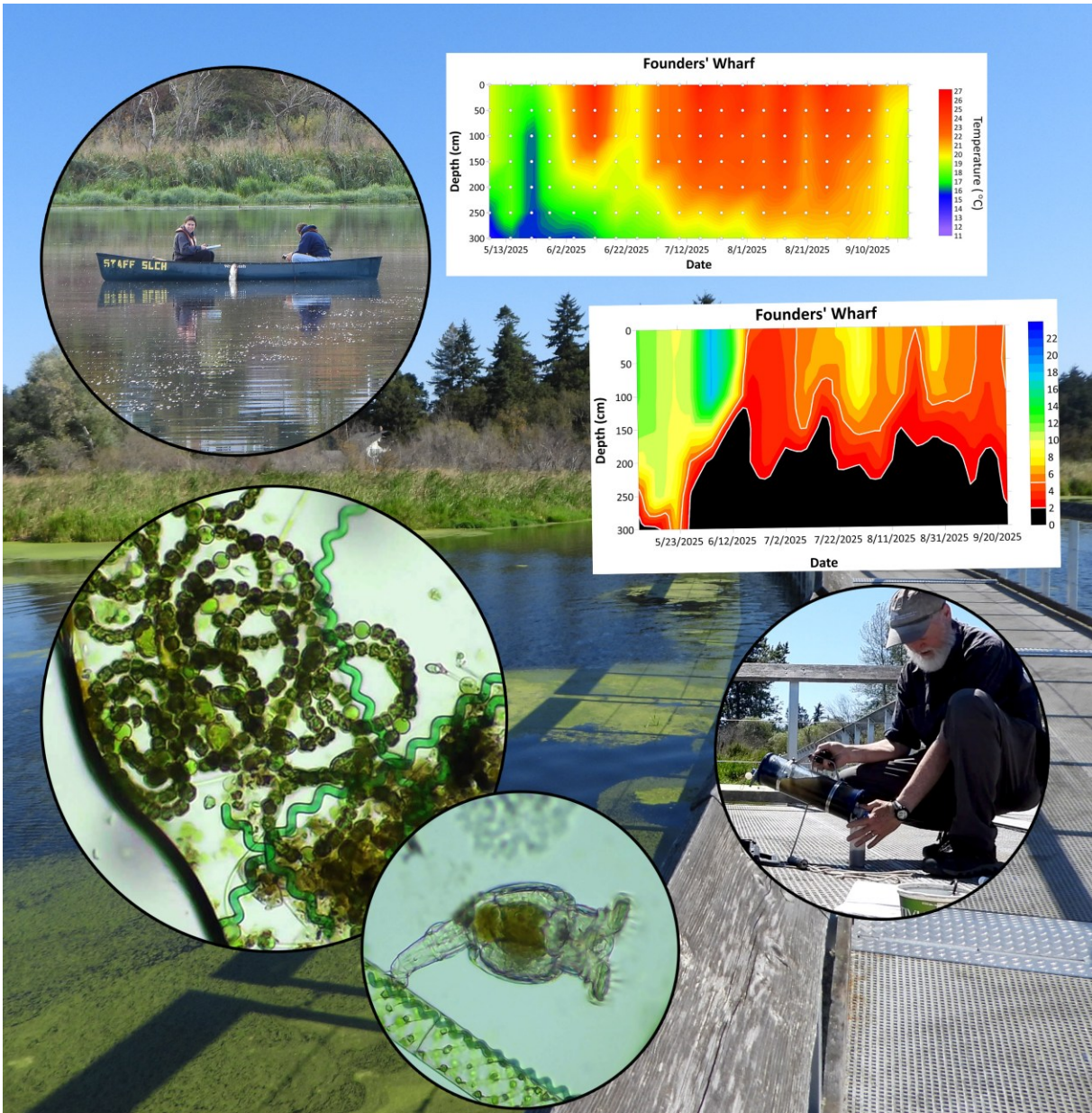


# Swan Lake Water Quality Monitoring May–September 2025



Submitted to Dr. Cara Gibson

By Robert Bowen  
Diversified Scientific Solutions

December 2025

## Executive Summary

This is the tenth consecutive year of water quality sampling using a consistent methodology. Key water quality parameters including dissolved oxygen, temperature, total dissolved solids, nutrients, chlorophyll-a and phycocyanin are summarized as time series plots and some interpretations are offered to address the interrelationships that influence the lake conditions. Data were collected at two lake sites and the inflow creek starting in May and ending near the end of September 2025. Data was also collected by Swan Lake staff at a deep-water site as part of a BC Lake Stewardship Society (BCLSS) level 3 study. To make a distinction between these two data sets, the water quality sampling carried out over the last ten years will be referred to as the long-term study and the level 3 study will be referred to as the deep-water site. Two solar lux loggers were deployed at a 60 cm depth to provide high temporal resolution within the limited photic zone. Data were collected every 30 minutes from mid-May to late September. In May, the dissolved oxygen levels were already elevated partially due to high values of chlorophyll from green algae as well as the presence of the cyanobacteria *Dolichospermum*. *Aphanizomenon flos-aquae* was present but never reached bloom state, an event that has happened in previous years in late spring periods. Of note, the filamentous morphology of the *Dolichospermum* was more linear than its typical coiled appearance based on surface samples examined under the microscope in mid-May. This year, the lake only experienced one extreme bloom in the beginning of June where the top 50 cm exceeded 18 mg/l largely due to high populations of *Dolichospermum*. During this time the DO concentrations became strongly stratified. As a result of this bloom, the phosphorus (P) levels within the top photic layer declined through metabolic processes until they were sufficiently depleted so that the bloom was unsustainable. Following this the lake saw a sharp reduction in dissolved oxygen. As the cyanobacteria died off and fell to the lake bed, there was a noticeable increase in water clarity from values of less than 0.5 m during the bloom to more than 1.6 m in late June as measured by Secchi disk depths. The DO levels slowly rebounded such that by the end of July, even down to a depth of 2 m, the DO level rose above the 2 mg/l threshold tolerance for fish. During this period, phycocyanin values rose at the deeper levels as did chlorophyll which may have been responsible for this deeper DO rise due to photosynthetic oxygen production. This is supported by an increase in light penetration during this time as measured by the lux loggers. The rest of the summer months maintained a relatively steady state with only small perturbations largely influenced by rain events and solar brightness. In this year's data, the lake volume with DO concentrations less than 2 mg/l was approximately 44% from early June to late September. This threshold was consistently at about the 2 m depth with hypoxic waters below.

Weekly water samples taken at one-meter intervals showed the dynamics of phosphorus, nitrogen, phycocyanin and chlorophyll as the lake cycled through algal bloom, die-off, decomposition and restoring forces. Contour maps of dissolved oxygen, water temperatures, phosphate and nitrates were created to help visualize lake dynamics through its various transitions. Multi-year plots are presented that compare interannual variability and a simplified dissolved oxygen seasonal pattern diagram is presented based on these data. Finally, recommendations are offered for future studies that would lead to a more comprehensive understanding of the dynamic processes at work at Swan Lake.

## Table of Contents

Executive Summary.....	i
Table of Contents.....	ii
List of Figures.....	iii
List of Tables.....	v
1.0 Introduction.....	1
2.0 Swan Lake Watershed.....	2
3.0 Selection of Sample Sites.....	3
4.0 Methodology.....	5
5.0 Data Collection.....	6
5.1 Weather.....	6
5.1.1 Air Temperature.....	6
5.1.2 Precipitation.....	7
5.1.3 Wind Speed.....	8
5.1.4 Solar Insolation.....	10
5.1.5 Barometric Pressure.....	10
5.2 Aquatic Parameters.....	11
5.2.1 Dissolved Oxygen Profiles.....	11
5.2.2 Water Temperature Profiles.....	17
5.2.5 Turbidity.....	20
5.2.6 Water Colour and Seasonal Changes.....	21
5.2.7 Chlorophyll-a and Phycocyanin.....	25
5.2.8 Lux Time Series.....	28
5.3 Collecting Water Samples.....	32
5.3.1 Phosphorus.....	32
5.3.2 Nitrogen.....	37
5.3.3 Turbidity.....	38
5.4 Water Levels.....	39
6.0 Interannual Comparisons.....	40

6.1 Dissolved Oxygen .....	40
6.2 pH.....	44
6.3 Secchi Depth .....	45
6.4 Nutrients .....	45
6.5 Water Temperatures.....	50
6.6 Microscope Imaging.....	51
7.0 Summary and Conclusions .....	52
8.0 Recommendations .....	53
9.0 Acknowledgements.....	54
10.0 References .....	54

## List of Figures

Figure 1. Swan Lake watershed boundary (source: CRD watershed maps). .....	3
Figure 2. Swan Lake bathymetry (source: Bowen 2021). .....	3
Figure 3. Water quality sample site. Red dots indicate data collected in this report and the yellow dot indicates the concurrent deep-water data collection. ....	4
Figure 4. Air temperature. ....	7
Figure 5. Decadal spring to summer surface water temperatures.....	7
Figure 6. Rainfall. ....	7
Figure 7. Wind speed from Colquitz Middle School weather station.....	8
Figure 8. Predominant wind direction. ....	8
Figure 9. Wind speed and direction from Colquitz Middle School 2025. ....	9
Figure 10. Solar insolation.....	10
Figure 11. Barometric pressure.....	10
Figure 12. Monthly dissolved oxygen (DO) profiles. ....	12
Figure 13. Deep-water site DO profiles.....	13
Figure 14. Dissolved oxygen time series plots for Founders’ Wharf, boardwalk and deep-water sites. ...	14
Figure 16. DO contour block diagrams of Founders’ Wharf (top) and boardwalk (bottom) sites. ....	15
Figure 17. DO contour block diagram of Founders’ Wharf site. The bathymetric plots and cross sections show the extent of the anoxic layer.....	16
Figure 18. Water temperature plots for Founders’ Wharf (top), boardwalk (middle) and deep-water sites (bottom). ....	18

Figure 19. Contoured block diagrams of water temperature at the Founders’ Wharf (top), boardwalk (middle) and deep-water sites (bottom).....	19
Figure 20. Dimictic stages at Swan Lake.....	20
Figure 21. Secchi depth time series plots for Founders’ Wharf and the boardwalk sites. ....	21
Figure 22. Time series of surface algae, water colour and microscope captures over the sampling season. ....	24
Figure 23. Wavelengths of light indicating the chlorophyll-a and cyanobacteria phycocyanin peaks. ....	25
Figure 24. Chlorophyll-a and phycocyanin plots of both lake sites. ....	26
Figure 25. Chlorophyll-a and phycocyanin plots of both lake sites for the years 2025 and 2023. ....	27
Figure 26. Ratio of Chlorophyll-a divided by phycocyanin at both lake sites. ....	28
Figure 27. Solar insolation from weather station plotted with the Founders’ Wharf and boardwalk lux loggers submerged at a depth of 60 cm. ....	29
Figure 28. Daily solar maximums at surface and 60 cm depth. ....	30
Figure 29. Percentage of surface sunlight reaching lux loggers at 60 cm depth. ....	30
Figure 30. Time series plot of lux, water temperature and Secchi disk depths for the Founders’ Wharf (top) and the boardwalk (bottom) sites. ....	31
Figure 31. The phosphorus cycle.....	33
Figure 32. Ortho-phosphate time series plots of Founders’ Wharf (top), boardwalk (middle) and deep-water (OP+TP bottom) sites.....	34
Figure 33. Phosphorus contour plot for the Founders’ Wharf. ....	35
Figure 34. Trophic State Index chart with Swan Lake ranges indicated by white arrows. ....	36
Figure 35. Diagram of lake characteristics of different trophic states (after Welch and Lindell, 1980). ...	37
Figure 36. Nitrogen time series plots for Founders’ Wharf (top) and boardwalk (bottom). ....	37
Figure 37. Nitrogen contour plots for Founders’ Wharf (top) and boardwalk (bottom). ....	38
Figure 38. Turbidity data for the two lake sites along with an integrated water column summary.....	39
Figure 39. Water level changes comparing pressure sensor data to line measured data. ....	40
Figure 40 overlays the 2025 data with previous data sampled near the surface of the Founders’ Wharf.....	41
Figure 41. Interannual comparison of DO time series at the Founders’ Wharf.....	42
Figure 42. Yearly DO concentration histograms (top). Scatter plot of percentage of DO models that are hypoxic (bottom). ....	43
Figure 43. Compilation plot of 2017 to 2025 DO concentration histograms.....	44
Figure 44. Interannual comparison of pH time series at Founders’ Wharf. ....	44
Figure 45. Interannual comparison of Secchi depth time series at Founders’ Wharf. ....	45
Figure 46. Interannual comparison of Founders’ Wharf phosphorus concentrations. ....	46
Figure 47. Comparison of phosphorus contour maps of the years 2020 to 2025. ....	47
Figure 48. OP and DO anoxic layer vertical migration coupling. ....	48
Figure 49. Interannual comparison of inflow creek phosphorus concentrations.....	49
Figure 50. Total phosphorus concentrations measured at Elk Lake (Nielsen, 2023). ....	49
Figure 51. Interannual comparison of nitrogen. ....	50
Figure 52. Surface and bottom temperatures for 2017–2025 (Founders’ Wharf). ....	50
Figure 53. Sample of microscope images.....	51

## List of Tables

Table 1. Daily extremal time of day for temperature, lux and solar insolation.....	31
Table 2. Lake trophic status (Environment Canada, 2004 and after Carlson, 1977).....	35

## 1.0 Introduction

This is the tenth year of monitoring Swan Lake following the steps and methods from the previous years. With the collection of water samples and water column profiles, year-to-year comparisons are providing insights into the physical, chemical and biological systems that govern the seasonal changes at Swan Lake.

The frequency of sampling a eutrophic, or at times, a hyper-eutrophic system where there are large diurnal oscillations, algal bloom states, responses to weather events and seasonal changes is an essential consideration. Unfortunately, the two HOBO U26 dissolved oxygen loggers were not deployed this year due to expired sensor caps. There were, however, two solar lux loggers deployed that measure temperature and light penetration which gave high temporal resolution of these two important parameters. The sample interval of these loggers was set to 30 minutes. These loggers were positioned in the water column at a depth of 60 cm at both the Founders' Wharf and the boardwalk. This was complemented by weekly site visits where an array of water parameters were tested along with a series of water column profiling at depth intervals of 50 cm to the bottom. Note that there was a disruption of nutrient sampling at these lake sites for the interval of June 14<sup>th</sup> to July 30<sup>th</sup>. Despite this gap in the long-term program, Swan Lake staff continued to sample nutrients, temperature and dissolved oxygen at the deep-water site throughout this gap and these data are presented as well to give further insights into the dynamic seasonal changes in the lake.

In this report, data is presented as time series plots to examine the temporal variations of each of the measured water properties including dissolved oxygen (DO), temperature, Secchi depth, nitrogen, phosphorus, chlorophyll-a, phycocyanin (PC), conductivity and total dissolved solids for the 2025 sampling period. 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 along with interannual time series comparisons with data spanning the years 2016–2025.

As this long-term study is a continuation from previous years, the initial sections of this report—those that define a brief history, the physical description of the lake and its watershed, the study site selection and the water quality monitoring methodology—will be repeated as they appeared in previous years' reports with a few updates.

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 large varieties of protected habitat in the midst of an increasingly developed landscape. Additional values of this feature are far-reaching as Swan Lake gives rest to migratory birds, provides water filtration and flood control, 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 low 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 nutrient imbalances result in conditions that exceed tolerable limits for fish and a host of organisms. During these algae blooms, visitors to the walkways around the lake can at times smell a pungent odor emitted from biomats that cover large parts of the lake and shore margins. It is quite common for the western end of the lake to be completely covered in algae. 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, May to the end of September 2017, April until the beginning of October 2018, April to the beginning of October 2019, May to the end of October 2020, May to October 2021, May to October 2022, May to October 2023, May to mid-October 2024 and most recently May to near the end of September 2025.

## **2.0 Swan Lake Watershed**

The general details about the location and attributes of Swan Lake are listed below (Figures 1 and 2).

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

Swan Lake watershed: Colquitz River 50 km<sup>2</sup> (Figure 1)

Swan Lake area: 9.3 hectares

Nature sanctuary: 48 hectares

Main inflow stream: Blenkinsop Creek

Main outflow stream: Swan Creek

Maximum depth: ~6 m (Figure 2)

Volume: ~ 317,872 m<sup>3</sup>

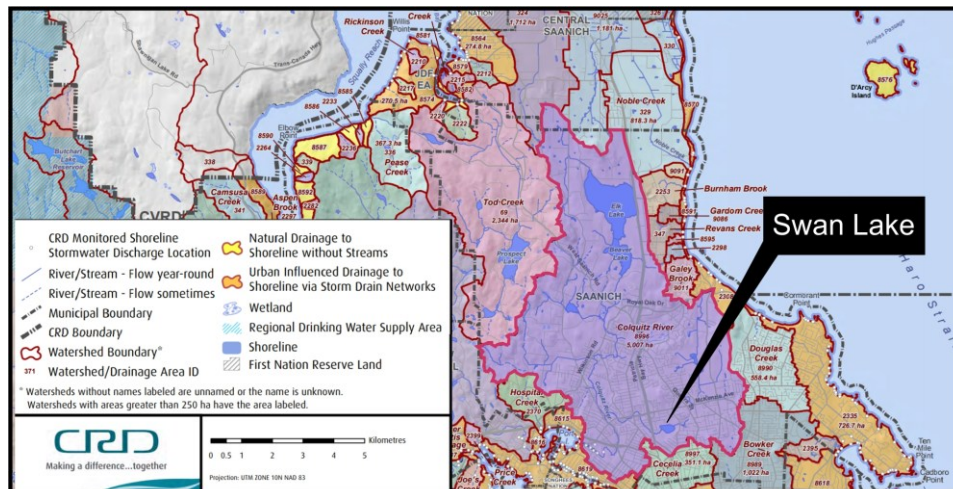


Figure 1. Swan Lake watershed boundary (source: CRD watershed maps).

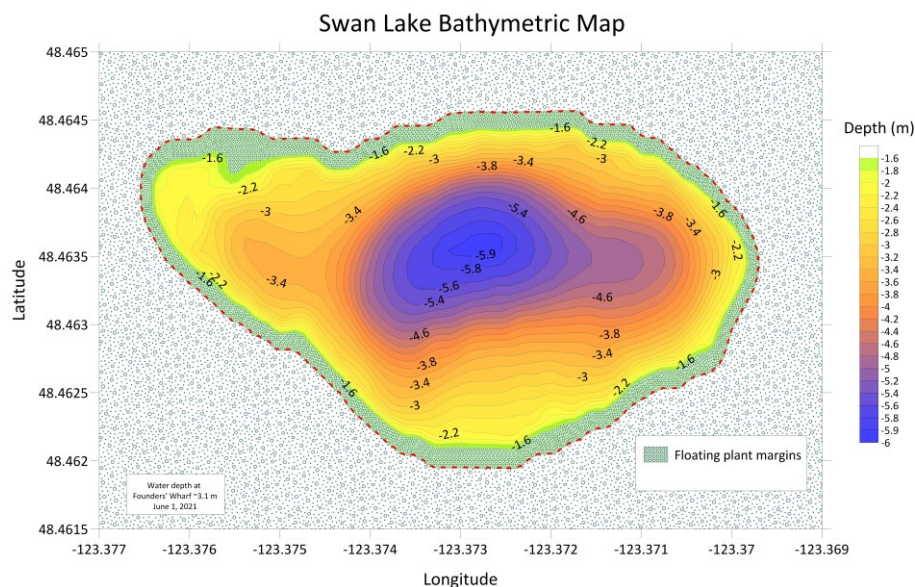


Figure 2. Swan Lake bathymetry (source: Bowen 2021).

### 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, two lake sites and the inflow creek were selected. In addition, a deep-water site was sampled as a separate initiative carried out by the good work of Deanie Harding and Kristen Banasch. Some of these data were used to fill in a gap in the summer data collections. The positions of these sites are indicated in Figure 3. Each site will briefly be described and the selection rationale will be discussed.

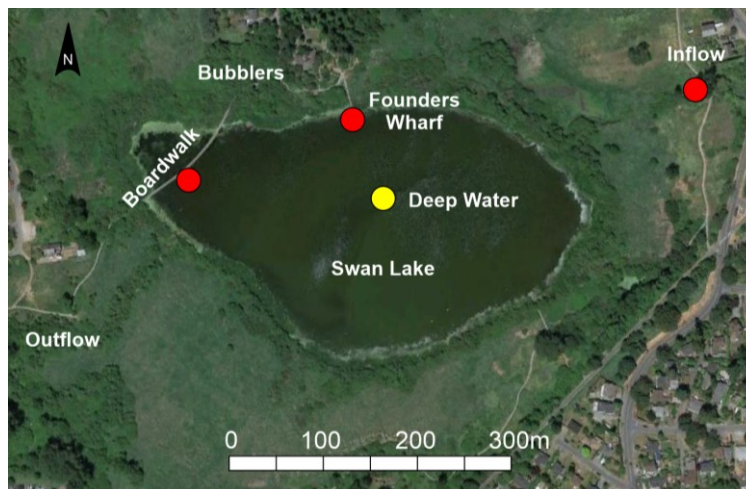


Figure 3. Water quality sample site. Red dots indicate data collected in this report and the yellow dot indicates the concurrent deep-water data collection.

Sampling was carried out around the lake with the first lake site, typically, located at the Founders' Wharf. This site was at the mid-point between the inflow and outflow creeks and the wharf structure extended out from the shoreline to a water depth of approximately three metres. This site provided easy access and was a good stable platform for deploying instruments such as the Acoustic Zooplankton Fish Profiler deployed in the 2018 field season (Bowen, 2018). As will be discussed, this site is where a solar lux logger and a bottom pressure sensor were deployed to examine diurnal cycling and changes in water levels over several months.

The second lake site was located at the mid-point of the boardwalk, typically. This site was away from the influence of the shore margins and was approximately 100 m from the outflow creek. Unfortunately, the dock that was located on the southeast side of the lake had been removed. This had been a key sampling site in years past as it was relatively close to where the inflow creek entered the lake. The final sample site was located at the Swan Lake trail bridge at Blenkinsop Creek, a potential input of urban and agricultural runoff carrying nutrients to Swan Lake. Elapsed field work time to complete the sampling typically was about three to four hours followed by another three hours of lab work to analyze nutrients. A complete set of sampling was done weekly from the beginning of May to near the end of September with a data gap in mid-June to the end of July. The deep-water site was selected as it was the deepest point in the lake to examine the complete water column. An anchor and surface float were placed using GPS coordinates that were taken from the deepest point from the bathymetric survey carried out in 2021 (Bowen, 2021). Weekly profiles were taken at this deep-water site spanning a 20-week period (May–October 2025).

Water chemistry to determine weekly phosphorus, phosphates, nitrogen and nitrates was done in the Diversified Scientific Solutions' laboratory for data collected for the long-term study. Water chemistry was also collected from the deep-water site and samples were sent out for analysis bi-weekly.

Water samples were also examined under a microscope to observe abundance and succession of algal and zooplankton species throughout the May to September 2025 study period.

## 4.0 Methodology

Profiles were taken at each lake site at the surface and at 50 cm intervals to the bottom. These profiles were taken with a YSI handheld meter and associated probe. The YSI “Pro ODO” measured barometric pressure, dissolved oxygen (DO) in percent saturation and mg/l of oxygen as well as water temperature. The YSI “Professional Plus,” a multiparameter probe, which measured pH and ORP suffered moisture damage and was not used this year. To replace this unit, a Hanna multiparameter pH/ORP/ DO/Temp and Barometric pressure sensor was ordered but arrived mid-way during the sampling season. Setting up this galvanic sensor along with sensor calibrations required some trouble shooting involving Hanna technicians. It was only near the end of the season that this instrument appeared to be working so only limited pH and ORP data was collected. Prior to winterizing this instrument, calibration procedures, sensor cap installation and maintenance were well documented in preparation for next year’s setup. In addition to the profiling, a Secchi disk was used to measure water clarity, and a GoPro 4 Silver was used to acquire underwater video for visual inspection of water colour and the presence of water column algae. Weekly single point 100% saturation DO calibrations were performed prior to the first set of profile measurements.

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: the DO probe was suspended such that the probe was just below the surface with all parts of the probes submerged. Readings from the meter was recorded once values stabilized. This stabilization usually took about two to three minutes but there were many situations where this interval was longer especially during algal blooms. The DO probe was then lowered at 50 cm increments and values were recorded at each increment. The final readings were taken with the probes resting vertically on the bottom.

Secchi depths were recorded by lowering the disk into the water column until the disk was no longer visible and then brought back up to being visible. Generally, each lake site had recorded Secchi depths with only a few exceptions. In some cases, in previous years, 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. In these cases, a Secchi depth of zero was recorded as light penetration was significantly impeded by the algae. In the 2025 data set, there were no cases where there was 100% algae coverage at the time of testing.

Video recordings using a GoPro camera 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, water colour, bottom plant life, bottom hardness and the presence of bottom detritus.

Water samples were taken at all three sampling sites weekly. At the lake sites, a Van Dorn bottle was used for collections at water depths of 10 cm, 1 m, 2 m and 3 m depths. Before bottling, capping and labeling these water samples, several water quality parameters were measured. Two Turner FluoroSense handheld fluorometers were used to measure chlorophyll-a and phycocyanin, key indicators to quantify algal blooms. In addition, total dissolved solids (TDS), conductivity and salinity were measured. All water samples taken for the long-term study were analyzed for nutrients at Diversified Scientific Solutions' lab using a YSI 9500 photometer. Nitrogen, nitrates, phosphorus and phosphates were tested by following strict procedures using reagents and timed mixing intervals. Water samples were processed the same day in order to capture accurate concentrations with only a few exceptions where samples were processed the following day. These values were recorded for temporal comparisons.

