Final

# Swan Lake Management Options

Swan Lake Long-Term Management Plan:
Water Quality Monitoring Program
Preliminary Review

Prepared for:

Fred Peters
Friends of Swan Lake Park

Project No. 3645 | November 2025

NATURAL RESOURCE SOLUTIONS INC.
Aquatic, Terrestrial and Wetland Biologists

**Swan Lake Management Options**

# Swan Lake Long-Term Management Plan: Water Quality Monitoring Program Preliminary Review

## Project Team

| | |
|---|---|
| Phil Anderson | Sr. Aquatic Biologist, Project Advisor |
| Blair Baldwin | Aquatic Biologist, Project Manager |

Report submitted on November 26, 2025

Blair Baldwin

Project Manager

Aquatic Biologist

# Table of Contents

## 1.0 Purpose and Objectives

Natural Resource Solutions Inc. (NRSI) was retained by the Friends of Swan Lake Park to complete a peer review of the monitoring and reporting completed to date as part of the City of Markham's 25-year water quality monitoring program preliminary (Phase 1). As part of this review, NRSI will assess:

- The adequacy of the monitoring program completed to date;
- The appropriateness and attainability of the water quality targets;
- Comparisons of the reported water quality conditions to recommended guidelines for the protection of aquatic life;
- General comparisons with similar surface water systems; and
- Potential enhancements or adjustments to the monitoring program.

In addition, this report will provide general guidance and recommendations to support the long-term Swan Lake water quality objectives, including:

- Lake management strategies to achieve and maintain surface water quality objectives;
- What level of water quality should be attainable or appropriate given the existing site conditions;
- Recommendations for specific areas that warrant further research or consideration; and
- Additional actions required to support future sustainable water quality targets for Swan Lake.

This review is intended to provide the Friends of Swan Lake Park with a concise summary of the water quality monitoring completed to date, and support the development of further rehabilitation and remediation strategies for Swan Lake.

## 1.1 Background and Scope

Swan Lake is an artificial, manmade water body within the City of Markham that was historically used as a gravel quarry until the late 1970s when it was decommissioned and allowed to fill with water. Following this, it was used as a local landfill until its naturalization in the 1990s. Swan Lake has no natural surface water connections, however between the 1990s and early 2000s it was integrated into the local stormwater management system acting as an ad hock stormwater management pond serving to accumulate and sequester surface water runoff from the surrounding residential developments. Currently, Swan Lake exists as a shallow, highly

eutrophic lake with a history of cyanobacterial blooms and consistently poor surface water quality conditions. The surface area of the lake is approximately 5.5 ha with an average depth of 1.65m and a maximum depth up to approximately 4.5 m.

Following the identification of poor water quality conditions and degraded fish habitats in 2010 the City of Markham considered treatment options to improve these conditions. A series of phosphorus controlling chemical treatments were undertaken between 2013 and 2024, Phoslock in 2013 and PAC in 2021 and 2024, with the intent of reducing phosphorus levels and algal blooms in the lake. Following these initial treatments the City of Markham completed a Water Quality Management Strategy for Swan Lake in 2019 to set both short and long-term management objectives. Following the approval of this management strategy, the City of Markham implemented the Swan Lake Long-Term Management Plan in 2021, which details an adaptive, phased management approach that incorporates core, complimentary, and alternative measures including a range of chemical treatments, shoreline rehabilitation, and annual water quality monitoring.

As part of this long-term management plan, Phase 1 core measures were to be implemented for a period of 5 years followed by a re-evaluation of the management strategy and implementation of preliminary rehabilitation measures. In advance of this Phase 1 re-evaluation the Friends of Swan Lake Park have requested a preliminary peer review of the works completed to date.

The scope of this review includes:

- Water Quality Monitoring Program as outlined in the Swan Lake Long-Term Management Plan (Markham 2021);
- Swan Lake Water Quality Monitoring 2021 Annual Report (Markham 2022);
- Swan Lake Water Quality Monitoring 2022 Annual Report (Markham 2023);
- Swan Lake Water Quality Monitoring 2023 Annual Report (Markham 2024); and
- Swan Lake Water Quality Monitoring 2024 Annual Report (Markham 2025);

## 2.0 Summary of Water Quality Monitoring Program Components

The surface water quality monitoring program outlined as part of the City of Markham's Swan Lake Long-Term Management Plan included a combination of bi-weekly (April-November) field and laboratory water quality analyses at two pre-established monitoring stations to characterize the conditions within Swan Lake (Markham 2021). In addition, water temperatures (2021-2024) and dissolved oxygen concentrations were measured by continuous data loggers (2023-2024) to supplement bi-weekly sample collection at the two monitoring stations.

Surface water quality samples were analyzed, either in the field or through laboratory analysis, for the following parameters:

- Water Clarity (Secchi Depth)
- Nutrients
    - Total Phosphorus
    - Ortho-Phosphours
    - Ammonia
    - Nitrate
    - Nitrite
    - Total Kjeldahl Nitrogen
- Chloride
- Colour
- Dissolved Organic Carbon
- Phytoplankton/Chlorophyll-a
- Temperature
- Dissolved Oxygen
- pH

These parameters were compared against a series of interim targets developed by the City of Markham to act as general numerical guidelines intended to be used as thresholds for hyper-eutrophic conditions. These interim targets were updated to generic thresholds for eutrophic/hyper-eutrophic conditions (Markham 2022), which are shown in Table 1.

References are made to additional total and dissolved Aluminum concentration monitoring as part of the ongoing phosphorus control chemical applications. However, this monitoring is omitted from annual monitoring results.

