Swan Lake Water Quality Monitoring 2021 Annual Report

March 2022

Project Number: 21163

MARKHAM
Environmental Services

Prepared By:

Zahra Parhizgari, M.Sc., P.Eng.
Senior Environmental Engineer,
Stormwater

Reviewed By:

Robert J. Muir, M.A.Sc., P.Eng.
Manager, Stormwater

Executive Summary

Background

Swan Lake is situated in the City of Markham at the intersection of Sixteenth Avenue and Williamson Road. Swan Lake has an approximate area of 5.5 ha and a maximum water depth of 4.5 m. A gravel pit in the 1960s and 1970s, Swan Lake is currently a community feature with multiple trails and urban development surrounding it.

Several issues were discovered with Swan Lake in 2010, including high phosphorus levels and significant algal blooms during the summer months, which led to low oxygen levels and degraded fish habitats. A Phoslock treatment was administered in 2013 to reduce the phosphorus levels and algal blooms in Swan Lake.

In 2019, the City of Markham conducted a study to define a water quality management strategy for Swan Lake. The strategy which was finalized in July 2020 recommended a chemical treatment in 2021.

In August 2021, 13 tonnes of Poly Aluminum Chloride (PAC) were applied to the Lake in a controlled manner over several days.

A long-term Management Plan was received by the Markham Sub Committee in November 2021 and approved by the Council in December 2021, including provisions for chemical treatment every three years.

Water quality monitoring of Swan Lake has been conducted almost annually since the first treatment in 2013 in order to track water quality and the continued effectiveness of the treatment. The collected data presented in this report is part of the ongoing monitoring program that will allow for continuous assessment of the water quality in Swan Lake and will be used to implement and adapt the long-term management plan for Swan Lake.

This report discusses observations at the three monitored stations throughout 2021. A separate report evaluates the impact of the 2021 chemical treatment on water quality in Swan Lake.

Results

Water quality is regularly monitored at two shoreline sites; the Dock, and the Bridge. Water quality is monitored bi-weekly throughout the summer (May-September) and monthly in the spring (April) and fall (October-November). Samples and measurements are taken at 0.5 m increments for the depth of the lake. A level logger is used to record the water level in the Lake.

Additional testing completed in 2021 included:

- Pre-treatment (January and March) and post-treatment (September to November) monitoring at the deepest part of the Lake (Central station)
- Monitoring of different treatment zones during treatment (August)

The following paragraphs provide the monitoring results for the 2021 monitoring period, as well as annual summaries of available data from 2011 to 2021. The respective figures include plots of measured dissolved oxygen (DO), water clarity, phosphorus concentration, chloride concentration, geese count, and algae.

Phosphorus concentration and water clarity were compared to the eutrophication thresholds, and/or the interim targets developed for Swan Lake through the 2019 water quality improvement study. For DO and chloride, Federal and/or Provincial water quality Guidelines or Objectives are shown for perspective. It should be noted that Swan Lake is not a natural waterbody, and there is no requirement for it to comply with these limits. Where technically and economically feasible, the City will aim to meet these limits to protect and enhance the aquatic environment.

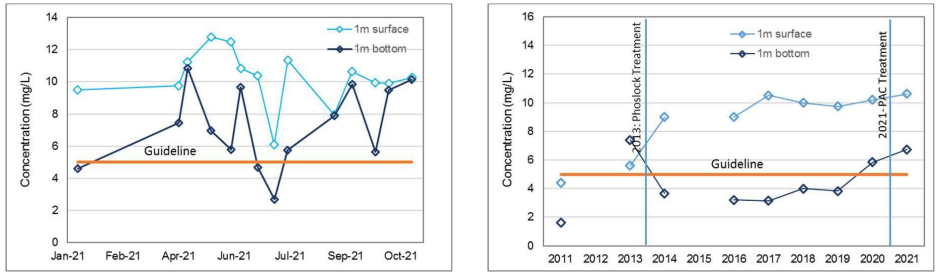
Dissolved Oxygen (DO), Temperature and pH

The minimum dissolved oxygen concentration required for the protection of warm water fish is 5 mg/L for water temperatures up to 20 °C and 4 mg/L for temperatures above 20 °C. DO concentrations for the 1m from the surface, and 1m from the bottom layers are shown below. Measured surface concentrations were above the DO guideline throughout 2021. DO concentration at 2 m increased significantly in August, but remained low at 2.5 m.

During the summer, the Lake was stratified with occasional mixing (resulting in similar surface and deep water concentrations). In the fall, the layers were mixed and similar concentrations were observed over depth.

When stratified, bottom concentrations were below the DO guideline thresholds. Lower concentrations could have lethal or sub-lethal (physiological and behavioral) effects on fish. However, some fish can acclimate to lower oxygen levels and survive concentrations between 1 and 3 mg/L, and oxygen levels nearer to the surface remained above the minimum guideline.

Figure ES-2: 2021 Monitoring Results and 2011-2021 Annual Results- Dissolved Oxygen



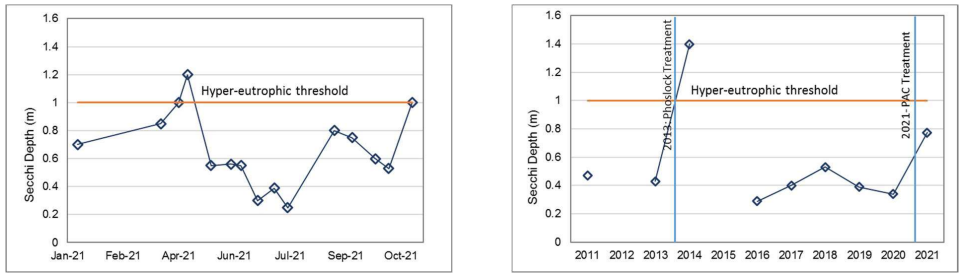
Note 1: DO concentrations are shown at 1 m from the surface and 1 m from bottom.
Note 2: Histotical data are shown for the average growing period.

pH measured at the lab ranged from 7.9 to 8.5 before the chemical treatment and 7.4 to 8.2 following the treatment.

Water Clarity (Secchi Depth)

Secchi depth represents water clarity, which declines when algae level increases. In the trophic state classification scheme, growing period average water clarity of under 1 m is the threshold for a hyper-eutrophic condition. In 2021, water clarity was under 0.5 m at the beginning of June, but increased to up to 1.2 m in August following chemical treatment..

Figure ES-3: 2021 Monitoring Results and 2011-2021 Annual Results- Secchi Depth

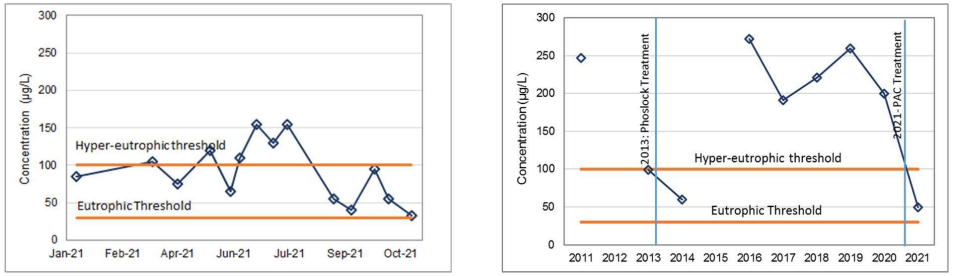


Phosphorus and Nitrogen Concentrations

Phosphorus concentration is the most important indicator of trophic state in Swan Lake. It is an indication of how prone the Lake is to algae growth.

Phosphorus concentrations above 100 µg/L represent a hyper-eutrophic condition, which entails high nutrient concentrations leading to high algae concentrations. Total phosphorus concentration in the top 1 m depth averaged at above 100 µg/L before the chemical treatment (March-July). The concentrations over the growing season (June-July) averaged about 140 µg/L (above the 100 µg/L threshold for a hyper-eutrophic condition) before dropping to about 50 µg/L after treatment.

Figure ES-1: 2021 Monitoring Results and 2011-2021 Annual Results- Total Phosphorus



Note 1: The 2021 values are averages of samples collected at 0.5 and 1.5 m from surface (1.5 m values are missing for mid-May to m0d-July).
Note 2: Annual concentrations are summaries of the growing period.
Note 3: The interim target shown is based on the water quality improvement strategy report (July 2020), and applies to the average over two consecutive years.

