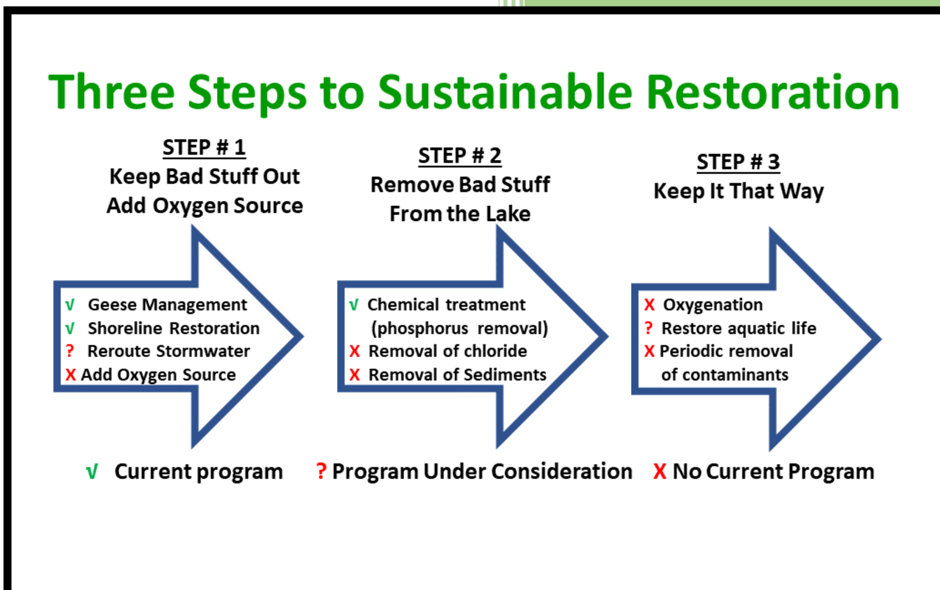
Friends of Swan Lake Park

Towards a Comprehensive Restoration Plan For Swan Lake



May 2023

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EXECUTIVE SUMMARY

Swan Lake Park in Markham is home to a rich diversity of wildlife. But this wildlife is threatened by the deteriorating water conditions in Swan Lake. The Friends of Swan Lake Park are residents of Markham committed to saving Swan Lake and Swan Lake Park through environmental best practices that will restore safe lake water for sustainable human and wildlife activity.

A) Current Long-Term Plan Water Quality Plan

In December 2021, Markham Council approved a Long-term Water Management Plan (the “Plan”) for Swan Lake. Details of the Plan are summarized in Appendix H.

The Plan is based on an evolving “adaptive” management approach and focuses on the reduction of algae through actions such as geese management and periodic chemical treatments to reduce phosphorus which is viewed as the critical nutrient spurring the algal growth. The program is expected to show marginal improvement in water quality but is not expected to attain the more stable and better-quality mesotrophic level the community is encouraging.

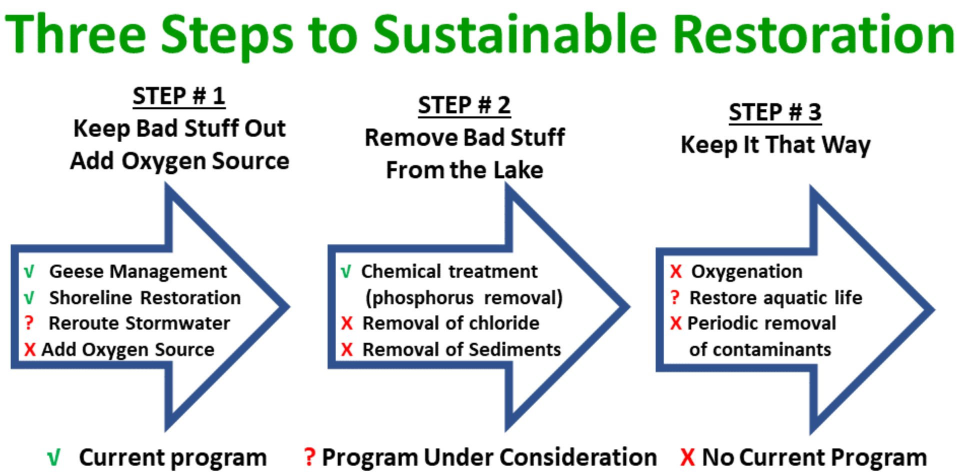
Since the passage of the Plan, additional efforts have been initiated to quantify and identify the sources of the stormwater inflows that are bringing chloride in the form of road salt into Swan Lake. Markham Council has approved a Flow Diversion Study into the feasibility of rerouting stormwater inflows away from the lake. As Markham staff have noted in their 2022 Water Quality report, additional efforts are required to identify approaches for the removal of chloride from Swan Lake.

As a minimum, the Plan needs to be updated to incorporate solutions to the chloride issues and to address the need for oxygenation. Ultimately what is required is a comprehensive plan that addresses all essential factors that influence water quality during the restoration phase leading to an ongoing sustainable cost-effective stewardship plan for water quality management.

B) Three Steps to Sustainable Restoration

There are three fundamental steps to a sustainable restoration plan. The initial challenge is to reduce the nutrients and chloride entering the lake followed by a focus on how to reduce the amounts already built up in the lake which spur the excessive algal growth and undermine the aquatic health of the lake. Once restoration is achieved, the challenge remains to identify a practical way to maintain the improved aquatic environment.

The geese management program is showing initial success in reducing the migratory geese population and thereby reducing the phosphorus and nitrogen entering the lake while the shoreline restoration project is expected to reduce the attractiveness of the shoreline as a nesting area for resident geese.



Investigation is underway to reduce the amount of road salt entering the lake which is the primary source of chloride. At present there is an estimated 40 tonnes of chloride active in the water. An unknown amount may be stored in the sediments.

The following report focuses primarily on identifying approaches for removing the build-up of chloride in the lake and explores the feasibility of removing the sediments which are a known storehouse of phosphorus and nitrogen and likely chloride.

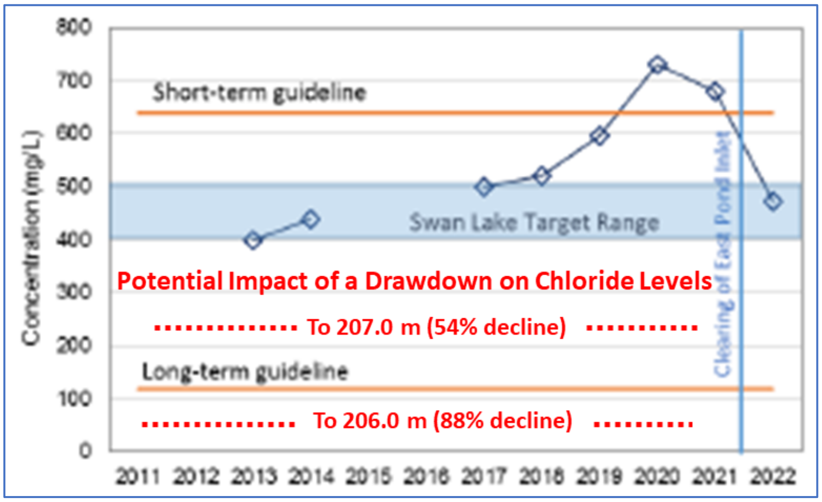
C) Low-cost, Winter Drawdown

Various techniques including use of desalination equipment and industrial filtration processes can provide very effective means for the removal of phosphorus, nitrogen and chloride but they are quite expensive. The lowest cost option would appear to be to drain water from the lake and let the lake naturally refresh through precipitation and from the aquifer. The lake naturally filled up in the 1970's after quarry operations ceased. Analysis is required to assess how long the refill process would take and whether it would be acceptable to pump water from the aquifer to accelerate the refill process.

A gravity-driven, controlled drawdown process could remove up to 54% of the lake water within 10 days. Additional volumes could be removed with the use of pumps. Undertaken during periods of low or no rain, the stormwater system can easily accommodate the controlled release flows. The maximum flow from the lake is well within the design capacity of the local stormwater system and the downstream system south of 16th Avenue. We recommend that the Flow Diversion Study be expanded to include a review to confirm that a drawdown of the lake is within the system design capabilities.

To minimize the impact on aquatic life, the drawdown should be scheduled in the early winter months.

Current Chloride Levels in Swan Lake



A drawdown to 207.0 m would remove 54% of the chloride laden water bringing the chloride level well below the interim target set out in the long-term management plan. Drawing down the lake to 206.0 m would bring the chloride levels below the Federal government long-term guidelines for aquatic life.

A winter drawdown is a low-cost and impactful means for reducing the chloride content in Swan Lake and warrants serious consideration.

D) Sediment Removal

The analysis by Freshwater Research[5] suggests that the sediments are a storage area for phosphorus and nitrogen. It is likely that some of the chloride in the lake is also absorbed in the sediments. Water treatment processes such as a drawdown remove elements active in the water, but the phosphorus and other elements are subsequently released from the sediments back into the water column. The current chemical program using Phoslock and Poly Aluminum Chloride attempts to neutralize the phosphorus in the sediments but has no impact on nitrogen and chloride.

Removing the sediments may provide a more permanent solution and has the potential to accelerate the restoration process and possibly reduce the cost of future chemical treatments. Removal of the sediments is a costly undertaking; however, it may be practical to remove at least a portion of the sediments and to use low-cost techniques to store some of the sediments onsite along the Swan Lake shoreline.

Further analysis is required to determine the technical feasibility and costs of removing the sediments. The next step is a cost/benefit analysis to see if the additional costs of removing the sediments provide a reduction in other costs such as the chemical program and to assess the likelihood of better outcomes in terms of the water quality and long-term sustainability.

E) Solution Design Workshop

In complex restoration situations such as Swan Lake, a common industry practice is to host a workshop with experts with diverse technical perspectives with the goal of narrowing the path to restoration.

We recommend that Markham host a workshop in early 2024 to outline a path forward for a comprehensive path to restoration. The recommendations of the workshop would provide the framework for the development of an updated comprehensive plan and provide Council and the community with guidance on four critical topics:

1) What level of water quality is achievable and sustainable and at what cost?
2) Is it worth investing to reroute the stormwater?
3) Is a drawdown of the lake beneficial and can it be managed safely?
4) Is it worth investing to remove the sediments?

Two Paths Forward

The recommendations of the workshop should provide the framework for the development of an updated comprehensive plan. Two possible outcomes are expected:

Path #1:
A water-only restoration plan that incorporates the ongoing chemical management program.

Path #2
An alternate plan that addresses the sediments and potentially permits savings by reducing or eliminating the chemical treatment program.

F) Recommendations:

1) **That Markham host a Solution Design Workshop in early 2024 with the goal of providing guidance on the appropriate path forward for an updated long-term water quality plan.**

   In preparation for the workshop, we recommend that the following activities be approved:

   a) Completion of current undertakings in 2023:
      i. Completion of the design phase of the shoreline restoration project.
      ii. Completion of the Flow Diversion Study into the feasibility, costs and timing of rerouting stormwater flows from the lake.
      iii. Expand the scope of the Flow Diversion Study to include a report on the technical feasibility of a drawdown of water from Swan Lake during periods of low or no precipitation.
      iv. AECOM report on the research efforts by Fleming College on use of calcium peroxide to support oxygenation efforts.
      v. An update on the York University research into means of removing nutrients and chloride using biochar.

   b) We recommend support for research in 2023 into the following:
      i. University of Toronto research into whether oxygenation will increase phosphorus release from the sediments during restoration.
      ii. Research into the biological benefits of using a drawdown of the lake as a management tool during the restoration phase and as a future management tool for sustainability.
      iii. Research into the cost/benefits of the removal of sediments as a management tool.
      iv. Research into whether oxygenation processes are helpful or a hindrance during the restoration phase and whether they should be a component of a long-term sustainable plan.

2) **That following the Solution Design Workshop that staff submit a draft Comprehensive Water Quality Plan for a "Peer Review" by the Workshop participants before submission to Council for consideration and approval.**

TOWARDS A COMPREHENSIVE RESTORATION PLAN

I) THE NEED FOR A COMPREHENSIVE PLAN

In December 2021, Mark ham Council approved a Long-term Water Management Plan (the "Plan") for Swan Lake. Details of the Plan are summarized in Appendix H.

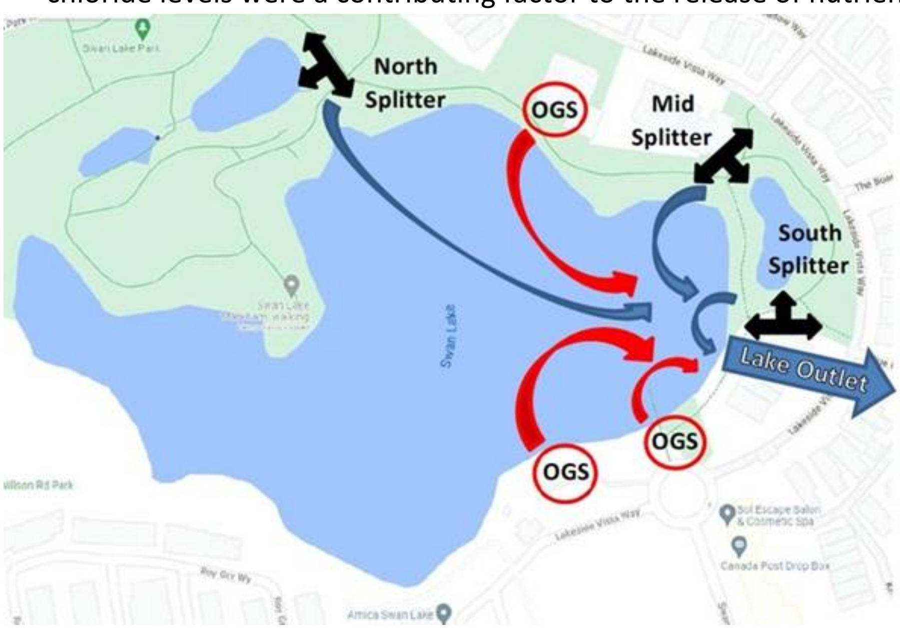
The Plan is based on an evolving "adaptive" management approach and focuses on the reduction of algae through actions to reduce phosphorus as the critical nutrient spurring the algal growth.

As a minimum, the Plan needs to be updated to incorporate solutions to the chloride issues and to address the need for oxygenation. The outcome should be a comprehensive plan that addresses all essential factors that influence water quality during the restoration phase leading to an ongoing sustainable stewardship plan for water quality management.

A) Chloride Issues

Chloride from road salt impacts the restoration in two basic ways:

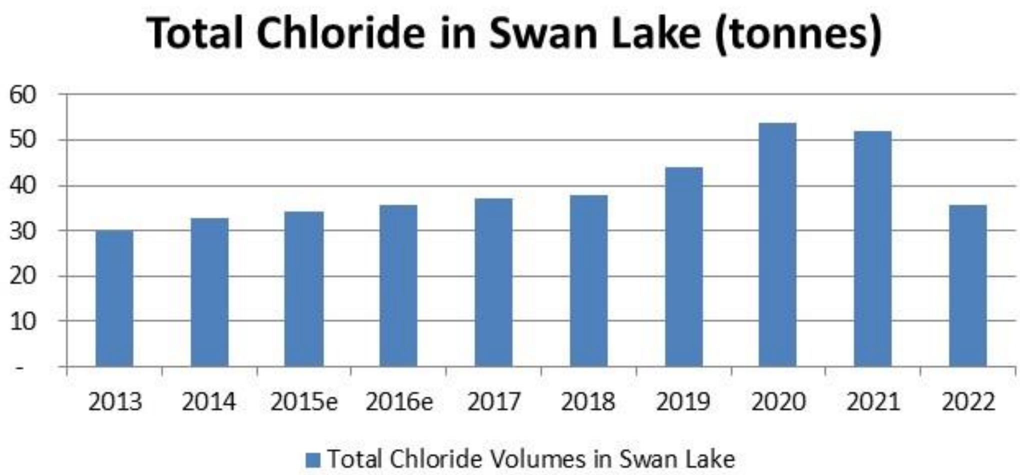
1) Chloride levels in Swan Lake are 4x – 6x the safe level for aquatic life under the federal guidelines, which threatens lower-level aquatic life such as zooplankton and many small fish species that consume algae and are an essential component of a balanced, sustainable solution.
2) Recent research[A3] indicates that high chloride levels can contribute to the release of phosphorus from the sediments. A recent report[A4] on Lake Wilcox in Richmond Hill concluded that while inflows of phosphorus from farmers' fields were reducing, algae continued to grow, suggesting the increasing chloride levels were a contributing factor to the release of nutrients from the sediments.



