Swan Lake Aquatic Conditions Review

Friends of Swan Lake Park

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October 2025 (rev Feb 2026)
300060899.0000

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Record of Revisions

Revision	Date	Description
-	October 31, 2025	Draft Submission to Friends of Swan Lake Park
1	November 7, 2025	Draft Submission to Friends of Swan Lake Park
2	November 26, 2025	Final Submission to Friends of Swan Lake Park
3	February 26, 2026	Revisions following meeting with City of Markham on February 10, 2026

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Executive Summary

- R.J. Burnside & Associates Limited (Burnside) reviewed aquatic habitat conditions in Swan Lake at the end of Phase 1 of the Long-Term Water Quality Management Plan, on behalf of the Friends of Swan Lake Park, to guide recommendations for Phase 2.
- Despite improvements to overall water quality, internal nutrient loads and chloride concentrations may impede current and future ecological restoration efforts if left unaddressed.
- Construction of a bioswale system in the north channel or adjacent to stormwater/ oil grit separator outlets could assist in water quality management by helping to remove and sequester internal nutrients and/or chloride loading.
- Elevated chloride concentration and predation from abundant Fathead Minnows may be suppressing zooplankton grazers (e.g., *Daphnia* spp.), although no study has yet confirmed this relationship.
- Burnside recommends assessing the present zooplankton community to determine whether the working hypothesis (i.e., low *Daphnia* spp. abundance may be contributing to elevated phytoplankton biomass) holds true. The initial survey may serve as a baseline to monitor if key zooplankton populations recover over the course of Phase 2.
- Largemouth Bass stocking in 2025 provides an opportunity to potentially reduce Fathead Minnows. Establishment of a population of bass may be supported by adding complex woody material structures. Future aquatic surveys (i.e., spring (i.e., winter kill) and summer during 2026) are recommended to determine whether current lake conditions are suitable for sustaining bass, especially to overwinter, or if further habitat modifications (e.g., deepening the pond or raising the lake level, addition of physical habitat) may be worth exploring to improve survivability.
- There are limited opportunities to use native Unionidae mussels or sunfish species to improve habitat quality.
- Due to turbidity from phytoplankton, efforts should focus on creating a sustained period of low turbidity before pursuing further submerged macrophyte restoration.

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List of Abbreviations

AI	Artificial Intelligence
BOD	Biological Oxygen Demand
DO	Dissolved Oxygen
FOSLP	Friends of Swan Lake Park
TRCA	Toronto and Region Conservation Authority
SWM	Stormwater Management
OGS	Oil Grit Separator
PAC	Poly-aluminum Chloride

Disclaimer

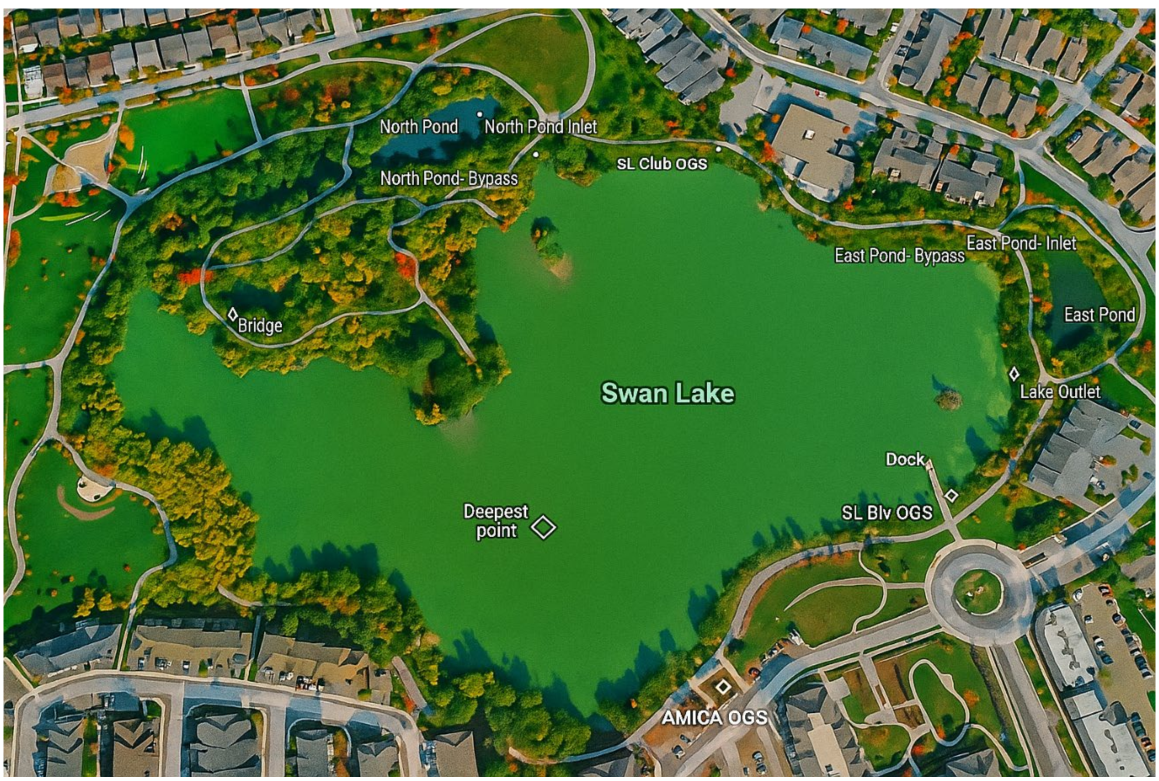
1.0 Background

Swan Lake is a 5.5 ha artificial lake in the City of Markham, created from a former gravel quarry excavated during the 1960s-1970s (FOSLP 2025a). Once dewatering operations ceased, the pit filled naturally with groundwater. During the 1970s, the site was used as a local landfill, and some illegal dumping occurred.

By the 1990s, the area surrounding Swan Lake was slated for urban development (FOSLP 2025a). The *Swan Lake Community Environmental Management Study* (December 1993) proposed converting the quarry into a public park and community feature with restored aquatic and terrestrial habitat. Markham accepted the plan in 2000.

Swan Lake has no natural surface inflows or outflows (FOSLP 2025a; Figure 1). It was incorporated into the stormwater management (SWM) system, receiving runoff from six stormwater sources and discharging through one outflow that regulates water levels at ~208.3 m above sea level, with an average depth of 1.65 m.