Total nitrogen concentrations over the growing season averaged about 2.39 mg/L before the chemical treatment to about 1.0 mg/L after treatment (below the 1.2 mg/L threshold for a hyper-eutrophic condition). In 2021, ammonia and nitrate concentrations (the forms available for uptake by biota) were generally very low, and nitrogen was mainly present as organic matter.

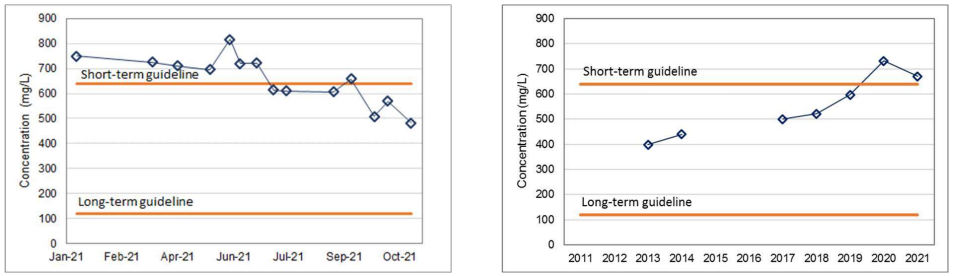
Chloride Concentration

Chloride concentration has been increasing in urban lakes as a result of de-icer application for winter maintenance of roads and walkways. Chloride does not biodegrade, readily precipitate, volatilize, or bioaccumulate. It does not adsorb readily onto mineral surfaces and therefore when introduced, concentrations remain high in surface water.

Chloride guidelines developed for generic environmental data include a long-term guideline (120 mg/L) and a short-term guideline (640 mg/L). The long-term guideline has been developed to protect all organisms (present in Canadian aquatic systems) against negative effects during chronic indefinite exposure. The short-term guideline aims to protect most species against lethality during a sudden hike in chloride concentration for an acute short period (24-96 hrs). These guidelines may be over-protective for areas with an elevated concentration of chloride and associated adapted ecological community. For such circumstances, it has been suggested that site-specific (higher) targets be derived considering local conditions such as water chemistry, background concentrations, and aquatic community structure.

Chloride concentrations have been increasing in Swan Lake over the past few years, and the long-term management plan for the Lake discusses practical approaches to manage this increase.

Figure ES-4: 2021 Monitoring Results and 2011-2021 Annual Results- Chloride



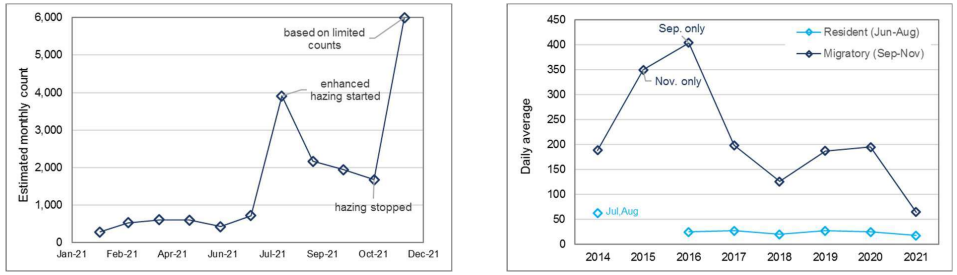
Geese Count

Geese are the primary external source of nutrients in the Lake. Therefore, active geese management is completed annually. The geese control program started in 2014, focusing on resident geese. The program extended to the management of migratory geese in 2016.

The 2021 program included an expanded hazing program starting in September, nest management and geese relocation, the installation of nine strobe lights on the Lake and adjacent stormwater ponds, and a volunteer-based geese count program.

In 2021, there was a significant decrease in the count of migratory geese as a result of increased hazing efforts. The strobe lights did not have any noticeable impact on the counts. The volunteer geese count effort resulted in the collection of a significant amount of data, which helps provide more certainty in the results, and was used to better time hazing efforts.

Figure ES-5: 2021 Monitoring Results and 2011-2021 Annual Results- Geese Count



Note 1: 2021 data are the sum of counts in each month, compensated for days with no count.
Note 2: Annual data are daily averages of counts over June-August and September to November, representing resident and migratory geese, respectively.

Algal Blooms and Cyanobacteria

In 2021, surface scums were observed along the shoreline around the Dock, as well as in the northern bay at the Bridge site.

Samples were collected before and after chemical treatment in 2021 and sent to the laboratory for phytoplankton and cyanobacteria. Test results are discussed in a report on chemical treatment evaluation.

Several algal blooms with potentially toxic cyanobacteria were observed in years before 2011; however, testing completed before 2011 and following treatment (2013-2016) did not detect any Microcystin in the water. In 2016, a bloom was tested and resulted in a Microcystin concentration of 73 µg/L. Extended blooms were observed at several sites in 2018; however, cell density was at half of WHO's threshold for significantly increased human health risk. These results suggest that in most years, toxin-producing cyanobacteria are not the dominant form of phytoplankton present in Swan Lake.

Summary and Recommendations

Based on the measured Secchi desk transparency and nutrient concentrations, Swan Lake was classified as low eutrophic in the post-treatment period in 2021.

In 2019, the City initiated a study to define a water quality management strategy for Swan Lake. The strategy was finalized in July 2020. The strategy which was finalized in July 2020 recommended a chemical treatment in 2021. In August 2021, 13 tonnes of Poly Aluminum Chloride (PAC) were applied to the Lake in a controlled manner over several days. A long-term Management Plan was received by Markham Sub Committee in November 2021 and approved by the Council in December 2021, including provisions for chemical treatment every three years, and enhanced geese management.

The 2022 monitoring program will follow the recommendation of the long-term water quality management report and will include the annual monitoring program, as well as enhanced monitoring to determine the effectiveness of the proposed chemical application.

Overall, the management activities in 2021 that focused on the significant nutrient loadings identified in the water quality management plan (i.e., PAC treatment to reduce internal loads and geese management to reduce external loads), was effective at improving water quality in the lake as shown in reduce phosphorus concentrations and improved water clarity and dissolved oxygen levels. These improvements represent a positive step towards improving aquatic habitat in the lake and meeting the long-term water quality goals.

Table of Contents

Appendices

Tables

Figures

1. Introduction

Swan Lake is situated in the City of Markham at the intersection of Sixteenth Avenue and Williamson Road, as shown below in Figure 1. Swan Lake has an approximate area of 5.5 ha and a maximum water depth of 4.5 m (from the deepest point to the Lake edges). Formerly a gravel pit in the 1960s and 1970s, Swan Lake is currently a community feature with multiple trails and urban development surrounding it.

Several issues were discovered with Swan Lake in 2010, including high phosphorus levels and significant algal blooms during the summer months, which led to low oxygen levels and degraded fish habitats. A Phoslock treatment was administered in 2013 to reduce the phosphorus levels and algal blooms in Swan Lake.

In 2019, the City of Markham conducted a study to define a water quality management strategy for Swan Lake. The strategy which was finalized in July 2020 recommended chemical treatment starting in 2021. In August 2021, 13 tonnes of Poly Aluminum Chloride (PAC) were applied to the Lake in a controlled manner over several days.

A long-term Management Plan was received by Markham Sub Committee in November 2021 and approved by the Council in December 2021, including provisions for chemical treatment every three years.

Water quality monitoring of Swan Lake has been conducted annually since treatment in 2013 in order to track water quality and the continued effectiveness of the Phoslock. The 2021 monitoring results presented in this report are part of the ongoing monitoring program that will allow for continuous assessment of the water quality in Swan Lake and will help establish a long-term plan for the treatment of Swan Lake.

Figure 1: Swan Lake Location and Monitoring Stations

2. Water Quality

2.1 Monitoring Program

2.1.1 Locations

Water quality was monitored at two shoreline sites, the Dock, and the Bridge, and at the deepest part of the Lake, the Central station, as shown in Figure 1. The water depth at the dock is approximately 2.5-3 meters, which allows it to represent Swan Lake as a whole. The water depth at the bridge is about 0.5 meters deep, and it is used to represent the conditions of the shallow bays around Swan Lake. Field testing and sampling for laboratory analysis were completed at both sites to ensure the water conditions at Swan Lake were properly represented.

During the bi-weekly monitoring, samples and measurements were taken at 0.5 m increments for the depth of the lake. The dock site was the deeper of the two sites, allowing for sampling and monitoring from 0.5 – 2.5 m, whereas the bridge site was shallow and sampling was typically only achievable under the surface, slightly above the bottom of the Lake to avoid sediment contamination.

The horizontal sampler was damaged in mid-May and until a replacement was obtained in mid-July, surface water samples were collected using a bucket at both sites.