The Friends of Swan Lake Park's 2022 report, "Action Plan to End Swan Lake's Stormwater Management Role" outlined options for reducing the inflow of stormwater into Swan Lake.

In 2023, Markham staff will undertake a Flow Diversion Study to investigate the feasibility of rerouting stormwater flows away from the lake in an effort to reduce the annual inflow of road salt.

As Markham staff note in their 2022 Water Quality Report, efforts are required to identify approaches for the removal of the 30 – 40 tonnes of chloride already in Swan Lake.



The sharp rise in chloride levels in 2019 - 2021 are attributed to a blocked pipe into the East Pond. The blockage was removed in 2021 reducing the inflow of additional road salt.

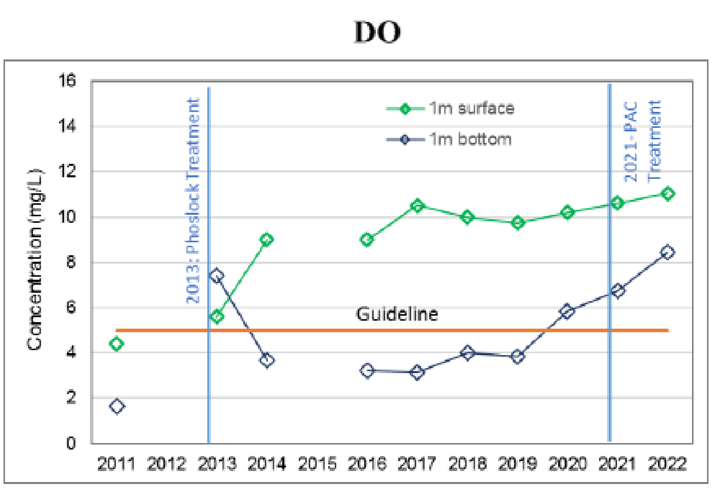
The decline in chloride levels in 2022 is attribute to outflows. The lake level was lower than normal during the summer so little water flowed from the lake into the stormwater system. The decline in chloride may reflect the loss of water through the aquifer and possibly some absorption in the sediments combined with dilution from precipitation.

B) Low Levels of Dissolved Oxygen

Dissolved oxygen (DO) is a measure of how much oxygen is dissolved in the water - the amount of oxygen available to living aquatic organisms. Dissolved oxygen in surface water is used by all forms of aquatic life; therefore, it is measured to assess the "health" of lakes and streams.

Rapidly moving water, such as in a mountain stream or large river, tends to contain a lot of dissolved oxygen, whereas stagnant water bodies such as Swan Lake contain less.

Bacteria in water consumes oxygen when organic matter, such as algae, decays. Thus, the decay of excess organic material in lakes can cause an oxygen-deficient situation that can cause a water body to "die." Aquatic life can have a hard time in stagnant water that has a lot of rotting, organic material in it, especially in summer when dissolved-oxygen levels are at a seasonal low. Water near the surface of the lake is too warm for aquatic life, while water near the bottom has too little oxygen.



Recent data shows some improvement in oxygen levels following the 2021 PAC treatment.

It is expected that the chemical treatments will reduce the algae and therefore less oxygen will be lost each year to the decaying algae. The question becomes whether this is sustainable or only a short-term benefit as observed in 2016-2017 following the Phoslock treatment.

Improving oxygen levels in Swan Lake should reduce phosphorus release from the sediments (internal loading) and reduce the amount and possibly the frequency of chemical treatments required in the future. Concern has been expressed that adding oxygenation processes during the restoration phase may in fact increase the release of phosphorus from the sediments. However, some researchers[A6] question the interaction of oxygen and phosphorus at the surface of the sediments.

A group of researchers from the University of Toronto have proposed testing a new wind-powered oxygenation unit on Swan Lake. The unit was designed to support fish farming in underdeveloped areas in the world. They have recently completed some tests on the effectiveness of the units in adding oxygen to the water and are interested in determining if the units would be a factor in releasing nutrients from the sediments.

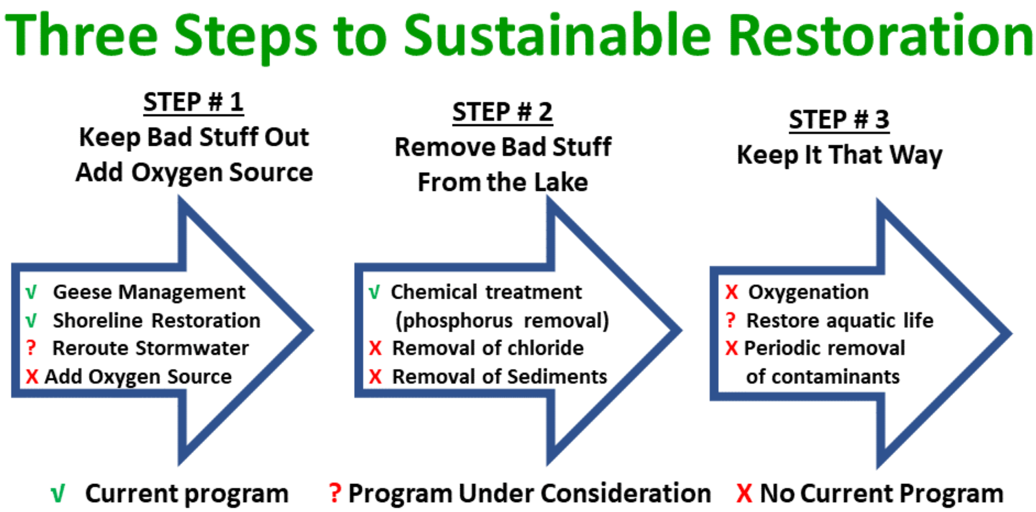
This experiment may shed some light into the complex interaction of the low oxygen levels in Swan Lake and the nutrients in the sediments.

While the chemical treatment may provide some benefit, the chronic issue is that Swan Lake is a stagnant body of water without many natural sources for oxygen. More sustainable options need to be considered. The challenge becomes finding a means to improve oxygenation levels in Swan Lake ideally in a manner that supports the phosphorus management challenges.

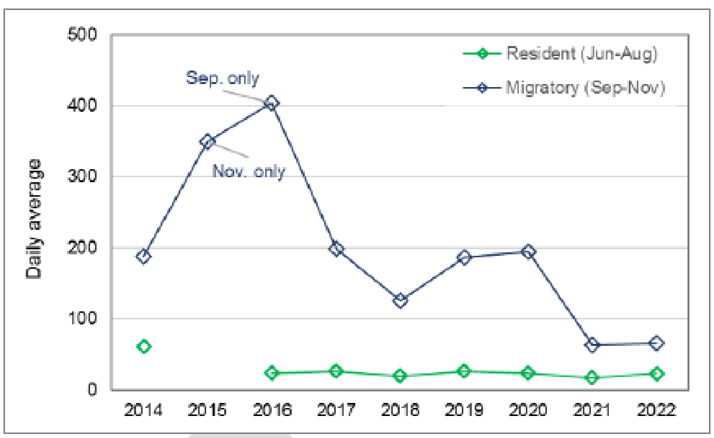
Markham staff reported that the Fleming College research proposal into the potential to use calcium peroxide as a means for enhancing oxygen levels has merit, but the concept is still at an early research stage and does not warrant involvement at this time.

II) THREE STEPS TO RESTORATION

There are three critical steps to a sustainable restoration plan for Swan Lake.



Step #1 – Controlling Inflows, Enhancing Oxygen Sources



Significant progress has been made on the first step of reducing algae by minimizing the nutrients (phosphorus and nitrogen) entering the lake.

The geese management program has been expanded to provide for increased hazing during the fall migration and in 2021 a program was introduced to relocate the geese that are resident during the summer months.

In concert with the geese management program, Markham parks staff are also engaged in redesigning the shoreline. The initial phase involved removing invasive phragmites reeds and redesigning the shoreline to reduce the attractiveness to resident geese.

At this point, there is no specific program targeted to add oxygen to the lake, so more research is required into whether adding oxygen during the restoration phase is helpful or a hindrance to restoration.

One of the primary challenges is to reduce the inflows of road salt from the stormwater system. Markham Council have approved funding for the Flow Diversion Study to determine if the inflows can be reduced. Even though average readings of chloride in Swan Lake have declined to 480 mg/L, the levels are still 4 times the federal guidelines for aquatic life of 120 mg/L. High chloride levels kill the lower-level aquatic life that consume algae, elements that could be contributing to controlling the algae levels. As shown in the following table, the annual inflows from the stormwater system are 20x – 30x the safe level for aquatic life.

Table 4: Chloride Concentrations in Runoff

Date	Inflow to Ponds		Bypass from Pond to Lake	Inflow to Lake from Ponds				Inflows to Lake from OGS	
	East Pond	North Pond	East Pond	East Pond- in pond	From south	North Pond- in pond	Road	Swan Lake Blvd.	AMICA
3/20/2012 *	577	673		572		56			
3/26/2021	957	98.5		343		199			
4/11/2021		79	131		673				
1/13/2022	13200**							3160	
2/15/2022	2340	2120					326	836	360
3/6/2022	380	410		410		180		1200	610
3/16/2022	3700	3100						4800	470
3/24/2022	1200	1100	150					1900	240
4/6/2022	2800		350						1100
Median/average	1029		210	345				1900	470

* Data were used cautiously since the exact location of samples and sampling conditions are not known.
** Standing water, not used in calculations.

Step #2: Removing Nutrients and Chloride from Swan Lake

In addition to the items outlined in Step #1, the current long-term plan consists primarily of a periodic chemical treatment program involving either Phoslock or Poly Aluminum Chloride ("PAC") focused on removing phosphorus from both the water and the sediments. The Plan called for initial treatments in 2021 and 2024 followed by treatments every 3 – 5 years thereafter.

Other than through the geese management program, the Plan does not address nitrogen as a material factor. Recent research studies[A2] recommend that a comprehensive water quality program should incorporate plans for both phosphorus and nitrogen.

The Plan does include initiatives to improve aquatic plant and fish as a component of the long-term restoration efforts. Staff reported that the research by York University professors into removal of nutrients and chloride via a carbon-based filtration process warrants further consideration and are planning to support the initial research phase in 2024.

While the chemical program has an impact on the reduction of phosphorus active in the water and stored in the sediments, there are no planned actions for removal of nitrogen or chloride from the water or the sediments. The primary focus of this report was to investigate options for removal of chloride in particular but also comprehensive processes that could address all three: phosphorus, nitrogen and chloride.

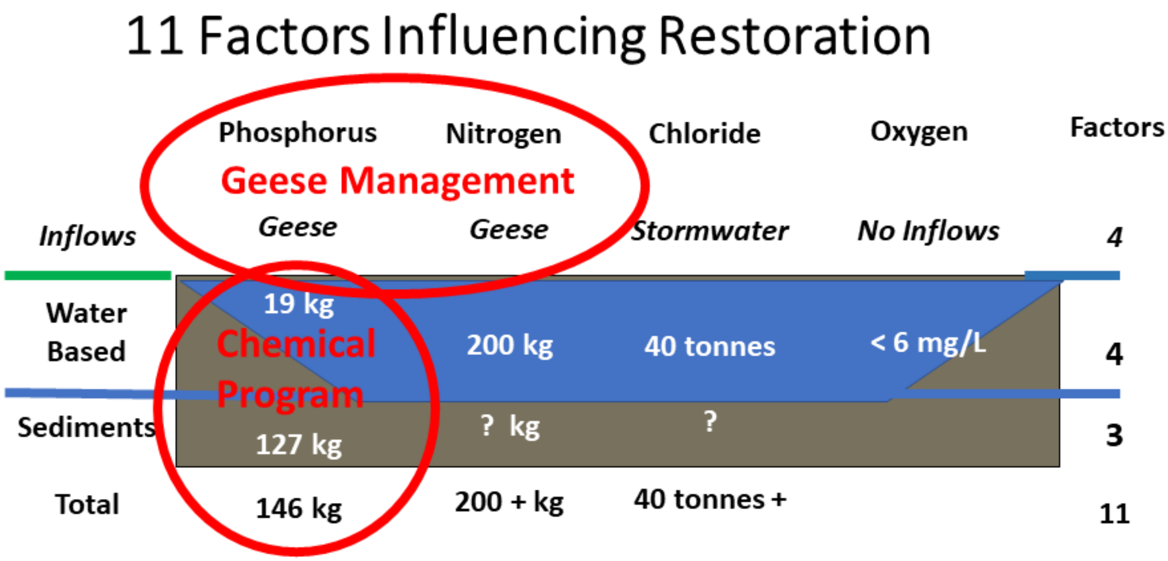
Step #3: Sustaining Restoration Efforts

The current long-term plan does not address how improved water quality will be sustained. It is suggested improvements in restoring aquatic animal and plant life and continuing periodic chemical treatments will be required but it is unlikely that these approaches can be successful unless the chloride levels within Swan Lake are significantly reduced.

The approach for sustaining water quality over the long-term will be greatly influenced by the decisions taken during the restoration process. Some restoration processes such as industrial filtration do not lend themselves to ongoing use whereas others such as a drawdown may serve as a practical long-term management tool.

III) FACTORS INFLUENCING RESTORATION

Research on water quality in Swan Lake suggests there are eleven (11) factors to be considered in a comprehensive program for restoring water quality.



Inflows (4): Four factors relate to Step #1. Three relate to reducing the inflows of phosphorus, nitrogen, and chloride. Swan Lake is a stagnant body of water, lacking any surface level inflows that naturally would add oxygen to the lake, so the fourth factor is to find ways to add oxygen to the lake on a continuing basis.

Water Based (4): Three factors relate to removal or reduction of phosphorus, nitrogen or chloride once they are in the lake while the fourth is improving oxygen levels in the water either directly or indirectly by reducing the loss of oxygen to decaying algae.

Sediment Based (3): The final three factors relate to the removal or reduction of phosphorus, nitrogen and chloride stored in the sediments.

The current long-term plan addresses four of the factors directly and indirectly is expected to reduce oxygen levels in the lake by reducing the algae levels which in turn means less oxygen is consumed as the algae dies in the fall.

	Nutrients		Cl	O	Factors Addressed	Restoration Timeframe	Costs	Concerns
Current Long-term Plan	P	N						
Geese, Fish Management & Monitoring	1	1			2/11	25 year	$3.3 m	Perpetual program
Chemical (Phoslock/PAC)	2			0.5	2.5/11	25 year	$1.4 m	Addresses only Phosphorus
2021 Long-term Plan	3	1	0	0.5	4.5/11	25 year	$4.7 m +	Uncertainty of success, timeline
* Costs exclude Shoreline Restoration								

IV) EXPECTED AND POTENTIAL COSTS UNDER THE 2021 PLAN

The Plan provides for $4.7 million for water quality restoration over the next 25 years.

Restoration Costs

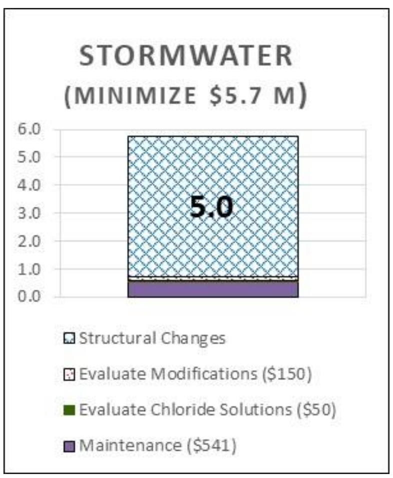
The budget provision in Markham's Life-Cycle Reserve Fund includes $2.3 million (49%) for Ecological Elements including geese management and restoration of fish and aquatic plants.

