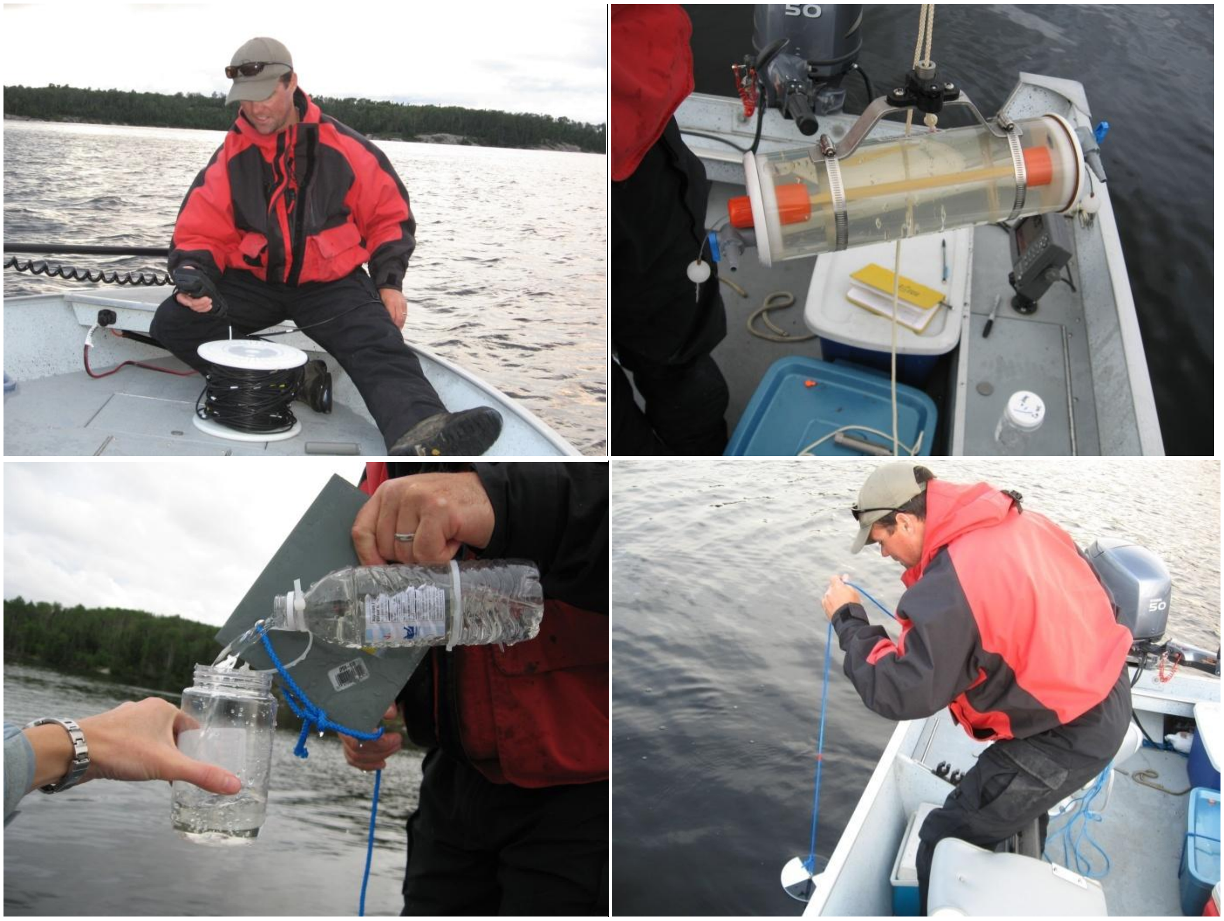
RYAN HAINES CONSULTING



# BLACK STURGEON LAKES

# WATER QUALITY MONITORING

## 2009 REPORT

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## 1.0 BACKGROUND

In the fall of 2007, the City of Kenora was presented with the results of the *Lake Capacity and Management Study for Black Sturgeon Lake*. One of the recommendations of this study was to conduct a water quality assessment on Lower Black Sturgeon Lake for two consecutive years to establish baseline data and then once every five years to monitor changes to the water quality in the lake.

In the spring of 2009, the City of Kenora awarded the contract to conduct the first year of water quality monitoring on Lower Black Sturgeon Lake to Ryan Haines Consulting. In addition, the City of Kenora expressed their intent to continue water quality monitoring for the 2010 sampling season to establish two years of baseline data for the water body.

## 2.0 METHODOLOGY

Ten sampling sessions were conducted during the 2009 season between May and November. Water samples were taken at two locations on Lower Black Sturgeon Lake during each sampling session. Sample locations correspond to sites identified in the *Lake Capacity and Management Study for Black Sturgeon Lake*. These sites provide the best data to determine the impacts of development on the water quality of Lower Black Sturgeon Lake as one of the sites is located at the closest location with sufficient depth to the outlet of Black Sturgeon Lakes into the Winnipeg River (site #2) and the other site is located in the closest location with sufficient depth to the inlet of Black Sturgeon Creek into Lower Black Sturgeon Lake (site #3). Site #2 was used to assess the impacts of development on water quality because the vast majority of new and proposed developments on Lower Black Sturgeon Lake are occurring upstream of this site. Information collected from sites #2 and #3 were compared to total phosphorous data collected by Ministry of the Environment (MOE) since 1997. These two sites have the largest dataset of all sites monitored on Lower Black Sturgeon Lake over the past decade (*Lake Capacity and Management Study for Black Sturgeon Lake*).

All field work was conducted from a small motorboat with a sonar unit mounted to the stern. At each sampling site, an anchor was used to keep the boat in one location.

Temperature/oxygen profiles were obtained at site #1, #2 and #3 (Figure 1) during each sampling session using an YSI 55 Dissolved Oxygen Meter. Site #1 was added to determine the distribution of oxygen and temperature throughout the water column at one of the deepest sections in the center portion of the lake. This report uses the definition of the thermocline as a change in water temperature of equal to or greater than 1$^{o}$C per meter change in depth. For the purposes of this report anoxic conditions refer to dissolved oxygen levels lower than 0.5 mg/L.

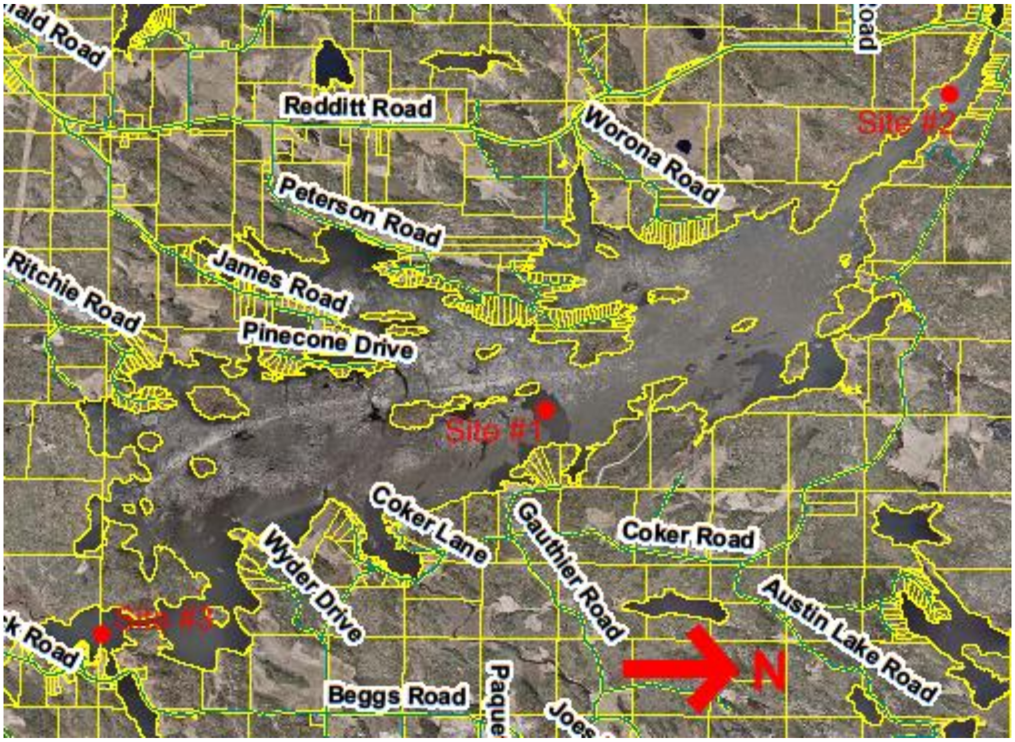


Figure 1 – Sampling Sites for Water Quality Monitoring on Lower Black Sturgeon Lake

Secchi depth was determined at each site by lowering a Secchi disk (20-cm disk with alternating black and white quadrants) over the shady side of the boat (Figure 2). The disk was lowered until the observer could no longer distinguish between the white and black quadrants and then raised until the disk came back into view. This was repeated three times and then the depths at which the disk disappeared and then reappeared were averaged to give the Secchi depth.


Figure 2 – Lowering of Secchi disk

Lake productivity samples were collected both as a euphotic zone composite and at a depth of 1 m from the bottom. The euphotic zone is the section of the water column where enough light penetrates to facilitate algae growth (measured as 2X the Secchi depth). In order to obtain a water sample containing water from the surface to the bottom of the euphotic zone, a weighted, 500 mL, small neck bottle (Figure 3) was lowered with a rope in the water column to a depth of 2X Secchi depth.

Figure 3 – Transferring water sample from euphotic zone composite into lab sample bottle

At each site, an additional water sample was taken approximately 1 m from the bottom of the lake using a Beta horizontal water sampler (Figure 4). Both ends of the water sampler were opened prior to lowering it (using a rope) to the desired water depth. At the desired depth, a small weight was sent down through the water column along the length of the rope triggering a release mechanism on the sampler and causing the sampler caps to close.

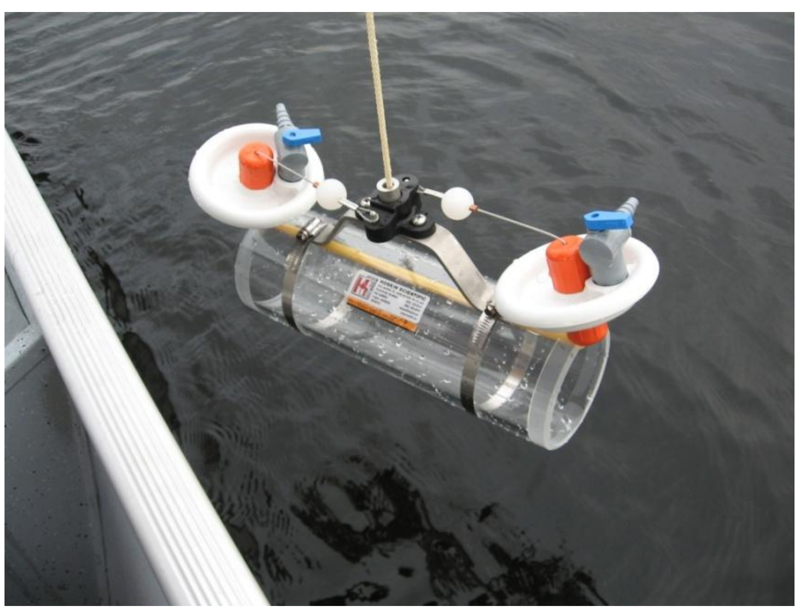


Figure 4 – Horizontal Beta Sampler prior to deployment

All euphotic zone samples and samples taken 1m from the bottom of the lake were transferred immediately upon collection to sample bottles for analysis at a laboratory. Two euphotic zone samples and two bottom samples were taken at each site and analyzed for total phosphorous. One additional euphotic zone water sample was taken and tested for chlorophyll a at each site throughout the sampling period. Euphotic zone water samples were collected in August and September from both site #2 and site #3 (one sample per site) and were analyzed for identification of the algal community. All water samples were shipped via Greyhound bus to ALS Laboratory Group in Winnipeg, MB, for analysis.

The results from the algal samples were used to determine the Algal Genera Pollution Index, which is an indicator of organic pollution as some genera of algae are more likely to be found in water bodies with high levels of organic pollution. These results were then used to determine a pollution index value using the Genus Pollution Index scores found in Table 1. For each genera present in each sample, the corresponding Genus Pollution Index score was added to the pollution index value for that site. A pollution index value of >20 indicates high organic pollution. Midrange values (15-19) indicate that pollution is moderate. Low scores (<15) indicate the absence of organic pollution.

**TABLE 1 - Algal Genera Pollution Index (Palmer, 1969)**

| **Genus Pollution Index** | |
|---|---|
| ***Anacystis*** | **1** |
| ***Ankistrodesmus*** | **2** |
| ***Chlamydomonas*** | **4** |
| ***Chlorella*** | **3** |
| ***Cyclotella*** | **1** |
| ***Euglena*** | **5** |
| ***Gomphonema*** | **1** |
| ***Lepocinclis*** | **1** |
| ***Melosira*** | **1** |
| ***Micractinium*** | **1** |
| ***Navicula*** | **3** |
| ***Nitzshia*** | **3** |
| ***Oscillatoria*** | **5** |
| ***Pandorina*** | **1** |
| ***Phacus*** | **2** |
| ***Phormidium*** | **1** |
| ***Scenedesmus*** | **4** |
| ***Stigeoclonium*** | **2** |
| ***Synedra*** | **2** |

## 3.0 RESULTS

### 3.1 Sampling Session Dates and Locations

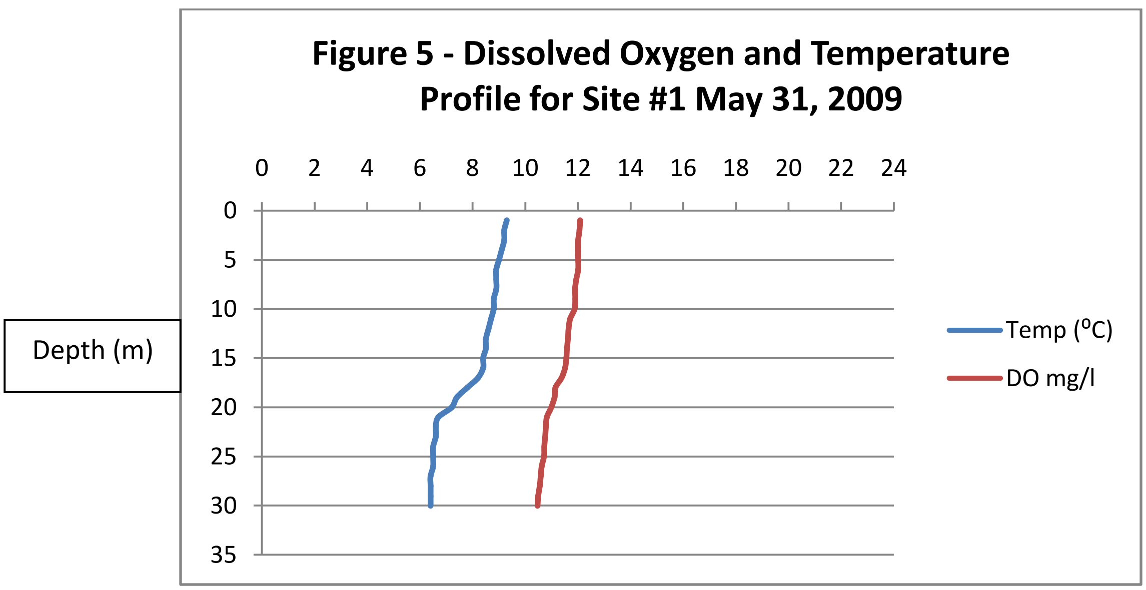
The sampling sessions were conducted on May 31, June 9, June 24, July 14, July 29, August 17, September 7, September 27, October 18, and November 8, 2009. Due to the later start in the sampling season, the first two sampling sessions were nine days apart and the during the rest of the first half of the season the time period between sampling sessions varied from 15 to 20 days. During the second half of the sampling season (from July 29 to November 8) the sampling sessions were separated by between 19 and 21 days.

