data and remarks codes etc. from the raw data set are have been removed and are not summarized.

It should be noted that there are keystroke errors in the raw data set. Where keystroke errors were obvious, corrections were made however in less obvious circumstances the data was considered anomalous and could not be used in this evaluation.

Over the period of record the reporting of results often resulted in changes in units between years and sometimes within years. In the raw data some results were initially recorded in milligrams per litre (mg/L) and then later in micrograms per litre (ug/L). Where this occurred the units have all been standardized in this summary to a common unit.

Where an individual value is identified in the raw dataset that is clearly anomalous it has been removed in order for the balance of the data set to be of value. In some situations the entire data set for a particular parameter was considered anomalous; the values are summarized and identified as anomalous but were not used for discussion purposes. The material in **Appendix 3** consists of photocopied pertinent material from various published reports and unpublished summaries from MOE and MNR.

The parameters of primary interest with respect to human impacts on water quality are the lake trophic status parameters. These include water clarity (Secchi disc depths), chlorophyll a, total phosphorus (TP), total nitrogen (TN), TN:TP ratios and oxygen concentrations in the hypolimnion. As such, these parameters received the greatest amount of sample effort over the period of record.

## 2.0 LAKE PROCESSES

To gain an understanding of lake water quality and some of the determining factors, it is necessary to have an understanding of lake processes. Water quality can be very different from lake to lake due to differences in lake shape, size, surrounding topography, watershed size and bedrock geology. Human impacts are also contributing factors to water quality.

Lakes undergo physical changes in temperate regions that determine many water quality outcomes. The ice sheet stratifies the lake during the winter ice-on period; there is no opportunity for mixing by wind energy. The temperature is zero at the surface and about 4 oC at the bottom. After the spring melt the lake undergoes spring overturn, essentially it is a period of time when the lake mixes from top to bottom before hot temperatures warm the surface waters to the point where mixing is no longer possible. After ice-out only a few calm sunny hot days are required to set up stratification.

The lake is stratified when a warm surface layer (epilimnion) forms over a colder bottom water layer (hypolimnion). The transitional layer between the two is called the metalimnion; the transitional layer contains the thermocline, that layer where there is the most rapid temperature change. The temperature gradient is a physical barrier that prevents the lake from mixing; the colder water is heavier than warm water. The oxygen acquired during the spring mixing period must sustain life in the hypoliminion until the fall mixing period replenishes the depleted oxygen. The stratification period usually lasts from mid-May to early November. The spring and fall overturn periods occur when the water temperature is the same from surface to bottom $\simeq$ 4.0 ºC. During the mixing periods, wind energy mixes the surface and bottom waters allowing for the concentration of all gases ($O_2$, $CO_2$, $H_2S$, $CH_4$ etc) to be equal concentration top to bottom.

During the stratification period, a continuous supply of algae growth from the surface waters settle into the deep water portion and causes oxygen depletion in the bottom waters; the greater the algae supply, the faster the oxygen depletion rate. Some lakes can experience complete anoxia in the hypolimnion by late summer; this of course is a serious problem in lakes with cold-water fish species such as lake trout.

The surface waters or epilimnion are continuously oxygenated through contact with the atmosphere and through photosynthesis by aquatic plants / algae. Nutrients, phosphorus and nitrogen, supplied to the surface water are used to grow algae. The supply of algae continuously settles into the hypolimnion and decomposes leaving the associated nutrients at the bottom. Nutrient concentrations at the bottom of some lakes may be many times greater than at the surface.

During the fall cooling period and overturn, the surface waters become the same temperature as the bottom waters; this allows for mixing and replacement of the depleted oxygen in the bottom waters and the release of other gases H2S, CH4, CO2 etc. to the atmosphere. Overturn also makes available at the surface the accumulated bottom nutrients and results in blooms of algae and diatoms. There is generally a long period of mixing prior to ice cover, allowing for complete rejuvenation of oxygen at the bottom.

## 2.1 Lake Sensitivity & Lake Morphometry

Lake sensitivity to water quality change is a function of flushing, dilution and assimilation capacity. Small lakes have less volume than large lakes and therefore less ability to dilute contaminants or nutrients.

Lakes with small watersheds are generally more sensitive than lakes with large watersheds (catchment size relative to lake volume). Large watersheds provide more runoff for lake flushing; the larger the watershed the more rainfall that is collected upstream of the lake and therefore the more flow-through water that can carry nutrients away from the lake through the outlet. .

Lake shape or morphometry is also a factor in lake sensitivity; the ratio between the volume of the warm surface water (primary productivity waters) and the cold deep waters (the decomposition zone) is very important. Saucer-shaped lakes are more sensitive to oxygen depletion than bowl or vase shaped lakes. The lakes with larger hypolimnion volumes than epilimnion volumes are less sensitive to oxygen depletion and accumulation of nutrients at the bottom.

**LAKE MORPHOMETRY – PARAMETERS**

- **Lake Volume (Vo)**
- **Lake Area (Ao)**
- **Lake Depth (D)**
- **Mean Depth (Z) = Vo /Ao**
- **V(epi) / V(hyp)**
- **Lake Shape & Surrounding Topography (islands, bays and protective hills)**
- **Flushing Rate (Water Exchange Rate)**

### 2.2 Buck Lake Morphometry

**Buck 'Lake' is really two distinct waterbodies separated by a small stream. The north and south basins are different sizes and shapes with different watershed sizes and bedrock geology and overburden characteristics and therefore experience different water quality.**

| (NORTH BASIN) | (SOUTH BASIN ) |
|---|---|
| **Ao ---------- 2.64 x 10*6 m2** | **Ao ---------- 4.91 x 10*6 m2** |
| **V(epi) ---- 20.658 x 10*6 m3** | **V(epi) ---- 38.139 x 10*6 m3** |
| **V(hyp) --- 7.571 x 10*6 m3** | **V(hyp) --- 22.851 x 10*6 m3** |
| **Vo -------- 28.299 x 10*6 m3** | **Vo -------- 60.990 x 10*6 m3** |
| **V(epi)/V(hyp) --------- 2.729** | **V(epi)/V(hyp) --------- 1.669** |
| **D(max) ----------------- 32.0 m** | **D(max) ----------------- 41.0 m** |
| **Z ------------------------- 10.5 m** | **Z ------------------------- 12.4 m** |
| **Area (At) --- 10.60 x 10*6 m2** | **Area (At) --- 51.28 x 10*6 m2** |
| **Flushing Rate - ------- 0.12/yr** | **Flushing Rate - ------- 0.28/yr** |
| **P Retention ------------ 0.91** | **P Retention ------------ 0.78** |

## 3.0 PARAMETER DISCUSSION AND SUMMARY

The parameters are listed below in alphabetical order. Each parameter has an introductory discussion with respect to the relevance to lake water quality and the PWQOs, if applicable. The discussion of the findings pertinent to each lake basin is provided in **BOLD FONT**. Graphs are intended to be standalone. The reader may wish to bypass the discussion altogether and simply read the graphs. Each graph contains a dialogue box with an abbreviated version of the discussion. The yearly mean values, the trend line, the regression formula and correlation coefficient and the descriptive statistics are all presented on the graphs where the dataset permits. Individual data for each parameter can be found summarized in the tables in **Appendix 1, Appendix 2** and also photocopies of water quality summaries provided by the various source agencies are located in **Appendix 3.**

### 3.1 ALKALINITY

Alkalinity is one of many chemical parameters that are determined to characterize water quality. The alkalinity value helps to distinguish hard water lakes from soft water lakes. The Provincial Water Quality Objective (PWQO) for alkalinity indicates that the alkalinity should not be decreased by more than 25% of the natural ambient concentrations. This type of an occurrence would only occur in the presence of some form of point source industrial discharge.

Alkalinity, pH and conductivity are commonly recorded together. The alkalinity of water is a measure of the capacity of the carbonate-bicarbonate system to buffer the water against a change in pH. Lakes with high alkalinity have a greater potential to neutralize runoff and precipitation that is high in acids.

The Acid Precipitation in Ontario Study (APIOS) classified lakes that had an alkalinity value of less than 10 mg/L as being susceptible to acidification and those of greater than 25 mg/L as not being sensitive to acidification. Lakes with high alkalinity values are referred to as hard water lakes and are able to buffer or neutralize the effects of acid precipitation. In hard water lakes, lakes located in limestone formations or with calcareous glacial deposits, the alkalinity values for temperate area lakes range from 30 to 150 mg/L. Soft water lakes on Precambrian Shield bedrock areas typically have alkalinity values in the range of 5 to 10 mg/L. In lakes highly productive in algae, the alkalinity values will rise during the summer in the epilimnion as a result of photosynthetic activity.

**The average alkalinity value in Buck Lake (South Basin) is 71.69 mg/L for the period of record (1975, 1979, 1987 and 2005). The average alkalinity value for Buck Lake (North Basin) is 35.83 mg/L (1975, 1979, 1987 and 2005). The Ministry of the Environment 1972 report indicates a range in values. The south basin has a range from 69 to 78 mg/L and the north basin alkalinity ranges between 36 and 56 mg/L. Lakes with alkalinity values above 25 mg/L are not sensitive to the effects of acid precipitation. Despite the fact that Buck Lake is located on Precambrian Shield bedrock it has a high alkaline content in the sandstone and glacial deposits within the watershed. This high alkalinity value is typical of a hard water lake and as a result one would expect to find elevated pH and conductivity values. The difference in alkalinity value between these two basins is directly related to the relative size of their watersheds and the amount of overburden deposits in each. The north basin**

**has a much smaller watershed with more rock outcrop and thinner soil deposits that does the south basin and therefore has a much lower alkalinity.**

Lakes with high alkalinity values while protected against acidification are prone to colonization by zebra mussels due to the availability of calcium carbonate.