Another $1.0 million (22%) is provided for water quality monitoring and site testing and $1.4 million (29%) for ongoing chemical treatment program for phosphorus.

The current plan does not include estimates of the costs for restoring the shoreline but provides an outline of potential additional costs related to rerouting stormwater flows and addressing potential issues related to former dump sites.

Stormwater Management Costs

In addition to the water quality program, the long-term budget includes $541,000 for future stormwater pond management and $50,000 for investigation into options for removal of chloride.



Finding a cost-effective approach for reducing stormwater inflows is an essential component of a restoration program.

Markham Council recently approved $150,000 for the Flow Diversion Study to investigate the feasibility of rerouting the stormwater away from the lake. Results are expected in 2024.

The long-term plan indicates a potential cost of $5 million for rerouting stormwater flows. It is expected that the Flow Diversion Study will provide a refinement to this estimate in 2024.

Potential Dump Site Related Costs

If it is determined that seepage from the old dump sites is undermining restoration success, the plan has indicated that costs for addressing groundwater issues could be in the range of $2.0 - $10.0 million.

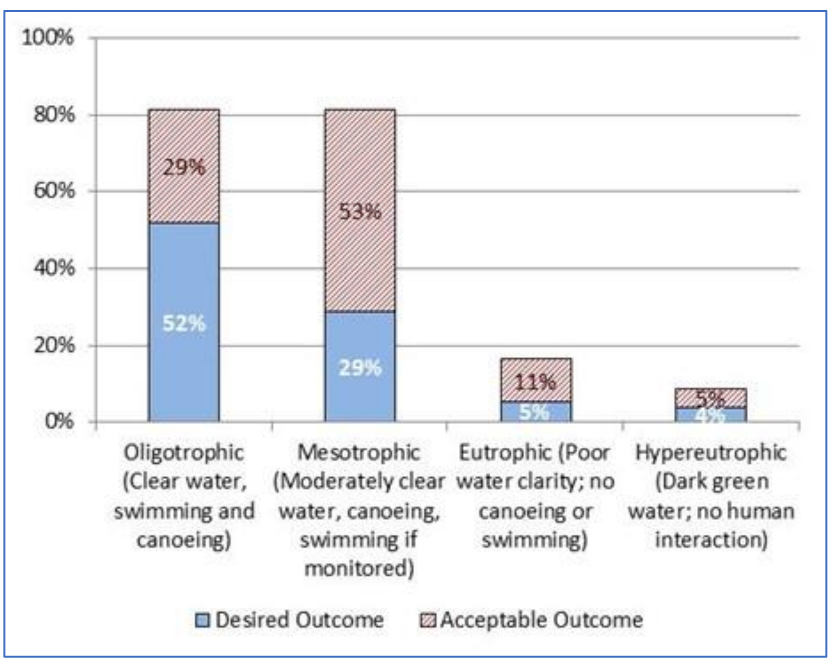
Development of a comprehensive plan for restoration should endeavour to minimize or avoid issues that may trigger costs related to the dump sites. Storage of sediments along the shoreline near the dump sites could possibly reduce the risk of seepage from the dump sites.

V) WATER QUALITY GOALS AND EXPERIENCE

Scientists categorize water quality environments into "Trophic States". Swan Lake is categorized as a hypereutrophic lake, the lowest quality and highest risk category. The lower quality levels of eutrophic and hypereutrophic are not environmentally stable and continual damage to the aquatic and plant life can be expected, as well as potential ongoing health risk to humans and animals due to cyanobacteria.

TROPHIC STATE	AQUATIC ENVIRONMENT	COMMUNITY OPTIONS
Oligotrophic	Lack of plant nutrients keep productivity low, lake contains oxygen at all depths, clear water.	Swimming, paddle sports, wide range of fish options.
Mesotrophic	Moderate plant productivity, lower levels may lack oxygen in summer, moderately clear water and warm water fisheries only.	Paddle sports, swimming possible if monitored, good range of fish options.
Eutrophic	**Contains excess nutrients, blue-green algae dominate during summer, algae scums are probable at times, lower levels lack oxygen in summer, poor transparency, rooted aquatic plant problems may be evident.**	**No swimming, paddle sports possible, limited range of fish options.**
Hypereutrophic	**Algal scums dominate in summer, cyanobacteria, few aquatic plants, no oxygen in lower levels, fish kills possible in summer and under winter ice.**	**No human interaction, potential health risk for humans and small animals.**

The mesotrophic category represents a more stable environmental goal with better community options. It is, however, a challenging objective that, if feasible, will require a comprehensive program that addresses all of the underlying factors contributing to the deterioration in water quality.



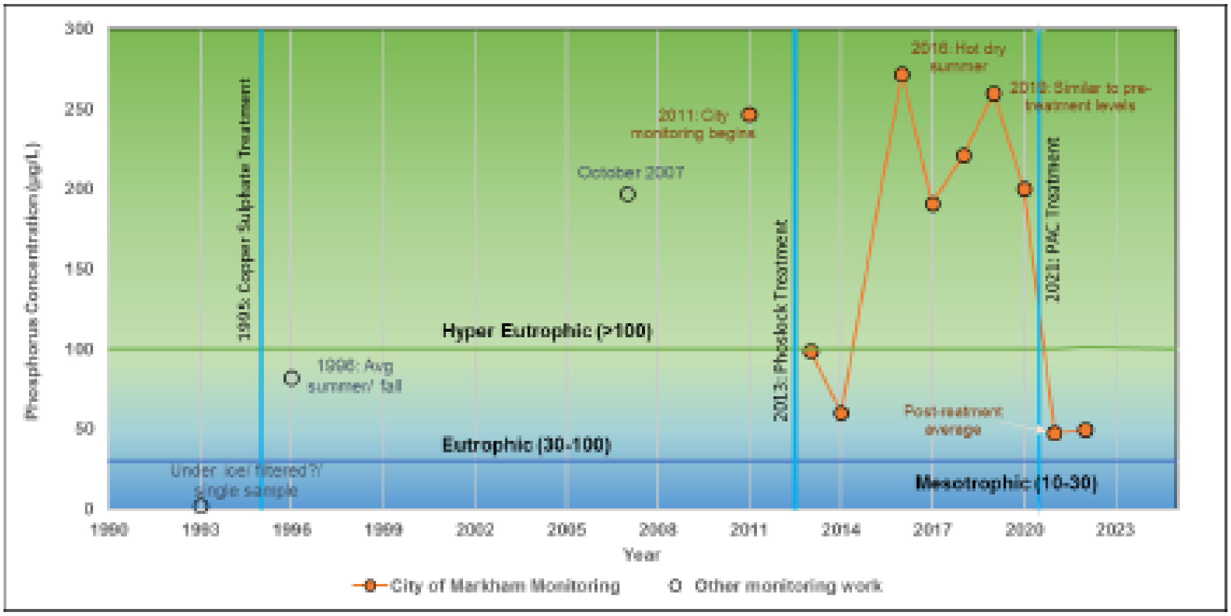
Park Improvement Survey

In a March 2021 survey, over 80% of the 367 responding area residents expressed the desire for restoration of Swan Lake to a mesotrophic or oligotrophic level of quality.

The challenge is to determine if a more comprehensive program can attain and maintain a mesotrophic level of quality.

Except for a 2-year period following the Phoslock treatment in 2013 and the PAC treatment in 2021, Swan Lake has been classified as hypereutrophic as shown in the chart below from the 2022 Water Monitoring Report.

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



The current chemical treatment program has the potential to increase the water quality to a eutrophic level, but it is not clear that the current program is adequate to sustain the eutrophic level.

Details of the current water quality measures for Swan Lake is provided in Appendix G: Executive Summary of 2022 Water Quality Report.

The following chart summarizes the 5-year interim goals set out in the December 2021 Long-Term Plan approved by Markham Council and the aspirational “mesotrophic” goals proposed by Friends of Swan Lake Park.

	Interim Goal Long-term Plan	**Community Aspirational Goals**	**2020**	**2021 (1)**	**2022 (1)**
Trophic State	Eutrophic	Mesotrophic	Hypereutrophic	Eutrophic	Eutrophic
Seechi depth (m)	0.6 – 0.8	➢ 2.0	< 0.5	0.8	0.4
Chlorophyll (µg/L) **(2)**	No goals	< 9.0	n/a	n/a	n/a
Phosphorus (µg/L)	50 – 100	< 30	183	50	50
Nitrogen (mg/L)	No goals	< 0.65	2.56	1.0	0.5
Chloride (mg/L)	400 – 500	< 120	720	700	480
Dissolved Oxygen (mg/L)	No goals	➢ 6.5	6.0	6.3	8.0
Note 1: Results for 2021 and 2022 reflect impact of Poly Aluminum Chloride (PAC) treatment in 2021					
Note 2: Chlorophyll last recorded in 2018 at 41.3 µg/L					

VI) TREATMENT OPTIONS REVIEWED

Treatment approaches were assessed for their effectiveness in addressing the three critical issues of nutrient reduction (phosphorus and nitrogen), chloride removal and oxygenation and their individual impact on the 11 major factors that influence restoration.

One objective is to develop a sense of the costs of a comprehensive restoration plan relative to the current budgeted amounts. In most cases specific costs are not known so an attempt was made to indicate relative cost structures.

The options were categorized into three different streams:
1) Single Purposed Options
2) Comprehensive Water Treatment Options
3) Comprehensive Sediment Treatment Options

In its July 17,2020 report[5], Freshwater Research commented on a variety of management options in the context of treating excessive phosphorus as the primary issue. Their analysis led to the development of the current chemical treatment program.

Our focus has been to build upon the current phosphorus focused program to address perpetual issues of excessive chloride and low oxygen levels and consequently this report revisits some of the management approaches previously rejected in the context of a phosphorus focused management program.

Freshwater's report outlined concerns on the following specific items revisited in this report including:
a) Withdrawal of water –" inefficient process "
b) Sediment removal – "High dredging and removal costs and potentially "toxic" sediment in Block 9"
c) Aeration, Oxygenation –" May fertilize upper layers and increase bloom."

The merit of these concerns needs to be considered in the context of the development of a broader more comprehensive restoration plan.

1) Single Purposed Options

a. Algae removal techniques
b. Nutrient focused programs
c. Chloride focused options
d. Oxygenation focused options

While the single-purposed options address only one or two specific factors, they may have merit when combined with other approaches. The primary limitation of water-only treatment options is that in most cases they have little or no effect on the contaminants stored and potentially releasable from the sediments.

Appendix A provides a review of the focused solutions while Appendix B outlines the details about oxygenation by recycling lake water through the North Channel.

Focused Solutions	Nutrients P	Nutrients N	Cl	O	Factors Addressed	Restoration Timeframe	Costs
a) Geese, Fish Management & Monitoring	1	1			2/11	10 + years	$3.2 m
b) Rerouting stormwater, maintenance			1		1/11	3 - 5 years	$0.7 m +
c) Algae Removal	1	1			2/11	1 year	$$$
d) Chemical (Phoslock/PAC)	2			0.5	2.5/11	10+ years	$1.4 m
e) Desalination			1	1	2/11	1 - 5+ years	$ - $$$
f) Oxygenation Equipment				1	1/11	3 - 5 years	$$
g) Recycle via North Channel (No filtration)				1	1/11	5+ years	$

2) Comprehensive Water Treatment Options

a. Recycling and Filtration via the North Channel
b. Industrial Filtration via Partitioning
c. Industrial Filtration via Recycling
d. Drawdown

The comprehensive water treatment options address multiple elements at the same time. Details of the options are outlined in Appendix D.

Comprehensive Water Based	Nutrients P	Nutrients N	Cl	O	Factors Addressed	Restoration Timeframe	Costs
a) Recycling & Filtration via North Channel	1	1	1	1	4/11	10+ years	$$
b) Industrial Filtration (Partitioning)	1	1	1	1	4/11	1 year	$$$$
c) Industrial Filtration (Recycling)	1	1	1	1	4/11	1 year	$$$
d) Drawdown	1	1	1	1	4/11	1 - 3 years	$

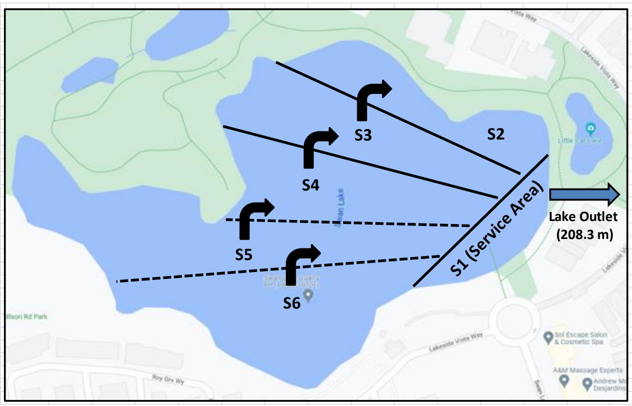
a) Recycling and Filtration Via the North Channel

Recycling of water via the North Channel as outlined in Appendix B will provide a basic means of enhancing oxygen levels. It is possible to add filtration materials such as:

1) In 2021, Fleming College[3] researchers suggested consideration of absorption material (such as Chlorocel, manufactured by Porocel) as a means for absorbing chloride from the water.
2) In 2022, researchers from York University[15] submitted a proposal to Markham to evaluate the effectiveness of carbon-based filters for removing phosphorus, nitrogen and chloride. Markham staff have indicated they plan further investigation of this concept.
3) A small industrial filtration unit outlined in the next section.
4) Expanding the existing bioswale elements of the North Channel and Turtle Inlet

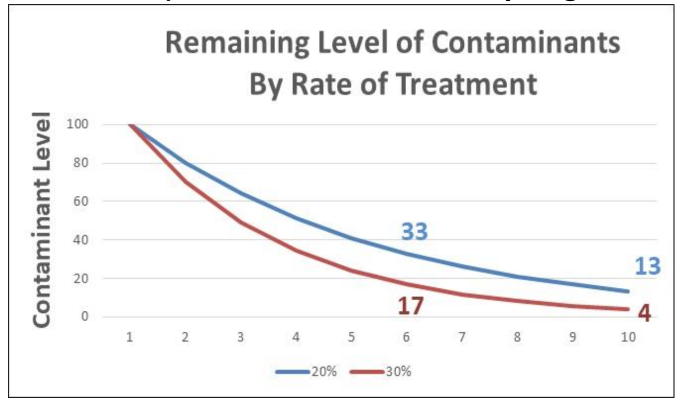
A high flow rate through the North Channel may be desired to maximize the benefits of lake circulation for oxygenation purposes. However, introducing a filtration process may require lower flow rates. The impact of filtration on the lake's water quality will be related to the effectiveness of the filtration process and the percentage of the lake that can be treated each growing season.