As the diurnal cycles of DO and sunlight vary significantly over the course of the study period, two HOBO Lux loggers were deployed at a depth of 60 cm at both lake sites. Each logger recorded continuously with sample intervals of 30 minutes.

## **5.0 Data Collection**

### **5.1 Weather**

Weather data were collected from the Swan Lake weather station located on the Nature House roof. The weather station is part of a school-based weather station network that can be found at this link: (<http://www.victoriaweather.ca/station.php?id=134>). These data are presented below as plots and are referred to in the text as discussion points that consider the influence of climatic factors and their role in modifying lake processes. Unfortunately, not all elements of the weather station were working during this sampling season. Data for wind speed and gusts did not present reasonable data at the Swan Lake station. Maintenance of these instruments is recommended. For wind data, the weather station at Colquitz Middle School was used as this station was approximately 1.5 km from Swan Lake.

#### **5.1.1 Air Temperature**

Air temperatures (Figure 4) influence water temperature through surface contact and through the agitation of wind and waves. It is also the interface where oxygen exchange between the atmosphere and the lake can occur. Some of the surface algae have the ability to sequester atmospheric nitrogen at this air/water interface. Warming and the lengthening of daylight hours in the spring increase the metabolic rates of aquatic species and the reverse occurs as temperature and daylight hours decline in the fall. Water temperatures for the month of June were examined as this is a month that typically sees a strong acceleration of algal growth and commonly has the most extreme seasonal algal blooms. The spring to summer rise in water temperatures for the past decade are displayed in Figure 5. The 2025 curve generally fell within a slightly higher than average to average range when compared to those measured over the 2017–2024 period (Figure 5).

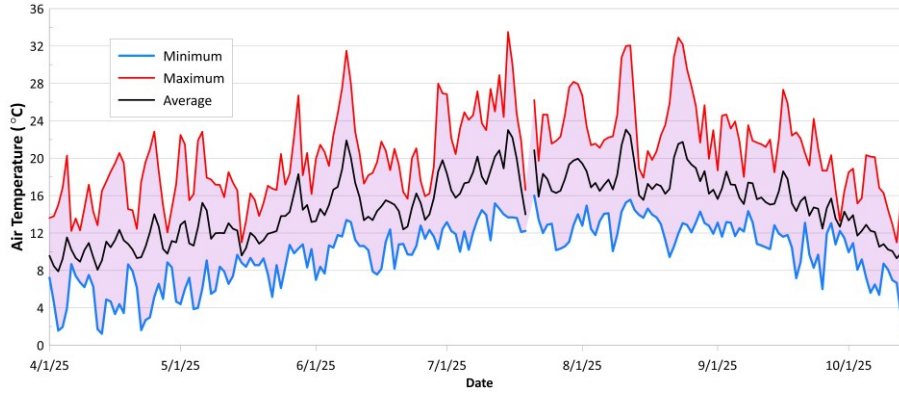


Figure 4. Air temperature.

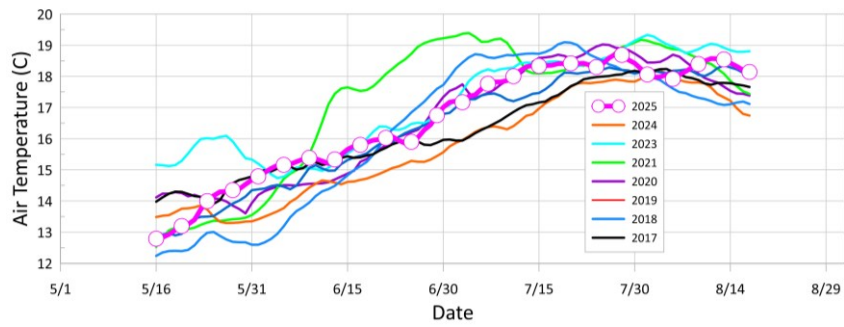


Figure 5. Decadal spring to summer surface water temperatures.

### 5.1.2 Precipitation

Rainfall (Figure 6) events can rapidly change the surface water temperature and introduce oxygen through raindrop impacts. It is also associated with low sunlight levels, reducing the photosynthetic processes and often results in fluctuations in dissolved oxygen concentrations. This figure represents the rain that fell within the study period.

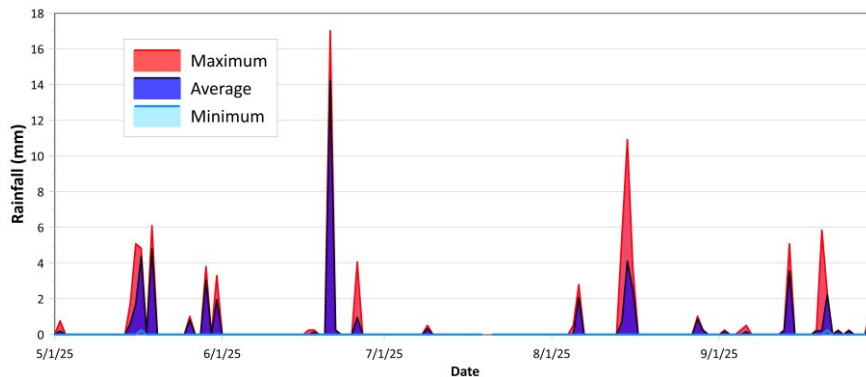


Figure 6. Rainfall.

### 5.1.3 Wind Speed

Unfortunately, the wind speed instrument located on the roof of the Nature House was not functioning properly during this sample season. This is a key parameter as it influences surface wave formation, the exchange of heat, orbital mixing and the atmosphere–water gas transfer exchange of dissolved oxygen and carbon dioxide. Wind data, however, were available from the Colquitz School weather station located approximately 1.5 km from Swan Lake and these data are reported here (Figure 7).

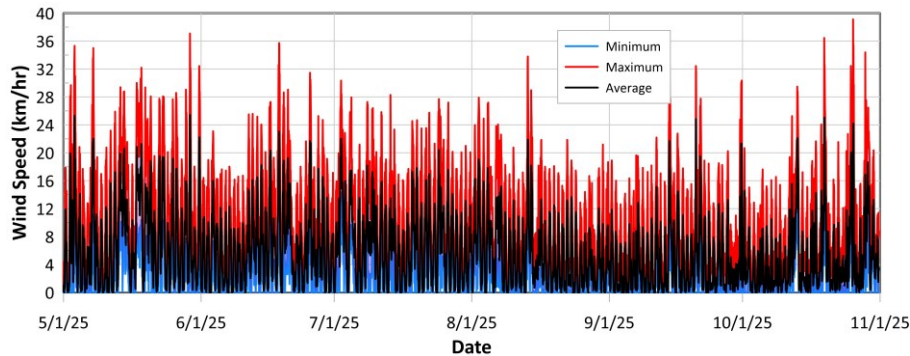


Figure 7. Wind speed from Colquitz Middle School weather station.

The predominant direction of wind along wind roses are reported in Figures 8 and 9. Each month has been plotted along with a summary plot of all wind data during the study period. Note the wind direction over the season was predominately from the southwest. This was observed most often while sampling at the Founders' Wharf where winds coming from the southwest propagated waves towards the wharf. Along with influences already mentioned, wind plays a significant role in modifying water quality at Swan Lake as it is responsible for the driving forces that move and redistribute the mobile surface algae. During calm wind conditions, duckweed and other plants such as the *Azolla filiculoides* in previous years like 2019 tend to spread out over the surface of the lake typically in the months of August and September. Calm conditions were most often during the night and early morning before the influence of solar convective currents. As winds picked up, these algae were driven to the shoreline margins, dynamically changing the light penetration within the water column at these affected areas.



Figure 8. Predominant wind direction.

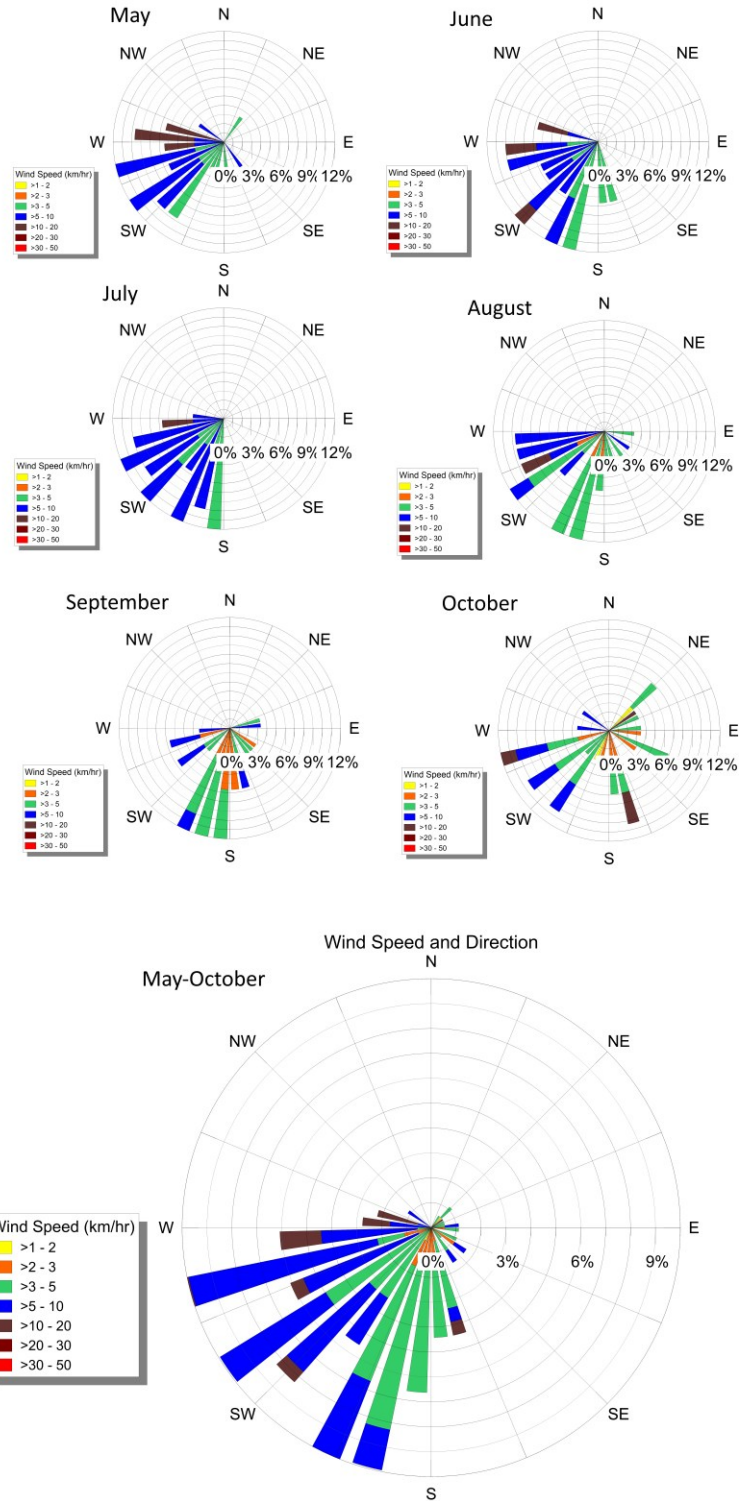


Figure 9. Wind speed and direction from Colquitz Middle School 2025.

### 5.1.4 Solar Insolation

As cyanobacteria and aquatic plants are dependent on solar input, solar insolation—which is a measure of solar energy—is vital to their required metabolic processes. Figure 10 displays the maximum and average solar input as measured at the Swan Lake weather station. The general curve shows the slow increase of sunlight insolation from May 1 (daylight duration 14 hr 35 min 0 sec) to its maximum on June 20, 2025 (longest day 16 hr 06 min 46 sec). This is followed by a tapering of daylight to a point on the last day of the sampling program of September 23<sup>rd</sup> where the sunlight duration was reduced to 13 hr 52 min 52 sec. The dips in the solar radiation are often associated with dips in dissolved oxygen concentrations as will be discussed with the dissolved oxygen data.

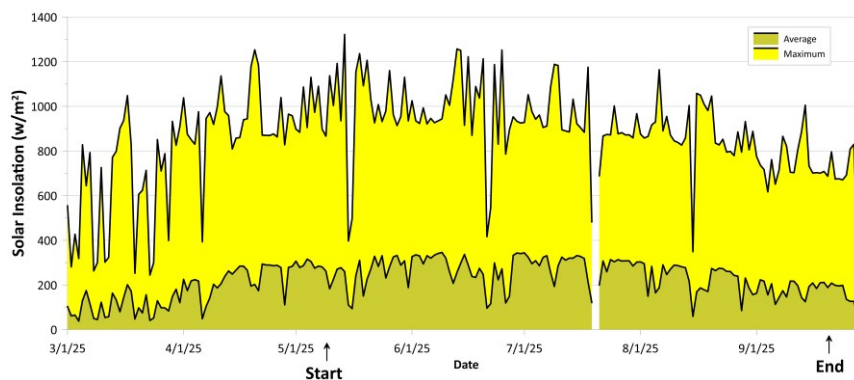


Figure 10. Solar insolation.

### 5.1.5 Barometric Pressure

The barometric pressure (Figure 11) is noted here as it is an important component for dissolved oxygen concentrations. The YSI ODO probe uses the barometric pressure and water temperature to calculate DO concentrations in  $\text{mg/l}$  or express DO concentrations as percent saturation. The barometric pressure is also used in calculating the water levels as the pressure sensors deployed at the bottom of the lake measure total pressure which includes the hydrostatic pressure of the weight of water above the sensor as well as the atmospheric pressure. The water depth requires the removal of the atmospheric barometric pressure and an adjustment for the elevation above sea level.

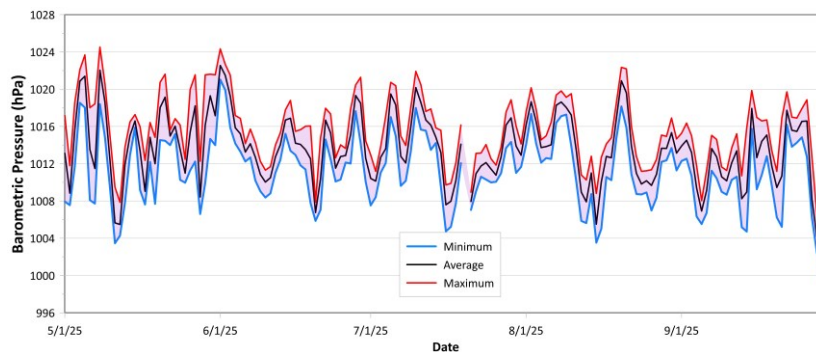


Figure 11. Barometric pressure.

## 5.2 Aquatic Parameters

Data collected from the various field instruments are presented in this section including the YSI optical DO/temperature probe, the Secchi disk, the fluorometers and other water properties. Plots are included with brief discussions of interesting features. Water samples collected for nutrient analysis will be discussed in a separate section.

### 5.2.1 Dissolved Oxygen Profiles

As has been observed in past seasons, the DO concentrations vary significantly throughout the year. Dissolved oxygen is largely influenced by temperature, solar input, mechanical mixing, air/water interface exchanges, nutrients and biological processes including photosynthetic oxygen production and oxygen consumption through respiration. The values measured in the collected profiles are the result of complex interactions that involve various players that change through the year. Just as terrestrial plants have a seasonal succession, so too do aquatic plants or macrophytes, phytoplankton, various algal species and zooplankton. This order, depending on the species, is largely governed by nutrient thresholds, predator–prey relationships, temperature and light penetration. These successions ripple through all parts of the food web and create feedback relationships. Understanding lake processes is a comprehensive task and DO is certainly one of the most important parameters that influence many of the organisms associated with the lake. To ensure that accurate data were obtained, a two-point calibration of 0% and 100% saturation was performed at the beginning of the sampling season and a 100% saturation calibration was performed prior to each sample day.

Figure 12 shows month-to-month seasonal variations of DO with respect to water depth. Note at the beginning of the study period, the DO values at both the Founders' Wharf and the boardwalk were oxygen rich with uniform concentrations of about 10 mg/l down to a depth of 2.0 m. Below this the DO values dropped to near half near the bottom indicating that weak stratification had already begun in early May. By June, strong stratification was well established. During the early days of June, a cyanobacteria bloom forced the top meter DO concentrations to their seasonal high of about 18.5 mg/l along with a well-established anoxic layer in the bottom one meter. It was at this time secchi disk depths were as low as 0.4 m, their seasonal lowest values. Within two weeks of the peak of this bloom, DO levels saw a dramatic drop clearly delimiting the cyanobacteria die-off as seen in the June 18<sup>th</sup> profile. Unlike several other years (2017, 2018, 2021, 2023, 2024), 2025 only experienced one major bloom and die-off event with only a relatively small minor rise in DO at the end of July. There was evidence that wind and wave action in the month of September was beginning to mix, but the sampling season for the long-term study ended before the fall overturn. Monthly profiles for the deep-water site are also presented in Figure 13.

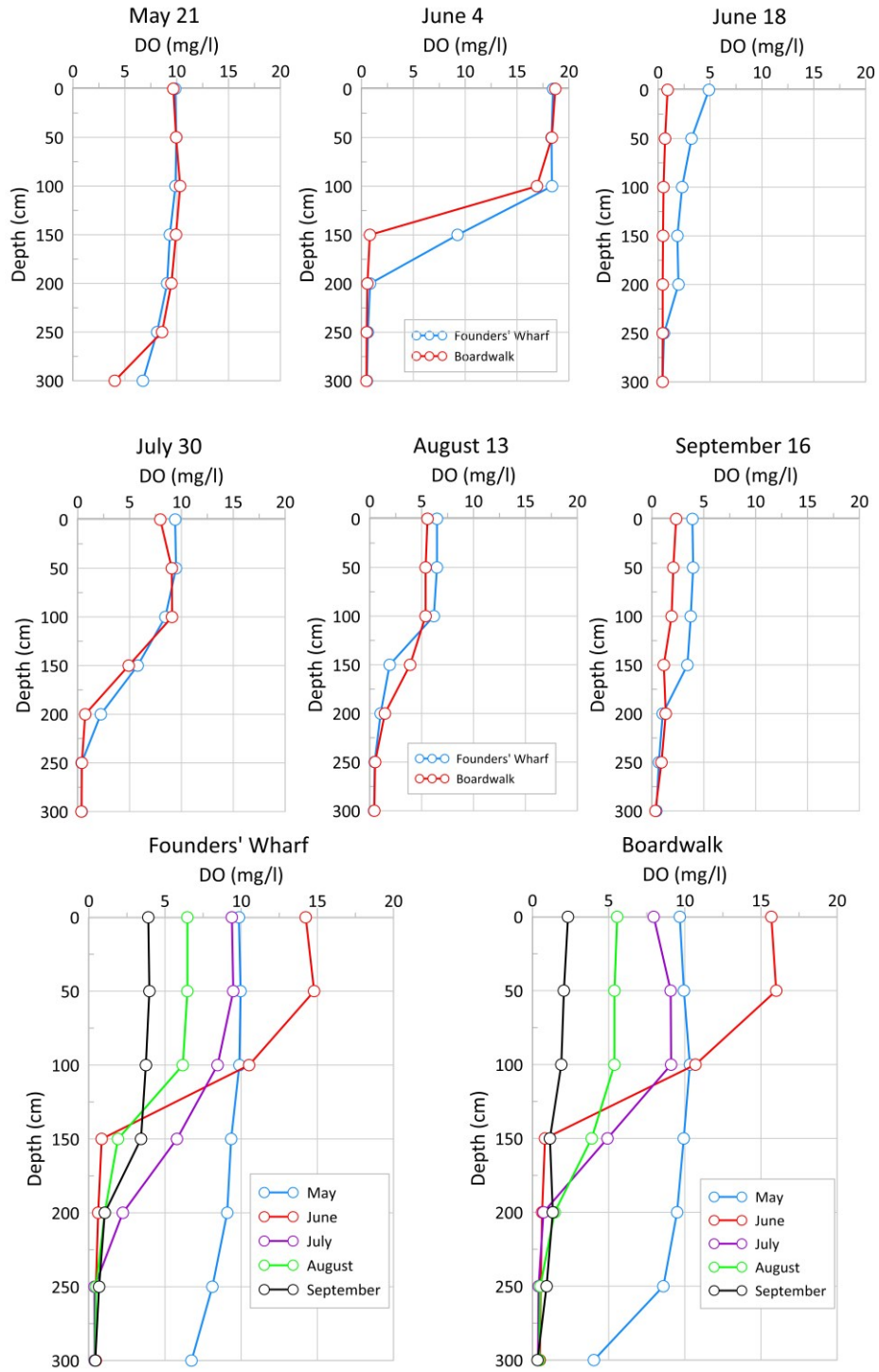


Figure 12. Monthly dissolved oxygen (DO) profiles.

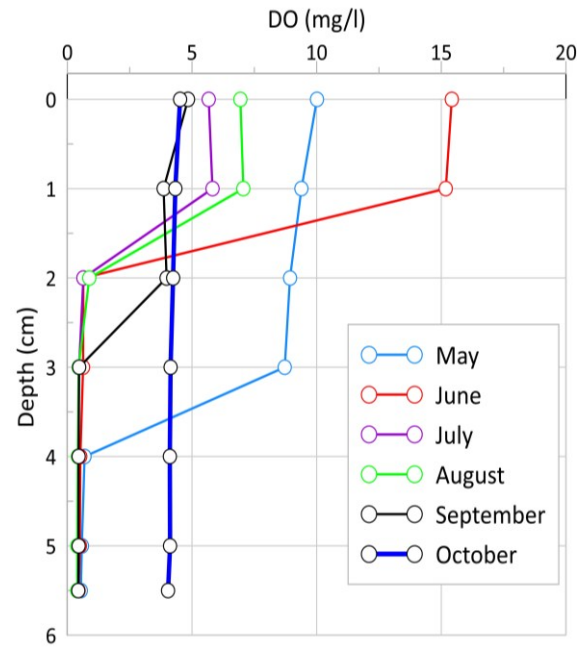
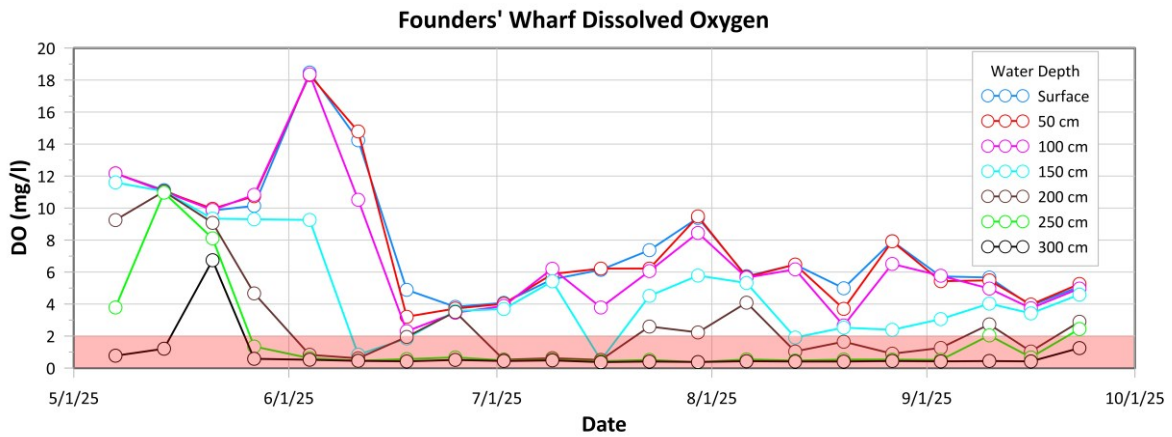


Figure 13. Deep-water site DO profiles.

The profiles recorded at the deep-water site show a similar story in the upper 3 m as the long-term study. In all data collected, below 3 m, the lake is anoxic from June through September. In October the deep-water site clearly shows the fall turnover with uniform DO concentrations right down to the bottom.

Time series for both the Founders' Wharf and the boardwalk as well as the deep-water site were plotted for each of the site visits throughout the study period (Figure 14).