When water level dropped to around 2 m, samples were not collected from the 2.5 m depth at the Dock station.

2.1.2 Duration and Frequency

In 2021, water quality was monitored bi-weekly throughout the summer (May-September) and monthly in the spring (April) and fall (October-November).

Additional testing completed in 2021 included:

- Pre-treatment (January and March) and post-treatment (September to November) monitoring at the deepest part of the Lake
- Monitoring of different treatment zones during treatment (August)

A total of 24 sampling events were completed.

2.1.3 Parameters and Methodology

Vertical water quality profiling, water transparency readings (Secchi depth), and photographic documentation were performed during each site visit.

Field testing was done utilizing an YSI ProODO meter to determine the temperature and dissolved oxygen (DO) at each sampling interval over the vertical profile of the lake. To ensure accurate readings, the meter and probe were stored in a proper carrying bag and regularly calibrated as instructed in the handheld quick-start guide.

Water transparency was measured as part of the field testing at both the dock and bridge monitoring sites. Transparency was measured using a Secchi disk by lowering it into the water while rotating the handle until the black and white pattern of the Secchi disk was no longer visible. The water depth read from the Secchi disk was then recorded as the transparency (i.e., water clarity) depth.

Water samples for laboratory testing were taken using a horizontal water sampler at different depths. Parameters analyzed at various stations and times included:

- Nutrients including total and ortho phosphorus, ammonia, nitrate, Total Kjeldahl Nitrogen (TKN)
- Chloride, color, Dissolved Organic Carbon (DOC), pH
- Alkalinity, aluminum, calcium, iron, magnesium, sulphate
- Chlorophyll a

Observations of Swan Lake were noted, and photographs were taken during each monitoring/inspection site visit. Photographs provide a way to record the condition of vegetation and algae around Swan Lake. Completed inspection forms can be found in Appendix A. All photographs from the 2021 monitoring period are provided in Appendix B.

2.1.4 Targets and Thresholds

The 2019 water quality improvement study proposed a set of interim targets for Swan Lake to be used as triggers for management actions if the triggers are tripped in two consecutive years. Numerical values were defined for total phosphorus (100 µg/L) and Secchi depth (0.45 m).

Generic thresholds for hyper-eutrophic conditions in the lakes are provided in Table 1.

Table 1: Eutrophic State Classification

Parameter	Eutrophic Condition	Hyper-eutrophic Condition
Secchi Depth (m)	1-2.1	<1
Total Phosphorus (µg/L)	31-100	100
Total Nitrogen (mg/L)	0.65-1.20	>1.20

For DO and chloride, Federal and/or Provincial water quality Guidelines[1] or Objectives[2] were considered for perspective. It should be noted that Swan Lake is not a natural waterbody, and there is no requirement for it to comply with these limits. Where technically and economically feasible, the City will aim to meet these limits to protect and enhance the aquatic environment.

The minimum dissolved oxygen concentration required for the protection of warm water fish is 5 mg/L for water temperatures up to 20 °C and 4 mg/L for temperatures above 20 °C. Lower concentrations could have lethal or sub-lethal (physiological and behavioral) effects on fish. However, some fish can acclimate to lower oxygen levels and survive concentrations between 1 and 3 mg/L.

Chloride guidelines developed based on generic environmental data include a long-term guideline (120 mg/L) and a short-term guideline (640 mg/L). The long-term guideline has been developed to protect all organisms (present in Canadian aquatic systems) against negative effects during indefinite exposure. The short-term guideline will protect most species against lethality during a sudden hike in chloride concentration for a short period (24-96 hrs). These guidelines may be over-protective for areas with an elevated concentration of chloride and associated adapted ecological community. For such circumstances, it has been suggested that site-specific (higher) targets be derived considering local conditions such as water chemistry, background concentrations, and aquatic community structure.

Total and dissolve aluminum were monitored this year to determine any impact of PAC application on aluminum concentration in Lake water.

For Cyanotoxins, the Health Canada guideline for recreational activities is 20 µg/L[3].

[1] Canadian Council of Ministers of the Environment (CCME) Water Quality Guidelines for the Protection of Aquatic Life (http://ceqg-rcqe.ccme.ca/en/index.html)
[2] Ontario Provincial Water Quality Objectives or PWQO (https://www.ontario.ca/page/water-management-policies-guidelines-provincial-water-quality-objectives#section-13)
[3] Health Canada, 2012. Guidelines for Canadian Recreational Water Quality, Third Edition. Water, Air and Climate Change Bureau, Healthy Environments and Consumer Safety Branch, Ottawa, Ontario.

2.2 2021 Water Quality Results

The following sections discuss observations at the three monitored stations (Dock, Bridge, and Central) throughout 2021. A separate report evaluates the impact of the 2021 chemical treatment on water quality in Swan Lake.

2.2.1 Dissolved Oxygen and Temperature

Table 2 provides the measured DO profile over the 2021 monitoring period.

At the Dock station, surface concentrations were above 5 mg/L throughout 2021. Below 2 m depth, the DO was under 2 m/L in most of the sampling events from late May through July, indicating anoxic conditions. DO concentration at 2 m increase significantly in August, but remained low at 2.5 m. All but one measurements at the Bridge indicated a DO concentration of above 2 mg/L, with most being above or close to 4 mg/L.

Table 3 provides the measured temperature profile in 2021, indicating warm water throughout the depth in the summer months.

Profiles of temperature and dissolved oxygen (see Figure 2) indicate that Swan Lake is thermally stratified during May and July despite its shallow depth. The separation of water layers is evident during the summer months as DO decreases very drastically as water depth increases.

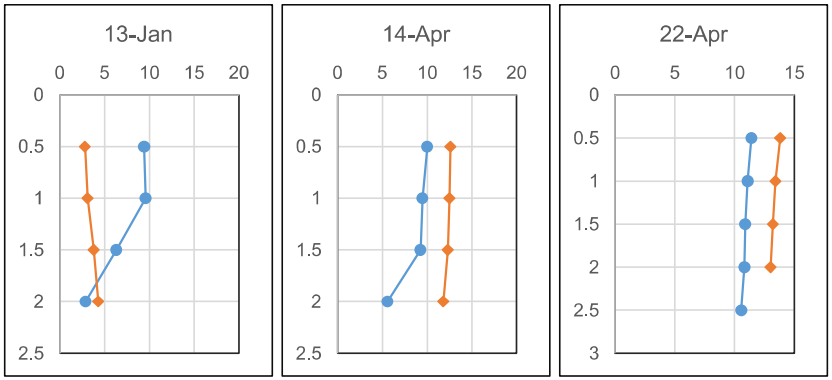
Table 2: Measured DO Profile (mg/L)