The depth of the sampling sites varied depending upon the anchoring location for each site and due to fluctuating water levels. Site #1 depths varied from 29.9 to 30.7 m. The deepest portion of site #2 was fairly isolated and difficult to locate, so the sampling depths at this site varied from 14.8 to 17.4 m. The sampling depths at site #3 varied from 9.8 to 10.6 m.

### 3.2 Dissolved Oxygen and Temperature Profiles

#### 3.2.1 Profiles for Site #1 (Deep, Center Portion of Lower Black Sturgeon)

On May 31, the temperature and dissolved oxygen(DO) values for site #1 were fairly uniform throughout the water column, with only a 1.62 mg/L variation in DO and a 2.9$^{o}$C variation in temperature (Figure 5).



On June 9, the surface waters began to warm to above 11$^{o}$C, but DO levels remained fairly uniform throughout the water column with only a 2.34 mg/L variation in oxygen concentration (Figure 6).

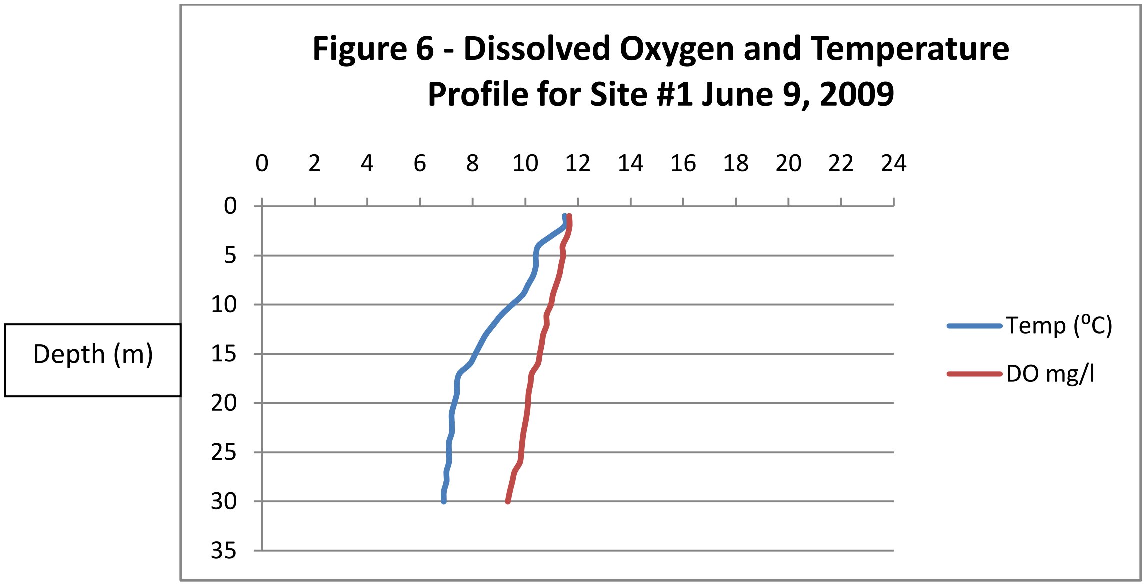



**Figure 6 - Dissolved Oxygen and Temperature Profile for Site #1 June 9, 2009**

The profile for June 24 begins to demonstrate thermal stratification and changes in DO concentrations through the water column. The surface waters had warmed to over 21$^{o}$C and a thermocline (greater than a 1$^{o}$C change in temperature per meter change in depth) occurred from 3 to 6 m. Dissolved oxygen levels were fairly uniform from the surface to a depth of 29 m, but there was a significant drop in DO concentrations at the reading at 30 m (0.2 m from the bottom) with a DO value of 0.17 mg/L (Figure 7).

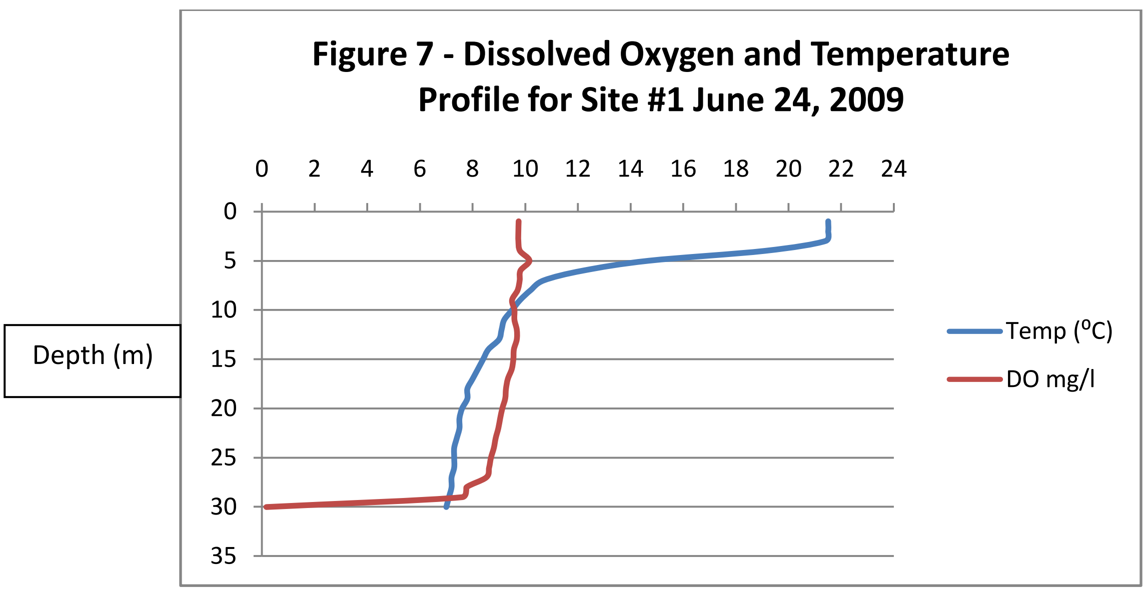
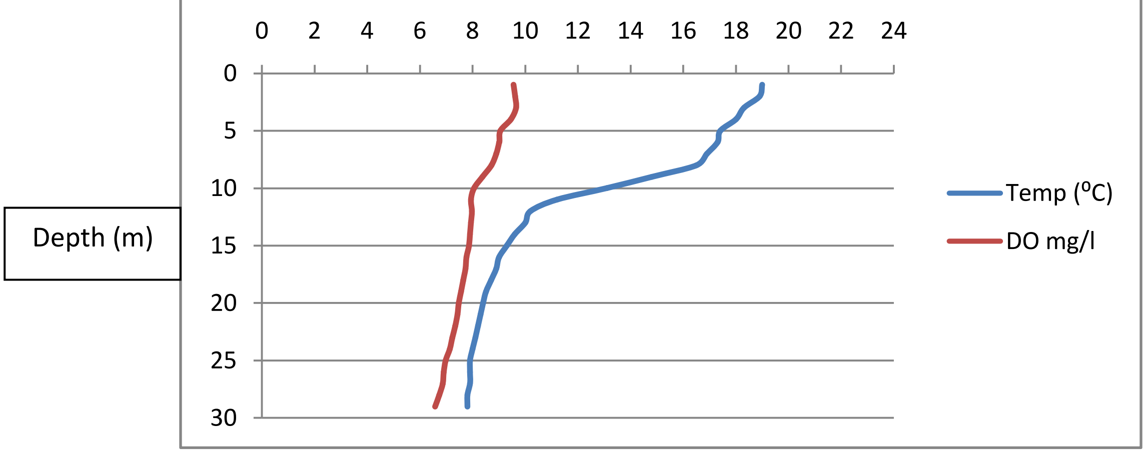



**Figure 7 - Dissolved Oxygen and Temperature Profile for Site #1 June 24, 2009**

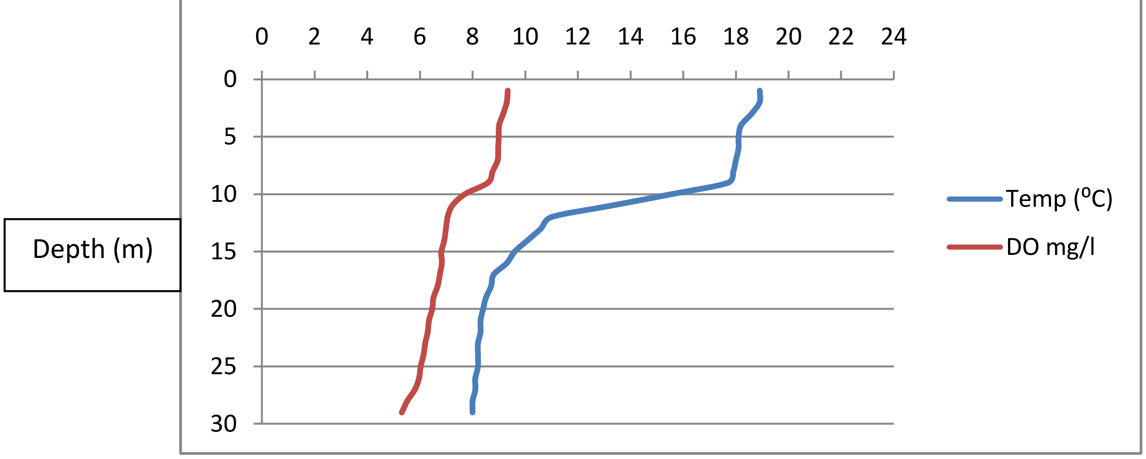
On July 14, the thermocline at site #1 was observed at a greater depth, located between 8 and 12 m. The dissolved oxygen levels continued to decline as the waters warmed, but remained relatively consistent throughout the water column, varying from 9.65 to 6.57 mg/L (Figure 8).

**Figure 8 - Dissolved Oxygen and Temperature Profile for Site #1 July 14, 2009**




During the July 29 sampling session, the DO and temperature profiles were beginning to show more of a direct relationship, with a marked decrease in DO of over 1.5 mg/L recorded over the thermocline depth of 9 to 12 m (Figure 9).

**Figure 9 - Dissolved Oxygen and Temperature Profile for Site #1 July 29, 2009**



On August 17, the DO readings showed a decline with depth, with a marked decrease continuing to reflect the drop in temperature associated with the thermocline. The thermocline was located between 8 and 12 m (Figure 8). There were hypoxic (i.e. low oxygen) conditions of 0.67 mg/L recorded at a depth of 30 m (0.2 m from the bottom).

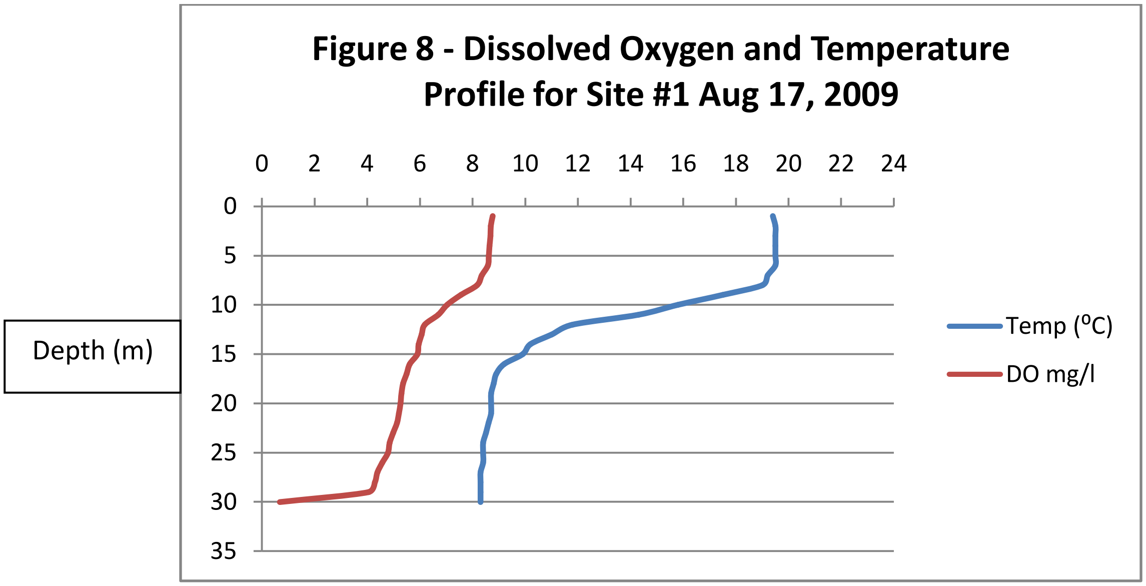



**Figure 8 - Dissolved Oxygen and Temperature Profile for Site #1 Aug 17, 2009**

Figure 11 demonstrates a continued relationship between the dissolved oxygen levels and temperature. There was a drop in DO levels from 7.84 to 4.92 mg/L over the 9 to 14 m depths where the thermocline was located (Figure 11).

