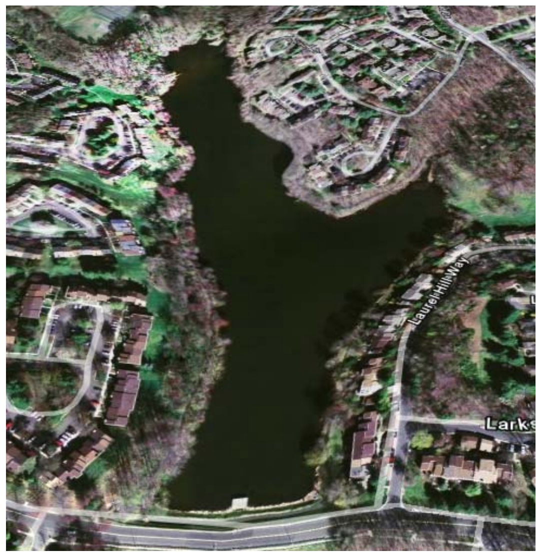
2008 Water Quality Monitoring Report
for
Lake Churchill



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1.0 Introduction

The Churchill Community Foundation, Inc. (the Foundation) contracted Princeton Hydro, LLC (Princeton Hydro) to continue to develop a multi-year database of water quality conditions in Lake Churchill by conducting a single-event water quality survey in 2008. As described in previous reports the impetus to collect water quality data over the course of several years was in response to the poor water quality conditions observed during the 2006 bathymetric and water quality survey marked particularly by a high density blue-green algae bloom. The value of implementing multi-year studies is highlighted by more comprehensive and complete data sets, additional statistical strength of collected data, identification of long-term trends, and the observation of varying water quality conditions with respect to hydrologic, meteorological, and watershed disturbance conditions.

This report is comparative and will be used in conjunction with the 2006 and 2007 datasets to evaluate whether the water quality conditions observed over the past three years have shown any change. Expansion of the dataset also allows for more sophisticated analysis of the expanded database with the third year of collected data significantly increasing the statistical strength of the data and interpretation.

As in past years, water quality was assessed in the lake through four specific survey techniques: the collection of *in-situ* water quality data measured with a multi-probe water quality meter, the collection of water samples for discrete water quality analysis at a third-party laboratory, a plankton survey of both phytoplankton (algae) and zooplankton, and a submerged aquatic macrophyte (plant) survey.

The following sections relate the sampling methodology, a discussion of the choice of data parameters, the results, and an analysis of water quality at the time of collection and in comparison to past years. Recommendations to mitigate water quality and improve lake ecology, aesthetics, and recreational value are included and are based on the findings of several years of water quality data. Data tables and graphs will be inserted as appropriate and included in the report appendices.

2.0 Methods

2.1 *In-situ* Water Quality Measurements

In-situ water quality sampling was conducted on August 21, 2008. At the time of sampling the ambient temperature was in the 80° F (27°C) range and sunny. Sampling was conducted at six (6) stations within the lake and the major tributaries to account for spatial variation in water quality throughout the lake, as well as variation with depth (Table 1). Princeton Hydro utilized a HydroLab 15-meter Quanta Multi-probe water quality sonde and Hydrolab Surveyor to collect all *in-situ* data. This instrument was calibrated according to Princeton Hydro and manufacturer's standard protocols and New Jersey Department of Environmental Protection (NJDEP) requirements immediately before data collection on August 21, 2008. Specifically, the instrument was calibrated for pH, Dissolved Oxygen, and Specific Conductance. All sampling was conducted in vertical profile throughout the water column at 0.5 to 1.0 meter (1.7 to 3.3') intervals.

Table 1: Summary of Sampling Stations

Station ID	2006 Station ID
East End of Lake	IS-1
South Cove	IS-5
Mid-Lake	IS-7
Spillway	IS-8
East Tributary	NA
South Tributary	NA

Temperature

Temperature is one of the most important factors affecting lake functions and is responsible for regulating many chemical and biological reactions within the lake. The temperature regime of a lake is a function of ambient air temperatures, lake morphometry and depth, placement within the landscape, incoming water temperatures, and various water quality metrics including turbidity levels and water color.

In turn, water temperature is responsible for biological growth rates, rates of chemical and biological reactions, the solubility of particulate compounds, and thermal stratification are also affected by temperature. One of the most biologically important temperature effects is the decrease in oxygen solubility with increasing temperature which can lead to the formation of hypoxic or anoxic dissolved oxygen concentrations (very low dissolved oxygen concentrations). Maintaining adequate dissolved oxygen concentrations, particularly at high temperatures, is important in sustaining most forms of aquatic life such as fish and invertebrates, and also limits the release of sediment bound nutrients.

As mentioned above, thermal stratification is a phenomenon observed in lakes of sufficient depth that is directly linked to water temperature. Thermal stratification describes the effect observed in lakes where distinct layers of water with different temperatures are formed in the water column. This is directly related to water temperature which in turn controls water density such that the coldest and densest water is found at greater depths. During the summer as one proceeds from the surface to the bottom of most lakes the temperature changes, and, along with its density. If the difference in density is too great along a given depth interval, there will be a tendency for these layers of water to resist intermixing. This condition is termed thermal stratification and is defined as the phenomenon whereby the deep water layers of the lake (hypolimnion) do not mix with the lake's shallow water layers (epilimnion). The area delineating these strata is known as the thermocline. Because these layers do not mix, the rate of atmospheric oxygen diffusion into the lower layer becomes negligible. Under such conditions, depending on the rate of bacterial respiration and temperature, it is possible for the deep layer to become oxygen depleted (anoxic) and to remain so until the density differences are no longer substantial enough to impair mixing.

In the fall, as surface temperatures cool and water temperatures become uniform from surface to bottom, the density differences between layers are reduced. Stratification breaks down and the lake experiences "turn-over", or undergoes a "purge". In temperate lakes of sufficient depth turn-over usually occurs twice annually, once in the spring and once in the fall. In smaller lakes which do not become stratified, density differences are usually too slight to impede internal circulation, and these lakes remain constantly mixed.

pH

pH is a unit-less measurement of the hydrogen ion concentration in water. Expressed on a negative logarithmic scale from 0 to 14, every change of 1 pH unit represents a 10-fold increase or decrease in hydrogen ion concentration. The pH of pure water, which has no ionic component, is 7 and is termed neutral. Any value less than 7 is termed acidic while any value greater than 7 is termed basic.

Rainwater for Maryland has an average pH value of 5.6. Regional waterbodies vary in pH due to differences in substrate composition, watershed geology, biological productivity, and anthropogenic inputs. Given these variations pH values in regional waterbodies generally fall between 6 to 9.

The pH of water is an important general water quality indicator because it is a major factor affecting most chemical and biological reactions, and in turn is affected by many chemical and biological reactions. Photosynthetic reactions affect pH values through uptake of hydrogen ions while releasing anions. This decrease in hydrogen ion concentration is represented by an increase in pH. Respiration serves to decrease pH values through the active release of carbon dioxide. Therefore, marked changes in pH values throughout the water column are strong indicators of relative rates of productivity versus respiration.

The pH typically ranges from 6 to 8 in mid-Atlantic temperate lakes. In seepage lakes which drain calcareous or limestone deposits, pH may be substantially in excess of 9. In contrast, the pH may be below 5 for lakes which drain igneous deposits and are subject to the accumulation of acidic runoff and humic substances. Lakes which display wide daily fluctuations in pH are indicative of a poorly buffered (low alkalinity) system.

Specific Conductance (SpC)

Specific conductance is defined as the ability of water to conduct an electrical current normalized for temperature. Increases in specific conductance are generally derived by an increase in ionic constituents from watershed soils and biological reactions and are also temperature dependent. Specific conductance can be used to estimate concentrations of dissolved solids and ions in the water column and to also estimate lake productivity. As with many other water quality parameters certain levels of dissolved ions, as indicated by specific conductance, are necessary to support aquatic life forms but extreme highs and lows can change species composition and impede growth.

Watershed geology, pH, and the dissolved solid load in stormwater runoff play an important part in conductance values for a particular lake. Some rocks and soils release ions very easily when water flows over them; for example, if water of low pH flows over calcareous rocks then calcium and carbonate ions will dissolve in water and raise the conductance values. Some rocks such as quartz are very resistant to weathering and in a predominately quartz geology conductance values would be low.

Many lakes with predominately suburban or urban watersheds experience an increase in specific conductance values following periods of significant rainfall. Increased volume and velocity of surface runoff often transports suspended solids and their associated nutrients into the waterbody. As the ionic constituents of these soils dissolve increases in specific conductance values occur. Therefore, increases in specific conductance are often times an excellent proxy measure of impairment due to watershed derived pollutant sources.

Dissolved Oxygen (DO)

Dissolved oxygen in lake ecosystems is a crucial indicator of productivity and may provide critical insight as to the overall health of a waterbody. Dissolved oxygen concentrations are highly dependent on lake location, water temperature, and the ratio of producers which are photosynthetic organisms like algae and plants versus consumers organisms that respire including microbes like bacteria and fish. Sources of dissolved oxygen in lake ecosystems include atmospheric diffusion and photosynthesis while sinks include organism respiration and bacterial decomposition of organic matter.

Large diel (daily) variations in dissolved oxygen concentrations are often times an indicator of excessive production and are therefore a proxy indicator of excessive nutrient loading. When plants, including single celled algae and submerged aquatic weeds, photosynthesize during the day they utilize light energy in combination with carbon dioxide and water to create simple sugars. This process effectively serves to increase the net amount of dissolved oxygen within the photic zone of the water column during the daylight hours. Problems arise when large amounts of autotrophic biomass is present as these organisms then respire during the night hours that consume expired organic matter, whereby dissolved oxygen is utilized to metabolize those simple sugars created during the daylight hours. This process effectively serves to provide large swings in dissolved oxygen concentration on a daily basis and may provide very stressful to aquatic organisms such as fish. Additionally, when algae die and drop through the water column this large amount of biomass is also respired by bacteria. Furthermore, this process becomes even more important in the overall health of the lake in the late summer months whereby low dissolved oxygen concentrations combine with warm water temperatures and may lead to fish kills.

Another important component of dissolved oxygen is its role in redox chemistry at the sediment-water interface. Essentially, oxygenated conditions serve to keep phosphorus bound to iron in the sediments. When anoxic conditions occur (DO < 1 mg/L) a change in redox chemistry occurs whereby this phosphorus-iron molecular complex is reduced (chemically) thereby releasing phosphorus into the water column. This process therefore serves to internally fertilize the lake with nutrients and may lead to further problems with increased algal and plant growth.

For healthy aquatic ecosystems Princeton Hydro recommends that dissolved oxygen concentrations remain above 4 mg/L to preclude stress on aquatic organisms and above 1 mg/L to prevent internal loading of phosphorus from the sediments.

Secchi Depth Transparency

A widely used, very simple method of determining the productivity of a lake is Secchi disk transparency. At it most basic the Secchi depth is simply a measure of clarity or transparency. Secchi disk transparency is affected by suspended sediment, algal cells, and water color. Low Secchi depths therefore are an indication of excessive particulate and dissolved matter in the water column indicating high concentrations of algae and inorganic suspended solids both of which are indicative of high levels of productivity. In its simplest interpretation, Secchi disk depths in excess of 8 meters are indicative of low productivity lakes (oligotrophic). Secchi depths of 8 meters to 4 meters are associated with medium productive lakes (mesotrophic). Lakes with Secchi disk depths of 2 meters or less are typically eutrophic lakes. To many people lower productivity lakes are generally recognized as having better water quality defined in part by decreased coloring and increased clarity. In contrast, high productivity systems are generally deemed to have lower water quality which in urbanized watersheds is likely related to nutrient pollution.

The Secchi depth is the depth at which a weighted, contrasting white and black disk known as the Secchi disk, when suspended from the shaded side of a boat, just disappears from view. Twice the Secchi depth generally corresponds to the depth in the lake where light penetration is 1% or less. This is defined by limnologists as the boundary of the limnetic zone; the lower limit of major photosynthetic activity. Rooted aquatic plants and algae will typically only grow at depths less than twice the Secchi depth.

2.2 Discrete Water Quality Measurements

Discrete water quality sampling is the process of collecting water samples which are then processed at an aqueous chemistry laboratory. Analytes collected for discrete analysis at Lake Churchill included Total Phosphorus, Soluble Reactive Phosphorus, Nitrate-Nitrogen, Ammonia-Nitrogen, Total Suspended Solids, Chlorophyll *a*, Alkalinity, and Hardness. Samples to be analyzed for the full battery of discrete analytes, less Chlorophyll *a*, were collected at the East and South Tributaries, East End of Lake, Mid-Lake Deep, and Spillway stations, while Chlorophyll *a* was analyzed for the in-lake stations including the East End of Lake, Mid-Lake, South Cove, and Spillway.