Figure 1: Swan Lake and Runoff Monitoring Stations. Image provided by FOSLP. Image Quality Improved through GPT-5 (OpenAI 2025a)



Persistent poor water quality and recurring algal blooms led local residents to form the Friends of Swan Lake Park (FOSLP) in 2019. Their goal is the rehabilitation of aquatic and terrestrial habitats to achieve sustainable water quality for long-term human and wildlife use. In 2020 FOSLP submitted *A Pathway to Sustainable Water Quality for Swan Lake* to City Council, prompting the 25-year *Long-Term Water Quality Management Plan* launched in 2021 (Parhizgari 2021). The plan's stated goal is "to improve the overall health of Swan Lake, which will provide opportunities for no-contact activities for the enjoyment of the community" (Parhizgari 2021).

Thus far, Phase 1 has been completed and now progressing into Phase 2:

- **Phase 1 (2021-2025)** targeted immediate water-quality improvements (chemical phosphorus reduction, geese management, invasive-species management, and pilot aquatic plantings)
- **Phase 2 (2026-2030)** is under review by Markham. FOSLP is recommending improved oxygen levels through circulation improvements, chloride reduction, sustaining nutrient levels and stronger ecological monitoring

FOSLP retained R.J. Burnside & Associates Limited (Burnside) to provide a preliminary review of aquatic habitat conditions at the end of Phase 1 and provide recommendations entering Phase 2. The following focuses on impacts and recommendations to support potential improvements for aquatic life (zooplankton, invertebrates, fish, and macrophytes).

2.0 Literature Review Methods

A literature review was conducted of the most recent reports commissioned in relation to the Swan Lake study, including those previously prepared for or by the FOSLP. Burnside visited Swan Lake with Fred Peters of FOSLP on October 15, 2025, to observe the condition of the lake, stormwater management facilities, and surrounding parklands.

Additional literature was reviewed on small, shallow, eutrophic, temperate lakes, with an emphasis on studies from North America or the northern hemisphere. While recent publications (post-2010) were prioritized, foundational and frequently cited papers were also referenced to provide context and theoretical background.

Portions of this report were edited using Artificial Intelligence (AI)-assisted editing tools in ChatGPT (OpenAI) to improve clarity and readability. AI was also used to help improve poor figure quality and to generate an illustrative figure (OpenAI 2025a; OpenAI 2025b). All research, technical analysis, writing, and interpretations are the author's own.

3.0 General Overview of End of Phase 1

Throughout Phase 1, total phosphorus and nitrogen species levels have improved from hypereutrophic conditions in 2020 to mesotrophic conditions by 2024 (Parhizgari 2025). The most recent FOSLP report indicates that the interim water-quality targets for Phase 1 were nearly achieved (Table 1). Monitoring data collected in 2025 support the continued positive trends observed during Phase 1 (Table 2). Nutrient concentrations (i.e., total phosphorus and nitrogen species) remain low and below target thresholds, indicating ongoing improvement in water quality. However, chloride concentrations and conductivity remain elevated (approximately 200 mg/L).

Table 1: Interim Water Quality Targets for the Phase 1 (2021-2025) Adapted from Parhizgari (2021) and FOSLP (2025a)

Parameter	Levels 2020	Interim Target	Objective and Rationale
Total Phosphorus (mg/L)	>0.2	0.05-0.1	Current Value: The average of the growing season TP values in the period since 2016 has been 0.2 mg/L. Interim target: will provide a low eutrophic condition in the first year after treatment increasing to eutrophic in year three.
Secchi Transparency (m)	<0.5	0.6-0.8	Based on correlation with the phosphorus target. Secchi is also a substitute for Chlorophyll a.
Frequency of Algae Blooms	Annual	Every Three Years	Trigger for treatment every three years.
Internal Phosphorus Load (kg/yr)	53	0-25	Both internal and external loads should be controlled to achieve the lake conservation target (see above)
External Phosphorus Load (kg/yr)	30	15	

Table 2: Average Inorganic Water Parameters (Mean ± SD) in Swan Lake during 2025 (April 24-Sept 24, 2025) n=1-6

Parameter	Surface (S2025)	Dock 0.5 m (S105)	Dock 1.5 m (S115)	Mid Lake (Ultrasound Transducer)	Interpretation
Total P (mg/L)	0.018±0.008	0.013±0.004	0.016±0.005	0.021±0.002	Below interim target range (<0.05)
Orthophosphate (mg/L)	0.006	ND	ND	ND	Minimal soluble P
Nitrate + Nitrite (m/L)	ND	ND	ND	0.11	Minimal Nitrogen species
Total Kjeldahl Nitrogen (mg/L)	0.59±0.13	0.56±0.05	0.56±0.10	0.53±0.06	Stable, moderate nutrient pool
Ammonia (µg/L)	0.130	0.072±0.023	0.120±0.028	0.070±0.009	Small fraction of total ammonia is the toxic un-ionized NH_3 at average Lake pH ≈8.1–8.2 (CCME 2010)
Chloride (mg/L)	213±17.1	217±17.5	200	190	Above >120 mg/L guidelines (CCME 2011)
Conductivity (µS/cm)	907±65	940±69	930	920	Elevated from road salt
Dissolved Organic Carbon (mg/L)	8.5±0.96	8.3±0.88	-	5.4±0.50	Moderate organic mat-ter
pH	8.1±0.27	8.2±0.28	-	8.1±0.01	Normal, slightly basic

ND = Not Detected at a concentration equal or greater than the indicated Detection Limit of 0.004 mg/L for Orthophosphate and 0.1 mg/L for Nitrate + Nitrite.
If a value appears without a ± SD, it indicates that dataset consisted of only one observation (n=1) or repeated identical observations

The improvements in water quality can be attributed to nutrient control measures enacted in Phase 1. Chemical treatment has been the main phosphorous control throughout the lake's history. Before the *Management Plan*, Copper-sulfate treatment was applied 1995, and a 25.2 t Phoslock® application in 2013 (FOSLP 2025a). Under Phase 1, Markham switched to poly-aluminum chloride (PAC), with a 13 t application in 2021 and 9.4 t application in 2024 (~$150,000 per application). While effective in the short-term, this approach treats symptoms rather than sources. External nutrient reduction has focused on Canada goose hazing and shoreline fencing to limit fecal loading (Parhizgari 2025; FOSLP 2025a). The underlying aquifer appears to facilitate limited flushing of nutrient-rich water, gradually improving chemistry.

Continuous dissolved oxygen (DO) monitoring began at the dock in 2023 (Parhizgari 2024). Daytime DO measurements in 2024 showed improvements, with biweekly monitoring at the bridge and dock (see Figure 1) showing surface and 1 m above the bottom near or above 6.0 mg/L (Parhizgari 2025). However, bottom-water anoxia (0 mg/L DO) continues to persist during the summer (Parhizgari 2025).

