

**Swan Lake Water Quality Monitoring  
June – September 2016**



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## 1.0 Introduction

The water quality of Swan Lake has significant impacts on the health and biodiversity of the lake and its surrounding ecosystems. As with many urban wetlands, Swan Lake concentrates wildlife and supplies vital nursery areas, food sources and supplies large varieties of protected habitat in the midst of an increasingly developed landscape. Additional values of this feature are far reaching as it gives rest to migratory birds, provides water filtration, enables aquatic transitioning for insects and terrestrial species and provides educational opportunities to observe the interactions of many natural systems.

Human impact has changed the state of the health of this lake over time. In the late 1800s and the early 1900s, people swam and fished the lake and local residents recall the lake as being clear and free from algae blooms. In 1927, a winery was constructed on Quadra Street and effluent from the winery began to have negative impacts on the water quality of the lake. Significant areas upstream of the lake introduce non-point source agricultural nutrients that follow the catchment basin via the inflow of Blenkinsop Creek. Such nutrient loading, as well as other elements from urban sources, have over time created a highly eutrophic aquatic system characterized by high turbidity, elevated phosphorus levels and at times poor dissolved oxygen concentrations. During the typical dry summers of Victoria, algae blooms are common and on occasion fish kills occur where lake temperatures, dissolved oxygen, algae overgrowth and various nutrients exceed tolerable limits for fish and a host of organisms. During these algae blooms, visitors to the walkways around the lake can smell a pungent odor emitted from biomats that cover large parts of the shore margins and the west end of the lake. As a result, the overall health and biodiversity of the wetland area is significantly impacted by these summer extreme signals that are measurable in the water quality of the lake.

Changes in lake systems can be subtle or dramatic, human induced or climatic. To better understand the processes at work within the lake and to observe temporal change, a water quality monitoring program was proposed, funded and carried out at Swan Lake measuring water parameters from the beginning of June until the end of September 2016.

In this report, data is presented which summarize measured water properties including dissolved oxygen, pH, temperature, nitrates and phosphates. These parameters are some of the key indicators of aquatic health. Although this is largely a data report, some interpretation of the factors that influence the measured parameters will be offered.

## 2.0 Swan Lake Watershed

Swan Lake location: 48 27'47.69"N 123 22' 21.79"W

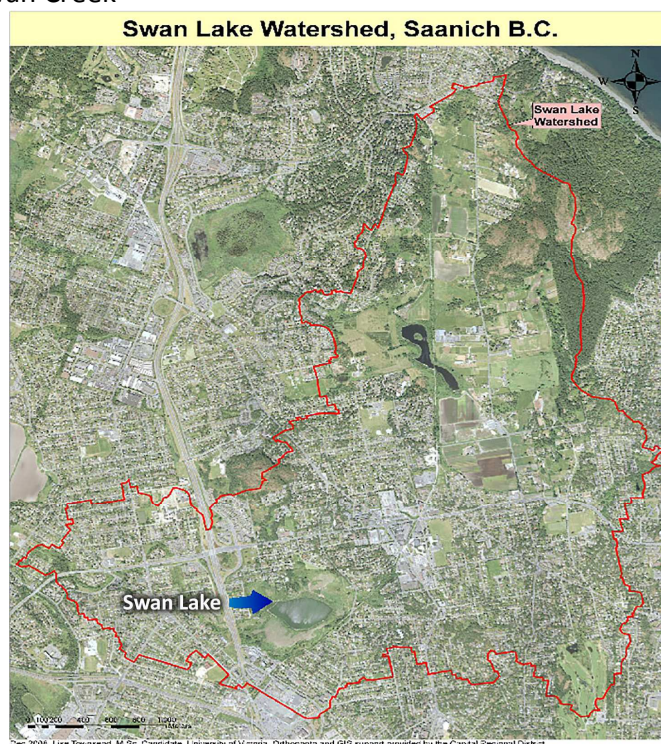
Swan Lake watershed: 12 square km (**Figure 1**)

Swan Lake: 9.3 hectares

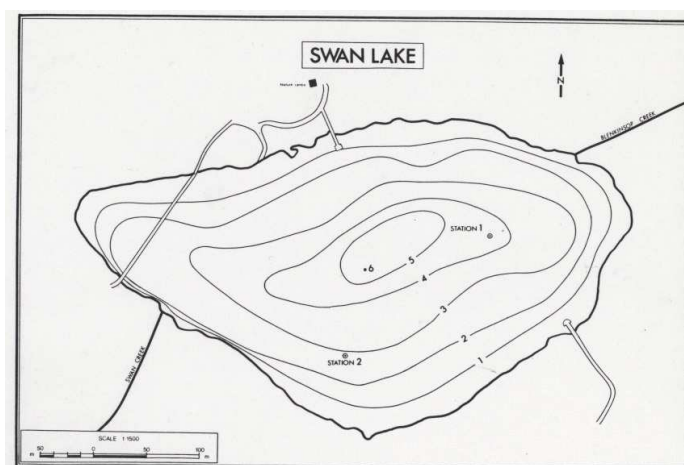
Nature sanctuary: 48 hectares

Main inflow stream: Blenkinsop Creek

Main outflow stream: Swan Creek



**Figure 1.** Swan Lake watershed boundary.



**Figure 2.** Swan Lake bathymetry.

### 3.0 Selection of Sample Sites

Key components to a successful sampling program are the selection of sample sites that represent a good spatial distribution of lake conditions as well as a rationale that justifies the sample site positions for profiling. In this study, several sites were selected and the positions of these sites are indicated in Figure 3. These sites were accessible by foot and offered a stable platform to work from. Each site will briefly be described and the selection rationale will be discussed.

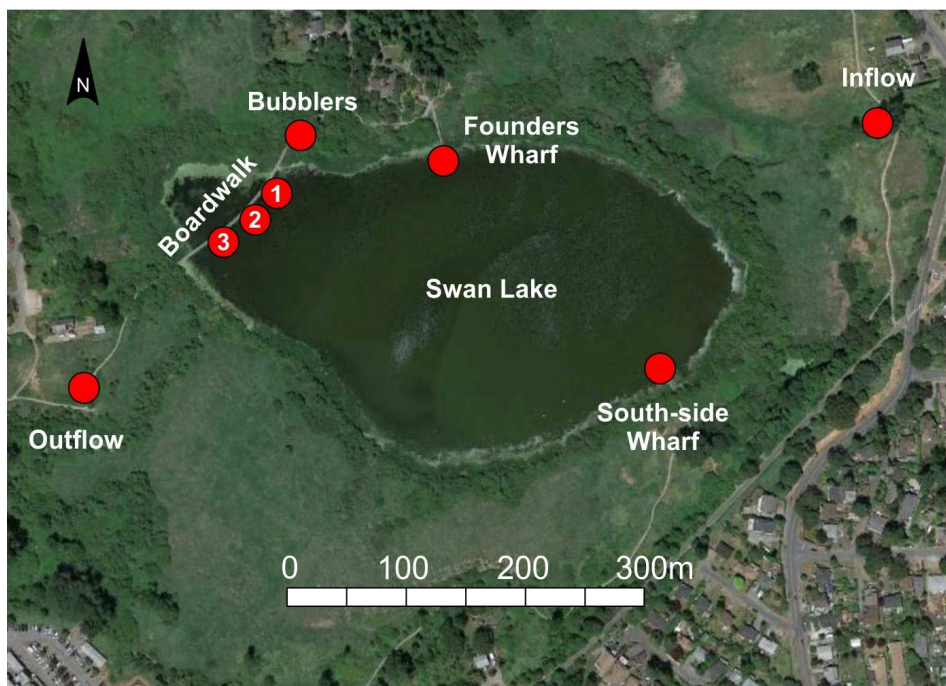


Figure 3. Water quality sample site.