Sampling for this project consisted of directly filling bottles with lake water from a depth of about 0.5 meters, with the exception of a deep water collection which was sampled using a decontaminated Van Dorn sampling bottle. The Van Dorn bottle is a sampling device capable of sampling at any depth to which it is lowered and sample collection is performed when a weighted messenger is slid down the rope which triggers plungers that seal the sample in the body of the bottle. To account for the variety of sampled parameters, the appropriate volume of lake water was collected and preserved according to the requirements of each parameter. All samples were cooled to 4°C (39°F) in an ice filled cooler and delivered to Environmental Compliance Monitoring, Inc. laboratory for sample processing and analysis.

Phosphorus

In lake ecosystems phosphorus is often the limiting nutrient, one whose abundance is lowest relative to demand. As a result, phosphorus is often the primary nutrient driving excessive plant and algal growth. Given this nutrient limitation only relatively small increases in phosphorus concentration can fuel algal blooms and excessive macrophyte production. Literature values have reported that 1 pound of phosphorus entering a lake may result in excess of 1000 pounds of wet algal biomass.

Phosphorus is available in a number of forms or species, some of which are more readily assimilated by phytoplankton. Soluble reactive phosphorus is a measure of soluble orthophosphates and to a lesser extent some organically bound phosphorus; the orthophosphorus ion (PO_4^{3-}) of soluble reactive phosphorus represents that form which is most readily assimilated by algae for growth. As such, this species of phosphorus is generally present in very limited quantities (< 0.005 mg/L) in all but the most eutrophic of lakes. Total phosphorus is the sum of all phosphorus species including particulate and soluble and organic and inorganic. Through the analysis of many regional waterbodies Princeton Hydro recommends total phosphorus values not exceed 0.02-0.03 mg/L in order to preclude extended nuisance algal blooms.

Some of the important external sources of phosphorus are fertilizers, septic leachate, sewage effluent, detergents and soaps, particulate material transported by stormwater, and even precipitation. Lake sediments, particularly those which are highly organic or mucky, can serve as an internal source of phosphorus loading, especially if the overlying waters become devoid of oxygen or anoxic. The decomposition of dead algal cells and aquatic weed tissue is another internal source of phosphorus.

Nitrogen

The nitrogen cycle in lakes is considerably more complicated than the phosphorus cycle. Nitrogen can exist in either oxidized forms, usually nitrate (NO_3-N) or nitrite (NO_2-N), or reduced forms, including ammonia (NH_3-N) and organic nitrogen. Atmospheric nitrogen (N_2) can also be used as a nutrient source by cyanobacteria (blue-green algae), which gives them a considerable competitive advantage especially when phosphorus concentrations are in high supply relative to soluble nitrogen forms, and various other reduced forms of nitrogen can be produced by decomposition processes. Of these various forms, NH_3 and NO_3-N are readily available to aquatic primary producers for metabolic uptake. In most monitoring programs, these nitrogen compounds are usually analyzed. Some regulatory agencies are now requiring the analysis of total nitrogen (TN), which includes all non-gaseous nitrogen forms.

In lakes ammonia is naturally produced and broken down by bacterial processes while also serving as an important nutrient in plant growth. In a process termed ammonification bacteria break down organically bound nitrogen to form NH_4^+. In aerobic systems bacteria then break down excess ammonia in a process termed nitrification to nitrate (NO_3^-). These processes provide fuel for bacteria and are generally kept in balance as to prevent accumulation of any one nitrogen compound.

Excessive fish production, plant production, oxygen depletion, pH, wastewater, and watershed inputs are all potential factors in elevated ammonia levels. The EPA recommends that ammonia levels not exceed 0.02 mg/L in freshwater systems as to preclude fish toxicity, although both temperature and pH are both important components of ammonia toxicity.

Nitrate, a dissolved inorganic form of nitrogen, is the most commonly utilized form of nitrogen by plants and algae. Formed through the bacterial processes termed *nitrification* nitrate is derived through the breakdown of ammonia in aerobic conditions by bacteria in the lake system. Nitrate is also derived from the associated watershed as its molecular structure is conducive to transport in groundwater and surface flow.

The high availability of nitrates in relation to phosphorus generally preclude nitrogen compounds as the limiting nutrient and its role is therefore minimal in relationship to phosphorus in terms of algal blooms.

Relatively "non-eutrophic" (moderately productive) lakes generally have nitrate levels below 0.05 mg/L. In summer months the top layers of a lake generally have levels lower than this due to plant uptake while levels generally remain a little higher at the bottom of the lake due to organic matter decay.

Total Suspended Solids (TSS)

The measure of suspended particles in a waterbody that will cause turbid or "muddy" conditions, total suspended solids is often a useful indicator of stormwater inputs into a waterbody. Because suspended solids within the water column reduce light penetration through reflection and absorbance of light waves or particles suspended solids tend to reduce the active photic zone of a lake while contributing a "muddy" appearance at values over 25 mg/L. Factors which increase TSS values include increased sediment runoff during storm events and high densities of algae whose cells are included in suspended solids measures.

Suspended solids are often elevated in conjunction with storm events. For lakes that are significantly affected by stormwater inputs or tributary flows, an increase in TSS concentrations is generally mirrored by increases in nutrient concentrations. This occurs because many nutrients, including certain forms of phosphorus, are adsorbed to sediment particles. As these sediments are mobilized and carried into the lake with stormwater runoff, along with the sediments comes large amounts of nutrients. This relationship is often times useful in determining the overall effect storm events have on nutrient dynamics within a waterbody and their relative inputs of nutrients. In such cases, by limiting or reducing the influx of sediments a significant reduction in nutrient loading may also be achieved. This explains the emphasis on the control of TSS as part of stormwater management regulations and the performance standards developed for BMPs.

Chlorophyll a

Chlorophyll *a* is the primary photosynthetic pigment found in all types of algae. As such, increases in Chlorophyll *a* concentration are often used as a proxy measure of total algal biomass. Chlorophyll *a* concentration is often used in trophic state calculations and as such is an excellent indicator of overall lake productivity. As increases in Chlorophyll *a* concentration are directly related to increases in nutrient concentrations this measure may serve as a visible indicator of nutrient enrichment.

While chlorophyll *a* concentrations greater than 6 µg/L are classically associated with eutrophic conditions, Princeton Hydro recommends concentrations to not exceed 20 µg/L in order to retain acceptable aesthetics.

Alkalinity and Hardness

Alkalinity and acidity are measures of the capacity of water to neutralize acids and bases, respectively. Alkalinity and acidity are capacity factors and not directly related to pH, which is a measure of the overall intensity of acid and base reactions in water.

Carbonate minerals are the major source of alkalinity in most waters, with bicarbonate ion representing the major form of alkalinity in natural waters at neutral pH levels. As a result, alkalinity is usually expressed as mg $CaCO_3$/L. The salts of other weak acids, such as borates, silicates and phosphates can be significant in some cases, particularly in more arid regions.

Hardness is the complimentary parameter to alkalinity. While alkalinity effectively measures the concentration of anions, particularly carbonates, hydroxides, and others, hardness is the concentration of positive ions or cations, particularly calcium and magnesium ions. In effect, alkalinity measures the buffering capacity of the system while hardness measures the concentrations of other necessary ions. Generally, both parameters are found in similar concentrations; any concentration in excess of 25 mg/L in lake water is capable of supporting most forms of aquatic life.

2.3 Plankton Survey

Plankton surveys were conducted to investigate two specific components of the lake plankton: phytoplankton and zooplankton. Phytoplankton are sampled by collecting whole water samples. Zooplankton have a different sampling methodology and are collected using the Schindler trap, a sampling device of known volume which is drained through a 153 µm mesh net. The zooplankton was sampled both at the surface and near the thermocline above anoxic waters. All sample processing was conducted in-house at Princeton Hydro and most groups identified to genus; quantitative analyses such as biomass and density were also performed.

Phytoplankton

Phytoplankton is the base of the trophic web in any lake system, and largely determines the quality of the waterbody from ecological, recreational, and aesthetic perspectives. Phytoplankton is described here as single cell and colonial algae forming surface and benthic (bottom) colonies that act as primary producers through photosynthesis within the lake. Phytoplankton growth is largely a function of nutrient concentrations, specifically phosphorus and nitrogen as discussed above. Excessive nutrient levels can cause undesirable phytoplankton blooms that negatively impact water clarity and may form dense, floating surface mats. In addition to limiting phytoplankton biomass, nutrient levels can directly affect the phytoplankton assemblage, most notably when there are low N:P environments that favor the undesirable Cyanobacteria division (blue-green algae).

Phytoplankton are often the most visible sign of impairment in lake systems exhibited by reduced clarity, high coloration, and the development of odors. While critical for maintaining the food web in lakes, excessive algal density leads to severe impacts aside aesthetic degradation. As discussed in the dissolved oxygen section above, algae blooms are capable of causing wild DO swings that can negatively impact other aquatic life.

Zooplankton

Zooplankton are the animals or protists that exist in the plankton (free floating, open water) of a lake ecosystem. The zooplankton of freshwater ecosystems is represented primarily by four major groups: the protozoa, the rotifers, and two (2) subclasses of Crustacea, the cladocerans and the copepods. The cladocerans are particularly important species within lake ecosystems and factor importantly in lake management. Cladocerans are typically regarded as large, highly herbivorous zooplankters capable of keeping algal densities naturally in check through grazing pressure. In certain systems, copepods function similarly. The presence of herbivorous zooplankters is beneficial for maintaining low phytoplankton densities, and zooplankton populations can be modified through biomanipulation techniques including stocking and watershed management techniques reducing runoff nutrient levels. Large bodied zooplankters are also the primary food source of almost all icthyoplankton and larval fish including gamefish species, and small to moderate sized adult fish- particularly members of the Cyprinidae family (Minnows) and the genus *Lepomis* (Sunfishes).

2.4 Macrophyte Survey

Macrophytes, or rooted aquatic vegetation, are an important component in the ecological function of most lake systems. Plants play an important role in the nutrient dynamics and nutrient recycling of the lake, serve as habitat for all aquatic life forms, are important forage for many aquatic species and terrestrial animals and waterfowl, and provide stability to sediments and can improve water clarity.

Macrophytes were surveyed visually in Lake Churchill, although weighted sampling devices were also used to sample rooted plants on the benthic substrate.

3.0 Results

Overall, many of the observations made in 2006 and 2007 were repeated in 2008. *In-situ* water quality in 2008 was nearly identical to that measured in 2006, with the exception of more moderated surface dissolved oxygen concentrations related to decreased phytoplankton density. Despite decreased algae density, the hallmarks of a eutrophic system are evident in this lake which is characterized by high surface water temperatures, moderate conductance values, dissolved oxygen concentrations approaching saturation, and relatively high pH values. 2007 was a slight outlier compared to the other two years worth of data due to precipitation during and before the monitoring event. In general though the overall trends show that intense algae blooms observed in 2006 are likely to be repeated as the conditions observed in mid to late August tend to be relatively constant from year to year without strong inter-annual variation.

Discrete data, like *in-situ*, shows only minor variation over time for most parameters measured in this study. The exception of course is Chlorophyll *a* which has shown continued diminishment over the three years studied. It is important to note that Chlorophyll *a*, as a biological metric, is inherently more variable than other metrics and can change significantly in the course of hours. Generally, total phosphorus values have remained high enough to support algae blooms in the lake. 2008 showed one other anomaly relative to past years which was the very high TP concentration measured in the hypolimnion at mid-lake. This may be due to stronger thermal stratification, prolonged period of stratification, or some loading to deep water of phosphorus such as senesced algal cells from an earlier bloom. In any case, upon turnover a pulse of nutrient rich water will be circulated throughout the water column. Because we sample only once a year it is unknown if stratification ever completely breaks down in Lake Churchill or perhaps does so only in the spring. In either case it bears scrutiny to observe any changes in the lake which if timing is correct could result in a huge algae bloom.