Frequent phytoplankton (i.e., algae in the water column) blooms contribute to anoxia as decomposing organic material consumes dissolved oxygen. To address elevated phytoplankton, a Water IQ Pulsar 4400+ ultrasonic unit was installed in 2024 (FOSLP 2025a). Secchi depth analysis (measure of phytoplankton-induced turbidity) showed that in 2024, Swan Lake was generally at or below the interim depth target of 0.6-0.8 m (Parhizgari 2025). However, concerns persist that the phytoplankton concentrations remain elevated, demonstrated by the fact that elevated lake turbidity likely contributed to the failed submerged aquatic macrophyte plantings (FOSLP 2025a) and chlorophyll-a (proxy for phytoplankton concentrations in water) at a depth of 1 m averaged 16 µg/L throughout 2024, indicating a eutrophic state (Parhizgari 2025).

Markham and FOSLP have diverging opinions on how to interpret the water quality results of Phase 1:

City of Markham / AECOM Position

- View surface-oxygen improvement and nutrient reduction as successes; believe nutrient control alone will maintain DO.

FOSLP Position

- Argues improvements are temporary; Swan Lake's artificial structure requires active oxygenation or circulation.
- Proposed calcium-peroxide dosing and mechanical oxygenation pilots (i.e., Fleming College 2022; University of Toronto 2023) were rejected for "unproven" or "sediment-disturbance" concerns (FOSLP 2025a).
- Maintains that controlled oxygenation could stabilize redox conditions and reduce internal P release.

In the following sections, we discuss the ecological consideration for aquatic life that could inform possible actions taken over the course of Phase 2.

4.0 Turbidity and Dissolved Oxygen

4.1 Artificial Aeration

FOSLP commissioned Natural Resource Solutions Inc. (Anderson and Baldwin 2025a) to review current oxygenation management strategies for Swan Lake. The resulting recommendations are summarized in Table 3. Overall, the report concludes that as Swan Lake recovers, its biological oxygen demand (BOD) will likely increase as aerobic organisms (e.g., bacteria, fish, and benthic invertebrates) become more active and abundant. Consequently, any aeration system must be capable of supporting both current and future BOD as the ecosystem responds to rehabilitation efforts. The report determined that diffused aeration and fountain aeration are the most suitable methods for improving oxygenation and circulation within the lake.

As detailed in the report (see reference within Anderson and Baldwin 2025a), improving DO levels may not only address the anoxia observed in the deeper portions of the lake (creating conditions that allow more characteristic aquatic life to thrive) but also help reduce the high levels of turbidity currently observed. In the presence of oxygen, phosphorus in the water binds to iron and clay particles and settles to the lake bottom, reducing its availability to phytoplankton in the water column and thereby limiting phytoplankton growth. Overtime, less phytoplankton in the water column should result in clearer water.

Table 3: Summary of Aeration Recommendations for Swan Lake from Anderson and Baldwin (2025a)

Method	Mechanism of Action	Advantages	Limitations	Feasibility for Swan Lake
Diffused Aeration	Agitates or circulates water at the surface to enhance gas exchange and disrupt localized stagnation. Releases compressed air through submerged diffusers to promote vertical mixing and oxygen transfer.	Immediate DO improvement; simple installation; visible circulation. Gentle, uniform oxygenation; low disturbance; energy-efficient; adaptable to seasonal use.	Limited spatial reach; energy-intensive; risk of sediment resuspension. Requires careful diffuser placement; effectiveness reduced in very shallow areas.	Highly suitable; offers broad coverage and sustained oxygenation when operated continuously.
Fountain Aeriation	Pumping water through surface-level diffusers into the air to promote gas exchange and surface agitation.	Uniform oxygenation; low disturbance; simple installation.	Limited spatial reach; requires careful fountain placement; non-functional during winter months.	Highly suitable; simple installation; offers sustained oxygenation when operated continuously.
Chemical Oxygenation	Introduces oxygen-releasing or oxidizing compounds that supply elemental oxygen or modify sediment redox conditions.	Direct oxygen delivery; long-lasting effect; no mechanical disturbance.	Requires precise dosing; limited circulation benefit; may provide only temporary improvement.	Moderate feasibility; useful as supplemental treatment for localized low-oxygen zones.
Destratification / Mixing	Induces circulation to break down stratification and promote natural oxygenation through gas exchange.	Reduces stagnation; minimizes hypoxic zone formation; enhances natural mixing.	Limited DO increase; potential warming; continuous operation required.	Partially feasible; could aid circulation but unlikely to raise overall DO significantly.

Despite the promise of mechanical aeration, recent studies suggest that such actions are not a "silver bullet." Artificial aeration in shallow, temperate lakes often have only modest effects in preventing further phosphorus release (May et al. 2020) and can be ineffective in systems with large surface areas (Kibuye et al. 2021), such as Swan Lake.

High internal phosphorus loading is a persistent challenge in shallow lake recovery (Søndergaard et al. 2003; May et al. 2020; Kibuye et al. 2021). While creating oxygenated conditions typically suppresses phosphorus availability, shallow lakes function differently than deeper systems because the distance between the sediment surface (where phosphorus is stored) and the photic zone (where phytoplankton grow) is short (Søndergaard et al. 2003). As a result, it takes little energy for nutrients to become resuspended. Wind events or the decomposition of settled organic material can quickly reintroduce phosphorus into the water column, where it becomes available for phytoplankton growth (Søndergaard et al. 2003). Therefore, mechanical aeration, if it is pursued, may not be an effective means of reducing phosphorus in Swan Lake.

4.2 Evaluation of Proposed Bioswale

In the case of Swan Lake, internal loading appears to be a more significant concern than external loading (FOSLP 2025a). With assistance from Fleming College (Siembida-Lösch 2021), FOSLP (2023) proposed investigating bioswale options, particularly within the 100 m North Channel and the Turtle Inlet (Figure 2), as a means of reducing internal nutrient loads has been investigated. Siembida-Lösch (2021) provides an extensive review of bioswale effectiveness, and a more recent study emphasizes that design should prioritize nutrient removal efficiency (Ali and Pickering 2022).

Figure 2: Proposed Route for Bioswales. Image from FOSLP (2023). Image Quality improved through GPT-5 (OpenAI 2025a)

Design outlines provided by Siembida-Lösch (2021) and FOSLP (2023) emphasize the importance of achieving a hydraulic detention time (HDT) of < 30 days to control phytoplankton growth. To meet this target for Swan Lake (80,000-102,000 m³), Siembida-Lösch (2021) recommended recirculating approximately 3,400 m³ per day. However, lower rates proposed by FOSLP (2023) could provide lower-cost alternatives while still achieving desirable outcomes, with up to 27% of the lake volume recycled (Table 4). Smaller pumps could be powered by existing on-site renewable electricity or by restoring the wind turbines currently present on-site.