On a typical sampling day, the first set of data would be taken at the bubbler site at about 9:30 am. This site was situated within a perched pond not connected to the lake during the summer months. At this site, aeration bubblers vigorously circulated air to keep this water from becoming stagnant. This site was largely selected as a calibration site to calibrate barometer pressure for the day's sampling and to run through optical dissolved oxygen calibrations. Values taken here showed uniform mixing with no gradients in temperature, pH and dissolved oxygen.

From this calibration site, sampling was carried out around the lake in a counter-clockwise manner with the first site on the lake located at the first boardwalk bench (bench #1). This site was relatively shallow and was the first of three in a cross-sectional transect of the western segment of the lake. This site was close to the coastal margin often covered in duckweed or surface algae mats. Moving along the boardwalk, the next site was located at bench #2 in deeper water. This site was away from the north and south margins of the lake perimeter and was often clear from surface algae. Bench #3 was located relatively close to Swan Creek, the outflow of Swan Lake. At this site, significant accumulations

of detritus were observed (GoPro video) on the lake bottom and generally algae mats or thick duckweed covered the surface.

Water properties were next taken from Swan Creek, the outflow pathway. This site dried up by mid July so only the month of June and the first week of July were measured. It was thought that this site would yield a total integration of the lake and could be useful to compare to the inflow creek data.

The southeastern part of the lake was sampled from the south-side wharf, a relatively shallow area with a large water lily population and often calm in comparison to other parts of the lake. From here water samples were taken and water properties measured at Blenkinsop Creek, a potential input of urban and agricultural runoff carrying nutrients to Swan Lake. The final sample site was located at the Founders Wharf, a mid-point between the inflow and outflow creeks and one of the deepest sites sampled on the lake. Elapsed time to complete the sampling typically was about 4.5 hours.

#### **4.0 Methodology**

Profiles were taken at each lake site at surface, 50 cm intervals and bottom. These profiles were taken with two YSI handheld meters and associated probes. The "ODO Profession" measured dissolved oxygen (DO) in percent saturation and mg/l of oxygen as well as water temperature. The YSI "ProfessionPlus" was used to measure pH at the same intervals. In addition, a secchi disk was used to measure turbidity and a GoPro 4 Silver was used to acquire underwater video for visual inspection. Daily barometric and DO calibrations were performed prior to the first set of profile measurements. The pH probe was calibrated monthly using a two point calibration process. As the range of pH is between 6.5 and 9.5, the buffers used in the calibration were pH 7.0 and pH 10.0.

Prior to sampling, observations were noted recording weather conditions including cloud coverage, wind and wave conditions and the surface presence of duckweed, algae mats or suspended cyanobacteria. Each profile was conducted in the following manner. Both DO and pH probes were suspended such that the probes were just below the surface with all parts of the probe submerged. Readings from the meters were recorded once values stabilized. This stabilization usually took about two to three minutes but there were many situations where this interval was longer. The probes were then lowered at 50 cm increments and values were recorded at each increment. The final readings were taken with the probe resting on the bottom. The sampling process was repeated twice to obtain two sets of data for each profile. These duplicate profiles were comparable and useful for data confidence.

Secchi depths were recorded by lowering the disk into the water column until the disk was no longer visible. Generally each lake site had recorded secchi depths with only a few exceptions. In some cases, where algae mats or thick duckweed were present, values could not be obtained as algae would close in immediately after the disk passed through the surface water.

Video recordings were made by lowering a two meter pole into the water. This became a useful tool to observe the presence of fish and where in the water column the fish tended to reside. It was also useful to examine suspended algae density, bottom plant life, bottom hardness and the presence of detritus.

Water samples were typically taken at the inflow creek and the Founders Wharf as well as a few spot samples taken from the boardwalk and the south-side wharf. These samples were analyzed for nutrients using the YSI "9500 photometer." Both nitrate and phosphorous were tested by following strict procedures using reagents and timed mixing intervals. These values were recorded for temporal comparisons.

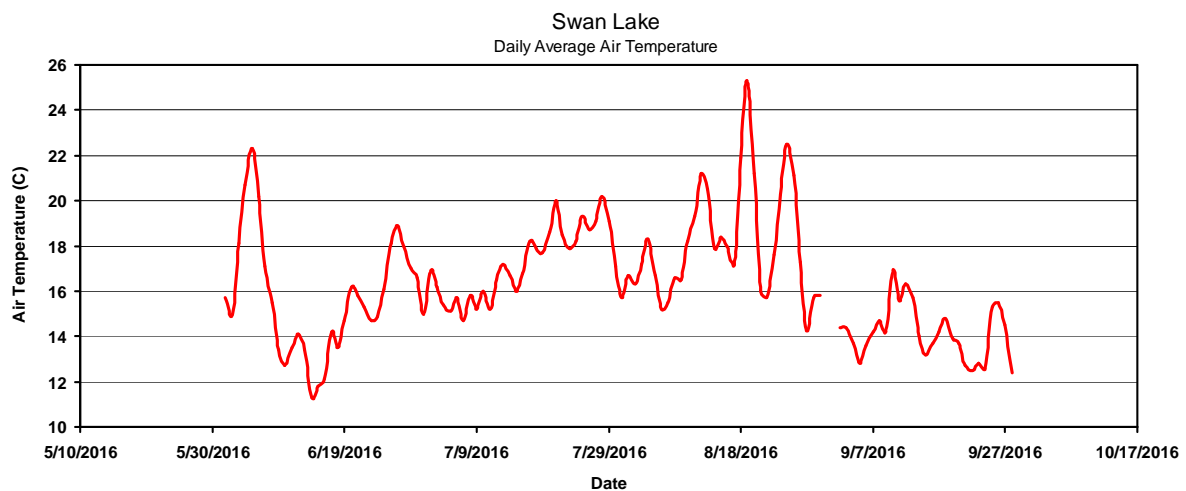
## 5.0 Results

A complete set of data has been compiled for this study and is supplied digitally in the form of Excel spreadsheets on a data DVD included with this report. Representative data plots are presented here with some discussion offered highlighting some of the physical and biological processes at work.