3.1 *In-situ* Results

Strong thermal stratification was once again observed in Lake Churchill and this phenomenon is likely linked to periodic intense algae blooms in the lake. As mentioned above *in-situ* data was generally very close to that measured in 2006. Surface water temperatures exceeded 27°C (80°F) which is sufficiently high to support a blue-green algae bloom. A somewhat broad thermocline was observed between 3 and 5 meters (9.8 to 16.4') and temperatures in the hypolimnion at the bottom of the lake were as low as 9.1°C (48.4°F), the lowest yet measured. At the time of sampling the tributary stations were respectively measured at 19.3°C (66.7°F) and 16.8°C (62.2°F), which was much lower than the main lake, and also indicates that the streams were being discharged at baseflow conditions which are sustained by cool groundwater.

pH was indicative of fairly vigorous primary production in the system related to algal photosynthetic activity. pH exhibited minor spatial variations across the in-lake stations and was measured in the 8.50 to 8.85 range in the lake. Compared with the previous water quality sampling events pH was more similar to those values measured in 2006 than in the previous year, however it was still lower than the 9 values seen in 2006 in the midst of dense algae bloom. pH was also indicative of the level of stratification with decaying values down through the water column with values as low as 7 measured at the deepest part of the lake. This shows not only the strong stratification of the lake but also the energetic respiration in the deep layers, a process that drives down pH values as respired CO_2 is released into the water. The pH of the inflowing tributaries was lower than the values measured in the lake which is again reflective of high levels of primary productivity occurring in the lake.

DO concentrations were similar in scope to those observed with pH, but did show some minor and important variations. DO concentrations at the surface varied somewhat between stations but stayed within a moderate range of 7.2 to 7.7 mg/L. From a different perspective DO concentrations showed 92 to 98% saturation. As with pH, DO measurements indicate a fairly high level of productivity which was significantly higher than 2007 values, which were lower due to recent precipitation and cloudy skies that limited photosynthetic activity, and lower than the 2006 values which were at supersaturated conditions due to extremely high productivity. DO exhibited precipitous declines with depth; the hypolimnion was anoxic. DO values at depth were the lowest yet measured and indicate a longer or stronger period of thermal stratification this year. While surface values were capable of supporting most aquatic life DO values deeper than 3 meters were insufficient to support fish and all but the most specialized invertebrates such as midge larvae that are adapted to surviving in hypoxic conditions which represents a major loss of usable fish habitat when considered in a three-dimensional perspective. The anoxic conditions measured at the bottom were responsible for extreme phosphorus release from the sediments which is confirmed by the discrete data. DO levels were at around 75% saturation in the stream which shows less energetic flows capable of fully oxygenating the stream waters.

Specific conductance measurements yielded some interesting results and showed significant difference due to depth, location, hydrology, and temporally when compared to previous years. Surface conductance values were acceptable and can be considered moderate levels for lakes in this region with similar watersheds. Values observed in 2007 were considerably higher and related to the dry conditions in that summer, which through evaporative loss and groundwater recharge can serve to drive up conductance values as well as a pulse of stormwater immediately preceding sampling. Values measured in 2006 were significantly lower than in 2008. While rainfall totals were similar the Germantown area received nearly 8 inches of rain in a three day period in late June in 2006 which likely flushed a large volume of the lake and overall reduced conductance values. Also as in past years conductance values increased multiple times with depth, and in fact was an order of magnitude (10-fold) higher at the bottom than at the surface. This disparity was greater than previous years and again shows the stability of stratification observed in 2008.

Interestingly tributary conductance showed some substantial variability with past data and between the stations. These differences are a result of the variable hydrology of these systems. Low values measured in 2007 which were consistent in both tributaries were likely a result of slightly elevated flows following rain events. Typically, stormwater is thought to carry high quantities of dissolved solids and other materials and while this is true after the so-called first flush concentrations typically drop. Loading remains higher during these periods since loads are a function of concentration multiplied by discharge value, but concentrations can be lower. In 2008 the eastern tributary in particular exhibited high conductance values twice that observed in the south tributary. Baseflow conductance can be higher since baseflow is sustained by groundwater which can have high conductance since it is mobilized through soils and is in contact with solids. The interesting disparity lies between the east and the south tributary. The difference is hard to explain, but when combined with the higher temperatures seen in the eastern tributary there may be some sort of pollutant stream or discharge on the eastern tributary.

Secchi depths were somewhat improved over last year with a maximum recorded value of 1.4 meters (4.6'). Generally this tends to be an acceptable value to many lake users, although it is still indicative of a eutrophic system. It must be pointed out that while clarity was acceptable the lake was still highly colored with an olive hue trending towards greenish near the spillway. Secchi depths may have been somewhat better this year due to decreased TSS concentrations and somewhat cooler mean temperatures during August than seen before.

A summary table of *In-situ* Water Quality Results is provided as Appendix I.

3.2 Discrete Water Quality Results

Most of the important discrete parameters showed decreased values compared to 2006 and 2007 which resulted in decreased algae intensity and better clarity. TP values measured at the eastern lake station and at the spillway were both 0.03 mg/L, slight decreases relative to last year but important in reducing algae concentrations. These values are at the cusp of phosphorus concentrations necessary to sustain algae blooms. Similarly SRP values were non-detectable (ND<0.003 mg/L) at all in-lake stations. Dependent on other conditions this may be a positive. SRP is the chief nutrient utilized by algae to grow and low values can indicate low growth potential or mean that algal biomass is at a high enough point that any available phosphorus of this species is immediately assimilated by the cells. TP concentrations increased by more than 10 fold in the hypolimnion showing both the release of phosphorus from the sediment under stable stratification and anoxia but also the concentration of senesced algae particles in this area. The disparity between surface and deep concentrations was much greater this year than in past years and shows the importance that internal nutrient loading has in the nutrient budget of this lake. As mentioned above, these very high concentrations mean that potentially pulses of very phosphorus-rich water are released into the water column which could result in algae blooms. Phosphorus values indicate this is a eutrophic system.

The tributaries continue to be contributors to phosphorus loading in the lake which is a natural phenomenon. Both had moderate SRP values, but the southern tributary in particular had a high TP concentration, 0.08 mg/L, which is over twice the value measured at the surface in the lake.

Both nitrogen species, NO_3 (nitrate) and NH_3 (ammonia), were measured at lower concentrations in the surface waters of the lake in 2008. Generally, the measured values are acceptable and do not indicate and elevated loading or cycling of these nutrients in the system. Both of these parameters showed relatively large increases in the deep waters of the lake due to the decomposition of plant matter at the bottom. Interestingly, the hypolimnetic concentration of ammonia was much lower than measured last year and poses no risk of toxicity at such concentrations. Ammonia concentrations in both tributaries were very low relative to 2007, but nitrate values were much higher. Again, this is typical of baseflow tributary conditions since nitrate is very mobile in groundwater. While much higher than in lake concentrations, these nitrate values are acceptable in tributary systems.

TSS concentrations were relatively low in Lake Churchill and the greatest contribution is likely to be algal cells. These measured values were lower than last year, which likely had some contributions of inorganic particulates from stormflows at the time, and less than 20% of any value measured in 2006 which was predominately driven by high algal concentrations. TSS values were very high in the hypolimnion which is a function of particulate settling through the water column. Tributary concentrations were below detectable limits and again were much lower than the previous year. Overall, low TSS concentrations were observed in Churchill in 2008.

Alkalinity and hardness were somewhat variable, but relatively consistent with values observed last in the previous two years, although slightly higher. This is likely a function of slightly higher rainfall totals this year which contributes these substances from the watershed. Measured values in the hypolimnion were much higher than at the surface consistent with the conductance profile and increased TSS loads. Alkalinity and hardness in the south tributary closely matched values observed in 2007, but the eastern tributary was much higher than last year and much higher than the south tributary. This is also confirmed in the conductance data and may be related to stormwater basin discharges or perhaps another source like a leaky septic line. However, even the tributary values are within an acceptable limit and both these parameters are consistent with the needs of aquatic organisms.

Chlorophyll *a* values were significantly lower than those observed in both 2007 and 2006. This was likely linked to reduced nutrient concentrations, particularly phosphorus values, seen this year. Additionally, lower than average temperatures in August may have contributed to overall less algal biomass and prevented the exceedingly high blue-green algae densities witnessed in 2006. Little spatial variability was detected between stations this year. As is usually the case lower Chlorophyll *a* concentrations were mirrored by greater clarity as measured by Secchi disk. The peak measured Chlorophyll *a* value in Lake Churchill in 2008 was 8.1 µg/L. While below what is typically considered a nuisance value threshold of 20 µg/L, the measured concentrations are still characteristic of a highly productive, eutrophic waterbody.

A summary of the Discrete Water Quality Results is included as Appendix II.

3.3 Plankton Survey

The plankton data from 2008 overall shows communities fairly consistent with those observed in 2006 and 2007. In particular, these communities are characterized by dominance of blue-green algae or cyanophytes and modest numbers of herbivorous zooplankters. Once again, the plankton analysis indicates that Lake Churchill is a eutrophic system and that elevated nutrient concentrations encourage nuisance plankton densities. However, phytoplankton density was much lower in 2008 relative to 2007 but still at high levels.

The phytoplankton communities at both the spillway and eastern end of lake stations exhibit the same composition. Both communities are dominated by the blue-green alga *Anabaena*, which accounts for around 77% of all algal biomass in the lake. From a density perspective the green algae or chlorophytes were well represented in the samples but consisted mostly of very small-cell type algae. Other phytoplankton observed in the communities included *Cryptomonas*. Again cyanophytes are the dominant algae, but previous communities were dominated by *Microcystis* and not *Anabaena.* The continued trend of cyanophyte dominance confirms the impairment of water quality in the lake.

The presence and dominance of cyanophytes is problematic for several reasons. First, nuisance cyanophytes growth indicates eutrophication of the lake and continued elevated nutrient loading. Blue-green algae do best in highly enriched TP waters because of their ability to utilize organic species of phosphorus that other algae cannot and because they fix atmospheric nitrogen, both of which provide a competitive advantage during warm periods. Aside from their indication of high nutrient concentrations cyanobacteria directly impair water quality by reducing clarity and producing noxious odors. Indirect effects of blue-green blooms include the depletion of dissolved oxygen at night and upon senescence of the bloom. Additionally, blue-greens are a poor source of forage for zooplankton and are not naturally controlled by herbivorous zooplankton.

The zooplankton community exhibited decreased quality in 2008 relative to 2007. While herbivorous zooplankton were still found within the samples, including the cladocerans *Ceriodaphnia* and *Diaphanosoma* and the copepod *Diaptomus*, they accounted for a decreased percent contribution of the overall zooplankton. Total zooplankton density and biomass has decreased from last year. As in years past though, the zooplankton community was fairly diverse. These fairly low concentrations of large zooplankton are likely a reflection of the phytoplankton composition. Decreased biomass of zooplankton may impact recruitment success of juvenile fishes and also means that algae are less effectively grazed.

The plankton composition of Lake Churchill continues to highlight the necessity of reducing nutrient concentrations in the lake to restore a more favorable composition at lower densities to improve the ecologic function of the lake.

A summary of the Plankton Survey Results is included as Appendix III.

3.4 Macrophyte Survey

Similar to past surveys conducted over the last two years no submerged aquatic vegetation was observed in 2008. Secchi depths were again slightly higher than those observed in previous years, with observed maxima of 1.4 meters, but additional clarity did not contribute to any colonization of the lake bed. Several emergent plants were again observed; the shoreline has a patchy distribution of common emergents such as cattails (*Typha* spp.) and the invasive plant purple loosestrife (*Lythrum salicaria*). Other plants found at a much lower density included pickerelweed (*Pontederia cordata*) and cardinal flower (*Lobelia cardinalis*). These plants are generally confined to areas immediately adjacent to the shore and rarely exhibit colonization in areas exceeding 0.4 meters. In addition almost no filamentous alga was documented either at the surface or on the sediment.

The lack of vegetation is typical of systems like Lake Churchill. Lakes typically exhibit two distinct phases in which the systems are either dominated by planktonic algae or macrophytes and filamentous algae. For the past three years of observation Lake Churchill is clearly a planktonic algae system. This phase is generally characterized by high levels of turbidity and relatively low clarity. Combined these two factors limit light penetration that is critical to plant growth. In the shallow eastern end of the lake plant growth may be inhibited not only by lack of light resources but potential smothering due to sediment loading.

3.5 Water Quality Summary and Historical Review

Overall, the characterization of water quality in Lake Churchill follows previous descriptions. The general characterization is that Lake Churchill is a moderately impaired system with symptoms characteristic of impounded lake systems with urbanized watersheds. The specific problems observed in 2008, as well as 2007 and 2006, include moderately high nutrient concentrations, elevated Chlorophyll *a* concentrations, which is indicative of algal biomass, poor clarity, coloration, and high algal density. These issues are largely the result of watershed loading of nutrients and solids, basin morphometry, and to a lesser degree the high degree of internal loading related to stable stratification. High nutrient concentrations have been confirmed over the last several years both in the lake and tributaries while solids loading evidence was presented in the 2006 bathymetric survey exhibiting increases in volume and delta formation relative to the 1999 survey. As mentioned in previous reports, artificial impoundments often have poor water quality due to a very large watershed compared to a relatively small volume. This is exacerbated in Lake Churchill by the highly developed nature of the watershed which contributes large amounts of nutrients and solids which impair water quality and contribute to rapid sedimentation in the lake.