### 3.2 ALUMINUM (Al)

The PWQO for total aluminum is 0.075 mg/L for waters with a range in pH of 6.5 to 9.0. Natural or ambient sources of aluminum occur as a result of weathering of minerals from bedrock. Aluminum is mobilized from poorly buffered soils and bedrock when subjected to acid precipitation. The high alkalinity, hardness, and pH of the water in Buck Lake indicate that mobilization of aluminum as a result of acid precipitation is not likely to be a significant factor.

**Only one aluminum value was found in the dataset. Buck Lake (South Basin) was determined to have an aluminum value of 0.021 mg/L on Nov 5, 1987; the value for the north basin on this date was 0.230 mg/L. These values are considerably below the PWQO.**

### 3.3 CALCIUM (Ca)

Calcium (Ca) is one of the four cations along with magnesium (Mg), sodium (Na) and potassium (K) that act in concert to determine water hardness. Waters with high alkalinity and high hardness typically have high cation concentrations. The four cations typically occur in concentrations with Ca>Mg>Na>K. There is no PWQO for calcium.

**Sampling for calcium on Buck Lake was undertaken during the years 1975, 1979, 1987 and 2005. The mean value over the period is 25.24 mg/L for the south basin and 12.55 mg/L for the north basin. Again, the difference in calcium content between the basins is related to bedrock geology and soil deposits in the watersheds.**

By comparison, Ashby Lake (Denbigh, Ontario) an acid sensitive lake with an alkalinity of 12 mg/L has a mean calcium concentration of 5.8 mg/L.

### 3.4 CHLORIDE (Cl)

Chloride is a natural salt found in most surface waters. Sources include atmospheric deposition from rainfall at concentrations of 0.3 to 1.5 mg/L in central North America (Hutchinson, 1975). Coastal maritime deposition rates are much higher due to atmospheric sources. Some limestone bedrock types may also contribute chloride through weathering and inflow of chloride contaminated ground water. Wetzel (1983) indicates that the average chloride content for uncontaminated lake waters is 8.3 mg/L.

Chloride concentrations are not typically influenced by human activities with the exception of industrial or agricultural sources. There is no PWQO for chloride.

**Buck Lake (South Basin) has chloride results for 1972; the values range from 4.0 to 8.0 mg/L. The 1972 values reported for the north basin are 2.0 to 5.0 mg/L. The mean values for the period 1975, 1979 and 1987 are 6.53 mg/L (South Basin) and 2.61 mg/L (North Basin).**

Other local lakes have similar chloride concentrations; Charleston Lake has a whole lake mean value of 7.06 mg/L while the whole lake mean value for Bobs Lake is 7.8 mg/L.

### 3.5 CHLOROPHYLL a, b, and c

Algae or phytoplankton densities are used as an indicator of lake trophic status. Since algae are microscopic plants that contain chlorophyll, a surrogate measurement of the algae density is a measure of the chlorophyll concentration. Chlorophyll is the green pigment in living plants. There are three chlorophyll pigments, chlorophyll a, b, and c. Chlorophyll c is sometimes referred to as acidified chlorophyll or corrected chlorophyll a. There is a strong relationship between water clarity, phosphorus concentration and chlorophyll a concentrations. As phosphorus concentrations increase, chlorophyll a concentrations increase and water clarity decreases. If phosphorus concentrations continue to increase, periodic blooms of blue-green algae will occur which can cause toxicity, taste and odour problems. An average phosphorus concentration in excess of 20 ug/L will lead to high chlorophyll a concentrations and potentially nuisance concentrations of algae.

Algal densities and algae community types are also indicators of aquatic ecosystem health. Algae growth is natural in lakes but becomes problematic when lakes become enriched with plant nutrients or fertilizers. In situations where nutrient concentrations become excessive, the algae community composition shifts from the green algae, indicators of a healthy ecosystem, to the blue-green algae, indicators of an enriched eutrophic or contaminated system.

Chlorophyll a is a parameter commonly analyzed for when determining lake trophic status. Increased algae concentrations result in increased chlorophyll concentrations. As algae concentrations increase water clarity decreases. Lakes may be categorized according to chlorophyll a concentrations as follows:

| | | | | |
|---|---|---|---|---|
| Chlorophyll a (ug / L) | (< 3) | (3 – 6) | (> 6 – 10) | (>10) |
| Trophic Status | Oligotrophic | Mesotrophic | Eutrophic | |
| Classification | Excellent | Good | Fair | Poor |

There is no PWQO for chlorophyll. Chlorophyll a samples and Secchi disc values are commonly collected at the same time. The greater the chlorophyll a concentration the more algae there is and therefore the less clear the water. The MOE Self-Help Program focused on sampling for these two parameters, most lake surveys have commonly sampled for these parameters. Chlorophyll pigments b and c have not been used to characterize lake trophic status. The analytical results for these pigments are provided in raw dataset on the CD but otherwise are not discussed herein.

Lake productivity as determined by chlorophyll a and the importance of the relationship between chlorophyll a and nutrient concentrations, primarily phosphorus, and water clarity, coupled with the long period of record for this parameter allow for an examination of the trend trough time.

**The mean chlorophyll a concentration for Buck Lake (North Basin) for the period of record is 3.20 ug/L (n=34). The period of record for chlorophyll a sampling is from 1972 to 1995. There is enough data for the north basin to examine the trend through time (see Figure 1 following this page). The data for this graph is derived mostly from the MOE Recreational Lakes Program and the MOE Self-Help Program. Chlorophyll a values for the years 1996 to 2008 are derived from total phosphorus values collected under the MOE Lake Partner Program (LPP). The algorithm is presented in the LPP Technical Notes (see Appendix 1-A Tables for Chlorophyll a data).**

**There is much variability in the data. The trend line appears to indicate a decline in chlorophyll a concentrations however the regression analysis indicates a weak relationship ($R^2$= 0.36). The mean of means value for chlorophyll a for the period of record is 3.20 ug/L; the north basin of Buck Lake would therefore be classified as mesotrophic on the basis of this parameter. If however one compares mean value for the period from 1975 to 1985 inclusive (mean value is 4.30 ug/L) with the mean value for the period 1998 to 2008 inclusive (mean value is 2.86 ug/L) it appears that this basin is shifting toward more oligotrophic conditions based on this parameter.**

**The mean chlorophyll a concentration for Buck Lake (South Basin) for the period of record is 2.55 ug/L (n=18). The period of record for chlorophyll a sampling is from 1972 to 1995. There is enough data for the south basin to examine the trend through time (see Figure 2). The data for this graph is derived mostly from the MOE Recreational Lakes Program and the MOE Self-Help Program. There is a data gap for the period 1996 to 2001 inclusive. Chlorophyll a values for the years 2002 to 2008 are derived from total phosphorus values collected under the MOE Lake Partner Program (LPP). The algorithm is presented in the LPP Technical Notes (see Appendix 1-B Tables for Chlorophyll a data).**

**There is less variability in this dataset than for the north basin. The trend line appears to indicate a decline in chlorophyll a concentrations however the regression analysis indicates a weak relationship ($R^2$= 0.36). The mean of means value for chlorophyll a for the period of record is 2.55 ug/L; the south basin of Buck Lake**

**would therefore be classified as oligotrophic on the basis of this parameter. The derived value for the year 2002 appears to be an anomaly, otherwise the data for all other years with the exception of 1975, 1978 and 1979 would have the south basin classified as oligotrophic based on this parameter.**

## 3.6 CLARITY (SECCHI DISC DEPTH) – WATER CLARITY

Water clarity is the parameter of which people are most familiar. The clarity is affected by suspended particles that include clay, and colloidal sized particles from shoreline erosion, agricultural runoff, tree pollen and also algae concentrations. Clarity is also affected by concentrations of tannins and lignin that may impart a dark colour to the water. Water clarity is measured using a Secchi disc, a 20 centimetre disc painted black and white on opposite quadrants. It is lowered into the water on a calibrated line to determine the depth of light penetration through the water.

The Secchi disc measures the depth to which light penetrates and therefore is a good indicator of how far down in the water column algae (phytoplankton) may grow and photosynthesize. It is also a good indicator of the depth to which aquatic vascular plants (aquatic weeds) may grow as long as suitable substrate exists at that depth for the establishment of a root mass. Because lake productivity (algae growth) varies with water temperature, photoperiod (daylight length) and changes in available nutrient supply over the growing season, water clarity needs to be documented many times over the ice-free season to get a meaningful average Secchi disc depth value.

Water clarity measurements were recorded as part of the MOE Self-Help Program and the Recreational Lakes Program. It is also a parameter that is included in the MOE Lake Partner Program. As such, an extensive database exists for this parameter from which a comparison can be made between present and historical values or with other lakes.

The PWQO for water clarity states that ‘water in swimming areas should be sufficiently clear to estimate depth or to see submerged swimmers who may require assistance. Water clarity should be such that, if the bottom is not visible, the water should have a Secchi disc transparency of at least 1.2 metres’. Lakes may be categorized according to clarity as follows:

| | | | | |
|---|---|---|---|---|
| Secchi Disc Depth (m) | ( > 5.0) | (3 – 5) | ( 1.2 - < 3.0) | (< 1.2 ) |
| Trophic Status | Oligotrophic | Mesotrophic | Eutrophic | |
| Classification | Excellent | Good | Fair | Poor |

There are large ranges in water clarity for natural waters that are unrelated to human influence. For this reason water clarity is a parameter that is not used alone to guide decisions regarding water quality management. Water clarity values are interpreted along with other parameters such as turbidity and suspended solids, nutrient concentrations (phosphorus and nitrogen), algae densities as determined through chlorophyll a analysis and oxygen concentrations when making management decisions with respect to protection of water quality.