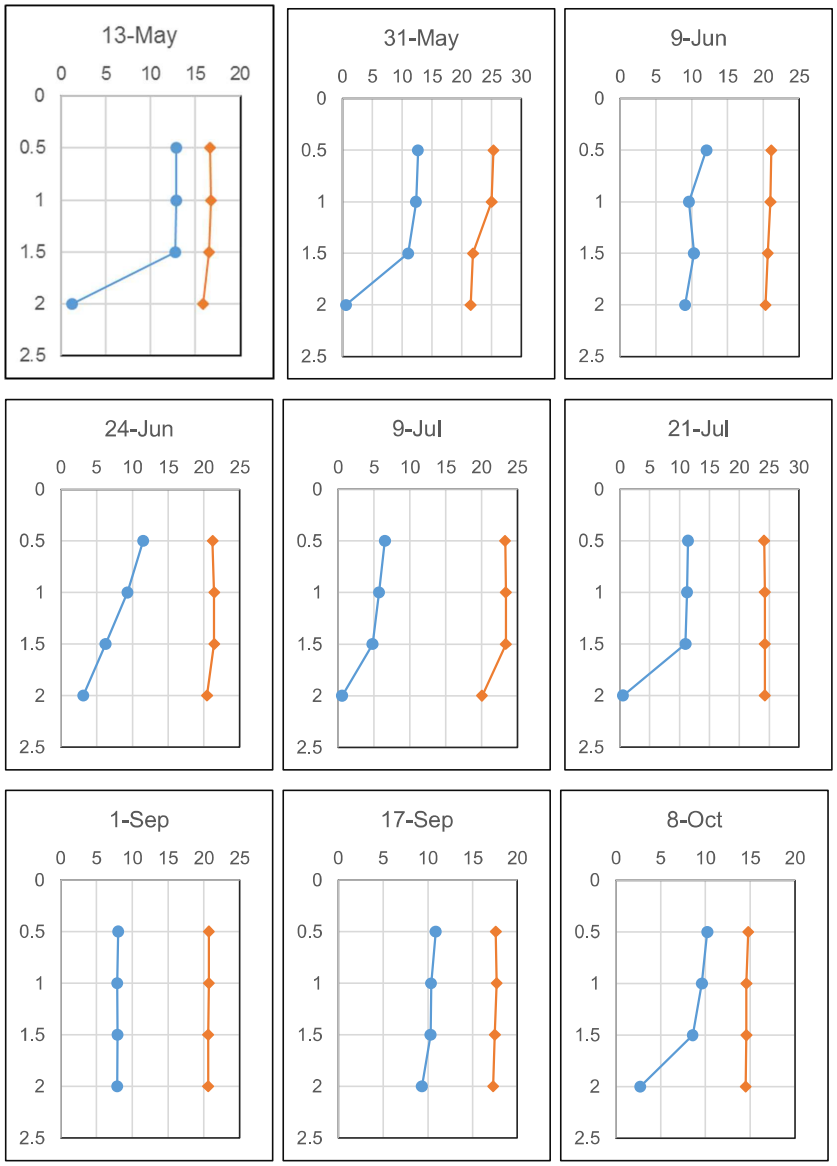
	Bridge	Dock				Central			
	Depth (m)	Depth (m)				Depth (m)			
Date	0.5	0.5	1	1.5	2	0.5	1.5	2.5	3
1/13/2021	-	9.4	9.6	6.3	2.9	-	-	-	-
3/29/2021	-	-	-	-	-	11.0	11.4	11.0	-
4/14/2021	8.5	10.0	9.5	9.3	5.6	-	-	-	-
4/22/2021	-	11.4	11.1	10.9	10.8	-	-	-	-
5/13/2021	9.8	12.8	12.8	12.7	1.3	-	-	-	-
5/31/2021	7.6	12.6	12.3	11.0	0.6	-	-	-	-
6/9/2021	1.8	12.0	9.6	10.3	9.0	-	-	-	-
6/24/2021	3.7	11.5	9.3	6.2	3.1	-	-	-	-
7/9/2021	2.3	6.5	5.7	4.8	0.6	-	-	-	-
7/21/2021	5.3	11.4	11.3	11.0	0.5	-	-	-	-
8/23/2021	-	-	-	-	-	6.3	7.3	1.9	1.0
9/1/2021	3.1	8.0	7.9	7.9	7.9	-	-	-	-
9/7/2021	-	-	-	-	-	10.4	9.2	1.3	-
9/17/2021	5.0	10.9	10.4	10.3	9.4	-	-	-	-
9/29/2021	-	-	-	-	-	7.8	8.3	7.5	-
10/8/2021	3.7	10.2	9.6	8.6	2.7	-	-	-	-
10/14/2021	-	-	-	-	-	10.8	9.2	0.1	-
10/20/2021	5.9	10.0	9.8	9.7	9.3	-	-	-	-
10/28/2021	-	-	-	-	-	10.3	9.8	4.2	-
11/10/2021	8.3	10.3	10.2	10.1	10.2	-	-	-	-

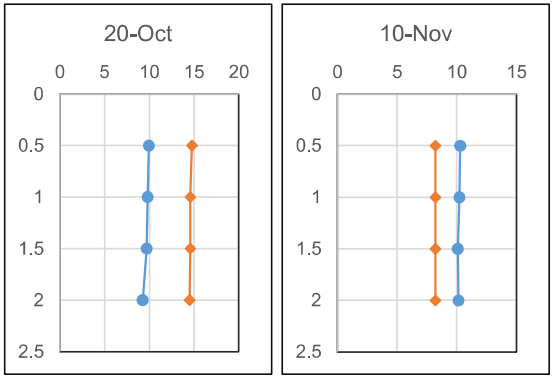
Table 3: Measured Temperature Profile (°C)

	Bridge	Dock				Central			
	Depth (m)	Depth (m)				Depth (m)			
Date	0.5	0.5	1	1.5	2	0.5	1.5	2.5	3
1/13/2021	-	2.8	3.1	3.8	4.3	-	-	-	-
3/29/2021	-	-	-	-	-	8.2	8.3	8.0	-
4/14/2021	14.0	12.6	12.5	12.3	11.8	-	-	-	-
4/22/2021	-	9.1	9.1	9.1	9.1	-	-	-	-
5/13/2021	13.2	13.8	13.4	13.2	13.0	-	-	-	-
5/31/2021	15.2	16.6	16.7	16.5	15.8	-	-	-	-
6/9/2021	24.5	25.3	25.0	21.9	21.5	-	-	-	-
6/24/2021	19.8	21.1	21.0	20.6	20.3	-	-	-	-
7/9/2021	20.0	21.2	21.4	21.4	20.4	-	-	-	-
7/21/2021	22.5	23.3	23.4	23.4	20.1	-	-	-	-
8/23/2021	-	-	-	-	-	27.7	-	22.3	23.4
9/1/2021	21.9	24.2	24.3	24.3	24.3	-	-	-	-
9/7/2021	-	-	-	-	-	22.0	21.4	21.1	-
9/17/2021	19.6	20.7	20.7	20.6	20.6	-	-	-	-
9/29/2021	-	-	-	-	-	18.3	18.2	17.2	-
10/8/2021	17.2	17.6	17.7	17.5	17.3	-	-	-	-
10/14/2021	-	-	-	-	-	19.2	18.7	17.3	-
10/20/2021	13.6	14.8	14.6	14.6	14.5	-	-	-	-
10/28/2021	-	-	-	-	-	10.8	10.8	11.2	-
11/10/2021	8.2	8.2	8.2	8.2	8.2	-	-	-	-

Figure 2: Temperature (orange) and DO (blue) Profile at the Dock Station

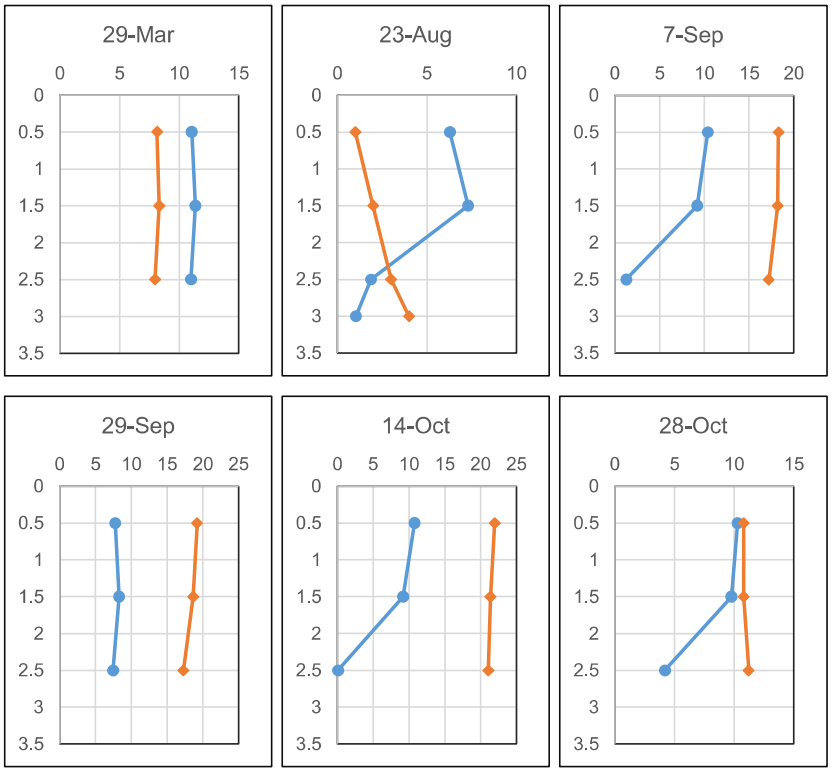



13-May
0 5 10 15 20
0 0.5 1 1.5 2 2.5
31-May
0 5 10 15 20 25 30
0 0.5 1 1.5 2 2.5
9-Jun
0 5 10 15 20 25
0 0.5 1 1.5 2 2.5
24-Jun
0 5 10 15 20 25
0 0.5 1 1.5 2 2.5
9-Jul
0 5 10 15 20 25
0 0.5 1 1.5 2 2.5
21-Jul
0 5 10 15 20 25 30
0 0.5 1 1.5 2 2.5
1-Sep
0 5 10 15 20 25
0 0.5 1 1.5 2 2.5
17-Sep
0 5 10 15 20
0 0.5 1 1.5 2 2.5
8-Oct
0 5 10 15 20
0 0.5 1 1.5 2 2.5



Note: The vertical axis shows depth (m), while the horizontal axis represents both Temperature (°C) and DO (mg/L).