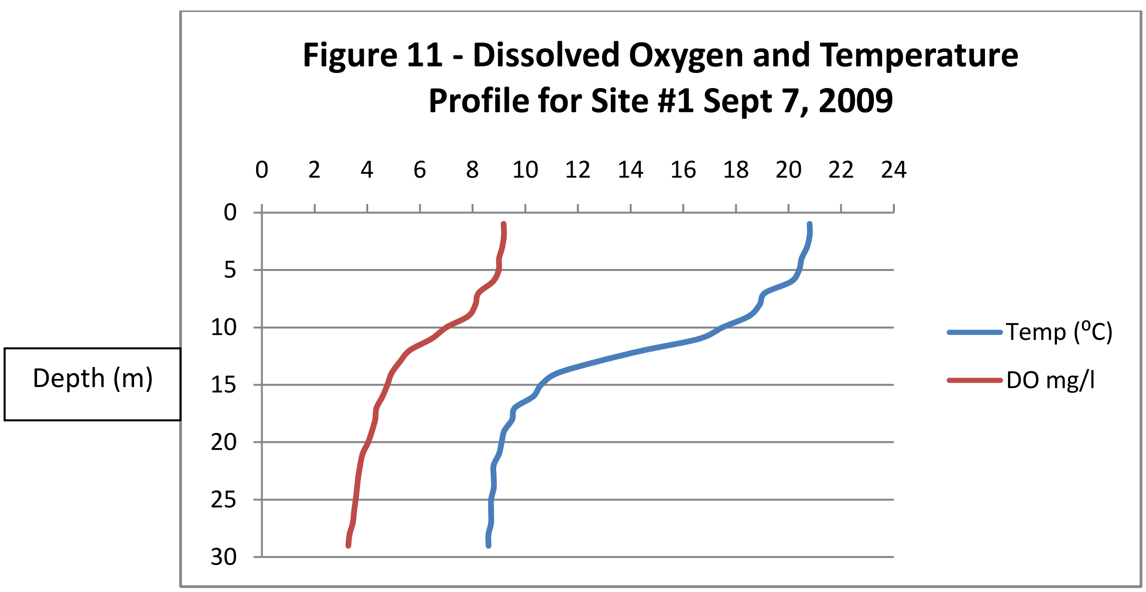
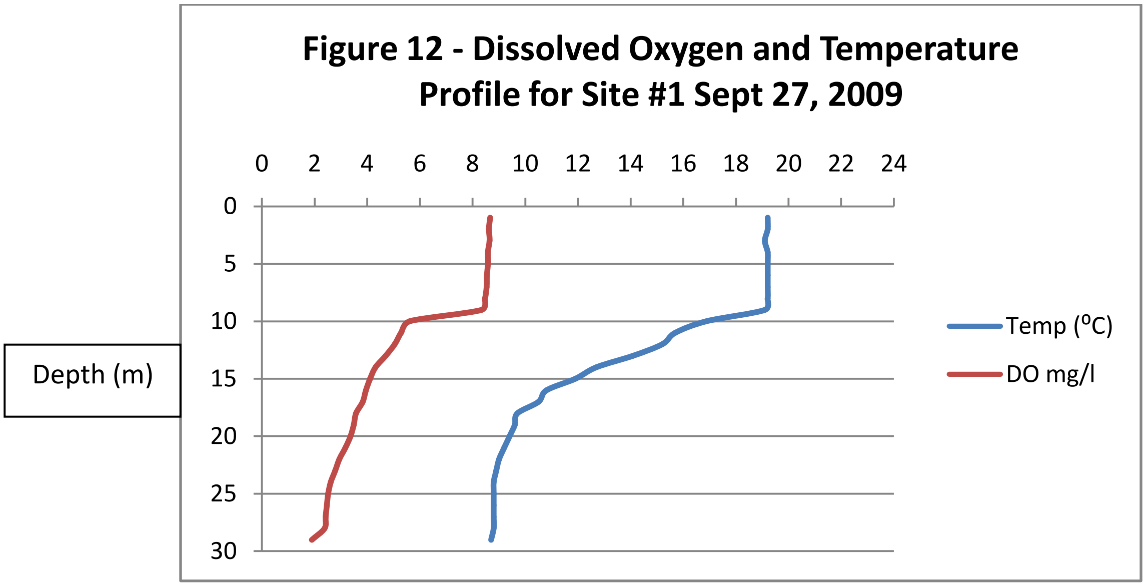
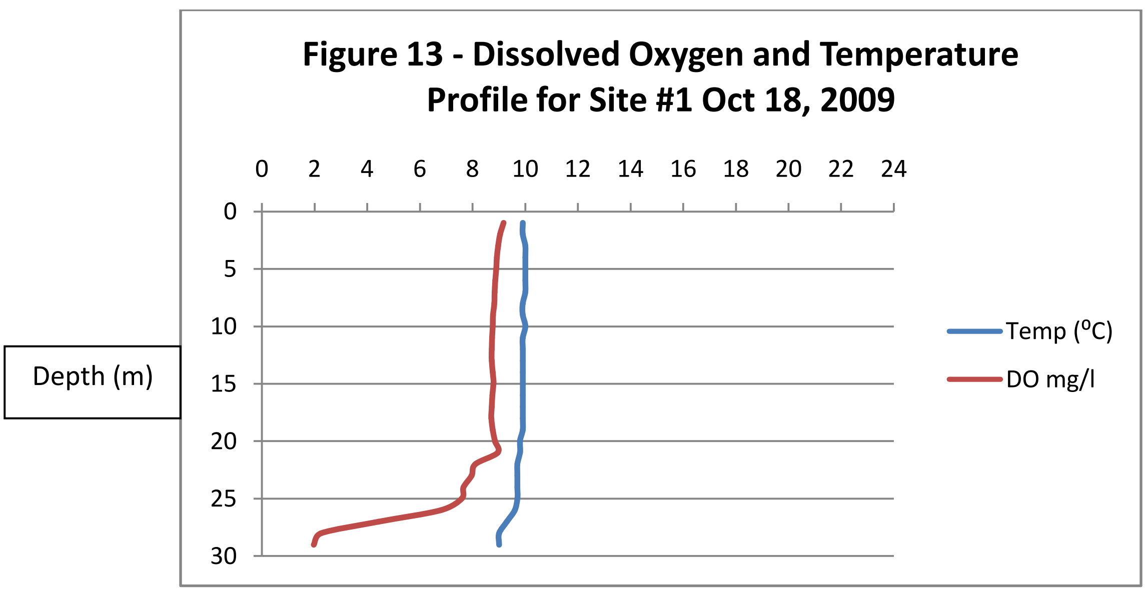



**Figure 11 - Dissolved Oxygen and Temperature Profile for Site #1 Sept 7, 2009**

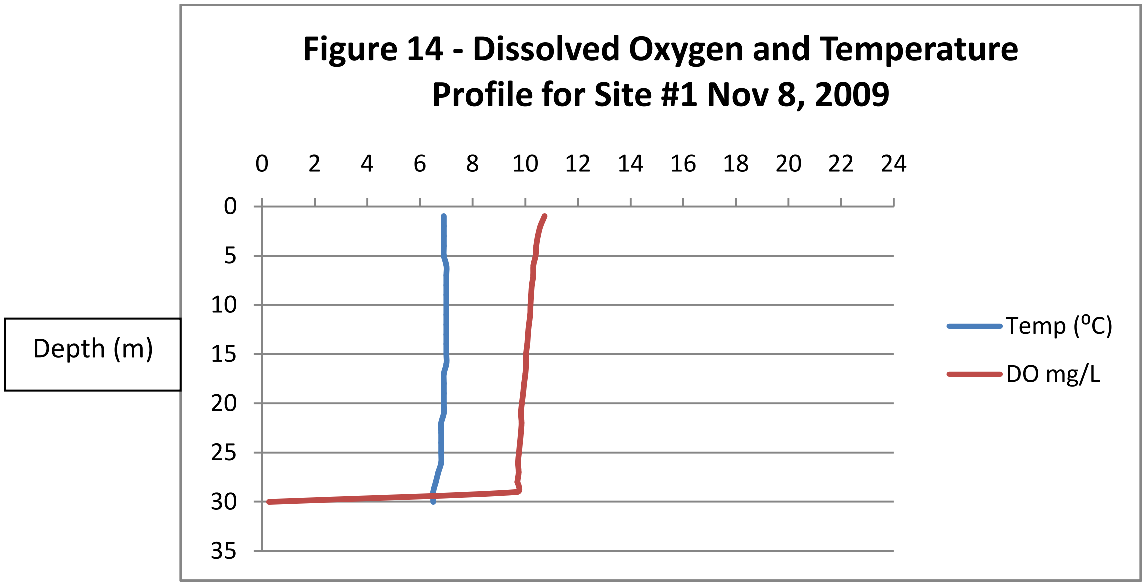
On September 27, the thermocline had extended over 7 m of the water column from 9 to 16 m. The thermocline marked a significant decrease in DO levels, with all of the water above the thermocline (epilimnion) having oxygen concentrations over 8 mg/L and all of the water below the thermocline (hypolimnion) having concentrations below 5 mg/L (Figure 12).




The temperature of the water column was nearly uniform on October 18, with all of the recorded temperatures within 1ºC of one another. The DO readings were within 1 mg/L of each other from the surface to a depth of 21 m. Below 21 m, there was a significant decrease in oxygen concentration with depth (Figure 13).

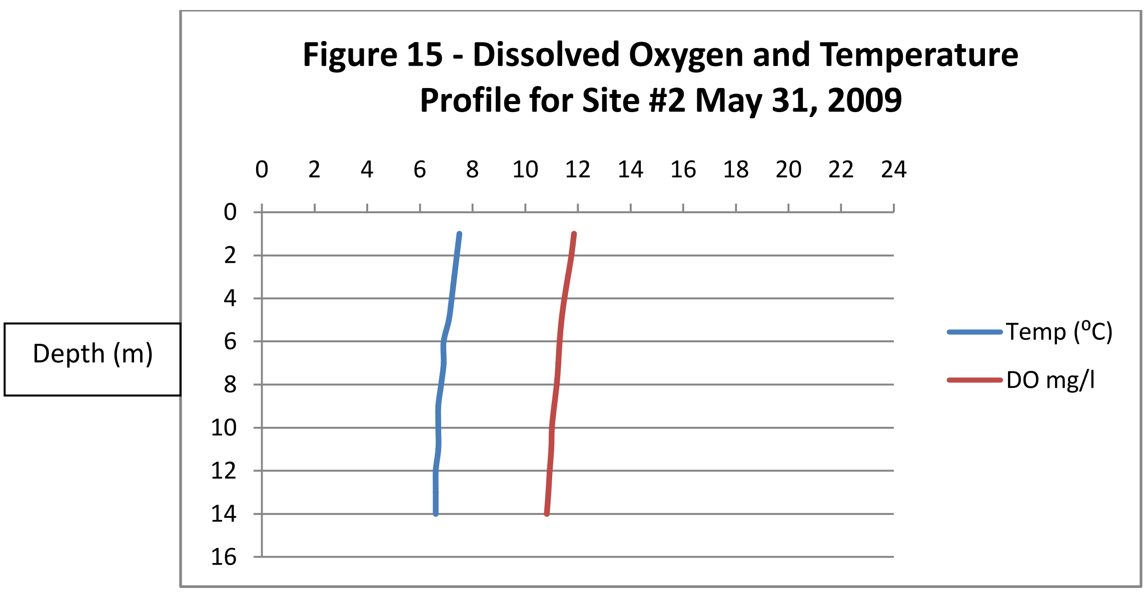


On November 8, temperature profiles were uniform throughout the water column, with a temperature variation of 0.5°C from top to bottom. A variation in DO values of 1.04 mg/L were observed from the surface to 1.3 m from the bottom. There were anoxic conditions (0.26 mg/L) at a depth of 30 m (0.3 m from the bottom) (Figure 14).




### 3.2.2 Profiles for Site #2 (Outlet of Lower Black Sturgeon Lake)

On May 31, the temperature and dissolved oxygen (DO) values for site #2 were fairly uniform, with only a 0.9°C variation in temperature and a 1.03 mg/L variation in DO (Figure 15).



Thermal stratification was demonstrated on June 9 with the thermocline present between 9 and 11 m. However, water temperature remained relatively cool with maximum temperature of 11.3°C at the surface. The DO profile followed a similar profile to the temperature profile with a reduction in DO from 11.38 to 6.72 mg/L in the bottom half of the water column (Figure 16).

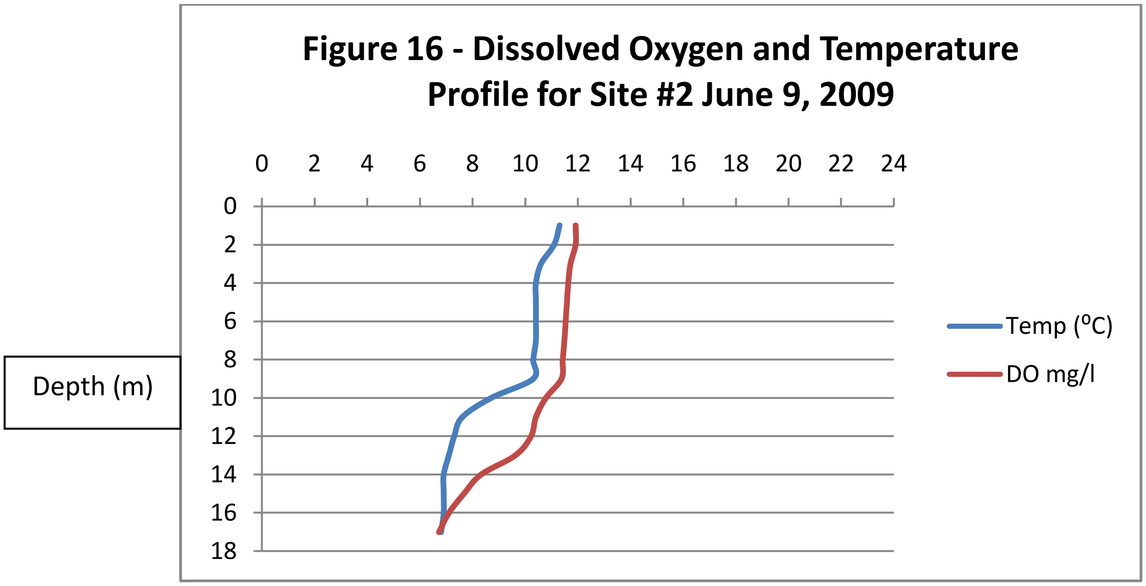
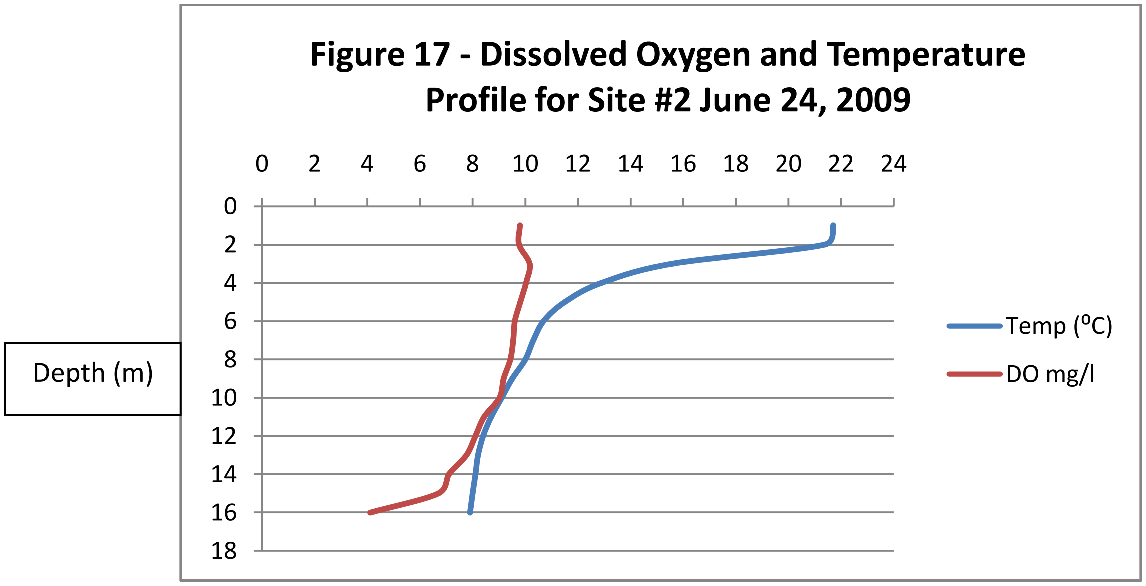
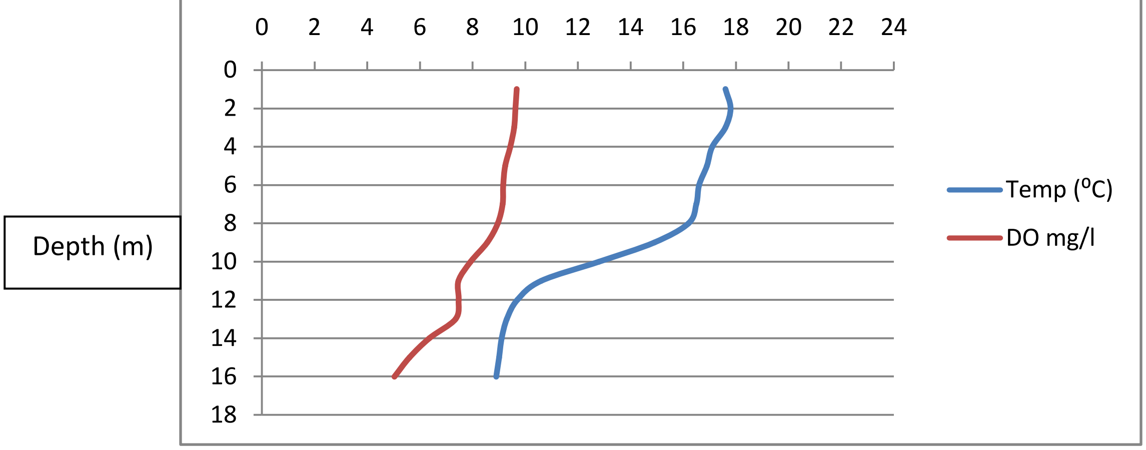



Figure 17 shows a warming of the surface waters to 21.7°C and the thermocline present at depths of 2 to 5 m below the surface. The dissolved oxygen concentration increased from 9.80 to 10.16 mg/L in the first three meters below the surface before gradually decreasing to 15 m below the surface. A significant decrease was observed in DO from 6.69 to 4.10 mg/L between 15 to 16 m depths.