Water quality metrics for the most part have painted a similar picture from year to year. 2007 was somewhat dissimilar relative to the other two water quality events data due to precipitation immediately preceding lake sampling at that time. The two most variable parameters over time have been Chlorophyll *a* concentration and Secchi depth, both of which are reflective of algal density. Despite relatively similar temperature patterns and nutrient concentrations algae growth has been disparate over time which begs the question why these differences exist. The expanded dataset has shed some light on this matter and it appears that stratification patterns and weather may be important factors in determining the difference.

In 2008, stratification was noted as very strong and as a result the hypolimnion was anoxic with very high measured conductance and phosphorus levels. While 2006 also exhibited strong stratification and anoxia there were several important differences, namely that phosphorus concentrations were much lower, conductance was reduced, temperature was slightly higher, and the thermocline was shallower. These are all indications that stratification was not as strong or as long. In turn this indicates that periods of mixing or partial mixing extended later into the summer in 2006. It seems likely therefore that the heavy rains in late June of 2006, over 8 inches in three days, caused stratification to break down for a brief period which made available a large slug of phosphorus rich water to the photic zone which was then assimilated by phytoplankton and caused the bloom conditions. This breakdown could explain decreased conductance and phosphorus concentration in the hypolimnion if this water was able to mix with the rest of the lake which is prohibited by the thermal zonation observed this summer. At the same time contaminated stormwater runoff was also transported to the lake via the tributaries and sheet flow. This occurred approximately six weeks prior to sampling in 2006 and seems the most likely explanation for differences in water quality relative to other years. While this cannot be fully confirmed based on discrete single event water quality studies collected over the course of years it is consistent with the patterns observed. It is likely that this pattern is repeated often and the very high concentrations of phosphorus measured in the hypolimnion in 2008 are certainly cause for concern, and unless stratification breaks down during biologically inactive times, like late fall or winter, or occurs in the spring and is immediately flushed by spring rains, intense bloom conditions may be imminent.

4.0 Recommendations

The same basic list of recommendations that was proposed last year remains in effect for this year. These recommendations are focused on addressing water quality impairment issues in Lake Churchill; specifically those problems that have been consistently observed over the last three year including high nutrient concentrations, high hypolimnetic internal nutrient loading, and nuisance algae blooms. Recommendations therefore must focus on reducing nutrient loading and controlling algae blooms and are based specifically on those issues identified during the water quality sampling events.

The first management goal is to commence a more regular cycle of water quality studies at the lake. It is evident at this time that a more thorough diagnostic feasibility study should be completed for the lake and its watershed. This would include at a minimum three monitoring events conducted along a similar scope as this study to track changes in water quality throughout the growing season. Sampling should be conducted in April, July, and early September to effectively sample the lake in the spring, mid-summer, and late summer. Sampling should focus on the interactions between water chemistry and algal response and should include both tributary and in-lake sampling with *in-situ* and discrete monitoring. This data can be used in several capacities: first, additional data will help expand the multi-year dataset that is currently collected to allow a refinement of the understanding of the ecosystem overtime within a single year, second, the data can then be used to aid in the employment of various water quality models which can then be used to formulate management plans specifically designed to address water quality issues within the watershed. Up to this point, each water quality survey has consisted of a single event. While valuable for describing a discrete moment in what is typically the worst water quality period for most lakes, this approach is inadequate for a thorough understanding of the nutrient dynamics that affect the lake. In addition to in-field sampling pollutant and hydrologic modeling should be performed that would include pollutant Unit Areal Loading models and the Modified Rational Method for describing annual hydrology. Thorough studies combining these various components will allow for much more effective management strategies.

The power of expanding the number of sampling events, at least in a temporal sense, has clearly been demonstrated in this report and comparative analysis of the data has allowed the identification of factors affecting inter-annual variability. At the same time it would increase predictive power of future water quality trends.

Based on the limited data available the best management strategy to implement at Lake Churchill will probably be the installation of a submerged destratification/aeration system. A destratification/aeration system mechanically mixes and aerates the water column using compressed air released from diffusers located on the lake bed. Keeping a lake thoroughly mixed accomplishes several goals. First, it maintains adequate dissolved oxygen levels throughout the water column which prohibits the release of nutrients bound in the lake sediments which effectively limits internal nutrient cycling. The effect of this is to limit nutrients that promote algae growth and thereby eliminating many of the problems associated with continued algae blooms. Also, by maintaining adequate aeration in the system it effectively increase usable habitat thereby benefiting the fishery of the lake. Aeration can also make algicide applications much efficacious. Finally, aeration is helps prevent the formation of blue-green algae blooms. Blue-greens in particular bloom at the lake surface because of increased light demands and vertical mixing helps to break up blooms and prevent their formation. Obviously internal nutrient cycling has been an important factor in water quality degradation in Lake Churchill and likely seems responsible for bloom conditions observed in 2006. Managing stratification is a significant step towards limiting the formation of nuisance algae blooms in the future. The installation of an aeration system in Lake Churchill could be expected to cost around $20,000 to $30,000. These revised cost estimates include more complete understanding of stratification patterns and extent and decreased equipment costs. Princeton Hydro is now a certified Vertex aeration system dealer and as such receives substantial cost savings and engineering design costs.

Another important strategy to consider is the use of chemical algicides to reduce phytoplankton concentrations. Chemical treatment is the most efficient means of short-term control for algae. However, chemical control requires periodic application throughout the growing season to maintain low algae densities in a lake. A shortcoming of chemical treatment is that it does not address the root causes of algae growth, namely elevated nutrient concentrations. As mentioned above, treatment efficacy is much improved when utilized in conjunction with aeration techniques. A chemical algicide treatment program could be expected to cost nearly $15,000 per year at Lake Churchill.

Some other management strategies should be considered for Lake Churchill but could not be enacted without further scientific and/or engineering studies. Biomanipulation may be an option that could work effectively in Lake Churchill. This strategy alters the fishery in a “top-down” manner in which the food web is altered at the top with resultant changes in the algae community. In Lake Churchill this would require a thorough fishery survey followed by the stocking of predators such as Largemouth Bass or hybrid Striped bass where necessary and the removal of unwanted species such as Carp or Golden Shiners.

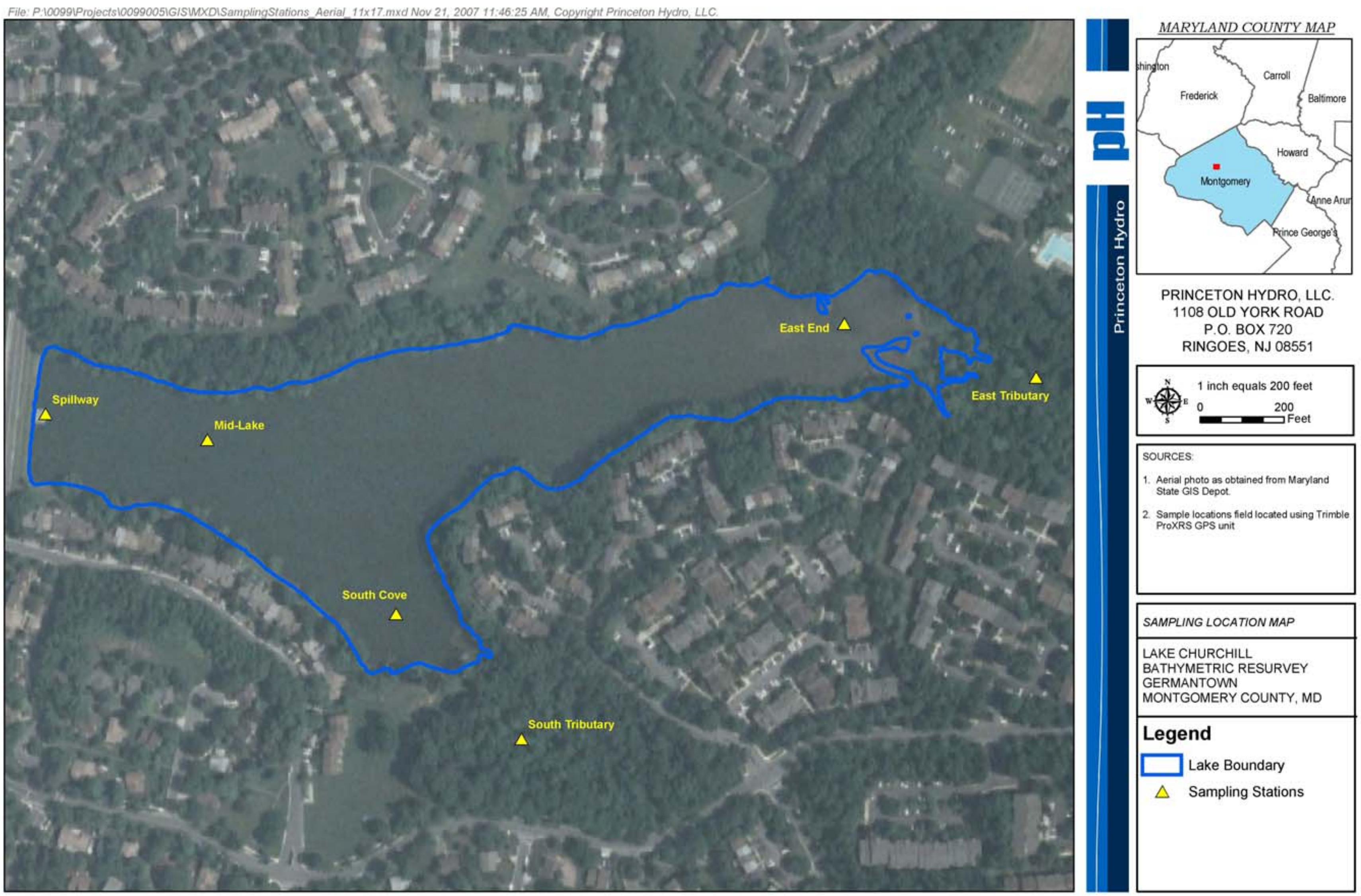
Another treatment strategy would be the application of alum (aluminum sulfate). Alum binds phosphorus and particulates both in the water column and in the sediments and makes them unavailable for algal uptake, and is especially effective in systems driven by internal nutrient loading such as Lake Churchill. Alum can have carry-over effects lasting several years, but prior to application numerous sediment and aqueous alum bench tests would need to be conducted.

Finally, watershed management strategies must be adopted to help control nutrient loading. This would include the installation, construction, or retrofitting of structural BMPs (best-management-practices) to control non-point source nutrient and sediment loading in storm water conveyance systems, which is especially important in urban and suburban environments. Watershed residents and other stakeholders can also be educated about various practices that reduce nutrient loading, such as the application of non-phosphorus fertilizers. A positive step that has been taken in this direction starts with the stream restoration activities on the eastern tributary. Stream restoration helps mitigate erosion, solids loading, and decrease nutrient concentrations. This type of active work within the watershed upstream of the impacted waterbody is a crucial step in urban lakes. Furthermore this type of work indicates the commitment of the Churchill Community Foundation to improving water quality within their watershed.