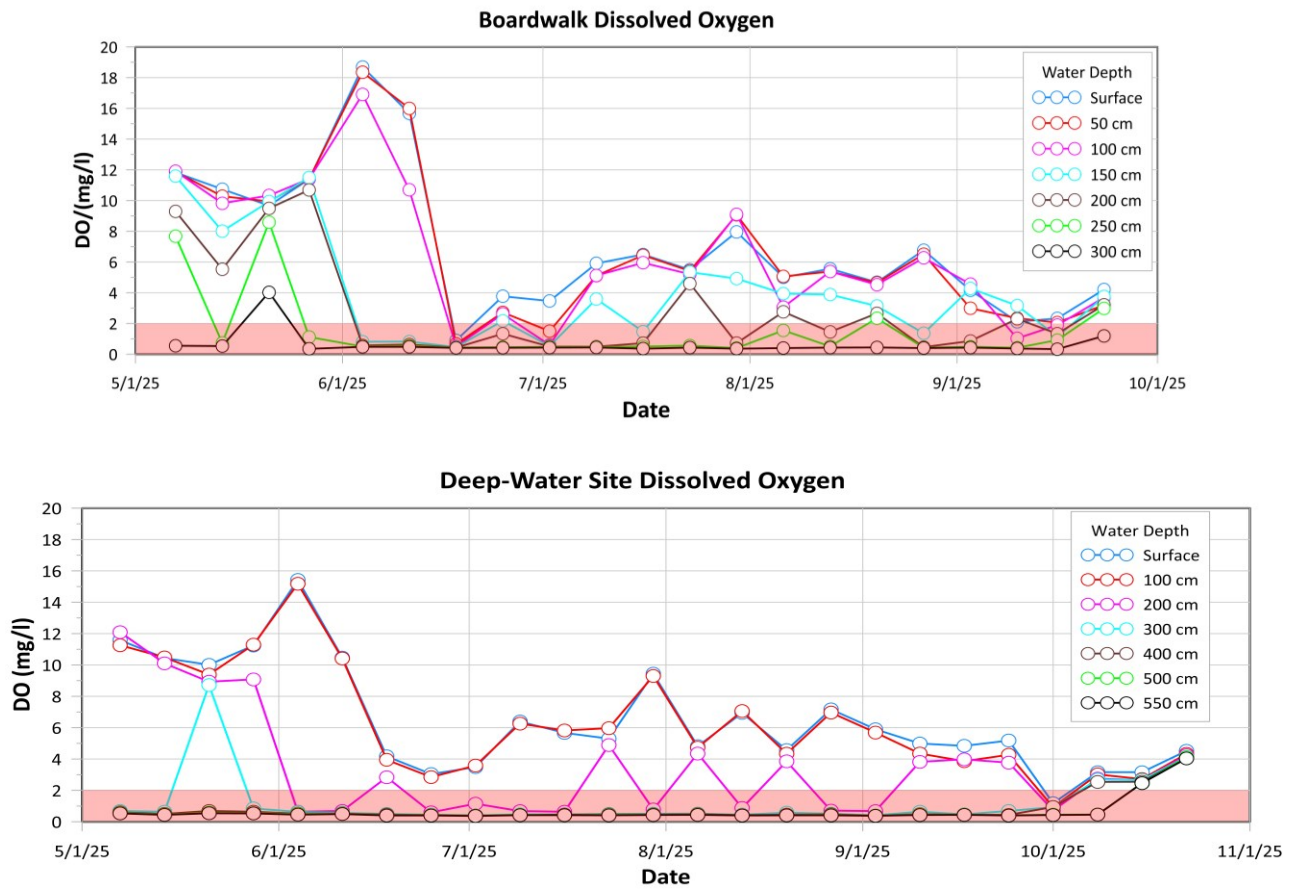


Figure 14. Dissolved oxygen time series plots for Founders' Wharf, boardwalk and deep-water sites.

These plots clearly show the onset and decline of the algal bloom and die-off as supported by field observations and microscope captures. The dominate species of this bloom was *Dolichospermum* which turned the water colour to a deep dull green colour as seen in the Figure 15.

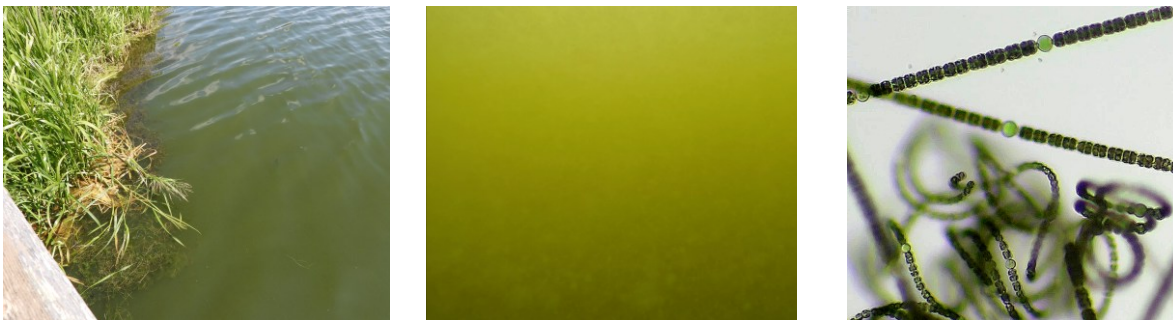


Figure 15. Dolichospermum bloom. Left to right: water surface, underwater capture, microscope image.

Another way to display DO data was to create a set of block diagrams that contour the DO concentrations with X as time, Y as depth and DO as the Z contours. These block diagrams are depicted in Figure 16. Note the distinct algal bloom at all three sites represented by high concentrations of DO (green shading).

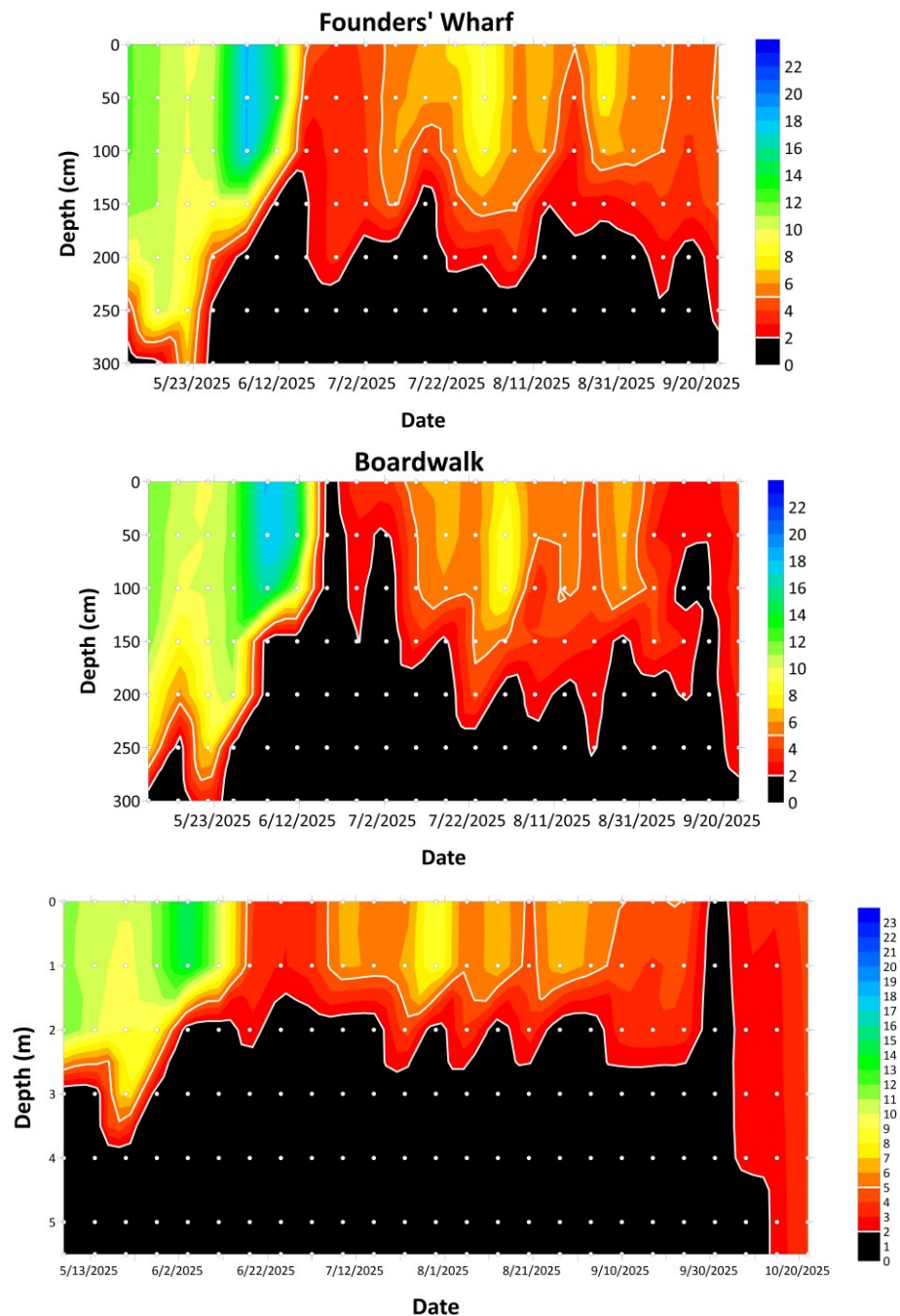


Figure 16. DO contour block diagrams of Founders' Wharf (top), boardwalk (middle) and deep water (bottom) sites.

From these contour maps, it can be seen that there is a large part of the water column that is hypoxic. To better appreciate the extent of hypoxia within the lake, two cross section profiles were extracted through the bathymetric model from the 2021 bathymetric survey (Bowen 2021). From late May throughout the summer until late September, a large portion of the lake experienced less than 2 mg/l of DO. In Figure 17, cross-sections of the lake show the hypoxic areas in black. A dotted line on the colourized DO model represents the 200 cm contour which is delineated on the cross sections. Using the volumetric values reported in the bathymetric survey of 2021, during the May to late September period, approximately 44% of the lake was in a state of hypoxia.

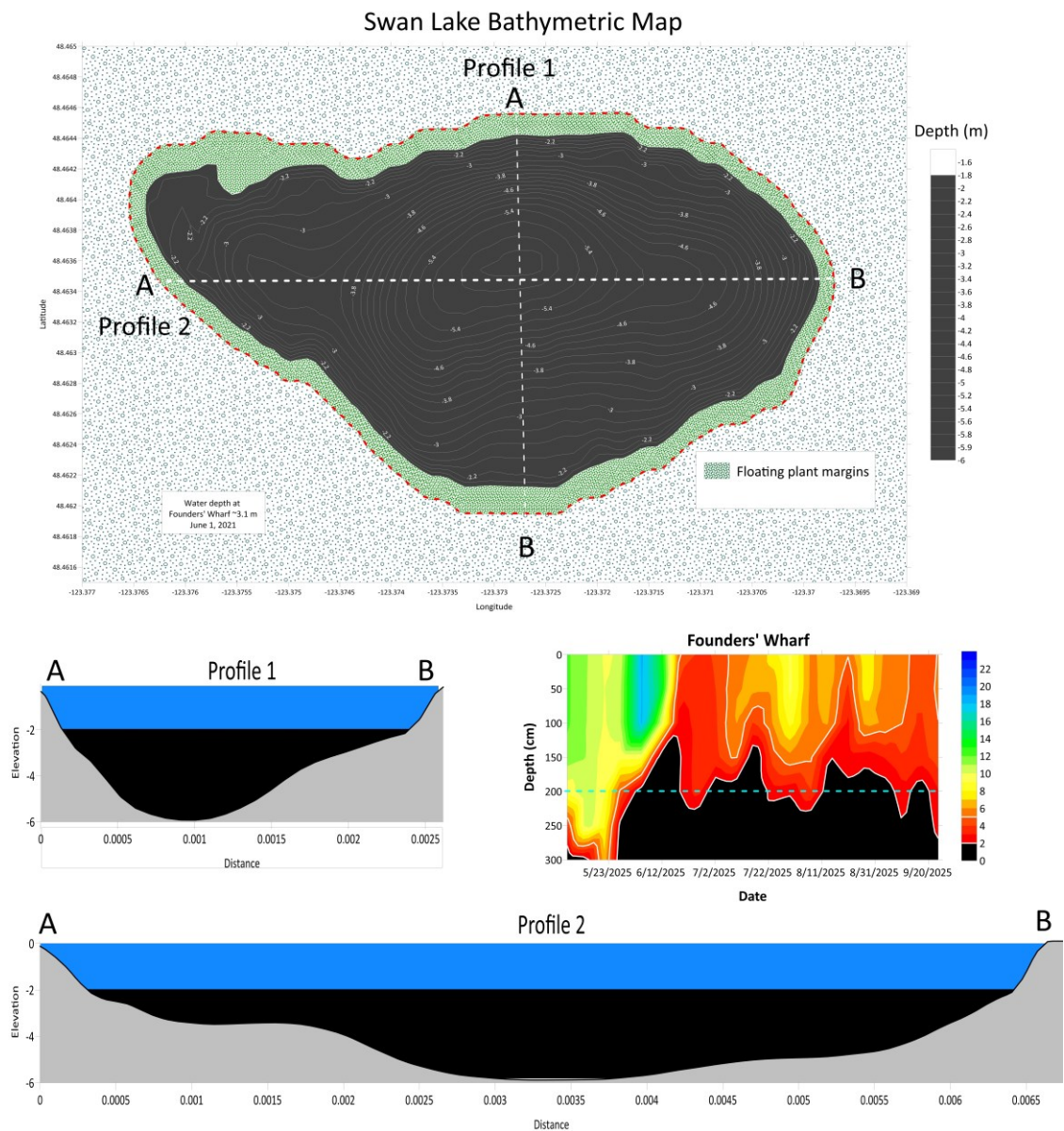
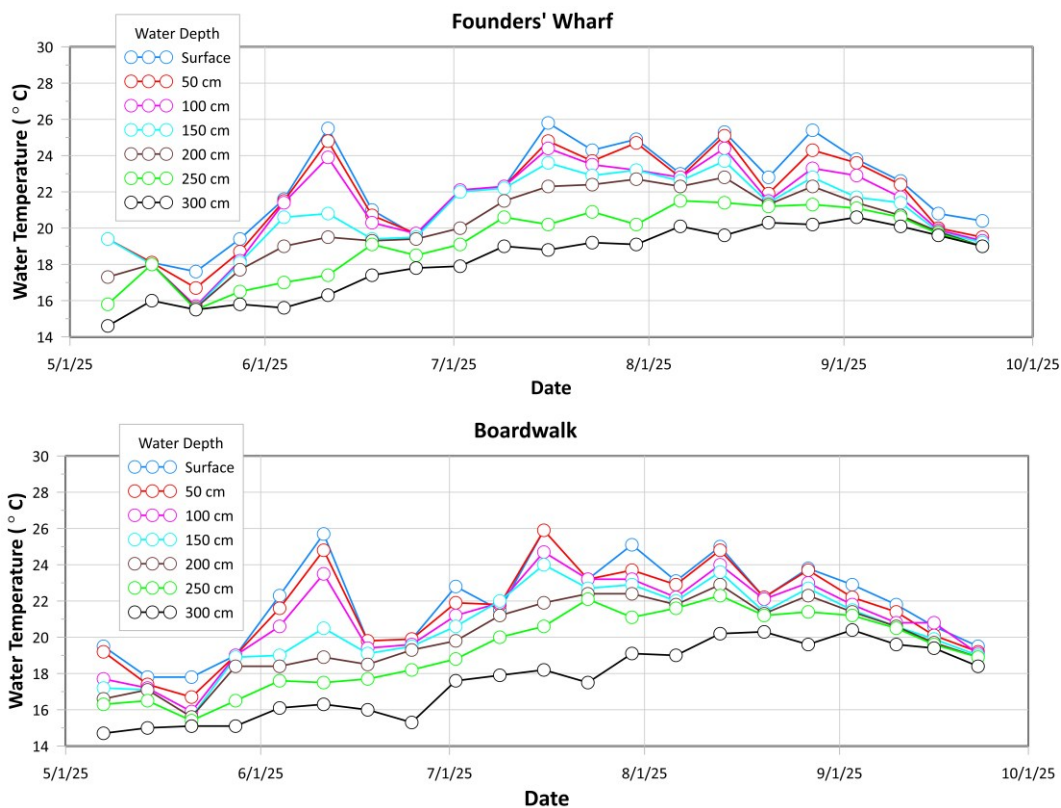


Figure 17. DO contour block diagram of Founders' Wharf site. The bathymetric plots and cross sections show the extent of the anoxic layer.

It is important to bring into this discussion the sampling interval of this data set and the diurnal nature of DO in a eutrophic system. Note that these data were taken during daylight hours between 10 am until 2:00 pm. The solar radiation that stimulates the photosynthetic processes changes significantly from the darkness of night to the bright rays of midday. The DO block diagram would be significantly different if profiles were taken at night during periods where respiration is the dominant mode affecting DO concentrations. From DO logger data from the past years that recorded nighttime DO, the hypoxic layer moved vertically upwards resulting in a higher volume of hypoxic waters during the night

### 5.2.2 Water Temperature Profiles

Water temperature profiles were assembled into a set of time series plots similar to the DO time series plots (Figure 18). During the sampling season, a maximum water temperature of 25.8°C occurred on July 16<sup>th</sup> at the surface at the Founders' Wharf site. The highest temperature difference between the surface and bottom water (300 cm depth) occurred June 11<sup>th</sup> at the boardwalk with values of 25.7°C at the surface to 16.3°C at the bottom for a difference of 9.4°C. In the case of the deep water site, the highest difference between surface waters and the 5.5 m depth also occurred on July 16<sup>th</sup>. The highest temperature spread at this site also occurred on July 16<sup>th</sup> with a range of 12.6°C. The lowest surface water temperature this year for the long-term study was 17.6°C occurring on May 14<sup>th</sup>. As the deep-water study continued into the third week of October, its lowest surface temperature was recorded on October 22 with a value of 12.4°C.



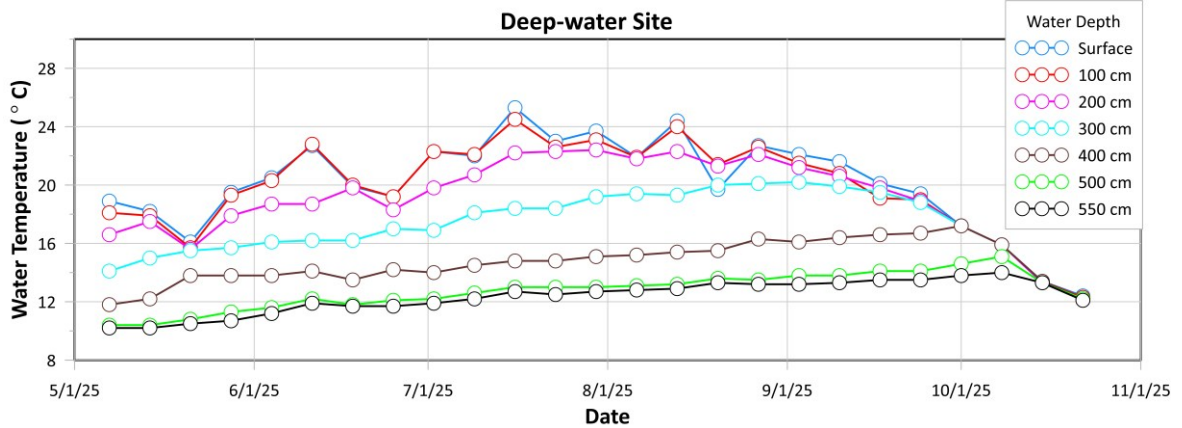
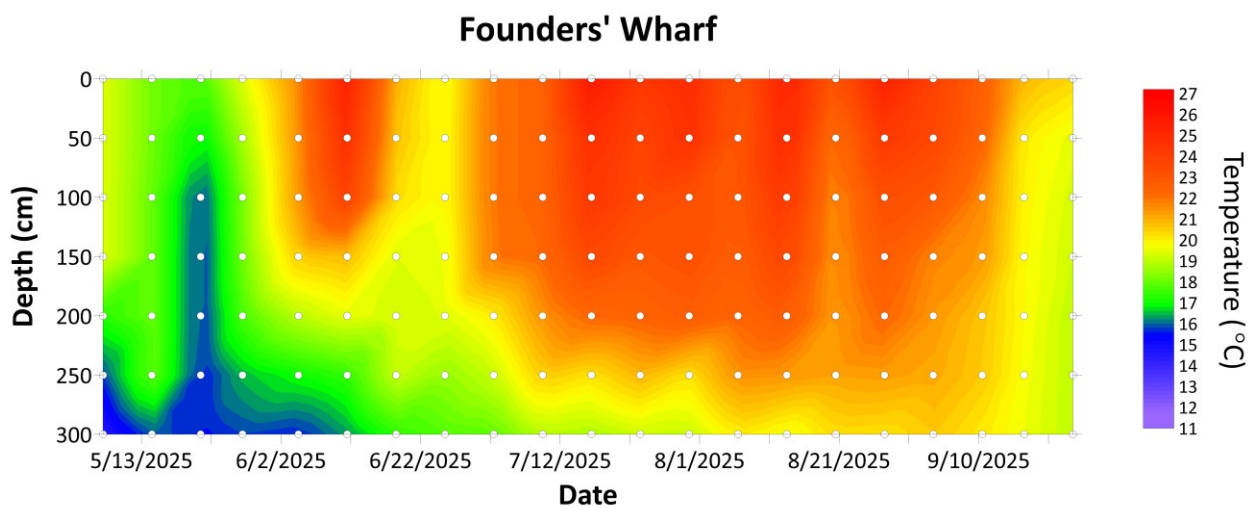


Figure 18. Water temperature plots for Founders' Wharf (top), boardwalk (middle) and deep-water sites (bottom).

To aid in the visualization of the water temperature, contoured temperature block diagrams were generated for all three sites and are displayed in Figure 19.

Swan Lake is a dimictic system that experiences two overturning events per year. At the beginning of the sample period, the water column had already showed signs of stratification moving away from the early spring isothermal conditions. Note the relatively cooler column of water in mid-May corresponding to a rain event, reduced sunlight and a period of cooler air temperature. Air temperature and increased solar intensity and duration led to strong stratification which then weakened near the end of June. Early July to mid-September saw the migration of heat into the deeper layers of the lake. The fall turnover began in the third week of September with full completion of an isothermal water column by October 15<sup>th</sup>.



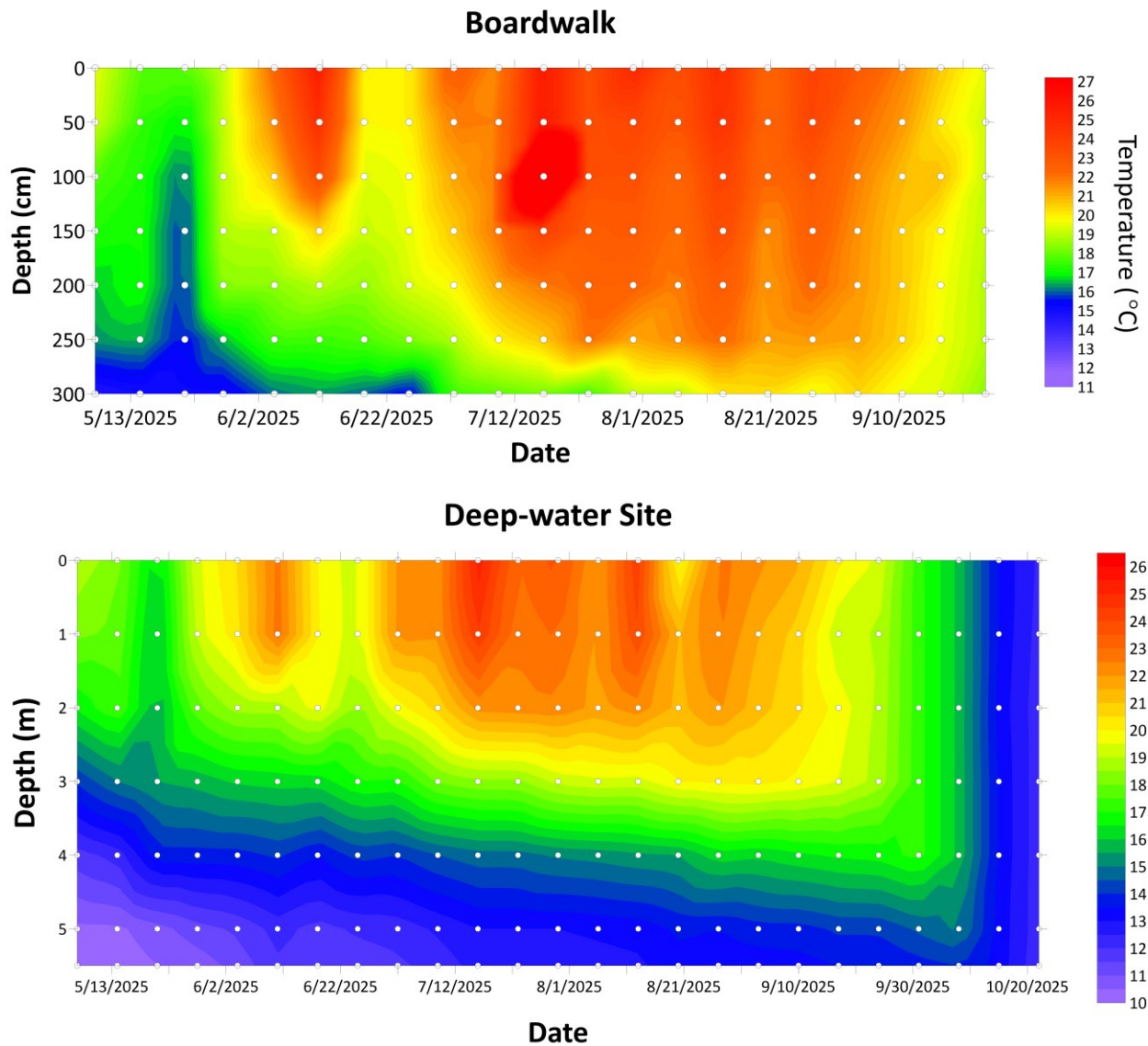


Figure 19. Contoured block diagrams of water temperature at the Founders' Wharf (top), boardwalk (middle) and deep-water sites (bottom).

The mechanisms that trigger overturning are largely the result of thermal momentum shifts affecting water density with heating in the spring and cooling in the fall, often coupled with wind events that force mixing. Figure 20 summarizes the dimictic stages of Swan Lake.