**Table 1. Swan Lake Water Quality Guidelines and Targets**

| General Eutrophic State Water Quality Targets | | | |
|---|---|---|---|
| **Parameter** | **Eutrophic Condition** | **Hyper-Eutrophic Condition** | **Rationale** |
| Water Clarity (Secchi Depth) (m) | 1-2.1m | <1 | Based on objective of low-eutrophic conditions as a surrogate for Phytoplankton/Chlorophyll-a. |
| Total Phosphorus (µg/L) | 31-100 | >100 | Based on low-eutrophic condition objective of the overall management plan. |
| Total Nitrogen (mg/L) | 0.65-1.20 | >1.20 | Based on low-eutrophic condition objective of the overall management plan. |

| Provincial/Federal Water Quality Guidelines | | |
|---|---|---|
| **Parameter** | **Guideline** | **Rationale** |
| Chloride Concentration (mg/L) | 640 | Based on the assumption that meeting the guideline for long-term exposure for the protection of aquatic life (120 mg/L) is not achievable at this time. |
| Total Cyanobacteria Cells (cells/mL) | 50,000 | Based on low-eutrophic condition objective and potential production of cyanotoxins as part of the overall management plan. |
| Total Cyanobacterial biovolume ($mm^3/L$) | 4.5 | Based on low-eutrophic condition objective and potential production of cyanotoxins as part of the overall management plan. |

| | | |
|---|---|---|
| Total Chlorophyll-a (µg/L) | 33 | Based on low-eutrophic condition objective and potential production of cyanotoxins as part of the overall management plan. |
| Cyanotoxins (µg/L) | 10 | Based on Health Canada Guideline for Recreational activities |

Following the completion of each monitoring year the results were compared to both the established guidelines and previous monitoring years' results in order to identify trends in surface water quality and note positive or negative changes in surface water quality conditions that could be attributed to ongoing Swan Lake rehabilitation operations.

## 2.1 Water Quality Monitoring Program Components and Recommendations

### 2.1.1 Water Quality Parameters

Based on NRSI's review of the components of the overall monitoring program, the surface water quality parameters identified as part of the core water quality monitoring program are consistent with eutrophication monitoring as part of an overall beneficial use impairment assessment (CWA 2025). These monitoring programs are intended to assess the potential risk of disruption to aquatic ecosystems, human health, and/or impairment to recreational use and serve as appropriate parameters to support the long-term condition monitoring within Swan Lake.

Despite Swan Lake's status as an artificial water body and not being intentionally constructed as a stormwater management facility (SWMF), the presence of multiple stormwater outlets to the lake make it a stormwater receiver and suggest that the lake serves as an ad hoc SWMF. Stormwater management facilities convey surplus surface water runoff from impervious surfaces for treatment and management and often convey additional contaminants from road runoff (such as heavy metals, hydrocarbons, and in-organic debris) which can have considerable degenerative effects on receiving aquatic ecosystems. The omission of common stormwater management pond contaminants from the overall monitoring program limits the comprehensiveness of the overall monitoring program and relevance of any overall water quality condition assessment.

In addition, the inclusion of additional supporting physical and organic parameters would be beneficial to provide context of the overall water quality conditions and effectiveness of the

ongoing rehabilitative and management operations. These supporting parameters would help to characterize additional elements of the aquatic ecology within Swan Lake and provide context for changes to the suitability of the lake to support aquatic life over the longer term. Additional parameters would also provide context to the overall water quality monitoring program. It is recommended that the following additional water quality parameters be included as part of the monitoring program going forward, including:

Physical Parameters

- Total Suspended Solids (TSS)
- Conductivity

Total Metals

- Aluminum, Antimony, Arsenic, Barium, Beryllium, Bismuth, Boron, Cadmium, Calcium, Cesium, Chromium, Cobalt, Copper, Iron, Lead, Lithium, Magnesium ,Manganese, Molybdenum, Nickel, Phosphorus, Potassium, Rubidium, Selenium, Silicon, Silver, Sodium, Strontium, Sulfur, Tellurium, Thallium, Thorium, Tin, Titanium, Tungsten, Uranium, Vanadium, Zinc, and Zirconium.

Organics

- Biochemical Oxygen Demand (BOD)
- E. Coli (*Escherichia Coli*)
- Oil and Grease
- Polycyclic Aromatic Hydrocarbons

### 2.1.2 Water Quality Sample Collection

The sampling program intervals outlined bi-weekly sample collection between April and November to provide high resolution water quality data on an annual basis. This sampling program would be appropriate to characterize the background conditions in support of the long-term condition monitoring within Swan Lake. However, the presence of multiple stormwater outlet structures Swan Lake and the assumed stormwater inputs have the potential to introduce high concentrations of surface water contaminants over a short timeline in response to spring freshet or significant precipitation events. The inclusion of additional spring freshet/precipitation event sampling events would be beneficial to provide context for the overall water quality conditions and effectiveness of the ongoing rehabilitative and management operations.

The omission of winter surface water quality monitoring, specifically for Dissolved Oxygen, limits the comprehensiveness of the overall monitoring program as it relates to the identification of hypoxic and anoxic conditions within Swan Lake.

It is recommended that additional spring freshet/precipitation event monitoring events and the extension of the monitoring window to include winter sampling events be included as part of the monitoring program going forward.