b) Filtration and Lake Partitioning



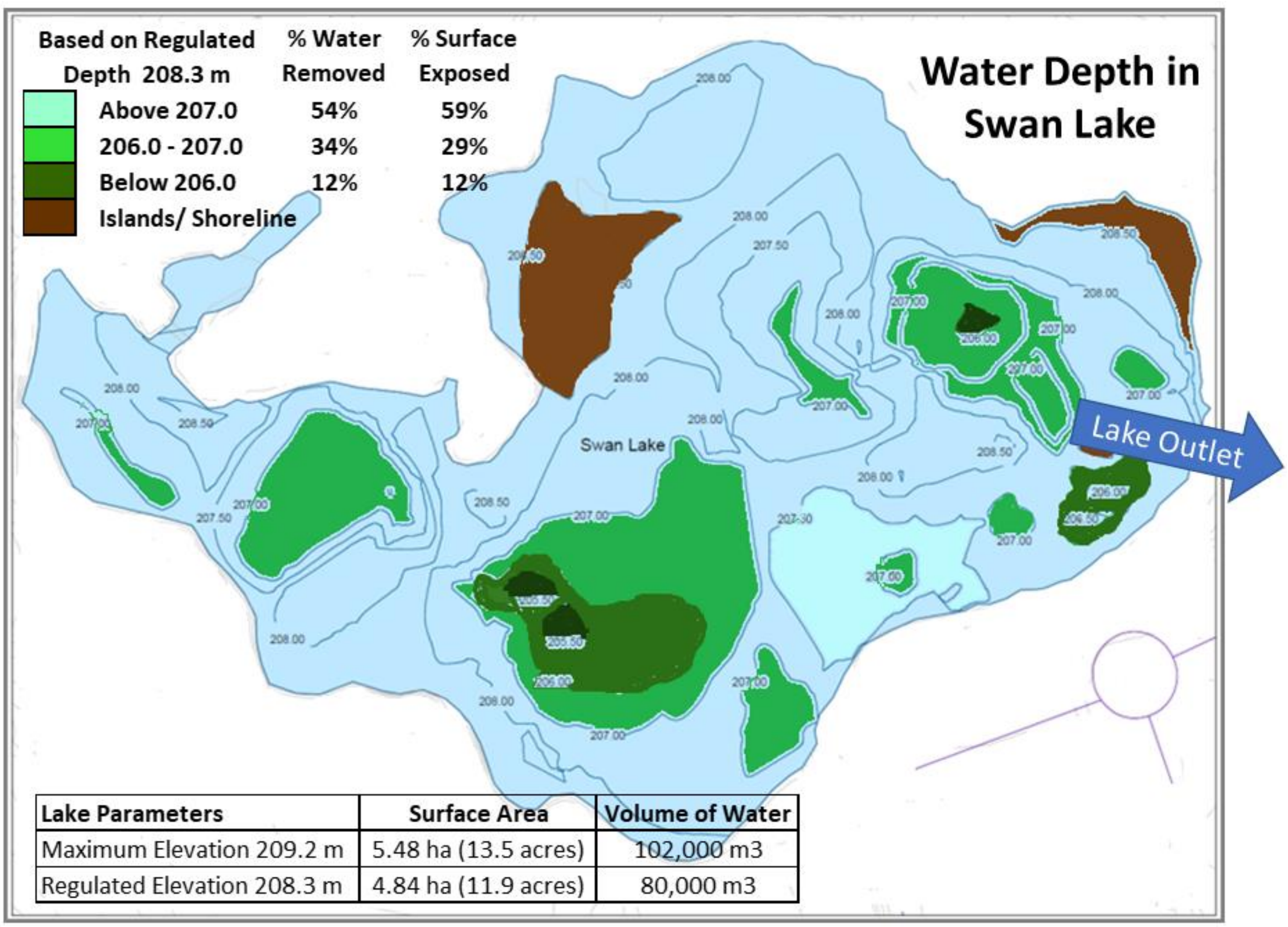
The more expensive industrial filtration option has the ability to restore the water within one season by partitioning sections of the lake and returning the clean water without mixing with the contaminated water. (See Appendix D)

c) Filtration and Lake Recycling



The recycling process using an industrial filtration system avoids the costs of partitioning but is less effective because it involves mixing the clean water back into the existing lake water and in effect retreating the diluted lake contents.

d) Drawdown of Lake Water



Lake Parameters	Surface Area	Volume of Water
Maximum Elevation 209.2 m	5.48 ha (13.5 acres)	102,000 m3
Regulated Elevation 208.3 m	4.84 ha (11.9 acres)	80,000 m3

The lowest cost option appears to be a drawdown of the lake. With some minor modifications to the lake outlet, a gravity-driven drawdown to an elevation of 207.0 metres has the potential to remove 54% of the contaminants and expose 59% of the lakebed. With the addition of pumping capacity, it would be possible to remove all of the contaminated water within one season.

The lake water is expected to be restored over 1 – 3 seasons through precipitation and replenishment from the aquifer. If permitted by regulatory authorities, the replenishment could be accelerated by pumping water from the aquifer.

Drawdown to	207.0 m	206.0 m	204.5 m
Volume of Water Removed (m3) *	44,000	70,000	80,000
Area of Lakebed Exposed (m2) *	28,000	43,000	48,000
% of Water Removed	54%	88%	100%
% of Lakebed Exposed	59%	88%	100%
* Source: Swan Lake Long-term Plan November 2021, Page 5			

The drawdown would direct nutrient and chloride laden lake water into the stormwater system. Analysis suggests that the current design of the stormwater structure will support a drawdown over 30 – 60 days. Volume control mechanisms would provide the ability to control the rate of outflow from the lake. A technical analysis is required to confirm the analysis and appropriate outflow management process to minimize any downstream issues.

3) Comprehensive Water & Sediment Options

a. Partitioning, Industrial Filtration and Removal of Sediments
b. Drawdown and Removal of Sediments

These are the most comprehensive options but trigger additional issues and expenses primarily related to dealing with the sediments. There are four factors to consider in dealing with the sediments:

i. Sediment Quantity

The depth of the sediments is unknown, so a range of potential volumes was estimated based on an average depth of 20 cm – 35 cm based on estimates provided in an early report. The amount of the lakebed exposed depends on the technique utilized. A low-cost gravity fed drawdown of the lake to an elevation of 207.0 m. will expose approximately 59% of the lakebed. With pumps it would be possible to expose up to 100% of the lakebed. The more expensive partitioning option has the potential to expose up to 100% of the sediments.

It may be feasible to store 5,000 – 8,000 m^3 of sediment onsite raising the possibility that most of the sediments could be stored onsite if the lake were drawn down to 207.0 m. Any sediments removed in excess of the local storage capacity would have to be trucked offsite at greater costs.

Estimate of Sediment Volume (M3)						
Lake drawdown to	**207.0 m**		**206.0 m**		**204.5 m**	
Lake Bed Exposure (m2)	28000		43000		48000	
Average Sediment Depth	**20 cm**	**35 cm**	**20 cm**	**35 cm**	**20 cm**	**35 cm**
Sediment Volume	5,600	9,800	8,600	15,050	9,600	16,800
Onsite Storage Capacity	**% Stored Onsite**					
5,000 m3	89%	51%	58%	33%	52%	30%
8,000 m3	143%	82%	93%	53%	83%	48%

Testing will be required to determine the expected depth of the sediments and an estimate developed as to the onsite storage capacity.

ii. Sediment Quality

PetoMacCallum Limited oversaw the cleanup/remediation plan for the Swan Lake development which included reworking about 400,000 m^3 of soils onsite and removal of 5,000 m^3 of contaminated soil and debris plus removal of three underground storage tanks. They reported that there were some contaminants in the sediments that were in excess of the province's lowest quality benchmarks but that the level of contaminants was not harmful to aquatic or human health and could remain in place. This conclusion was supported by two other consultants. A summary of historical comments on sediment quality are provided in Appendix E.

Updated sediment testing will be required to determine if contaminants are a factor that would impact the onsite storage or removal options.

iii. Disturbing Former Dump Sites

There are former dumpsites along the southern (Block 9) and western shorelines (Block 15) of the lake that may contain additional contaminants so due to seepage there may be higher levels of contaminants in the sediment adjacent to these areas.

Removal of sediments from these areas would need to be managed to minimize any disruption to the shoreline. It may be feasible to design the onsite storage in a way to minimize the future risk of seepage from these sites.

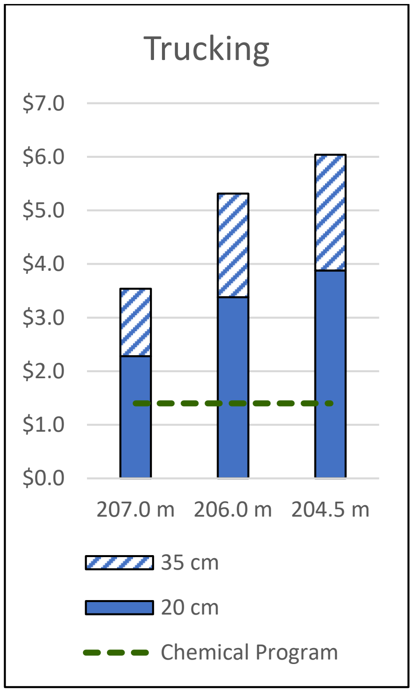
iv. Sediment Removal Costs

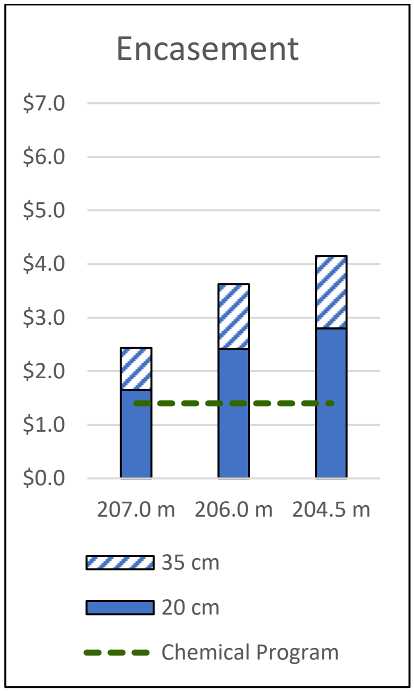
Three processes were considered in terms of managing the sediments:

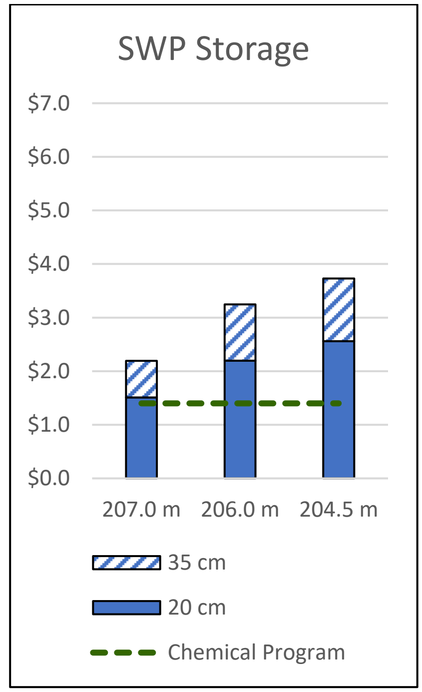
a) Offsite Disposal – trucking the sediments to a land fill site.
b) Storage onsite – using concrete encasements.
c) Storage onsite – using lower-cost stormwater pond techniques.

Cost estimates were development based on a basic project management cost of $0.6 - $1.0 million plus the costs for disposal or storage of the sediments. Sediment disposal costs and onsite storage costs were based on estimates outlined in a stormwater management guide developed by the Toronto and Region Conservation Area ("TRCA") and on information provided by Markham staff. Disposal costs including fees and trucking costs were assumed to be $300 per m^3, onsite concrete encasement to be $75 per m^3 and onsite storage using lower cost impermeable materials practices to be $25 per m^3. If the risk of seepage from the former dump sites is seen as a significant issue, the concrete encasement option may provide a more secure way for storing the sediments. The cost estimates assume 50% of the sediments are stored onsite and 50% were trucked to a land fill site.

The following charts illustrate the costs of addressing the sediments relative to the $1.4 million budgeted for the chemical treatment program.







The development of the estimates of sediment volume and total project costs are outlined in detail in Appendix F and summarized in the table below.

Sediment Removal Options	Nutrients		Cl	O	Factors Addressed	Restoration Timeframe	Costs
	P	N					
a) Disposal Offsite (100%/0%)	1	1	1	1	4/11	1 year	$2.3 - $6.0 m
b) Concrete Encasement Onsite (50%/50%)	1	1	1	1	4/11	1 year	$1.7 - $4.2 m
c) SWM Storage Onsite (50%/50%)	1	1	1	1	4/11	1 year	$1.5 - $3.7 m

The estimates illustrate that the costs of removing the sediments may be significant however the costs may be justified:

a) If the costs are at least partially offset by a reduction in other costs, such as fewer chemical treatments and a reduction in ongoing monitoring costs.
b) If the additional costs provide a timelier improvement or greater certainty of improvement in water quality and a more stable environmental long-term outcome.
c) If the removal of the sediments increases the likelihood of a better outcome such as achieving a mesotrophic level of water quality, or
d) If the restoration of water quality will restore the ecological habitat and the community's use and pride in Swan Lake Park as the "Jewel of Markham".

VII) HOSTING A SOLUTION DESIGN WORKSHOP

The issues facing Swan Lake are complex and interrelated. The solution requires input from a multidisciplinary pool of talent. It has been suggested that often, in complex cases such as Swan Lake, an effective technique is to host a "Solution Design Workshop" which brings the various talents together to discuss the range of options and to narrow down the approach following which a plan is developed for a subsequent "peer review" by the workshop participants.

We recommend that Markham host a workshop in early 2024 to discuss the various restoration options. Skills in attendance would include: an independent facilitator with extensive restoration experience; limnologist (2); water resource engineer(s); someone experienced in management of sediments; fish and aquatic plant scientist(s); researchers; someone with broad project management experience on a similar project; representatives from City of Markham and Friends of Swan Lake Park.

Background Information Available for Consideration at the Workshop

We are fortunate in that there is extensive background information and data available on the issues facing Swan Lake.

The following existing information would be available for review by the participants prior to the workshop.

1) Swan Lake Long-term Management Plan, November 2021
2) 2023 Swan Lake Water Monitoring Report (with 2023 updated water quality measures).
3) Various analyses and reports provided by Freshwater Research.
4) Various reports provided by Friends of Swan Lake Park
5) Flow Diversion Study recommendations on feasibility of rerouting stormwater flows.
    a. Possible approaches:
        i. Altering local Swan Lake infrastructure and/or
        ii. Developing a solution in sync with upgrading of the system south of 16th Avenue in 2027-2028
    b. Expected impact of reducing annual inflows of road salt once implemented.
    c. Expected cost and potential timing of implementation.
6) Recommendations on the shoreline restoration.
    a. Original goals/ objectives and estimated costs of the design by TRCA/Markham Parks Operations
    b. Impact of rerouting stormwater flows on original design.
    c. Impact of onsite storage of sediments on original design.

Additional information that could be developed in 2023 and submitted to the workshop for consideration:

1) Review of feasibility/benefits of drawing down the lake water.
    a. Outline of issues/ concerns.
    b. Outline of regulatory approvals required/ issues/concerns.
    c. Alterations required to modify the lake outflow chamber (costs, flow management approaches.)
2) Review of the feasibility/benefits of removing the sediments
    a. An assessment of sediment quality and quality:
        i. Sediment analysis undertaken in 2020.
        ii. Possibly more extensive testing of samples taken in 2020.

iii. Possibly additional testing for contaminants.
iv. Estimate of sediment depth and volume of sediments within the lake.

b. Feasibility and estimate of volume that potentially could be stored onsite and cost parameters.
c. Estimate of project costs including offsite removal costs and onsite storage costs.

3) Recommendation on the planned chemical treatment for 2024 (Phoslock or PAC)
4) Reports on the research work undertaken by:
   a. 2021 Fleming College report on possible engineering techniques.
   b. AECOM review of the Fleming College research proposal on the use of calcium peroxide for oxygenation enhancement.
   c. York University research findings on the use of charcoal filters for removal of nutrients and chloride.
   d. University of Toronto research findings on the impact of circulation on the release of nutrients from the sediments.

Workshop Discussion Items

a) If the drawdown of the lake is feasible from an engineering perspective:
   i. What are the restoration benefits in terms of removal of nutrients and chloride?
   ii. Should a drawdown be only to 207.0 m – removing 54% of the water or should more be removed?
   iii. What are the issues/concerns relating to refilling of the lake?
   iv. Is this an approach that would have long-term benefit as a management tool to periodically clear out the buildup of nutrients and chloride. If so, what frequency?
b) Is removal of sediments feasible?
   ii. Would removal result in material improvement and/or greater certainty of water quality outcomes?
   iii. Are there any potential reductions in other costs?
   iv. When could/should removal occur (before/after realignment of stormwater routes)?
c) Should the chemical program be continued and at what frequency?
   i. Temporarily until sediment removal completed. Thereafter?
   ii. Permanently if sediments are not removed?
d) Are oxygenation techniques required?
   i. Are they helpful or harmful during the restoration phase?
   ii. Are they essential/beneficial for sustaining improved water quality post-restoration?
   iii. Recommended oxygenation techniques: 1) mechanical bubblers 2) circulation equipment 3) recycling via the North Channel?