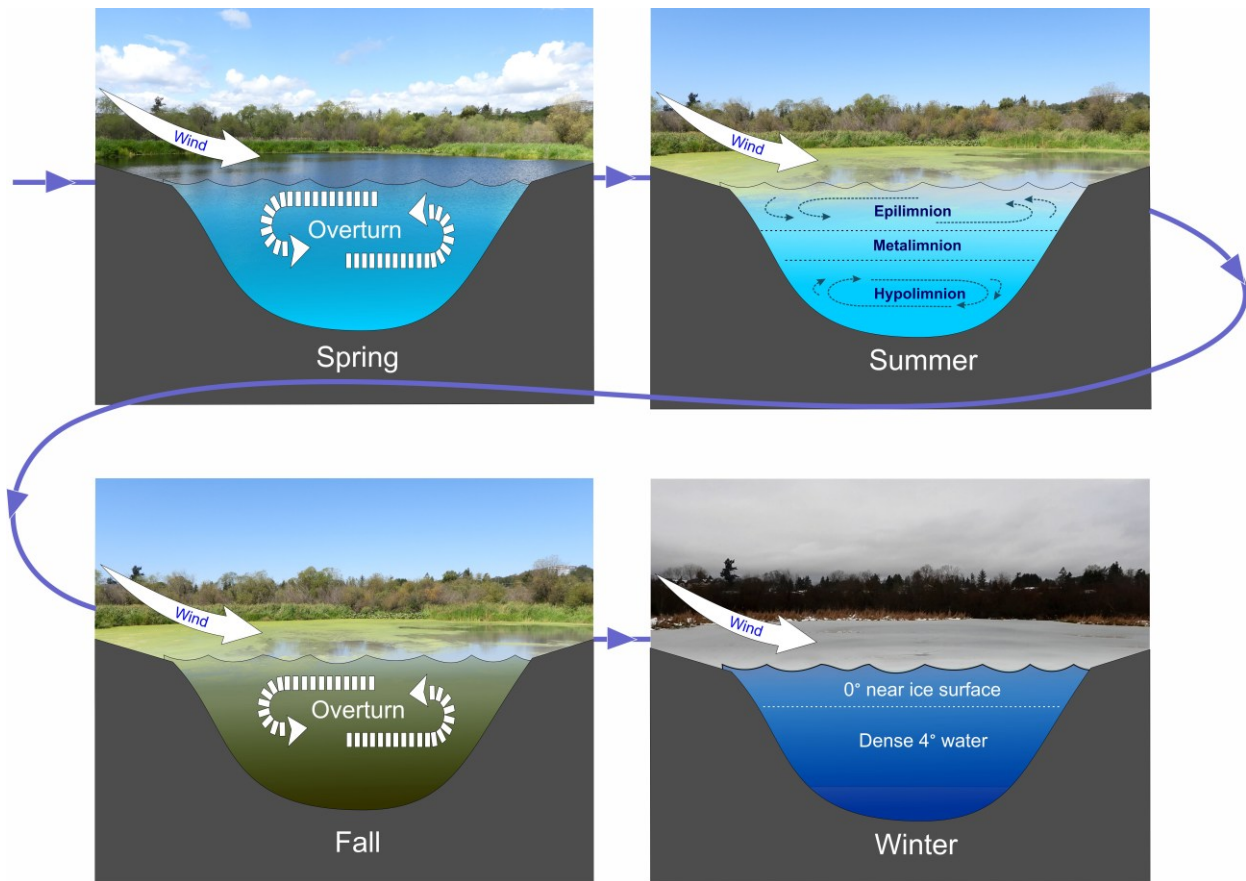


Figure 20. Dimictic stages at Swan Lake.

### 5.2.5 Turbidity

The turbidity of the water column was measured at each lake site visit to give an index of the clarity of the water. This parameter has both physical and biological associations and indicates the presence of both visible and microscopic organic and inorganic 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 21 shows the Secchi disk depths for the long-term study and deep-water sites. During the early June algal bloom, the Secchi disk depth dropped to 0.4 m—its study period seasonal low. This lowest point coincided with the peak DO values. About a week later, Secchi disk depth values improved to some of their best values of the study season, likely due to the die-off vertical migration of the water column cyanobacteria as they settled to the bottom. This pattern repeated itself, to a lesser extent, when there was a slight elevation in DO at the beginning of August.

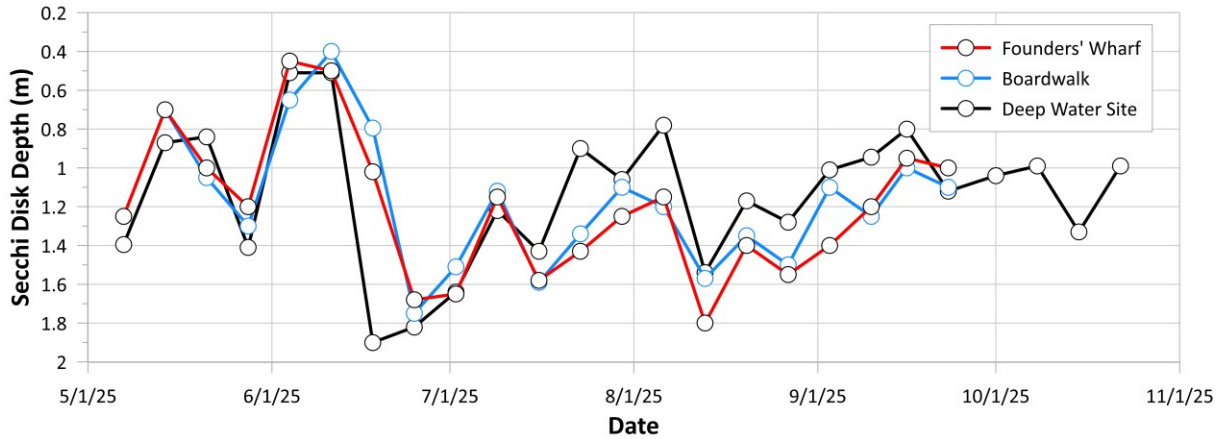


Figure 21. Secchi depth time series plots for Founders' Wharf and the boardwalk sites.

### 5.2.6 Water Colour and Seasonal Changes

Figure 22 displays surface observation photos, underwater GoPro captures and microscopic communities for many of the site visits. This is meant to provide a quick visual snapshot of changes that occur over the sampling period. The surface observations display the evolution of the algal mats that form on the shoreline margins. In previous years, these algal mats would typically form up in June but, as was the case last year, their formation wasn't until the beginning of July. The GoPro images give qualitative insights about clarity, suspended solids such as algae and detritus, dissolved solids affecting colour hue and, to some degree, light penetration and specular light conditions. These captures were taken at a depth of approximately 20 cm for consistency. These images, when viewed in a time series, are indicators of the complex relationships of the succession of phytoplankton such as cyanobacteria, green algae and hue-altering dissolved solids. With each site visit, water samples were taken for nutrient analysis and for careful viewing under the microscope. These observations added explanatory support to better understand the dynamics and driving forces influencing dissolved oxygen, chlorophyll and phycocyanin values. For completeness, dissolved oxygen, temperature, chlorophyll and phosphorus data are listed for each of site visits displayed. Note the June 4<sup>th</sup> observations coincide with the seasonally high extreme DO values associated with the algal bloom. Microscope images captured at this time showed high concentrations of the cyanobacteria *Dolichospermum*. The microscope images also shed light on the zooplankton species present within the lake, a major component of the food web as they consume phytoplankton and in turn are consumed by larger organisms such as fish. Note that this year a web dashboard was added to display near-real time lake parameters. The link to this dashboard is as follows:

[https://www.dssolutions.bc.ca/Swan\\_WQ-2025.html](https://www.dssolutions.bc.ca/Swan_WQ-2025.html)

May 21

May 27

June 4

June 11

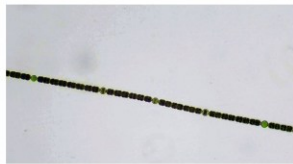
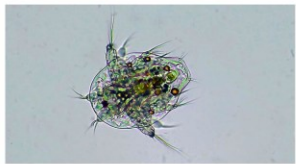
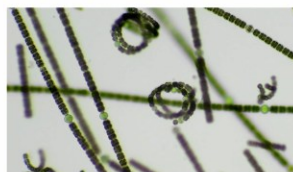
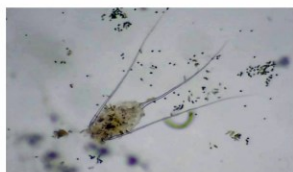
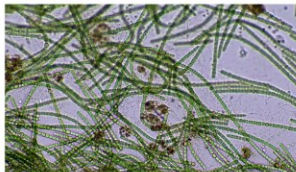
Surface observations



Underwater



Microscopic community



DO	9.85 mg/l
Temp	17.6 C
Chl	10 µg/l
P	0.21 mg/l

DO	10.14 mg/l
Temp	19.4 C
Chl	13 µg/l
P	0.17 mg/l

DO	18.47 mg/l
Temp	21.6 C
Chl	9 µg/l
P	0.06 mg/l

DO	14.24 mg/l
Temp	25.5 C
Chl	8 µg/l
P	0.07 mg/l

July 30

Aug 6

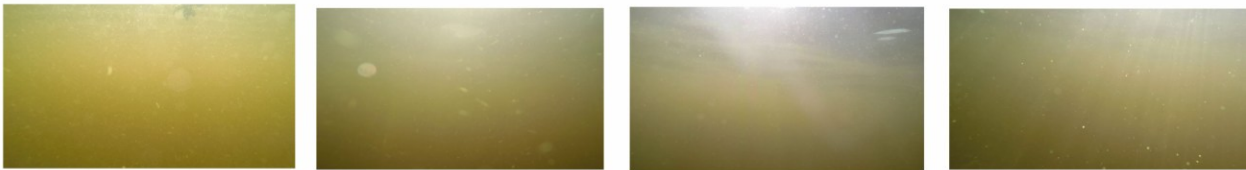
Aug 13

Sept 10

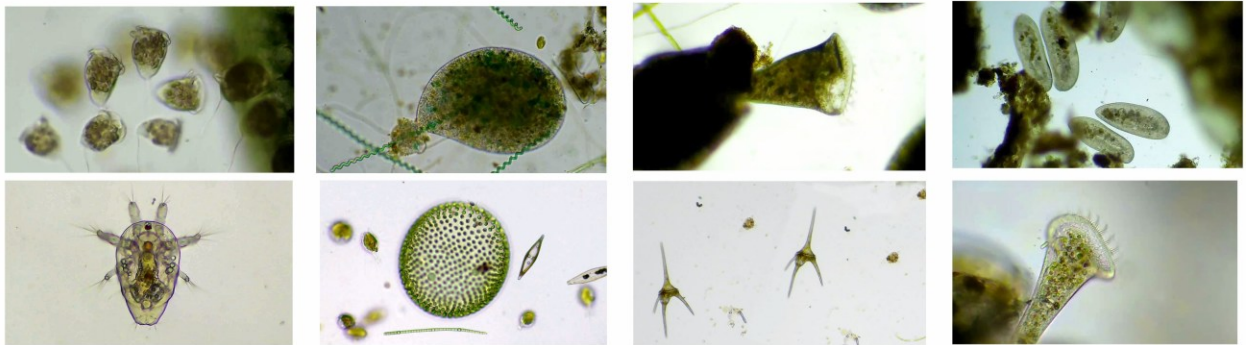
Surface observations



Underwater



Microscopic community



DO	9.39 mg/l
Temp	24.9 C
Chl	8 µg/l
P	0.09 mg/l

DO	5.74 mg/l
Temp	23.0 C
Chl	21 µg/l
P	0.10 mg/l

DO	6.47 mg/l
Temp	25.3 C
Chl	7 µg/l
P	0.08 mg/l

DO	5.66 mg/l
Temp	22.6 C
Chl	14 µg/l
P	0.07 mg/l

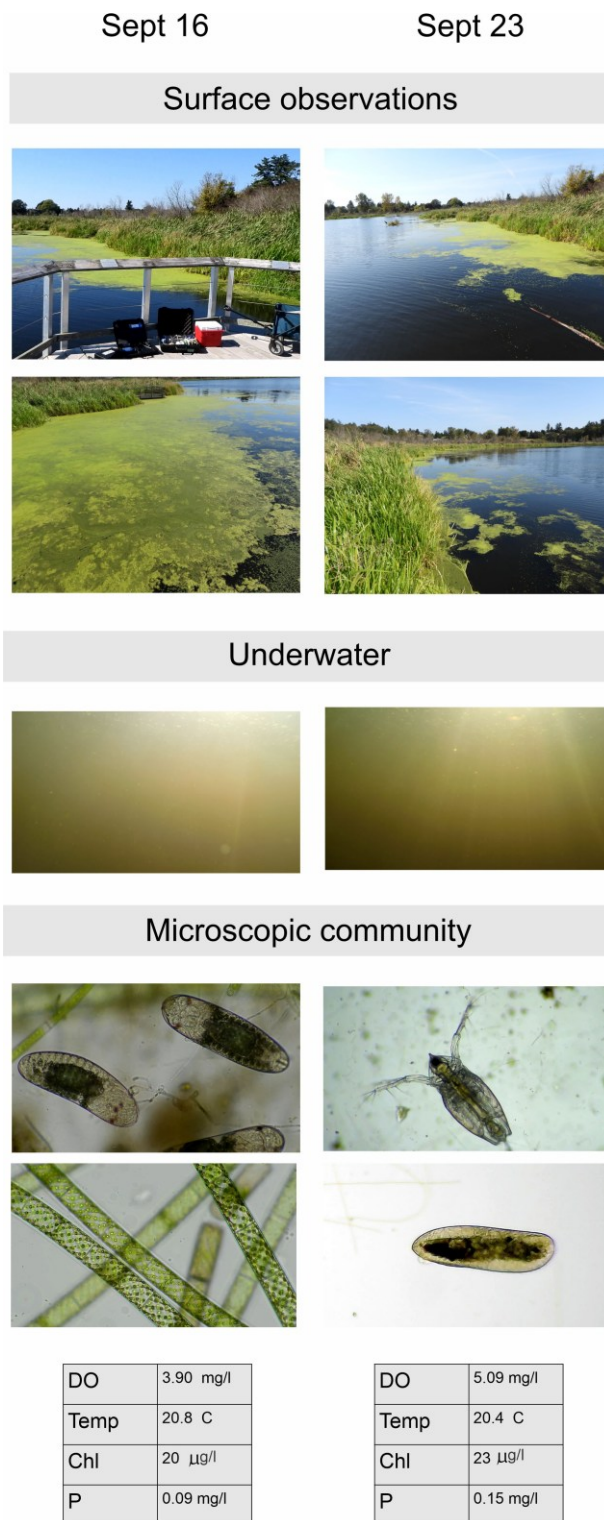


Figure 22. Time series of surface algae, water colour and microscope captures over the sampling season.

### 5.2.7 Chlorophyll-a and Phycocyanin

Two handheld Turner fluorometers were used to examine chlorophyll-a and phycocyanin. These instruments measure plant-based pigments that indicate overall algal biomass. Chlorophyll-a is a broad spectrum measure of green pigment present in all plants and algae. Photosynthetic organisms use a variety of chlorophyll molecules to improve their ability to capture solar radiation. This is true of macrophytes, phytoplankton and, to a lesser extent, cyanobacteria. Cyanobacteria utilize specialized phycobiliproteins to enhance their photosynthetic efficiency. As only a few algal classes possess these pigments, measuring phycocyanin (PC), the most common of the phycobiliprotein, enables the detection of the subset of cyanobacteria within a mixed phytoplankton assemblage (Lauceri et al. 2017). Figure 23 shows the wavelengths at which chlorophyll-a and phycocyanin pigments fluoresce.

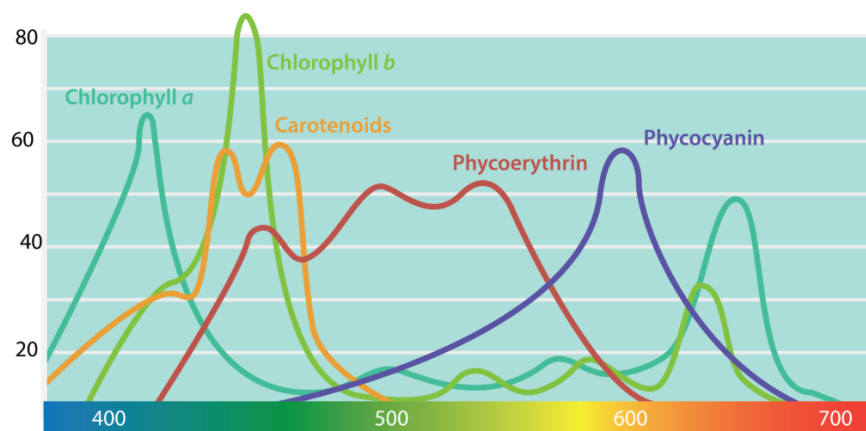


Figure 23. Wavelengths of light indicating the chlorophyll-a and cyanobacteria phycocyanin peaks.

Figure 24 shows both chlorophyll-a and PC curves for the Founders' Wharf and the boardwalk sites taken from four depths. At the beginning of the sample season, the chlorophyll levels were relatively high. Microscope captures during the first two site visits showed the presence of large populations of euglenoids and *Mallomonas* which contain chloroplasts that are detectable by the chlorophyll-a fluorometer. Within a month of sampling, the phycocyanin plots show an abrupt rise in concentration of this pigment, a pigment that detected the abundance of bloom forming cyanobacteria. This early June event coincides with the super-saturated DO levels at that time (215.8%, 18.47 mg/l). To highlight this bloom period, chlorophyll-a and PC values from the surface photic zone were plotted together (Figure 25). Periods where phycocyanin values exceeded chlorophyll-a values indicate cyanobacterial dominance within the algal community, consistent with conditions associated with cyanobacterial blooms. The 2025 DO block diagram shows elevated surface DO coinciding with these PC peaks. For comparison, the 2023 record is also shown in Figure 25. That year similarly demonstrates that increases in phycocyanin closely track the onset and decline of cyanobacterial dominance. Since fluorometers were added to the monitoring program in 2022, this pattern has repeated annually.

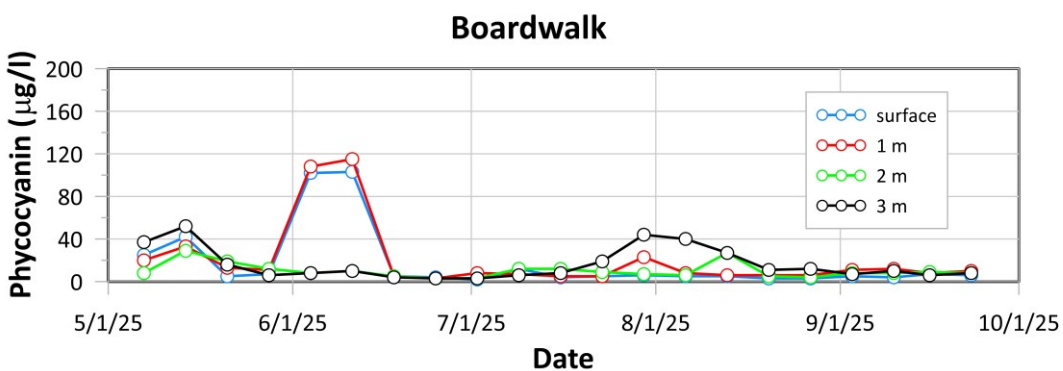
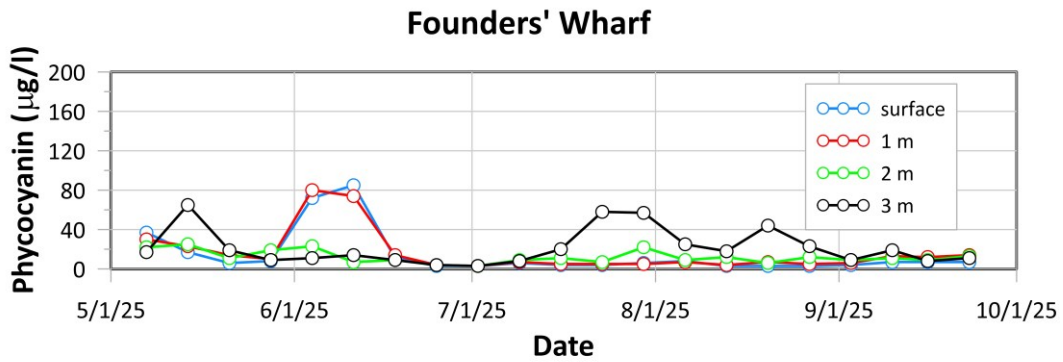
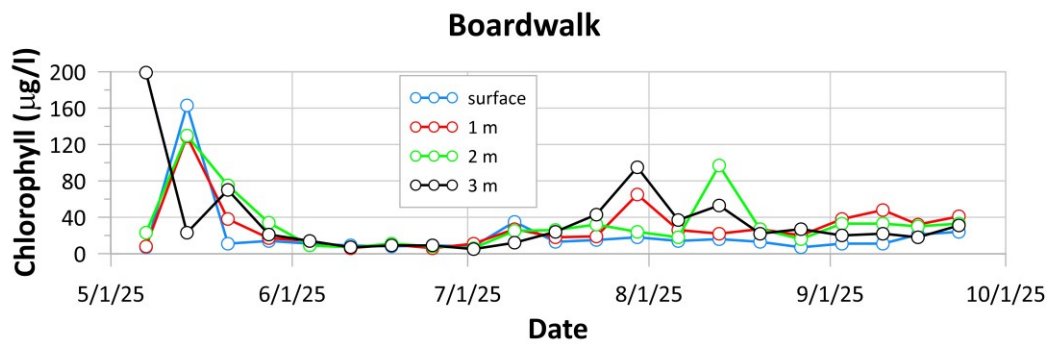
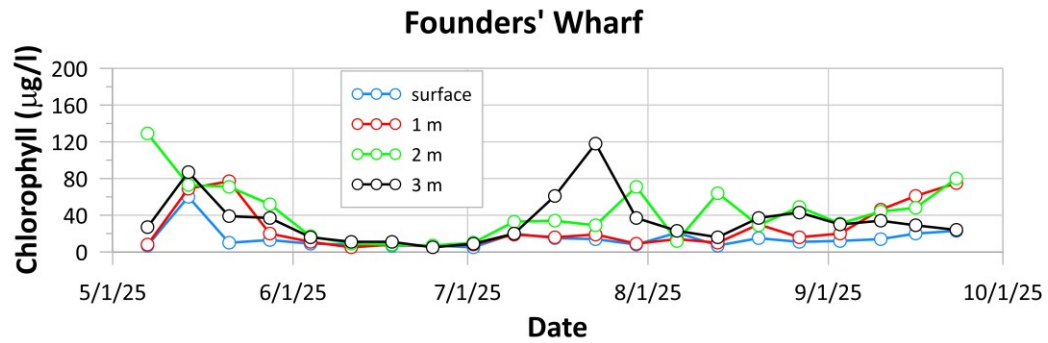


Figure 24. Chlorophyll-a and phycocyanin plots of both lake sites.

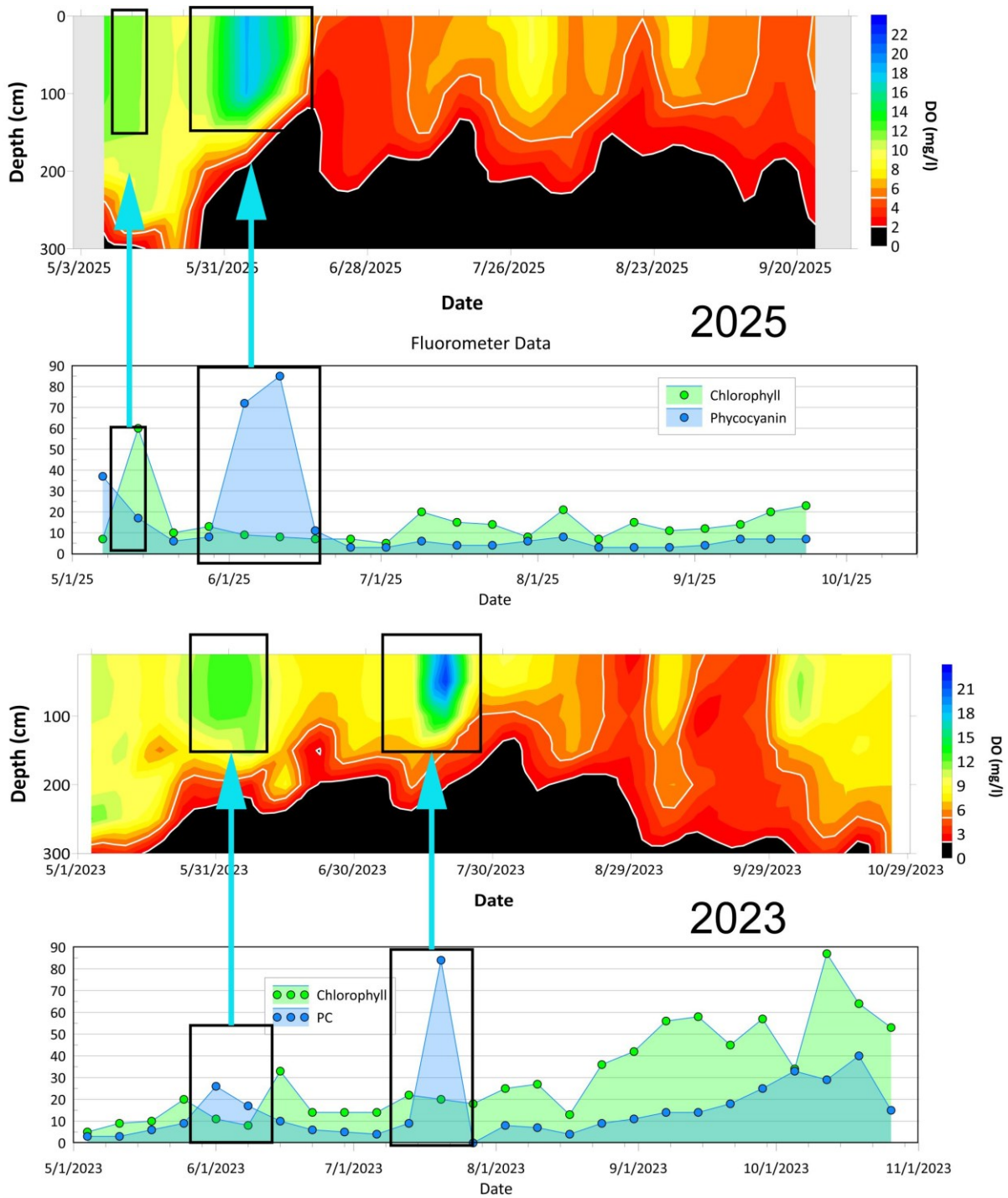


Figure 25. Chlorophyll-a and phycocyanin plots of both lake sites for the years 2025 and 2023.