Table 4: Lake Turnover (80,000 m³) from April-October (214 days). Adapted from FOSLP (2023)

Pump Size	Capacity (m³/24h)	% of Lake Volume per Day	% of Lake Volume (50% Operation)
1 HP	50	13%	7%
2 HP	200	54%	27%

It should be noted that properly designed bioswales can effectively remove particulate phosphorus but may struggle to remove dissolved phosphorus from the water column (Ali and Pickering 2022). Fortunately, dissolved phosphorus concentrations in Swan Lake appear to be very low as of 2025 (Table 2). The addition of biochar, recommended by York University as a means of aiding nutrient and chloride filtration (FOSLP 2025a); however, recent studies have demonstrated variable effectiveness at removing nutrients (Ali and Pickering 2022).

The underused North Channel, which is currently dry, may represent the most suitable location for an initial bioswale pilot, as it would minimize disturbance to the Turtle Inlet habitat. In addition, because the North Channel contains remnants of the former landfill (Photo 1), selecting this site could also present an opportunity to beautify and ecologically restore this area within the existing channel.

Photo 1: North Channel Dry at Time of Inspection, Containing Remnants of Landfill Waste. Represents a Beautification and Bioswale Opportunity

Even if a bioswale is constructed, ensuring a reduction (or current levels) of nutrient inputs will help. Migratory geese are identified as the largest contributors to external nutrient inputs into the lake (FOSLP 2025a). Geese hazing has proven effective and may be the only feasible action to deter migratory geese in an urban environment, as shoreline plantings (i.e., replacing manicured lawns with forests) are mainly targeted for residential geese (Parhizgari 2025).

Photo 2: Splitter Outlets of the East (A) and North (B) SWM Pond

A

B

In addition, or alternatively, the creation of smaller bioswale-like structures at the outlets / splitters of the two SWM ponds (North Pond #104 and East Pond #105) and/or Oil Grit Separators (OGS) that flow into Swan Lake may provide opportunities to address point-source pollutants. Observations during October 15, 2025, showed that many of these stormwater outlets had minimal vegetation that could help to absorb pollutants (Photo 2). The stormwater inputs are not significant sources of nutrients into Swan Lake; however, interventions at these locations could help reduce chloride inputs.

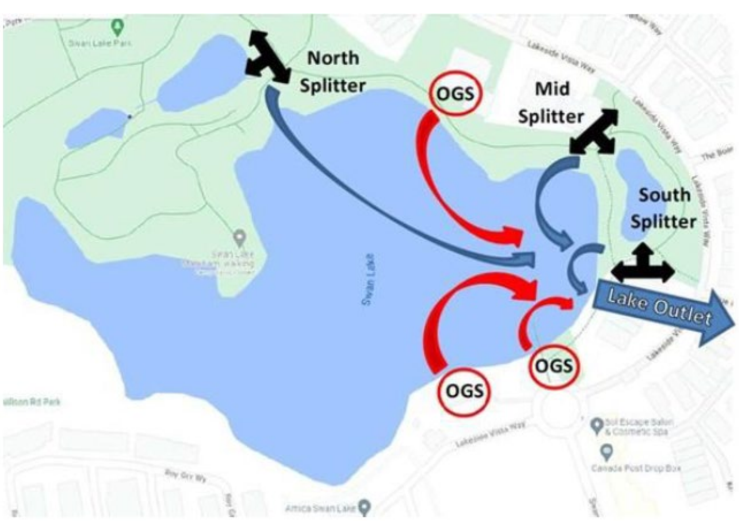
Recent studies in the Toronto area have demonstrated that select native halophytes (i.e., salt-tolerant plants) can absorb chloride runoffs from roads in urbanized ditch ways (Narwroth et al. 2025). Cordgrass (*Sporobolus michauxianus*) native to Ontario was demonstrated at removing approximately 22,000 mg/m^2 of chloride over a growing season (Narwroth et al. 2025) and may present the best-suited plant for Swan Lake. These small bioswales would be complementary to other efforts to reduce chloride concentration as they could only reduce input into Swan Lake. Biological / ecological issues surrounding chlorides are discussed in the following section.

5.0 Chloride

Chloride levels have significantly improved over Phase 1, declining from over 700 mg/L in 2020 to approximately 200 mg/L (range 180 – 270 mg/L) by 2024; a reduction of more than 70 % (Parhizgari 2025). No active measures were taken to achieve this reduction in chlorides, which is likely a result from clearing blockages at the east SWM Pond (#105) that had increased flow bypassing the pond and exchange with the underlying aquifer, combined with minimal surface outflow during the summers of 2022-2023 (FOSLP 2025a).

Three OGS units have been identified as point-source contributors responsible for roughly 56% of chloride inputs (Figure 3), as they discharge directly into the lake rather than first passing through SWM ponds (FOSLP 2025a). Debate remains whether to eliminate these discharges entirely by rerouting the stormwater.

Figure 3: Location of Three Oil Grit Separators (Red Circles) Responsible for 56% of Chloride Inputs. From FOSLP (2023)



Continuing to use Swan Lake as an ad hoc SWM pond will likely impair improvements of its water quality (see Anderson and Baldwin 2025b). The feasibility of rerouting the stormwater outlets and OGSs has been studied in a recent AECOM report (see Xu 2025). Rerouting all OGS flow and 65% of the SWM pond by-pass could reduce chloride inputs by 85% (Xu 2025). However, building on the AECOM report, FOSLP notes that alterations to the flow splitters could reduce chloride inputs by 30% ($124,767).

At the current chloride concentration (~200 mg/L), further ecological improvement is unlikely. Persistent chloride enrichment may be sustaining high phytoplankton levels by suppressing zooplankton grazers that normally control phytoplankton (Hintz et al. 2022). The following section examines this theory and related aquatic ecosystem issues.

6.0 Zooplankton and Macroinvertebrates

Often overlooked in favor of more charismatic species such as sport fishes (e.g., bass and sunfish), zooplankton, macroinvertebrates (e.g., aquatic insects, worms, and crustaceans visible with naked eye), and freshwater mussels form the base of the freshwater food web (Hintz et al. 2022), supporting fish, amphibians, and birds. Ontario has few native obligate herbivorous or planktivorous fish; thus, zooplankton, macroinvertebrates, and mussels act as the principal phytoplankton / algae grazers in these systems (Newman 1991; Sarnelle 1993). Consequently, maintaining healthy communities of these taxa may be critical for phytoplankton control.