### 2.1.3 Water Quality Sampling Locations

Swan Lake is a relatively stagnant lake with no significant currents and very minimal mixing throughout the lake. This limits the degree of water quality parameter concentrations evenness throughout the lake. Sampling within Swan Lake has occurred at two sampling locations; "Bridge" and "Dock," limiting the resolution of the water quality sampling results and the comprehensiveness of the overall monitoring program. The limited number of sampling stations has the potential to lead to a misinterpretation of the overall conditions within Swan Lake by omitting areas of comparatively high or low water quality conditions. In addition, the presence of multiple stormwater outlet structures within Swan Lake and a lack of monitoring in their immediate vicinity limits the ability to characterize the potential effects of SWM outflows on surface water quality conditions. The inclusion of additional monitoring stations throughout Swan Lake and in the vicinity of the existing stormwater outlet structures would improve the comprehensiveness of the overall monitoring program.

It is recommended that additional monitoring stations be included as part of the monitoring program going forward to improve overall coverage across Swan Lake.

### 2.1.4 Water Quality Guidelines and Targets

The general eutrophic state water clarity targets established as part of the Swan Lake water quality monitoring program incorporate the expected ranges of water quality parameters for eutrophic and hyper-eutrophic conditions. For parameters not generally covered by the Canadian Council of Ministers of the Environment (CCME) Recommended Guidelines for the Protection of Aquatic Life the ranges are generally consistent with the expected range of conditions within shallow urban water bodies as opposed to the guidelines established under the Provincial Water Quality Objectives (CCME 2001 and MOEE 1994).

The City of Markham maintains that, given the manmade nature of Swan Lake, there is no requirement to comply with Ministry of Environment and Energy's (MOEE) guidelines or

recommendations. However, it should be noted that the MOEE has indicated that all Provincial Water Quality Objectives (PWQO) are applicable to "*all waters of the province (e.g. lakes, rivers and streams) except in those areas specifically designated, such as areas influenced by MOEE approved point source discharges*." (MOEE 1994). No specific exemptions are identified for private or manmade water bodies. As such, the omission of applicable PWQO from comparison due to the general nature of Swan Lake may not be the most appropriate application of the relevant guidelines.

However, exemptions to PWQO guidelines may be applicable for areas where water quality does not meet the identified PWQO, provided that conditions not be allowed to degrade further and all practical measures are taken to upgrade the water quality to the objectives (MOEE PWQO Policy 3.2.2). These exemptions and accommodations are available where it is clearly demonstrated that all reasonable and practical measures to attain the Provincial Water Quality Objectives have been undertaken but where:

- Provincial Water Quality Objectives are not attainable because of natural background water quality;
- Provincial Water Quality Objectives are not attainable because of irreversible human-induced conditions;
- Attaining or maintaining Provincial Water Quality Objectives would result in substantial and widespread adverse economic and social impact; or
- Suitable pollution prevention techniques are not available.

In this scenario deviations from the PWQO may be allowed, subject to the approval of the MOEE, under the "Guideline for Handling Requests for Deviations" (MOEE 1994). In general, these guidelines are numerical concentrations recommended as levels that should result in negligible risk of adverse effects to be used as benchmarks or targets in the assessment and remediation of impacted sites.

It is recommended that PWQO guidelines be included for analysis as part of the Swan Lake monitoring program going forward.

**Water Clarity**

Water clarity, measured by secchi depth, was utilized within the monitoring program and is intended to be used as a surrogate to monitor for Phytoplankton (algae) blooms as a component

of eutrophic and hyper eutrophic conditions. Though water clarity itself is not directly associated with water quality conditions for the protection of aquatic life, the Health Canada has established water clarity guidelines for the protection of recreational water uses based on public health and aesthetic considerations (Health Canada 2024). Despite Swan Lake never being intended to support recreational uses, incorporating these recreational guidelines as part of the Swan Lake monitoring program would generally coincide with the water quality range for Eutrophic conditions while serving to support a degree of water safety applicable for recreational uses within and around Swan Lake.

It is recommended that the water clarity recreational water quality guideline (>1.2m) be incorporated as part of the monitoring program going forward (Health Canada 2024).

**Total Phosphorus**

Total phosphorus targets established under the Swan Lake monitoring program are generally consistent with the CCME guidelines for the protection of aquatic life trigger ranges for Canadian lakes and rivers. Phosphorus concentrations are not directly associated with water quality conditions to protect aquatic life, but they are directly associated with the risk of eutrophic conditions. The stated water quality guidelines currently omit the total phosphorus ranges for other eutrophic conditions (from Oligotrophic to Hyper-eutrophic) somewhat limiting the comprehensiveness of the overall monitoring program.

It is recommended that the total phosphorus water quality targets include the additional trigger ranges outlined as part of the Canadian Water Quality Guidelines for the Protection of Aquatic Life as part of the monitoring program going forward (CCME 2001).

**Total Nitrogen**

Total nitrogen targets are based on the general assessment ranges for eutrophic conditions. However, total nitrogen concentrations typically incorporate both organic nitrogen and ammonia concentrations within an environment and while there are recommended CCME guidelines for the protection of aquatic life for both nitrate and ammonia there are no specific guidelines for total nitrogen concentrations (CCME 2001). As such the application of general eutrophic condition assessment ranges for total nitrogen concentrations serve as appropriate water quality targets for the Swan Lake water quality monitoring program. However, the incorporation of additional guideline ranges for nitrogen-associated parameters, such as nitrate and ammonia,

which are already included in the surface water monitoring program, would serve to increase the overall comprehensiveness of the Swan Lake monitoring program.

It is recommended that the nitrate and ammonia guidelines established through the Canadian Water Quality Guidelines for the Protection of Aquatic Life be incorporated into the monitoring program going forward (CCME 2001).