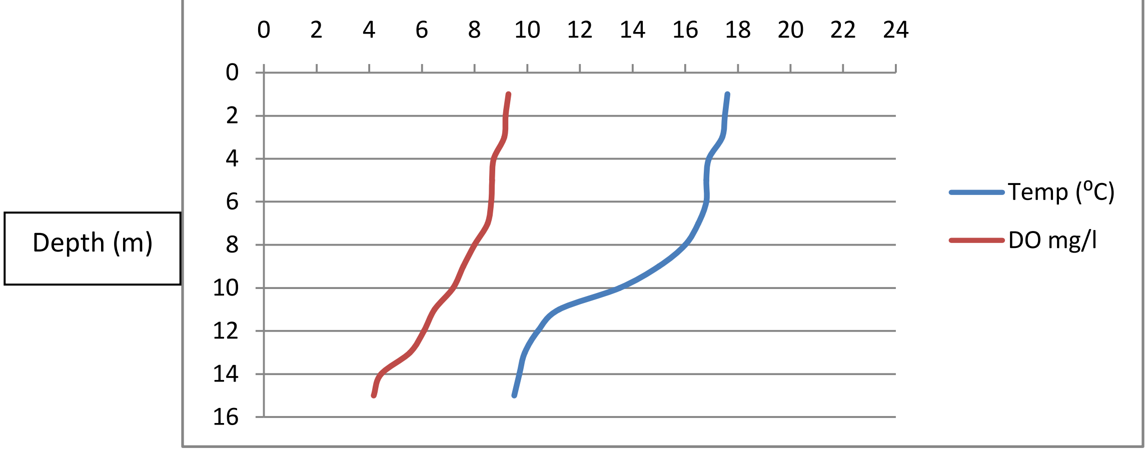
On July 14, the thermocline had moved deeper and was present between 8 and 11 m depths. The highest temperature recorded in the water column was 17.8$^{o}$C. The DO profile mirrored the declines with depth of the temperature profile with DO concentrations declining at the thermocline. A marked decline was observed in the bottom 4 m of the water column, where oxygen concentrations ranged from 7.35 to 5.03 mg/L (Figure 18).

**Figure 18 - Dissolved Oxygen and Temperature Profile for Site #2 July 14, 2009**

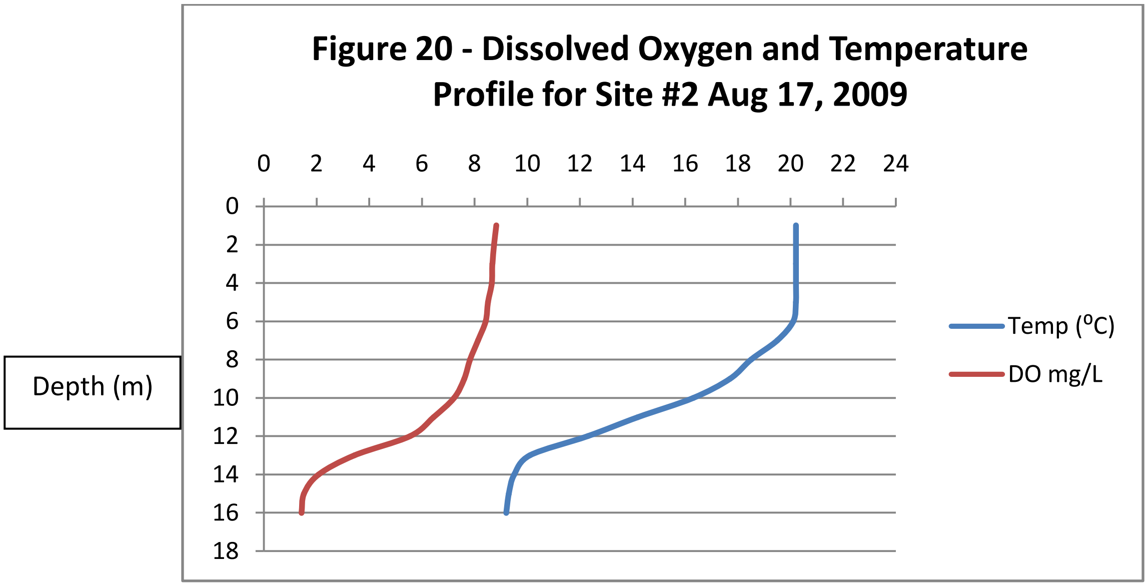



On July 29, the dissolved oxygen and temperature profiles for site #2 were very similar to those recorded during the July 14 sampling session (Figure 19).

**Figure 19 - Dissolved Oxygen and Temperature Profile for Site #2 July 29, 2009**



The depth and temperature difference of the thermocline was greater on August 17, with temperature varying from 19.5 to 10.1°C over the 7 to 13 m depths of the thermocline. The temperature decline was accompanied with a reflected decline in dissolved oxygen levels. Between depths of 10 m to 16 m, the DO readings gradually fell from 7.22 to 1.41 mg/L (Figure 20).




On September 7, the temperature profile ranged from 22.1 to 10.3°C, with the thermocline located between 8 and 13 m depths. The DO readings varied from 9.36 to 0.24 mg/L, with the greatest decline occurring between 9 and 14 m (Figure 21).

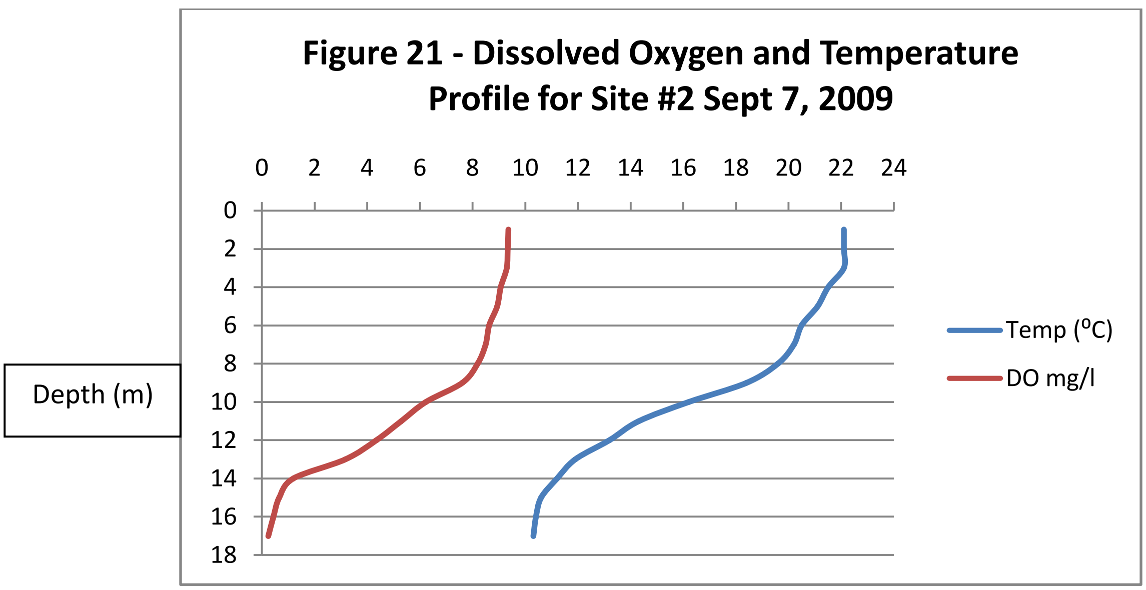
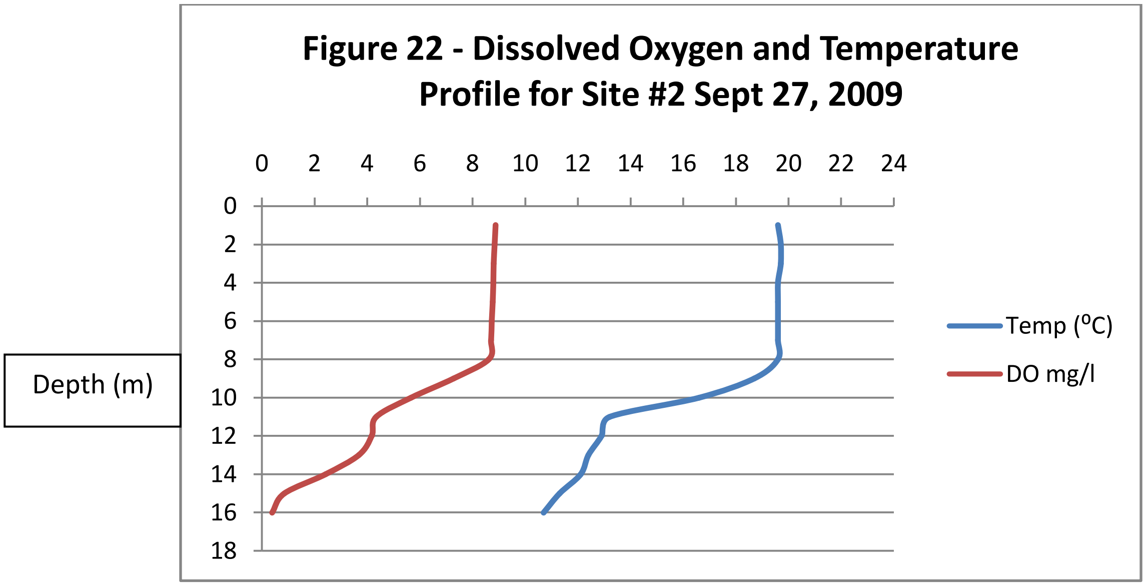
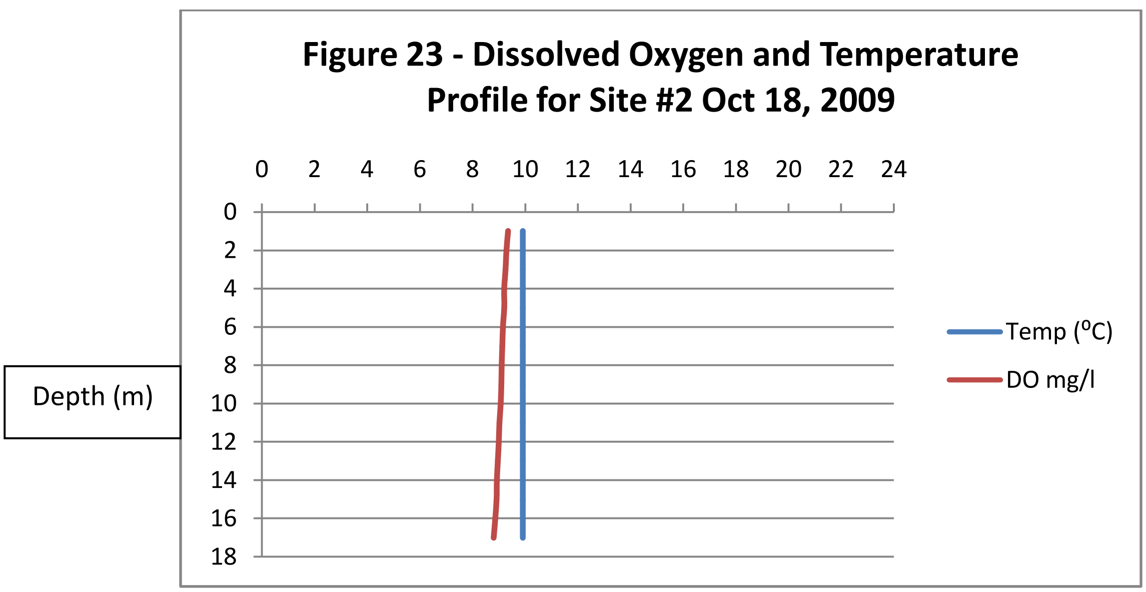


Figure 19 shows temperature and dissolved oxygen levels declining between depths of 8 and 11 m. This decline continues at a slightly reduced rate for both variables until the final measurements at 16 m (Figure 22).




On October 18, the temperature profile was completely uniform with every reading being 9.9°C from the surface to the bottom. The dissolved oxygen profile was almost uniform with the values only varying from 9.34 to 8.80 mg/L (Figure 23).



On November 8, the temperature reading continued to be uniform, with a measurement of 6.7°C at 1 m and 6.6°C throughout the remainder of the water column. This is a similarly sloped line to the October 18 temperature profile, but 3.3°C cooler. The November 8 DO profile has the same slope as the October 18 data, but the November 8 results are approximately 1 mg/L greater (Figure 24).

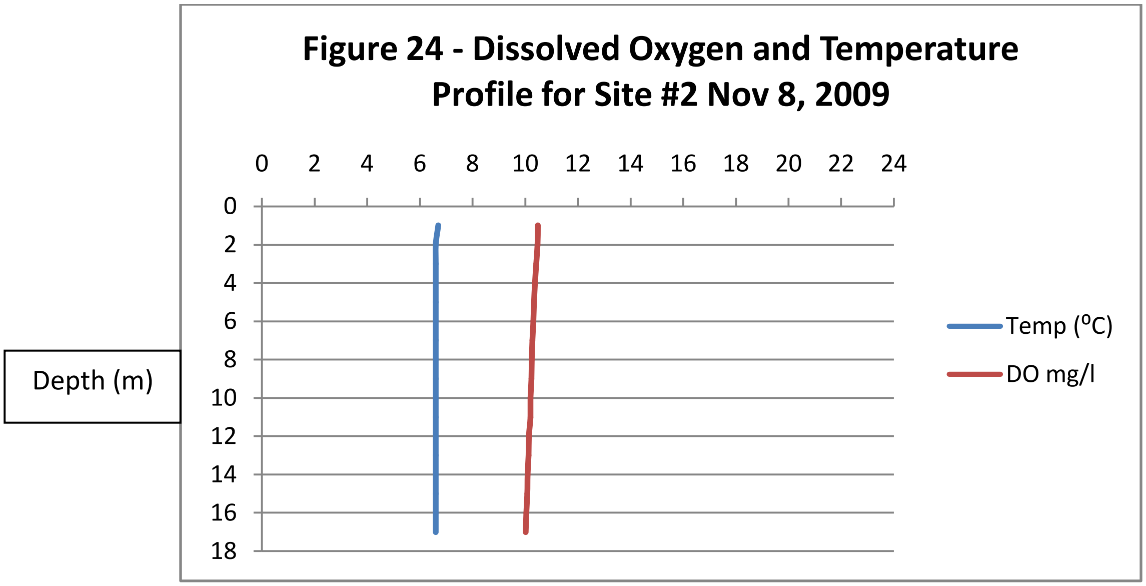



**Figure 24 - Dissolved Oxygen and Temperature Profile for Site #2 Nov 8, 2009**

### 3.2.3 Profiles for Site #3 (Inlet of Lower Black Sturgeon)

The dissolved oxygen (DO) profile and temperature readings for site #3 on May 31 were relatively uniform throughout the water column. The recorded DO readings varied between 11.31 and 10.42 mg/L. The temperature profile results dropped from 11.2 to 10.6°C between the surface and the bottom (Figure 25).