6.1 Zooplankton (*Daphnia* spp.)

Zooplankton are more sensitive to chloride than fish (CCME 2011; Hintz et al. 2022). The current chloride concentration (~200 mg/L) is below levels harmful to most fishes but falls within, or slightly above, the chronic exposure range for key grazers such as water fleas in the *Daphnia* genus, reducing phytoplankton/algal grazing capacity (CCME 2011; Hintz et al. 2022). Even at the 120 mg/L federal target, some *Daphnia* spp. populations show reduced survival and reproduction (Hintz et al. 2022; Woodley et al. 2023).

Zooplankton, especially *Daphnia* spp., are the dominant grazers of phytoplankton in temperate freshwater lakes (Sarnelle 1993). They can help regulate cyanobacteria through grazing but do not provide a reliable or sustained means of cyanobacteria bloom elimination (May et al. 2020; Kibuye et al. 2021). Thus, *Daphnia* spp. may be uniquely suited to aid in the recovery of Swan Lake directly in a way no fish species likely could. FOSLP (2025b) has already noted the possibility of chloride-driven suppression of zooplankton, though no formal studies of Swan Lake have been completed to confirm this pattern.

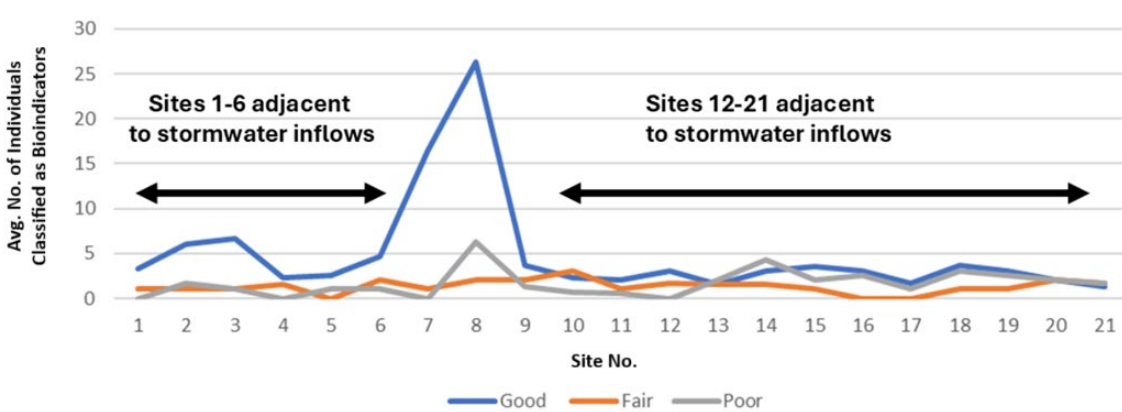
Daphnia spp. stocking has been demonstrated as an effective strategy in other eutrophic temperate lakes when implemented in tandem with the introduction of piscivorous fish (see Section 7; Ha et al. 2012). However, other studies have shown that natural recovery of zooplankton communities can occur when environmental conditions improve (Albright et al. 2004; May et al. 2020; Kibuye et al. 2021). Since there is no current data available on the existing zooplankton community composition (i.e., whether it is dominated by inefficient grazers such as rotifers or includes effective grazers such as *Daphnia* spp.), *Daphnia* spp. stocking is not recommended at this time.

Instead, assessing the present zooplankton community is advised to determine whether the working hypothesis (i.e., low *Daphnia* spp. abundance may be contributing to elevated phytoplankton biomass) holds true. Albright et al. (2004) provide a template for an annual summer collection to determine whether the community is currently dominated by smaller-bodied, poor-grazing zooplankton (e.g., Rotifera) and whether there are any observed changes in larger-bodied grazers such as *Daphnia* spp. Such a program could be implemented over the course of Phase 2 if the initial survey suggests low abundances of key grazers.

6.2 Macroinvertebrates

Macroinvertebrates, while important benthic phytoplankton/algal grazers (Newman 1991), are strongly influenced by eutrophication but do not directly mitigate it (May et al. 2020). Many macroinvertebrates are more resilient than zooplankton and are unlikely to be severely affected by current chloride levels (CCME 2011). Instead, in a system such as Swan Lake, the macroinvertebrate composition reflects improvements in oxygen, sediment quality, and habitat during recovery (May et al. 2020). Although FOSLP requested a macroinvertebrate study, the City of Markham declined (FOSLP 2025a). In 2023, FOSLP independently commissioned Mr. Chris Reeves to conduct a macroinvertebrate survey (FOSLP 2025b). The results indicated that Swan Lake supports a fair-to-intermediate water quality community, with reduced diversity near stormwater inflows (Figure 4), suggesting that poor water quality continues to shape community structure (FOSLP 2025b).

Figure 4: Summary of Swan Lake Macroinvertebrate Survey (2023). Image Modified from FOSLP (2025b)