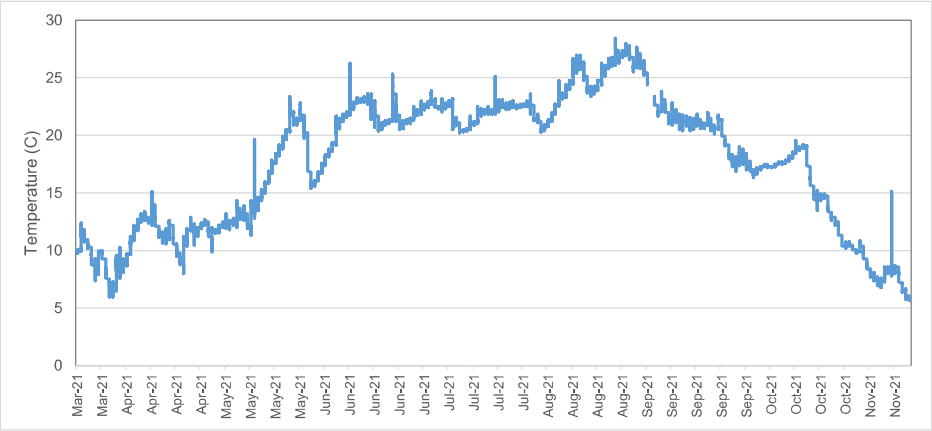
Figure 3: Temperature (orange) and DO (blue) Profile at the Cental Station



Note: The vertical axis shows depth (m), while the horizontal axis represents both Temperature (°C) and DO (mg/L).

Water temperature was also recorded by the level/temperature logger installed at the Dock station. The probe was located at 1 m from the Lake bed. Figure 4 provides recorded temperature at 15-min intervals. Water temperature was lower in 2021 relative to 2020.

Figure 4: Temperature Recorded by the Level/Temperature Logger at the Dock Station (1m from bottom)



2.2.2 Water Transparency

Table 4 summarizes the results of the water transparency readings. Transparency at the Dock station was under 0.5 m at the beginning of June but increase to up to 1.2 m in August following chemical treatment.

Table 4: 2021 Secchi Depth Results (m)

Date	Dock	Bridge	Central
13-Jan	0.7		
29-Mar	0.85		0.5
14-Apr	1	0.62	
22-Apr	1.2		
13-May	0.55	0.54	
31-May	0.56	0.51	
9-Jun	0.55	0.41	
24-Jun	0.3	0.4	
9-Jul	0.39	0.26	
21-Jul	0.25	0.26	
23-Aug			1.2
1-Sep	0.8	0.55	
7-Sep			0.7
17-Sep	0.75	0.64	
29-Sep			0.7
8-Oct	0.6	0.4	
14-Oct			0.75
20-Oct	0.53	0.53	
28-Oct			0.8
10-Nov	1	0.52	

2.2.3 pH

On-site measurements of pH in 2019 and 2020 were very high and therefore were investigated through lab analysis for pH in 2021. pH measured at the lab ranged from 7.9 to 8.5 before the chemical treatment and 7.4 to 8.2 following the treatment.

2.2.4 Nutrients Concentrations

Samples collected during each visit were transported to Caduceon Environmental Laboratories and tested for Total Phosphorus, Phosphate, Total Kjeldahl Nitrogen, Nitrate, and Ammonia.

The results can be found in Figure 5 for the Dock site and Figure 6 for the Bridge site. The Certificate of Analysis from Caduceon Environmental Laboratories in Appendix C.

Nutrient concentrations are shown for the depths sampled.

Total phosphorus concentration in the top 1 m depth averaged at above 100 µg/L before the chemical treatment (March-July). The concentrations over the growing season (June-July) averaged about 140 µg/L (above the 100 µg/L threshold for a hyper-eutrophic condition) before dropping to about 50 µg/L after treatment.

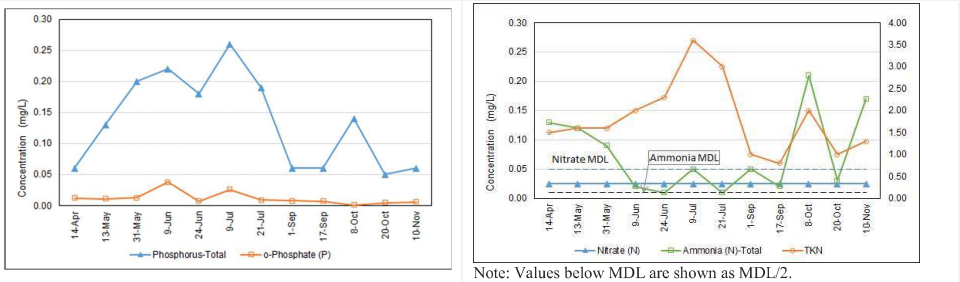
Nitrogen concentration was analyzed in terms of Total Kjeldahl Nitrogen (TKN), Ammonia (NH_3) and Nitrate (NO_3). Total nitrogen concentrations over the growing season averaged about 2.39 mg/L before the chemical treatment to about 1.0 mg/L after treatment (below the 1.2 mg/L threshold for a hyper-eutrophic condition). Before and after concentrations at the Bridge site were 2.77 mg/L and 0.96 mg/L, respectively.

Ammonia and nitrate are the forms that are directly bioavailable, with ammonia being the most usable form for algae. In 2021, Ammonia and Nitrate concentrations were generally close to or below Method Detection Limit (MDL), and nitrogen was mainly present as organic compounds (i.e., TKN less Ammonia) with the exception of spring samples.

Figure 5: Measured Nutrients Concentrations in 2021 - Dock Site

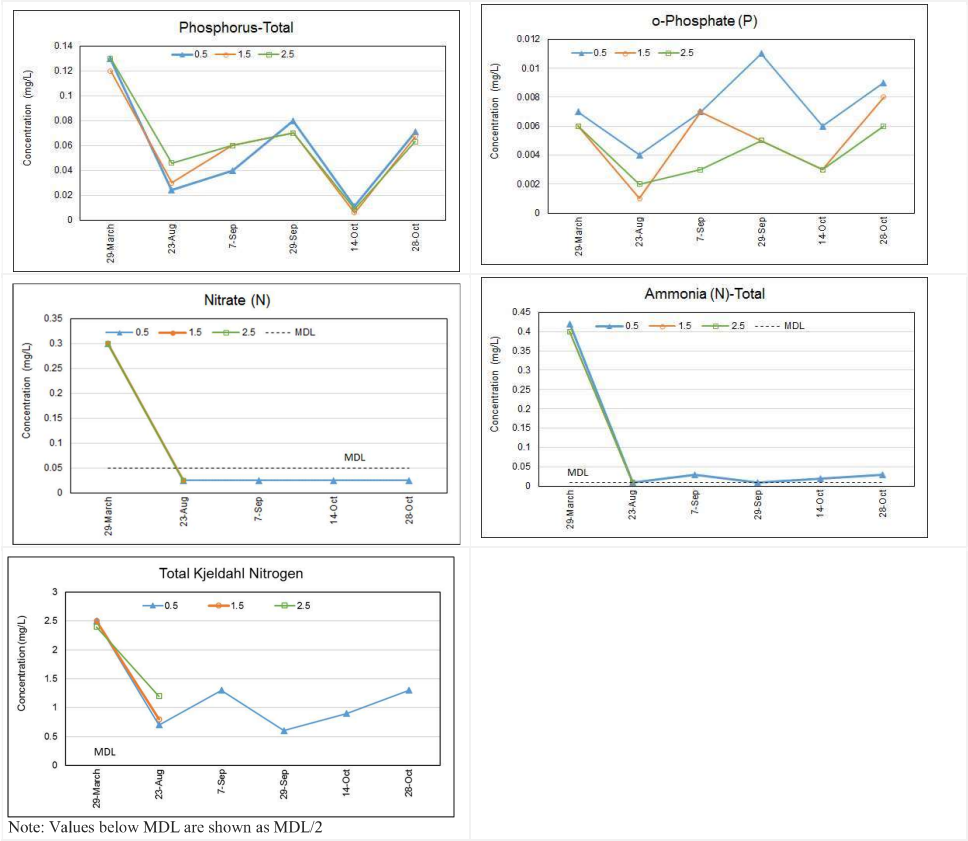
Note: Values below MDL are shown as MDL/2

Figure 6: Measured Nutrients Concentrations in 2021 - Bridge Site



Note: Values below MDL are shown as MDL/2.
TKN is shown on the secondary (right) axis.