APPENDICES

APPENDIX I

SAMPLING STATION LOCATION MAP


File: P:\0099\Projects\0099005\GIS\MXD\SamplingStations_Aerial_11x17.mxd Nov 21, 2007 11:46:25 AM, Copyright Princeton Hydro, LLC.
Spillway
Mid-Lake
East End
East Tributary
South Cove
South Tributary
Princeton Hydro
MARYLAND COUNTY MAP
Frederick
Carroll
Baltimore
Howard
Montgomery
Prince George's
PRINCETON HYDRO, LLC.
1108 OLD YORK ROAD
P.O. BOX 720
RINGOES, NJ 08551
1 inch equals 200 feet
0
200
Feet
SOURCES:
1. Aerial photo as obtained from Maryland State GIS Depot.
2. Sample locations field located using Trimble ProXRS GPS unit
SAMPLING LOCATION MAP
LAKE CHURCHILL
BATHYMETRIC RESURVEY
GERMANTOWN
MONTGOMERY COUNTY, MD
Legend
Lake Boundary
Sampling Stations

APPENDIX II

In-situ Water Quality Results

Mid-Lake 2008							
Total Depth	7.60	meters	24.93	feet			
Secchi Depth	1.40	meters	4.59	feet			
Depth		Temperature		SpC	DO	DO	pH
meters	feet	°C	°F	mS/cm	mg/L	%	S.U.
0.00	0.00	27.44	81.39	0.336	7.73	97.90	8.85
1.00	3.28	26.16	79.09	0.337	7.59	94.00	8.90
2.00	6.56	25.44	77.79	0.343	6.79	82.90	8.59
3.00	9.84	23.74	74.73	0.386	3.03	35.90	8.02
4.00	13.12	18.39	65.10	0.676	0.59	6.30	7.70
5.00	16.40	11.94	53.49	2.030	0.32	3.00	7.33
6.00	19.68	9.91	49.84	3.050	0.24	2.40	7.17
7.00	22.97	9.30	48.74	3.360	0.20	1.90	7.09
7.50	24.61	9.12	48.42	3.500	0.20	1.80	7.02

Mid-Lake 2007							
Total Depth	6.10	meters	20.01	feet			
Secchi Depth	1.15	meters	3.77	feet			
Depth		Temp		SpC	DO	DO	pH
meters	feet	°C	°F	mS/cm	mg/L	%	
0.00	0.00	24.13	75.43	0.461	6.28	74.60	7.76
1.00	3.28	24.14	75.45	0.461	6.46	76.74	7.75
2.00	6.56	23.45	74.21	0.417	6.01	70.06	7.74
3.00	9.84	22.10	71.78	0.359	4.36	49.87	7.54
4.00	13.12	18.77	65.79	0.630	0.51	5.39	7.15
5.00	16.40	13.06	55.51	1.069	0.20	1.90	6.98
6.00	19.68	10.31	50.56	2.580	0.13	1.15	6.78

Mid-Lake 2006 (IS-7)							
Total Depth	6.71	meters	22.00	feet			
Secchi Depth	0.80	meters	2.62	feet			
Depth		Temp		SpC	DO	DO	pH
meters	feet	°C	°F	mS/cm	mg/L	%	
0.00	0.00	26.82	80.28	0.253	10.48	129.18	9.00
0.30	1.00	26.60	79.88	0.253	10.49	129.30	8.99
0.61	2.00	26.43	79.57	0.253	10.51	129.55	8.99
0.91	3.00	26.42	79.56	0.253	10.53	129.79	8.98
1.22	4.00	26.20	79.16	0.253	10.48	129.18	8.73
1.52	5.00	26.11	79.00	0.254	9.43	116.23	8.56
1.83	6.00	25.99	78.78	0.255	7.62	92.22	8.20
2.13	7.00	25.58	78.04	0.256	6.40	77.45	7.55
2.44	8.00	24.16	75.49	0.260	4.81	57.14	7.43
2.74	9.00	23.50	74.30	0.281	3.15	36.72	7.17
3.05	10.00	22.90	73.22	0.295	2.20	25.16	7.07
3.35	11.00	22.22	72.00	0.312	2.03	23.22	7.08
3.66	12.00	19.19	66.54	0.515	1.87	20.16	7.10
3.96	13.00	17.32	63.18	0.616	1.80	18.62	7.14
4.27	14.00	16.53	61.75	0.685	1.44	14.59	7.04
4.57	15.00	14.43	57.97	0.793	1.10	10.67	7.01
4.88	16.00	13.95	57.11	0.813	0.93	8.83	6.99
5.18	17.00	13.02	55.44	1.097	0.70	6.64	6.86
5.49	18.00	13.17	55.71	1.230	0.68	6.45	6.85
5.79	19.00	12.57	54.63	1.540	0.58	5.38	6.82
6.10	20.00	11.02	51.84	1.870	0.50	4.53	6.80
6.40	21.00	10.84	51.51	1.900	0.48	4.25	6.79
6.71	22.00	10.57	51.03	1.950	0.43	3.81	6.59

Spillway 2008							
Total Depth	5.10	meters	16.73	feet			
Secchi Depth	1.40	meters	4.59	feet			
Depth		Temperature		SpC	DO	DO	pH
meters	feet	°C	°F	mS/cm	mg/L	%	S.U.
0.00	0.00	27.65	81.77	0.339	7.53	95.80	8.50
1.00	3.28	26.21	79.18	0.340	7.58	93.90	8.86
2.00	6.56	25.59	78.06	0.341	7.01	85.90	8.70
3.00	9.84	23.57	74.43	0.393	2.18	25.10	8.14
4.00	13.12	17.79	64.02	0.679	0.47	4.90	7.77
5.00	16.40	12.85	55.13	1.790	0.31	2.60	7.46

Spillway 2007							
Total Depth	5.80	meters	19.03	feet			
Secchi Depth	1.20	meters	3.94	feet			
Depth		Temp		SpC	DO	DO	pH
meters	feet	°C	°F	mS/cm	mg/L	%	
0.00	0.00	24.12	75.42	0.463	6.23	74.01	7.70
1.00	3.28	24.12	75.42	0.465	6.37	75.67	7.68
2.00	6.56	24.11	75.40	0.464	6.32	75.08	7.68
3.00	9.84	21.83	71.29	0.416	2.85	31.97	7.61
4.00	13.12	19.01	66.22	0.625	0.62	6.68	7.41
5.00	16.40	12.69	54.84	1.232	0.27	2.51	7.18
5.70	18.70	11.56	52.81	1.750	0.16	1.45	6.97

Spillway 2006 (IS-8)							
Total Depth	2.59	meters	8.50	feet			
Secchi Depth	0.85	meters	2.79	feet			
Depth		Temp		SpC	DO	DO	pH
meters	feet	°C	°F	mS/cm	mg/L	%	
0.00	0.00	27.05	80.69	0.253	10.28	129.02	8.96
0.30	1.00	26.93	80.47	0.253	10.30	126.96	8.96
0.61	2.00	26.71	80.08	0.254	10.17	125.35	8.96
0.91	3.00	26.52	79.74	0.255	10.08	124.25	8.97
1.22	4.00	26.38	79.48	0.257	8.31	102.43	8.91
1.52	5.00	26.16	79.09	0.260	5.67	69.89	7.88
1.83	6.00	25.92	78.66	0.262	3.75	45.38	7.42
2.13	7.00	25.38	77.68	0.268	2.01	24.33	7.23
2.44	8.00	24.95	76.91	0.278	1.50	17.82	7.09

South Cove 2008							
Total Depth	2.50	meters	8.20	feet			
Secchi Depth	1.30	meters	4.27	feet			
Depth		Temperature		SpC	DO	DO	pH
meters	feet	°C	°F	mS/cm	mg/L	%	S.U.
0.00	0.00	28.03	82.45	0.339	7.36	94.10	8.70
0.50	1.64	26.68	80.02	0.336	7.68	96.80	8.95
1.00	3.28	26.36	79.45	0.336	7.68	95.70	8.95
1.50	4.92	25.79	78.42	0.337	7.16	88.30	8.85
2.00	6.56	25.18	77.32	0.352	5.80	70.50	8.33
2.40	7.87	24.95	76.91	0.363	0.88	13.20	7.92

South Cove 2007							
Total Depth	2.60	meters	8.53	feet			
Secchi Depth	1.10	meters	3.61	feet			
Depth		Temp		SpC	DO	DO	pH
meters	feet	°C	°F	mS/cm	mg/L	%	
0.00	0.00	24.14	75.45	0.465	6.58	78.17	7.73
0.50	1.64	24.15	75.47	0.464	6.61	78.52	7.75
1.00	3.28	24.14	75.45	0.466	6.61	78.52	7.77
1.50	4.92	24.06	75.31	0.459	6.46	76.74	7.76
2.00	6.56	23.39	74.10	0.419	5.24	61.09	7.72
2.50	8.20	22.93	73.27	0.379	5.14	58.79	7.58

South Cove 2006 (IS-6)							
Total Depth	2.53	meters	8.30	feet			
Secchi Depth	0.75	meters	2.46	feet			
Depth		Temp		SpC	DO	DO	pH
meters	feet	°C	°F	mS/cm	mg/L	%	
0.00	0.00	26.39	79.50	0.254	9.32	114.88	8.93
0.30	1.00	26.42	79.56	0.254	9.62	118.58	8.90
0.61	2.00	26.44	79.59	0.255	9.80	120.79	8.86
0.91	3.00	26.45	79.61	0.255	9.75	120.18	8.86
1.22	4.00	26.45	79.61	0.255	9.65	118.94	8.85
1.52	5.00	26.34	79.41	0.256	9.50	117.10	8.77
1.83	6.00	26.10	78.98	0.255	9.21	113.52	8.63
2.13	7.00	25.88	78.58	0.256	8.84	106.98	8.35
2.44	8.00	25.75	78.35	0.260	4.00	48.41	7.05

East End of Lake 2008							
Total Depth	0.95	meters	3.12	feet			
Secchi Depth	0.95+	meters	3.12+	feet			
Depth		Temperature		SpC	DO	DO	pH
meters	feet	°C	°F	mS/cm	mg/L	%	S.U.
0.00	0.00	27.52	81.54	0.339	7.23	91.70	8.59
0.50	1.64	27.46	81.43	0.338	7.05	89.30	8.69
0.90	2.95	26.77	80.19	0.337	7.18	89.9	8.80

East End of Lake 2007							
Total Depth	0.55	meters	1.80	feet			
Secchi Depth	0.55+	meters	NA	feet			
Depth		Temp		SpC	DO	DO	pH
meters	feet	°C	°F	mS/cm	mg/L	%	
0.20	0.66	23.66	74.59	0.457	7.34	85.57	7.74

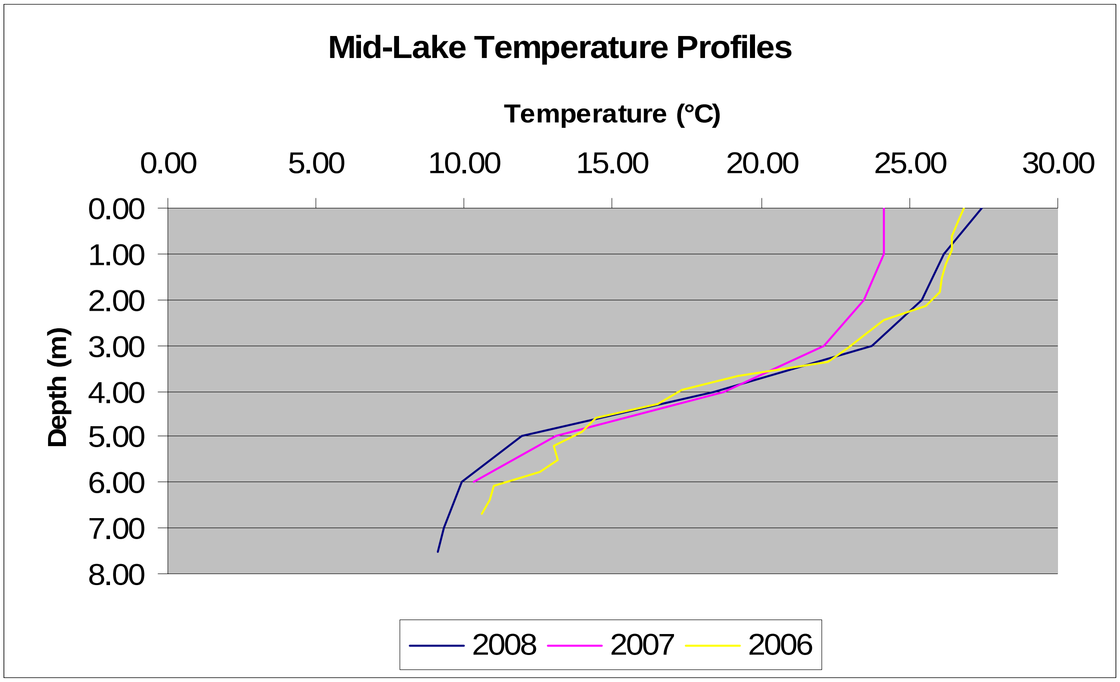
East End of Lake 2006 (IS-1)							
Total Depth	0.30	meters	1.00	feet			
Secchi Depth	0.30+	meters	1.00+	feet			
Depth		Temp		SpC	DO	DO	pH
meters	feet	°C	°F	mS/cm	mg/L	%	
0.00	0.0	25.44	77.79	0.266	7.26	87.86	7.82
0.27	0.90	24.80	76.64	0.320	7.13	84.70	7.52