**Chloride**

Chloride targets as part of the Swan Lake monitoring program were established to coincide with the short-term exposure guideline, following the assumption that achieving the long-term exposure guideline was not possible at this time. The Canadian Water Quality Guidelines for the Protection of Aquatic Life are intended to protect against the direct toxic effects of chloride (CCME 2001). Where exceedance of the long-term guideline is observed due to anthropogenically enriched water, such as within Swan Lake, toxic effects may not be observed due to the potential for adapted ecological communities within chronically exposed environments and highly tolerant species (CCME 2011). Though these guidelines are not legally enforceable limits, they are intended as benchmarks or targets in the assessment and remediation of contaminated sites and aid in evaluating the effectiveness of site controls on water quality. Despite the assertation that meeting the long-term exposure limit as not achievable at this time, the omission of the guidelines from the water quality monitoring program conclusions does somewhat limit the comprehensiveness of the annual analysis.

It is recommended that the long-term guideline be included as part of the monitoring program going forward to provide additional context to changes in chloride conditions (CCME 2001).

**Dissolved Oxygen**

The dissolved oxygen target as part of the Swan Lake monitoring program was established as the minimum dissolved oxygen concentration for the protection of warmwater fish species, as established by the PWQO (MOEE 1994). However, this guideline is intended as a general guide and the MOEE further indicates that where additional physical or chemical stressors are operating more stringent criteria may be required. Low oxygen levels are common in eutrophic lakes, such as Swan Lake, where oxygen depletion is facilitated by anaerobic activity. Chronic exposure to low dissolved oxygen levels lead to reduced growth in fish, and other aquatic species, and increased stress on aquatic ecosystems, which can include an increase in juvenile

fish mortality (CCME 1998). More recent water quality guidelines have been established by CCME with the understanding that oxygen concentrations near the bottom of water bodies are further actively reduced as a result of sediment oxygen demand, which magnifies the effects of low dissolved oxygen levels on developing fish embryos and benthic aquatic organisms (CCME 2001). As such, the Canadian Water Quality Guidelines for the Protection of Aquatic Life for Dissolved Oxygen establish slightly higher concentration guidelines for the protection of warmwater ecosystems during both early and other life stages (CCME 2001).

It is recommended that the dissolved oxygen concentration guidelines established as part of the Canadian Water Quality Guidelines for the Protection of Aquatic Life, for both early and other life stages be incorporated as part of the monitoring program going forward (CCME 2001).

**Cyanobacteria and Cyanotoxins**

Cyanobacteria related guidelines set out as part of the Swan Lake monitoring program are consistent with the Health Canada Guidelines for Canadian Recreational Water Quality (Health Canda 2024). Though these guidelines are intended to address the human health and safety of recreational surface water bodies, they do provide appropriate guidelines to comprehensively address microbiological hazards within Swan Lake.

**Chlorophyll-a**

Guidelines for Chlorophyll-a have been established as an index for eutrophication and cyanobacteria biomass to further address the human health and safety of recreational surface water bodies. These guidelines are consistent with Health Canada Guidelines for Canadian Recreational Water Quality and provide appropriate guidelines to comprehensively address microbiological hazards within Swan Lake (Health Canada 2024).

## 3.0 Water Quality Monitoring Results

The results of the City of Markham's 2021-2024 water quality monitoring program show relatively consistent water quality conditions within Swan Lake on an annual basis, with notable changes during each monitoring year that can be attributed to specific remediation activities. The results of specific water quality monitoring parameters are further discussed below.

### Water Clarity

Water clarity monitoring results between 2021 and 2024 were reported on an annual basis as being generally below the guidelines for the duration of the growing season. This is an appropriate characterization of the conditions based on the reported water quality results. However, as part of each year's annual monitoring report the overall Secchi depths were averaged for comparison with identified water quality guidelines as part of the representation of the annual Secchi depth conditions. As the annual monitoring data incorporates monitoring from outside the growing season it has the potential to lead to the misinterpretation of the water clarity conditions present within Swan Lake. The conditions reported within Swan Lake appear to be approximately consistent with those seen in shallow eutrophic surface water bodies.

It is recommended that both the minimum and maximum Secchi depths be included as part of the annual water quality guideline analysis to note potential seasonal changes in water clarity.

### Total Phosphorus

Total phosphorus concentrations between 2021 (following phosphorus control treatment) and 2024 were reported as consistently below the Eutrophic threshold and were well below the elevated levels reported for 2021 prior to phosphors control treatment applications. This is reported as an improvement from prior conditions, which is an appropriate characterization of the conditions with Swan Lake. However, the omission of additional trophic status trigger ranges from further analysis has the potential to lead to the misinterpretation of the surface water conditions, providing in potentially inaccurate characterization of the conditions as unimpacted and a false representation of improved surface water quality within Swan Lake. The inclusion of the greater granularity of Total Phosphorus condition ranges would provide a more comprehensive representation of the conditions within Swan Lake. The conditions reported within Swan Lake appear to be generally consistent with those seen in shallow eutrophic surface water bodies.

It is recommended that further trophic status ranges established under the Canadian Water Quality Guidelines for the Protection of Aquatic Life, including Eutrophic, meso-eutrophic, mesotrophic, oligotrophic, etc., be included as part of the annual water quality analysis to provide context as to the overall water quality conditions (CCME 2004).