Potential Outcome from Workshop

The recommendations of the workshop would provide the framework for the development of an updated comprehensive plan and provide Council and the community with guidance on four critical topics:

1) What level of water quality is achievable and sustainable and at what cost?
2) Is it worth investing to reroute the stormwater?
3) Is a drawdown of the lake beneficial and can it be managed safely?
4) Is it worth investing to remove the sediments?

Two possible outcomes are expected: A water-only restoration plan or a restoration plan that addresses the sediments. Two illustrative examples are provided.

Path #1: An illustration of a possible "Water Only" outcome

A water-treatment only option that would build upon the current geese management and chemical treatment program and likely incorporate an initial drawdown to address chloride loads in the lake plus a sustainable oxygenation program such as recycling via the North Channel

Path #1: Water Treatment Only	Factors Addressed	Restoration Timeframe	Costs	Benefits/Concerns
Geese, Fish Management & Monitoring	**2/11**	10 + years	$3.2 m	Includes monitoring costs of $0.9 m
Rerouting stormwater, maintenance	**1/11**	3 - 5 years	$0.7 m +	Essential. Excludes rerouting costs
Drawdown	**4/11**	1 - 3 years	$	Addresses chloride, Downstream, Refill
Recycling Via North Channel	**1 - 4/11**	10 + years	$ - $$	Additional costs if filtration added
Chemical (Phoslock/PAC)	**2.5/11**	**10 + years**	**$1.4 m**	**Addresses only Phosphorus**
Comprehensive Water Treatment Plan	**9/11**	**10 + years**	**$5.3 m +**	**Continuing sediment impact, uncertainty of success, timeline**
* Costs exclude Shoreline Restoration & Rerouting Stormwater				

Path #2: An illustration of a possible "Water and Sediment" outcome

A plan including a drawdown to reduce chloride combined with removal of some of the sediments plus a sustainable oxygenation program such as recycling via the North Channel may provide an opportunity to discontinue the chemical treatment program.

The core question to be answered is whether the potential additional costs of addressing the sediments materially increases the environmental outcomes and reduces other costs.

Path #2: Water & Sediment	Factors Addressed	Restoration Timeframe	Costs	Benefits/Concerns
Geese, Fish Management & Monitoring	**2/11**	10 + years	$3.2 m	Potential to reduce water monitoring costs
Rerouting stormwater	**1/11**	3 - 5 years	$0.7 m +	Essential. Excludes rerouting costs
Drawdown	**4/11**	1 - 3 years	$	Addresses chloride, Downstream, Refill
Recycling Via North Channel	**1 /11**	10 + years	$	Reduces need for additonal filtration
Sediment Removal & Storage (SW)	**7/11**	**1 year**	**$1.5 - $3.7 m**	**Shoreline Restoration Impact, Capacity**
Comprehensive Water & Sediment Plan	**11/11**	**10 + years**	**$5.4 - 7.6 m +**	**Faster aquatic recovery, greater assurance of success, potentially better results, potential to reduce monitoring costs**
* Costs exclude Shoreline Restoration & Rerouting Stormwater				

VIII) RECOMMENDATIONS

1) That Markham host a Solution Design Workshop in early 2024 with the goal of providing guidance on the appropriate path forward for an updated long-term water quality plan.

In preparation for the workshop the following activities should be approved:

a. Completion of current undertakings in 2023:
   i. Completion of the design phase of the shoreline restoration project.
   ii. Completion of the Flow Diversion Study into the feasibility, costs and timing of rerouting stormwater flows from the lake.
   iii. Expand the scope of the Flow Diversion Study to include a report on the technical feasibility of a drawdown of water from Swan Lake during periods of low or no precipitation.
   iv. Support for the York University research into means of removing nutrients and chloride**.**

b) Support research in 2023 into the following:
   i. University of Toronto research into whether oxygenation will increase phosphorus release from the sediments during restoration.
   ii. Research into the biological benefits of using a drawdown of the lake as a management tool during the restoration phase and as a future management tool for sustainability.
   iii. Research into the cost/benefits of the removal of sediments as a management tool.
   iv. Research into whether oxygenation processes are helpful or a hindrance during the restoration phase and whether they should be a component of a long-term sustainable plan.

3) That following the Solution Design Workshop that staff submit a draft Comprehensive Water Quality Plan for a "Peer Review" by the Workshop participants before submission to Council for consideration and approval.

REFERENCES:

Swan Lake Reports:

1) "Swan Lake Monitoring Report (March 2023)" – City of Markham
2) "Swan Lake Long-term Water Quality Plan", City of Markham, November 16, 2021
3) "Literature Review of Potential Engineering Solutions for the Restoration of Swan Lake", Barbara Siembida-Lösch, Fleming College, February 2021.
4) "A Pathway to Sustainable Water Quality for Swan Lake", Friends of Swan Lake Park, Dec. 2020
5) "Swan Lake Water Quality Management", Freshwater Research, July 17, 2020
6) "Geo-Environmental/Hydrogeological Investigation and Analysis Lake Water and Sediment Quality Assessment", PetoMacCallum Ltd., March 1994
7) "Report of Site Cleanup/Remediation Swan Lake Development", PetoMacCallum Ltd., Sept. 1995
8) "Environmental Assessment Swan Lake Block 15, Proposed Parkland", Barenco, March 2000
9) "Environmental Quality Assessment of Sediment Samples, Swan Lake, Block 9", Gartner Lee Limited, February 2003
10) "Review of Environmental Reports and Assessment of Proposed Land Severance Block 9 of Swan Lake", Jacques Whitford Environmental Limited, May 23, 2003
11) "Environmental Quality Assessment of Swan Lake, Block 9", Gartner Lee Limited, Jan. 2006
12) "Risk Assessment for Block 9", Water and Earth Sciences Associates, March 2006
13) "Swan Lake Sediment Analysis, Summary Report", Dr. Nowak Institut, October 23, 2020
14) Research Proposal on Use of Oxygen Releasing Compounds, Dr. Barbara Siembida-Lösch, Centre for Water and Wastewater Technologies, Fleming College, April 2022
15) Research into Removal of Nutrients and Chloride from Swan Lake, Dr. Rama Pulicharla, Dr. Satindar K Brar, York University, May 2, 2022
16) Research Proposal into Nutrient Release from Sediments, Dr. Amy Bilton, University of Toronto
17) "Rules for Soil Management and Excess Soil Quality Standards, Ontario
18) "Calcium Peroxide and Biochar Proposals – Review", Tammy Karst-Riddock, AECOM, April 18, 2023
19) Markham Sewer Use By-law 2014-71

Selective Academic References

A1 T. Shatwell, J. Kohler, "Decreased nitrogen loading controls summer cyanobacterial blooms without promoting nitrogen-fixing taxa: Long-term response of a shallow lake", Limnology and Oceanography, 2019

A2 Stephen C Maberly, Jo-anne Pitt, P. Sian Davies, "Nitrogen and phosphorus limitation and the management of small productive lakes", Taylor & Francis Online, March 23, 2020

A3 Xiaodan Jin, Yiliang He, Bo Zhang, "Impact of Sulfate and Chloride on Sediment Phosphorus Release in the Yangtze Estuary Reservoir, China" , 2013

A4 Jovana Radosavljevic, Stephanie Slowinski, Mahyar Shafii, "Salinization as a driver of eutrophication symptoms in an urban lake (Lake Wilcox, Ontario)", Science of the Total Environment 2022

A5 Alexandra McClymont, "The Effect of Increasing Chloride Concentration and Temperatures on Freshwater Zooplankton Communities" , Queens University, February 2020

A6 R. Gachter and B. Wehrli, "Ten Years of Artificial Mixing and Oxygenation: No Effect on Internal Phosphorus Loading of Two Eutrophic Lakes", October 15, 1998.

Appendix A: Focused Solutions

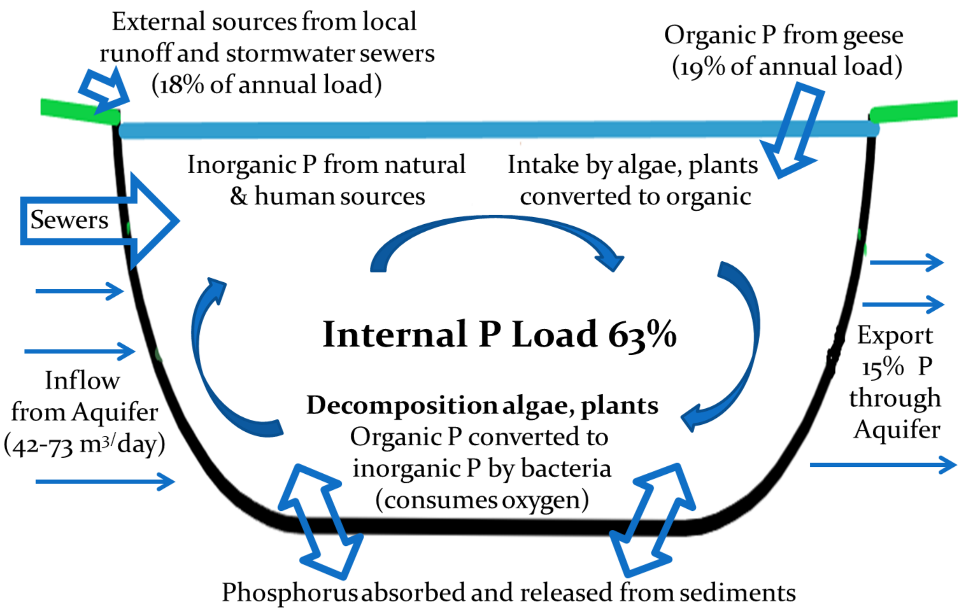
a) Algae Removal Options

A variety of techniques for targeting algae and cyanobacteria were reviewed by Freshwater Research[5] and considered to be ineffective.

Equipment, such as the Aecom unit shown here, are capable of harvesting concentrated amounts of algae.

Freshwater Research concluded that the high-water content and low concentration of algae within Swan Lake make this approach ineffective as a management tool.

b) Nutrient Focused Programs: Phosphorus and Nitrogen



The Phosphorus Cycle in Swan Lake (2017 – 2018)

Nutrients, such as nitrogen ("N") and phosphorus ("P"), are essential for plant and animal growth and nourishment.

Excess nutrients can cause overstimulation of growth of aquatic plants and algae. Excessive growth of these organisms block sun light to deeper waters and use up dissolved oxygen as they decompose.

Goose feces contain both phosphorus and nitrogen. Studies have shown that the contribution of nitrogen and phosphorus attributed to waterfowl can account for as much as 40% of the nitrogen and 85% of the phosphorus input to a lake. Markham has introduced a successful geese management program that has reduced the number of resident and migratory geese visiting Swan Lake.

Other than the years immediately after the Phoslock treatment in 2013 and the PAC treatment n 2021, phosphorus and nitrogen levels in Swan Lake are consistently reported to be within the hypereutrophic range.

Freshwater Research describes Swan Like as "polymictic" because of its relatively shallow depth.

In a 2019 study[A1], Shatwell and Kohler note that ”currently there is a lack of scientific consensus about whether eutrophication is best managed by controlling P alone, or by controlling both N and P”. Their study reviewed 37-years of data on a German lake during periods of reduced phosphorus and nitrogen loading and concluded that “dual N and P control can be an effective strategy to mitigate eutrophication. Particularly in polymictic lakes where summer internal P-loading and denitrification rates are potentially high, the lower N-loading can induce stronger summer N-limitation and in turn effectively control cyanobacterial blooms in the long term.”

Another study released in 2020 by Maberly, Pitt and Davies[A2], of shallow lakes in England concluded that “even in P-limited sites, once input of P has been reduced, further ecological benefit of reducing N at targeted sites should be explored”. The study noted that a Policy Forum Review in Science concluded that “amelioration of the negative impacts of nutrient enrichment should be made by control and reduction of both N and P.”

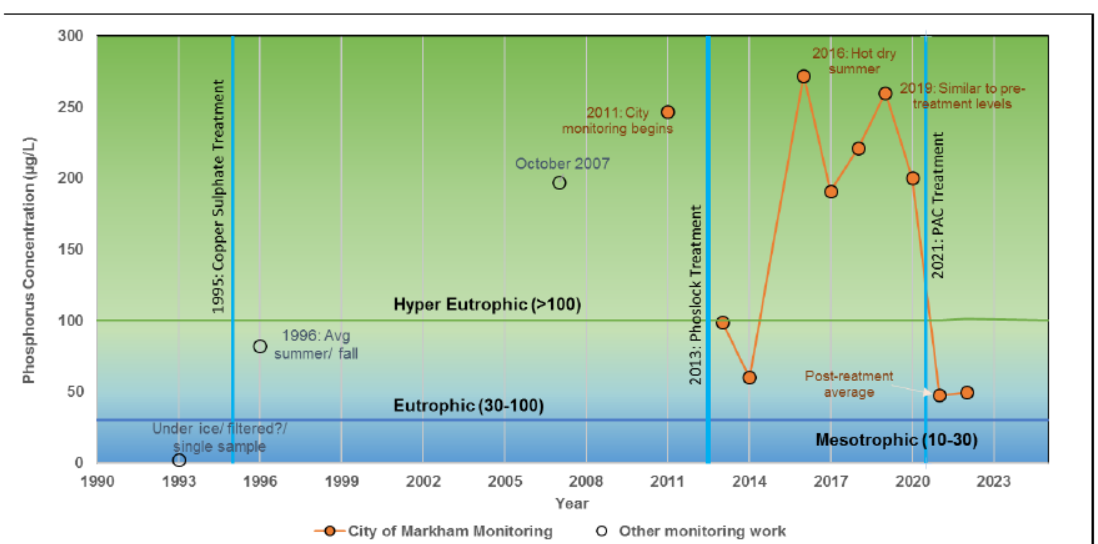
Swan Lake’s Phosphorus Focused Program

The focus of the Swan Lake Long-term Management Plan is on reducing phosphorus as the primary nutrient by adding Phoslock or Poly Aluminum Chloride (“PAC”) every few years. In 1995, a treatment of Copper Sulphate was applied.

An application of 25.2 tonnes of Phoslock was applied in 2013 and there was a reduction in phosphorus for two years. In 2021, Freshwater Research outlined the benefits of more frequent applications of Phoslock and subsequently a program was implemented to apply Phoslock in 2021 with a follow up application planned for 2024. Due to import restrictions Phoslock was not available in 2021 so an application of 13 tonnes of PAC was applied in August 2021. Recent analysis of the 2022 water quality suggests that some improvement in phosphorus levels in 2021 and 2022 to eutrophic levels following the PAC treatment in July 2021.

The following chart from the 2022 monitoring report (Appendix G) illustrates the impact of the three phosphorus treatment programs administered. Indications are that the benefits are short-lived.

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



Is a Nitrogen Focused Program Needed?
Nitrogen, in the forms of nitrate, nitrite, or ammonium, is a nutrient needed for plant growth but is also one of the core nutrients that can contribute to excessive growth of algae.

Lake sediments represent an important source of nitrogen. Nitrogen is released from the sediments in the form of ammonium which can then be transformed into forms that are readily usable for algal growth. The 2022 monitoring report (Appendix G) notes that:

> "Total the nitrogen concentrations the growing season averaged 0.60 mg/L (below the 1.2 mg/L threshold for a hyper-eutrophic condition. In 2022, Ammonia and nitrate concentrations (the forms available for uptake by biota) were generally very low (except in April), and nitrogen was mainly present as organic matter."

The chemicals used to control phosphorus do not directly impact nitrogen levels and at present there is no program focused on addressing nitrogen levels in Swan Lake.

As noted above, recent research suggests that an effective restoration program needs to consider the impact of both phosphorus and nitrogen triggering the following questions:

1) What options other than geese management are available for reducing nitrogen levels in Swan Lake?
   a. Is there a chemical program that can help manage nitrogen levels in Swan Lake?
   b. Would the drawdown of the lake materially reduce nitrogen levels?
   c. Would removal of sediments materially contribute to a reduction of nitrogen levels in Swan Lake?
2) Can we achieve mesotrophic levels of water quality without dealing with nitrogen levels?

c) Chloride Focused Options: Desalination

Chloride levels in Swan Lake are very high and are 4x-6x the safe level for aquatic life. The high levels undermine restoration of the lake in at least two ways:

1) Researchers[A3] believe that chloride enhances the release of phosphorus from the sediments which in turn spurs algae growth. A recent study [A4] of Lake Wilcox in Richmond Hill associated an increase in algae to an increase in chloride levels.
2) Other research[A5] concludes that chloride kills lower-level aquatic life (zooplankton) that consumes algae and is a natural ally in controlling algae.