Figure 26 examines the ratio of PC to chlorophyll-a (PC/Chl). Higher ratios reflect increasing dominance of cyanobacteria within the phytoplankton assemblage (Haggard et al., 2023).

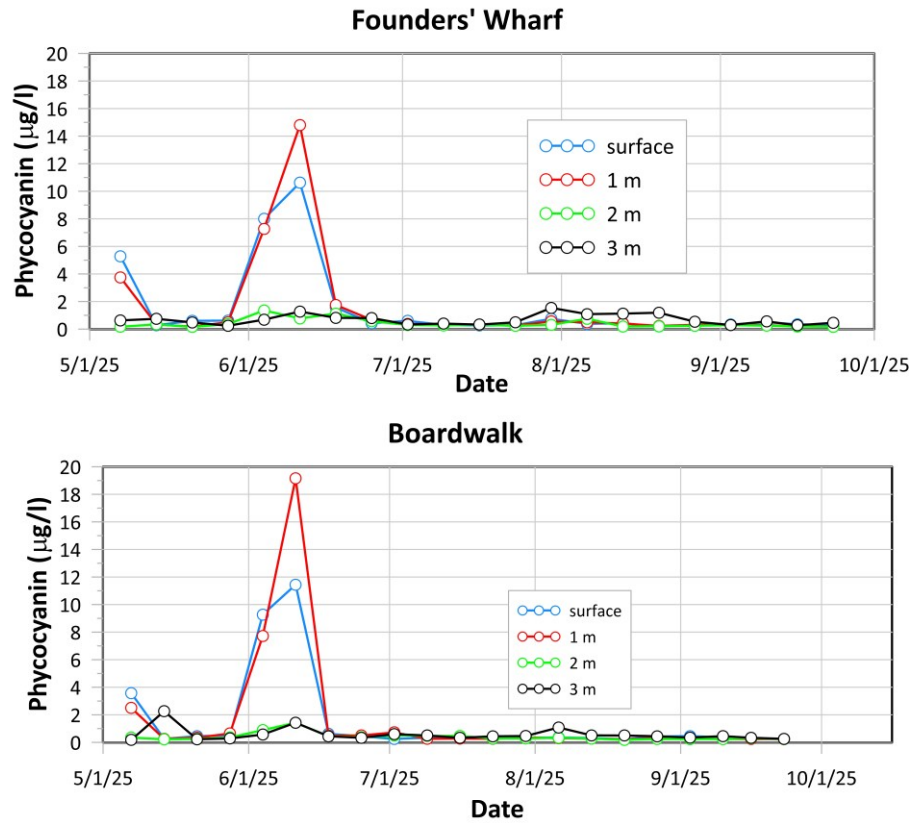


Figure 26. Ratio of Chlorophyll-a divided by phycocyanin at both lake sites.

### 5.2.8 Lux Time Series

Light plays an important role in the thermal and biological metabolic processes at Swan Lake. Light from the sun reaches the lake surface directly and through atmospheric diffusion. As light projects into the lake, it quickly attenuates with depth as it gets absorbed and scattered by particles such as algae and suspended solids. The deeper the light penetration, the deeper the potential for photosynthetic processes. The two HOBO lux loggers measure lux in units of Lumens/m<sup>2</sup>. Solar insolation as measured by the Swan Lake weather station is measured in watts/m<sup>2</sup>. To convert the lux values into solar insolation values, a multiplier of 0.0079 was applied to the lux values. Figure 27 shows the solar insolation at the surface along with the values measured at depth from the lux loggers.

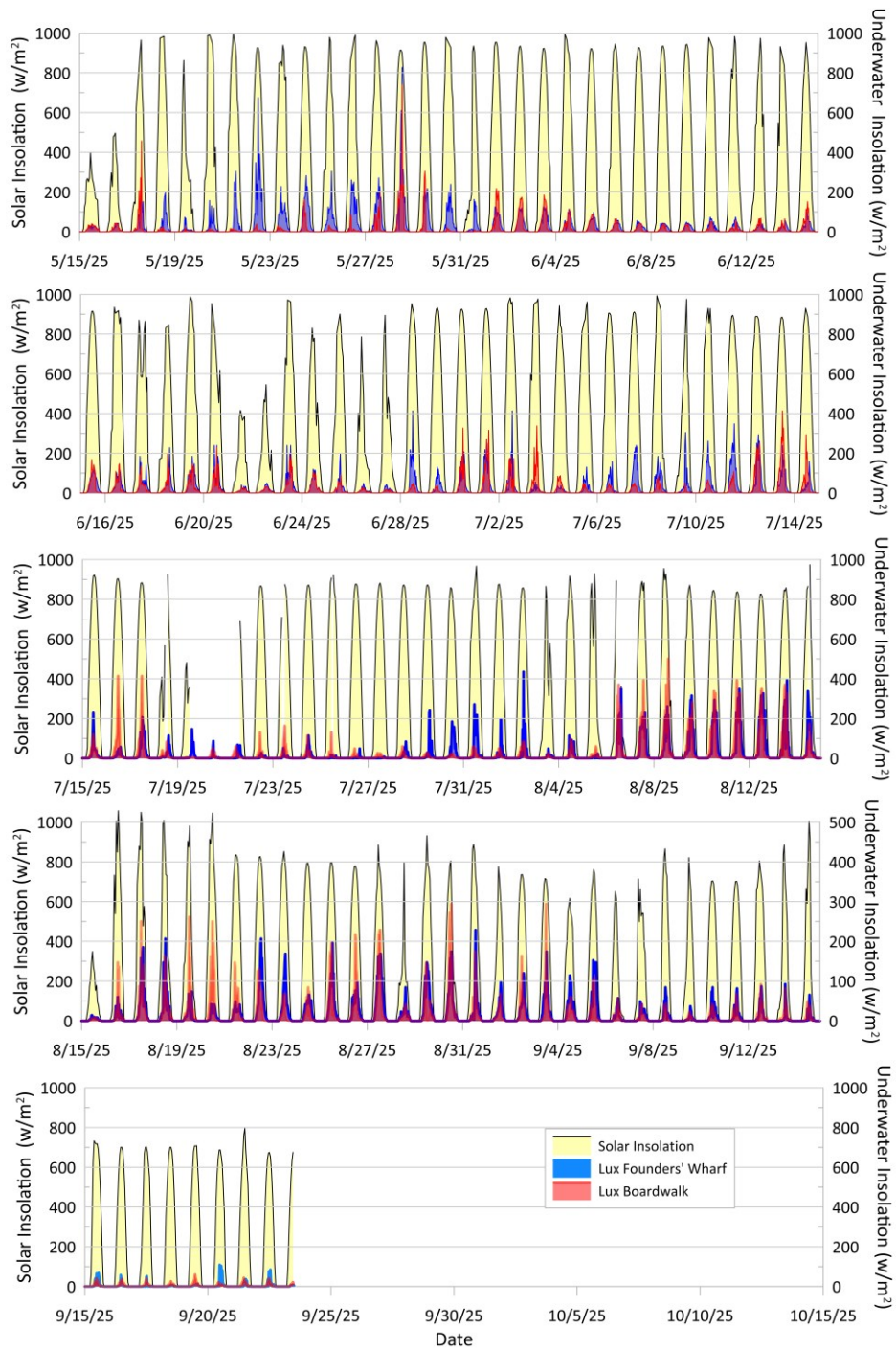


Figure 27. Solar insolation from weather station plotted with the Founders' Wharf and boardwalk lux loggers submerged at a depth of 60 cm.

The daily maximum solar insolation was calculated at the water's surface as well as at the submerged Founders' Wharf and boardwalk lux loggers. These data were plotted in Figure 28. The average time of day for the maximum insolation was also calculated for each data set.

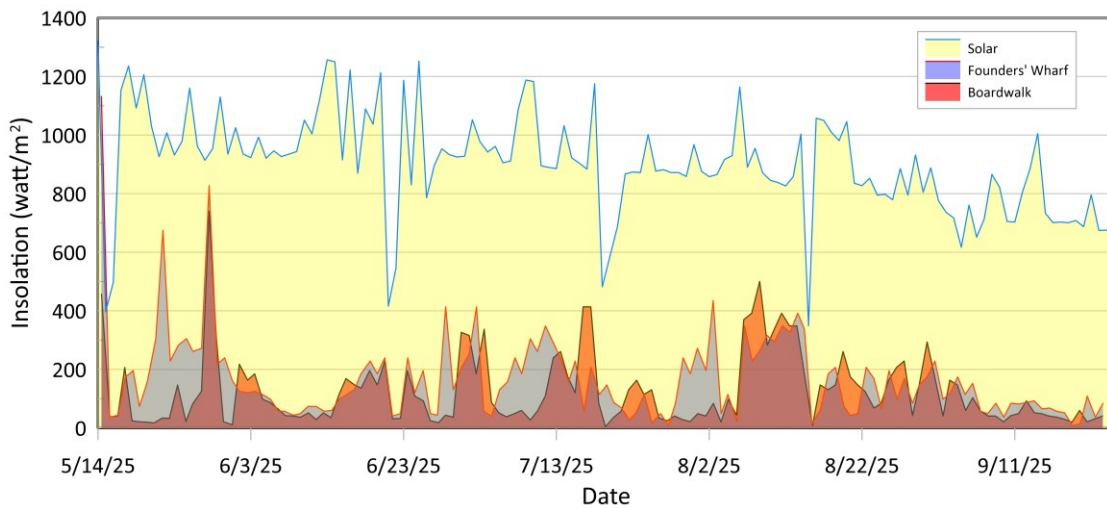


Figure 28. Daily solar maximums at surface and 60 cm depth.

The daily maximum light penetration was plotted as a percent of the total peak surface solar insolation in Figure 29. Light quickly attenuates with depth in this lake setting.

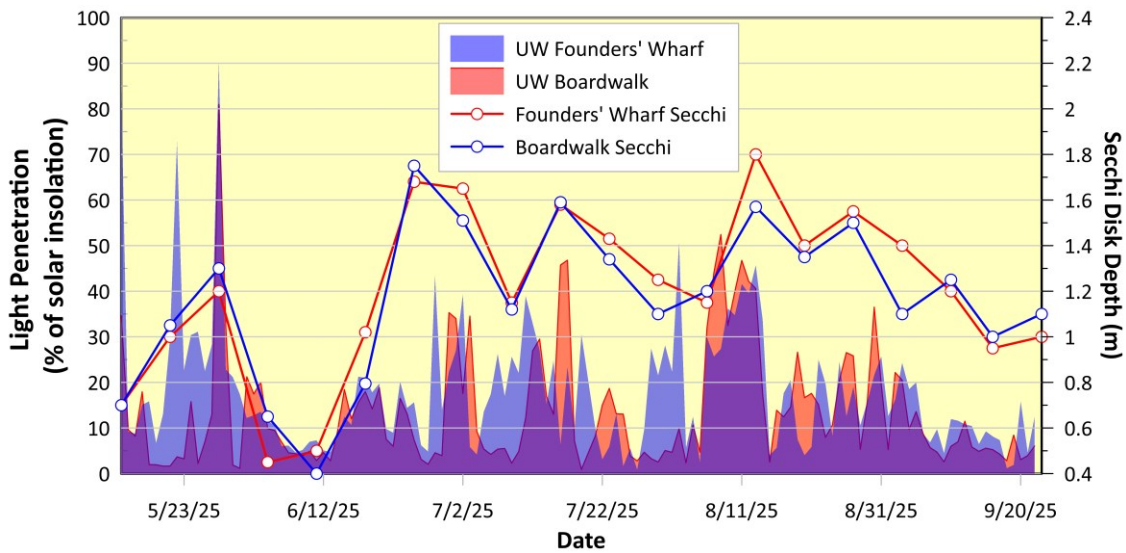


Figure 29. Percentage of surface sunlight reaching lux loggers at 60 cm depth.

Time of day details for minimum and maximum values of Lux, water temperature and solar insolation are summarized in Table 1.

**Table 1.** Daily extremal time of day for temperature, lux and solar insolation.

Depth	Water Temperature		Average Daily Temperature Range (at 60 cm depth)	Lux	Solar Insolation
	min	max		max	max
Founder's Wharf	10:54 am	3:14 pm	2.25 C	12:54 pm	11:36 am
Boardwalk	11:12 am	3:30 pm	2.13 C	12:08 pm	11:36 am

Figure 30 displays the entire sampling season for the lux loggers and water temperatures as recorded at the 60 cm Lux logger depths. Draped onto this data are the Secchi disk depths as measured during site visits. Note the weak coupling between light penetration and water clarity.

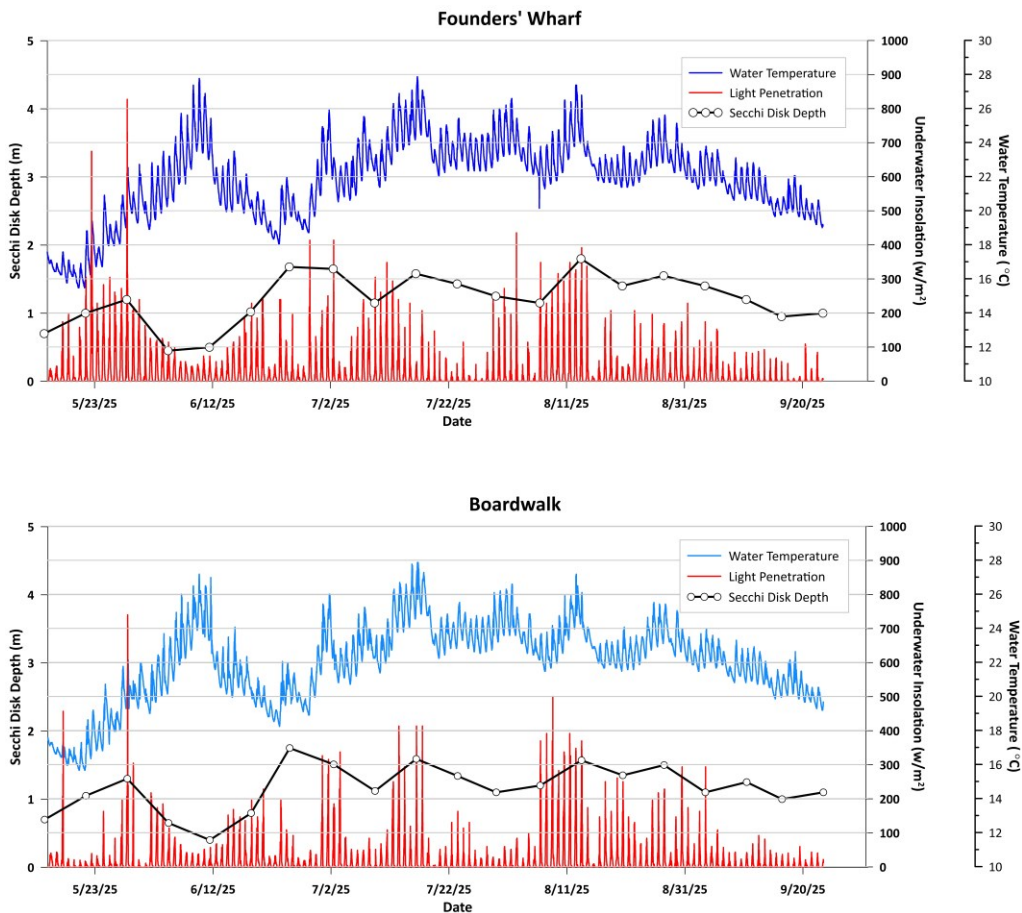


Figure 30. Time series plot of lux, water temperature and Secchi disk depths for the Founders' Wharf (top) and the boardwalk (bottom) sites.

During the early June algal bloom, light penetration in the the water column was reduced by the presence of *Dolichospermum* which also reduced the Secchi disk depth values. During this time, water temperatures climbed significantly from 18°C to 26°C—favourable conditions for the ramping up of the bloom. Water clarity began improving after the peak of the bloom and water temperature saw an unusual cooling event of about 8°C in mid-June.

### 5.3 Collecting Water Samples

Water samples were taken weekly at the two lake sites using a Van Dorn bottle and samples were taken at the surface at the inflow creek. The inflow creek site was a potential vector for external nutrient loading through the various urban and agricultural land use practices upstream. At both the Founders’ Wharf and the boardwalk samples were taken at the surface, 1.0 m, 2.0 m and 3.0 m depths. These samples were analyzed for nutrients and biological constituents at the Diversified Scientific Solutions’ laboratory using a YSI 9500 photometer and imaging trinocular. Concurrently, samples were taken by the Swan Lake team at the deep-water site bi-weekly. These samples were sent into a lab as part of the level-3 BCLMP study.

#### 5.3.1 Phosphorus

The phosphorus cycle is a key component to the biological processes at Swan Lake. Phosphorus is considered, in general, to be a major nutrient that leads to global lake eutrophication and algal blooms due to increasing anthropogenic sources (Reynolds and Davies, 2001 and Paerl and Otten, 2013). It is an essential nutrient for cyanobacteria, algae, and aquatic plant metabolic processes. The concentration of phosphorus has detrimental effects at either extremes in the water column. As observed at Swan Lake, high surface concentrations have led to lake-wide algal blooms. Conversely, the subsequent consumption of this phosphorus during the bloom often drives surface concentrations to near zero, causing a mass die-off. The decomposition of this biomass, in turn, consumes DO, leading to a rapid decline in DO and severe lake-wide hypoxia—a key factor in events such as the 2017 fish kill. The collapse of DO at the benthic layer is the necessary condition that triggers the chemical release of legacy phosphorus from the sediment (Wang, et.al., 2025).

The phosphorus cycle within eutrophic lakes has been likened to a biochemical engine where the inflow streams provide the power supply (external loading from the watershed) and the legacy phosphorus deposited in the sediments (internal loading) is like the engine’s battery (Dr. Sean Waters [https://ourlakesourfuture.co.nz/lake\\_story/pulling-the-plug-on-phosphorus/](https://ourlakesourfuture.co.nz/lake_story/pulling-the-plug-on-phosphorus/)). This analogy is useful when considering mitigation techniques to reduce phosphorus from lake systems such as cutting off the “power supply” by reducing the in-flow phosphorus to the lake.

Figure 31 illustrates the phosphorus cycling process. Generally, the input inorganic phosphorus is converted to organic phosphorus through plant assimilation. This organic phosphorus can be deposited as these plants die or are consumed by other organisms such as grazing zooplankton. In time, phosphorus is either excreted or deposited to the lakebed as these organisms die. Bacteria at the lakebed break down the organic phosphorus and through this process of decomposing rerelease inorganic phosphorus back into the water column (The Phosphorus Cycle, 2021 <https://bio.libretexts.org/@go/page/12394>).

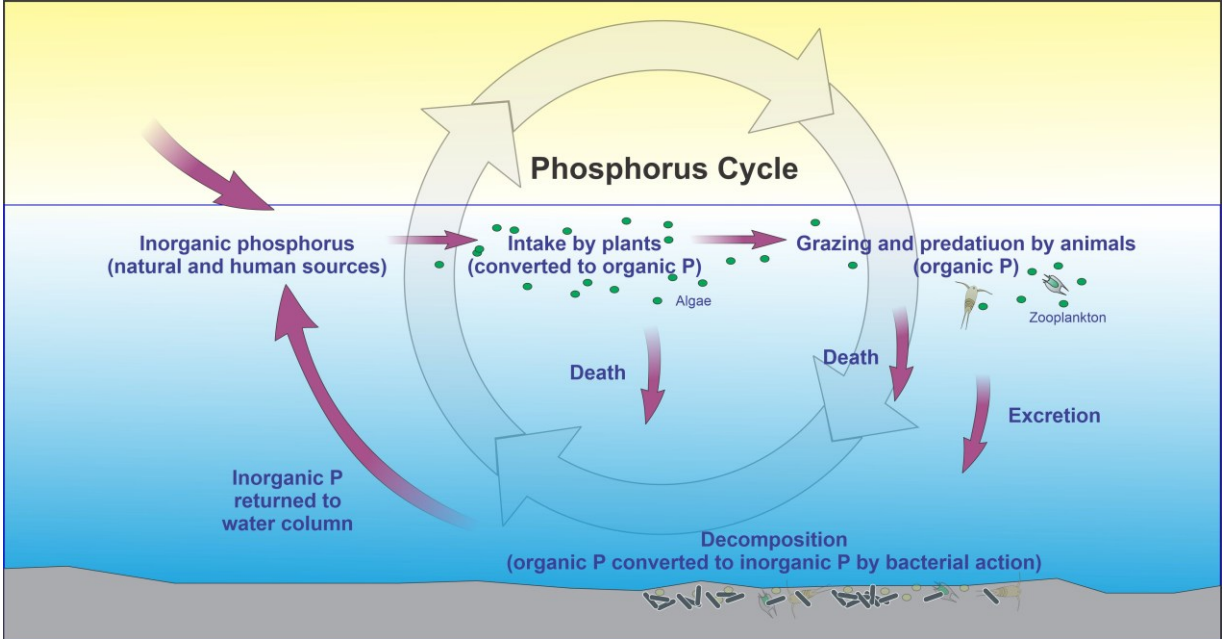


Figure 31. The phosphorus cycle.

Figure 32 shows plots of ortho-phosphate (OP) concentrations from the Founders’ Wharf, the boardwalk and the deep-water sites. Ortho-phosphorus is a component of total phosphorus. OP is the bioavailable portion of phosphorus which is most readily available for plants and algae. Of note in this plot there is good agreement between the two methods of determining phosphate concentrations (Diversified Scientific Solutions and BCLSMP labs). Both labs use similar procedures and reagents using a spectrophotometer. BCLSMP total phosphorus is also plotted on the lower panel of this figure. As there was a gap in collecting samples at the long-term study site, the deep-water site data fills this gap reasonably well. At the deep-water site, the 5 m samples show an increase in high levels of this nutrient building from the spring and intensifying right through the summer.

Water samples collected at the 5 m depth at the deep-water site show a very strong vertical gradient of this nutrient towards the bottom, building right up until mid-September and reaching a seasonal high concentration of 3.28 mg/l. This value is extremely high, suggesting a massive reservoir of phosphorus in the system from legacy accumulations. The anoxic conditions of the bottom water drive a process called reductive dissolution at the water–sediment interface resulting in internal phosphorus loading. As ortho-phosphate is primarily bound to ferric iron oxides (Fe<sup>3</sup>) in the sediment, the anoxic conditions chemically reduce the ferric iron to soluble ferrous iron (Fe<sup>2</sup>) thereby liberating the ortho-phosphorus back into the water column (Wang, et al., 2025).

A turning point occurred in the latter part of September and by October 15<sup>th</sup> as the fall turnover occurred, OP values became well mixed and reduced to 0.324 mg/l, about one-tenth of its value at its September peak.

Some OP analysis was done on samples collected from Blenkinsop Creek but, unfortunately, our supply of reagents ran out. A total of eight weeks were sampled with values that ranged from 0.28 mg/l to as high as 0.41 mg/l. These values are quite high so this creek, although the discharge is greatly reduced in the summer months, should still be considered a vector for phosphorus input.

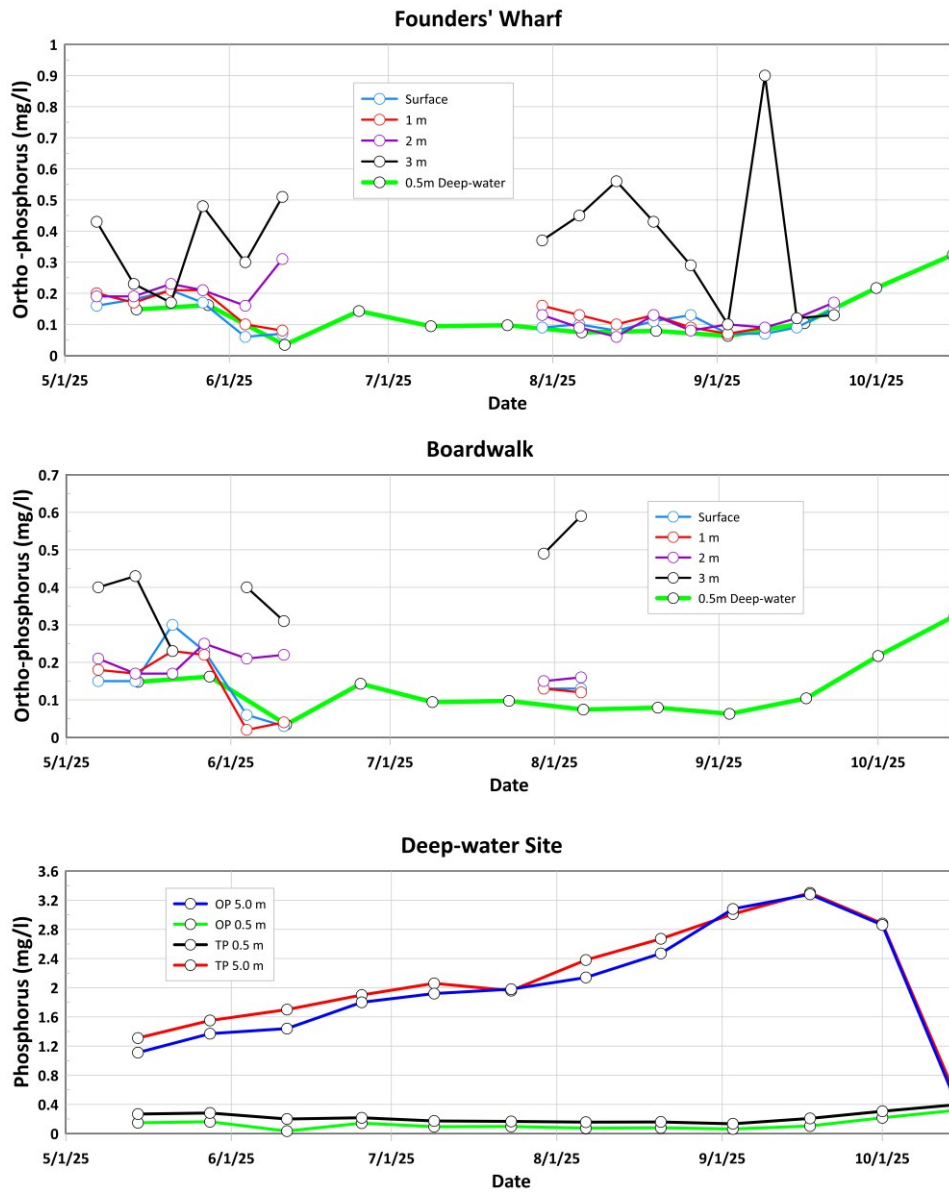


Figure 32. Ortho-phosphate time series plots of Founders' Wharf (top), boardwalk (middle) and deep-water (OP+TP bottom) sites.