During the sampling interval between June and the end of September, the summer heating of the lake and the presence of algae blooms were observed as well as the dying off of suspended cyanobacteria as the temperatures and the daylight hours diminished into the fall season. Weather conditions played a significant role in the water properties for both oxygen and pH profiles. Sunny weather tended to create higher levels of oxygen as would be expected due to photosynthesis and cloudy weather tended to result in lower levels of oxygen.

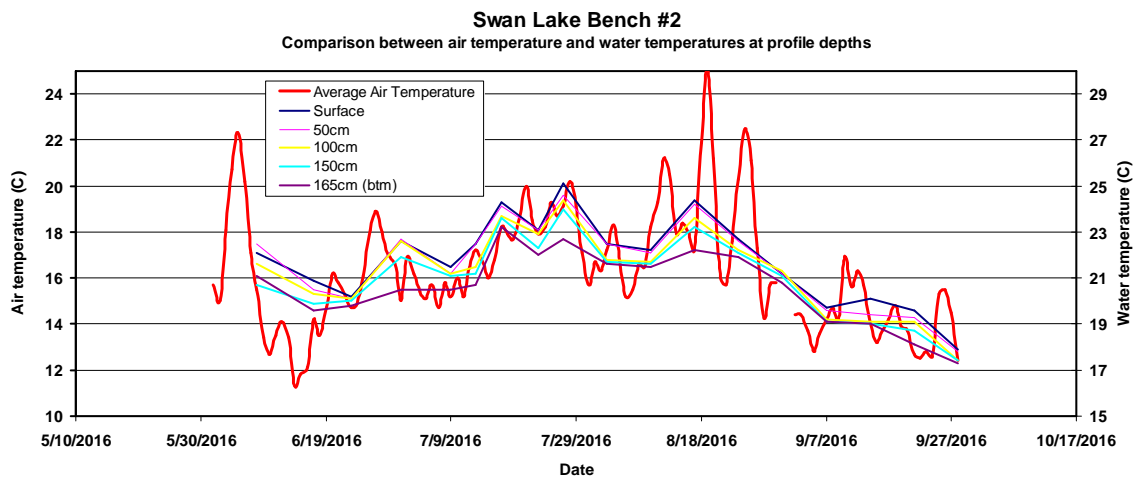
### *Temperature*

To initiate a comparison of the water quality parameters, a plot was generated showing the daily average air temperature variations as measured at the Swan Lake weather station (Figure 4). It was assumed that surface water temperatures would respond to the thermal input from contact with the air.



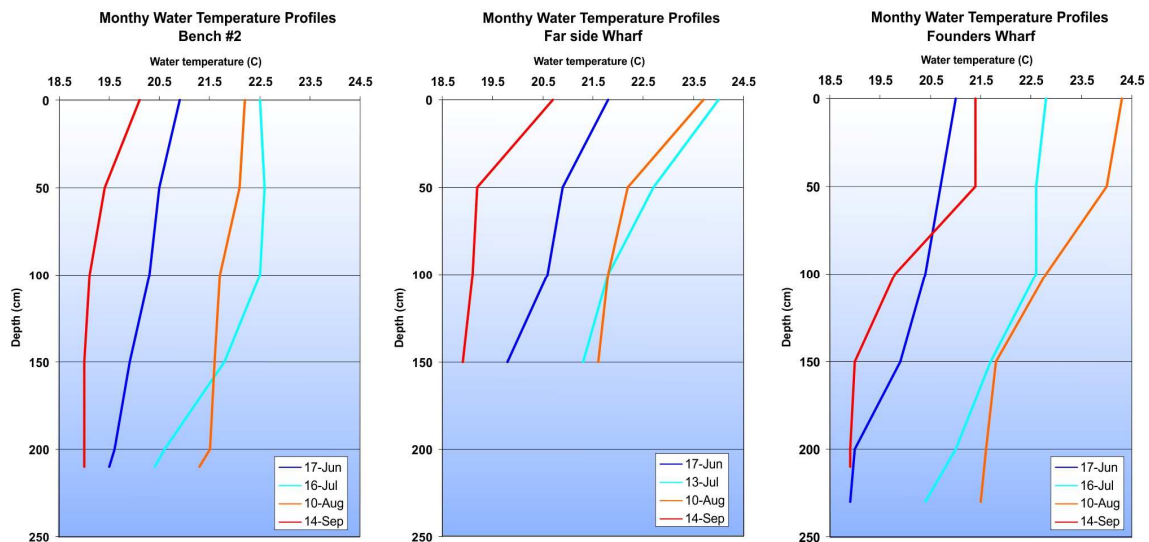
**Figure 4.** Air temperature measured at the Swan Lake weather station.

Figure 5 shows a comparison between daily air temperature and weekly water temperature at profile depths at bench #2. Note the structure of the water temperature curves generally respect that of the air temperatures, with an offset at the surface of approximately five degrees Celsius, the lake temperature being warmer than the average daily temperature. This would suggest that the effect of solar heating during the day has more of an impact on lake temperatures than the cooling during the night. The curves of the water temperatures, although sampled less frequently, responds to air temperature even at the lake bottom which at this site is about 2.2 m.



**Figure 5.** Daily air temperature compared to profile water temperature.

Temperature profiles were recorded at each sample site. A small selection of these temperature profiles are displayed below in Figure 6. These plots were taken from data collected at bench #2, the far side wharf and the Founders Wharf sample sites and curves depicted mid-month data for the months of June, July, August and September.