Figure 7: Measured Nutrients Concentrations in 2021 - Central Site



Note: Values below MDL are shown as MDL/2

2.2.5 Chloride and DOC Concentrations and Color

Samples collected during each visit were also analyzed for Chloride, Dissolved Organic Carbon (DOC), and Colour. The results are summarized in Table 5.

Water quality testing results indicated that all samples taken at all sites contained high chloride levels in Swan Lake until the end of June (>640 mg/L). Samples collected in July and later on contained lower chloride concentrations with an average of 590 mg/L. Chloride levels tend to rise in the spring as runoff containing de-icing agents are discharged to the Lake. Once introduced to a waterbody, chloride does not biodegrade, readily precipitate, volatilize, or bioaccumulate. It does not adsorb readily onto mineral surfaces, and therefore when introduced, concentrations remain high in surface water.

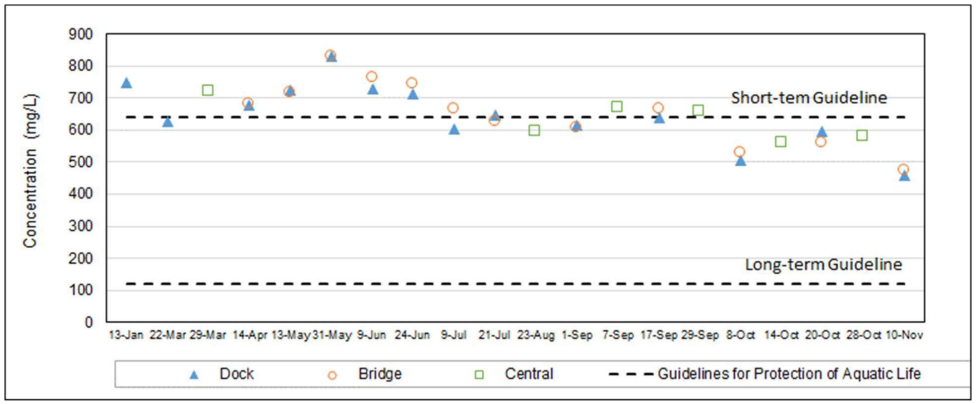
Chloride guidelines developed based on generic environmental data include a long-term guideline (120 mg/L) and a short-term guideline (640 mg/L). These guidelines may be over-protective for areas with an elevated concentration of chloride and associated adapted ecological community. For such circumstances,

it has been suggested that site-specific (higher) targets be derived considering local conditions such as water chemistry, background concentrations, and aquatic community structure.

Table 5: Measured DOC, Color and Chloride

Date	Dock			Bridge			Central		
	Cl	Colour	DOC	Cl	Colour	DOC	Cl	Colour	DOC
13-Jan	749	10	5.9	-	-	-	-	-	-
22-Mar	725	11	2.2	-	-	-	-	-	-
29-Mar	-	-	-	-	-	-	684	12	2.4
14-Apr	711	14	3.8	681	15	3.8	-	-	-
13-May	696	11	1.6	715	11	1.5	-	-	-
31-May	817	10	1.5	831	15	1.7	-	-	-
9-Jun	720	12	1.7	764	21	1.9	-	-	-
24-Jun	721	12	2.9	744	14	1.6	-	-	-
9-Jul	614	15	1.6	666	17	1.6	-	-	-
21-Jul	611	14	1.3	627	16	1.2	-	-	-
23-Aug	-	-	-	-	-	-	594	3	0.5
1-Sep	607	3	0.8	607	4	0.7	-	-	-
7-Sep	-	-	-	-	-	-	671	3	0.8
17-Sep	659	3	1.3	666	3	0.9	-	-	-
29-Sep	-	-	-	-	-	-	657	4	0.8
8-Oct	508	5	0.9	529	5	1.0	-	-	-
14-Oct	-	-	-	-	-	-	560	3	1.0
20-Oct	569	3	1.8	561	8	2.1	-	-	-
28-Oct	-	-	-	-	-	-	579	3	1.7
10-Nov	483	4	1.2	475	6	1.3	-	-	-

Figure 8: Chloride Concentrations in 2021



2.2.6 Algae Growth and Toxicity

Algae blooms, which have been a problem in Swan Lake in previous years, reoccurred during the 2021 monitoring period. During the summer, surface scum was found at both the Dock and Bridge sampling sites. The surface scum found at the Bridge site was generally worse upon visual inspection, likely due to the stagnant conditions in the bay.

Samples were collected before and after chemical treatment and sent to the laboratory for phytoplankton and cyanobacteria. Test results are discussed in the report on chemical treatment evaluation.

Signs warning the public against water contact for humans and pets remained in place throughout 2021 (see **Error! Reference source not found.**).

2.2.7 Summary of Monitoring Results in 2021

Profiles of temperature and dissolved oxygen indicated that Swan Lake was mostly thermally stratified during the summer.

DO concentrations measured in the 1 m surface water were above the DO guideline for the protection of aquatic life. When stratified, bottom concentrations were lower than the DO guideline. DO concentration at 2 m increased significantly in August, but remained low at 2.5 m.

Transparency at the Dock station was under 0.5 m at the beginning of June but increase to up to 1.2 m in August following chemical treatment.

pH measured at the lab ranged from 7.9 to 8.5 before the chemical treatment and 7.4 to 8.2 following the treatment. Total phosphorus concentration in the top 1 m depth averaged at above 100 µg/L before the chemical treatment (March-July). The concentrations over the growing season (June-July) averaged about 140 µg/L (above the 100 µg/L threshold for a hyper-eutrophic condition) before dropping to about 50 µg/L after treatment.

Total nitrogen concentrations over the growing season averaged about 2.39 mg/L before the chemical treatment to about 1.0 mg/L after treatment (below the 1.2 mg/L threshold for a hyper-eutrophic condition). Chloride concentrations were very high (close to 640 mg/L), but slightly lower than 2020.

Throughout the 2021 monitoring period, surface scum was found at both the Dock and Bridge sampling sites. Samples were collected before and after chemical treatment and sent to the laboratory for phytoplankton and cyanobacteria. Test results are discussed in the report on chemical treatment evaluation.

2.3 Water Quality Trends

Water quality monitoring of Swan Lake has been conducted annually since treatment in 2013 to track water quality and the continued effectiveness of implemented mitigation measures.

The following paragraphs and Figure 9 provide a summary of water quality trends for the period of monitoring.

Dissolved Oxygen (DO)

Historical records of DO and temperature profile show that Swan Lake thermally stratifies during the summer despite its shallow depth. Anoxic conditions have been observed at depths below 2 m, to a depth as high as 1 to 1.5 m (in 2016). The majority of surface concentrations have been above 5 mg/L since 2014.

Water Clarity (Secchi Depth)

In Swan Lake, Secchi depth has typically been quite low throughout the summer, but it increases in November, reflecting the end of the growing period for phytoplankton. The average annual values shown in Figure 9 are all below 1 m, except in 2014 and 2021 following chemical treatment.

Total Phosphorus (TP)

Average growing period (May - October) TP concentrations indicate hyper-eutrophic conditions in all monitored years except for the post-treatment years, 2013 and 2014 as well as 2021.

Nitrogen Compounds

Total nitrogen concentration over the growing period has always been above the 1.2 mg/L threshold for a hyper-eutrophic condition, except in the post-treatment year, 2014 and in 2021. Nitrogen is, however, not believed to be the limiting nutrient for eutrophication in Swan Lake (i.e., the nutrient that elicits the largest response in algae growth).