6.3 Freshwater Mussels

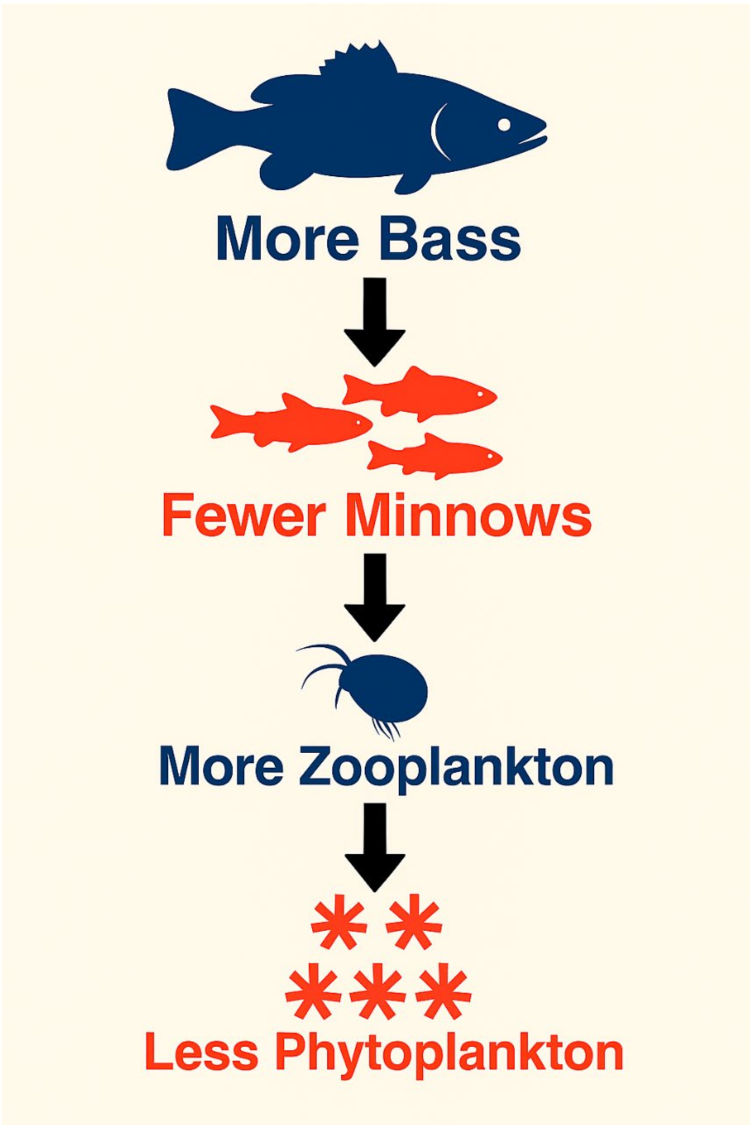
The use of freshwater mussels to control phytoplankton may be limited in Swan Lake. Although mussels have been shown to reduce phytoplankton / algal biomass, most demonstrations have involved the invasive Zebra Mussel (*Dreissena polymorpha*), making such applications undesirable (Geletu 2023). Native Unionidae mussels in Ontario have limited tolerance to polluted waters and possess complex reproductive strategies that require specific host fish (Metcalfe-Smith et al. 1998). As a result, they are generally poor colonizers of new habitats. Many species are also restricted by chloride sensitivity during their larval (glochidia) stage, with reductions to survival (EC_{10}) ranging from 24 to 789 mg/L, while adults may tolerate chloride concentrations near 200 mg/L (CCME 2011). While native floater mussels (subfamily Anodontinae) tend to be more pollution-tolerant, the Paper Pondshell (*Utterbackia imbecillis*) may represent a potential candidate species, as it is more tolerant of degraded water quality, inhabits shallow ponds, and uses readily available host fish such as Largemouth Bass (*Micropterus salmoides*) and sunfishes (*Lepomis* spp.) (Keller and Ruessler 1997; Metcalfe-Smith et al. 1998).

7.0 Fish Community

7.1 Control of Minnows via Biomanipulation

In Swan Lake, high populations of species such as Fathead Minnow (*Pimephales promelas*) may contribute to reduced zooplankton abundance and weakened phytoplankton control within the water column, consistent with a trophic cascade dynamic (Power 1992). In addition, in shallow lakes such as Swan Lake, zooplankton are more exposed to predation and thus exert weaker grazing pressure on phytoplankton than deeper systems that provide refuge zones (May et al. 2020). Adequate macrophyte coverage can offer such refuge and restore balance (Kibuye et al. 2021). Currently, submerged aquatic vegetation is observed in Swan Lake, this some physical coverage is offered.

Figure 5: Proposed Biomanipulation to Achieve a Top-Down Trophic Cascade in Swan Lake. Created with assistance from GPT-5 (OpenAI 2025b)



Introducing or enhancing piscivore populations such as Largemouth Bass, could help to improve water quality through biomanipulation via top-down trophic control (Carpenter et al. 1987; May et al. 2020; see Figure 5). A classic example of such biomanipulation is described by Albright et al. (2004), who studied a small, shallow eutrophic pond (15.6 ha, mean depth 1.8 m) in upstate New York that, prior to intervention, contained only minnows (e.g., Golden Shiner, *Notemigonus crysoleucas*) and Brown Bullhead (*Ameiurus nebulosus*). The lake exhibited high phytoplankton biomass, elevated turbidity, and a zooplankton community of low diversity, dominated by rotifers and few *Daphnia* spp. In 1999, Largemouth Bass and Smallmouth Bass (*Micropterus dolomieu*) were introduced, and by 2002 water quality visibly improved as minnow populations declined and *Daphnia* spp. increased in abundance and diversity. However, controlling planktivorous fish populations does not always yield such clear results; some studies report that biomanipulation has little or no measurable effect on zooplankton communities (Setubal and Riccardi 2020).

Largemouth Bass are currently stocked into the lake as of 2025 (FOSLP 2025a). Bass were also stocked 1992, but fish surveys conducted by the Toronto Region Conservation Authority (TRCA) do not seem to list Largemouth Bass among species capture (Table 5).

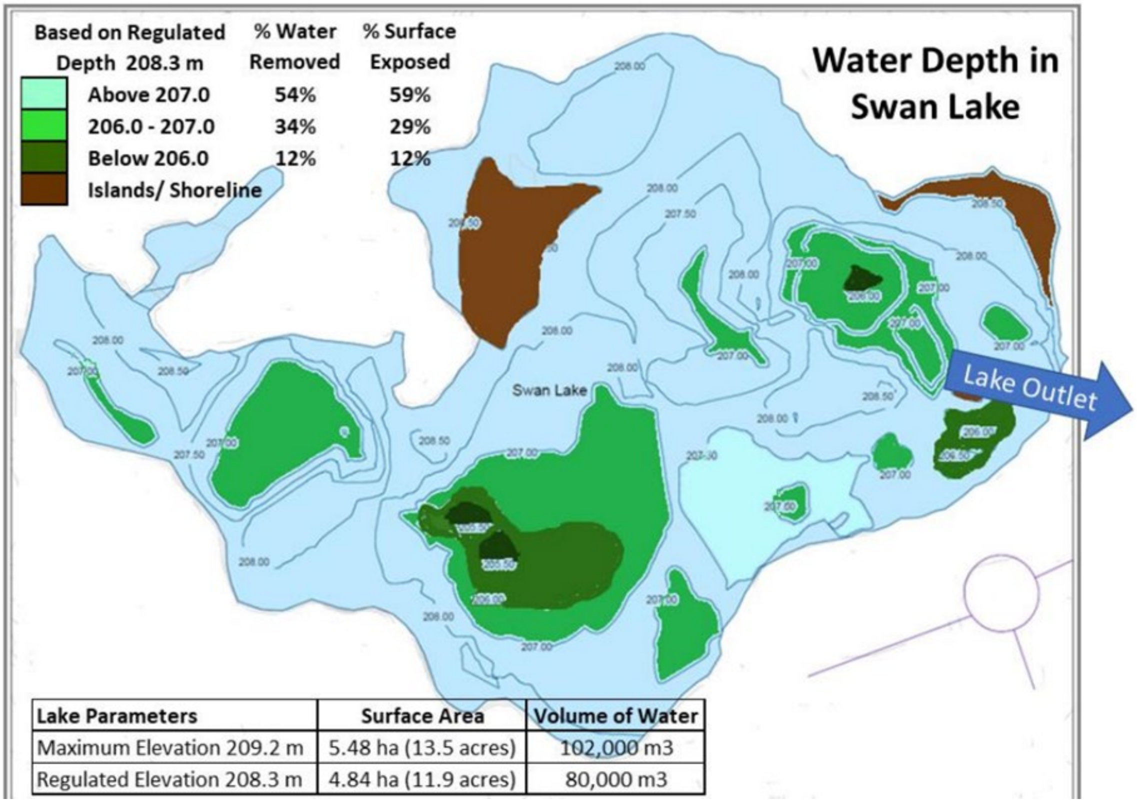
Table 5: TRCA Swan Lake Fish Surveys During Phase 1. Bottom Feeding Fish (Catfish, Common Carp, and Goldfish) Were Euthanized. All Other Species Returned Alive to the Lake (FOSLP 2025b)