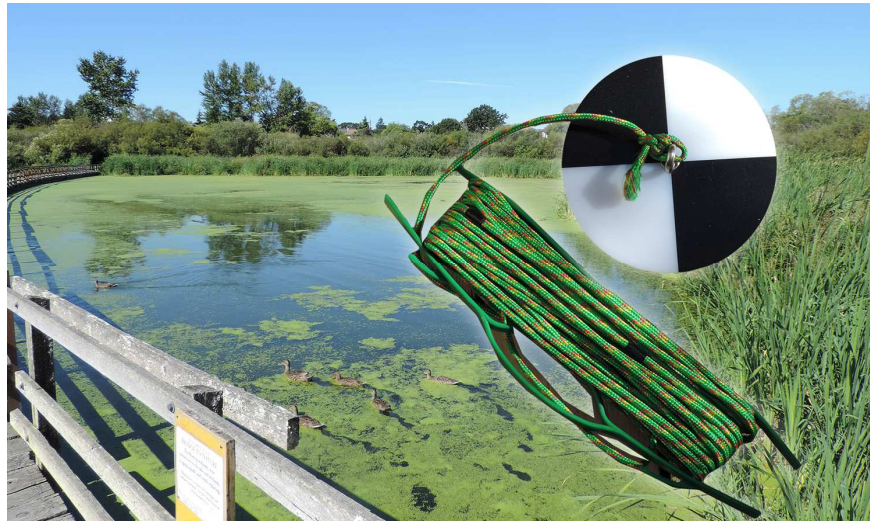


**Figure 6.** Mid-month water temperature profiles from three sites.

### 5.1 Turbidity

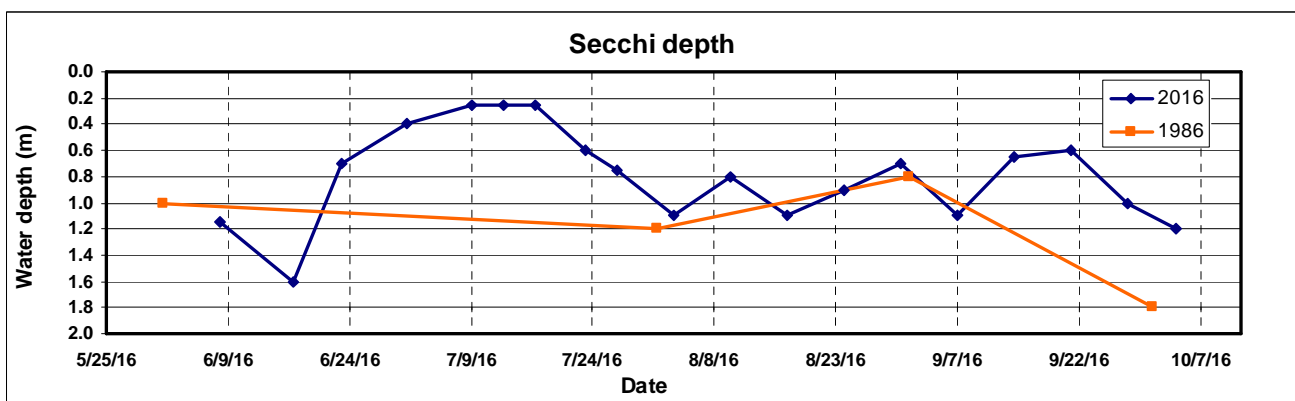
The turbidity of the water was measured throughout the study period to give an index of the clarity of the water. This parameter has both physical and biological implications and indicates the presence of both visible and invisible particles suspended within the water column.

Light penetration into the water column plays a key role in terms of heat flux and provides the necessary energy inputs for plant photosynthesis. Figure 7 shows the secchi disk used to make these measurements.



**Figure 7.** Secchi disk used to measure turbidity.

It was noted throughout the summer months that there was an abundance of suspended filaments-like algae distributed vertically within the water column. In mid July, populations of this organism as well as surface algae including duckweed impeded light penetration significantly as can be seen by the secchi depth plot (Figure 8). Secchi depths from 1986 were also plotted on Figure 8 for comparison. Note shallow water depths on this curve represent shallow light penetration. There appears to be similar light penetration in August and September in this two years comparison. October, however, show a significant difference. This is likely due to the prolonged summer-like weather conditions experienced in 2016, conditions which continued to promote algae growth.



**Figure 8.** Temporal secchi disk depths taken from the boardwalk.

Algae blooms were noted in several areas of the lake over the summer. The portion of the lake west of the boardwalk was often completely covered in algae as shown in Figure 9.



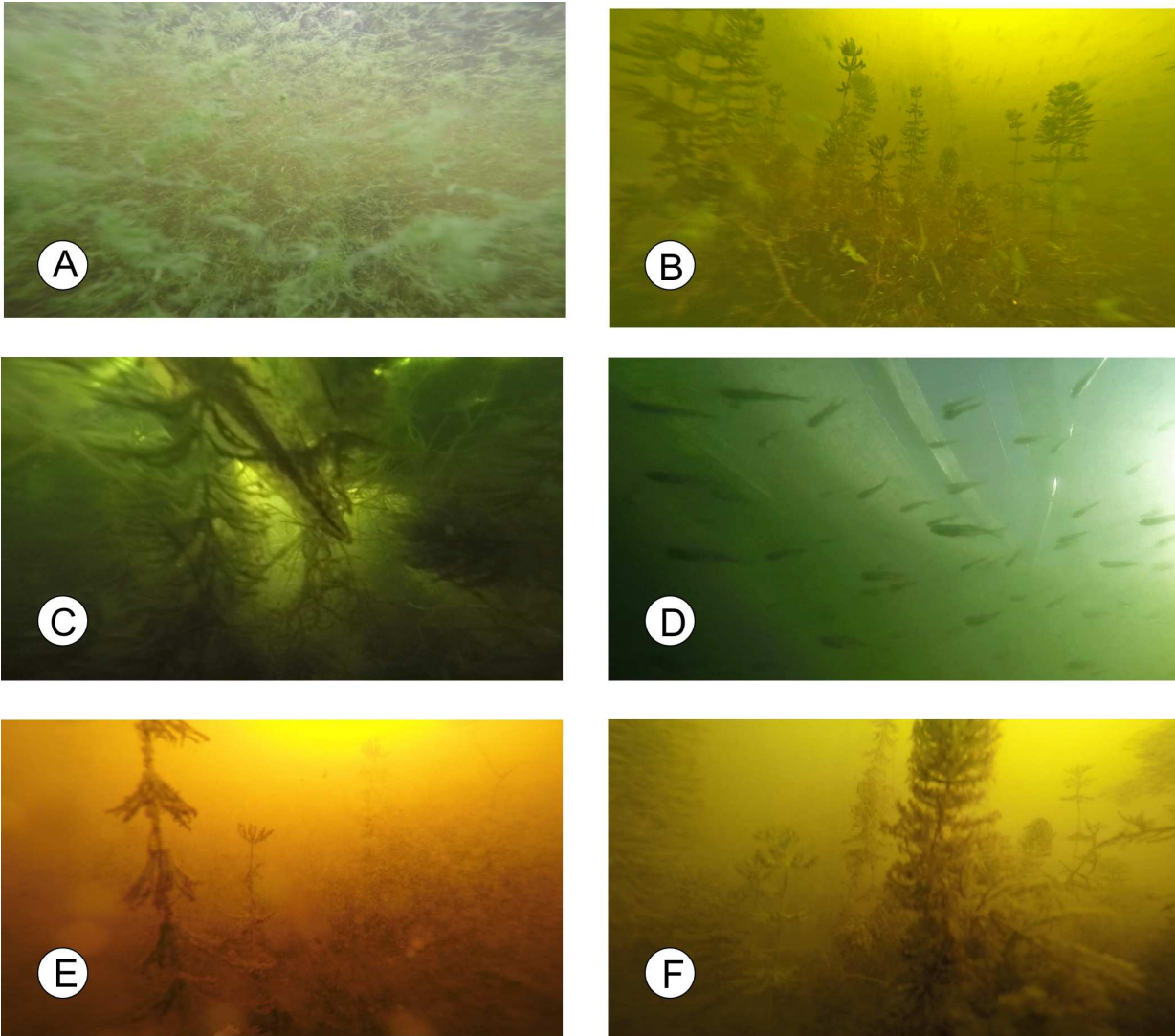
**Figure 9.** Impeded sunlight penetration on the western part of the lake.