**Total Nitrogen**

Total nitrogen concentrations were reported as consistently below the eutrophic thresholds between 2021 and 2024. This appears to be an appropriate characterization of the conditions within Swan Lake. However, reported findings during 2021 and 2023 are not presented with direct comparison to the identified guidelines and bi-weekly sampling results were not reported for 2024 monitoring, so this statement cannot be verified. This has the potential to lead to the potential misinterpretation of the surface water conditions as unimpacted and the potential misinterpretation as overall improved surface water quality within Swan Lake. An analysis of water quality and nutrient trends in major drainage areas by Environment Canada identified the median national concentration range as between 0.002 - 6.9 mg/L, and between 0.005 - 0.382 mg/L for unimpacted sites with the highest concentrations identified within the Great lakes area (Environment Canada 2011). The conditions within Swan Lake, generally below 0.65 mg/L, suggest the conditions reported within Swan Lake appear to be generally consistent with those seen in shallow eutrophic surface water bodies, shallow eutrophic surface water bodies.

It is recommended that bi-weekly water quality results be reported alongside the identified guidelines as part of the annual water quality analysis to provide context for the overall water quality conditions.

**Chloride**

Chloride concentrations have been reported as relatively consistent within each monitoring year, with a significant improvement in chloride concentrations attributed to rehabilitation works completed at the East Pond Inlet and Swan Lake Club Oil and Grit Separator (OGS) during 2024. Overall results were reported as consistently within and below the target concentration ranges and short-term Guideline for the Protection of Aquatic Life, but consistently in excess of the long-term guidelines. This is an appropriate characterization of the existing conditions within Swan Lake. However, multiple gaps in full sampling coverage are noted within the reported data. Specifically, omissions of some bi-weekly monitoring events during each monitoring year. No explanation is presented for these sampling omissions, which potentially leads to the

potential misinterpretation as improved surface water quality within Swan Lake. The elevated chloride conditions reported within Swan Lake are consistent with those seen in online shallow water bodies that are subjected to road salt runoff contamination, such as with stormwater management ponds and their receiving water bodies.

It is recommended that the full bi-weekly water quality results be reported, with explanations provided for gaps in water quality sampling coverage.

**Dissolved Oxygen**

Dissolved oxygen concentration monitoring reported oxygen levels consistently above the established guidelines, suggesting stable, albeit still impaired conditions between 2021 and 2024, as shown by the repeated low dissolved oxygen events below the identified guideline. This is an appropriate characterization of the existing conditions within Swan Lake. However, multiple gaps in full sampling coverage were noted within the reported data. Specifically, omissions of some bi-weekly monitoring events during each monitoring year. No explanation is presented for these sampling omissions, which potentially leads to the potential misinterpretation of improved surface water quality within Swan Lake. In addition, the overall validity of the assertation that the conditions within Swan Lake are in excess of the recommended guidelines is somewhat in question based on the results of the 2024 Trent University continuous dissolved oxygen monitoring, which reported anoxic conditions within Swan Lake. This suggests that the sampling coverage within Swan Lake may not adequately characterize the overall water quality conditions. The expansion of dissolved oxygen concentration monitoring to include additional sampling locations, depths, and sampling events would help to support the characterization of overall water quality conditions. In addition, the dissolved oxygen conditions reported between 2021 and 2024 are not presented alongside the recommended guidelines limiting the context and implications that can be drawn from the reported results. Low, though not critically, dissolved oxygen conditions are typical of shallow eutrophic water body and are approximately consistent with the conditions within Swan Lake.

It is recommended that dissolved oxygen conditions alongside identified guidelines, with explanations provided for gaps in water quality sampling coverage, be included as part of the annual water quality analysis to provide context as to the overall water quality conditions.

**Cyanobacteria and Cyanotoxins**

Cyanobacteria monitoring reported cell counts generally in excess of the recommended guidelines, with a general decreasing trend between 2022 and 2024, implying that this is a result of successfully reduced nutrient concentrations. However, specific cyanobacterial count results were not reported as part of the annual monitoring reports with no corresponding overall water quality improvements represented by the monitoring data. This can potentially lead to misinterpretation as to overall improved water quality conditions. In addition, it appears that cyanobacterial monitoring was not completed on the same monitoring schedule outlined as part of the Swan Lake Monitoring Program, with no explanation provided for the variance.

Total cyanobacterial biovolume results were omitted from annual reports between 2022 and 2024 despite the identification of specific guidelines as part of the overall monitoring program, with no explanation provided for the variance.

Cyanotoxin concentrations were only reported from 2022 monitoring, which reported concentrations below the identified guideline. Specific sampling results were not reported as part of the annual monitoring reports, potentially mischaracterizing the conditions within Swan Lake. In addition, it appears that Cyanotoxin monitoring was not completed during 2023 and 2024 with no explanation provided as to the variance from the Swan Lake Monitoring Program.

Overall, the annual monitoring reports attribute the improvement in cyanobacteria conditions to successfully reduced nutrient concentrations. However, the reports still indicate conditions in excess of the identified guidelines and omit any specific monitoring results. All of this combined has the potential to mischaracterize the overall water quality conditions within Swan Lake.

It is recommended that cyanobacteria conditions alongside identified guidelines, with explanations provided for gaps in water quality sampling coverage, be included as part of the annual water quality analysis to provide context as to the overall water quality conditions. Any assertations of significant improvements should be presented alongside supporting evidence.

**Chlorophyll-a**

Chlorophyll-a monitoring reported concentrations “within the eutrophic state”. However, average concentrations reported in 2023 and 2024 were below the guidelines established as part of the Swan Lake Monitoring Program. No Chlorophyll-a concentrations were reported as part of 2022 monitoring with a lack of specific monitoring results reported during 2023 and 2024. In addition, it appears that Chlorophyll-a monitoring was not completed on the same monitoring schedule

outlined as part of the Swan Lake Monitoring Program with no explanation provided for the variance, which could mischaracterize the conditions within Swan Lake.