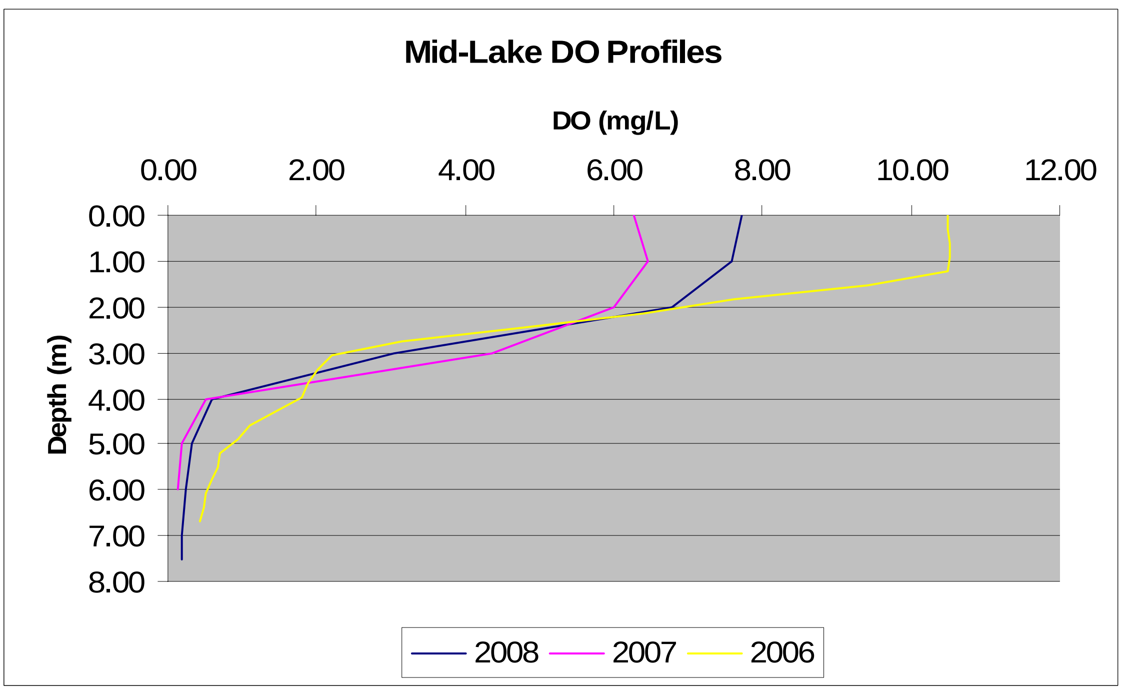
East Tributary 2008							
Total Depth	0.20	meters	0.66	feet			
Secchi Depth	NA	meters	NA	feet			
Depth		Temperature		SpC	DO	DO	pH
meters	feet	°C	°F	mS/cm	mg/L	%	S.U.
0.10	0.33	19.34	66.81	0.511	6.90	75.1	7.87

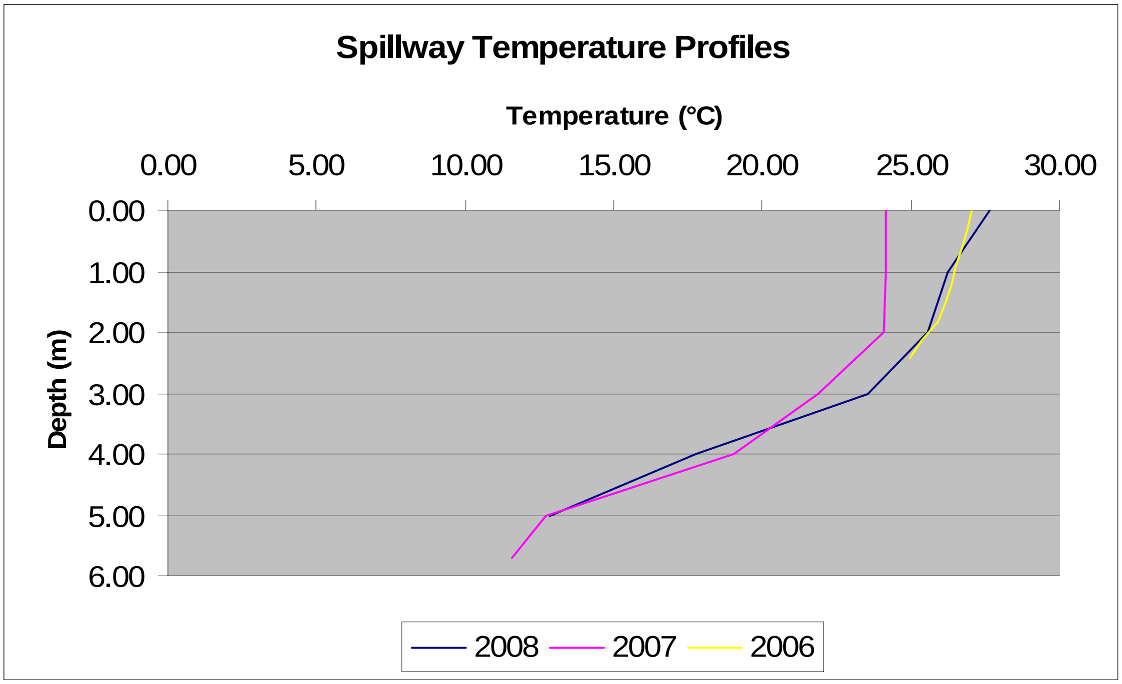
East Tributary 2007							
Total Depth	0.20	meters	0.66	feet			
Secchi Depth	NA	meters	NA	feet			
Depth		Temp		SpC	DO	DO	pH
meters	feet	°C	°F	mS/cm	mg/L	%	
0.00	0.00	19.82	67.68	0.214	8.43	90.88	7.63

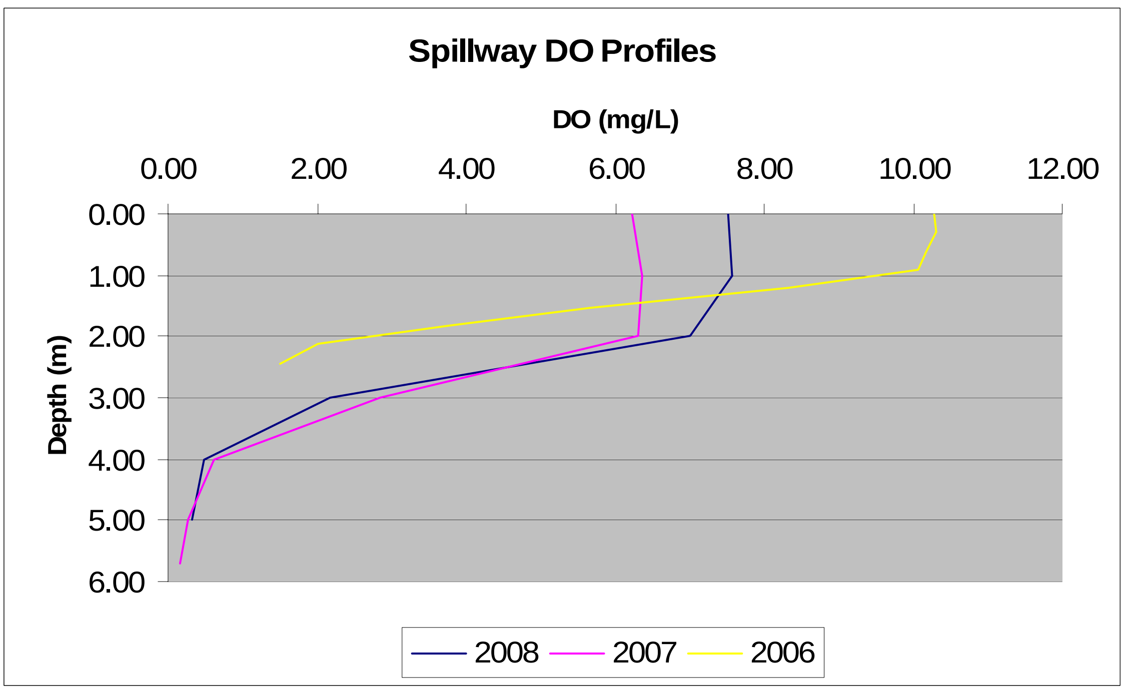
South Tributary 2008							
Total Depth	0.20	meters	0.66	feet			
Secchi Depth	NA	meters	NA	feet			
Depth		Temperature		SpC	DO	DO	pH
meters	feet	°C	°F	mS/cm	mg/L	%	S.U.
0.10	0.33	16.77	62.19	0.244	7.25	74.80	8.18

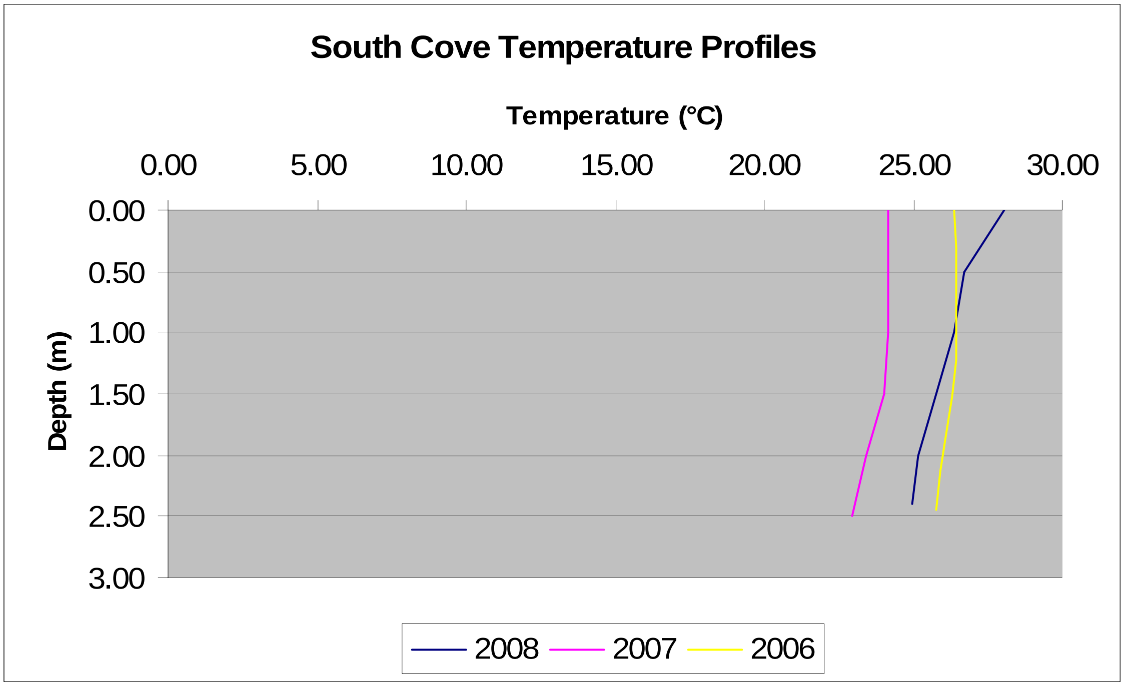
South Tributary 2007							
Total Depth	0.20	meters	0.66	feet			
Secchi Depth	NA	meters	NA	feet			
Depth		Temp		SpC	DO	DO	pH
meters	feet	°C	°F	mS/cm	mg/L	%	
0.00	0.00	19.70	67.46	0.200	7.52	81.07	7.62

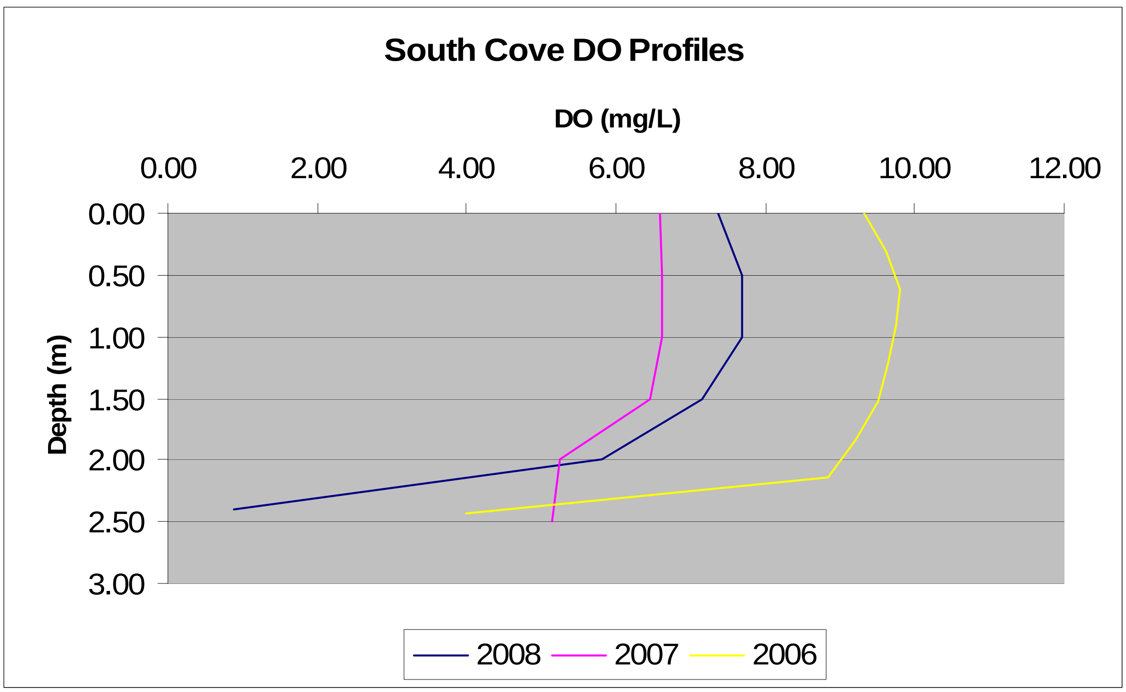

Mid-Lake Temperature Profiles
Temperature (°C)
0.00
5.00
10.00
15.00
20.00
25.00
30.00
Depth (m)
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
2008
2007
2006