It was observed that winds create surface circulation transporting duckweed and algae mats in the direction of flow. This material would often be pushed up against the shoreline creating zones or margins of dense green biota. On several occasions during the sampling process, it was observed that algae mats were free floating and moved much like clouds impeding light penetration directly below. Figure 10 shows a photograph taken July 13, 2016 which corresponds to the limited light penetration of that date on the secchi depth plot of Figure 8.



**Figure 10.** Algae bloom of July 13, 2016.

To better understand the distribution of biota within the water column, a GoPro camera was used to visually examine the water column qualitatively noting colour, relative densities of plant material, the presence of fish and the bottom plant life. The light penetration varied for different reasons. Sometimes light was impeded by algae overgrowth at the surface as was the case during algae blooms. Other times it was impeded by decaying plant matter suspended in the water column which created a dark tea brown hue. Several video captures were made to illustrate a variety of facets of the underwater environment as depicted in Figure 11.



**Figure 11.** Underwater video captures. (A) August dense leaf-like blue-green algae (*Aphanizomenon*), (B) summer bottom plant life, (C) dense floating surface plants, (D) school of sticklebacks, (E) September bottom plant life showing settling detritus, (F) bottom plant life coated in detritus.

## 5.2 Dissolved Oxygen

Probably the single most important measurable parameter of the lake is the amount of oxygen. This element promotes and sustains biological activities. Oxygen enters into the aquatic environment via two main pathways. Some atmospheric oxygen diffuses into the water at the air/water interface. This process can be accelerated through mechanical mixing such as wind and wave action, surface rain impacts or through turbulent flow such as water moving through creeks and rivers. The second pathway, which contributes to most of the dissolved oxygen at Swan Lake, is through plants.

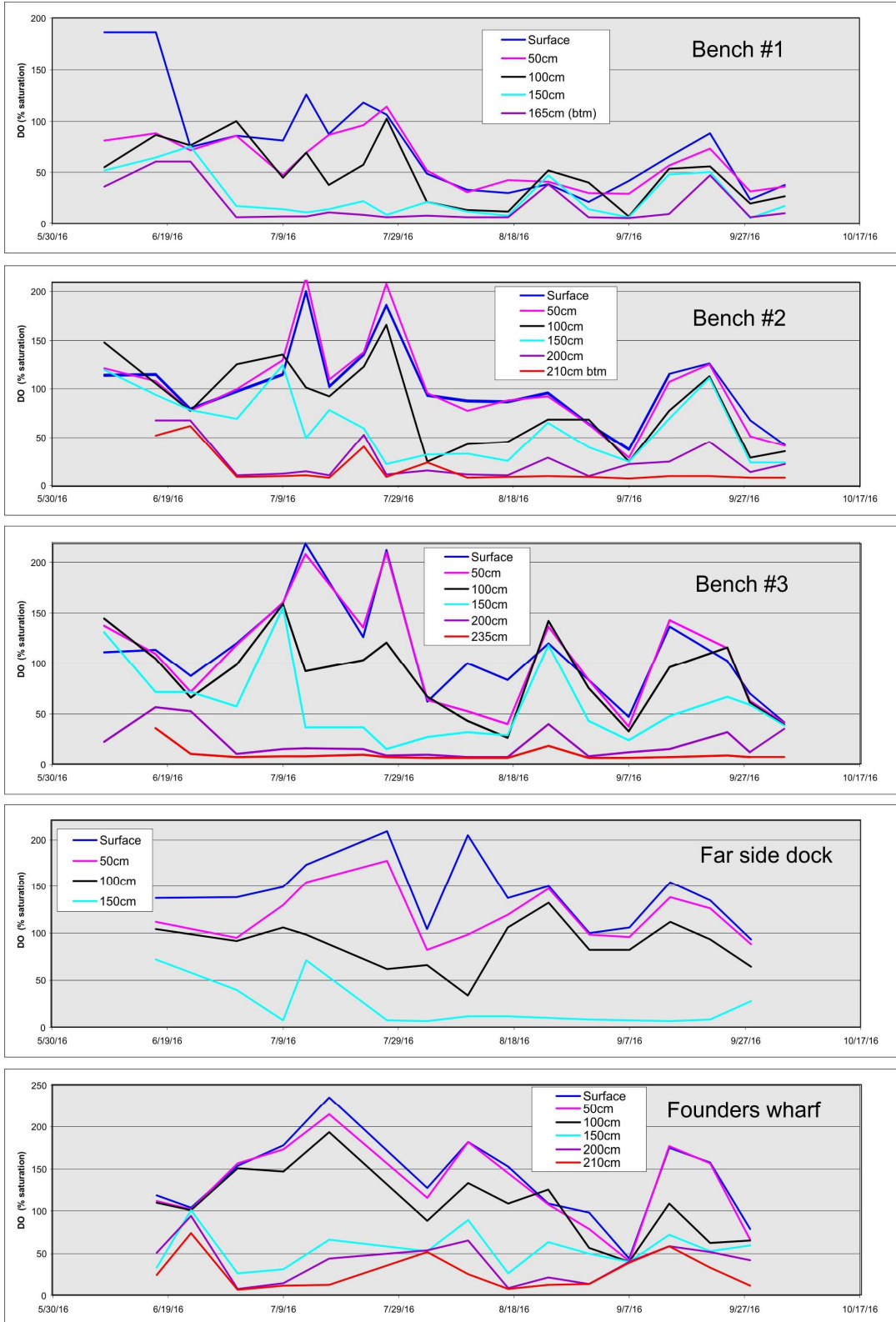
During the summer months, the bright sunlight, warm water temperatures and the supply of nutrients present ideal conditions for algae and bacteria growth. This has both positive and negative impacts. The positive impact is the prolific production of oxygen through the process of photosynthesis. In this process, CO<sub>2</sub> combines with water and sunlight to produce glucose that feeds the plants. As a byproduct of this reaction, oxygen is liberated and made available. The negative impacts of surface plant overgrowth is the blocking of sunlight to bottom plants as well as the potential die-off of biota should nutrients be consumed or if sunlight is obscured for a series of consecutive cooler cloudy days. The bacteria employed in the decomposition of these large number of plants results in a significant depletion of oxygen. Should the oxygen level become anoxic throughout the water column, fish kills can occur.

The YSI ODO probe was used to measure profiles at each of the sample sites. All sites typically had oxygen gradients where values at the surface were typically high and values at the bottom were, for the most part, anoxic. During summer algae blooms, oxygen levels at the surface were often super saturated. During these events, small oxygen bubbles could be observed at the surface or within algae mats as displayed in Figure 12.



**Figure 12.** Super saturation of oxygen shown here trapped within surface algae.

Temporal plots were made for each sample site with curves depicting dissolved oxygen at each profile depth. The sampling was conducted weekly between June 8 to October 4, 2016. These plots are presented in Figure 13.