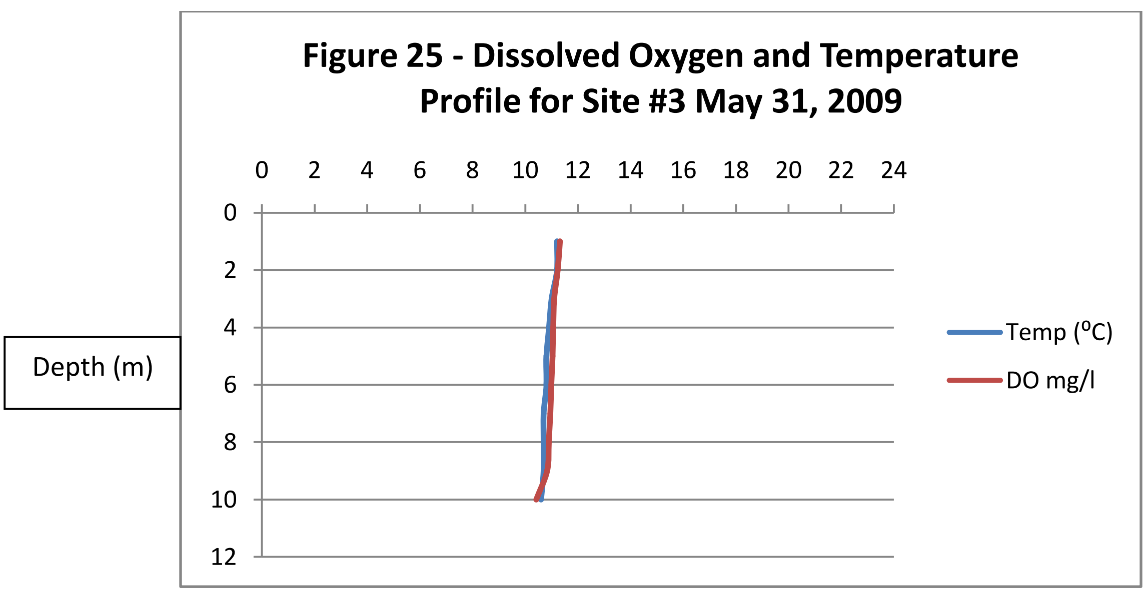



**Figure 25 - Dissolved Oxygen and Temperature Profile for Site #3 May 31, 2009**

On June 9, the temperature profile was fairly uniform, with temperatures ranging from 12.6 to 11.5°C. The DO readings were between 10.77 and 10.11 mg/L for the top 8 m, with a slight drop to 9.04 mg/L over the bottom 2 m (Figure 26).

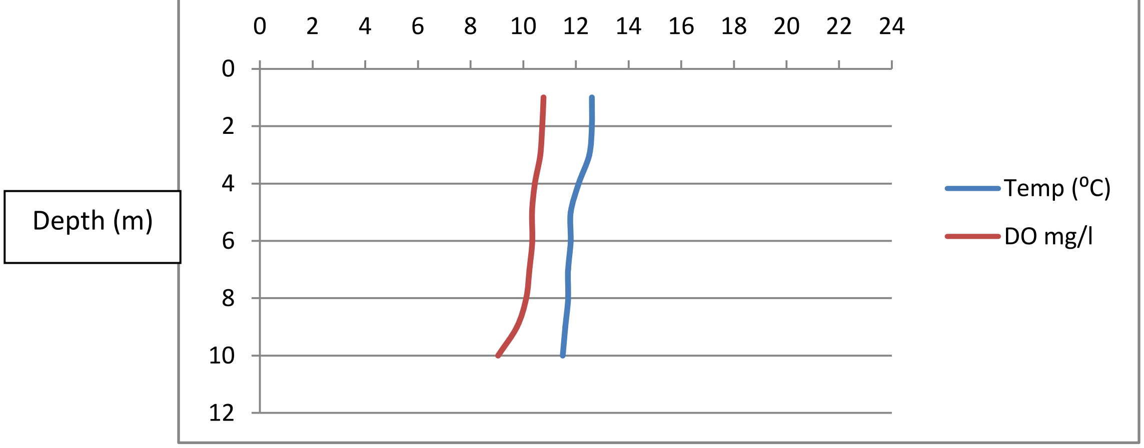



**Figure 26 - Dissolved Oxygen and Temperature Profile for Site #3 June 9, 2009**

Figure 27 shows the warming of the surface waters by June 24 to 22.3°C. The thermocline was present between 2 and 7 m depths. The dissolved oxygen readings varied slightly, from 9.05 to 7.00 mg/L, for the readings from 1 to 8 m. The final reading at 9 m showed a marked decline in DO with a reading of 3.40 mg/L.

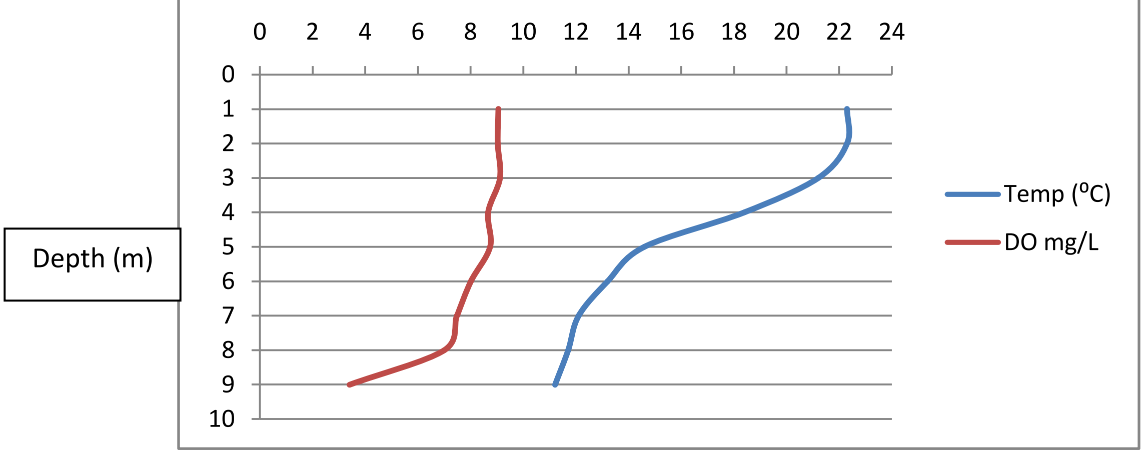
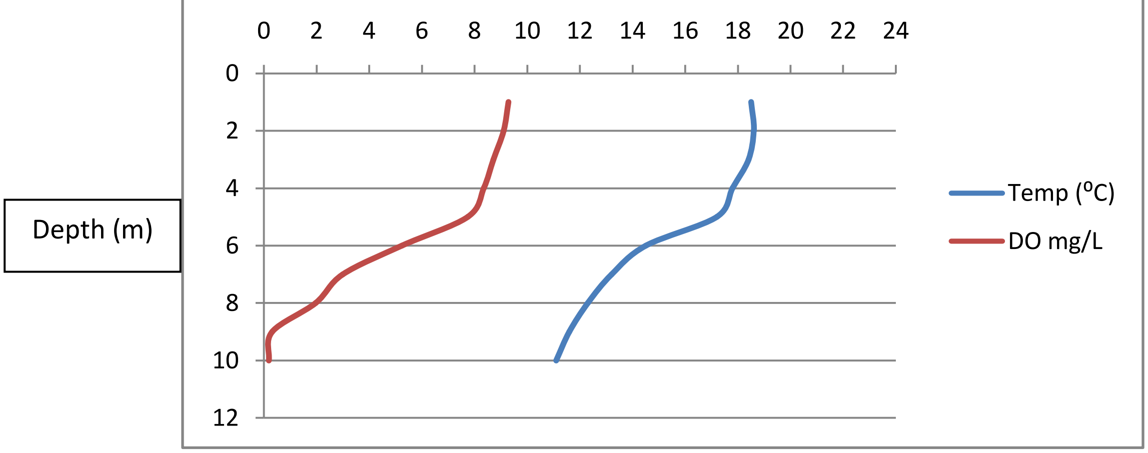



**Figure 27 - Dissolved Oxygen and Temperature Profile for Site #3 June 24, 2009**

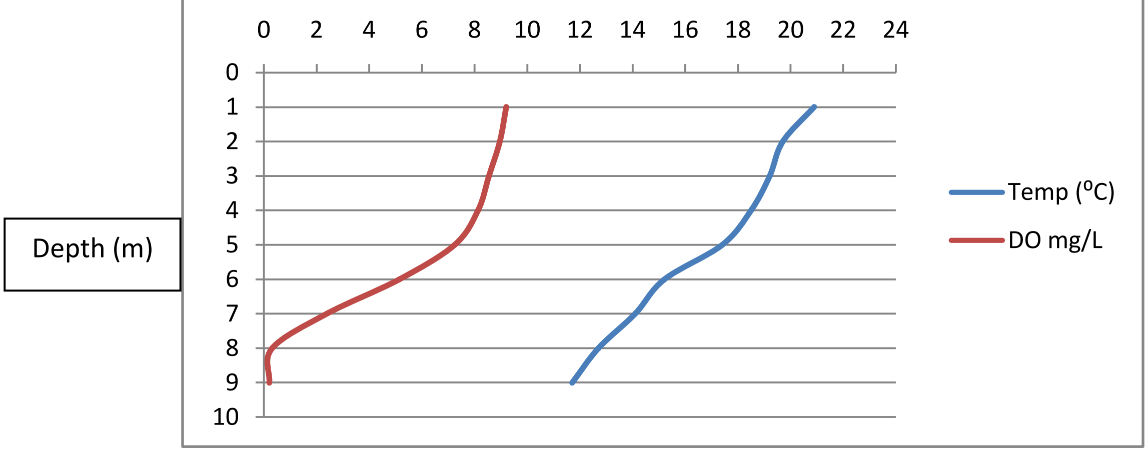
The thermocline was present at depths of 5 to 7 m on July 14. The DO profile demonstrates a reduction in oxygen concentration beginning at the upper boundary of the thermocline, and ending at the deepest measurement, with values declining from 7.74 mg/L at 5 m to 0.18 mg/L at 10 m (Figure 28).

**Figure 28 - Dissolved Oxygen and Temperature Profile for Site #3 July 14, 2009**



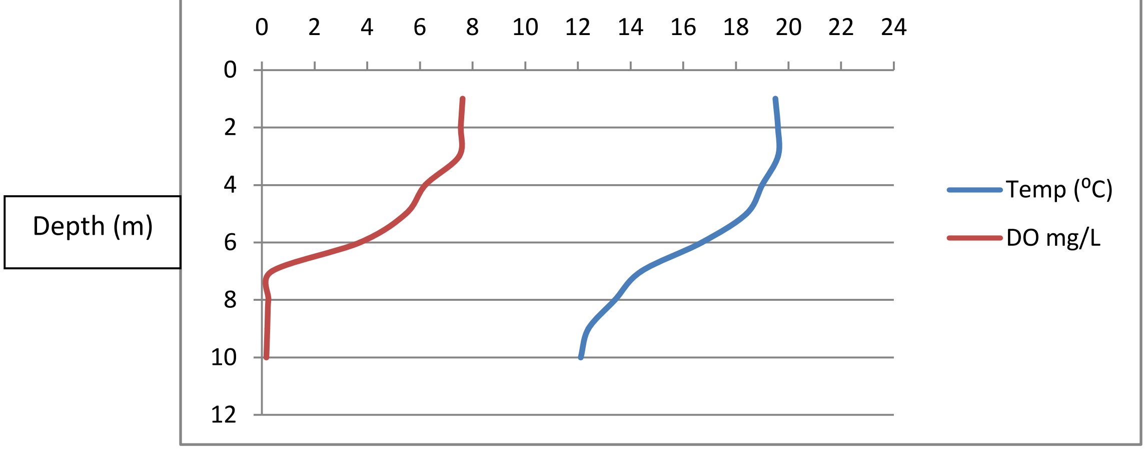

The July 29 recorded temperatures created a profile that shows a fairly steady decline in temperatures from 20.9 to 11.7°C with a thermocline present between the 4 and 9 m readings. The dissolved oxygen profile shows a more pronounced decline in DO readings from 5 m to 8 m of 7.24 and 0.31 mg/L, respectively (Figure 29).

**Figure 29 - Dissolved Oxygen and Temperature Profile for Site #3 July 29, 2009**



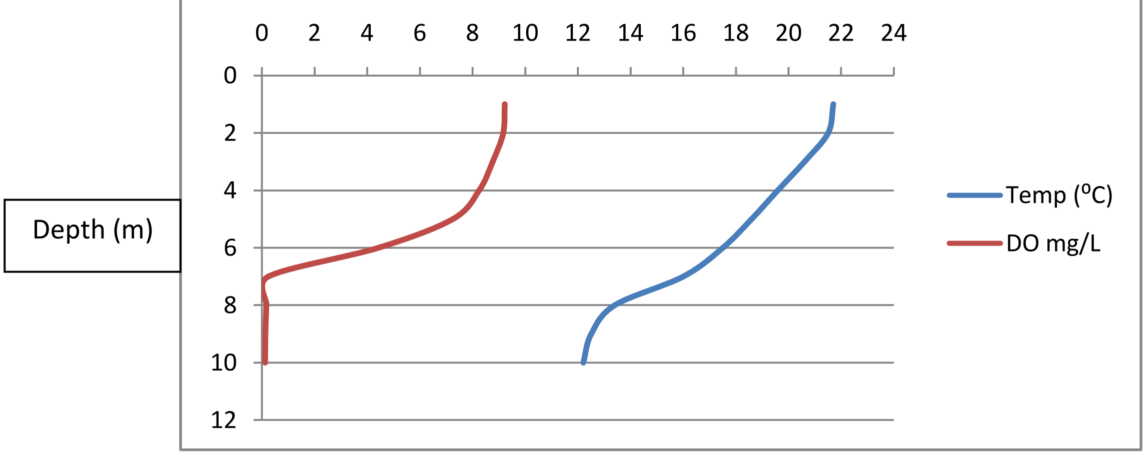
The dissolved oxygen and temperature profiles were similarly shaped on August 17. The temperature profile ranged from 19.5°C at the 1 m depth to 12.1°C at the 10 m depth with the thermocline present at the 5 to 9 m depth readings. The DO readings declined from 7.62 to 5.47 mg/L from the 1 m to 5 m depths followed by a rapid decline to 3.72 mg/L at 6 m and then anoxic conditions of 0.37 to 0.16 mg/L throughout the remaining depths (Figure 30).