A contour plot was created for the Founders' Wharf data to visualize the dynamics of phosphorus in the water column throughout the study period (Figure 33). Although there was OP data collected at the deep

water site, there was insufficient data to make a continuous model for the mid-June to July 31 period as the deep-water site only had two depths (0.5 m and 5.0) taken every two weeks. Just before the early June algal bloom, there was a flush of OP in the upper water column. During the algal bloom, OP was consumed. It was during this time that the anoxic layer began to form and OP began to concentrate near the bottom.

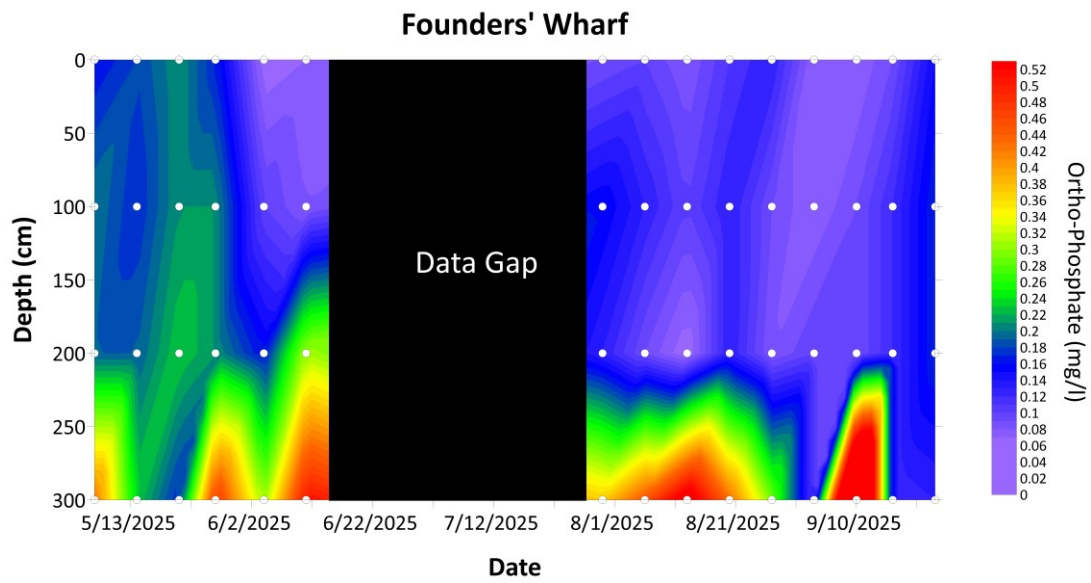


Figure 33. Phosphorus contour plot for the Founders' Wharf.

The trophic status of lakes has been divided into several distinct class-based categories based on lake parameters such as phosphorus concentrations. These states are summarized in Table 2 along with Carlson's trophic state index (see: <https://www.nalms.org/secchidipin/monitoring-methods/trophic-state-equations/>). Swan Lake has been referred to as a eutrophic lake but at times presents as hyper-eutrophic. For much of the study period, the 0.1 mg/l threshold is exceeded. Throughout the site visits, Secchi depths range from as high as 1.9 m to as low as 0.4 m during the *Dolichospermum* blooms (see Figure 21). The chlorophyll-a values at Swan Lake are also in the hyper-eutrophic range as they were elevated in May and measured as high as 200 µg/l (see Figure 24).

Table 2. Lake trophic status (Environment Canada, 2004 and after Carlson, 1977).

Trophic Status	Total Phosphorus (µg/l)	Total Phosphorus (mg/l)
Ultra-oligotrophic	< 4	< 0.004
Oligotrophic	4-10	0.004-0.01
Mesotrophic	10-20	0.01-0.02
Meso-eutrophic	20-35	0.02-0.035
Eutrophic	35-100	0.035-0.1
Hyper-eutrophic	>100	> 0.1

From these parameters (white arrows indicating ranges), the Trophic State Index for Swan Lake, depending on the time of year, would range as low as 50 to much higher due to the combination of high phosphorus, high chlorophyll-a and low Secchi depths (Figure 34).

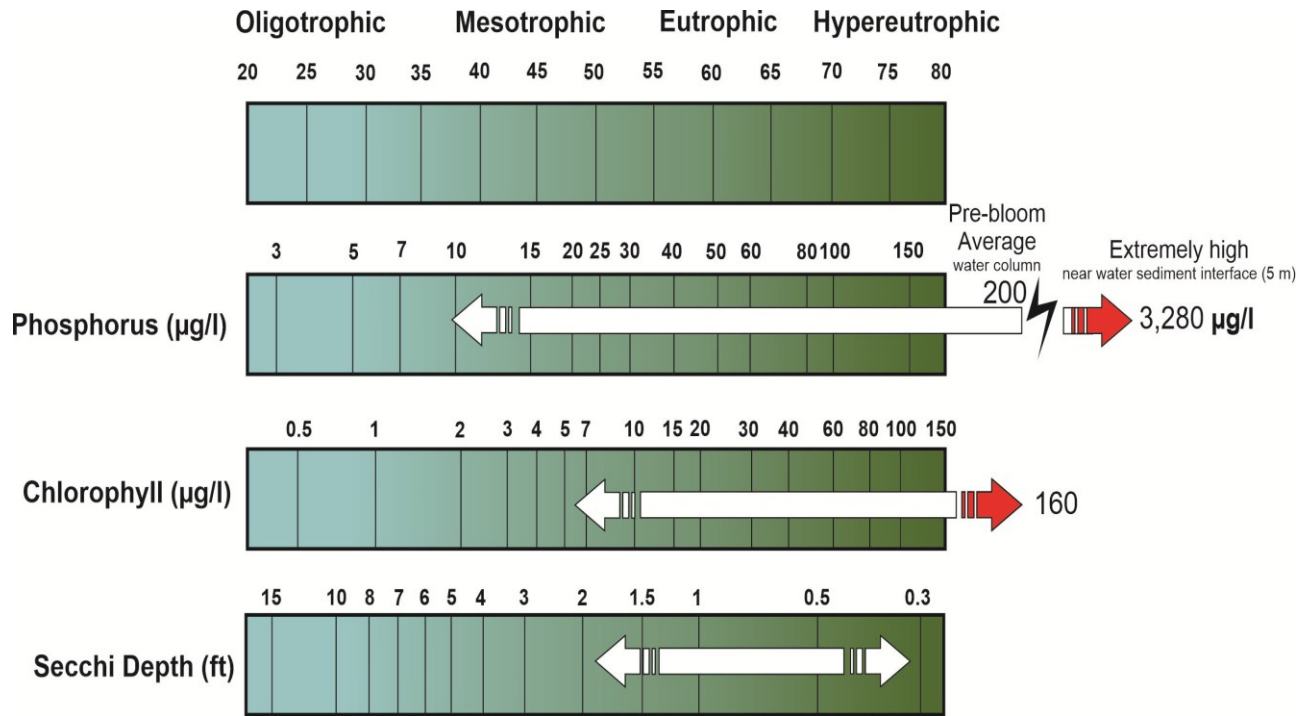


Figure 34. Trophic State Index chart with Swan Lake ranges indicated by white arrows.

Figure 35 is a simplified diagram showing the characteristics of the various trophic states of a lake. Although a eutrophic lake initially tends to be a much more productive system in terms of biomass, the biodiversity is lost as the most successful species, often invasive ones, outcompete and displace rival species. At Swan Lake, because of the shallow, warm, high nutrient concentrations, cyanobacteria can very quickly ramp up and completely inundate the water column. With such blooms, the dissolved oxygen can have extreme oscillations bordering on concentrations that are too high (causing gas bubble disease in fish) or too low (hypoxia) for such desirable fish as cutthroat trout. With algal blooms, huge amounts of organic material form during onset. Once conditions are no longer favourable or life cycles expire, these organisms die off and form large volumes of detritus that are either suspended in the water column or drop to the bottom.

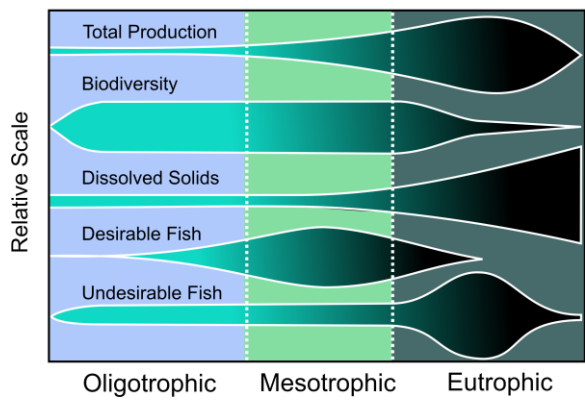


Figure 35. Diagram of lake characteristics of different trophic states (after Welch and Lindell, 1980).

**5.3.2 Nitrogen**

Nitrogen data in the form of nitrates were also plotted for the 2025 field season (Figure 36). In this year’s data, there was a rapid decline of nitrates at the Founders’ Wharf where values within the water column were initially high and then dropped from 3.8 mg/l to 0.58 mg/l in the course of a week. These initial high values were not observed at the boardwalk site. At both sites, the various depths saw curves that had low concentrations throughout the early June algal bloom period. There was a data gap for the last part of June until July 30. Values into the latter part of the sample saw a shallow sloped incline with the last points showing a more rapid rise in values.

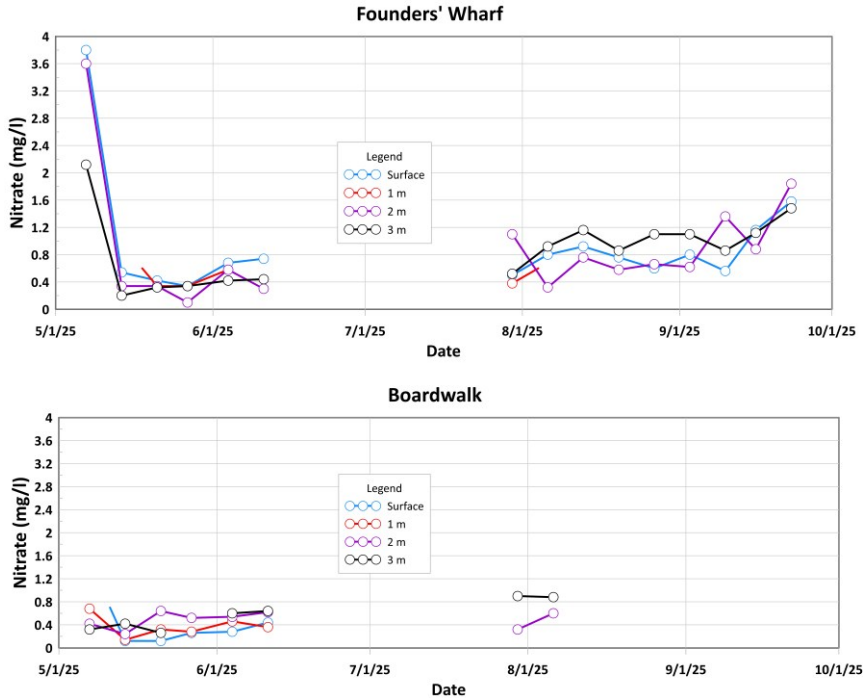


Figure 36. Nitrogen time series plots for Founders’ Wharf (top) and boardwalk (bottom).

A contour plot was made for the nitrate concentrations for the 2025 data. It is worth noting that there was a significant contrast between the nitrate concentrations of 2025 and 2024 as illustrated in Figure 37. In 2024, high levels of nitrates throughout the water column persisted at least into the early part of July whereas nitrate values immediately declined by mid-May in 2025.

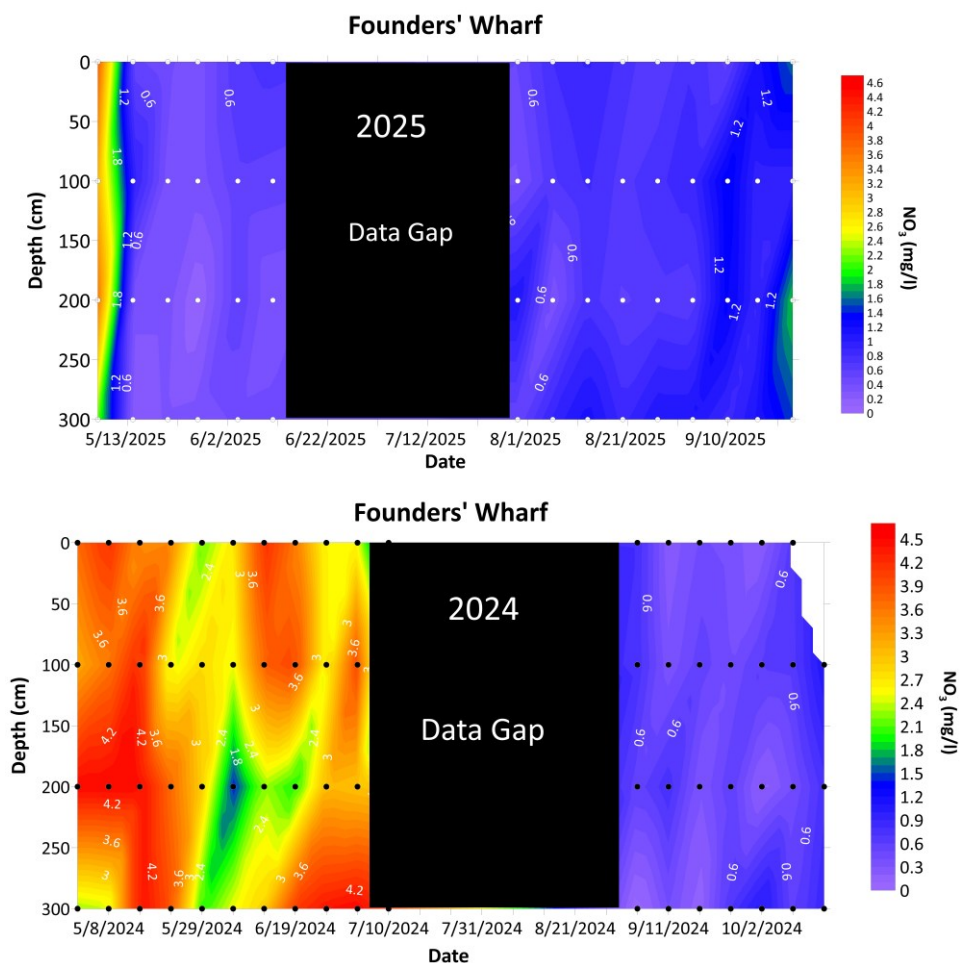


Figure 37. Nitrogen contour plots for Founders' Wharf (top) and boardwalk (bottom).

### 5.3.3 Turbidity

Figure 38 displays the turbidity for the two lake sites. Note both sites show a gradual upward trend as more organic materials enter the water column. The bottom panel of this figure shows the two integrated water column curves for these two sites. It is only near the end of the sampling season that the values begin to decline. It is interesting to note that the turbidity values did not spike during the early June algal bloom whereas the Secchi disk depths were highly affected by the concentration of *Dolichospermum* suspended in the water column. Perhaps a reason for this disparity is the fact that the turbidity meter is

measuring over a very small area in close proximity to the sensor whereas the Secchi disk depth is a qualitative measurement of looking through the water column where suspended material impedes the visibility of the Secchi disk.

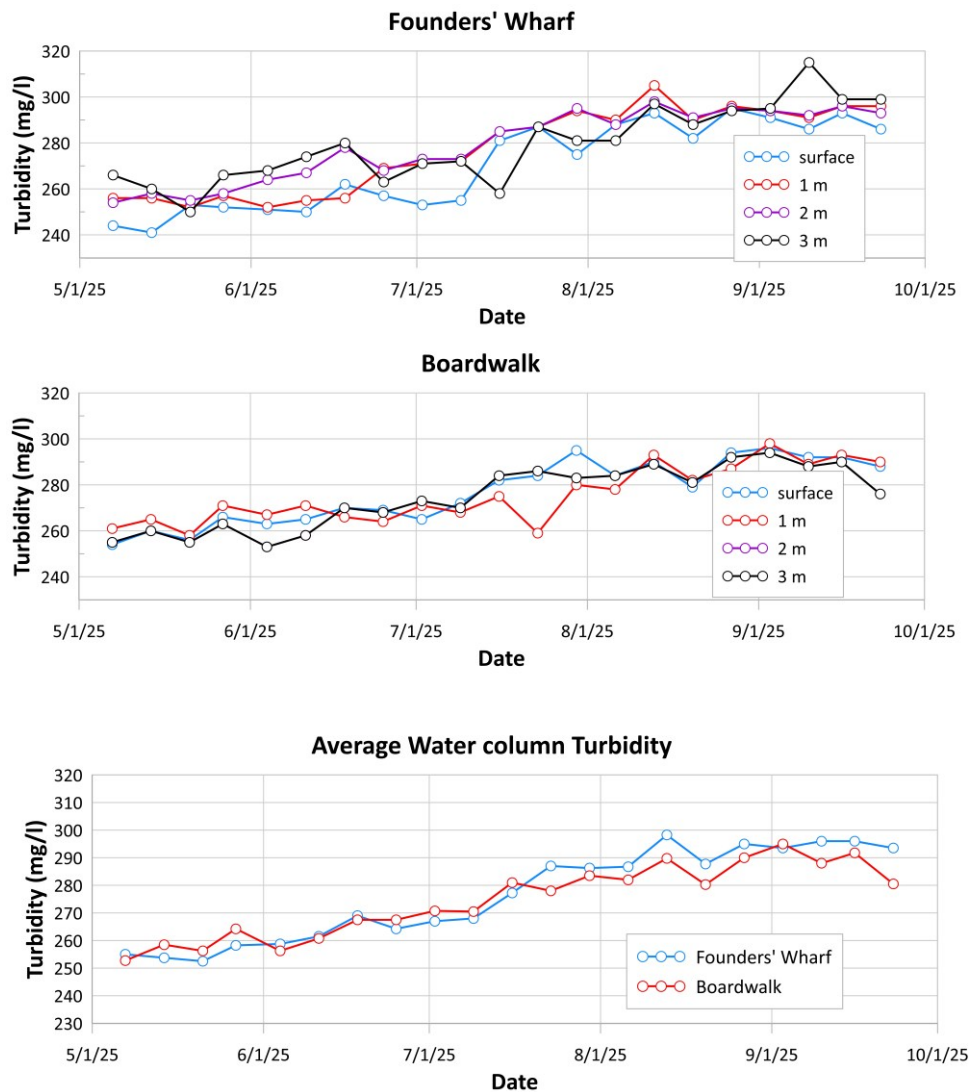


Figure 38. Turbidity data for the two lake sites along with an integrated water column summary.

### 5.4 Water Levels

Water levels for this year’s data collection are displayed in Figure 39. The continuous red curve is taken from the barometric pressure compensated Solinst water level sensor placed on the lake bottom near the Founders’ Wharf. This sensor logged data every 30 minutes. Draped onto this curve are weekly water depth measurements at the same location that verified the accuracy of the pressure sensor. Note the impact of rain events and how the water levels changed based on the amount of rain. The Solinst logger

was brought to the surface on May 27<sup>th</sup> and downloaded. There is an obvious upward red spike at this time as water pressure was reduced to zero when brought to the surface. The level logger was recovered September 23, 2025 and the data were retrieved. It was then re-deployed to collect over winter data of changes in water levels and bottom temperatures.

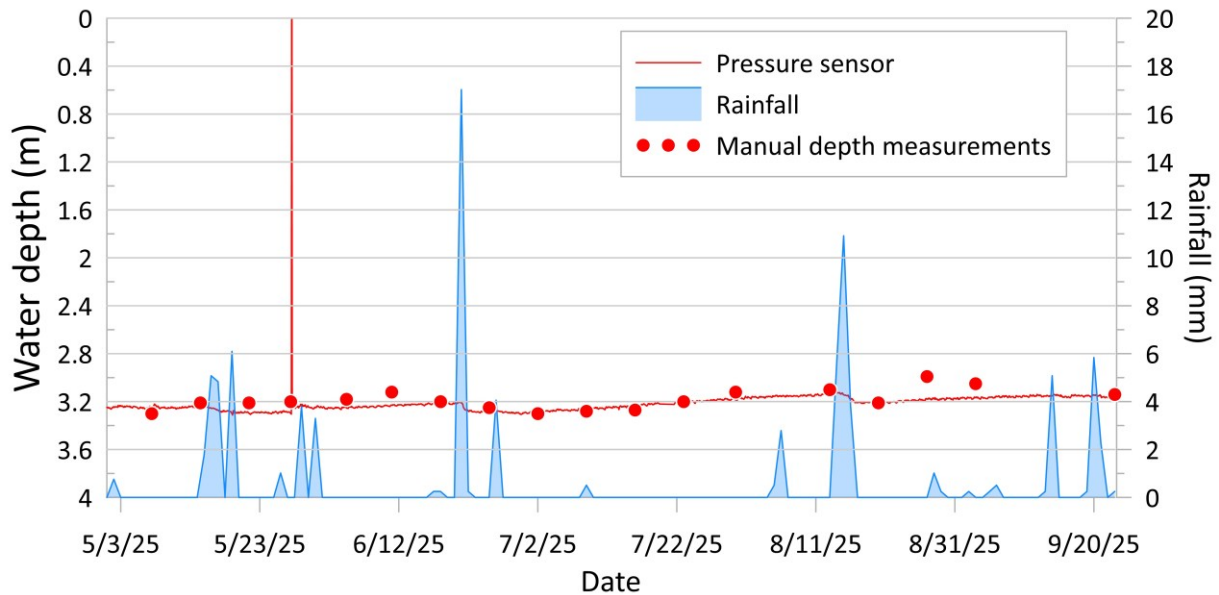


Figure 39. Water level changes comparing pressure sensor data to line measured data.

## 6.0 Interannual Comparisons

Swan Lake is far from existing in a steady state as it undergoes significant seasonal changes physically, biologically and chemically. These changes vary over many different time scales including minute by minute, diurnally and monthly. With ten years of data, interannual comparisons can be made to examine year-to-year variability. These comparisons are useful for detecting longer term trends and provide insights into how the system responds to different climatic influences such as drought and changes in algal blooms. Only a cursory treatment of these comparisons is offered here.

### 6.1 Dissolved Oxygen

Dissolved oxygen concentrations from 2017 through 2025 reveal a highly consistent seasonal pattern typical of eutrophic, strongly stratified freshwater systems. Despite year-to-year variability in bloom magnitude and time of occurrence, several interesting features have emerged across this dataset. Three figures are presented to help characterize the DO dynamics. Figure 40 shows the surface DO concentrations at the Founders' Wharf site from data collected during this long-term study as well as some historical data from previous studies. Some annotations have been added to show generalized patterns of DO increase and decline associated with algal bloom and die-off cycles. These patterns are particularly clear during the years 2017, 2018, 2021 and 2023 and to a lesser extent in the years 2019, 2020, 2022 and 2025.

There appears to be a period after the second bloom where the lake DO levels are at their seasonal low where the anoxic layer migrates right up to the surface at times as was the case in 2017, 2018, 2019, 2021 and 2024.

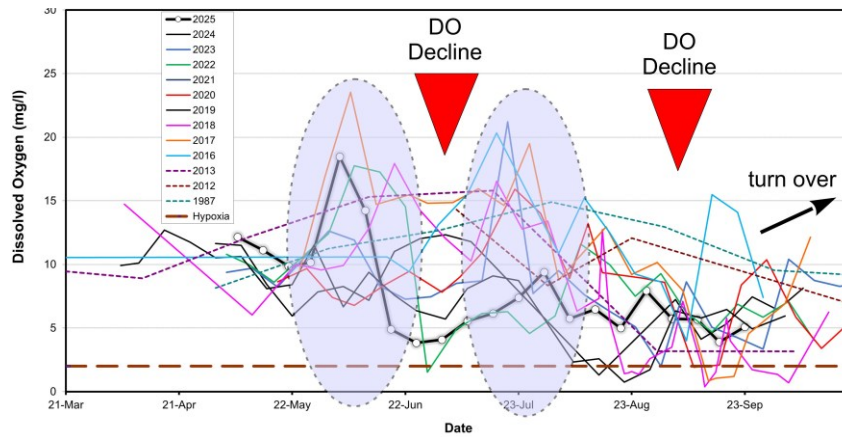


Figure 40. overlays the 2025 data with previous data sampled near the surface of the Founders’ Wharf.