There are no simple chemical treatment processes for removing chloride arising from road salt. Investigation is underway to minimize the future inflow of road salt, but it is expected that while it may be possible to significantly reduce the inflows there will likely be continuing inflows into Swan Lake because of its role as a flood control mechanism.

There is an estimated 40 tonnes of chloride within the water in Swan Lake. The amount of chloride that is now stored within the sediments but could potentially be released is unknown. Three approaches were considered for the removal of the 40+ tonnes of chloride currently active in Swan Lake water:

1) Use of desalination equipment outline below.
2) Drawdown of lake water as outlined in Appendix C.
3) Use of filtration techniques as outlined in Appendix D.

Addressing the chloride in the sediments would require removal of the sediments or a continuing program to remove chloride from the water.

Desalination Equipment

Equipment and processes have been developed to remove salt from water, primarily for the purpose of generating drinking water.

The approaches range from low-cost wind and solar driven devices designed for use in remote villages as illustrated here, to multi-billion-dollar plants for generating large volumes of drinking water for major cities.

To remove 40+ tonnes of chloride already in Swan Lake will likely require sizable processing equipment which suggests that a more comprehensive treatment process such as industrial filtration or a drawdown which address other elements as well as chloride would be more viable solutions for restoration.

d) Oxygenation Options

Dissolved oxygen (DO) is a measure of how much oxygen is dissolved in the water - the amount of oxygen available to living aquatic organisms. Dissolved oxygen in surface water is used by all forms of aquatic life; therefore, it is measured to assess the "health" of lakes and streams.

Rapidly moving water, such as in a mountain stream or large river, tends to contain a lot of dissolved oxygen, whereas stagnant water bodies such as Swan Lake contain less.

Bacteria in water can consume oxygen when organic matter, such as algae, decays. Thus, the decay of excess organic material in lakes can cause an oxygen-deficient situation that can cause a water body to "die." Aquatic life can have a hard time in stagnant water that has a lot of rotting, organic material in it, especially in summer when dissolved-oxygen levels are at a seasonal low. Water near the surface of the lake is too warm for aquatic life, while water near the bottom has too little oxygen.

It is expected that the current chemical treatment process, which is focused on reducing phosphorus levels will indirectly improve oxygen levels by reducing the algae in the lake and thereby reducing the consumption of oxygen in the autumn as the algae decays.

Investigation is required into the best options for improving oxygen levels in Swan Lake. There are two dimensions to the issue:

i. Are improved oxygen levels helpful or a hindrance to the restoration process?
ii. Once restoration is achieved, are processes to improve oxygen levels essential to sustaining the restored water quality?

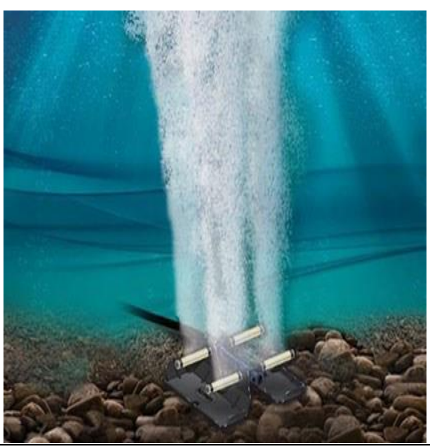
Several of the processes, such as drawdown, desalination or industrial filtration provide an indirect opportunity to add oxygen to the water as it is returned to the lake. These processes tend to provide a one-time benefit during the process but do not address the long-term challenges of sustaining restored oxygen levels.

Three possible options were considered:

a) A proposal by Fleming College[14] on the use of calcium peroxide as a means to stimulate oxygen levels is under review by Markham staff. Staff have concluded that the process may have potential but is still at a very early stage of research and is not worth pursing at this time. It is recommended that this review be shared with the participants in the proposed workshop.
b) Permanent recycling via the North Channel as outlined in Appendix B.
c) Installation of oxygenation equipment.

Oxygenation Equipment

There are several styles of equipment options for directly adding oxygen to lakes and ponds. These approaches are aimed at reducing the internal sources of phosphorus and can have a material impact on increasing dissolved oxygen levels. The equipment options include the ability to not interfere with the stratification of the different layers of water or alternatively to intentionally mix the layers. Further analysis is required to assess the best options in a post-restoration environment. Fountains tend to provide only surface level aeration. The fountain that had been in use until recently in Swan Lake was considered decorative, providing only minimal aeration benefit.

Bubblers	**Solar Bee® Lake Circulators**	**U of Toronto Research**
Bubblers add oxygen but tend to mix the layers.	Active lake circulation can be limited to only the top layer or to treat the bottom water.	Researchers have designed a low-cost wind powered aeration device for use in fishponds in remote areas.
		

Oxygenation through mechanical means such as circulators has been rejected by Freshwater Research, as ineffective during the restoration phase because the sediment demand for oxygen is so high and increased temperatures at the lower levels may also add to the increased release of phosphorus.

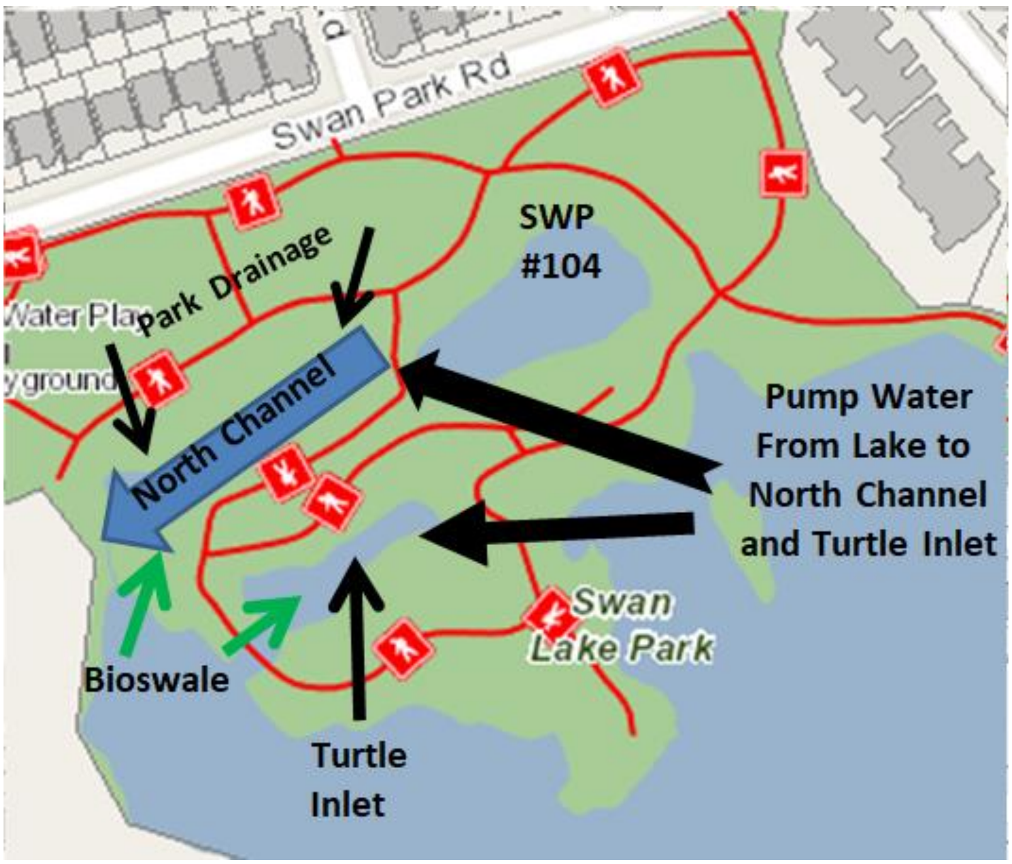
Consideration needs to be given as to whether increasing the release of phosphorus from the sediments may in fact be beneficial when done in combination with a chemical treatment program such as Phoslock or PAC.

Appendix B: Recycling Through the North Channel

Swan Lake is a stagnant body of water with no natural surface level inflows or outflows and has a very long hydraulic detention time ("HDT").

Circulation is considered one of the primary methods for increasing oxygen levels. Fleming College[3] indicated that a lake mixing strategy may need to be developed as a tool in the control and prevention of excessive algal growth. The report notes that as a general rule, an HDT between 20 – 30 days at least 80% of the time is recommended and cites reports indicating the most sensitive lakes are those with a detention time greater than 30 days.

Removing water from the lake and returning it to the lake oxygen enhanced with possibly fewer nutrients could provide a natural enhancement to the water quality in the lake and reduce the dependency on future chemical treatments. This could be accomplished by recycling lake water through the North Channel, a dry channel along the north end of Swan Lake that serves to drain stormwater from the north end of the park. A small portion of the channel is a bioswale which it may be possible to extend. It also may be feasible to circulate water from the lake into Turtle Inlet, creating a decorative waterfall.



The North Channel, about 100 metres long, is designed as an emergency spillway for overflow from the north stormwater pond (SWP #104); however, it has rarely been used. The channel is typically dry, though during wet periods it will hold water from the runoff from the surrounding parkland.

Turtle Inlet is a small, shallow inlet that has potential to be enhanced as a bioswale.

Pulling from and returning water to the lake will create circulation throughout the lake. Concern has been raised that the circulation will lead to more frequent mixing of the cool lower water with the warmer surface level waters resulting in more nutrients being released from the sediments and potentially stimulating further algae growth. However, one study[A6] indicated that increasing lower-level oxygen content had no effect on the release of nutrients from the sediment.

Consideration must be given as to whether increased mixing is a detriment to the restoration effort. Potentially the possible release of nutrients from the sediments, if any, may in fact be beneficial in combination with a regular chemical program designed to reduce the phosphorus contribution from the sediments.

Circulation: A Tool for Sustaining Restoration Efforts

Once the water quality is restored the challenge remains to sustain the improved water quality. Without circulation, Swan Lake will continue to be a stagnant body of water and face the inherent challenges.

Recycling provides a low-cost, perpetual oxygenation process. Whether or not recycling is beneficial during the restoration phase, recycling and filtering via the North Channel and should be considered as an inherent component of a long-term sustainable plan for lake management.

Pumping Options

It is essential to clarify the primary objectives of recycling water via the North Channel and Turtle Inlet:

a) If the emphasis is primarily oxygenation and reducing the hydraulic detention time in the lake, then a high-volume pump may be required.
b) If the emphasis is a combination of filtration and oxygenation, then pumping lower volumes in line with the capabilities of the filtration process will be needed.

Lake Turnover (80,000 m3) April - October (214 days)		
Pump Size	**1 HP**	**1.5 HP**
Capacity (m3/24 hr)	**50**	**200**
100%	13%	54%
50%	7%	27%

Swan Lake contains approximately 80,000 m^3 of water. To recycle that volume over the 7-month period from April – October period would require a pump capable of pumping 360 m^3/24 hour.

A small “cottage” style pump (1.0 – 1.5 hp), connected to a continuous power source, could recycle 13% - 54% of the lake water through the North Channel.

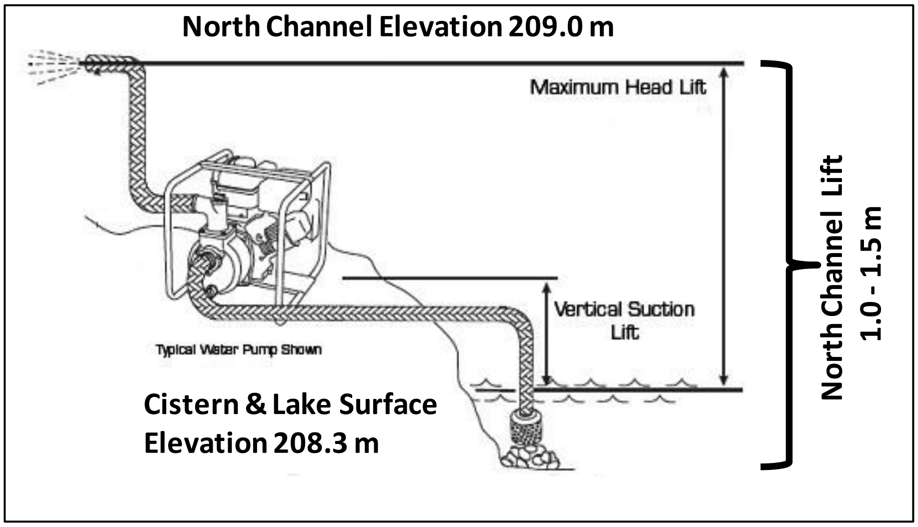
Driven by either solar sources or by repurposing the existing windmill on the north pond, assuming 50% efficiency, the small pumps would have the capability to recycle 7% - 27% of the 80,000 m^3 of lake water over the summer months.

Greater lake circulation and improved levels of oxygenation could be achieved if industrial scale pumps, such as those used by Markham’s stormwater management department, were deployed. With more powerful pumps, it may be possible to recycle more than 100% of the lake water through the North Channel each season.

To reduce the energy required for the pumps it may be feasible to create cisterns at the start of the North Channel and near Turtle Inlet. The distance from the edge of the lake to the North Channel or Turtle Inlet is approximately 50 - 100 m. A downward sloping pipe from the lake to the cistern would provide a gravity-fed mechanism for getting lake water to the North Channel or Turtle Inlet without pumping. Water in the cistern will rise to the level of the lake water. Pumps would be required to raise the water from the cistern to the North Channel or to a waterfall.

Creation of a decorative waterfall into Turtle Inlet may provided a means for increasing oxygenation content and could be accomplished by pumping the water 5 metre higher to approximately 214.0 m.

It may be possible to install a filtering process as the lake water enters the cistern.



The North Channel is at an elevation of 209.0 m. or 0.7 m. above the regulated lake level. Depending on the location of the intake head within the cistern, the maximum head lift height to the North Channel surface is expected to be 1.0 – 1.5 m.

Repurposing the Existing Windmill

It may be possible to repurpose the existing windmill and to add solar panels as a low-cost energy source for supporting a "cottage-style" pump.