**Figure 30 - Dissolved Oxygen and Temperature Profile for Site #3 Aug 17, 2009**

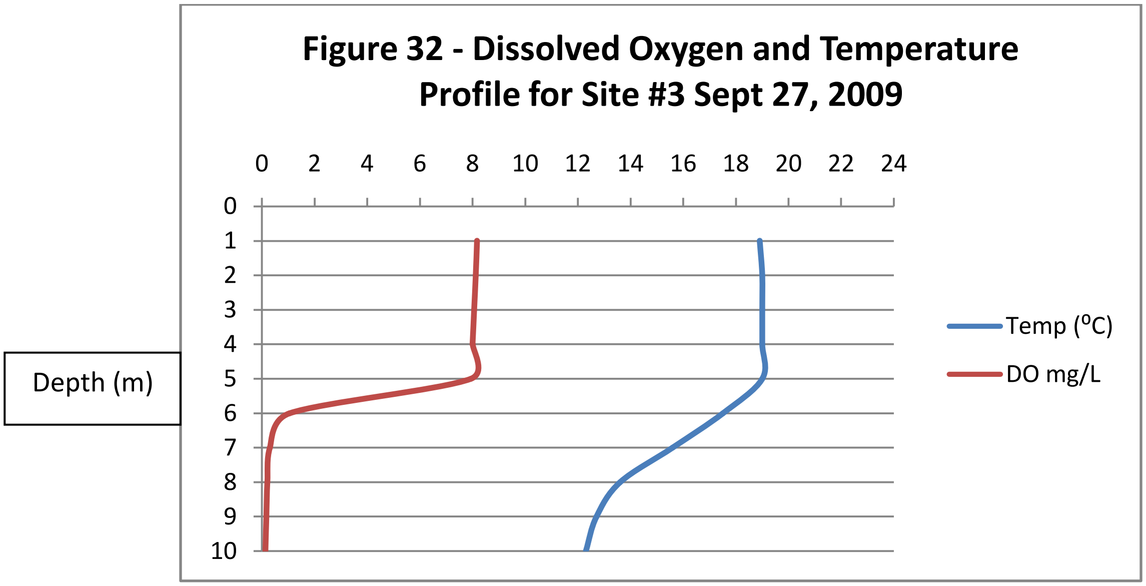



The temperature and dissolved oxygen profiles for September 7 were similar to those shown for August 17, with the only significant difference being an increase in temperature near the surface to 21.7°C. Anoxic conditions were still present in the readings from 7 to 10 m depths (Figure 31).

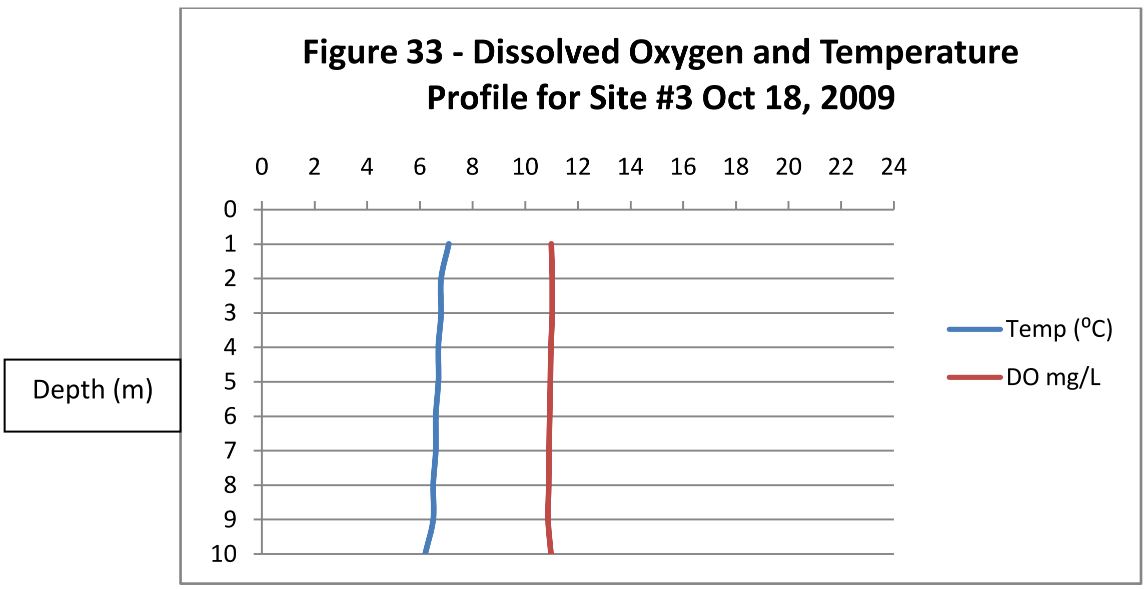
**Figure 31 - Dissolved Oxygen and Temperature Profile for Site #3 Sept 7, 2009**



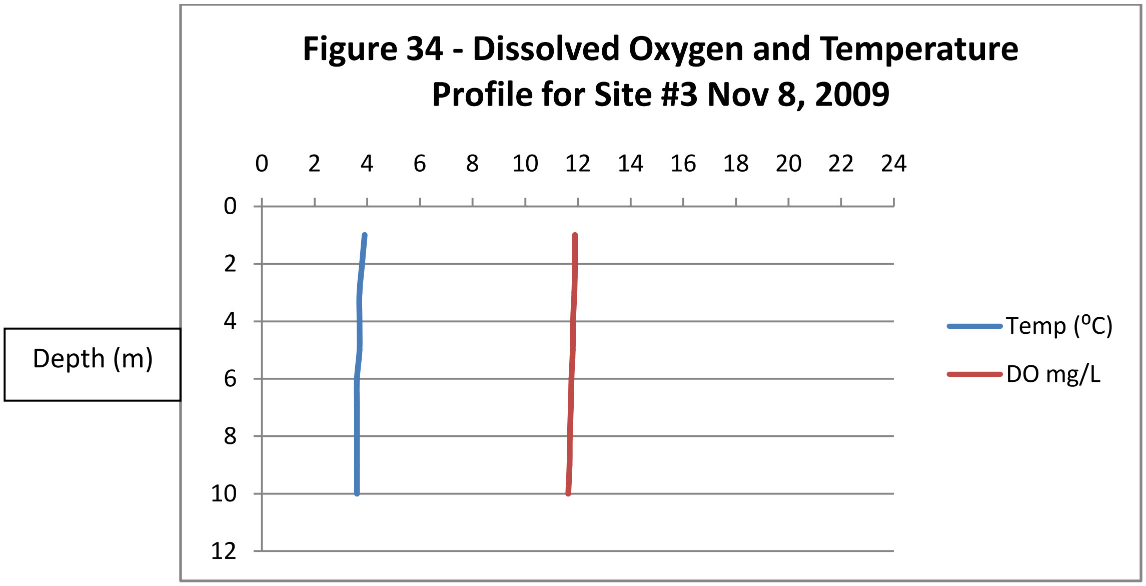
Data collected on September 27 indicate expanding hypoxic conditions into the water column from 6 to 10 m depths (DO readings ranging from 1.04 to 0.13 mg/L). The temperature profile shows relatively uniform temperatures of 18.9 to 19.0°C for the first 5 m of depth, with the thermocline present from 5 to 8 m, and then similar readings for the 9 and 10 m depths of 12.7 and 12.3°C, respectively (Figure 32).




Uniform temperature and dissolved oxygen profiles were documented on October 18. The temperature readings varied with a decrease in temperature from 7.1 to 6.2°C with depth. The DO profile demonstrates a nearly straight vertical line with all readings being within 0.1 mg/L of 11.00 (Figure 33).



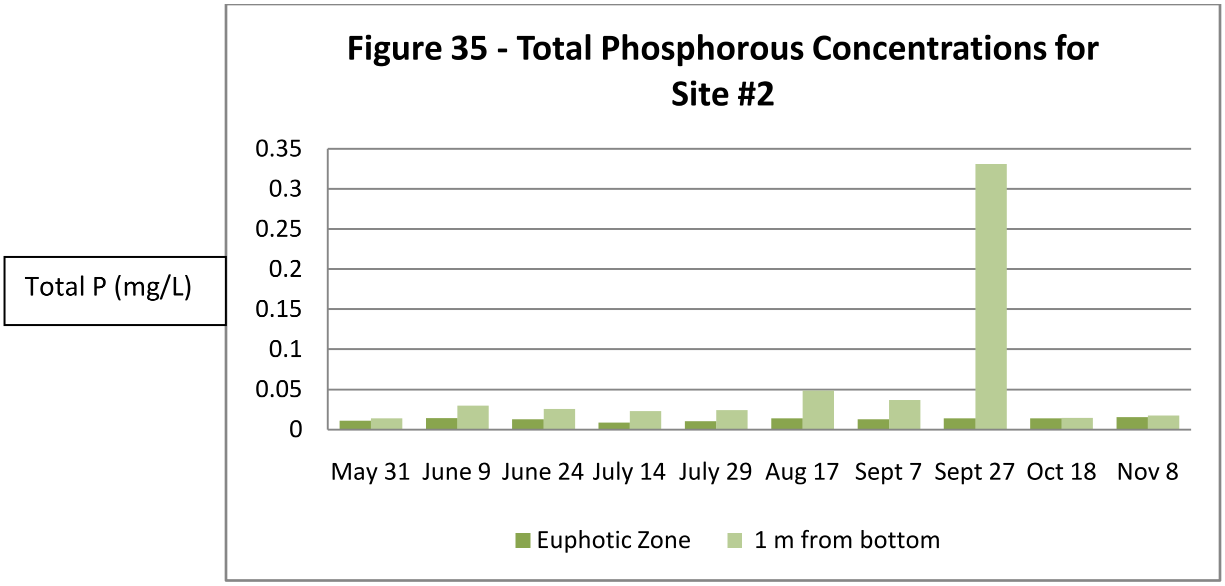
Similar to the profile for October 18, the November 8 profiles are virtually straight vertical lines for both temperature and dissolved oxygen. The only difference between this profile and the one collected on October 18 is a decrease in temperature (range 3.9 to 3.6°C) and an increase in DO (range 11.89 to 11.63 mg/L) (Figure 34).



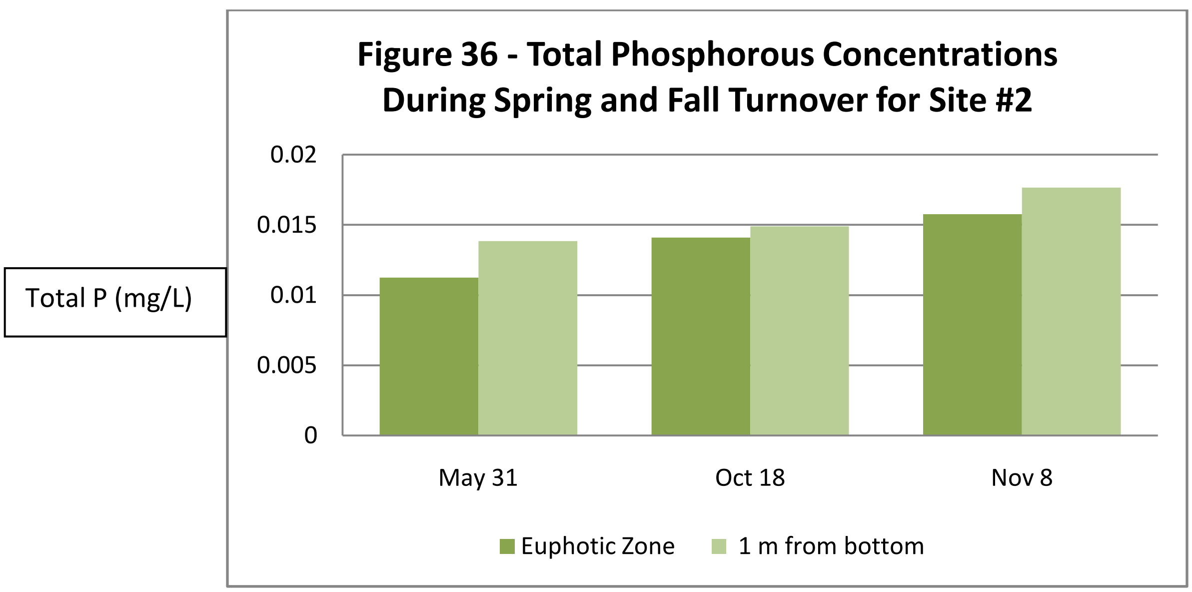

### 3.3 Total Phosphorous

#### 3.3.1 Total Phosphorous for Site #2 (Outlet of Lower Black Sturgeon)

The total phosphorous concentrations for site #2 demonstrated higher phosphorous levels in samples collected from a depth of 1 m from the lake bottom when compared with those taken from the euphotic zone for all 10 sample dates. The ratio of phosphorous concentrations in bottom to euphotic zone water samples ranged from 1.23:1 to 3.50:1 for all of the dates with the exception of September 27. The bottom sample from site #2 for September 27 yielded a significantly higher concentration (0.331 mg/L) and ratio (23.60:1) when compared to all of the other samples collected during the 2009 season at site #2 (Figure 35).



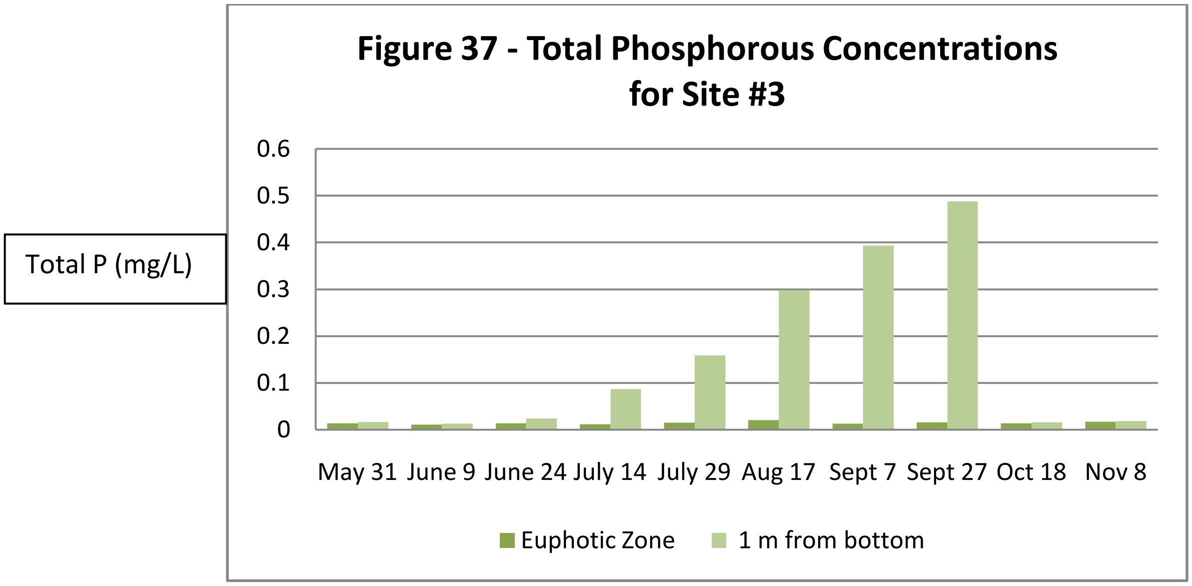

The spring and fall turnover results for the total phosphorous concentrations for site #2 were all below the provincial water quality objective of 0.0200 mg/L, with the lowest concentration found in the euphotic zone sample taken on May 31 (0.0113 mg/L) and the highest found in the sample taken 1 m from the bottom on November 8 (0.0177 mg/L) (Figure 36).