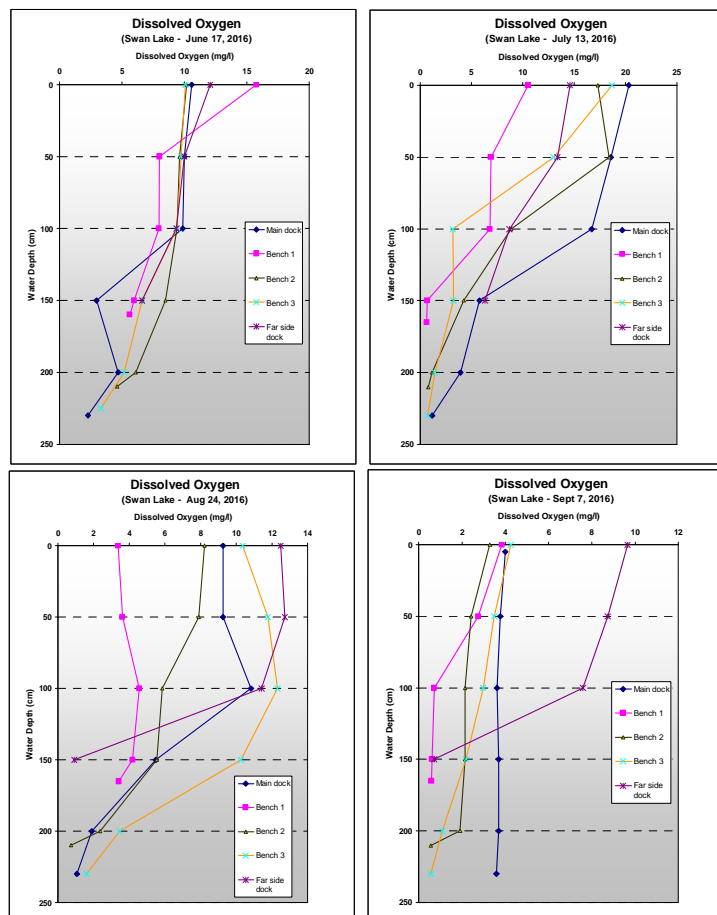


**Figure 13.** Dissolved oxygen curves for each sample site and profile depth.

Examining the dissolved oxygen curves of Figure 13 shows that the lake profiles are far from uniform. Although there are similarities in the boardwalk transect of benches 1, 2 and 3, variations from site to site suggesting that oxygen production in the lake is site specific. This could relate to the occurrence of plant species and abundance, prevailing winds as a vector to surface algae transport or proximity of sample sites to shallow shoreline influences. From GoPro video, the shallow shorelines tend to have an abundance of bottom plants that have access to light despite build ups of wind-blown duckweed.

Algae blooms do not necessarily affect the entire lake but can be localized. For instance, the boardwalk, which is somewhat permeable to surface algae drift, does create a collection zone which thickens biota, and, given the right conditions of sun and heat, can create an algae bloom which can temporally drive surface dissolved oxygen levels to well above 200% saturation. During these events (benches 2 and 3 – July 13 and July 27, 2016) visible bubbles could be seen bursting at the surface or suspended in the surface waters.

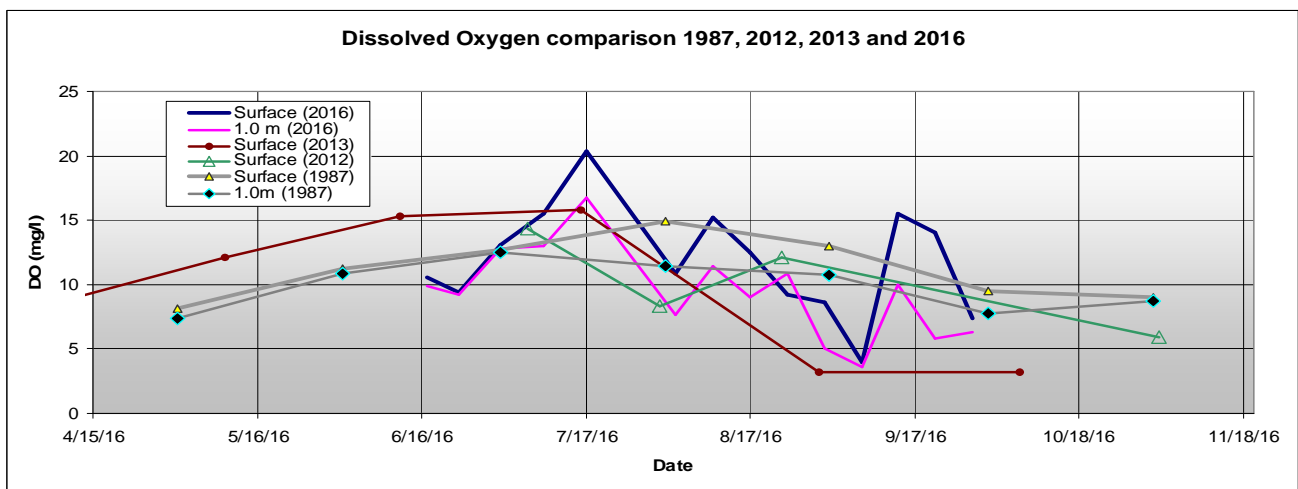
Along with the time series plots of Figure 13, a number of profiles are plotted in Figure 14 which depict typical dissolved oxygen profiles in units of mg/l.



**Figure 14.** Dissolved oxygen profiles.

The first three curves of Figure 14 clearly show a gradient of relatively high oxygen at the surface and anoxic conditions at the lake bottom. The September 7<sup>th</sup> data differs as it shows a significant drop in the dissolved oxygen levels with the exception of the far side dock. During the interval between August 24 and Sept 7, the water surface temperature dropped from about 22.5° C to 20° C and the number of daylight hours dropped by about 37 minutes. Just prior to September 7, the biological community was enjoying bright sunshine and relatively warm temperatures. Heavy rains and much cooler temperatures slowed the biological momentum and the dissolved oxygen profile curve, rather than displaying a downward slope with respect to depth, became almost vertical. Air temperatures within this interval also dropped from a daily average of 22.5° C on August 25 to a daily averaged of 12.8° C on September 5. This abrupt change rendered a mark decline in plant based oxygen production in the upper metre of water.