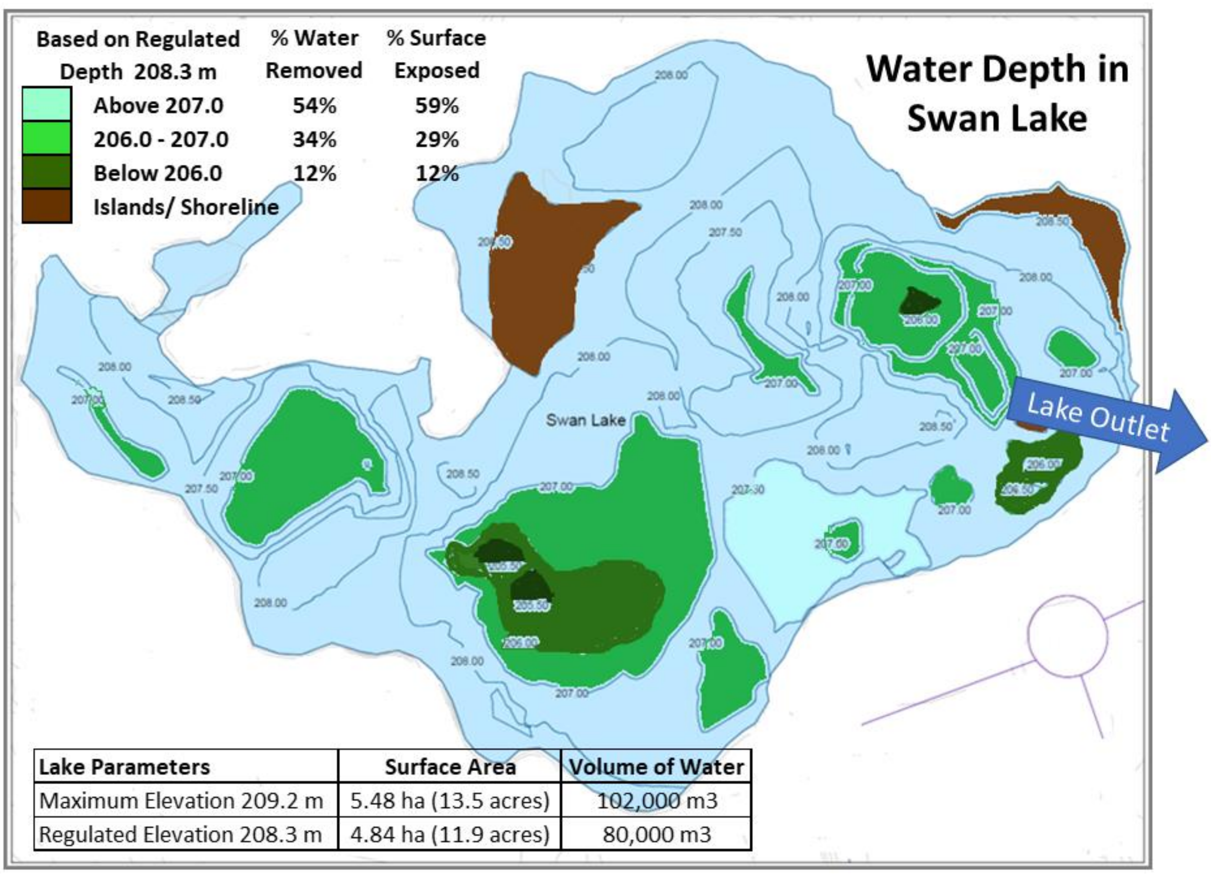
Appendix C: Controlled Winter Drawdown of Swan Lake

Swan Lake is a very shallow lake. Its depth is regulated to an elevation of 208.3 m. by a concrete control structure on the south-eastern shoreline. There is an outlet pipe near the bottom of the chamber at an elevation of 207.0 m, 1.3 m below the top edge of the chamber, making it feasible to develop a low cost, controlled gravity-driven drawdown to 207.0 m.

The 2021 Swan Lake Long-term Plan provided data on the depth and volume of water in Swan Lake and the lakebed exposed at various depths.

Drawdown to	207.0 m	206.0 m	204.5 m
Volume of Water Removed (m3) *	44,000	70,000	80,000
Area of Lakebed Exposed (m2) *	28,000	43,000	48,000
% of Water Removed	54%	88%	100%
% of Lakebed Exposed	59%	88%	100%
* Source: Swan Lake Long-term Plan November 2021, Page 5			

Reducing the lake depth by 1.3 m to 207.0 m would remove over 54% of the contaminated water and expose all the light blue areas in the chart below – suggesting that approximately 59% of the lake bottom sediments would be exposed thus providing an opportunity for the treatment and/or removal of the sediments.



Additional efforts could be undertaken to pump water down to 206.0 m which would remove 88% of the water and expose 88% of the sediments. A full drawdown would occur at 204.5 m.

A drawdown of water from the lake would be categorized as a "dewatering activity" under Markham's Sewer Use By-law 2014-71 which regulates quality standards for water entering the sewer system. Swan Lake water would appear to satisfy the By-law requirement that water entering the storm sewer system not be categorized as "contaminated" as defined by Table 2 within the By-law and that it falls within the acceptable pH range of 6.0 – 9.0. Notably Table 2 excludes a standard for chloride. Approval may be required to discharge the high chloride content of Swan Lake water into the downstream system.

Removal of water contaminated with nutrients and chloride would refresh the water within the lake with cleaner water from the aquifer and through precipitation. In the 1970's, once quarry operations ceased, the lake filled up naturally. As it may take 2-3 seasons for the lake to naturally refill, this process could be accelerated by pumping water into the lake from the local aquifer. A previous report noted that the static ground water level was about 9 metres below grade in Block 15, which is elevated about 3 metres above the lake level suggesting the aquifer is 5 – 6 metres below the lake surface. An analysis of the hydrology and hydrogeology involved in refilling the lake is required as well as an investigation of any possible regulatory issues related to drawing water from the aquifer.

Managed Drawdown Option

At its regulated elevation of 208.3 m, Swan Lake contains 80,000 m^3 of water. A drawdown to 207.0 m would remove approximately 44,000 m^3 or 54% of the total water volume in the lake through the downstream storm sewer system.

Since the lake outflow pipe is 1.3 m below the regulated lake surface, it should be possible to draw the lake water down by 1.3 m without the use of pumps. Pumps would be needed to remove water from areas where the water does not flow freely towards the lake outlet at 207.0 m and for removing water below 207.0 m.

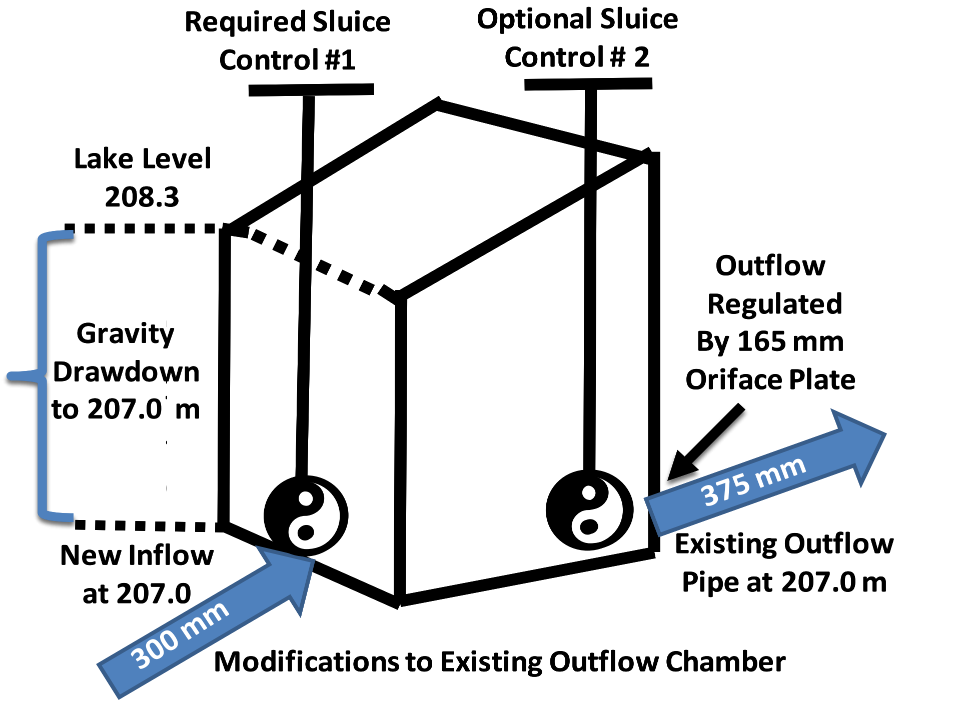
Lake Outflow Grate **Inflow from East Pond Bypass**

Two basic modifications would be required to support the gravity-driven drawdown. These modifications would not reduce the existing flood protection elements within the original design and in fact there is an opportunity to improve the flood protection mechanism by installing an additional outlet control mechanism. They include:

1. The lake is very shallow near the lake outlet. The first modification required would be to dig a 1.3 m deep trench from the lake outlet area about 10 - 20 metres towards one of the deeper areas so the lake can drain naturally down to 207.0 m. Sloping the sides of the trench would help minimize any erosion activity along the length of the trench. Near the outlet chamber, installation of 2-3 large stones should help stabilize the side slopes.
2. The second modification would be to create a new 300 mm opening in the upstream wall to enable flows into the chamber at the 207.0 m level.

   To control the flows through this new opening a Sluice Control Gate (#1) would be required. The gate would be opened only during the drawdown process – either fully or only partially depending on the rate of flow desired for the drawdown. It may be necessary to provide a platform on the existing chamber to provide operators with easy and safe access to the sluice control gate mechanisms.

Illustration of a Circular Sluice Control Device



Modifications to Existing Outflow Chamber

Though not necessary for the drawdown, installation of a second sluice control gate (#2) would provide the city with a means for stopping outflows from the lake and help alleviate downstream issues during periods of future flooding.

System Capacity Restrictions

Outflows from the Swan Lake and Swan Lake Village stormwater system are regulated at two levels by use of orifice plates. The first stage of regulating flows is at the source – at the East Stormwater Pond and at the lake outlet. Additional protection is provided at the 16th Avenue outlet where the combined pond, lake and Foundation Collector System flows leave the area and proceed south of 16th Avenue.

Orifice plates are used to reduce average flows leaving an area and to reduce surges in the outflow. An orifice plate consists of a large medal plate that is placed over a large pipe with a hole smaller than the pipe.

At the lake outlet, the orifice plate covers the 375 mm stormwater pipe, and the cutout is 165 mm in diameter. The lake level is 1.3 m above the outlet. The flow rate and volume of water that can flow through the small orifice is influenced by the water pressure. For the lake and pond this is primarily determined by the depth of water above the outlet (the "head").

The East Pond is regulated to stay at an elevation of 208.3 m but could increase by 0.5 m to an elevation of 208.8 m. during normal operations.

Detailed information is available on the expected outflows from the East Pond based on the water depth. The following table provides some estimates for the lake outlet and for the outlet to 16th Avenue based on use of an on-line calculator for flows through an orifice using the parameters specified for the East Pond. More detailed calculations would be part of a comprehensive drainage study.

	Diameter of SW Pipe	Diameter of Orifice	Area of Orifice (m2)	Depth of Water (m) (Head)		Discharge Rate (m3/s)		Discharge Volume (m3) Per Day (24 hr)	
				Max	Avg	Max	Avg	Max	Avg
East Pond Outlet	250 mm	66 mm	0.0034	1.6	0.5	0.012	0.006	1,037	518
Lake Outlet	375 mm	165 mm	0.0214	1.3	0.7	0.067	0.049	5,789	4,234
Combined Flows								6,826	4,752
16th Avenue Outlet	450 mm	190 mm	0.0284	1.0	0.5	0.078	0.055	6,739	4,752

The summary indicates that combined flows from the East Pond outlet system and the lake outlet system would support daily output volumes of 4,752 – 6,826 m^3, comparable to the flow rate supported at the 16th Avenue system. The maximum flow release from the lake outlet alone is approximately 85% of maximum outflow rate supported at 16th Avenue, so during periods of no rainfall an unrestricted release from the lake is within the system design limits for flows entering the area south of 16th Avenue.

Days to Release Water From Lake

Total Volume (m3)	Lake Discharge Rate (m3) Per Day: Avg	Lake Discharge Rate (m3) Per Day: Max
	4,234	5,789
44,000	10.4	7.6
70,000	16.5	12.1
80,000	18.9	13.8

Due to the 165 mm orifice plate, outflows from the lake are limited to a maximum of 5,789 m^3 per day.

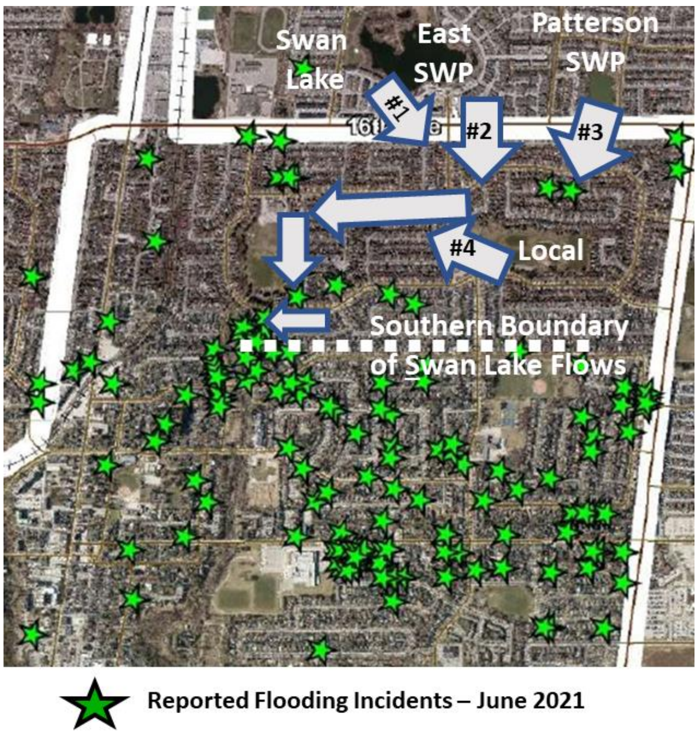
Releasing 4,000 – 5,800 m^3 every day suggests the initial release of 44,000 m^3 could be accomplished over 8 – 10 days if there are no rainfall events. The entire lake (80,000 m^3) could be drawn down in 14 – 19 days during periods of no other rainfall.

Even if the sluice gates were used to reduce the outflow to 2,500 m^3 day, full drawdown of the lake can be accomplished in 30 – 40 days. In the event of pending rain, the sluice gates provide the opportunity to completely stop the outflow from the lake at any time. The above analysis suggests that a managed daily release of lake water from 2,500 – 5,800 m^3 during periods of no rain is well within the design parameters of the stormwater system.

Areas of Concern South of 16th Avenue

Stormwater and lake outlet flows from the Swan Lake Park and Swan Lake Village flow southward through a residential area south of 16th Avenue before flowing into Mount Joy Creek in Paramount Park at Fincham Avenue and Paramount Road.

The area south of 16th Avenue down to Highway #7 has been designated by Markham as an area at risk for basement flooding and plans are in place to expand the stormwater system south of 16th Avenue in 2028 or later. Concern has been expressed about moving additional lake water into this area, particularly before the area stormwater system is expanded.



Stormwater from two stormwater ponds and water from Swan Lake join with flows from a residential area bounded on the north by 16th Avenue and on the south by Ramona Boulevard before entering Mount Joy Creek near Paramount Park.

As of June 2021, there have been only a few incidents of basement flooding reported in the servicing area.

A managed release of 2,500 – 5,000 m^3 of Swan Lake water during periods of low rainfall when there is no stormwater in the system south of 16th Avenue should avoid any downstream complications.

A technical assessment is required to determine whether a controlled drawdown of Swan Lake is feasible and if it can be done in a manner that avoids downstream issues.

Appendix D: Comprehensive Water Treatment Options

Three comprehensive water treatment options that influence 4 factors were reviewed:

I) Drawdown of the lake
II) Recycling via the North Channel
III) Industrial Filtration (i) recycling (ii) partitioning

	Nutrients		Cl	O	Factors Addressed	Restoration Timeframe	Costs
Comprehensive Water Based	P	N					
a) Drawdown	1	1	1	1	4/11	1 - 3 years	$
b) Recycling & Filtration via North Channel	1	1	1	1	4/11	10+ years	$$
c) Industrial Filtration (Recycling)	1	1	1	1	4/11	1 year	$$$
d) Industrial Filtration (Partitioning)	1	1	1	1	4/11	1 year	$$$$

I) Winter Drawdown

Drawdown, outlined in detail in Appendix B, involves the removal of a large volume of water from the lake and will remove a significant portion of the active contaminants in the lake water.

A drawdown may be an effective technique for the removal of chloride in particular. Depending on the success of rerouting stormwater flows from the lake, additional drawdowns may be required in the future to manage chloride content. To minimize the impact on aquatic life, a drawdown would be planned during the winter months. It is likely that only partial drawdowns will be feasible in the future if the aquatic life rebounds.

A drawdown is one of the lowest cost options and should impact the water borne content of phosphorus, nitrogen and chloride while the refill process should improve oxygen content.

Three primary benefits associated with drawdown:

1) Low cost.
2) Significant reduction of water contaminants over one season.
3) Exposing sediments provides an opportunity to address the contaminants in the sediments.

II) North Channel Filtration Options

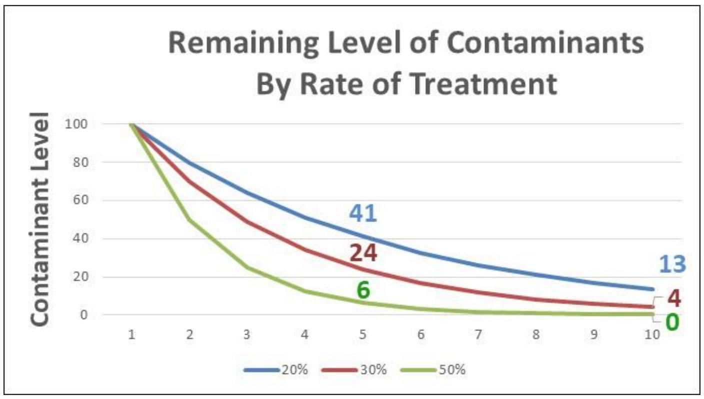
Recycling lake water via the North Channel has the potential as a low cost, sustainable tool for oxygenation.