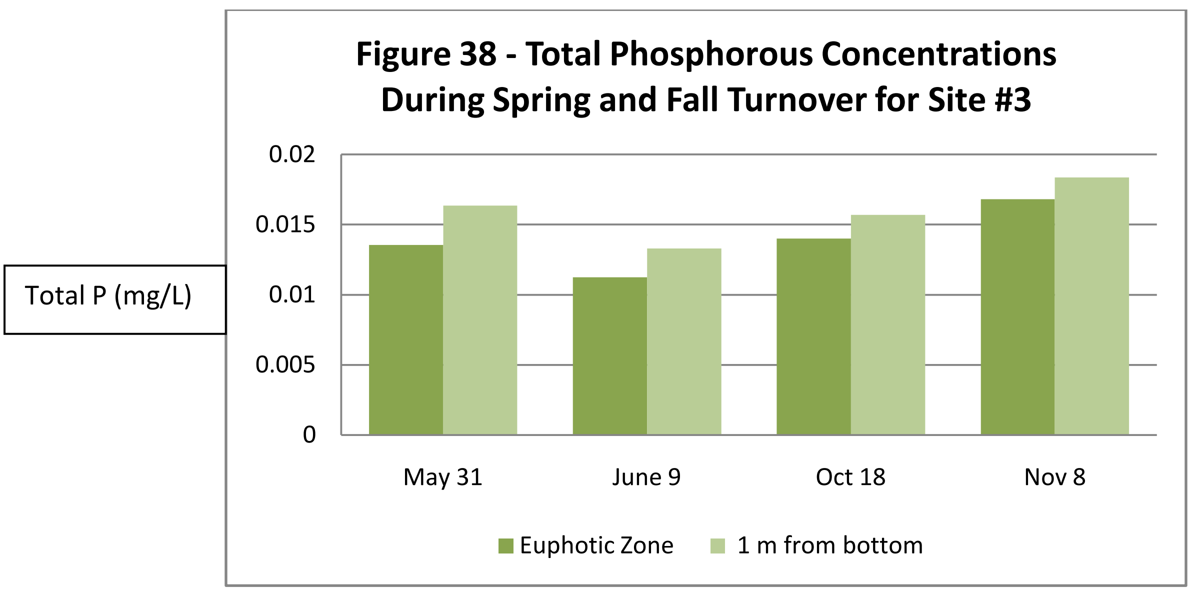

### 3.3.2 Total Phosphorous for Site #3 (Inlet of Lower Black Sturgeon)

Total phosphorous concentrations for site #3 were relatively consistent throughout the sampling season for euphotic zone analyses, but varied considerably for analysis of samples taken 1 m from the bottom. The euphotic zone concentrations varied from 0.0113 mg/L (June 9) to 0.0205 mg/L (August 17). The samples taken at 1 m from the bottom showed a steady increase in phosphorous concentrations from

0.0133 mg/L on June 9 to 0.4875 mg/L on September 27, dropping steeply on October 18 with a concentration of 0.0157 mg/L (Figure 37). On August 17, September 7 and September 27, water samples had a strong sulphur smell.

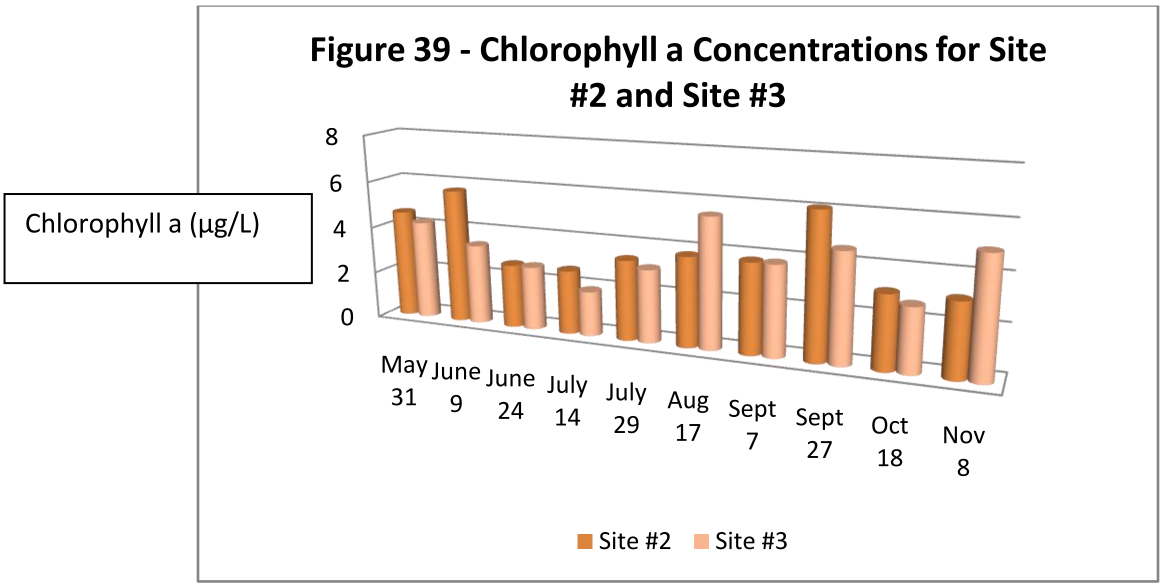



The spring and fall turnover results for the total phosphorous concentrations for site #3 were all below the provincial water quality objective of 0.0200 mg/L, with the lowest concentration found in the euphotic zone sample taken on June 9 (0.0113 mg/L) and the highest found during turnover events in the sample taken 1 m from the bottom on November 8 (0.0184 mg/L) (Figure 38).



### 3.4 Chlorophyll a

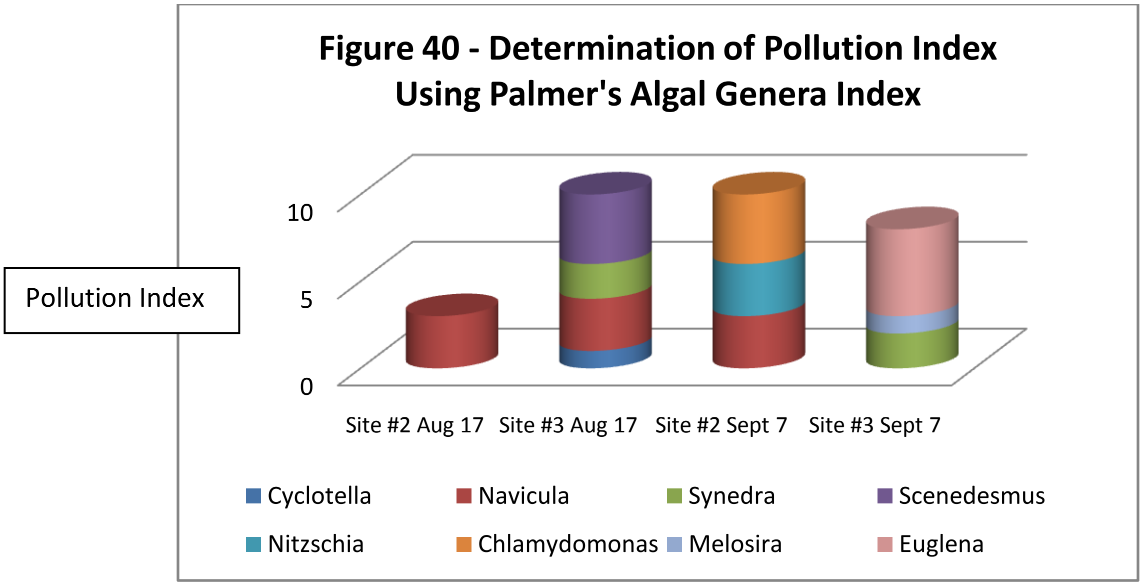
The chlorophyll a concentrations for both site #2 and site #3 varied considerably between sampling dates. In addition, there was not a strong relationship between the samples taken at site #2 and site #3. On five of the sample dates, there was greater than a 30 percent difference between the chlorophyll a concentrations at site #2 and site #3, with site #2 having higher concentrations on three of these dates (June 9, July 14, September 27) and site #3 having the higher concentration on the other two dates (August 17, November 8). The remaining five dates yielded similar results with less than 15 percent difference between the two sites (Figure 39). The seasonal average for the sites was 3.9 µg/L for site #2 and 3.7 µg/L for site #3.




### 3.5 Algal Community

Samples for algal analysis were collected during the two sampling dates when the water column was the warmest (August 17 and September 7). In these samples, 31 genera of algae were identified. A complete list of these genera by sample site and date can be found in Appendix 1. The Palmer Pollution Index (Palmer 1969) calculations for each of the samples were as follows:

- site #2 on August 17 had an index of 3 (Navicula present),
- site #3 on August 17 had an index of 10 (Navicula, Cyclotella, Synedra, and Scenedesmus present),
- site #2 on September 7 had an index of 10 (Navicula, Chlamydomonas and Nitzschia present), and
- site #3 on September 7 had an index of 8 (Melosira, Synedra, and Euglena present) (Figure 40).




### 3.6 Secchi Depths

The Secchi depths for site #2 ranged from 2.5 m to 3.25 m with an average of 2.95 m. The Secchi depths for site #3 ranged from 1.75 m to 2.75 m with an average of 2.48 m. Secchi depths were often taken in the early morning or in the evening on overcast days, which would result in a reduction in visibility (and thus, Secchi depth) when compared to mid-day measurements on sunny days.

## 4.0 DISCUSSION

### 4.1 Dissolved Oxygen and Temperature Profiles

The dissolved oxygen and temperature profiles for sites #1, #2, and #3 were all typical for dimictic lakes, with spring and fall turnovers and the establishment of a thermocline within the water column during the summer months. However, 2009 was a relatively cool summer and the peak surface water temperature occurring in June (at 22.3$^{o}$C on June 24) was unusual and indicative of the unseasonably cool temperatures in July and August. This resulted in cooler than normal water temperature readings. Due to the typical profiles for all three sites, a detailed analysis of each profile is not warranted. This discussion will focus on the profiles that provide important indicators of the health of the lake.

#### 4.1.2 Dissolved Oxygen, Anoxia, and Internal Loading

One of the reasons that dissolved oxygen concentration readings throughout the water column are important is that they can determine when anoxia (DO readings of less than 0.5 mg/L) is occurring. An oxygen layer at the sediment-water interface will prevent the release of phosphorous stored in the sediment. The lack of oxygen due the decomposition of organics in the hypolimnion can result in the removal of this oxygen barrier and the release of phosphorous from the sediments, thereby increasing the amount of phosphorous in the water column (Wetzel 1983). This release of phosphorous from the sediments to the water column is called internal loading. There were anoxic conditions found at all three sites, but the extent and duration of the anoxia varied.

Site #1 oxygen profile recorded values of less than 0.5 mg/L on three separate dates: June 24, August 17, and November 8. These three dates do not correspond with the expected seasonal change in anoxia. Anoxic conditions typically persist and expand over the mid-summer months when the lake is stratified. Also of interest is that the only anoxic conditions recorded were those taken at a depth of 30 m, where measurements were obtained approximately 20 to 30 cm from the bottom. It is felt that these anoxic readings were caused by the probe becoming too close to the substrate and receiving DO readings from the substrate instead of the water column.

Anoxic conditions were found at site #2 (outlet) on September 7 and September 27, with both dates exhibiting lack of oxygen from 15 m depth to the bottom. This is the result of the establishment of the thermocline by June 9, after which time mixing throughout the water column ceased and the hypolimnetic oxygen supply was limited until fall turnover in October. The decomposition of organic matter on the bottom of the lake, along with biological activity in the hypolimnion, would have reduced the oxygen concentrations steadily throughout the summer, resulting in the anoxic conditions shown. This anoxia may be a natural process in this section of Lower Black Sturgeon Lake. Future water quality studies should be conducted to monitor anoxic conditions in this part of the lake over time.

Site #3 (inlet) exhibited anoxia on July 14, July 29, August 17, September 7 and September 27. On July 14, the anoxia was located from 9 m below the water surface to the bottom of the lake; on July 29 from 8 m to the bottom; and on August 17, September 7, and September 27 from 7 m to the bottom. This prolonged period of anoxia is likely due to a combination of the small basin area with limited hypolimnetic oxygen supplies, and decomposing organic matter which consumes oxygen in the hypolimnion.

### 4.1.3 Dissolved Oxygen, Temperature, and Fish

Freshwater fish species that are most sensitive to the summer increases in temperature and subsequent decreases in dissolved oxygen concentrations are cool water species. The cool water species that are found in Black Sturgeon Lakes include lake whitefish (*Coregonus clupeaformis*) and cisco (*Coregonus artedii*). While the upper lethal temperature for these species is high [26$^{o}$C (Edsall and Colby 1970)], the preferred temperature range for lake whitefish is 10 to 14$^{o}$C (Mosindy pers. comm. 2009) and the optimum temperature for lake whitefish is 12$^{o}$C (Christie and Regier 1988). Temperatures above 14$^{o}$C for extended periods of time will stress lake whitefish and cisco which will affect their life processes. This is due to the fact that fish are cold-blooded and their internal temperature (and thus metabolism) is directly related to water temperature. Temperatures above 14$^{o}$C will cause lake whitefish and cisco to metabolize food at a faster than ideal rate, resulting in reduced body size and reproductive capacity.

The Ontario provincial water quality objectives for dissolved oxygen for cold water biota, which includes lake whitefish and cisco, is 6 mg/L for the temperature range of 10 to 15$^{o}$C (MOE 1994).

Due to these requirements, lake whitefish and cisco found in Lower Black Sturgeon Lake are likely to be found in the deeper, center section of the lake such as site #1 during the summer months. Therefore, any time the water column at site #1 does not have a layer of water with temperatures equal to or less than 14$^{o}$C and dissolved oxygen concentrations equal to or greater than 6 mg/L, cool water fish species such as lake whitefish and cisco may become stressed. These conditions were found at site #1 on September 7 and September 27. On September 7, the temperature was below 14$^{o}$C for the depths of 13 to 30 m, and DO concentrations were declined from 5.23 to 3.28 mg/L over these depths (Figure 11). Similarly, on September 7 the temperature was below 14$^{o}$C at depths between 14 and 29 m, and DO concentrations were below 6 mg/L (4.31 to 1.89 mg/L) along this portion of the water column (Figure 12).

During the entire sampling season, there were no water temperatures observed at or over the 26$^{o}$C lethal temperature (highest temperature reading was 22.3$^{o}$C at site #3 on June 24).

The lack of ideal conditions for lake whitefish and cisco for a period of approximately one month is not uncommon for moderately productive lakes such as Lower Black Sturgeon, which cannot support lake trout (*Salvelinus naymaycush*), a cool water species with higher oxygen requirements and lower temperature tolerances than lake whitefish and cisco. These findings are consistent with information collected by the Ontario Ministry of Natural Resources in 1988, indicating that similar midsummer DO and temperature profiles were found in Black Sturgeon Lakes over two decades ago.