**The period of record (34 years) for water clarity on the north basin of Buck Lake is 1975 to 2008 (see Figure 3 following this page).**

**The trend line indicates virtually no change in water clarity over the period of record. The graph shows the mean value for water clarity for each year. The mean of means value for the period of record is 4.06m. Based solely on this parameter the north basin would be classified as mesotrophic.**

**For the years with a complete Secchi disc depth dataset Buck Lake (North Basin) begins the season (May) with the same average water clarity. The lake has just completed spring overturn and the accumulated nutrients in the bottom become mixed with the water column and results in increased productivity in the form of a diatom and algae bloom. This results in similar average water clarity values each year. As the season progresses, diatom and algae concentrations decline and water clarity generally increases during the late summer as a result. Water clarity generally declines again at the time of the fall mixing period as the accumulated nutrients in the bottom waters are returned to the surface and promote increased algal growth again. Viewed from above, the difference in water clarity and colour between the north basin and the south basin is obvious during the spring and fall overturn periods when the basins are the most productive (personal observations).**

**The period of record (24 years) for water clarity on the south basin of Buck Lake is 1975 to 2008 (see Figure 4 following this page). This dataset is not as complete as for the north basin however there is a weak relationship over time indicating water clarity may be improving; the important point here is that water clarity has not declined. The graph shows the mean value for water clarity for each year. The mean of means value for the period of record is 5.64 m. Based solely on this parameter the south basin would be classified as oligotrophic.**

**The south basin did not meet the oligotrophic criteria of ≥ 5.0m of water clarity based on annual mean values during only four years (1975, 1979, 1986 and 2006) out of the twenty-four-year period of record. In contrast, the north basin only exceeded the criteria on one occasion, in the year 1996.**

## 3.7 COLOUR

The colour of water is determined as a further method to characterize water type. The main determinant of colour is dissolved organic matter. Extremely hard waters with marl sediments are aqua blue in colour while soft waters with bogs in the headwaters may be dystrophic and range in colour from dark brown to tea coloured. Different analytical methods produce results as either true colour (after filtration) or apparent colour (before filtration). Colour is imparted to the water as a result of reflection of light from dissolved substances and seston. Seston refers to all particulate material found in the water column.

There is no PWQO for colour.

**For Buck Lake (North Basin) sampling for colour was undertaken in 1975 and 1979; one sample result is reported for 1987. The mean value for the surface is of 8.75 Hazen Colour Units (HCU); the bottom mean colour is 15.0 hazen units.**

**The south basin was also sampled for colour during the same years as above. The mean value for the surface is 7.25 HCU and the bottom mean value is 13.0 HCU. Both basins experience darker colours with depth due to the accumulation of humic acids high in organic material, tannins and lignins that impart a tea colour to the water as part of the decomposition process.**

## 3.8 CONDUCTIVITY OR SPECIFIC CONDUCTANCE

Specific conductance or conductivity is a numerical expression of the ability of water to conduct an electric current. It is reported in either microsiemens per centimeter (uS/cm) or micromhos per centimeter (umhos/cm)[the reciprocal of ohms]. It is a measure of both dissolved ions especially dissolved minerals and particulate concentrations in the water. As more dissolved solids are added to the water the conductivity increases. Specific conductance in natural surface waters range between 50 and 1000 uS/cm. Conductivity levels are higher in contaminated waters. Conductivity in the laboratory is always measured at 25 oC; ambient conductivity is recorded on site at ambient temperatures.

An empirical relationship exists between conductivity and total dissolved solids; specific conductance multiplied by 0.65 closely approximates total dissolved solids (TDS).

The conductivity value can also be used as a quick estimate of the concentrations of a number of anions and cations. For example Hutchinson (1975) indicates that for a lake with a conductivity of 220 umhos/cm, the following could be expected: salinity 129.7 mg/L, sodium 8.7 mg/L, potassium 3.2 mg/L, magnesium, 5.2 mg/L, calcium 31.1 mg/L, carbonate 54.4 mg/L, sulphate 18.4 mg/L and chloride 8.7 mg/L.

**From the preceding discussion it was already shown that for Buck Lake (North Basin) the mean calcium concentration is 12.55 mg/L and the mean chloride value was 2.61 mg/L. For the south basin the mean calcium value is 24.24 mg/L and the mean chloride value 6.53 mg/L. One should infer from this that the conductivity level for Buck Lake should be less than 220 umhos/cm.**

There is no PWQO for specific conductance (conductivity).

**Conductivity values are available for 1975, 1979 and 1987. The mean value for Buck Lake (North Basin) is 101.9 umhos/cm (conductivity @25oC). The mean conductivity value for the South Basin for the same period is 182.6 umhos/cm. This confirms the alkalinity, calcium and chloride values discussed earlier. The bedrock geology, soil overburden and watershed size associated with the south basin all act to confer different water chemistry to the south basin from that of the north basin.**

### 3.9 HARDNESS

The hardness of water is a surrogate measurement of the concentration of calcium and magnesium salts, largely combined with bicarbonate and carbonate as well as sulphates, chlorides and other anions of mineral acids. The carbonate hardness can be removed by boiling. This causes precipitation of $CaCO_3$, essentially it is the hard water scale that deposits on a kettle. The fraction of calcium and magnesium that remains in solution as sulphates, chlorides and nitrates after boiling constitutes the residual non-carbonate hardness.

Hardness is expressed in mg/L of $CaCO_3$ equivalents.

There is no PWQO for hardness.

Hard water lakes, lakes located in limestone formations or with calcareous glacial deposits have hardness values on the order of 100 mg/L for temperate area lakes. Soft water lakes on Precambrian Shield bedrock areas typically have hardness values below 50 mg/L.

As a comparison, Ashby Lake (Denbigh, Ontario) an acid sensitive soft water lake with an alkalinity of 12 mg/L has a mean calcium concentration of 5.8 mg/L and a hardness value of 25 mg/L. Loughborough Lake (South Frontenac Township) is a hard water lake that lies completely in a limestone basin; it has an alkalinity of 114 mg/L and a hardness value of 127 mg/L.

**The mean hardness value for Buck Lake (South Basin) is 83.2 mg/L; the north basin has a mean hardness value of only 46.4 mg/L. The hard bedrock, shallow soils and small watershed size of the north basin all contribute to the much lower hardness value.**

### 3.10 IRON (Fe)

The PWQO for total iron in an unfiltered water sample should not exceed 300 ug/L in order to protect aquatic life. Iron is present in most rocks and soils as well as in ore deposits. Weathering and mineralization processes act to mobilize iron. Other sources include the atmospheric deposition from the burning of fossil fuels and the corrosion of iron fabricated products. Iron concentrations are usually higher in the bottom waters where there is opportunity for re-suspension from the sediments.

Iron has a complex chemistry in water and the form of iron is dependant upon the amount of oxygen, carbon dioxide and the pH. Iron easily complexes with many other chemicals. Iron is not known to accumulate in fish flesh and is relatively easily metabolized. The toxic or detrimental effects stem from the ability of some iron complexes to adsorb to gill surfaces, egg masses etc.

The PWQO of 0.300 mg/L (300 ug/L) is more stringent than the USEPA value of 1.000 mg/L (1,000 ug/L).

**Buck Lake (North Basin) has analytical results for iron (Fe) during the years 1975, 1979 and one value for 1987. The basin average value is 0.142 mg/L (142ug/L). The bottom water iron concentrations are about three times more concentrated than at the surface. The poor deep-water oxygen concentrations are a contributing factor to the elevated iron values in the north basin. Wetzel (1983) reports that where decomposition of organic materials occur in productive, thermally stratified lakes with small deep basins, especially those that receive flow of bog waters high in humic organic matter, hypolimnetic accumulations of iron can be excessive with levels exceeding 250 mg/L (250,000 ug/L). The north basin has all of these characteristics including the expected poor oxygen conditions in the hypolimnion (see the discussion under oxygen). There are two occasions (May 3$^{rd}$, 1975 and the bottom water sample collected on August 20$^{th}$ 1979) when the PWQO of 0.300 mg/L (300 ug/L) was exceeded.**

**The PWQO was also exceeded on both these dates in the south basin as well. The mean value for iron for the south basin is 0.136 mg/L (136 ug/L).**

### 3.11 MAGNESIUM (Mg)

There is no PWQO for magnesium. Magnesium (Mg) is one of the cations along with calcium (Ca), sodium (Na) and potassium (K) that are quantified to characterize water. Typically these cations have concentrations with Ca>Mg>Na>K. Hutchinson (1975) reports that for lakes with conductivity values of 180 umhos/cm that Mg and Ca values should be 4.2 and 25.0 mg/L respectively.