Date	Fish Species	Number of Fish
April 2021 (three days electrofishing + two days nets)	Brown Bullhead	210
	Common Carp	7
	Fathead Minnow	>10,000
April 2022 (one day electrofishing + one day nets)	Brown Bullhead	80
	Common Carp	20
	Fathead Minnow	875
April 2023 (one day electrofishing)	Brown Bullhead	84
	Common Carp	103
	Fathead Minnow	14
	Goldfish	2
April 2024 (one day electrofishing + one day nets)	Brown Bullhead	193
	Common Carp	1
	Fathead Minnow	1,521
	Goldfish	13
	Common Carp X Goldfish	59
	Emeral Shiner	1

7.2 Limitations to Largemouth Bass Survival in Swan Lake

The shallow morphometry of Swan Lake, with its broad surface area and limited depth, may constrain the successful establishment of Largemouth Bass. Although Largemouth Bass occupy a wide range of depths, from very shallow (<1 m) to deeper water (~12 m) (Peat et al. 2016), they typically prefer depths of 2-3 m., especially in winter (Bunt et al. 2021). Such depths are scarce in Swan Lake, where nearly 60% of the basin is less than 1 m deep (Figure 6). Shallow lakes are especially vulnerable to meteorological variability and experience rapid temperature fluctuations in response to changes in air temperature (Piccioni et al. 2021), creating thermal instability that challenges overwintering bass. Feeding activity ceases below 6°C, making Largemouth Bass sensitive to prolonged cold periods (Fullerton et al. 2000; Bunt et al. 2021). DO is another critical factor for overwinter survival, ideally remaining within the 2-6 mg/L range (Hasler et al. 2009). Current DO measurements are limited to nearshore summer readings, but values at ~2 m depth suggest potential for winter anoxia.

Figure 6: Bathymetric Map of Swan Lake. Provided by FOSLP



Bass stocking efforts should prioritize introducing larger individuals (>100 mm total length) to improve survival and establishment (Fullerton et al. 2000; Post et al. 1998). Bass strongly prefer in-water structure provided by macrophyte beds and coarse woody material (Bunt et al. 2021). Field observations indicate that Swan Lake's littoral zone is dominated by the macroalgae *Chara* spp., but was otherwise featureless (e.g., lack of large rock or woody structure, nearly uniform depth). Installing coarse woody material (e.g., upright stumps with root mass, properly elevated logs and branches) could provide immediate cover and overwintering refuge habitat, that can be locally sourced until native vegetation recovers (Czarnecka 2016). TRCA has proposed shoreline restoration efforts that include addition of woody material and rock complexes in the littoral zone (TRCA 2022). Thus, such efforts have already been under consideration in the case of Swan Lake. Consideration of placing deeper water structures (stumps and log cover) is also required to provide refuge from predatory birds and human anglers.

Deepening portions of Swan Lake could create refuge pools suitable for overwintering Largemouth Bass, although suitable water quality needs to be confirmed during all seasons. Such modifications may also align with community goals to enhance recreational opportunities around the lake. Alternatively, modestly increasing the lake's regulated water level could expand available overwintering habitat and would be less expensive than dredging. Currently, approximately 12% of Swan Lake offers adequate depth for overwintering, assuming the lake does not become anoxic.

Future aquatic surveys will confirm whether Largemouth Bass can successfully overwinter under current lake conditions and help determine if habitat enhancements are warranted. Spring surveys around Swan Lake may provide opportunities to note if dead fish are observable along the shoreline. If live Largemouth Bass are captured in the summer 2026 surveys, then continued stocking of larger individuals (>100 mm) is recommended, along with the placement of woody material complexes (stumps with root masses and elevated log structures) to provide habitat until macrophyte recovery occurs. Re-evaluation of the need for more extensive interventions (e.g., dredging) should be deferred until bass survival is confirmed, as the current stocking provides an opportunity to assess the effectiveness of existing conditions before pursuing additional modifications.

7.3 Other Fish as a Means of Biomanipulation

As previously noted, there are few planktivorous fish that could be introduced to control phytoplankton growth suitable to Ontario, with the most common species being the highly invasive Bighead Carp (*Hypophthalmichthys nobilis*) and Silver Carp (*Hypophthalmichthys molitrix*), which are undesirable species in most circumstances (Geletu 2023). One of the few native planktivorous fish in Ontario is the Gizzard Shad (*Dorosoma cepedianum*), but its effectiveness in controlling phytoplankton remains unclear. Although Gizzard Shad feed on phytoplankton, their high waste excretion rates rapidly recycle nutrients back into the water column, often stimulating rather than reducing algal growth (Schaus et al. 2010). In fact, removal of Gizzard Shad has been demonstrated as an effective means to reduce phytoplankton levels (Godwin et al. 2011).

Bluegill (*Lepomis macrochirus*) were also considered for stocking in Swan Lake by TRCA (Parhizgari 2025); however, smaller sunfishes such as Bluegill may not be desirable for improving the water quality of Swan Lake. Sunfishes are important zooplankton feeders in North American lakes and may therefore contribute to increased phytoplankton biomass by preferentially consuming *Daphnia* spp. or other zooplankton such as rotifers (Noda and Maruyama 2013; Bernes et al. 2015). Accordingly, the addition of sunfish species is not recommended at this stage, as it may exacerbate the elevated phytoplankton levels currently observed in Swan Lake.

8.0 Aquatic Vegetation

Macrophytes are effective at stabilizing sediments, improving water clarity, and reducing nutrient concentrations (Kibuye et al. 2021). However, the current turbid conditions in Swan Lake are likely to prevent their establishment, limiting these benefits. Previous macrophyte plantings have failed under the lake's turbid, nutrient-rich, and high-chloride conditions. Plantings of Wild Celery (*Vallisneria americana*) in 2023 and 2024 experienced >90% mortality, primarily due to light limitation and turbidity (Parhizgari 2025). However, *Chara* spp., a macroalgae, is present throughout Swan Lake as of 2025; thus, turbidity has reduced enough to allow fast growing macroalgae to establish. Considering the limited success of past plantings and supporting literature, further submerged macrophyte restoration efforts are not recommended until sustained periods of water clarity can be demonstrated.