## 4.2 Total Phosphorous

There are two aspects of the total phosphorous readings that are of the most interest for water quality analysis. One is the amount of phosphorous in the water column during turnover events, as this is when the phosphorous is mixed throughout the water column and it is also when past phosphorous concentrations have been measured to enable analysis of trends over time. The second important relationship is the ratio of total phosphorous concentrations between the surface and bottom water samples. The surface to bottom ratio gives an indication of the amount of phosphorous entering the water column from the sediments via internal loading.

### 4.2.1 Turnover Phosphorous Concentrations and Lake Productivity

The Ontario provincial water quality objective for total phosphorous concentrations is less than 20 µg/L (0.02 mg/L) “to avoid nuisance concentrations of algae in lakes” (MOE 1994). The spring and fall turnover phosphorous concentrations collected during the 2009 sample season (average of euphotic zone and bottom samples) were below Ontario’s provincial water quality objective for sites #2 and #3.

The spring total phosphorous concentrations of 0.0126 mg/L (site #2) and 0.0150 mg/L (site #3) were within the range of total phosphorous samples analyzed between 2001 and 2007 on Black Sturgeon Lakes (0.014 to 0.020 mg/L) and are both below the mean of 0.017 mg/L (Ministry of Environment 2009a). This indicates that the phosphorous concentrations on Lower Black Sturgeon Lake appear to have been stable (and below the water quality objective) over the past decade.

These values indicate that lower Black Sturgeon Lake has not increased in productivity since 2001 and the phosphorous values are below the water quality objectives for nuisance algae concentrations.

With the exception of the two sampling sessions in June, all of the phosphorous results were higher for the inlet (site#3) of Lower Black Sturgeon Lake then they were for the outlet (site #2). This suggests that

Lower Black Sturgeon Lake is currently diluting the phosphorous concentrations from Upper Black Sturgeon Lake before the system flows into the Winnipeg River. Therefore, the average phosphorous concentrations for all of the other sources of water for Lower Black Sturgeon Lake are lower than the phosphorous concentrations flowing in from Upper Black Sturgeon Lake via the Black Sturgeon River.

#### 4.2.2 Euphotic Zone and Bottom Phosphorous Comparisons: Internal Loading

For both site #2 and site #3, the bottom phosphorous concentrations were greater than the euphotic zone concentrations for every sample session. This is to be expected as small amounts of phosphorous will release from the sediments even with well-oxygenated water at the sediment-water interface (Wetzel 1983). However, the degree of difference between the concentrations at the bottom and euphotic zone increased as the season progressed and thermal stratification took place. The increase in the ratio of concentrations was particularly pronounced at site #3 under anoxic conditions.

Site #2 yielded a range of ratios from 2.04:1 to 3.50:1 (1 m from bottom: euphotic zone) for phosphorous concentrations during the time period when a thermocline was established from June 9 to September 8. However, the concentration of the bottom sample at site #2 increased significantly on September 27, yielding a ratio of 23.6:1. This large increase in phosphorous concentration at site #2 coincides with a period of anoxia near the bottom over the month of September as is shown in the dissolved oxygen profile for this time period (Figures 21 and 22). The results from site #2 indicate that, for a brief period in September, internal loading of phosphorous was likely taking place.

The ratio for site #3, during the time period when a thermocline was established, ranged from 1.01:1 to 31.50:1. The large increase to a greater than thirty-fold difference in relative bottom phosphorous concentrations at site #3 began with the anoxic conditions found on July 14 (ratio 7.42:1) and continued to accelerate dramatically until peaking at the end of the anoxic conditions on September 27.

The results at site #3 indicate that internal loading was taking place causing an increase in contribution of phosphorous to the water column from the sediments. Internal loading often results in a positive feedback loop. The increase in phosphorous released from the sediments causes the area to become more productive, resulting in more algal blooms and other biological activity. When these organisms die, they contribute to the organic matter on the bottom and increase the amount of oxygen-consuming decomposition occurring in the hypolimnion. This further reduces the oxygen layer on the bottom, releasing more phosphorous, and the positive feedback cycle continues.

The anoxia occurring at site #3 resulting in internal loading of phosphorous is likely the result of a couple of factors. First is the bathymetry of the area. The deep water of site #3 is isolated from the deep water of the main basin of Lower Black Sturgeon Lake by a shallow channel. Once the thermocline has been established at site #3, this pocket of deep water has all of its supply of oxygen until fall turnover. This results in a more limited area of oxygenated water for site #3 when compared to site #2. Site #2 is connected to the main basin of the lake by a large, fairly deep channel and therefore in midsummer when the hypolimnion is established the deep water of site #2 will receive oxygen through mixing with the hypolimnetic oxygen in the main basin. The second factor affecting the anoxia is the amount of organic matter being deposited on the bottom. Increased external sources of organic matter will increase the amount of decomposition and result in further extension of the period of anoxia.

While the anoxic conditions at site #2 and site #3 are causing internal loading, it is difficult to determine if this has increased over time or is a natural process at these sites. The fact that the turnover phosphorous concentrations remained below the provincial water quality objective of 0.020 mg/L indicates that current phosphorous levels at site #2 and site #3 are unlikely to cause adverse water quality in the area. However, these sites should be monitored in the future to track the internal loading and its impact upon the phosphorous levels in Lower Black Sturgeon Lake.

#### 4.3.3 Sulphur

There was evidence that purple sulphur bacteria were present at site #3, releasing sulphur into the water column and producing the sulphur smell in the bottom water samples in August and September. The presence of purple sulphur bacteria in anoxic waters is not uncommon. Purple sulphur bacteria use hydrogen sulfide as their reducing agent, which is oxidized to produce granules of elemental sulphur. These bacteria thrive in anoxic conditions. Sulphur is not listed in the Ontario provincial water quality objectives.

### 4.3 Chlorophyll a

Chlorophyll a is an indicator of water quality because it is an indicator of phytoplankton biomass. Knowing the concentration of chlorophyll a is related to primary production of a water body. It has been demonstrated experimentally (Cole 1975; Ryther and Yentsch 1957) that a relatively constant relationship exists between chlorophyll a and photosynthesis at any given light intensity. Therefore, chlorophyll a concentrations will reflect any increases in primary production including algal growth that may be the result of shoreline development and other anthropogenic impacts on the watershed . While there are no provincial water quality objectives for chlorophyll a, changes in the concentration of chlorophyll a over time will provide an indication of the eutrophication (increase in productivity) of Lower Black Sturgeon Lake. The chlorophyll a sample results and the seasonal averages of 3.9 µg/L (site #2) and 3.7 µg/L (site #3) will provide important baseline data to draw upon for future comparisons.

### 4.4 Algal Community

The Palmer Pollution Index for the algal samples ranged from values of 3 to 10. The fact that all three sites have scores less than 15 indicates the absence of organic pollution. The collection of algal samples on two dates during the open water season, while providing a snapshot of the algal community, is definitely not a comprehensive algal analysis, as concentrations and species of algae present can vary daily. Comprehensive algal sampling is beyond the scope of this project. It is felt that collecting samples on two dates during midsummer for algal analysis should continue in the future as it provides valuable information at a reasonable cost.

### 4.5 Secchi Depths

Both of the mean Secchi depths for site #2 (2.95 m) and site #3 (2.48 m) were within the mean range of 2.4 m to 3.9 m determined as part of the lake partner program from 1997 to 2006 (Ministry of the

Environment 2009b). It is to be expected that the Secchi depths for this project would be slightly lower than those found during the lake partner program as scheduling of the sampling dates did not permit the Secchi depths to all be taken under ideal conditions.

## 5.0 SUMMARY AND RECOMMENDATIONS

Lower Black Sturgeon Lake is within the provincial water quality objectives for a healthy lake and all of the parameters measured and analyzed in this study indicate that it has the characteristics expected in a dystrophic lake (i.e. heavily coloured due to presence of humic compounds of plant origin) located in northwestern Ontario. In addition, the data collected are consistent with results of previous studies conducted on Lower Black Sturgeon Lake. This indicates that the health of the water body has remained consistent and is not deteriorating over time.

Of particular interest is the fact that the total phosphorous readings were typically greater at the inlet (site #3) of Lower Black Sturgeon Lake than they were near the outlet (site #2). This decrease in total phosphorous over the length of Lower Black Sturgeon Lake suggests that Upper Black Sturgeon Lake is a significant contributor of phosphorous to Lower Black Sturgeon. The only major development on the system and a potential source of phosphorous is an 18-hole golf course located on Upper Black Sturgeon Lake. Another potential source of phosphorous is the wetland areas along the Black Sturgeon River between Upper and Lower Black Sturgeon Lakes. Therefore, it is recommended that during the 2010 field season, additional sites be sampled on Upper Black Sturgeon Lake to determine the phosphorous inputs from this water body. This will assist in identifying potential sources of nutrients and cultural eutrophication on the Black Sturgeon Lakes watershed.

The collection of duplicate samples for phosphorous analysis at each site is not a common practice in the scientific community. The protocol for the collection of two phosphorous samples in Ontario is a product of the Lake Partner Program, where administrators of the program have little control over ensuring that proper sampling procedures are being used by volunteers. To help ensure the accuracy of the data collected, the Lake Partner Program requires two samples be taken for each site. When analyzed, if the two samples vary significantly, both of the samples collected are disregarded. In other jurisdictions, where sampling is conducted primarily by researchers and trained personnel, the standard practice is for the collection of one sample at each site. This is found to be a more efficient use of resources as, when the same people are collecting all of the samples for a project, there are consistent sampling methods and variability of results is minimized. During the 2009 sampling season, there were 80 samples analyzed for total phosphorous concentrations and duplicates were averaged to produce 40 results used to establish the baseline data. None of the duplicate samples collected during the 2009 season yielded significantly different results. For these reasons, it is recommended that only single samples be taken for analysis in future years. This will provide reliable results and allow for samples from additional sites (such as the recommended sites on Upper Black Sturgeon Lake) to be analyzed without increasing the sampling costs of the project.

The atypical weather experienced during the 2009 sampling season demonstrates the importance of collecting multiple years of data to establish robust baseline information. The summer was cooler than average, and therefore the information collected during this season provides a detailed synopsis of Lower Black Sturgeon Lake water quality during a cool summer.  An average summer or exceptionally warm summer may yield different results than those found during the 2009 season.  Thus, the 2010 water quality work will ensure that the baseline data used in the future to monitor changes in the water body will be based upon the foundation of two consecutive years of data collection.

The 2009 Water Quality Monitoring for Lower Black Sturgeon Lake provides the first year of baseline data.  This information, combined with the work to be done during the 2010 season, will provide the critical basis required to assess the long-term health of the water in Black Sturgeon Lakes.

## 6.0 REFERENCES


Christie, G.C. and H.A. Regier. 1988. *Measures of optimal thermal habitat and their relationship to yields for four commercial fish species*. Can. J. Fish. Aquat. Sci. 45:301-314.

Cole, G.A. 1975. *Textbook of Limnology*. The C.V. Mosby Company, St. Louis.

Edsall, T.A., and P.J. Colby. 1970. *Temperature tolerance of young-of-the-year cisco, Coregonus artedii.* Trans. Amer. Fish. Soc. 99(3): 526-531.

Gartner Lee Ltd. and Kelli Saunders Environmental Management. October 2007. *Lake Capacity and Management Study for Black Sturgeon Lake, City of Kenora*.

Ministry of the Environment. 2009a. Lake Partner Total Phosphorous Data. Found on website at: http://www.ene.gov.on.ca/en/water/lakepartner/docs/2008%20Lake%20Partner%20Total%20Phosphorus%20Data.pdf

Ministry of the Environment. 2009b. Lake Partner Secchi Depth Data. Found on website at: http://www.ene.gov.on.ca/en/water/lakepartner/docs/2008%20Lake%20Partner%20Secchi%20Data.pdf

Ministry of Environment and Energy. July 1994. *Water Management: Policies; Guidelines; Provincial Water Quality Objectives of the Ministry of Environment and Energy.*

Mosindy, Tom. December, 2009. Personal Communications via telephone.

Palmer, C. Mervin. 1969. A *composite rating of algae tolerating organic pollution.* Journal of Phycology. 5 (1): 7882

Ryther, J.H. and Yentsch C.S. 1957. *The estimation of phytoplankton production in the ocean from chlorophyll and light data*. Limnol. Oceanogr. Volume 2: 281-286.

Wetzel, R.G. 1983. *Limnology*. Saunders College Publishing

**APPENDIX 1 – Algal Samples Identified to Genera**

| Site #2 August 17 | | Site #4 August 17 | |
|---|---|---|---|
| **Algal Identification** | **Amount** | **Algal Identification** | **Amount** |
| Asterionella | Small | Asterionella | Small |
| Diatoma | Small | Cyclotella | Small |
| Navicula | Small | Diatoma | Small |
| Closterium | Small | Fragilaria | Small |
| Dictyosphaerium | Small | Navicula | Small |
| Quadrigula | Small | Rhizosolenia | Small |
| Sphaerocystis | Small | Stephanodiscus | Small |
| Cryptomonas | Small | Synedra | Small |
| Mallomonas | Small | Closterium | Small |
| Rhodomonas | Moderate | Crucigenia | Small |
| Anabaena | Small | Quadrigula | Small |
| Aphanocapsa | Small | Scenedesmus | Small |
| Aphanothece | Small | Cryptomonas | Small |
| Gomphosphaeria | Small | Dinobryon | Small |
| Pseudoanabaena | Small | Mallomonas | Small |
| Ceratium | Small | Rhodomonas | Moderate |
| Planktolyngbya | Small | Anabaena | Small |
| | | Aphanizomenon | Small |
| | | Aphanocapsa | Small |
| | | Aphanothece | Small |
| | | Merismopedia | Small |
| | | Pseudoanabaena | Small |
| | | Ceratium | Small |
| | | Planktolyngbya | Small |

**Site #2 Sept 7**

| Algal Identification | Amount |
|---|---|
| Asterionella | Small |
| Diatoma | Small |
| Fragilaria | Small |
| Navicula | Small |
| Nitzschia | Small |
| Rhizosolenia | Small |
| Chlamydomonas | Small |
| Closterium | Small |
| Coelastrum | Small |
| Pediastrum | Small |
| Quadrigula | Small |
| Staurastrum | Small |
| Cryptomonas | Small |
| Dinobryon | Small |
| Mallomonas | Small |
| Anabaena | Small |
| Aphanizomenon | Small |
| Aphanocapsa | Small |
| Aphanothece | Small |
| Gomphosphaeria | Small |
| Merismopedia | Small |
| Glenodinium | Small |

**Site #4 Sept 7**

| Algal Identification | Amount |
|---|---|
| Asterionella | Small |
| Diatoma | Small |
| Fragilaria | Small |
| Melosira | Small |
| Rhizosolenia | Small |
| Stephanodiscus | Small |
| Synedra | Small |
| Closterium | Small |
| Pediastrum | Small |
| Dinobryon | Small |
| Mallomonas | Small |
| Rhodomonas | Moderate |
| Synura | Small |
| Euglena | Small |
| Aphanothece | Small |
| Gomphosphaeria | Small |
| Merismopedia | Small |
| Ceratium | Small |