**Buck Lake (south basin) has a mean conductivity value of 180.7 umhos/cm, a mean Mg value of 4.85 mg/L and a mean Ca value of 25.24 mg/L. The values for the North Basin are very similar, a mean Mg value of 3.46 and a mean Ca value of 12.55 mg/L and a mean conductivity value of 101.9 umhos/cm.**

### 3.12 NITROGEN - Total Nitrogen = (Ammonia + Ammonium, Nitrate and Nitrite and Total Kjeldahl Nitrogen)

The chemistry of nitrogen in natural ecosystems is very complex. The five major forms of nitrogen in fresh water are organic nitrogen (TKN), ammonia ($NH_3$), ammonium ($NH_4$), nitrate ($NO_3$), and nitrite ($NO_2$). Only the last three, NH4, NO3 and NO2 are readily available to aquatic plants. In most monitoring programs these three nitrogen compounds, plus total Kjeldahl nitrogen (TKN), which is a measurement of organic nitrogen, are usually determined.

### 3.12.1 AMMONIUM (NH4)

Ammonium ($NH_4$) is considered non-toxic. The conversion of ammonium to ammonia occurs more readily in the presence of low pH (acidic conditions) and also with increasing temperature. There is no PWQO for ammonium ($NH_4$).

### 3.12.2 AMMONIA ($NH_3$)

Ammonia ($NH_3$) and ammonium ($NH_4$) are transitional forms of nitrogen. In the presence of oxygen in the water these forms become nitrite ($NO_2$) and nitrate ($NO_3$); it is also incorporated into living organic matter where it is quantified as total Kjeldahl nitrogen (TKN). The toxicity of ammonia is very complex and is also affected by both pH and temperature.

The PWQO for concentrations of un-ionized ammonia ($NH_3$) should not exceed 0.020 mg/L (20 ug/L) for the protection of aquatic life. Ammonia nitrogen ($NH_3$) is present in most healthy systems at a low concentration, usually less than 1.0 ug/L. It is a by-product of decomposition. In eutrophic systems and lake bottoms where oxygen concentrations are depleted, ammonia concentrations can increase and become lethal to benthic organisms and some fish.

Ammonia enters natural water systems from many sources including precipitation, agricultural runoff, municipal and industrial discharges. Indirect sources are the biochemical transformation of nitrogenous organic material during the decomposition process and also from the excretion of ammonia by biota.

### 3.12.3 NITRATE, NITRITE and TKN

Nitrate nitrogen ($NO_3$) is available for uptake by plants and values are important in defining lake trophic status. Typical concentrations are less than 0.05 mg/L (50 ug/L) for healthy lakes. In eutrophic water bodies the concentration of nitrate ($NO_3$) is usually low in the surface waters due to demand and uptake by algae. Total Kjeldahl nitrogen (TKN), the organic nitrogen values become high in eutrophic waters because the nitrogen is tied up in the algae. In the deep portion of eutrophic lakes where there is little or no oxygen the $NO_3$ becomes replaced by $NH_3$. Ammonium nitrogen ($NH_4$) is a transient form between ammonia nitrogen ($NH_{3)}$ and $NH_4$ under anoxic conditions. Nitrite nitrogen

($NO_2$) in healthy systems is typically at very low concentrations of less than 0.005 mg/L (5 ug/L); it occurs as a transient form of nitrogen between $NH_3$ and $NO_3$ under conditions where oxygen is present.

Total nitrogen (TN) is simply the sum of the concentrations of all the forms. Total nitrogen (TN) to total phosphorous (TP) ratios are important. TN: TP ratios are generally greater than 20:1 in oligotrophic, very healthy lakes. A ratio of 16:1 is found in algae communities typical of mesotrophic lakes. In eutrophic systems TN: TP ratios are about ≤12:1 and favour the production of blue green algae.

There are no PWQOs set for TKN, nitrate or nitrite, nor is there an objective set for total nitrogen. The only form of nitrogen considered to be toxic is ammonia (see discussion under ammonia and ammonium).

**A comprehensive nitrogen dataset for Buck Lake is available for the years 1975 and 1979; only three sample dates for nitrogen are reported for the years 1987 and only two sample dates in the year 2005. Since both the north and south basins of Buck Lake stratify and both experience some late season anoxia, the nitrogen values are discussed below for both surface and bottom samples.**

**The Kjeldahl nitrogen (TKN) results (See Table 1 below) for the surface for both basins show that the majority of the nitrogen occurs as TKN; this is the nitrogen that is tied up in pelagic biomass or algal cells; it is the organic nitrogen. Due to the higher productivity of the north basin in the way of algal production one would expect the TKN values for the north basin to be higher than the south basin. This does not hold true in the dataset. The TKN values and the total nitrogen values are very similar for both basins.**

**It is noteworthy that the TKN values increase in the bottom waters of the north basin. This basin also experiences severe oxygen loss in the hypolimnion. The TKN value is a measure of the organic nitrogen reaching the bottom. This organic load is then results in oxygen depletion. For the south basin, the TKN values are higher in the surface waters than the bottom. The much larger depth and volume of this basin act to dilute the organic TKN load from the surface.**

**There is a good probability of late summer ammonia concentrations exceeding the PWQO in the bottom waters of the north basin due to the high NH4 values.**

### TABLE 1 NITROGEN SUMMARY

**NITROGEN SUMMARY - SURFACE SAMPLES (1.0 m below surface)**

| | Mean TKN mg/L | Mean NH4 mg/L | Mean NO2 mg/L | Mean NO3 mg/L | Total Nitrogen mg/L |
|---|---|---|---|---|---|
| Buck Lake (North Basin)* | 0.3116 | 0.0149 | 0.0029 | 0.0262 | 0.3556 |
| Buck Lake (South Basin)* | 0.3309 | 0.0115 | 0.0025 | 0.0227 | 0.3676 |

***1975, 1979, 1987, 2005**

**NITROGEN SUMMARY - BOTTOM SAMPLES (1.0 m above bottom)**

| | Mean TKN mg/L | Mean NH4 mg/L | Mean NO2 mg/L | Mean NO3 mg/L | Total Nitrogen mg/L |
|---|---|---|---|---|---|
| Buck Lake (North Basin)* | 0.3650 | 0.0214 | 0.0030 | 0.0504 | 0.4398 |
| Buck Lake (South Basin)* | 0.2671 | 0.0143 | 0.0019 | 0.1681 | 0.4885 |

***1975, 1979, 1987, 2005**

### 3.12.4 TOTAL NITROGEN (TN)

Total nitrogen is the sum of all four of the forms of nitrogen. The total nitrogen values below have been calculated using the surface sample results for all the years of record for all four forms of nitrogen.

**There are not enough years of data to develop a trend through time analysis for total nitrogen for either of the lake basins. The surface TN values are Buck Lake (North Basin) (0.3556 mg/L) and Buck Lake (South Basin) (0.3676 mg/L).**

### 3.12.5 TOTAL NITROGEN to TOTAL PHOSPHORUS RATIO (TN:TP)

Total nitrogen (TN) is simply the sum of the concentrations of all the forms of nitrogen. Total nitrogen (TN) to total phosphorous (TP) ratios are used to characterize lake trophic status. TN:TP ratios greater than 20:1 are considered to represent oligotrophic lakes or very healthy lakes. In eutrophic systems TN:TP ratios are about 12:1 or lower and favour the production of blue green algae. The year 2000 Lake Partner Program Technical Notes deviate from this definition and uses the TN:TP ratio of 25:1 as the lower criteria for oligotrophic lakes.

**TABLE 2**

**BUCK LAKE (NORTH BASIN) TN:TP RATIO**

| | | | |
|---|---|---|---|
| 1975, 1979, 1987 and 2005 | 355.6 | 13.47 | 26.4 |

**Using only the data for the years with measured nitrogen data and the phosphorus data for all the years of record, based on the calculated TN/TP ratio of 26.4:1 Buck Lake (North Basin) would be classified as oligotrophic (i.e. TN/TP ratios > 20:1).**

**BUCK LAKE (SOUTH BASIN) TN:TP RATIO**

| YEAR | MEAN TN (ug/L) | MEAN TP (ug/L) | TN:TP |
|---|---|---|---|
| 1975, 1979, 1987 and 2005 | 367.6 | 11.55 | 31.8 |

**Buck Lake (South Basin) would be considered to be oligotrophic on the basis of the TN:TP ratio (365.5/11.55 = 31.8:1).**

## 3.13 ORGANIC CARBON – Dissolved Organic Carbon (DOC) Total Organic Carbon (TOC)

Total organic carbon (TOC) consists of both dissolved and particulate organic carbon. It is composed of humic substances and degraded plant (algae) and animal (zooplankton) materials. It can be considered as a surrogate measurement for algae levels, similar to chlorophyll a. TOC content in natural waters range from 1 to 30 mg/L. The higher values are indicative of eutrophication. Runoff from agricultural lands and nutrients from septic systems can increase the TOC values when algae concentrations rise. Values of 3.0 mg/L or lower are considered to represent oligotrophic conditions, an indication of a healthy lake.

**Only dissolved organic carbon (DOC) is available in the dataset. DOC is reported for the years 1987 and 2005. Mean DOC values for these years are 3.620 mg/L for the North basin and 4.040 mg/L for the South Basin. These values indicate that for**

**this parameter at least, both basins would be considered to be marginally above the criteria for an oligotrophic lake.**

## 3.14 OXYGEN and TEMPERATURE

The importance of documenting oxygen and temperature conditions for the basins in Buck Lake cannot be understated. Maintaining oxygen conditions below the thermocline is critical to the management of habitat for coldwater fish species such as lake trout, and splake as well as for other coldwater biota; maintaining good oxygen values in the hypolimnion also plays an important role in nutrient re-suspension from the sediments. Considerable effort has been undertaken by MNR and MOE to document surface to bottom oxygen and temperature values. These profiles are typically collected during the ice-free period from prior to the spring mixing period until fall overturn. For any given year, the most critical period during the year for deep-water oxygen concentrations is late summer or early fall. Conditions in the hypolimnion become progressively poorer towards the end of that window and may extend well beyond the end of September until the fall overturn.