Mid-Lake DO Profiles
DO (mg/L)
0.00
2.00
4.00
6.00
8.00
10.00
12.00
Depth (m)
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
2008
2007
2006


Spillway Temperature Profiles
Temperature (°C)
0.00
5.00
10.00
15.00
20.00
25.00
30.00
Depth (m)
0.00
1.00
2.00
3.00
4.00
5.00
6.00
2008
2007
2006


Spillway DO Profiles
DO (mg/L)
0.00
2.00
4.00
6.00
8.00
10.00
12.00
Depth (m)
0.00
1.00
2.00
3.00
4.00
5.00
6.00
2008
2007
2006


South Cove Temperature Profiles
Temperature (°C)
0.00
5.00
10.00
15.00
20.00
25.00
30.00
Depth (m)
0.00
0.50
1.00
1.50
2.00
2.50
3.00
2008
2007
2006


South Cove DO Profiles
DO (mg/L)
0.00
2.00
4.00
6.00
8.00
10.00
12.00
Depth (m)
0.00
0.50
1.00
1.50
2.00
2.50
3.00
2008
2007
2006

APPENDIX III

Discrete Water Quality Results

2008 Discrete Data

Station	Alk.	Chl *a*	Hard	NH_3-N	NO_3-N	SRP	TP	TSS
	mg/L	µg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
East End of Lake	58.3	7.7	92.2	0.03	0.04	ND<0.003	0.03	5
Spillway	57.7	8.0	88.2	0.04	0.04	ND<0.003	0.03	4
Mid-Lake, Deep	125		153.0	0.17	0.28	ND<0.003	0.40	76
South Cove		8.1						
Mid-Lake, Surface		7.1						
East Tributary	71.4		161.0	ND<0.01	3.20	0.012	0.02	ND<3
South Tributary	42.8		88.2	0.01	3.00	0.013	0.08	ND<3

2007 Discrete Data

Station	Alk.	Chl *a*	Hard	NH_3-N	NO_3-N	SRP	TP	TSS
	mg/L	µg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
East End of Lake	42.8	9.8	88.2	0.05	0.33	0.006	0.04	12
Spillway	52.8	19.8	100	0.02	0.08	0.002	0.03	5
Mid-Lake, Deep				6.80	0.11	0.003	0.15	
South Cove		14.5						
Mid-Lake, Surface		18						
East Tributary	27.9	3.7	60.8	0.06	0.59	0.011	0.04	7
South Tributary	45.8	2.8	62.7	0.06	1.4	0.045	0.09	5

2006 Discrete Data

Station	Alk.	Chl *a*	Hard	NH_3-N	NO_3-N	TKN	SRP	TP	TSS
	mg/L	µg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
East End of Lake (IS-1)	54	33	93	0.3	0.25	0.71	ND <0.002	0.06	43
IS-6	48.6	23.2	77	0.03	ND <0.02	0.5	ND <0.002	0.04	34
Mid-Lake (IS-7)	46.4	26.2	77	0.09	0.34	0.5	ND <0.002	0.04	38
Mid-Lake Deep (IS-7 DEEP)	81	29.4	101	2.7	0.1	6.4	0.002	0.06	27

APPENDIX IV

Plankton Survey Results

Phytoplankton Spillway 2008		
Taxon	**Cells/mL**	**µg/L**
Chlorophyta		
Coelastrum	7,376.6	512.7
Oocystis	719.7	100.0
Chlamydomonas	8,816.0	919.0
Gloeocystis	719.7	400.1
Eudorina	719.7	575.7
Haematococcus	989.5	1,074.7
Total	**19,341.2**	**3,582.2**
Cryptophyta		
Cryptomonas	179.9	174.1
Total	**179.9**	**174.1**
Cyanophyta		
Anabaena	5,307.6	12,651.7
Total	**5,307.6**	**12,651.7**
Grand Total	**24,828.7**	**16,408.0**

Zooplankton Spillway 2008		
Taxon	**Animals/L**	**µg/L**
Cladocera		
Ceriodaphnia	34.6	60.9
Diaphanosoma	34.6	46.3
Chydorus	6.9	5
Bosmina	6.9	7
Total	**83.0**	**119.2**
Copepods		
Nauplii	152.2	118.9
Cyclops	69.2	14.1
Diaptomus	27.7	46.9
Mesocyclops	13.8	30
Total	**262.8**	**209.9**
Rotifers		
Polyarthra	69.2	67
Keratella	110.7	3.7
Trichocerca	27.7	9.2
Conochilus	27.7	3.4
Total	**235.2**	**83**
Grand Total	**581.0**	**412.4**

Phytoplankton Spillway 2007		
Taxon	**Cells/mL**	**µg/L**
Bacillariophyta		
Cyclotella	539.1	246.9
Chlorophyta		
Kerichalmys	5,929.9	3,296.8
Scenedesmus	70,215.6	3,292.4
Asterococcus	808.6	808.6
Chlorella	134.8	106.7
Protococcus	269.5	213.4
Ankistrodesmus	269.5	5.6
Pediastrum	269.5	1,706.9
Staurastrum	269.5	2,702.5
Oocystis	539.1	74.9
Total	78,706.2	12,207.9
Cyanophyta		
Microcystis	37,735.8	70,806.8
Chroococcus	48,921.8	39,137.5
Coelosphaerium	77,493.3	86,167.1
Aphanothece	3,234.5	229.6
Total	167,385.4	196,341.0
Phyrrophyta		
Ceratium	134.8	1,212.9
Total	134.8	1,212.9
Grand Total	**246,765.5**	**210,008.8**

Zooplankton Spillway 2007		
Taxon	**Animals/L**	**µg/L**
Cladocerans		
Diaphanosoma	56.7	75.8
Ceriodaphnia	113.3	199.7
Bosmina	181.3	183.1
Total	**351.3**	**458.6**
Copepods		
Cyclops	45.3	9.2
Nauplii	90.7	70.8
Diaptomus	90.7	153.8
Total	**226.7**	**233.9**
Rotifers		
Keratella	45.3	1.5
Kellicotia	11.3	1.1
Polyarthura	56.7	54.9
Asplanchna	22.7	30.2
Total	**136.0**	**87.7**
Grand Total	**714.0**	**780.2**

Phytoplankton IS-7 2006 Taxon
Chlorophyta
Pediastrum
Staurastrum
Cosmarium
Chlorella
Synedra
Cyanophyta
Microcystis
Anaphanocapsa
Anabaena
Coelosphaerium
Phyrrophyta
Ceratium

Zooplankton IS-7 2006 Taxon
Cladocerans
Daphnia
Ceriodaphnia
Diaphanosoma
Copepods
Diaptomus
Cyclops
Rotifers
Kerratella
Conochilus

Phytoplankton East End of Lake 2008		
Taxon	**Cells/mL**	**µg/L**
Chlorophyta		
Chlamydomonas	11,629.8	1,212.3
Haematococcus	211.5	229.6
Scenedesmus	1,127.7	52.9
Coelastrum	9,515.3	661.3
Eudorina	2,607.9	2,086.3
Total	**25,092.2**	**4,242.4**
Cryptophyta		
Cryptomonas	141.0	136.4
Total	**141.0**	**136.4**
Cyanophyta		
Anabaena	6,555.0	15,625.1
Total	**6,555.0**	**15,625.1**
Grand Total	**31,788.1**	**20,003.9**

Zooplankton East End of Lake 2008		
Taxon	**Animals/L**	**µg/L**
Cladocera		
Bosmina	21.7	21.9
Total	**21.7**	**21.9**
Copepods		
Nauplii	86.7	67.7
Cyclops	10.8	2.2
Total	**97.5**	**69.9**
Rotifers		
Keratella	32.5	1.1
Asplanchna	10.8	14.4
Trichocerca	10.8	3.6
Total	**54.2**	**19.1**
Grand Total	**173.3**	**110.9**

Phytoplankton East End of Lake 2007		
Taxon	**Cells/mL**	**µg/L**
Chlorophyta		
Kerichlamys	1,617.3	899.1
Ankistrodesmus	134.8	2.8
Scenedesmus	5,256.1	246.5
Staurastrum	269.5	2,702.5
Chlorella	134.8	106.7
Total	**7,412.4**	**3,957.6**
Cyanophyta		
Chroococcus	8,490.6	6,792.5
Aphanizomenon	3,099.7	181.5
Microcystis	2,695.4	5,057.6
Total	**14,285.7**	**12,031.6**
Grand Total	**21,698.1**	**15,989.2**

Zooplankton East End of Lake 2007		
Taxon	**Animals/L**	**µg/L**
Copepods		
Nauplii	113.3	88.5
Total	**113.3**	**88.5**
Rotifers		
Keratella	260.7	8.7
Total	**260.7**	**8.7**
Grand Total	**374.0**	**97.2**

µ

Phytoplankton IS-1 2006 Taxon
Chlorophyta
Pediastrum
Haematococcus
Chrysophytes
Cymbella
Cyanophyta
Coelosphaerium
*Microcystis**
Anabaena
Anaphanocapsa
Synedra
Phyrrophyta
Ceratium

Zooplankton IS-1 2006 Taxon
Cladocerans
Bosmina
Copepods
Nauplii
Rotifers
Keratella

APPENDIX V

Glossary of Terms

Glossary of Key Terms

- Acidity - The state of being acid that is of being capable of transferring a hydrogen ion in solution; solution that has a pH value lower than 7.

- Alkalinity - The capacity of water for neutralizing an acid solution. Alkalinity of natural waters is due primarily to the presence of hydroxides, bicarbonates, carbonates and occasionally borates, silicates and phosphates. It is expressed in units of milligrams per liter (mg/l) of $CaCO_3$ (calcium carbonate). Low alkalinity is the main indicator of susceptibility to acid rain. Increasing alkalinity is often related to increased algal productivity. Lakes with watersheds having a sedimentary carbonate rocks geology then to be high in dissolved carbonates (hard-water lakes), whereas those in a watershed with a granitic or igneous geology tend to be low in dissolved carbonates (soft water lakes).

- Anthropogenic activities – Impacted by, created by, or resulting from human activities.

- Aeration - A process which promotes biological degradation of organic matter in water. The process may be passive (as when waste is exposed to air), or active (as when a mixing or bubbling device introduces the air).

- Algae - Microscopic plants and other organisms which contain chlorophyll and live floating or suspended in water. Algae may also form dense colonies and mats. Algae also may be attached to structures, rocks, or other submerged surfaces. It serves as food for fish and small aquatic animals. Excess algal growths can impart tastes and odors to potable water. Algae produce oxygen during sunlight hours and use oxygen during the night hours. They can affect water quality adversely by lowering the dissolved oxygen in the water during the night or after die-off. See also phytoplankton.

- Alum Treatment - Process of introducing granular or liquid alum (aluminum sulfate) into the lake water, to create a precipitate or floc that is used to strip the water column of fine particles and algae or used to treat the bottom sediment for the purpose of limiting the internal recycling of phosphorus.

- Ammonia - A colorless gaseous alkaline compound that is very soluble in water, has a characteristic pungent odor, is lighter than air, and is formed as a result of the decomposition of most nitrogenous organic material. A key nutrient.

- Anoxic – Devoid of oxygen or dissolved oxygen. DO concentrations less than 1.0 mg/L are generally treated as anoxic.

- Autotroph – Autotrophs are primary producers that sustain their energy from photosynthesis. Phytoplankton and macrophytes are autotrophs.

- Bathymetry - (1) The measurement and mapping of water depths and bottom contours.