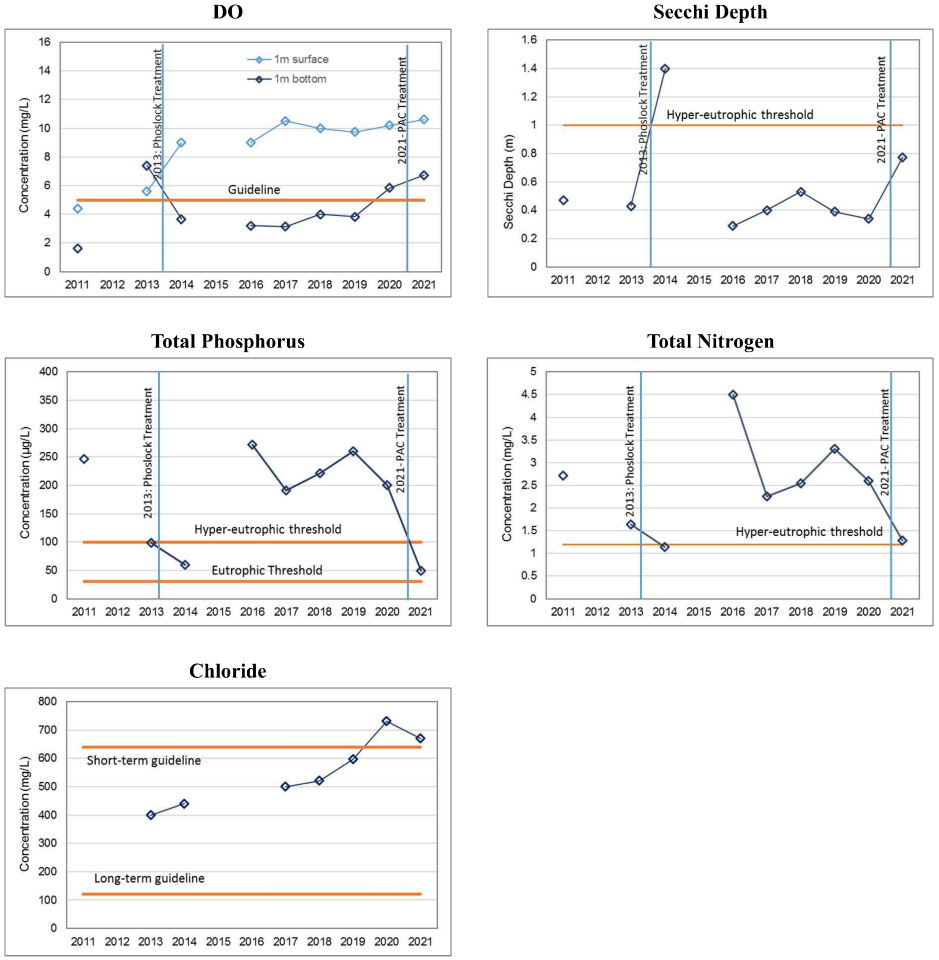
Inorganic nitrogen-compounds (NO_2, NO_3, and NH_3) have often been below detection limits, indicating relatively low levels of bioavailable nitrogen concentrations. In 2021, ammonia and nitrate concentrations were generally very low, and nitrogen was mainly present as organic matter.

Chloride

Chloride concentration has been increasing in urban lakes due to de-icer application for winter maintenance of roads and walkways. Chloride does not biodegrade, readily precipitate, volatilize, or bioaccumulate. It does not adsorb readily onto mineral surfaces, and therefore when introduced, concentrations remain high in surface water.

Chloride concentrations have been increasing in Swan Lake over the past few years with slight drop in 2021. The long-term management plan for the Lake suggests that the main mechanism for lowering chloride levels would be source control. Emerging technologies and flow redirection may be considered in future.

Figure 9: Historical Water Quality Results (Growing-Season Averages)



Algae Blooms and Cyanobacteria

Table 6 provides a summary of the observed algae blooms in the Lake over the years. It also shows any tests conducted to measure toxins (mainly in terms of microcystin concentration) in the Lake water.

Table 6: Records of Algae Blooms and Toxicity

Year/Period	Algae Blooms Observation	Toxicity Test Result
Before 2011	Several blooms of cyanobacteria were observed	Microcystin concentration under detection limit
2013-2016	No apparent cyanobacteria proliferation and blooms; no resident concern related to the Lake's water quality	Microcystin concentration under detection limit
2016	A bloom was detected at one location	Microcystin concentration of 73 µg/L in one sample tested (recreational guideline is 20 µg/L)
2017	No bloom was observed	-
2018	Extended blooms were observed at several sites	Not tested for toxicity; cell density was at half of WHO's threshold for significantly increased risk for human health
2019	Extended blooms were observed at several sites	Microcystin toxicity was measured with test strips; all samples were below 10 µg/L
2020	Blooms were observed at several sites	Microcystin toxicity was measured with test strips; all samples were below 10 µg/L
2021	Blooms were observed at several sites	(see memo on treatment performance)

3. Water Level Monitoring

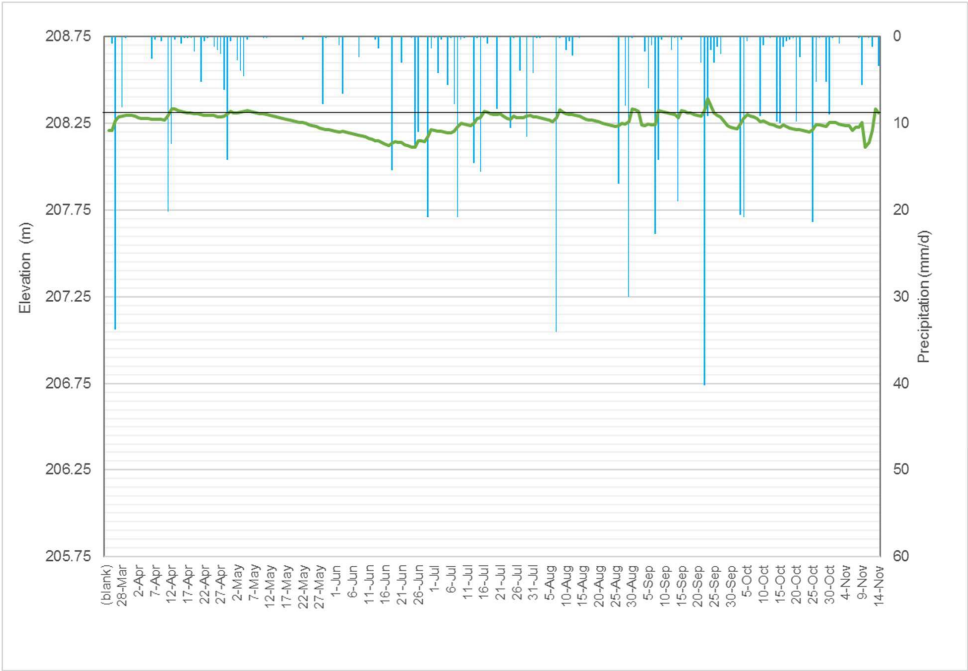
Water level and temperature were monitored using HOBOware U20 Water logger mounted at the Dock. The data logger records the pressure and temperature of the water every 15 minutes. The measured pressure is compensated using a baro-logger to calculate water depth.

The deepest site in the Lake is at 204.8 m. The sensor is located 1 m above the lakebed (at 205.75). The calculated water level changed from 208.11 m (2.36 m depth) in June to 208.39 (2.64 m depth) in September.

The maximum water level recorded in 2017, 2018 and 2020 were 208.48,208.35 and 208.25 m, respectively. The 2019 water level data were incomplete.

Rain data from the nearby rain gauge located at the Markham Museum are shown in Figure 10.

Figure 10: Lake Elevation Records and Precipitation in 2021



4. Geese Management

4.1 Geese Management Approach

Geese reduction at Swan Lake is necessary due to the nutrient load they contribute to the Lake.

In 2021, the geese management program was completed by two external contractors.

Border Control Bird Dogs, an external consultant, was hired to chase (i.e., 'haze') terrestrial geese by border collies (including the Toogood Pond where they also performed egg oiling). Program activity frequency was modified from previous years to focus on the migration seasons. The frequent geese chasing would encourage the geese to relocate to a quieter place and reduce the number of resident geese at Swan Lake.

The Toronto Region Conservation Authority (TRCA) was hired to relocate resident geese from Swan Lake and to remove the nests and eggs from the area. In total, 73 Canada Geese were rounded up from Swan Lake on June 18th 2021. Four adult Canada geese and four goslings were left at Swan Lake. In addition, a total 13 nets containing 52 eggs were managed at Swan Lake during April to June.

The strobe lights purchased in 2020 at the request of Friends of Swan Lake Park were also installed on the Lake and the two adjacent stormwater management ponds. Strobe lights work by using a solar-powered LED light that flashes every two seconds and is intended to disrupt the geese's sleep patterns and discourage them from staying on the Lake.

4.2 Geese Count

In 2021, the geese count was completed by the consultant, City staff, and volunteers from the community.

Border Control Bird Dogs recorded the number of geese observed during each visit. Staff counted the number of geese every two to four weeks, coinciding with the water quality sampling site visits.