Figure 41 shows contour models of data collected over this 2017–2025 period. Across all contour maps the lake develops a persistent anoxic zone (0–1 mg/L) near the bottom each summer.

- The anoxic layer typically develops between 150–250 cm depth, depending on the year and the strength of thermal stratification.
- In most years, the anoxic zone expands upward as summer progresses, often reaching mid-depths by late July or August.
- The duration of anoxia is substantial—commonly from late June through September or later, depending on the seasonal fall turnover.
- The years 2017, 2018, 2021, 2022, and 2025 exhibit the thickest, longest-lasting anoxic layers.

With the formation of this thick and prolonged anoxic layer, there is strong internal loading potential (e.g., phosphorus release) which can create a feedback link to create subsequent algal blooms—a possible explanation of the second mid-summer bloom.

Multiple years show early-summer and mid-summer peaks in DO associated with algal blooms. In these periods, surface waters often exceed super-saturation with values that range from 10–14 mg/L to even higher.

- The years 2017, 2018, 2021, 2022, 2023, and 2025 show the clearest bloom-related surface oxygen spikes.
- There are examples of two distinct bloom events per year (e.g., early June and midsummer blooms in 2017, 2018, 2021 and 2023).
- These pulses are brief: they raise oxygen in the upper 1–2 m but rarely transfer this oxygenation to the deeper water.

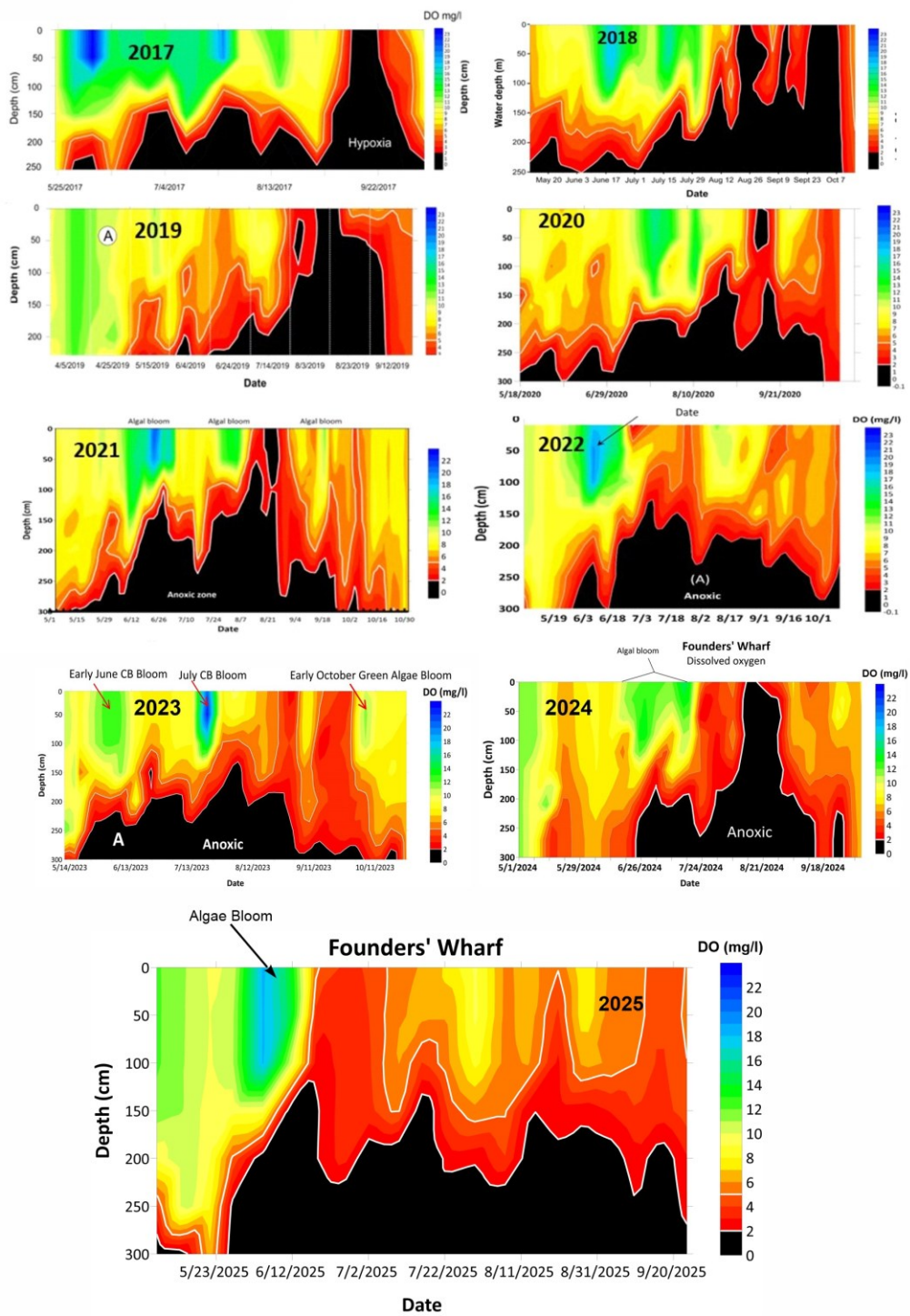


Figure 41. Interannual comparison of DO time series at the Founders' Wharf.

Histograms of DO concentrations were extracted from the DO models of Figure 41. Figure 42 depicts these histograms where the bin size was set to 1 mg/l. This gives a quick visual of the DO dynamics within each year of collected data. The scatter plot below the histograms shows the yearly percentage of grid nodes (0 to 3 m depths) that were hypoxic (less than or equal to 2 mg/l). This reveals the significance of this low oxygen layer.

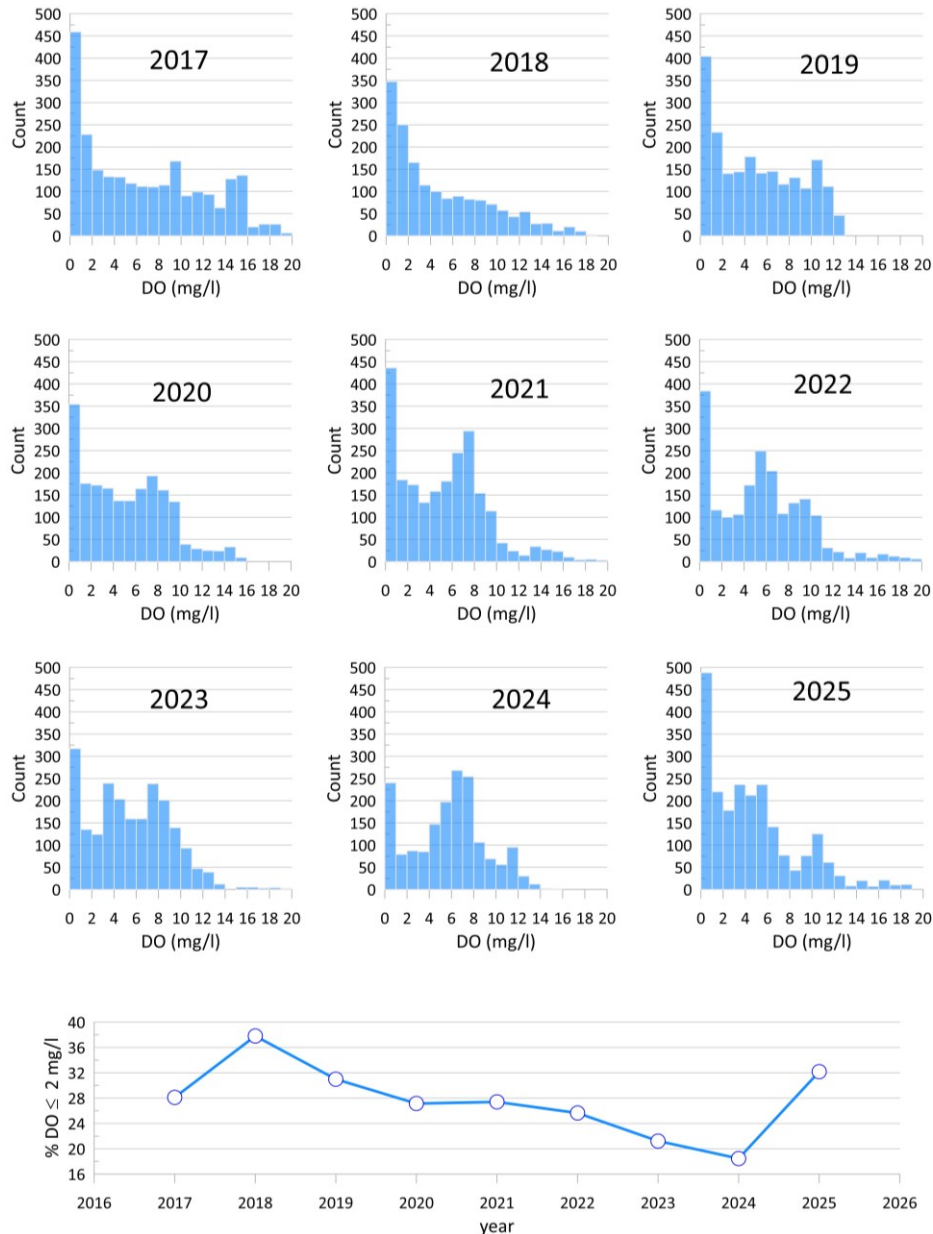


Figure 42. Yearly DO concentration histograms (top). Scatter plot of percentage of DO models that are hypoxic (bottom).

Figure 43 shows a compilation plot of all histograms on the same axes for comparison.

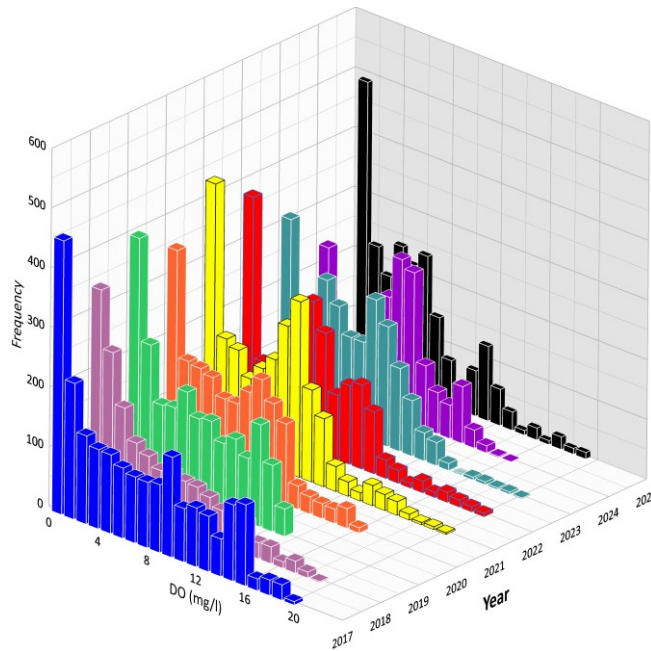


Figure 43. Compilation plot of 2017 to 2025 DO concentration histograms.

## 6.2 pH

Both pH and ORP were not routinely measured for the 2025 field season due to an instrument failure and unstable reading from a new Hanna multiparameter meter. Figure 44 shows the seasonal surface water pH taken at the Founders' Wharf site. Note the extreme range of about 6.9 to nearly 10, indicating high biological activity. The higher 9–10 range were observed during algal blooms where gradients from surface to bottom showed ranges of 3.5 units in only 3 m of water. The pH and DO curves were highly correlated.

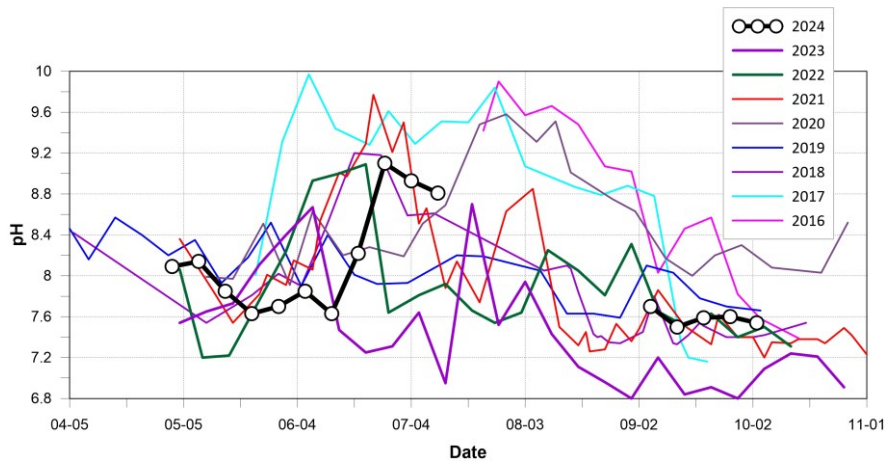


Figure 44. Interannual comparison of pH time series at Founders' Wharf.

### 6.3 Secchi Depth

The Secchi depth data for the last ten years are plotted in Figure 45. Water clarity this year improved by 1.23 m between the June 4<sup>th</sup> bloom and June 25<sup>th</sup>. The best measured condition at Swan Lake this year occurred in the middle of August nearly a meter deeper than the average of the nine previous years.

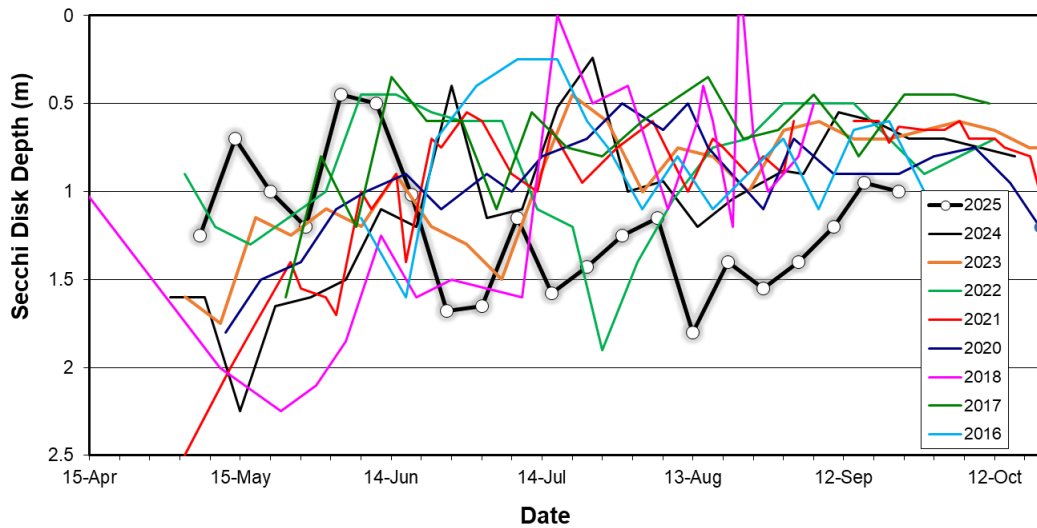


Figure 45. Interannual comparison of Secchi depth time series at Founders’ Wharf.

### 6.4 Nutrients

Nutrients were plotted for the last ten years to compare annual variations of these parameters. Generally, when Swan Lake is not stratified, ortho-phosphorus (OP) is well mixed with early spring and late fall values approximately the same. Once the lake begins to stratify, surface OP begins to decline as biological uptake drives concentrations downward (Figure 46).

The cycling of phosphorus is a repeatable pattern at Swan Lake with relatively high levels in the spring followed by a drop as the lake stratifies and biological uptake processes begin to dominate. Historical phosphorus values have been placed on this plot as well, indicating phosphorus concentrations of the 1970s and 1980s (Harnadek, 1987). It’s important to note that these are surface water concentrations and do not necessarily reflect the deeper water legacy concentrations that influence phosphorus internal loading in the lake. Unfortunately, none of the historical data were available during the late June to mid-September period, a period where surface phosphorus concentrations dip due to active algal blooms. As was noted in the deep-water site, benthic phosphorus is extremely high during anoxic periods. These values indicate a massive reserve of phosphorus that will continue to be an issue at Swan Lake. Although not part of this study, oxygenation saturation chambers were being installed in the fall of this year which replace oxygen-poor water with oxygen-rich water at the deeper layers of the lake thereby reducing the reductive dissolution of phosphorus at the water–sediment interface. This reduction of internal phosphorus loading from the high legacy phosphorus-rich sediments could prove to limit nutrients that typically feed algal blooms.

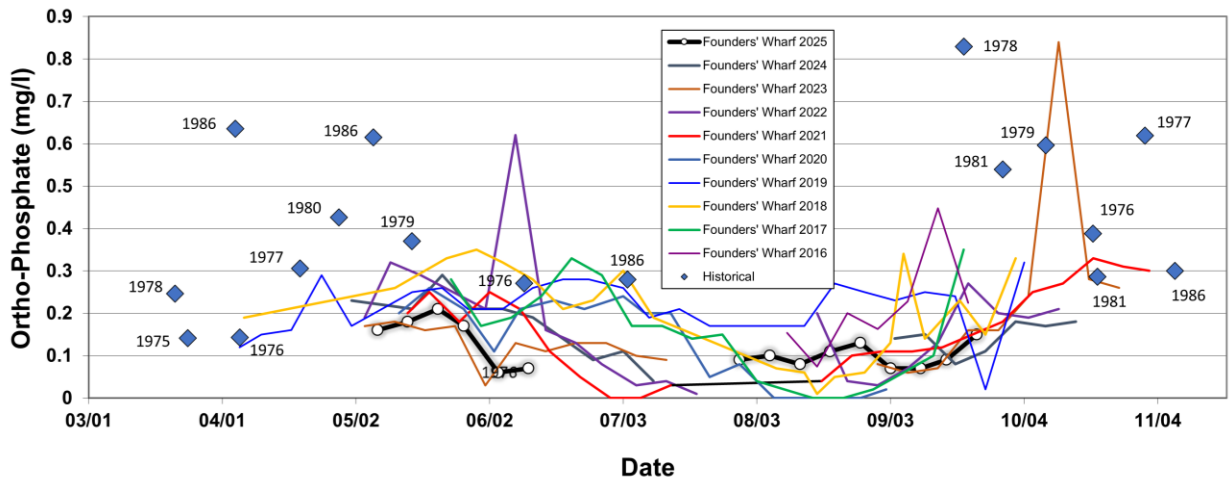
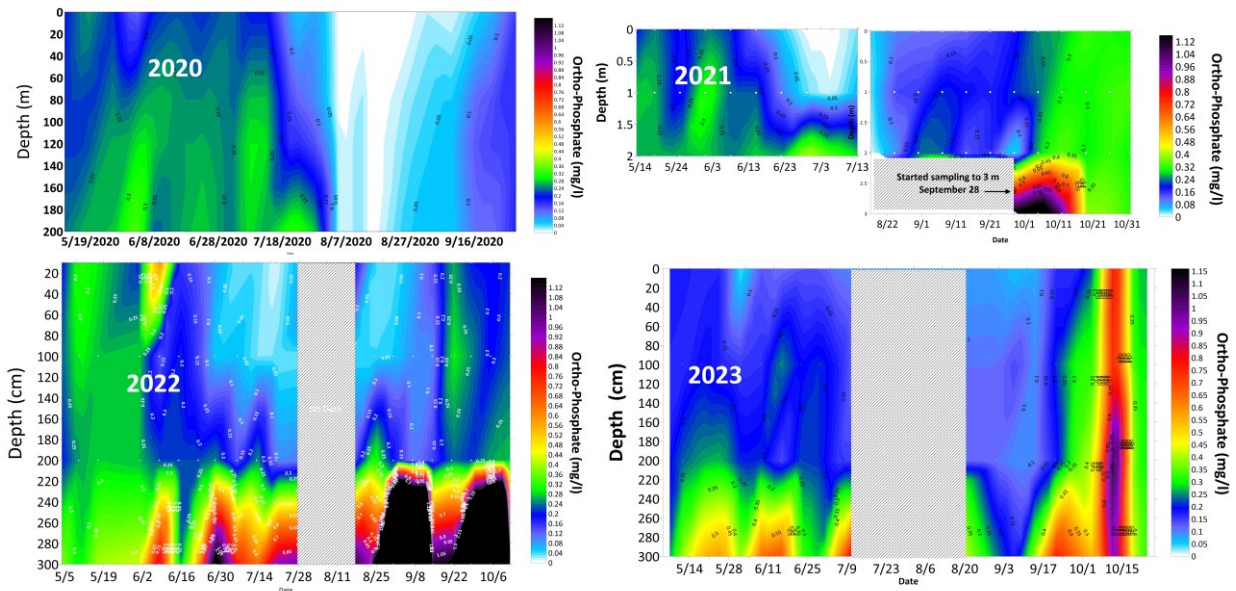


Figure 46. Interannual comparison of Founders' Wharf phosphorus concentrations.

Figure 47 displays contour maps of the last five years of phosphorus over the sample seasons spanning 2020 to 2025.

### Founders' Wharf



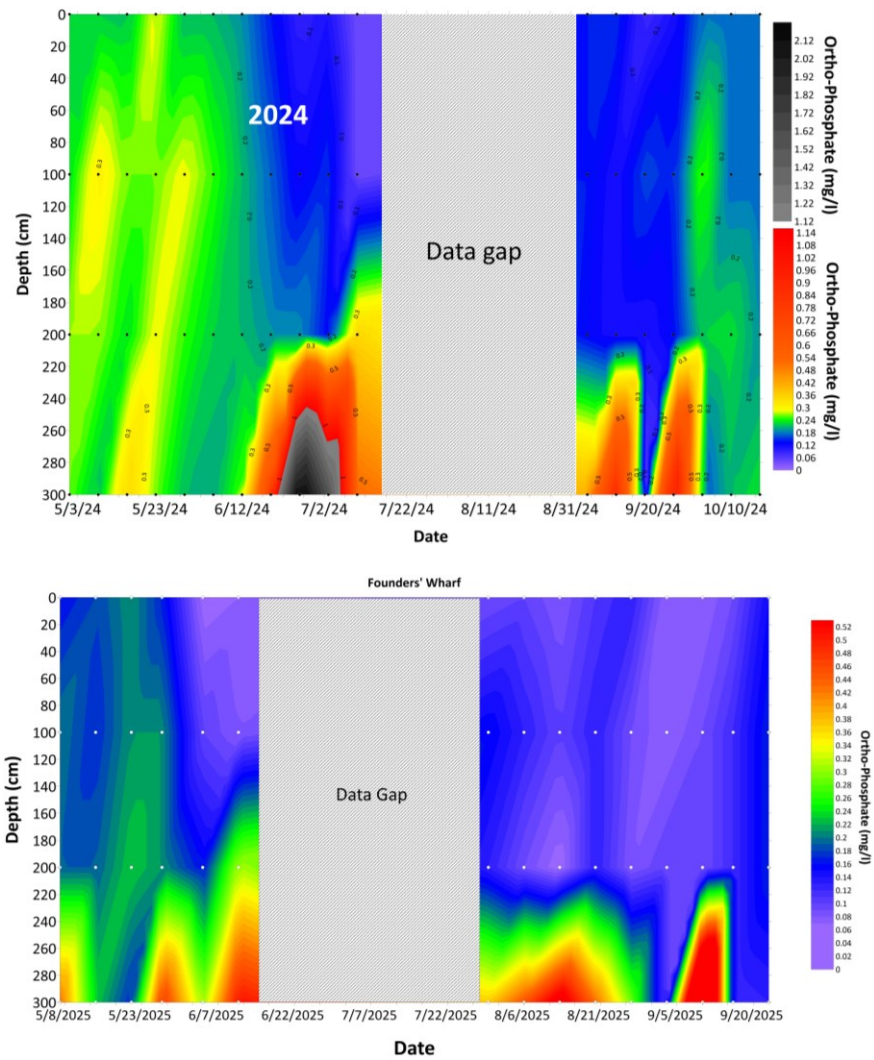


Figure 47. Comparison of phosphorus contour maps of the years 2020 to 2025.

There appears to be a threshold occurring each year at about the 220 cm depth. Note the rounded peaks of elevated OP concentrations that intensify and then subside. These perturbations are somewhat mirrored in the migration of the anoxic layer as seen for this year's data (Figure 48). Generally, as the DO anoxic layer migrates vertically towards the surface past the 220 cm depth, OP concentrations increase and move vertically with the anoxic waters. The same correlation appears in the 2023 data until the fall turnover when the high concentrations of OP at depth are mixed into the water column—an event that led to an early October green algae bloom as seen in the chlorophyll data of Figure 25 in the 2023 Swan Lake water quality report (Bowen, 2023).