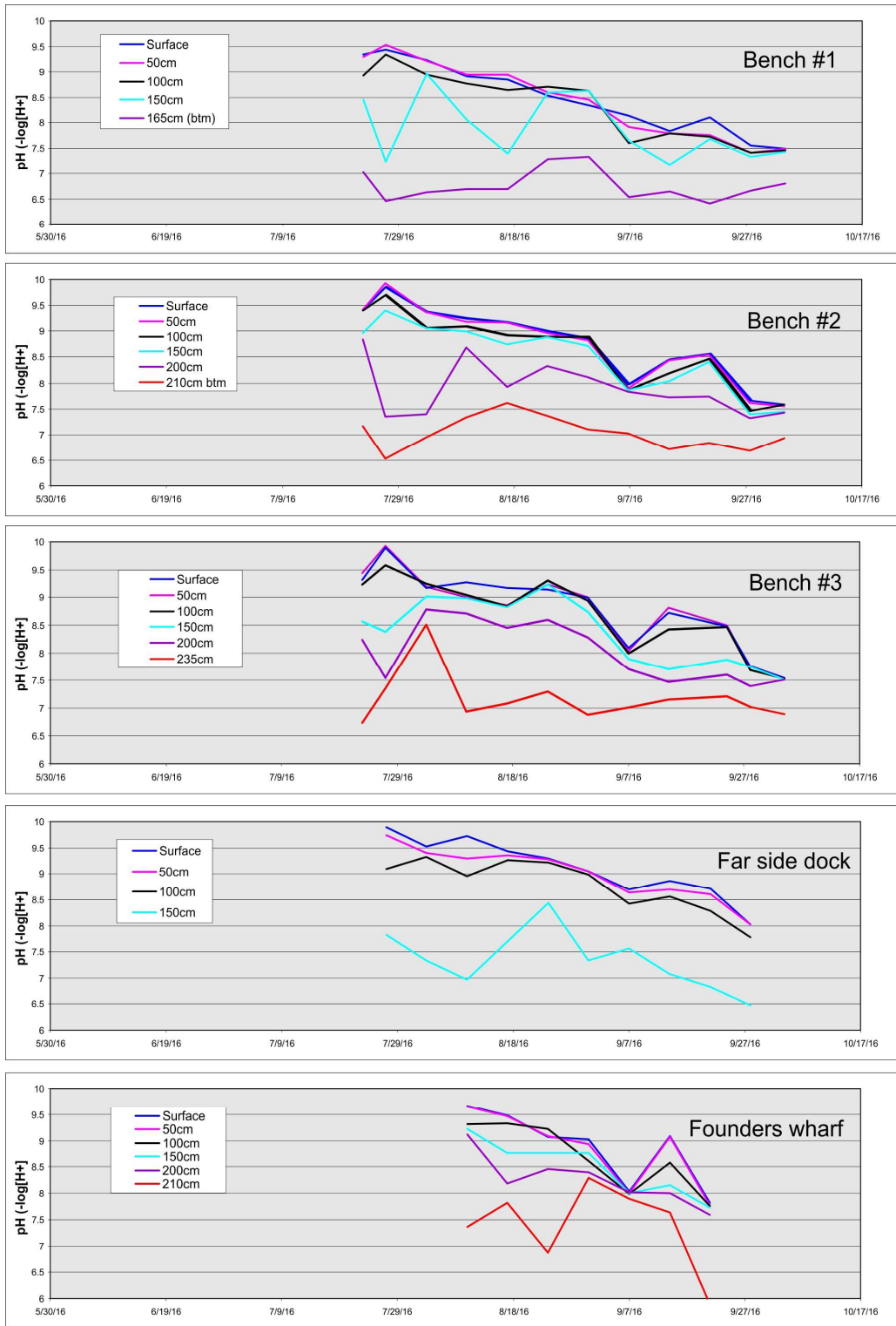
Dissolved oxygen data collected by Shelly Harnadek in 1987 and from field notes from 2012 and 2013 (yellow note book with initials JPT) were compared to the values obtained in 2016. Figure 15 shows this comparison in units of mg/l. Although the sampling interval in 2016 was weekly and other sources less frequently, the values show a similar magnitude of a common summer time elevation in the top 1.0 m. It can be seen here that increased sampling frequency reveals that lake conditions vary on time scales less than a month and likely even less than a week. As photosynthesis (plant-based oxygen production) is dependent on available daylight, even the time of day or the brightness of the day can affect the oxygen levels. To try and minimize the diurnal cycle, sampling was carried out consistently at the same time of day.



**Figure 15.** Dissolved oxygen profiles comparing samples taken in 1986 to the 2016 results.

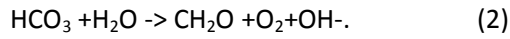
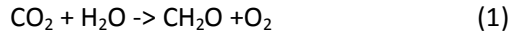
### 5.3 pH

The expired pH probe was replaced and became part of the sampling routine in mid July. Figure 16 shows profile curves for each site. Note there is a general decline in pH values at all sites moving from summer to fall.



**Figure 16.** pH curves for each sample site and profile depth.

To discuss pH in an aquatic setting, it is important to draw attention to available dissolved CO<sub>2</sub> and the respiration of aquatic plants. The equations that governs the photosynthesis process can be summarized in the following two equations:



Note in equation 2 the production of OH<sup>-</sup>. This ion creates alkaline conditions that tie up H<sup>+</sup> ions. During algae blooms where photosynthetic activities are highly active, the production of OH<sup>-</sup> tends to drive the pH level up at the surface. Lower down in the water column, where light penetration is limited, decomposing processes dominate and consume biota liberating H<sup>+</sup>. This hydrogen ion combine with H<sub>2</sub>O and dissolved CO<sub>2</sub> to create carbonic acid as describe in equation 3.

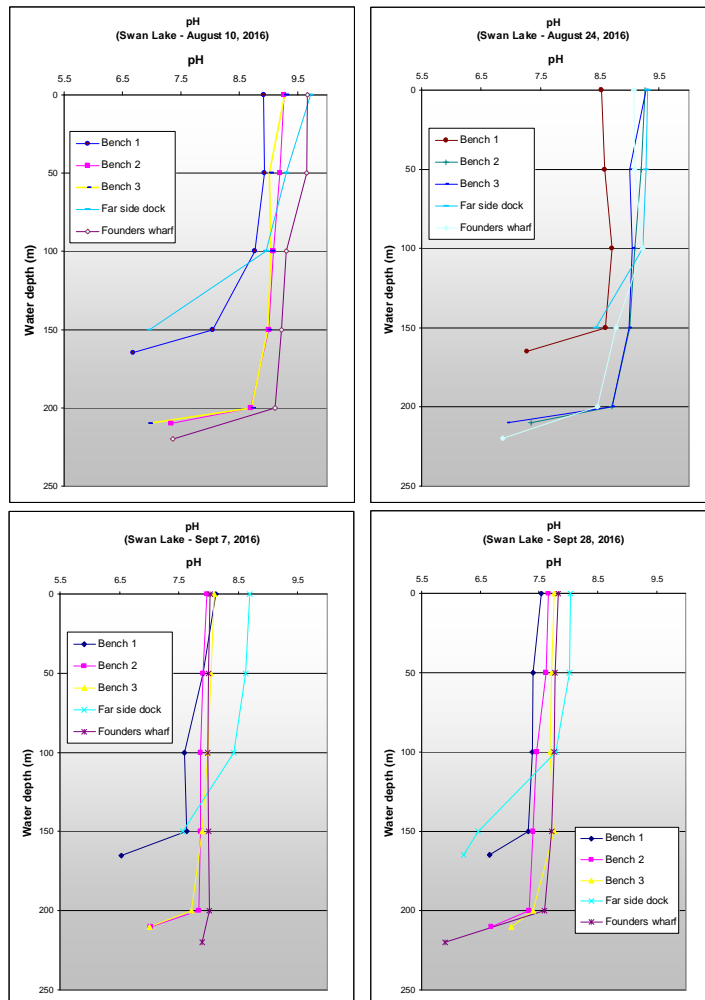


Figure 16. pH profile curves.