- Best Management Practices - Schedules of activities, prohibitions of practices, maintenance procedures, and other management practices to prevent or reduce the pollution of waters of the United States. BMPs also include but are not limited to treatment requirements, operating procedures, and practices to control plant site runoff, spillage or leaks, sludge or wastewater disposal, or drainage from raw material storage. Practices or structures designed to reduce the quantities of pollutants -- such as sediment, nitrogen, phosphorus, and animal wastes that are washed by rain and snow melt from farms into surface or ground waters.

- Chlorophyll *a* - A green pigment found in photosynthetic organisms; used as an indicator of algal biomass.

- Clarity - The transparency of a water column. Commonly measured with a Secchi disk

- Conductivity or Conductance – See Specific Conductivity.

- Cyanobacteria – This group of algae is also known as blue-green algae or cyanophytes. This taxon consists of algae that are prone to bloom formation. This is due to certain competitive advantages including the ability to fix atmospheric nitrogen and to utilize organic forms of phosphorus, traits which no other algae share. They are also not consumed by zooplankton. As a result they are not subject to nitrogen limitation, grazing, and can utilize other forms of phosphorus. Blooms produce foul odors and can deplete dissolved oxygen levels at night and upon senescence.

- Debris - A broad category of large manufactured and naturally occurring objects that are commonly discarded (e.g., construction materials, decommissioned industrial equipment, discarded manufactured objects, tree trunks, boulders).

- Detritus - Any loose material produced directly from disintegration processes. Organic detritus consists of material resulting from the decomposing organic materials or from terrestrial sources like leaves.

- Diel – Refers to the course of events over a day and includes both diurnal and nocturnal cycles. In limnology diel variations are measured in a variety of parameters.

- Dissolved oxygen – The concentration of the gas oxygen (O_2) present in water. Dissolved oxygen (DO) can be an indicator of the ecologic function of the waterbody. Oxygen is more soluble at lower temperatures and less soluble at higher temperatures. Contributors to DO in water include atmospheric diffusion and photosynthetic processes of algae and aquatic vegetation. Percent saturation refers to maximum concentration of DO per a given temperature due to atmospheric diffusion. Supersaturated conditions occur when excessive photosynthesis contributes more DO to a system than would occur through inorganic processes alone at a given temperature.

- Dredging - Removal of sediment from the bottom of a water body.

- Epilimnion- The upper layer of water in a thermally stratified lake or reservoir. This layer consists of the warmest water and has a fairly uniform (constant) temperature. The layer is readily mixed by wind action.

- Eutrophication - A process that occurs when a lake or stream becomes over-rich with nutrients; as a consequence it becomes overgrown in algae and other aquatic plants. These autotrophs senesce or die and are decomposed by microbes. This decomposition or respiration by microbes can significantly reduce dissolved oxygen levels to the impairment of other aquatic organisms. Eutrophication can be a natural process or it can be a cultural process accelerated by an increase of nutrient loading to a lake by human activity. Fertilizers, which drain from the fields, and nutrients from animal wastes and sewage are examples of cultural processes and are often the primary causes of the accelerated eutrophication of a waterbody.

- Erosion- The wearing away of land surface by wind or water. Erosion occurs naturally but can be caused by farming, residential or industrial development, mining, or timber-cutting.

- Fecal contamination - The presence in water bodies of living organisms (bacteria and viruses) or agents derived by fecal bacteria that can cause negative human health effects. Fecal contamination may be a result of wildlife, livestock, pet, waterfowl or septic and sewage discharges.

- Herbicides - A compound, usually a man-made organic chemical, used to kill or control plant growth.

- Hydrology - The occurrence, circulation, distribution, and properties of the waters of the earth, and their reaction with the environment. For lakes this is usually associated with the quantification of the water flow into and out of the system and the study of pollutant transport that occurs in concert with the inflow.

- Hypereutrophic - Pertaining to a lake or other body of water characterized by excessive nutrient concentrations such as nitrogen and phosphorous and resulting high productivity. Such waters are often shallow, with algal blooms and periods of oxygen deficiency. Slightly or moderately eutrophic water can be healthful and support a complex web of plant and animal life. However, such waters are generally undesirable for drinking water and other needs. Degrees of eutrophication typically range from oligotrophy (maximum transparency, minimum chlorophyll-a, minimum phosphorus) through mesotrophy, eutrophy, to hypereutrophy water (minimum transparency, maximum chlorophyll *a*, maximum phosphorus). Also see Trophic State.

- Hypolimnion - Bottom waters of a thermally stratified lake. This layer consists of colder, denser water. Temperatures may remain relatively constant year around and it may experience little or no mixing with the upper warmer layers of the water body, although almost all lakes of moderate depth (<100 feet) will periodically mix. The hypolimnion of a eutrophic lake is usually low or lacking in oxygen.

- Hypoxic – low or depressed dissolved oxygen concentrations generally less than 2.0 mg/L, but may be applied to DO concentrations less than 4.0 mg/L.

- *In-situ* water quality parameters - in place; *in-situ* measurements consist of measurements of water quality parameters in the field, rather than in a laboratory.

- Invasive species - A species whose presence in the environment causes economic or environmental harm or harm to human health.

- Limnology - The study of bodies of fresh water with reference to their plant and animal life, physical properties, geographical features, etc. The study of the physical, chemical, hydrological, and biological aspects of fresh water bodies.

- Littoral Zone - 1. That portion of a body of fresh water extending from the shoreline lakeward to the limit of occupancy of rooted plants. Sometimes characterized as twice the Secchi depth or at a depth equal to 1% of incident light penetration at the surface. 2. A strip of land along the shoreline between the high and low water levels.

- Land use/ Land cover - The arrangement of land units into a variety of categories based on the properties of the land or its suitability for a particular purpose. It has become an important tool in rural land-use planning.

- Macroinvertebrates – Large aquatic invertebrates. Generally applied to aquatic insects, mollusks, and crustaceans.

- Macrophyte – Vascular (higher order) plants that grow in water. Includes different growth forms such as emergents, submerged, rooted floating-leaf, and floating. Also known as submerged aquatic vegetation or aquatic weeds. Includes waterweeds, pondweeds, water lilies, and duck weed amongst others.

- Mesotrophic - Reservoirs and lakes which contain moderate quantities of nutrients and are moderately productive in terms of aquatic animal and plant life.

- Microbes – Bacteria, fungus, and other microscopic life forms. Generally responsible for the decomposition of organic materials.

- Morphometry or Lake Morphometry – The three-dimensional shape of lake including depth. This term is generally interchangeable with bathymetry. Lake morphometry is characterized by bathymetry surveys.

- Nitrate – The most common form of nitrogen nutrient in most aquatic ecosystems and the nitrogen species most often utilized by plants and algae. Nitrates are generally found in high supply relative to phosphorus and highly mobile in water.

- Nitrogen - An essential nutrient in the food supply of plants and the diets of animals. Animals obtain it in nitrogen-containing compounds, particularly amino acids. Although the atmosphere is nearly 80% gaseous nitrogen, very few organisms have the ability to use it in this form with the exception of cyanobacteria or blue-green algae. The higher plants normally obtain it from the soil after micro-organisms have converted the nitrogen into ammonia or nitrates, which they can then absorb. There are various forms of both oxidized and reduced nitrogen including Ammonia and Nitrates.

- Non-point source pollution – Non-point source pollution is the enrichment of pollutants or nutrients through stormwater runoff. Natural or human-induced pollution caused by diffuse, indefinable sources that are not regulated as point sources, resulting in the alteration of the chemical, physical, and biological integrity of the water.

- Oligotrophic - Deep lakes that have a low supply of nutrients and thus contain little organic matter. Such lakes are characterized by high water transparency and high dissolved oxygen.

- pH - A measure of the acidity or basicity of a material, or the concentration of the positive hydrogen ion, liquid or solid. pH is represented on a scale of 0 to 14 with 7 representing a neutral state, 0 representing the most acid and 14, the most basic.

- Periphyton abundance - Microscopic underwater plants and animals that are firmly attached to solid surfaces such as rocks, logs, and pilings. In smaller streams this can indicate nutrient and thermal enrichment.

- Phosphorus - An element that while essential to life, contributes to the eutrophication of lakes and other bodies of water. There are various species or forms of phosphorus including Total Phosphorus (sum of all species), Organic Phosphorus, and Dissolved Phosphorus amongst others. Soluble reactive phosphorus is a measure of soluble orthophosphates.

- Photic Zone – The upper layers of lake in which photosynthesis occurs. Generally depths less than twice the Secchi depth.

- Photosynthesis - The process by which plants and algae transform carbon dioxide and water into carbohydrates and other compounds, using energy from the sun captured by chlorophyll in the plant. The rate of photosynthesis depends on climate, intensity and duration of sunlight, nutrient availability, temperature, and carbon dioxide concentration.

- Phytoplankton - Very tiny, often microscopic, plants and other photosynthetic or autotrophic organisms found in fresh and saltwater. Phytoplankton drift near the surface of the water where there is plenty of sunlight for growth. Phytoplankton form the base for most lake food chains.

- Point-source pollution - Easily discernible source of water pollution such wastewater treatment plants and other facilities that directly discharge to waterways.

- Pollutant loading - The amount of polluting material that a transporting agent, such as a stream, a glacier, or the wind, is actually carrying at a given time.

- Residential discharge - Any flow of surface water or the collective flow of residential development generated in single and multi-family homes. May include storm water collected from the roof, lawn, driveway, a basement sump pump, or effluent from a malfunctioning septic system.

- Respiration – The consumption of organic materials by living organisms in a lake. All aquatic life forms, including microbes, algae, zooplankton, and fish respire organic materials. Respiration can lower pH values and for most organisms except certain bacteria requires dissolved oxygen.

- Secchi disk transparency - A flat, white disc lowered into the water by a rope until it is just barely visible. At this point, the depth of the disc from the water surface is the recorded Secchi disc transparency.

- Sedimentation - 1. Process of deposition of waterborne or windborne sediment or other material; also refers to the infilling of bottom substrate in a waterbody by sediment (siltation). 2. When soil particles (sediment) settles to the bottom of a waterway.

- Specific conductance - A rapid method of estimating the dissolved-solids content of a water supply. The measurement indicates the capacity of a sample of water to carry an electrical current, which is related to the concentration of ionized substances in the water. Also called conductance.

- Stormwater runoff - Stormwater runoff, snow melt runoff, and surface runoff and drainage; rainfall that does not infiltrate the ground or evaporate because of impervious land surfaces but instead flows onto adjacent land or watercourses or is routed into drain and sewer systems.

- Stratification - Formation of water layers each with specific physical, chemical, and biological characteristics. As the density of water decreases due to surface heating, a stable situation develops with lighter water overlaying heavier and denser water. During stratification there is no mixing between layers, establishing chemical as well as thermal gradients.

- Submerged aquatic macrophyte - Large vegetation that lives at or below the water surface; an important habitat for young fish and other aquatic organisms.

- Suspended solids - 1) Solids that either float on the surface or are suspended in water or other liquids, and which are largely removable by laboratory filtering. 2) The quantity of material removed from water in a laboratory test, as prescribed in standard methods for the examination of water and wastewater.

- Thermal Stratification – A natural phenomenon in which lakes of sufficient depth are divided into distinct depth zones of varying temperatures. In the summer months the coolest and densest water is located at the lake bottom. In winter months the upper depths of a lake may be warmer than the bottom. The maximum density of freshwater occurs at 39°F. Thermal stratification prevents the mixing of the entire water column.

- Thermocline - The middle layer in a thermally stratified lake or reservoir. In this layer there is a rapid decrease in temperature with depth. Also called the Metalimnion.

- Trophic State – Indicates the level of primary production as measured by photosynthetic activity or other metrics. Various models exist to describe trophic state. Perhaps the most widely used is Carlson's Trophic State Index (TSI) which relies on the use of summer average chlorophyll, Secchi depth, and Total Phosphorus values.

- Tributary – A stream or other flowing waterbody discharging to a lake or a larger stream.

- Turbidity - A cloudy condition in water due to suspended silt or organic matter often attributable to algae blooms or increased sediment loads.

- Water quality - The biological, chemical, and physical conditions of a waterbody.

It is a measure of a waterbody's ability to support beneficial uses.

- Watershed management - A holistic approach applied within an area defined by hydrological, not political, boundaries, integrating the water quality impacts from both point and nonpoint sources. Watershed management has a premise that many water quality and ecosystem problems are better solved at the watershed scale rather than by examining the individual waterbodies or dischargers. Use, regulation and treatment of water and land resources of a watershed to accomplish stated objectives.

- Zooplankton - Tiny, sometimes microscopic, floating, aquatic animals and protozoans. Zooplankton generally feed upon phytoplankton, organic detritus, microbes, and other zooplankters.