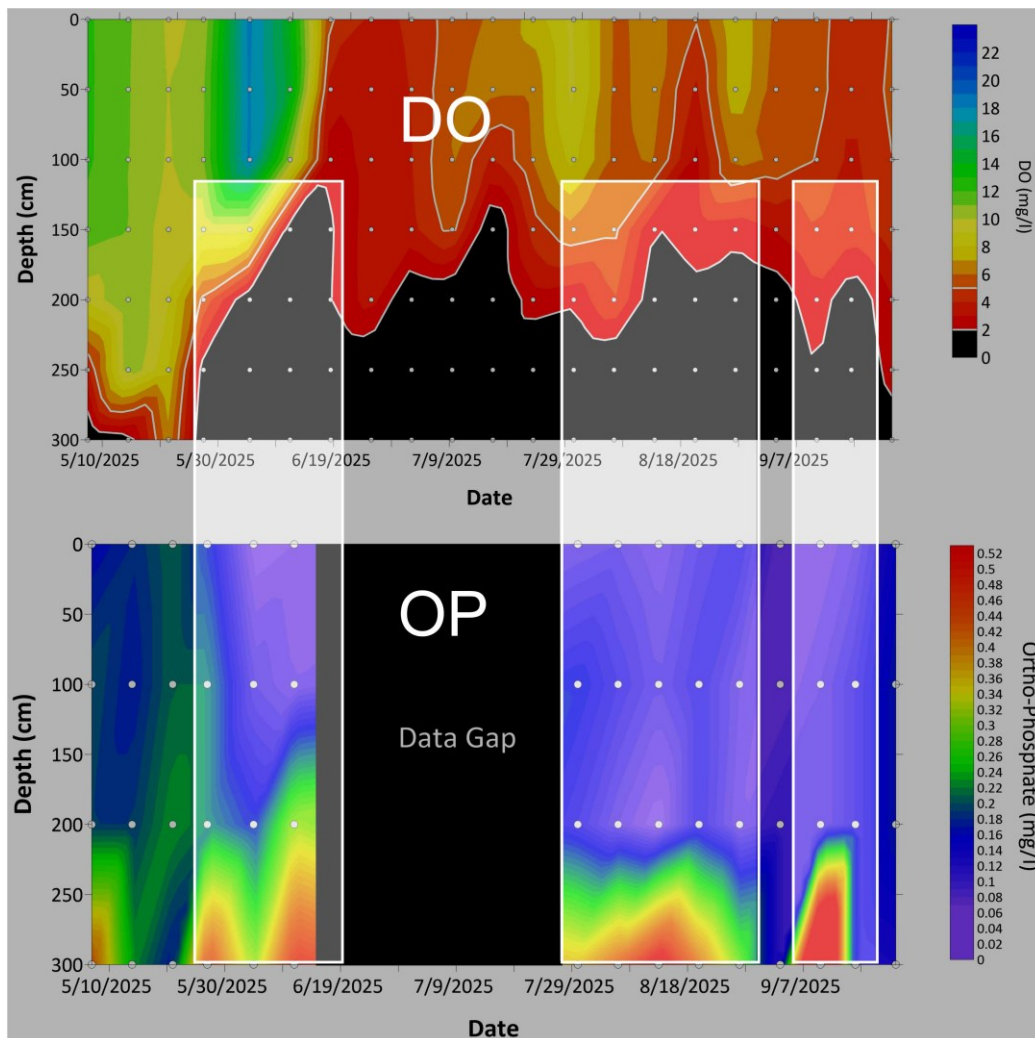


Figure 48. OP and DO anoxic layer vertical migration coupling.

Figure 49 shows the Blenkinsop Creek phosphorus values over the sample seasons. This creek continues to contribute to the high phosphorus load going into the lake well above the defined threshold of eutrophic in terms of trophic state classification. Fortunately, the discharge of this creek tapers to very low flow conditions in the summer months, reducing its phosphorus impact as a source of external loading.

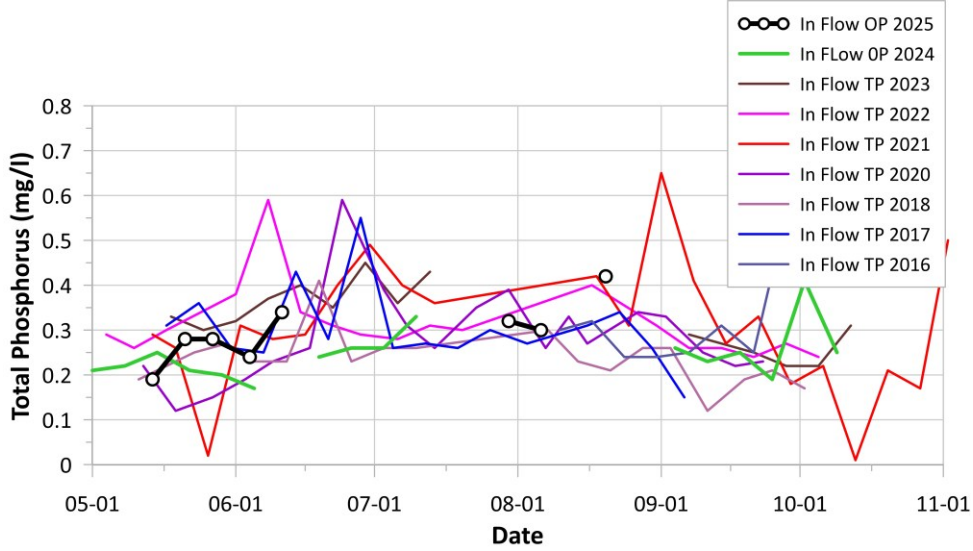


Figure 49. Interannual comparison of inflow creek phosphorus concentrations.

To put Swan Lake in the context of other lakes of the area, Figure 50 shows the total phosphorus concentrations at Elk Lake over a 35-year period. Note the axis is in micrograms per liter. The values displayed here at their highest point are about six to seven times less than the ortho-phosphorus, a component of total phosphorus, measured at Swan Lake.

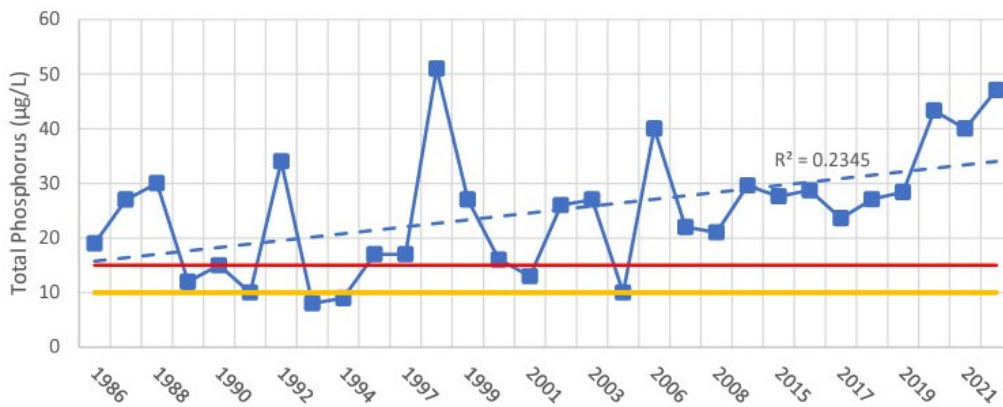


Figure 50. Total phosphorus concentrations measured at Elk Lake (Nielsen, 2023).

Nitrate concentrations were plotted for the last nine years (Figure 51). There is considerable scatter during the early part of the season when examining previous years. The values tend to be bimodal, starting off either high or low and tend to decline with relatively steady state values throughout the months of July and August. By September and into October, the values begin to climb generally.

What is unusual about the 2025 nitrate data is the rapid decline one and a half months earlier than is typical. In years where the values start off low, there is a rise in nitrate concentration in June (2017, 2021, 2022). At the onset of the June *Dolichospermum* blooms, nitrates are consumed and all concentration curves are reduced and flattened.

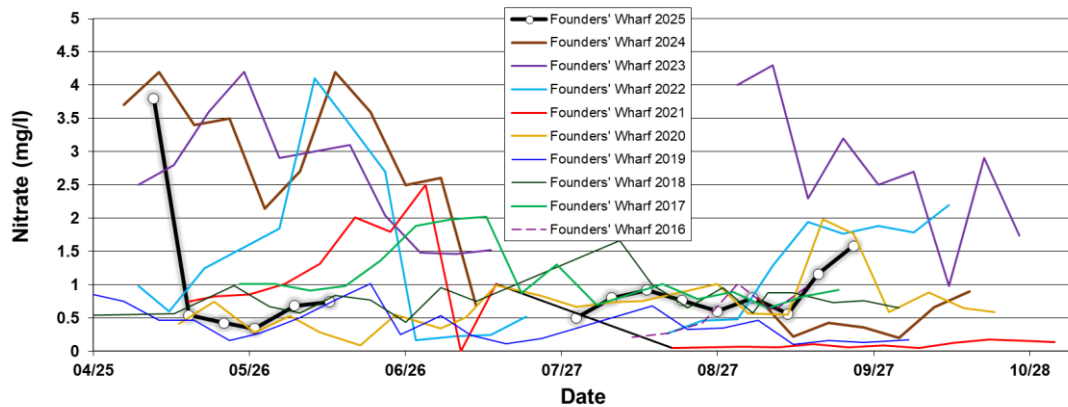


Figure 51. Interannual comparison of nitrogen.

### 6.5 Water Temperatures

Figure 52 displays both the surface and bottom water temperatures for the last nine years at the Founders' Wharf site. The 2021 heat dome saw lake temperatures rise to nearly 30°C and still stands out as an anomaly. The scatter between curves in the spring is relatively high when compared to the near uniform collapse of the curves in the fall. Note the a-symmetrical shape of the curves where water temperatures rise over a longer period of time than the cooling period of the fall where mixing due to fall storms accelerates the release of heat from the lake.

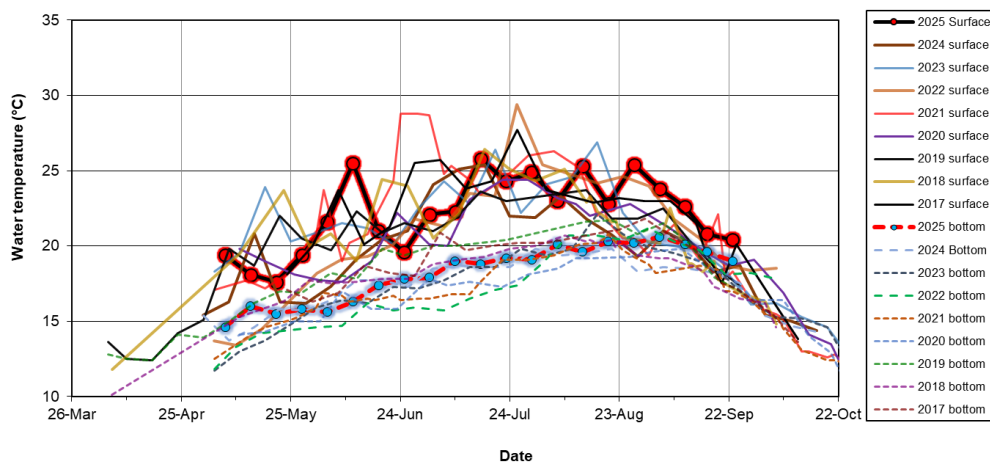


Figure 52. Surface and bottom temperatures for 2017–2025 (Founders' Wharf).

## 6.6 Microscope Imaging

Water samples taken throughout the study period were examined under the microscope, revealing the key algal species responsible for photosynthesis as well as the zooplankton species that play key roles in the food web at Swan Lake. Although this work is not reported here, the following link refers to a collection of [organisms found in Swan Lake](#) over the last six years (Figure 53) .

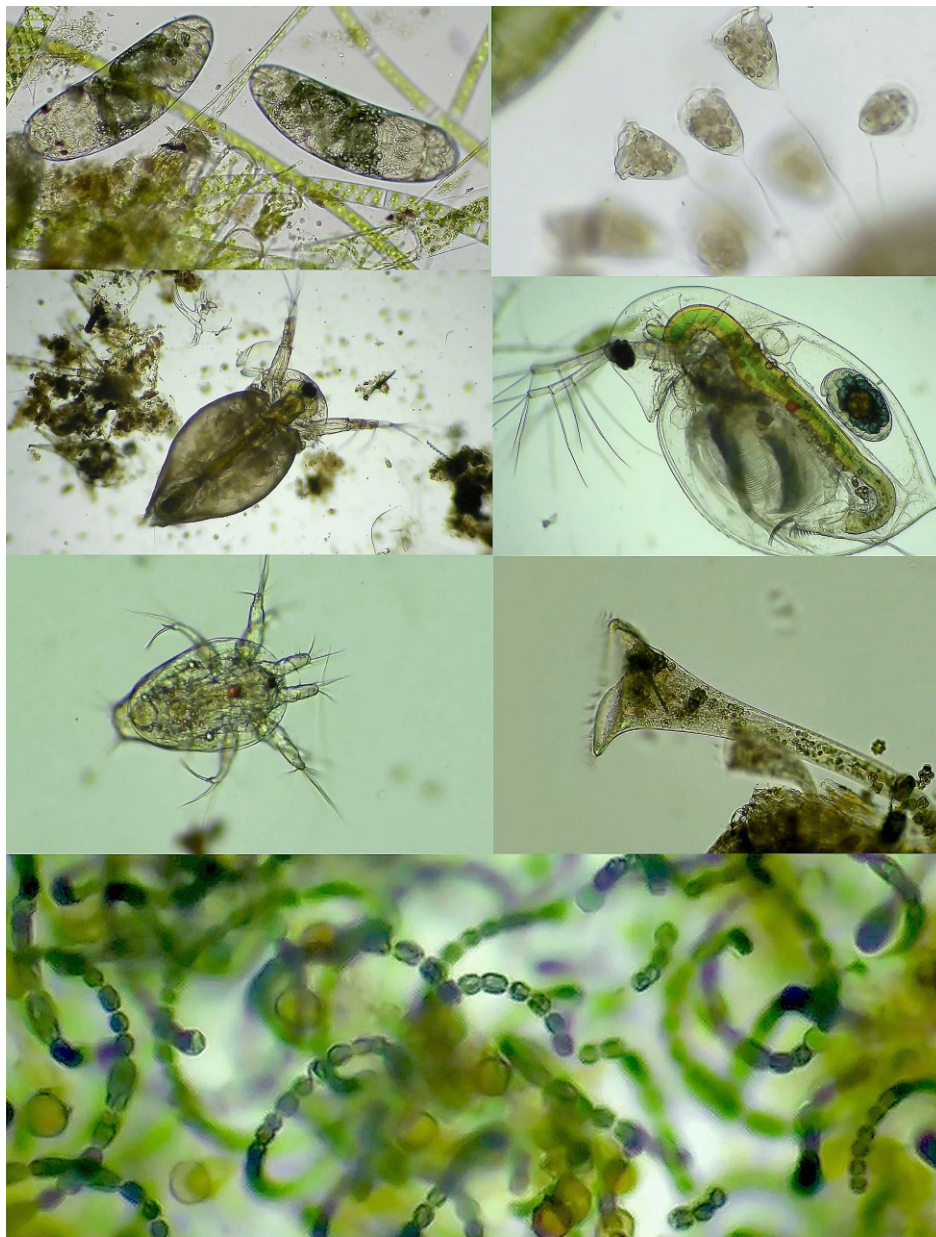


Figure 53. Sample of microscope images.

## 7.0 Summary and Conclusions

This is the tenth consecutive year of a consistent sampling program measuring some of the major water quality indicators. Each year, the lake responds to a series of triggers such as temperature, sunlight, nutrients and biological processes. With variations in weather patterns, lake responses differ from year to year with the succession of the biological constituents constantly adjusting and competing to optimize their unique position in the ecosystem. These changing weather patterns make it difficult to extract trends in the data as the physical, biological and chemical attributes all respond in concert to these variations. For instance, a few years ago in 2021 we saw the extreme heat dome and several atmospheric rivers. The last number of years we have seen long periods of drought. In previous years, thick smoke has had a detrimental effect on DO during the late summer when the lake is at its lowest point of resilience. Despite these significant variations, Swan Lake is demonstrating consistent seasonal patterns of DO, pH, temperature and nutrient cycling. By collecting several lake and weather data parameters, these efforts afford explanatory insights into the various shifts in algal bloom onsets and general lake responses to driving forces. Swan Lake continues to be dimictic, has very high concentrations of legacy phosphorus and experiences the development of vast volumes of anoxic waters throughout the summer months such that much of the water below the 2 m depth is less than 2 mg/l.

Each year water quality measurements continue to contribute to a greater understanding of the processes at work at Swan Lake. The benefits of a consistent monitoring program are numerous.

- Monitoring provides a method to document physical, chemical and biological characteristics of the lake.
- Monitoring provides data for a science-based approach to possible interventions.
- Lake studies give insights into complex interrelationships such as DO and nutrients.
- Monitoring provides useful educational opportunities through interpretive programs or citizen science involvement.
- Monitoring gives insights useful to explain lake events such as algal blooms and fish kills.
- Well documented long-term monitoring is often a prerequisite for obtaining grants and funding for lake restoration proposals.

During the sampling site visits, numerous visitors asked a wide range of questions pertaining to the lake. This provided opportunities to describe lake processes and the instruments that are used to collect data. There were many very satisfying exchanges with people of all ages. This was also a time where people spoke of their knowledge of birds, dragonflies and the local history of the lake and surrounding area. On numerous occasions people commented that they were glad that this work is being done and valued Swan Lake as a special place to protect.

During this past year, level 3 (deep-water) data collection was carried out for 20 consecutive weeks, complying with the BCLSS guidelines measuring Secchi disk depth, DO and temperature profiles. Water chemistry was also collected bi-weekly to measure nutrients and chlorophyll-a. Sampling was carried out at the deepest part of the lake down to a depth of 5.5 m by Swan Lake staff Deanie Harding and Kristen Banasch.

As this report is essentially a data summary, the collection of data can be used to further examine the following issues:

- the influence of water temperature, solar light penetration and DO production,
- nutrient cycling and internal phosphorus loading due to anoxic conditions,
- modeling onset of algal blooms based on multiparameter inputs, and
- the impact of wind and its direction on mobile suspended algae.

Note that this year a data dashboard was added to view near-real time data of various lake parameters. The link to this site is as follows: [https://www.dssolutions.bc.ca/Swan\\_WQ-2025.html](https://www.dssolutions.bc.ca/Swan_WQ-2025.html)

## 8.0 Recommendations

The following recommendations are listed to improve the sampling program.

- (1) Consider extracting phosphorus during periods where the benthic layer concentrates phosphorus. This method of hypolimnetic withdrawal syphons phosphorus from the benthic layer (Silvonen et. al., 2022) during times where seasonally high phosphorus levels concentrate in a narrow vertical band near the bottom of the lake.
- (2) Consider ways to quantify cyanobacteria populations to better define thresholds of bloom states.
- (3) Conduct a topographic survey of the wetland area so that the estimates of flood volumes can be better constrained.
- (4) Continue to develop a catalogue of surface algae, macrophytes and water column zooplankton and phytoplankton.
- (5) Sample bottom sediments and image, using a microscope, the bottom decomposers.
- (6) Add to the photometry testing the element iron as this is a key element that interacts with phosphorus in the benthic zone.
- (7) Create educational posters or an interactive multimedia on lake processes to be displayed in the Nature House. With the now extensive collection of water quality data, microscope images and insights about the various processes at work, there is opportunity to create interesting static or dynamic education content.
- (8) Place a lake water level staff to enable visual checks of water level changes.
- (9) Monitor surface algae extent using a time-lapse trail camera mounted to a pole overlooking the lake. This would provide another metric and be expressed as daily percentage coverage.
- (10) Re-configure the LG Sonic so that the transducer is in deeper water out of the influence of macrophyte interference.
- (11) In next year's data collection, create a webpage portal that posts the weekly data so that viewers can see near real time plots of the current conditions of the lake.
- (12) Recommend scheduling profiling collection of nutrients during the summer months to avoid data gaps.
- (13) Recommend that all sensitive water quality monitoring equipment be kept indoors to prevent condensation damage to electronics.

- (14) Ensure all reagents and replacement sensors caps are ordered and in hand before the field season begins.
- (15) Consider a method to trace urban runoff by sampling high runoff events. Blenkinsop Creek shows high levels of phosphorus which enrich Swan Lake with detrimental external loading.
- (16) Examine sediment chemistry for legacy phosphorus and iron by extracting core samples.
- (17) During blooms, sample for cyanotoxins.
- (18) Conduct a literature review of phosphorus extraction.
- (19) Monitor deep water DO in association with the newly installed oxygenation saturation chambers.
- (20) Investigate instrumentation that could measure in-flow and out-flow volumes to the lake.

## 9.0 Acknowledgements

The 2025 Swan Lake Water quality monitoring program was funded by Swan Lake and Christmas Hill Nature Sanctuary under the direction of Dr. Cara Gibson.

The author would like to acknowledge Deanie Harding and Kristen Banasch of Swan Lake who completed the Level 3 water quality study. Some of the level 3 data from that study have been included in this report.

## 10.0 References

Andersen, M.R., Kragh, T. and Sand-Jensen, K. 2017. Extreme diel dissolved oxygen and carbon cycles in shallow vegetated lakes. *Proceedings of the Royal Society B: Biological Sciences* 284: 20171427.

Bowen, R. 2016–2024. Swan Lake Water Quality Reports. Contractor reports

Bowen, R. 2021. Swan Lake Victoria BC Bathymetric Survey. Contract report submitted to Swan Lake Christmas Hill Nature Sanctuary.

Bulc, T.G., Istenic, D. and Klemencic, A.K. 2011. The efficiency of a closed-loop chemical-free water treatment system for cyprinid fish farms. *Ecological Engineering* 37 (2011) 873–882.

<https://doi.org/10.1016/j.ecoleng.2011.01.004>

Bus, A., Karczmarczyk, A. and Baryla, A. 2018. Permeable reactive barriers for preventing water bodies from a phosphorus-polluted agricultural runoff-column experiment. *Water* 2019, 11, 432. doi:10.3390/w11030432

Carlson, R.E. 1977. A trophic state index for lakes. *Limnology and Oceanography* 2(2):361–369.

Haggard, B.E., Grantz, E., Austin, B.J., Wagner, N.D. and J.T Scott. 2023. Chlorophyll and Phycocyanin Raw Fluorescence May Inform Recreational Lake Managers on Cyanobacterial HABs and Toxins: Lake Fayetteville Case Study. *Journal of Contemporary Water Research & Education*, Issue 177, Pages 63-71

Inform Recreational Lake Managers on Cyanobacterial

## HABs and Toxins: Lake Fayetteville Case Study

Harnadek, S., L., 1987. Documentation of the biological and physical/chemical characteristics of Swan Lake, Victoria, including a discussion of the present state of eutrophication. (Period: April 1986–March 1987). Submitted as partial fulfillment of requirements of Biology 490A and 490B: Directed studies in Botany and Ecology, University of Victoria.

Health Canada. (2022). Guidelines for Recreational Water Quality: Cyanobacteria and Their Toxins. Ottawa, ON: Health Canada. Cat.: H129-129/2022E-PDF. ISBN: 978-0-660-41541-3. Available [Link](#)

Khan, F. A. and Ansari, A. A. 2005. Eutrophication: An ecological vision. *The Botanical Review* 71(4): 449–482.

Kidwell, D.M., 2015. [Programmatic Environmental Assessment for the Prevention, Control, and Mitigation of Harmful Algal Blooms Program](#), NOAA NOS, 87pp.

Klememcic, P. and Klememcic, A.K. 2021. The effect of ultrasound for algae growth control on zooplankton. *Acta hydrotechnica*, 34 (60): pp. 1–9. <https://doi.org/10.15292/acta.hydro.2021.01>

Kumar K., Mella-Herrera, R.A. and Golden J.W. 2010. Cyanobacterial heterocysts. *Cold Spring Harb Perspect Biol.* 2010;2(4):a000315. doi:10.1101/cshperspect.a000315

Nielsen, R., 2023. Elk Lake Centre Water Quality Trends from 1986–2022. Contract Report.

Nordin, R. 2015. Water Quality Sampling Program for Elk Lake 2014-2015: Overview, Status and Phosphorus Budget. Consulting report submitted to the Freshwater Fisheries Society of BC.

Paerl, H.W. and Otten, T.G. 2013. Harmful cyanobacterial blooms: Causes, consequences, and controls. *Microb Ecol* 65, 995–1010 (2013). <https://doi.org/10.1007/s00248-012-0159-y>

Pedersen, O., Colmer, T.D. and Sand-Jensen, K. 2013. Underwater photosynthesis of submerged plants: Recent advances and methods. *Frontiers in Plant Science*. doi: 10.3389/fpls.2013.00140.

Phosphorus: Canadian Guidance Framework for the Management of Freshwater Systems. In: Canadian environmental quality guidelines, 2004, Canadian Council of Ministers of the Environment, Winnipeg.

Reynolds, C. S. and Davies, P. S. 2001. Sources and bioavailability of phosphorus fractions in freshwaters: A British perspective. *Biological Reviews* 76: 27–64.

Silvonen, S., Niemisto J., Myrskylainen J., Kinnunen O., Huotari S., Nurminen L., Horppila J. and T. Jilbert. 2022. Extracting phosphorus and other elements from lake water: Chemical processes in a hypolimnetic withdrawal and treatment system. *Water Research* Vol 218, 118507 <https://doi.org/10.1016/j.watres.2022.118507>

Suthersan, S.S. 2001. *Natural and Enhanced Remediation Systems*, 1st ed., CRC Press, 240–267.

The Phosphorus Cycle. 2021, January 3. <https://bio.libretexts.org/@go/page/12394>

Wang, J., Gao, J., Wang, Q., Liu, L., Zhou, H., Li, S., Shi, H. and Wang, S. 2025. Phosphorus Cycling in Sediments of Deep and Large Reservoirs: Environmental Effects and Interface Processes. *Sustainability* 2025, 17, 7551. <https://doi.org/10.3390/su17167551>

Welch, E.B. and Lindell, T. 1980 *Ecological Effects of Wastewater*. Cambridge University Press, London.

Wetzel, R.G. 1983. *Limnology* (2nd ed.). Saunders College Publishing, Philadelphia, Penn. 767 p.

For interannual comparisons, data were used that were acquired during the previous nine years of lake study including Bowen, 2016, 2017, 2018, 2019, 2020, 2021, 2022, 2023 and 2024 contract reports submitted to Swan Lake Christmas Hill Nature Sanctuary.