Examining Figure 15, there is a clear trend at all sample sites of pH declining from high summer values during peak plant production and respiration to values in the fall that are moving towards neutral as plant abundance drastically diminishes.

### 5.4 Nutrients

Water samples were taken at a number of sample sites around the lake. The inflow creek site was considered of great important as this has the potential to be a vector for external nutrient loading. Water samples were taken in a shady area just downstream from the walking trail wooden bridge at Blenkinsop Creek. Figure 17 presents both nitrate and phosphate concentrations.

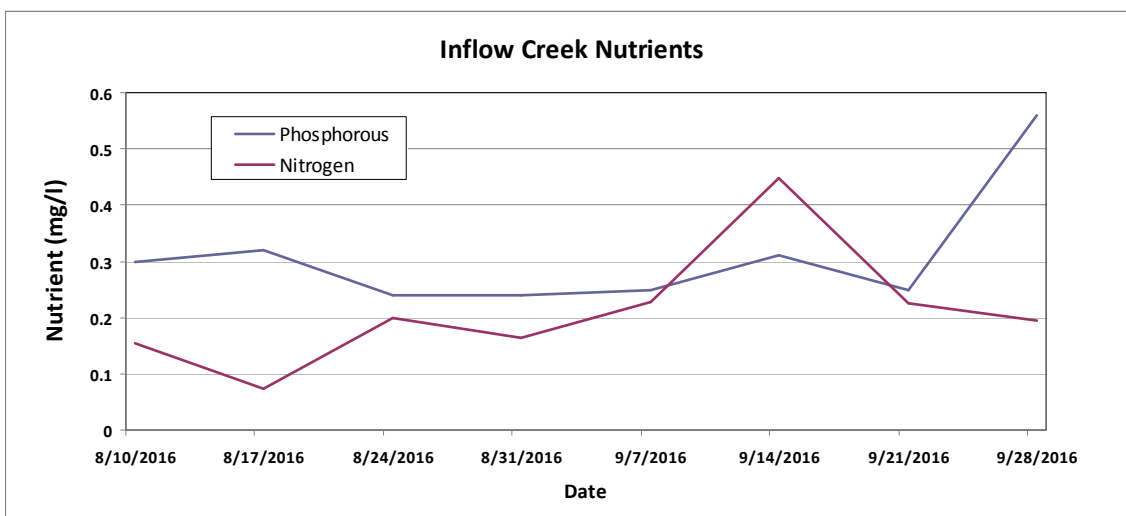


Figure 17. Surface water samples of nutrients taken from the inflow creek.

### Founders Wharf

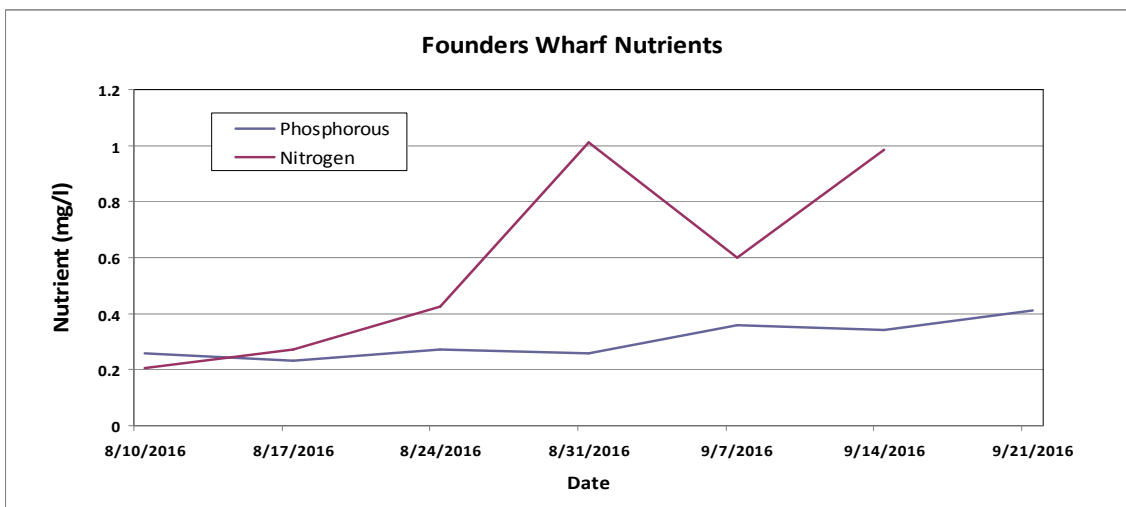


Figure 18. Surface water samples of nutrients taken from the Founders Wharf.

Note that these nutrient values fall within the same limits of measurements made in the 1970s, 1980s and 2013.

## 6.0 Conclusions and Recommendations

Swan Lake is a eutrophic lake that exhibits steep dissolved oxygen, pH and temperature gradients during the summer months. Algae blooms were observed during this sampling period especially in the west bay where the boardwalk sheltered the surface waters from the long east–west fetch of the lake. The boardwalk effectively acted as a barrier to wave action allowing the algae to form thick organic mats that blocked sunlight penetration to the water column. No fish kills were observed during this sampling period; however, there were brief periods where a pungent odor was present. Nutrient concentrations were measured during the latter half of the study as ordered reagents were delayed. These values will be useful for annual comparisons.

The following points outline a few recommendations for future consideration.

- 1) Monitoring water quality at Swan Lake is a proactive approach to detect changes in nutrient loading and ecosystem health. It is recommended that monitoring be a continuous strategy, especially as we observe an increase in weather extremes and climate change.
- 2) Data collected from this and other studies could be used as an educational tool as to how oxygen, pH, temperature and nutrients are inter-related and have influence on the overall health of the environment. One way to provide this educational tool would be to add a new component to the touch screen on water quality.
- 3) A GoPro camera was used during the study to observe the water column and lake bottom characteristics. This visual tool proved useful in several ways. Fish were observed at distinct depths. As specific fish have specific tolerances to dissolved oxygen, pH and temperature, these fish are constantly seeking favorable conditions. Using a camera could provide a method to correlate fish location with water quality perimeters. Better still would be to use a small portable fish finder to record the fish abundance and the water depth. Several models of fish finders are available for under \$300.
- 4) As the bathymetric chart for Swan Lake is several decades old, it is recommended that a new survey be conducted to update this data.
- 5) It is recommended that a species inventory be done for the lake to determine the biodiversity which would provide a benchmark to monitor changes.