Profiles recorded for dates outside of the critical period are also important in order to document the success of the spring and fall mixing periods as well as to document the rate of oxygen depletion in the hypolimnion during the period when the lake is stratified. Lakes or lake basins with ample oxygen in the deepwater portion (hypolimnion) may not become depleted over the entire season while other lake hypolimnions or distinct lake basins may become depleted of oxygen by early August. It is therefore important not to rely on the oxygen conditions of any one lake basin to characterize conditions for the lake as a whole.

Some variability should be expected in the spring oxygen concentrations in the hypolimnion after stratification is set up in any given year. A long cold spring period with lots of wind ensures complete mixing and infusion of oxygenated water to the lake bottom. A short spring with a few hot calm days may be enough to set up stratification early; this may occur before complete mixing and therefore the hypolimnion has the potential to begin the season with less than saturated oxygen conditions or begin the period of lake stratification at an earlier date; this sets the stage for a longer than normal lake stratification period.

Once a lake becomes stratified after the spring warming period, oxygen depletion begins in the bottom water portion and continues through to the fall mixing period. The surface waters warm and oxygen is depleted from the bottom up. For cold water species such as lake trout, habitat is reduced from above due to heating and from below due to loss of oxygen. Warm water species such as bass, walleye and pike are less affected because oxygen concentrations at the depth of or immediately above the thermocline are replenished due to mixing from above through photosynthesis by phytoplankton in the euphotic zone and through infusion from the atmosphere.

While a change in the rate of heating of the surface waters is not typically associated with shoreline development practices, the advent of global warming may play an important role in the number of days each year that a lake is stratified. With global warming the probability exists that lakes will warm earlier each spring and stay stratified for a longer period into the fall. This increases the number of days for oxygen depletion to act. This possibility alone brings added importance to the need for control of nutrient export from shoreline development and tributary sources. There is a direct relationship between nutrient concentrations at the lake bottom, the number of days of stratification and oxygen loss from the hypolimnion. An increase in nutrient supply to the lake results in an increase in plankton growth and subsequently an increase in the rate of loss of oxygen from the hypolimnion. Under anoxic conditions at the mud-water interface, nutrients previously sequestered in the sediments will be released into the water column again and may be available for algae/plant growth when the lake mixes again.

After about September 30$^{th}$ the surface waters begin to slowly cool; the cooling continues until fall overturn when the lake mixes and oxygen conditions are restored to the hypolimnion in early to mid November.

Oxygen concentrations are of course critical to the survival of lake trout. Optimal conditions for lake trout are waters with a temperature ≤ 10 oC with oxygen concentrations ≥ 6.0 mg/L. Lake trout can exist in less than optimal conditions at temperatures below 15.4 oC and at oxygen concentrations ≥ 4.0 mg/L. Lake trout populations become confined to a narrow layer in the late summer due to warming of the surface waters and due to oxygen depletion in the bottom waters. A recently new Ontario Provincial Water Quality Objective (PWQO) has been set at 7.0 mg/L for the volume weighted mean hypolimnion oxygen concentration.

## BUCK LAKE OXYGEN and TEMPERATURE PROFILES

### 3.14.1 BUCK LAKE (North Basin) – Temperature and Oxygen

**<u>NORTH BASIN</u>**
**1975 – 2 Profiles**
**1979 – 6 Profiles**
**1987 – 7 Profiles**
**1998 – 2 Profiles**
**2005 – 2 Profiles**
**2007 – 1 Profile**
**2008 – 1 Profile**

**Oxygen and temperature data are available for the North Basin of Buck Lake at site 12-0004-708-01 recorded during the years 1975, 1979, 1987, 1998, 2005, 2007 and 2008. Profiles have been recorded on 21 different occasions during this period (see Appendix 2 for data and graphs).**

**Only two profiles were completed in 1975; one in May and one in July. The May 3rd profile indicates that the lake was completely mixed this year and had good oxygen concentrations (11.4 mg/L) in the bottom. It is quite probable that incomplete mixing will occur in some years prior to stratification. The bottom of the thermocline becomes firmly established at a depth of 11 metres by the time of the July 31st profile. The oxygen values remain good above the thermocline but quickly decline to very low concentrations in the hypolimnion below the thermocline (See Figure 5 - July 31st, 1975 profile following page). The bottom water value is only 1.3 mg/L and there is no value above 6.0 mg/L in the hypolimnion.**

**There are six recorded profiles in the year 1979. The basin is already stratified by May 22nd; oxygen values in the hypolimnion indicate that the lake mixed well and the oxygen concentration in the bottom is 10.1 mg/L. The August 3rd, 79 profile is very similar to the July 31st, 1975 profile however profiles recorded on August 20th and September 17th, 1979 exhibit very poor oxygen concentrations in the hypolimnion, by the latter date there were no values in the hypolimnion >2.9 mg/L.**

**Six profiles were recorded in between June 4th and November 5th, 1987. Again, the July 27th profile this year is representative of values recorded in 1975 and 1979 for the same period. This profile shows > 4.0 mg/L of oxygen to a depth of 25 metres however there are no values ≥ 6.0 mg/L in the hypolimnion even at this early season date. The profile recorded on September 1st, 1987 shows all the hypolimnion values are <3.5 mg/L and by October 5th all are <2.5 mg/L; from 16 metres depth to 29 metres depth all values are < 2.0 mg/L. The November 5th, 1987 profile shows that the basin has not undergone fall mixing to date.**

**Two oxygen profiles were recorded in 1998, July 15th and August 28th. Again, the late season hypolimnion oxygen values are poor but are marginally better than previous years; no values ≥ 6.0 mg/L were recorded in the hypolimnion but values > 4.0 mg/L were recorded for depths between 13m and 18m depth.**

**Two oxygen profiles were recorded in the year 2005, June 28th and September 12th. The June 28th profile shows >4.0 mg/L of oxygen to a depth of 24m but there are no values ≥ 6.0 mg/L in the hypolimnion. The September profile confirms that late season values are very poor with oxygen concentrations depleted to below 2.0 mg/L from 16m depth to 26 metres depth; no values are greater than 4.0 mg/L in the hypolimnion.**

**Profiles recorded on September 6, 2007 and September 8, 2008 confirm all the other years of late season oxygen data. Poor hypolimnetic oxygen conditions exist overall and only the depths 13m to 16m have oxygen concentrations ≥ 4.0 mg/L. These are marginally better oxygen concentrations than for previous years. No oxygen values were recorded ≥ 6.0 mg/L in the hypolimnion.**

**Oxygen concentrations for all the years indicate that Buck Lake (North Basin) has difficulty maintaining good hypolimnetic oxygen values after mid-summer. This situation occurs because the basin is relatively small in surface area and large hills and islands protect the deepest location. There is not a large fetch (distance from shore to shore) to allow for strong winds to act; it takes a lot of wind energy to cause the lake to mix to the bottom resulting in spring overturn and infusion of oxygen into the bottom waters. It only takes a few days in early May of stable hot weather to set up stratification and prevent the lake from complete mixing; the lake therefore could begin some stratified seasons in an oxygen deficit. This basin also has a very small hypolimnion and a relatively large epilimnion. The volume of water receiving nutrients and sunlight and producing algae is much larger than the deep-water portion that decomposes the settling algae and therefore becomes depleted of oxygen.**

**3.14.2 Buck Lake (South Basin) – Temperature and Oxygen**

**SOUTH BASIN**
1975 – 3 Profiles
1979 – 7 Profiles
1987 – 7 Profiles
1998 – 1 Profile
2005 – 2 Profiles
2007 – 2 Profiles
2008 – 1 Profile

**Oxygen and temperature data are available for the South Basin of Buck Lake at site 12-0004-707-01 recorded during the years 1975, 1979, 1987, 1998, 2005, 2007 and 2008. Profiles have been recorded on 23 different occasions during this period (see Appendix 2 for data and graphs).**

**Only three profiles were completed in 1975; one in each of May, July and November. The May 2nd profile indicates that the lake was completely mixed this year and had good oxygen concentrations (11.3 mg/L) at the bottom (36.6m). The difference in temperature top to bottom is only 2 oC. It is possible that incomplete mixing could occur in some years prior to stratification in this basin. The bottom of the thermocline is firmly established at a depth of 10 metres by the time of the July 3rd 1975 profile. The oxygen values remain good above the thermocline and decline**

**to 4.61 mg/L at 30.5 metres depth; there is 6.4 mg/L recorded at 12.2 metres depth. (See Figure 6 - July 31st, 1975 profile following page). The 6.0 mg/L oxygen concentration occurs at about 13.5 m depth. The basin has not undergone fall turnover as of the November 5th survey date. Lake trout however have ample habitat at the surface above 15m of depth on this date.**

**There are seven recorded profiles in the year 1979. The basin is already stratified by May 22nd; oxygen values in the hypolimnion indicate that the lake mixed well and the oxygen concentration at the bottom is 9.73 mg/L (38m). The June 7, 1979 profile continues to show good oxygen conditions with 6.85mg/L at bottom (38.5m). The June 28th and July 18th profiles show continued good oxygen conditions in the hypolimnion; the ≥ 6.0 mg/L oxygen value is at 25m deep and the top of the hypolimnion is at 10-11 meters depth. The August 3rd, 1979 profile indicates conditions have declined somewhat. The bottom of the thermocline is established at 10 metres; the oxygen concentration at this depth is 7.04 mg/L. There is no value ≥ 6.0 mg/L at any depth in the hypolimnion. Oxygen concentrations ≥ 4.0 mg/L exist down to a depth of 30 m; the bottom O2 value is 1.75 mg/L (37.5m).**