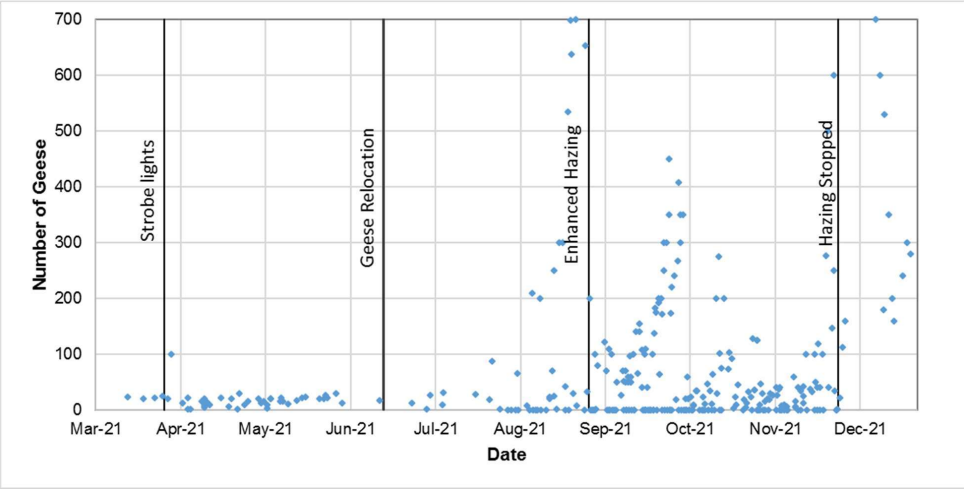
Friends of Swan Lake organized a geese count campaign and provided a spreadsheet of the counts to the City. Staff also developed a geese count App using ArcGIS Survey123, which a number of residents used to record geese count and note other wildlife observations.

4.3 Results

Figure 11 illustrates the number of geese counted at Swan Lake throughout the 2021 monitoring period.

In this figure, a significant increase in geese during the fall months is evident, which occurs when they migrate south; however, the increased hazing frequency (starting on September first) was very effective in reducing the number of geese present at different times of the day. Following the enhanced hazing, daily numbers dropped to below 500, and remained much lower than previous years. Any impact that strobe lights might have had on the geese count is not readily evident from the data.

Figure 11: 2021 Geese Count Results

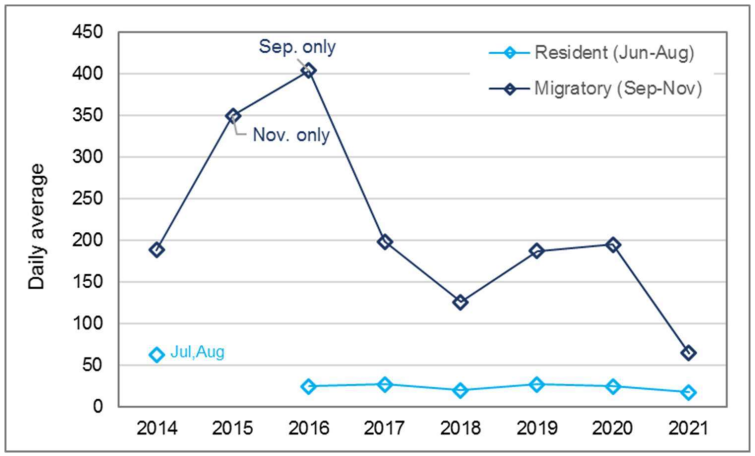


4.4 Historical Trends

Active geese management has been completed annually since 2014. The geese control focusing on resident geese at the beginning and extended to the management of migratory geese in 2016.

Daily Averages of counts are shown for each year in Figure 12. Data are summarized for June to August, and September to November, representing resident and migratory geese, respectively. Despite a general increase in geese population in Southern Ontario, the numbers at Swan Lake have been controlled over the past years.

Figure 12: Historical Geese Counts



5. Summary and Conclusions

Through the Swan Lake monitoring program, data were collected from January to November 2021. The collected data provide insight into long-term trends in water quality and will also help determine the need for and impact of chemical treatment of Swan Lake.

Dissolved oxygen, temperature, and water transparency were measured at two stations through bi-weekly site visits and at the Central station pre and post-treatment. Profiles of temperature and dissolved oxygen indicated that Swan Lake was thermally stratified during the summer despite its shallow depth. The minimum dissolved oxygen concentration required for the protection of warm water fish is 5 mg/L, which was met in the surface water but not the deep water pre-treatment.

pH measured at the lab ranged from 7.9 to 8.5 before the chemical treatment and 7.4 to 8.2 following the treatment.

Transparency at the Dock station was under 0.5 m at the beginning of June, but increased to up to 1.2 m in August following chemical treatment.

Water samples were analyzed for nutrients (phosphorus and nitrogen compounds). Total phosphorus concentration in the top 1 m depth averaged at above 100 µg/L before the chemical treatment (March-July). The concentrations over the growing season (June-July) averaged about 140 µg/L (above the 100 µg/L threshold for a hyper-eutrophic condition) before dropping to about 50 µg/L after treatment.

Total nitrogen concentrations over the growing season averaged about 2.39 mg/L before the chemical treatment to about 1.0 mg/L after treatment (below the 1.2 mg/L threshold for a hyper-eutrophic condition).

Chloride concentrations were frequently high (upwards of 640 mg/L) in 2021), but slightly lower than 2020. Chloride concentration exceeded the long-term (120 mg/L) and short-term (640 mg/L) guidelines for the protection of aquatic life.

Throughout the 2021 monitoring period, surface scum was found at both the Dock and Bridge sampling sites. Samples were collected before and after chemical treatment and sent to the laboratory for phytoplankton and cyanobacteria. Test results are discussed in the report on chemical treatment evaluationA level logger was used to record the water level in the Lake. The water level at the logger location changed from 208.11 m (2.36 m depth) in June to 208.39 (2.64 m depth) in September.

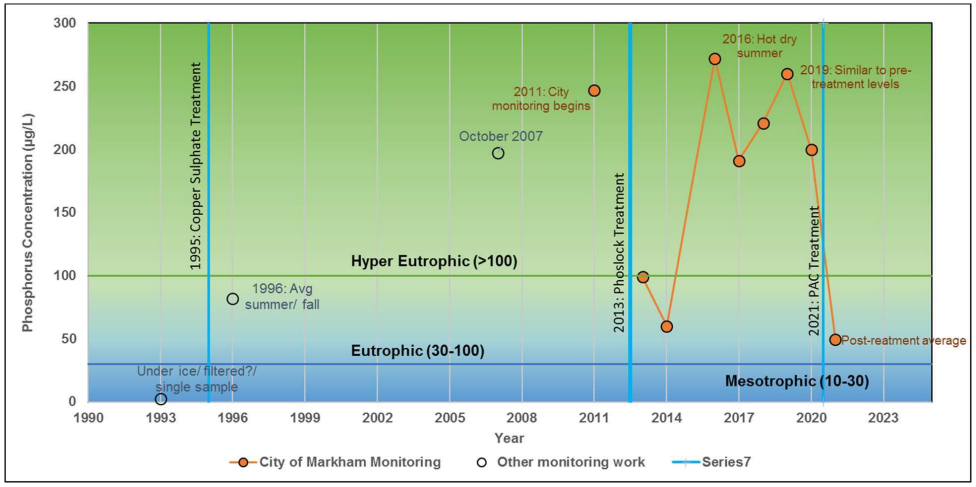
In 2021, geese management was completed by chasing terrestrial geese by border collies and egg oiling, as well as nest management and geese relocation in the spring. Program frequency was modified from previous years to focus on the migration seasons. Nine strobe lights were also installed on the Lake and the two stormwater management ponds. The increased hazing frequency (starting on September 1st) was very effective in reducing the number of geese present at different times of the day to about 50% of numbers in 2020. Any impact that strobe lights might have had on the geese count is not readily evident.

Based on the measured Secchi desk transparency and nutrient concentrations in 2021, Swan Lake is classified at a low-eutrophic condition post-treatment. Figure 13 provides a summary of phosphorus concentrations for all the years with available data.

Overall, the management activities in 2021 that focused on the significant nutrient loadings identified in the water quality management plan (i.e., PAC treatment to reduce internal loads and geese management to reduce external loads), was effective at improving water quality in the lake as shown in reduce phosphorus concentrations and improved water clarity and dissolved oxygen levels. These improvements

represent a positive step towards improving aquatic habitat in the lake and meeting the long-term water quality goals.

Figure 13: Trophic State Classification for Swan Lake based on Phosphorus Concentration



Appendix A : Swan Lake Water Quality Inspection Forms

Appendix B : Photographic Documentation

Appendix C : Certificate of Analysis