It is recommended that Chlorophyll-a conditions alongside identified guidelines, with explanations provided for gaps in water quality sampling coverage, be included as part of the annual water quality analysis to provide context as to the overall water quality conditions. If Chlorophyll-a monitoring has been removed from the overall water quality monitoring program, it is recommended that the rational for its removal be provided as part of the annual monitoring report.

## 3.1 Adequacy of Water Quality Monitoring Program

Based on our review of the overall Swan Lake Monitoring Program it is NRSI's opinion that the existing water quality monitoring program is sufficient for a high-level characterization of the water quality from the perspective of monitoring the risk of eutrophic conditions within Swan Lake. However, the inclusion of the recommendations outlined above would support a more comprehensive characterization of surface water conditions and the evaluation of ecological conditions and functions within Swan Lake.

A review of the annual water quality monitoring reports between 2022 and 2024 further supports this with the results presented as part of each year's annual monitoring program sufficient for the high-level characterization of the existing conditions within Swan Lake. However, minor omissions and limitations inherent in the monitoring program limit the overall comprehensiveness of the monitoring program and some of the conclusions that can be drawn from observable water quality trends. The inclusion of the recommendations outlined above would support a more comprehensive monitoring program and support the identification of changes in surface water conditions.

## 3.2 Water Quality Monitoring Program Limitations

Despite the limited scope of the Swan Lake Monitoring Program and the high-level characterization of potential eutrophic conditions, the program itself does have some notable limitations to the extent of the conclusions that can be drawn. Including.

- Omitted results of water quality monitoring events (between 2021 and 2024 for water clarity, phosphorus, nitrogen, dissolved oxygen) has the potential to mischaracterize the conditions and provide a false representation of improved conditions within Swan Lake.

- Limited sampling locations and depths as part of the monitoring program limit the comprehensiveness of sampling results.

By their nature the water quality parameters included as part of the overall Swan Lake Monitoring Program are associated with eutrophication and algae blooms and limited implications can be drawn as to the health of the aquatic habitat conditions and suitability to support a healthy aquatic ecosystem. Despite the overall monitoring program's intentional omission of aquatic health as a monitoring parameter, the inclusion of additional aquatic health specific monitoring components would serve to improve the comprehensiveness of the monitoring program.

## 4.0 Water Quality Monitoring Program Enhancements

While the overall Swan Lake Water Quality Monitoring Program, if applied correctly, is appropriate to meet the intent of high-level eutrophic condition characterization, the opportunity exists to expand it to provide a more comprehensive and high resolution water quality characterization to support the overall Swan Lake Water Quality Management Plan. This expanded water quality monitoring program is recommended to include the following new and refined monitoring components:

- Additional spring freshet and significant precipitation event sampling to account for potential stormwater runoff effects on surface water conditions;
- Inclusion of PWQO Guidelines alongside Swan Lake Monitoring Program guidelines;
- Inclusion of Recreational Water Quality Guidelines for water clarity;
    - Inclusion of minimum and maximum water clarity readings, along side the applicable targets/guidelines, as part of the annual water quality analysis to detail the range in conditions;
- Inclusion of CCME Canadian Water Quality Guidelines for the Protection of Aquatic Life guidelines for total phosphorus, nitrate, ammonia, and dissolved oxygen concentration analysis;
- Completion of all water quality monitoring components identified as part of the Swan Lake Monitoring Program on an annual basis;
    - A summary of omissions or alterations in monitoring from workplan components outlined as part of each annual report;
- Include complete bi-weekly water quality results as part of each annual report, along with explanations and justification for gaps in water quality sampling coverage;
- Any assertations of significant water quality improvements be presented alongside supporting evidence in each annual report;
- The inclusion of aquatic health specific monitoring components to increase the comprehensiveness of the monitoring program.
    - Annual aquatic health monitoring can include the inclusion of benthic macroinvertebrate, zooplankton, and fish community composition, aquatic vegetation biomass, or composition assessment, herpetofauna nesting and overwintering assessment.

## 4.1 Swan Lake Management Strategy Program Considerations

Specific management and habitat restoration activities offer the potential to further support the improvement of water quality and aquatic habitat conditions within Swan Lake. These strategy considerations are intended to address some of the causes of degraded water quality conditions as opposed to addressing their symptoms, which support the foundation of an improved long-term strategy for Swan Lake to enhance aquatic ecosystem health, reduce eutrophication, and restore more natural lake function. Based on our understanding of the history of Swan Lake and its role in the wider stormwater system, both historic and ongoing high concentration nutrient loading is understood to be one of most significant factors contributing to the existing water quality conditions within Swan Lake. To support the enhancement of the surface water quality conditions within Swan Lake the following activities are proposed for this purpose:

- **Comprehensive Oxygenation Program:** The inclusion of targeted oxygenation measures will serve to directly address low dissolved oxygen levels within Swan Lake. It should be noted that while supplemental oxygenation alone will not induce meaningful long-term improvements in surface water conditions, it does have the potential to address some short-term habitat limitations. An oxygenation program may act to minimize the potential for hypoxia/anoxia, address anaerobic sediment conditions, and generally support widespread aquatic ecosystem health.

    - The implementation of a multipart oxygenation program, in line with the design proposed by the FOSLP as part of their December 2025 submission for Markham's Swan lake Water Quality Review, including the installation of multiple diffused aeration systems, fountain aeration systems, and the circulation of surface water through Swan Lake to introduce current flows, has the potential to significantly improve surface dissolved oxygen conditions and contribute to the improvement of overall surface water quality conditions.