**The August 20th profile confirms the earlier findings in August. The bottom of the thermocline is at 11 metres depth and the oxygen concentration at this depth is 6.9 mg/L. There is no value ≥ 6.0 mg/L at any depth in the hypolimnion. Oxygen concentrations ≥ 4.0 mg/L exist down to a depth of 33 m; the bottom O2 value is 1.50 mg/L (38.0m). These results indicate that this basin has difficulty maintaining oxygen values that are ideal for lake trout.**

**The last profile recorded for this year was September 17, 1979. The top of the hypolimnion on this date was at 12 metres depth; oxygen concentrations in the hypolimnion are all below the ≥ 4.0 mg/L concentration. The lake trout population would be under physiological stress at this time.**

**Seven profiles were recorded between June 4th and November 5th, 1987. The June 4th profile shows the top of the hypolimnion at 11 metres depth and the 6.0 mg/L oxygen concentration at 38 metres; 4.6 mg/L was recorded at the bottom (39m). The June 30th profile confirms the values recorded on June 4th. The July profile is incomplete. The August 13th 1987 profile confirms the August conditions recorded 12 years earlier in 1979; the top of the hypolimnion is at 12m depth and there is no oxygen concentration ≥ 6.0 mg/L in the hypolimnion; there is ≥ 4.0 mg/L of oxygen down to 35 metres depth; 1.0 mg/L of oxygen was recorded at the mud-water interface (38.2m).**

**The September 1st 1987 profile shows the top of the hypolimnion to be at 13m depth; there is no oxygen concentration in the hypolimnion ≥ 6.0 mg/L on this date. The ≥ 4.0 mg/L oxygen value occurs at 35 metres depth. The ≥ 6.0 mg/L value occurs at 12.5m and the ≤ 10.0 oC temperature is at 10.5 m depth therefore there is 2 metres**

**of water column available as optimal habitat for lake trout. Fortunately there is 30 metres of water depth that meets the criteria for vital habitat on this date. The October 5th profile confirms the September data with not much further change in oxygen conditions; the ≥ 4.0 mg/L is at 32m depth on this date. Again, these results indicate that this basin has difficulty maintaining oxygen values that are ideal for lake trout.**

**The November 5th, 1987 profile shows that the basin has not undergone fall mixing to date however it is very close to overturn.**

**A profile recorded on August 28th was the only one for the year 1998; on this date the ≥ 6.0 mg/L value occurs at 15.5m depth and the 10 oC value is at 12.5m depth thus providing 3m of water column suitable as optimal habitat for lake trout. The top of the hypolimnion is at 12m depth. There is ≥ 4.0 mg/L of oxygen to 30.5 metres depth; 1.4 mg/L of oxygen was recorded at the bottom (32m). On this date in the thermocline there is an increase in oxygen concentration. This is not an uncommon occurrence; it indicates that the water is very clear and that there is photosynthesis occurring at this depth by the green phytoplankton; this acts to pump oxygen into the water column at this depth.**

**Two oxygen profiles were recorded in the year 2005, June 28th and September 12th. The June 28th profile shows the top of the hypolimnion to be at 12m depth, ≥6.0 mg/L of oxygen to a depth of 22 metres and ≥4.0 mg/L of oxygen to a depth of 32.5m. The 10 oC isotherm is located at 9.5 metres depth; there is 12.5 metres of water column suitable as optimal habitat for lake trout on this date. The September 12th, 2005 profile confirms that late season values are very similar to those recorded in 1987 for the same period. The top of the hypolimnion is at 12m; the 10 oC isotherm is at 10.5 m depth; the ≥ 6.0 mg/L of oxygen is at 15.5 m depth. On this date there is only 5m of water column suitable as optimal lake trout habitat. There is ≥ 4.0 mg/L of oxygen to a depth of 28.5m and only 0.06 mg/L at the mud-water interface (33m). It is not unusual to have very low late summer oxygen concentrations at the mud-water interface.**

**The profile for September 6th 2007 (MNR – Site 1) is not representative of any other late season oxygen profiles and should not be considered to be reliable. Profiles recorded on September 26th, 2007 and September 8, 2008 each confirm all the other years of late season oxygen data. There remains a very small depth of optimal habitat, 3 to 4 m in thickness, at the top of the hypolimnion that is optimal habitat for lake trout. The ≥ 4.0 mg/L oxygen value exists down to a depth of 30 metres for most years. This results in a large volume of this basin having late season conditions suitable as vital habitat for lake trout, but again, these results indicate that this basin has difficulty maintaining oxygen values that are ideal for lake trout.**

**The Ministry of Natural Resources provides oxygen and temperature profiles for other sites (indicated as sites 2 and 3) for the years 2007 and 2008. These sites are for locations other than the deepest sounding; the data is included IN appendix 2 but there is no discussion of the results in this report.**

**From the above data and discussion it is apparent that neither the North Basin nor the South Basin of Buck Lake can meet the new Ontario Provincial Water Quality Objective (PWQO) for oxygen of 7.0 mg/L for the volume weighted mean hypolimnion oxygen concentration. Victor Castro (MOE) completed the calculations for oxygen profiles completed on June 28, 2005 and September 12, 2005 for the South Basin (see Tables 3 and 4 following page). The calculations confirm that the 7.0 mg/L objective cannot be achieved for either date.**

### 3.15 pH

The PWQO states that pH should be maintained within the range of 6.5 to 8.5 units in order to protect aquatic life. Both alkaline and acidic waters may cause irritation to anyone using the water for recreational purposes. The range in pH for body contact recreational purposes is much wider than the objective. The objective is set to protect aquatic life.

The acidity of water is measured by determining pH values. The pH scale is from zero to 14 units with 7.0 representing a neutral value. Values below 7.0 are acidic and values above 7.0 are basic. Because the pH scale is a logarithmic scale every pH unit is a factor of 10 times difference from the next closest unit. A lake with a pH of 8.0 is therefore 10 times more basic than a lake with a pH of 7.0 units. Lakes with high alkalinity can neutralize acids and therefore the pH of these lakes would be expected to be above 7.0 units.

Photosynthesis fixes or removes carbon dioxide. Carbon dioxide in water forms a weak carbonic acid. Therefore in productive lakes the surface waters have pH values that are higher than the bottom waters. Under conditions of excessive productivity the pH may raise to 8.0 or 9.0 units. When pH levels are reduced to 6.0 units or lower, acidity levels begin to become toxic to the life stages of many aquatic organisms and some species of fish.

**Analytical pH data is available for the years 1975, 1979, 1987 and 2005. For Buck Lake (North Basin) the surface pH values range from 7.40 units to 8.30 units with a mean value of 7.864 units. The South Basin of Buck Lake has a mean surface pH value of 8.255 units and a range in values from 7.87 units to 8.60 units. The south basin is more basic than the north basin for the same reasons as discussed under the headings alkalinity, calcium and hardness.**

**The bottom waters are more acidic in both basins than the surface waters. Both basins have bottom pH results on the order of ten times more acid than the surface waters. The mean bottom pH for the North Basin is 7.039 units and the South Basin has a mean bottom pH of 7.364 units. This condition only persists while the lake is stratified and disappears once the lake undergoes mixing or turnover in the fall.**

**These values indicate that acidity levels remain well within the PWQO for the protection of aquatic life for all three lakes.**

### 3.16 PHOSPHORUS (TOTAL PHOSPHORUS – TP)

Total phosphorous concentrations are important indicators of lake trophic status. Phosphorous is a natural plant nutrient found in lakes. It provides one of the building blocks needed for plant growth. Phosphorous is typically in limited supply, outperformed by nitrogen by a ratio of greater than 20:1. Total phosphorous is the limiting nutrient in aquatic ecosystems. It is for this reason that the Ontario Lakeshore Capacity Study (OLCS) focused on phosphorous as the key parameter. It is also the reason the Policies, Guidelines and Provincial Water Quality Objectives (PWQOs) of the Ministry of the Environment July 1994 set objectives for phosphorous on lakes.

The PWQOs have two thresholds for total phosphorous; one is set at average TP concentrations for the ice-free period of $\leq$10 ug/L. This level protects lakes that are at or below 10 ug/L from becoming enriched to a level above 10 ug/L; these lakes are categorized as oligotrophic. The second threshold of average TP concentrations of 20 ug/ L is the upset limit for lakes. This limit is set to avoid nuisance concentrations of algae in lakes; lakes exceeding an average of 20 ug/L of phosphorous are eutrophic. Elevated phosphorous concentrations lead to increased surfactant foaming, increased aquatic vascular plant growth in some lakes and in severe situations the production of excess algae, which limits light penetration and deep-water oxygen loss.

The PWQO states 'the following phosphorous concentrations should be considered as general guidelines which should be supplemented by site specific studies: To avoid nuisance concentrations of algae in lakes, average total phosphorous concentrations for the ice-free period should not exceed 20 ug/L. A high level of protection against aesthetic deterioration will be provided by a total phosphorous concentration for the ice-free period of 10 ug / L or less. This should apply to all lakes naturally below this value'. Lakes which at present have TP values which are above but close to 10 ug / L would have to be modeled to determine if natural values would fall below the 10 ug / L objective.