Submerged macrophytes, not rigid emergent species such as reeds or cattails, provide superior habitat complexity for Largemouth Bass and other fish, supporting higher growth and recruitment at moderate coverage (~60 %) (Stahr and Shoup 2015; Nohner et al. 2018). Future planting should therefore focus on submerged and floating-leaved species, rather than emergent vegetation, to maximize habitat value and promote long-term ecological balance (Table 6). In fact, macrophyte recovery in similarly sized eutrophic lakes has been linked to the introduction of piscivorous fish (Albright et al. 2004). Thus, these efforts are likely to synergize.

While macrophyte beds can reduce nutrient concentrations (particularly phosphorus) by absorbing nutrients, stabilizing sediments, and increasing oxygen near the substrate, they can also, under certain conditions, contribute to internal phosphorus loading. Dense vegetation may create localized anoxia and elevated pH, both of which can enhance phosphorus release from sediments (Søndergaard et al. 2003). This potential effect should be monitored as vegetation is re-established.

Table 6: Macrophyte Types Observed and Recommended Plantings in Swan Lake 1993 and 2024. Adapted from FOSLP (2025b)

Open Waters: 0.5 m to 1.5 m Deep		**Identified in 1993**	**Identified in 2024**	**Recommended**
Pond Lily	*Nuphar variegata*			Yes
Water Lily	*Nymphaea odorata*			Yes
Pondweed	*Potamogeton richardsonii*			Yes
Pondweed	*Potamogeton pectinatus*			Yes

Lake Margins and Water to 0.75 m Deep		**Identified in 1993**	**Identified in 2024**	**Recommended**
Bur-reed	*Sparganium eurycarpum*			
Sweet Flag	*Acorus calamus*			
Soft-stem Bulrush	*Schoenoplectus tabernaemontani (*formerly *Scirpus validus)*			

Shores and Waters to 0.5 m Deep		**Identified in 1993**	**Identified in 2024**	**Recommended**
Narrow-leaved Cattail	*Typha angustifolia*	X	X	
Wide-leaved Cattail	*Typha latifolia*		X	
Giant Reed	*Phragmites australis*	X	X	
River Bulrush	*Bolboschoenus fluviatilis* (formerly *Scirpus fluviatillis*)			
Wild Celery[1]	*Vallisneria americana*		X	Yes

Shores and Waters to 0.25 m Deep		**Identified in 1993**	**Identified in 2024**	**Recommended**
Blue Flag	*Iris versicolor*			
Pickerelweed	*Pontederia cordata*			
Arrowhead	*Sagittaria latifolia*			Yes
Water Plantain	*Alisma plantago-aquatica*			
Cordgrass[2]	*Sporobolus michauxianus*			Yes

[1]Not included in original 1993 recommendations. Planted in 2023

[2]Added after Burnside's review of Nawroth et al. 2025

9.0 Recommendations

Burnside recommends the following for consideration to support aquatic life as Phase 2 rehabilitation begins.

Table 7: Summary of Recommendations to Improve Biological / Ecological Conditions During Phase 2

Biotic Group	Mechanism of Action	Effectiveness in Eutrophic Systems	Burnside Recommendations
Native Fish	Biomanipulation via top-down control	Moderate – High minnow population may be suppressing desirable zooplankton.	Largemouth Bass stocking (>100 mm) may help reduce minnows if overwintering can be demonstrated. Determine whether Largemouth Bass stocked in 2025 survive until 2026 through spring (brief walk around) and summer (fish capture) surveys.
Native Mussels	Nutrient sequestration	Low – many native mussels sensitive to poor water quality.	Paper Pondshell may provide some filtration, but unlikely to contribute significantly.
Zooplankton (esp. Daphnia spp.)	Grazing on phytoplankton	Moderate to high – if predation and chlorides are controlled.	Analysis of zooplankton community recommended before considering stocking. Initial survey could serve as baseline to monitor changes cover Phase 2 activities.
Macrophytes	Nutrient sequestration, habitat	High local effect; supports DO and stability.	Further plantings not recommended until sustained periods of water clarity can be demonstrated.
Habitat Complexity	Increase habitat complexity	High – Placement of woody material (stumps with root mass and elevated logs) or boulder complexes may enhance available habitat for Largemouth Bass.	Swan Lake currently offers limited structural habitat. Establishment of a bass population may be aided by increasing habitat complexity through addition of woody debris complexes. Deepening not recommended – evaluate after spring / summer 2026 fish surveys to determine bass survivability.

Additional comments are provided below.

Nutrient Management

- Construction of bioswale presents opportunity to further reduce internal nutrient levels
- Enhance the existing bioswale to provide opportunities to beautify section of Swan Lake

Chloride Reduction

- Maintain focus on source control (grit-separator rerouting, winter salt management, etc.)
- Target ≤120 mg/L Cl^- to aid restore zooplankton communities
- Reducing chloride inputs into Swan Lake is likely to improve biological / ecological conditions
- Creation of small bioswale-like structures at the outlets of SWM pond splitters or OGSs may provide opportunity to mitigate chloride inputs provided with the proper halophyte plantings (i.e., Cordgrass (*S. michauxianus*))
- Rerouting the stormwater outlets and OGSs present a hard-engineering option to chloride reduction

10.0 Conclusion

Success of Swan Lake's aquatic communities depends on improving water quality before attempting further biological restoration. Phase 1 has resulted in improved water quality from 2020; however, problems persist especially with elevated chlorides and internal nutrient load.

Further recovery may require

1. Nutrient stabilization via bioswale

2. Chloride control by some means of reduction

3. Improvement to *Daphnia* spp. populations through reductions in chloride concentrations and selective predator stocking

Chloride-induced suppression of *Daphnia* spp. populations is likely exacerbating Swan Lake's phytoplankton blooms. Increasing *Daphnia* spp. abundance can yield short-term improvements (< two years) in water clarity and phytoplankton control (Kibuye et al. 2021) and should be considered as part of broader lake-management planning. While some mechanism for chloride reduction is recommended, it alone will likely not resolve the issue. Creating or maintaining a population of Largemouth Bass may help to improve the *Daphnia* spp. populations through the reduction of Fathead Minnow. However, the current zooplankton community is unknown.

Improvement to the water quality of shallow, eutrophic lakes, such as the case in Swan Lake, are impeded by its slow recovery, as it is hard for people to maintain interest (May et al. 2020). However, actions for the improvements of Swan Lake are promising, and should encourage managers to maintain support and interest.

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