- **Sediment & Nutrient Management:** Identifying and addressing the internal and external nutrient sources will directly influence long-term aquatic ecosystem condition stability. Mitigating and controlling the additional nutrient inputs that originate from stormwater and natural sources (e.g., goose droppings) is critical to addressing the underlying cause of the degraded aquatic ecosystem conditions in Swan Lake. While PAC and other phosphorus controlling chemical treatments temporarily help to mitigate surface water concentrations, it does not address the elevated concentrations within the

sediment, nor does it influence long-term habitat stability. Following the implementation of targeted sediment and nutrient monitoring, the appropriateness of the additional chemical treatments can further assessed.

An overall sediment and nutrient management strategy would support a more targeted phosphorus-controlling chemical treatments by using a science-based approach to determine scheduling and planning of applications as opposed to only applying the treatment following algae mat formation. The reliance on algae mat formation as the key metric for determining when to apply supplemental chemical treatments is limiting. While algae mat formation does imply a degraded water quality, it has a limited ability to address the underlying cause of the water quality conditions before they degrade to the point where treatment is necessary.

In addition, the characterization of sediment quality conditions throughout Swan Lake would help to characterize the overall sediment nutrient concentrations and support future management opportunities, including potential targeted sediment removal operations to address areas of significantly elevated sediment nutrient conditions.

While natural phosphorus loading from Canada Goose populations is understood to be short-lived, with most nutrients settling into the sediment, the Canada Goose monitoring and management operations completed to-date appear to have been effective at reducing resident goose populations, thereby helping to reduce additional external nutrient loading (Unckless and Makarewicz 2007). The continuation of these monitoring and management operations would support wider management and restoration operations and contribute to the improvement of surface water quality conditions.

A detailed sediment and nutrient management program, including the characterization of sediment conditions within upstream stormwater management facilities, their sediment and nutrient contributions into Swan Lake, as well as a detailed characterization of the sediment conditions throughout Swan Lake would help to direct restoration and management strategies to address the underlying sources of degraded habitat conditions within Swan lake and support the long-term improvement on surface water and aquatic ecosystem quality conditions.

- **Chloride Management:** Chloride concentrations have reduced somewhat, but still remain above the long-term exposure guidelines. Addressing the inputs from

upstream stormwater management, either by addressing outflow to Swan Lake or through application of targeted chloride-reducing measures (such as biochar), is critical to achieving any long-term improvements in surface water and aquatic ecosystems quality. FOSLP chloride reduction programs included as part of their December 2025 submission for Markham's Swan lake Water Quality Review has the potential to significantly reduce Swan Lake's annual chloride loading, contributing to the overall improvement of the surface water quality conditions. Supplementary filtration, through the inclusion of Biochar (or similar) filter systems, would help to further reduce the chloride levels within Swan Lake. If used in conjunction with reducing annual chloride loading this would serve to potentially address the elevated chloride concentrations and support the improvement of the overall surface water quality conditions.

- **Enhanced Monitoring Program:** It is suggested that the water quality monitoring program be expanded and/or enhanced to include sediment quality monitoring (aligned with the Sediment Quality Guidelines for the Protection of Aquatic Life) and should consider the addition of sampling locations to help support the characterization of the existing conditions within Swan Lake, and to provide additional context for supplementary treatments and rehabilitative measures (such as limited targeted removal of contaminated or high concentration sediment deposits). Previous sediment monitoring, completed in 2020, was in line with the assessment of the risk of eutrophication but did little to assess the overall health and suitability of the aquatic ecosystem. Ideally this monitoring would continue an annual basis during and following any restoration and management activities to monitor for changes in sediment conditions.

- **Shoreline Habitat Enhancement:** Shoreline restoration and plantings would help to support the development of aquatic ecosystem structure, stabilize the nearshore aquatic ecosystem conditions, and contribute to the ongoing aquatic vegetation establishment program. Enhanced riparian habitats would also help to mitigate some of the natural nutrient and sediment loading. Engaging the Toronto and Region Conservation Authority to advise and support shoreline enhancements, included as part of the FOSLP's December 2025 Markham's Swan lake Water Quality Review, would strengthen the aquatic and shoreline enhancement program. But, as with other management strategies, shoreline enhancements would be most effective when implanted alongside measures

that anticipated root causes of degraded water quality conditions, high nutrient concentration sediments.

It is understood that one management strategy being considered involves the removal of excessive nearshore aquatic plants (e.g., phragmites), previously completed in 2022. Future aquatic vegetation removals have been proposed by the FOSLP to remove additional aquatic vegetation has the potential to contribute to further reducing internal organic nutrient loading going forward. However, given the high legacy concentrations of organic nutrients within the sediment, this proposed strategy wouldn't provide a notable improvement to the overall conditions, but would need to be applied along with other management strategies.

- **Algae Management:** The continuation of ultrasonic control measures, to inhibit algae bloom formation, has the potential to support natural ecosystem stabilization, improving surface water clarity and supporting aquatic vegetation growth. Similarly, direct algae treatment chemical applications have the potential to address the risk of algae blooms but would do little to address the perceived root causes of the degraded aquatic ecosystem within Swan Lake, the historic and ongoing high concentration nutrient sediments.

No single Swan Lake Management Strategy component will completely address the degraded water quality or remove impediments to improving the conditions within the local aquatic ecosystem. However, the integration of a combination of these strategies has the potential to improve and enhance the overall sediment and water quality conditions, and foster a more balanced and resilient aquatic ecosystem within Swan Lake. It is recommended that future Swan Lake Management Strategies consider the following components to enhance the effectiveness of individual management strategies and contribute to the improvement and enhancement both sediment and water quality conditions within Swan Lake:

- Inclusion of a sediment quality monitoring program within Swan Lake and the adjacent Stormwater Ponds to characterize the existing conditions and support wider sediment and nutrient management programs. It is recommended this program continue through Phase 2 and 3 to monitor for changes in sediment loading and quality conditions.
- Implementation of targeted oxygenation measures to address low dissolved oxygen concentrations and contribute to improved surface water and aquatic habitat conditions.