In situations where there are high concentrations of phosphorous, light penetration is reduced due to increased algae and blue-green algae blooms replace aquatic vascular plants. High concentrations of algae and aquatic plants lead to excessive oxygen depletion in the deeper bottom water portions of the lake both during the summer stratification period and under the ice cover. Lake that experience severe oxygen depletion in the hypolimnion (deep water portion) also have elevated nutrient levels in the bottom.

Phosphorous concentrations in lakes are increased by changes in landuse that results in increased supply from the land, shoreline septic systems, removal of shoreline trees (buffer strips) and the addition of fertilizer to shoreline lawns and agricultural applications as well as others. Phosphorous became the focus of interest for lake surveys and was included as a parameter for analysis in the MOE Recreational Lakes Program more recently in the Lake Partner Program.

There is an established algorithm with chlorophyll. Chlorophyll a concentrations can be calculated using phosphorous values. The formula for predicting total phosphorous concentration [TP] from chlorophyll a and visa versa is taken from the Ontario Lakeshore Capacity Study (OLCS) trophic status model. The formula is:

**Log CHL a = 1.45 log (TP ug/L) – 1.14**

There are many other accepted algorithms for this relationship. The Lake Partner Program Technical Notes offer the following formula:

**CHL a = 0.323 (TP ug/L) – 1.46 R2 = 0.78; n = 74**

Using the 1.84 ug/L mean chlorophyll a value from the 1993 Self-Help Program volunteer effort on BuckLake and applying each of the above algorithms the predicted total phosphorous is 9.3 ug/L and 10.2 ug/L respectively. These predicted phosphorous values fall within the year-to-year natural variability for BuckLake and closely match the more recent LPP results since the year 2000.

**3.16.1 Phosphorus (TP) - Buck Lake (South Basin)**

**Measured phosphorous data is available for surface samples for Buck Lake (South Basin) for seven years spanning the period 1975 to 2008. For the years 1975 and 1979 sampling was undertaken from early season to late fall and included both surface samples (1.0 metre depth) and bottom samples (1.0 metre off bottom). For the period 2002 to 2008 a less intensive sample effort was undertaken.**

**Sampling for phosphorous since the year 2000 has only included spring-time samples collected under the Lake Partner Program (LPP). While the analytical procedures used under the LPP are much improved and more accurately represent TP values, only one sample is collected per year; as a result the dataset is not as strong for more recent years.**

**The surface phosphorous results indicate that phosphorous levels have declined in Buck Lake (South Basin) since 1975 (Figure 7 following page). This apparent**

**decline may be partially due to new sampling and analytical procedures. The data represented in this graph include both the measured TP values and predicted TP values as derived from chlorophyll a values.**

**The mean of means value is 11.55 ug/L over this time period. The trend line for TP indicates a decline in TP values for the period of record 1975 to 2008. The relationship is relatively weak with an $R^2$ value of only 0.31. Any changes in analytical protocol are not addressed and may play a role in the trend results. The mean of mean value of 11.55 ug/L places the South Basin in the moderately enriched or mesotrophic category based on this parameter. When the TN:TP ratio is considered (367.6/11.55 = 31.8:1) then the South Basin would be considered to be oligotrophic on the basis of this ratio.**

**The mean of means value of 11.55 ug/L also exceeds the PWQO of 10ug/L for lake trout lakes; it should be clear that the PWQO applies only to surface water TP values. Typically bottom water samples have higher TP concentrations than the surface samples.**

**3.16.2 Phosphorus (TP) Buck Lake (North Basin)**

**For lakes such as Buck Lake (North Basin) that may undergo partial mixing in the spring and that experience very poor to anoxic oxygen conditions at the bottom, nutrient concentrations are elevated both due to accumulations as a result of decomposition of organic material settling from above and also from the re-suspension or release of nutrients from the sediments in the presence of anoxic conditions at the mud-water interface.**

**Buck Lake (North Basin) becomes stratified and experiences poor oxygen conditions in the hypolimnion; as a consequence there is a significant difference in TP values between surface and bottom sample results. The mean surface TP value is 13.47 ug/L (see Figure 8) and the bottom TP values are 26.0 ug/L (1979) and 48 ug/L (1975); the concentration of phosphorous in the hypolimnion of Buck Lake (North Basin) is two to four times as much as is in the surface waters. The consequence of this accumulation of both phosphorous and nitrogen (see discussion under nitrogen above) leads to heavy blooms of diatoms and algae at the time of fall turnover when these nutrients are made available at the surface again.**

**The surface mean TP value of 13.47 ug/L places the north basin in the mesotrophic category based on this parameter. The mean of means value of 13.47 ug/L also exceeds the PWQO of 10ug/L for lake trout lakes When the TN:TP ratio is considered (355.6/13.47=26.4:1) then the North Basin would be considered to be oligotrophic on the basis of this ratio.**

### 3.17 RESIDUE (TOTAL), RESIDUE (PARTICULATE) and RESIDUE (FILTERED)

There is no PWQO for either total or particulate residue.

Total residue is a measure of the material left after a measured amount of water is evaporated. The residue remaining consists largely of only a few salts. These include the carbonates, sulphates, chlorides of calcium, magnesium and potassium, silicic acids, and small amounts of nitrogen, phosphorus, iron, manganese and organic material such as algal cells (Rutner, 1963). Rutner reports that the majority of lakes fall in the 100 to 200 mg/L range for total residue and lakes with low alkalinity (low dissolved salts) typically have total residue concentrations of less than 50 mg/L. The determination of specific conductance is used as a surrogate method to estimate the concentrations of these same salts.

**Residue results are reported for Buck Lake (North Basin) for the years 1975 and 1979. There is no difference between surface and bottom sample results. The mean value for 9 samples collected over the period of record is 68.1 mg/L. Residue values can be found summarized in Appendix 1A and 1B. This mean value is in keeping with the range of values reported by Rutner, (1963).**

**The mean residue value for the South Basin of Buck Lake (1975, 1979) is 118.1 mg/L. The residue value is roughly double that of the North Basin for the same reasons as discussed under the headings alkalinity, calcium and hardness.**

As a comparison, Ashby Lake (Denbeigh, Ontario) an acid sensitive lake with an alkalinity of 12 mg/L and a mean calcium concentration of 5.8 mg/L has a mean residue value of 34 mg/L.

### 3.18 SODIUM (Na)

There is no Provincial Water Quality Objective (PWQO) set for sodium.

Sodium (Na) is one of the four cations along with calcium (Ca) magnesium (Mg), and potassium (K) that act in concert to determine water hardness and salinity. Waters with high alkalinity and high hardness typically have high cation concentrations. The four cations typically occur in concentrations with Ca>Mg>Na>K.

Wetzel (1983) reports that the mean sodium level for hard water lakes is 4.0 mg/L. Sodium is a requirement of blue green algae. The enrichment of waters with high levels of sodium combined with phosphorus promotes the blue green algae blooms associated with eutrophication. High levels of sodium and phosphorus are found in domestic effluent. Wetzel reports further that maximum growth of several species of blue green algae occurs at a concentration of sodium of 40 mg/L.

**The whole lake mean sodium value for Buck Lake (North Basin) is 2.17 mg/L (n=10; 1975, 1979, 1987). The South Basin has a mean sodium concentration of 3.63 mg/L. These values fall in the range of what might be expected for a soft water lake.**

## 4.0 SUMMARY

Buck Lake has received much attention over the period of record (1972 – 2008) with respect to documentation of water quality. However, since 1979 there has not been an intensive spring to fall water chemistry survey undertaken. The Ministry of Natural Resources (MNR), Ministry of the Environment (MOE), and the Buck Lake Association has each played a role in monitoring water quality since 1972. The Buck Lake Association or other lake volunteers have participated in water sampling under the former MOE Self-Help Program (1976 to 1995) and in more recent years under the MOE Lake Partner Program (1996 to 2008).

Both basins of Buck Lake are managed for a cold-water lake trout fishery by the MNR. As such, it has been the focus of some recent efforts (2005, 2007 and 2008) to document water quality, particularly as it pertains to recording oxygen and temperature conditions. A new more restrictive oxygen objective is being applied; the recent efforts are to determine if the objective can be achieved late in the summer. Neither the north nor the south basin can achieve the new oxygen objective. The data reconfirms the need for the 'at capacity' designation now applied to both basins of Buck Lake.

From this analysis of the available data it is apparent that there has not been much change in water quality over the 36-year period of record (1972 to 2008), although there are gaps in the dataset for some parameters and the sample effort is sporadic and/or incomplete for some years. There is analytical data on greater than 20 different parameters, the most relevant of which are discussed above.

The trophic state indicator parameters (water clarity, total phosphorous and chlorophyll a) and the oxygen-temperature profile data have received the most sample effort. These are important parameters because they have direct links to human use of lake shorelines. It is these parameters that may allow for a trend analysis and are used to characterize the lake trophic status.

The period of record for water clarity for both basins on Buck Lake is 1972 to 2008. Very good complete ice-free season Secchi depth recordings were made for most years during the period 1975 to 2008 inclusive. Unfortunately, there are some gaps in the data, for the South Basin in particular, over the period of record and in the more recent years, 2001 to 2008, there were very few recordings completed each year.

The indication from the analysis is that water clarity has not declined on Buck Lake (South Basin) and this basin is classified as oligotrophic on the basis of a mean Secchi disc depth of 5.64 metres (24-year mean). Water clarity in the North Basin is not as good with a mean value of 4.06 metres (34-year mean); the north basin is classified as mesotrophic based on water clarity. There is no trend to either better or poorer water clarity in either basin.

Another trophic state indicator is chlorophyll a; it is the green pigment found in photosynthetic algae and is used as a measure of the algal productivity. Analysis for this parameter was undertaken from 1975 to 1995. There is much variability in the chlorophyll a data set for Buck Lake (North Basin); this is a common observation for more nutrient enriched waters. The trend analysis indicates a decline in algal levels over the period of record. This observation is in keeping with the decline in lake productivity levels across the Province in general. The mean of means value for chlorophyll a for the period of record is 3.20 ug/L; the North Basin is classified as mesotrophic on the basis of this parameter.

The dataset for chlorophyll a is not as complete for the South Basin. The trend analysis shows a similar decline in algal levels over the period of record. The South Basin of Buck Lake has a mean chlorophyll a value of 2.55 ug/L; on the basis of this one parameter the lake would be classified as oligotrophic.

Phosphorous concentration is also a trophic state indicator. The dataset for total phosphorus is sparse until 1996, the year when analysis for TP became part of the MOE Lake Partner Program. The above analysis uses the measured TP values where possible and includes derived TP values from chlorophyll concentrations for years without TP sampling. This allows for an examination for a trend through time.

The trend analysis indicates that TP concentrations for both basins have declined over the period of record although the relationship is generally weak. The mean TP value for the North Basin is 13.47 ug/L; the South Basin mean TP value is 11.55 ug/L. Both of these mean values exceed the PWQO of 10 ug/L for oligotrophic lake trout lakes; both basins would be classified as mesotrophic based on these findings.

Collectively, while the three parameters are separate and distinct, the data indicates that each individually is supportive of the other. Water clarity has changed little if any, total phosphorous appears to have declined and chlorophyll a concentrations have declined. This observation provides some confidence to the conclusion that conditions for these three parameters have not changed and may in fact have improved very slightly over the period of record.

For lakes such as the North Basin of Buck Lake that may undergo partial mixing in the spring and that annually experience very poor to anoxic oxygen conditions at the bottom, nutrient concentrations become elevated both due to accumulations as a result of decomposition of organic material settling from above and also from the re-suspension or release of nutrients from the sediments in the presence of anoxic conditions at the mud-water interface.

The North Basin experiences between two and four times as much phosphorous in the lake bottom as is measured at the surface. The consequence of the accumulation of both phosphorous and nitrogen often leads to heavy blooms of diatoms and algae at the times of spring and fall turnover when these nutrients are made available at the surface again. This can become very problematic if nutrient loadings from shoreline development or other sources are not controlled.

The nitrogen to phosphorus ratio is also an indicator of lake trophic status. Both basins of Buck Lake are classified as oligotrophic based on TN:TP ratios; the north basin has a TN:TP ratio of 26.4:1; the south basin is 31.8:1. Lakes with TN:TP ratios of $\leq$ 12:1 are considered to be eutrophic; lakes with TN:TP ratios $\geq$ 20:1 are considered to be oligotrophic.

The most critical parameter for Buck Lake (North Basin) is the poor oxygen concentrations recorded in the hypolimnion. Oxygen and temperature recordings have been undertaken on 21 different occasions on the North Basin. The oxygen data indicates very poor conditions exist from mid-summer through to fall turnover each year. The probability is that due to lake morphometry and local topography, the lake does not experience complete mixing during the spring overturn period for some years. This basin has a small volume, a large epilimnion relative to the small hypolimnion, a small watershed, and a slow flushing rate; all factors that contribute to poor oxygen conditions. This basin is sensitive to nutrient loadings due to the above factors and nutrient supply shoreline development is contributing to the poor water quality.

While the Southern Basin maintains better oxygen conditions in the hypolimnion, the concentrations are still low enough to be a concern during late August and September. Oxygen and temperature recordings have been undertaken on 23 different occasions on the South Basin over the period 1975 to 2008. The better oxygen conditions in this basin are directly related to the basin morphometry and the watershed size. This is a much larger and deeper basin with a small epilimnion relative to the hypolimnion and the basin has a much larger watershed with a much higher flushing rate. Oxygen conditions at the end of the summer are marginal for lake trout and for that reason it is important for shoreline owners to become vigilant about reducing nutrient loadings to the lake. An intensive spring to fall oxygen and temperature profile has not been completed on either basin since the year 1987.

## 5.0 RECOMMENDATIONS

Both of the North and South Basins of Buck Lake are deficient in a good complete-season phosphorous dataset since at least 1979. The Buck Lake Association should try to acquire, for at least one year, a more intensive phosphorous sampling effort throughout the ice-free season. This may be possible through the Ministry of Environment Lake Partner Program or privately. It is important also to document bottom water nutrient concentrations as well.

In addition, water clarity can easily be recorded for each of these lakes on an annual basis. Water clarity recordings can provide the longest dataset for the best value to allow for trend through time analysis. This will require volunteers to commit to recording the clarity at least twice monthly from as soon after ice-out as possible until the fall overturn period. The recordings should be recorded at the same locations in each basin every time and preferably under conditions of light winds with the boat anchored.

Because each of the basins on Buck Lake experience poor deep-water oxygen conditions and because intensive whole season oxygen–temperature profiles have not been completed since 1987, it is time to collect current data for these parameters. Profiles should be recorded on both basins as soon after ice-out as possible to document spring overturn conditions and then at least monthly thereafter until late season in the fall. The findings will have ramifications with respect to fisheries management and shoreline development decisions.

Due to the poor oxygen conditions and moderately high nutrient concentrations on the North Basin and similar although less severe conditions on the South Basin it is important for the Buck Lake Association to partner with other agencies or groups to educate all the shoreline owners on Buck Lake regarding their nearshore activities and the effect of human changes to the nearshore landscape on water quality.

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**GLOSSARY**

Algae – microscopic photosynthetic unicellular plants commonly found in water

Algorithm – a mathematical relationship one parameter to another

Alkalinity – a measure of the ability of water to neutralize acids; directly related to water hardness and calcium carbonate concentrations.

Anoxic – having a deficiency of oxygen

Benthic organisms – living things associated with the lake bottom

Biota - living organisms

Blue-green algae – microscopic plants associated with nutrient enriched conditions; known taste, odour and toxin producers; blue-green in colour ; often float on the surface

Cations – positively charged atoms (e.g. $Na^{+1}$, $K^{+1}$, $Mg^{+2}$, $Fe^{+2}$, $Ca^{+2}$ etc)

Chlorophyll a – the green photosynthetic pigment found in living plants including algae

Diatoms – algae of the family Bacillariophyceae, 5000 species are known, may be unicellular, colonial or filamenteous

Epilimnion – the warm surface water layer in a lake of equal temperature that is mixed by the wind during the stratified period

Eutrophic – a nutrient enriched lake, high in phosphorous and nitrogen, high in algae concentrations, poor in clarity and with poor or no deep water oxygen concentrations.

Fetch – the uninterrupted straight line distance between two points across water

GPS - Global Positioning System; used to pin point locations on the earth surface.

Gram (gm) - is 1000 times smaller than a kilogram.

Humic – derived from humus; colloidal organic matter as the result of decomposition of plant and animal matter

Hypolimnion – the deep cold water layer below the bottom of the thermocline; lies below the metalimnion

Ion – the smallest size of particle; atom

Mesotrophic – lakes which are moderately enriched; between eutrophic and oligotrophic

Metalimnion – zone between the epilimnion and the hypolimnion; zone of most rapid temperature change with depth called the thermocline.

Metalimnetic minima – a condition where oxygen concentrations decline to low values at the bottom of the thermocline; oxygen concentrations then improve in the hypolimnion

Microgram (ug) - is 1000 times smaller than a milligram.

Milligram (mg) - is 1000 times smaller than a gram.

Minima – refers to an oxygen sag (low oxygen values) in the metalimnion

Morphometry – refers to lake size and shape; includes area, volume, fetch, maximum depth, mean depth, shoreline length etc.

Nutrients – elements required for plant growth; include phosphorous and nitrogen

Oligotrophic – lakes which are nutrient poor, deep, clear, cold, oxygen enriched, low algae concentrations, low phosphorous and nitrogen concentrations

PWQO – Ontario Provincial Water Quality Objectives

Organic – all living or dead and decomposing material from carbon based sources

Overturn – a physical process which a lake undergoes each spring and fall when water temperatures are equal top to bottom; wind energy mixes the lake causing overturn

Percent Saturation – refers to the amount of oxygen that water has relative to how much it would have at saturation for a specific temperature; 60 % saturation implies that 40% of what it could hold has been depleted.

Phytoplankton – free floating microscopic photosynthetic plants, algae, found throughout the water column pH – a measure of the hydrogen ion concentrations; expressed as a measure of acidity on a scale from zero to fourteen with seven as neutral, less than 7 as acid, greater than 7 as basic.

SDF – Station Description File (number) – used by MOE to document sample locations

Seston – the totality of all free-floating living and non-living suspended matter in the water column

Summer stratification – the period when temperature difference between top and bottom are so great that the water in the lake is layered into warm surface epilimnion, a cold bottom hypolimnion and a zone of rapid temperature change in the middle called the metalimnion.

Thermocline – the depth at which the temperature changes by $\geq$ 1.0 oC / metre

Total organic carbon (TOC) – a measure of dissolved and particulate forms of carbon, carbon is an element in all living and formerly living things.

Trophic status – refers to the level of nutrient enrichment

UTM - Universal Transverse Mercator Grid; 1000 metre square grids laid over the globe which allows for detailed position locations; sometimes called military grid.

Zooplankton – microscopic and small aquatic animals that typically found throughout the water column