The FOSLP oxygenation program included as part of their December 2025 submission for Markham's Swan lake Water Quality Review would address these recommendations. It is recommended this program be implemented during Phase 2.

- Implementation of an improved chloride management program, through stormwater pond bypassing and filtration, to reduce annual chloride loading. The FOSLP chloride reduction programs included as part of their December 2025 submission for Markham's Swan lake Water Quality Review would address these recommendations. It is recommended this program be implemented during Phase 2.
- Shoreline habitat enhancement and rehabilitation to contribute to the enhancement of aquatic habitat and nearshore aquatic ecosystem conditions, supporting the ongoing aquatic vegetation establishment program while mitigating some of the natural nutrient and sediment loading. The FOSLP oxygenation program included as part of their December 2025 submission for Markham's Swan lake Water Quality Review would address these recommendations. It is recommended this program continue through Phase 2 and 3 to account for wider  monitor for changes in sediment loading and quality conditions.

## 5.0 Conclusions

Within Swan Lake the overall water quality monitoring program completed between 2021 and 2024 provides an appropriate, if limited, high-level assessment of the water quality conditions as they relate to the risk of eutrophication. The parameters included as part of the overall Swan Lake Monitoring Program offer a high-level assessment of the potentially degraded surface water quality conditions and the effectiveness of the treatment and remediation activities as part of the overall Swan Lake Management Strategy. Based solely on the results of the water quality monitoring program, the existing management activities appear to have had some success at improving the water quality conditions within the lake. However, even though many of the water quality parameters met the identified guidelines/targets, several were still noted to be in exceedance. With that said, the high-level nature of the water quality parameters included as part of the monitoring program, and the limited guidelines applied as part of the annual analysis, limit the overall comprehensiveness of the monitoring program and the conclusions that can be drawn from observable water quality trends as they relate to the health of the aquatic ecosystem.

Given artificial nature of Swan Lake, its urbanized nature, and proximity to the local Stormwater Management Ponds, the monitoring guidelines established as thresholds for hyper-eutrophic conditions are attainable and reasonable minimum thresholds. Achieving these minimum thresholds would present an appropriate starting point to support future strategies as the management of Swan Lake moves from a restoration/mitigation to improvement/enhancement approach.

In addition, the eutrophication focus of the monitoring program has a limited ability to address the effects of historic and ongoing nutrient and contaminant loading on aquatic ecosystem health or to assess the effectiveness of the treatment and remediation activities completed to-date. It is, therefore, difficult to properly identify and address the underlying sources of many of the surface water quality concerns. The expansion and enhancement of the water quality monitoring program, including the additional sampling recommendations, would improve the comprehensiveness of the monitoring program and support greater refinement of the overall management and restoration strategies for Swan Lake.

## 6.0 References

Canadian Council of Ministers of the Environment. (1999). Canadian water quality guidelines for the protection of aquatic life: Dissolved oxygen (freshwater). In: Canadian environmental quality guidelines, 1999, Canadian Council of Ministers of the Environment, Winnipeg.

Canadian Council of Ministers of the Environment (CCME). (2001). Canadian water quality guidelines for the protection of aquatic life: CCME Water Quality Index 1.0, Technical Report. In: Canadian environmental quality guidelines, 1999, Canadian Council of Ministers of the Environment, Winnipeg.

Canadian Council of Ministers of the Environment. (2004). Canadian water quality guidelines for the protection of aquatic life: Phosphorus: Canadian Guidance Framework for the Management of Freshwater Systems. In: Canadian environmental quality guidelines, 2004, Canadian Council of Ministers of the Environment, Winnipeg.

Canadian Council of Ministers of the Environment. (2011). Canadian water quality guidelines for the protection of aquatic life: Chloride. In: Canadian environmental quality guidelines, 1999, Canadian Council of Ministers of the Environment, Winnipeg.

Canada Water Agency. (2025). Great Lakes water quality agreement: areas of concern. Available at: https://www.canada.ca/en/canada-water-agency/freshwater-ecosystem-initiatives/great-lakes/great-lakes-protection/canada-united-states-water-quality-agreement/areas-concern.html updated: May 29, 2025.

Environment Canada. (2011). Water Quality Status and Trends of Nutrients in Major Drainage Areas of Canada. Water Science and Technology Directorate Technical Summary.

Health Canada. (2024). Guidelines for Canadian Recreational Water Quality: Summary Document. February 2024

Markham Environmental Services. (2021). Swan Lake Long-Term Management Plan. November 2021.

Markham Environmental Services (2022). Swan Lake Water Quality Monitoring 2021 Annual Report. Project Number:21163. March 2022.

Markham Environmental Services (2023). Swan Lake Water Quality Monitoring 2022 Annual Report. Project Number:22198. March 2023.

Markham Environmental Services (2024). Swan Lake Water Quality Monitoring 2023 Annual Report. Project Number:23032. February 2024.

Markham Environmental Services (2025). Swan Lake Water Quality Monitoring 2024 Annual Report. Project Number:24254. February 2025.

Ontario Ministry of the Environment and Energy (MOEE). (1994). Water Management: Policies, Guidelines, Provincial Water Quality Objectives. Updated: August 16, 2021.

Unckless, R.L. and Makarewicz, J.C. (2007). The Impacts of nutrient loading from Canada Geese (Branta canadensis) on water quality, a mesocosm approach. Hydrobiologia 586, 393-401.