Adding filtration mechanisms may also be an effective means to remove nutrients as part of the restoration process if the drawdown process is not used. As a restoration tool the process is likely to take several years to have a material impact on water quality. The process may be a viable alternative as a low-cost sustainable means for removing contaminants as part of the on-going sustainable process post-restoration.

Some possible filtration options:

1. In 2021, Fleming College[3] researchers suggested consideration of absorption material (such as Chlorocel, manufactured by Porocel) as a means for absorbing chloride.
1) In 2022, researchers from York University[15] submitted a proposal to Markham to evaluate the effectiveness of carbon-based filters for removing phosphorus, nitrogen, and chloride. Markham staff have indicated that this process may have merit and recommends further investigation.
2) A small industrial filtration unit outlined in the next section.
3) Expanding the existing bioswale elements of the North Channel and Turtle Inlet

A high flow rate may be required to maximize the benefits of circulation for oxygenation purposes. However, introducing a filtration process may require lower flow rates. The impact of filtration on the lake's water quality will be related to the effectiveness of the filtration process and the percentage of the lake that can be treated.

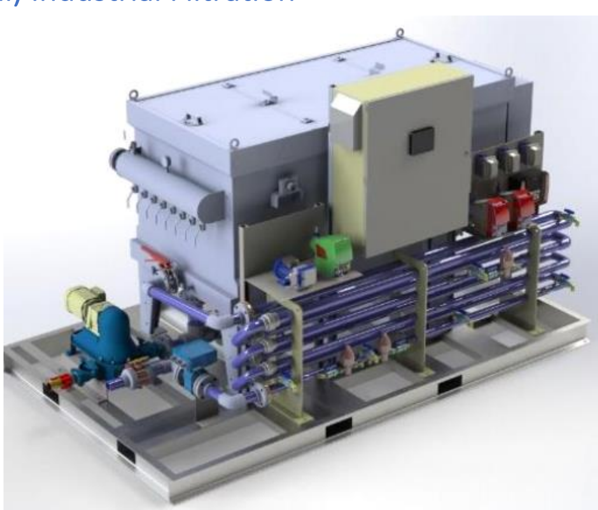


The adjacent chart illustrates that if 20% of the lake can be circulated through the channel filtration process each year and the cleaner water returned to the lake, after 5 years the nutrients in the lake could be reduced to 41% of the original levels (assuming no new inflows of contaminants).

If 50% of the lake could be filtered each year the contaminants could be brought down into the range of 6% or original levels after 5 years.

An industrial filtration unit could handle higher flow rates and may warrant consideration as a primary tool for restoration. Filtration mats or a natural bioswale are expected to be able to process lower flow rates and may be better suited for use as a long-term tool for maintaining restored water.

iii) Industrial Filtration



Veolia's ACTIFLO System

There is an established industry providing water filtration equipment to chemical and mining companies and municipalities utilizing a variety of treatment processes.

The systems are capable of producing drinking water or water suitable for release back into natural water bodies.

The equipment is typically used in permanent installations, but some equipment is available on a rental basis for site clean-up activities.

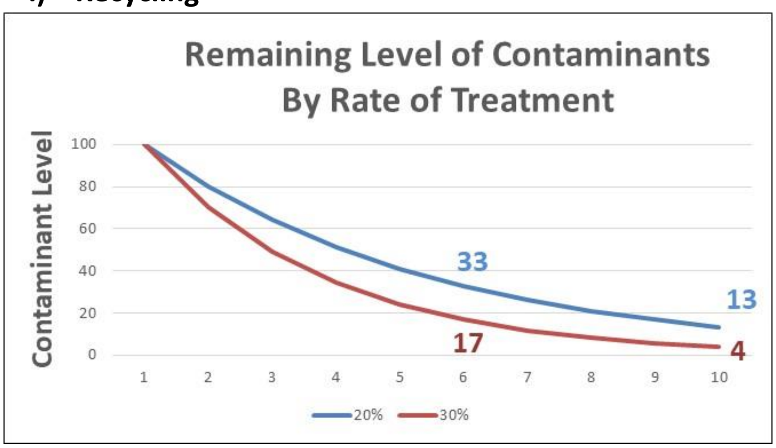
The following table summaries a sample of information available on various suppliers' websites.

Filtration Equipment Suppliers	Throughput m3/ hr	Days to Filter 80,000 m3 8 hr days	24 hr days	Equipment Purchase
H2Flow (Rental)				
a) Skid Mounted DAF Pilot	5	2,000	670	
b) Containerized DAF Pilot	10	1,000	335	
Samco Illustration				
Microfiltration (MF) and	2.3 - 4.5	2,200 - 4,400	700 - 1,500	< US $100,000
Ultrafiltration (UF) system	23 - 45	220 - 440	70 - 150	US$150 - 450k
Samco Illustration				
Nanofiltration (NF) and Reverse	1 - 2.3	4,400 - 8,800	1,500 - 2,900	< US $60,000
Osmosis systems	68	150	50	US $2 million

The permanent installation of a small scale and lower cost system (US$100,000) filtering 2 – 10 m^3/hr. could be installed in the North Channel and would be capable of processing approximately 10% - 30% of the lake volume each year.

The entire lake volume could be filtered within 1 year by renting one of the larger systems through either recycling or by partitioning the lake.

i) Recycling



Industrial units are capable of processing 20% - 30% of the lake volume per month.

By returning the cleaner water immediately back into the lake, the contaminants in the lake could be reduced to 17% - 33% of the original levels after 6 months.

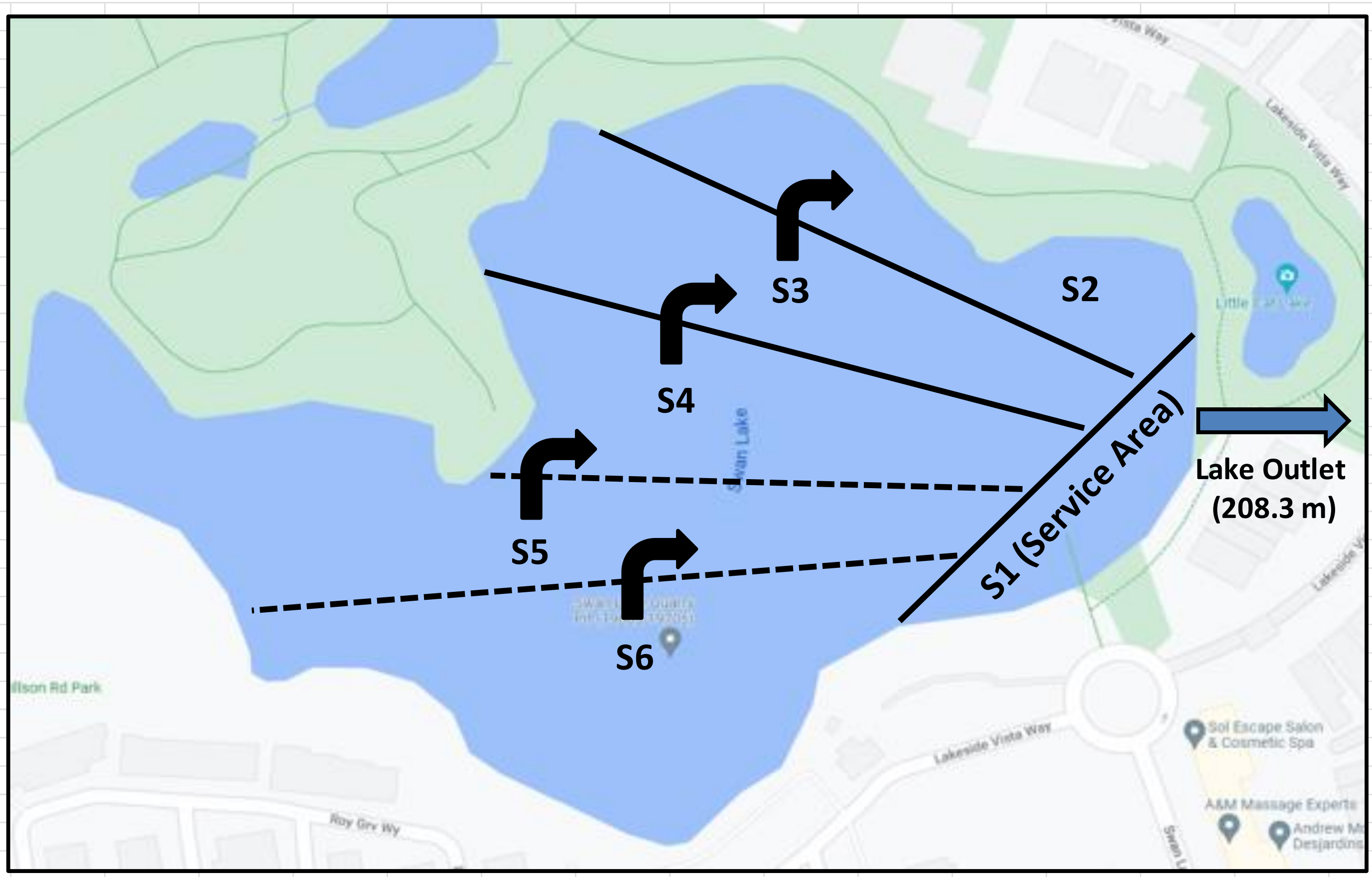
The large-scale filtration equipment has the potential to have a significant impact on water quality within one season. The costs of renting the large-scale equipment needs to be compared to the relatively low cost of a draw down which could reduce the contaminants by 50% or more.

Consideration should be given as to whether a stirring of the sediments during the filtration process would release more contaminants from the sediments increase the effectiveness of the filtration process.

ii) Partitioning

Partitioning the lake is a more expensive option than recycling filtered water or a drawdown but may be warranted in the event a drawdown of the lake is not permitted or deemed feasible. Partitioning would provide two benefits:

1) a timely means of eliminating up to 100% of the water-born contaminants.
2) provides the opportunity for sediment removal.



The process, including removal of sediments, is summarized as follows:

Step #1: Partition two sections of the lake. S1 to serve as a service area for the duration of the process. Pump untreated water from S1 and S2 back into the main lake (S4).

Step #2: Remove sediments from S1 & S2.

Step #3: Partition section S3. Remove chloride & nutrients from water in S3 and pump treated water into S2. Remove sediments from S3.

Step #4: Partition section S4. Treat water in S4 and pump treated water into S3. Barrier between S3 and S2 can be removed and reused. Once completed remove sediments from S4.

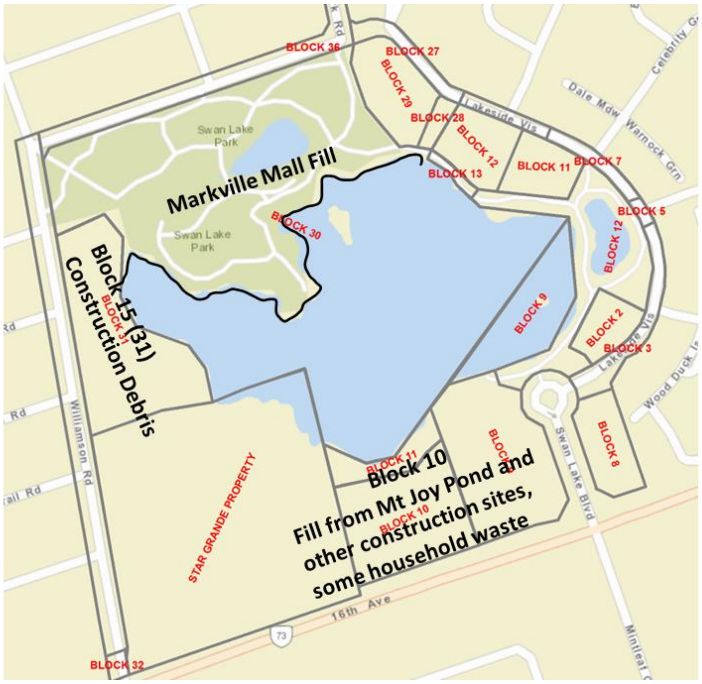
Step #5-6: Repeat until entire lake is treated.

Appendix F provides a summary of the options for managing the sediments.

Appendix E: Historical Assessment of Lake Sediments

Dumping of Fills and Household Waste

In a report dated September 1995, PetoMacCallum Ltd. identified areas where distinct stockpiles of fill materials were located:



1) Fill with construction debris apparently from indiscriminate dumping during the early 1980s was stockpiled along the west shore of the lake.
2) Fill from a 1983 pond excavation at the Mount Joy Community Centre and possibly fill from other construction sites were stockpiled in the southern parts and stockpiled on the south shore of the lake.
3) In 1998, fill comprising sandy silt from construction of the Markville Mall was stockpiled beyond the north shore.
4) Small berms consisting of stripped topsoil and native materials were created in the north part of the lake.

Other reports note the dumping of household waste along the southern shoreline. The Ontario government classified the site as a “waste disposal site" in 1984 and ordered operations to cease.

Historical Sediment Analysis

Extensive analysis of the sediments and soils were undertaken during the early stages of development. Analysis was based on Ontario’s Provincial Sediment Quality Guidelines (“PSQG”) which were designed to protect the community of organisms found in aquatic sediments.

At that time, the guidelines provided for a “Low Effect Level” (LEL) and a “Severe Effect Level” (SEL). Exceedance of the LEL had no requirement for management action.

In a report[6] dated March 1994, PetoMacCallum Consulting Engineers summarized its assessment of the potential impact of chemical quality of the lake water and sediments on aquatic life and benthic organisms. The report noted that in some test areas lake sediment had levels marginally exceeding the province’s “lowest level effect” guidelines with one exception. In borehole #206, measured concentrations of chromium, copper, lead, mercury, zinc, and phosphorus considerably exceeded the province’s “lowest effect” criteria. The report recommended that:

> “Based on these results, the fill materials in the vicinity of borehole 206 (to an approximate depth of 1.3 m below the lake bottom) are considered to be a source of lake water contamination from continued leaching. It is therefore recommended that these materials be dredged out or be capped over with clay fill during the proposed shoreline rehabilitation grading and filling activities.”

In a review dated October 2, 1995, Gartner Lee Limited commented that they agreed "that this sediment, while mildly contaminated, should not cause a problem to lake water quality".

We have not been able to confirm if the area in the vicinity of borehole 206 was dredged or capped with clay.

Remediation Efforts: Block 10 and Block 15

Remediation work was undertaken over the years for Block 10, site of the original Amica building and for Block 15 (originally known as Block 31). In both areas, methane barriers were installed to minimize migration of methane to adjacent properties.

Block 15 was filled with excess soil and construction debris during the early 1980's. Potential sources of contaminants also included petroleum related impacts from truck traffic in the 1980's and the rail spur line that was built in the 1870's. Block 15 became new parkland in 2019.

Subsequent Assessment of the Shoreline and Lake Sediments: Block 9

Block 9 was initially formed in 1995 to align exposure for undefined risk and liabilities associated with the sediment impacts. The area consists of the new Amica building and extends along the shoreline from the dock area to the northern portion of the East Pond. As of 2023, this area remains under private control.

In February 2003, Gartner Lee Limited[9] reported that the contaminants in the sediments in Block 9, along the south-eastern shoreline, are not directly related to past activities:

> *"Our review led to the conclusion that the present-day sediment quality in Swan Lake* ***is not related to past activities or historic contaminants on the lands surrounding the site.*** *[emphasis added]. We concluded that, although low levels of some contaminants were present, sediment quality did not threaten either the use of Swan Lake by aquatic life or the health of aquatic life in Swan Lake. Sediment quality was typical of that in other aquatic systems in Southern Ontario. We therefore recommend that the sediments be left in place as part of the lake system and that this could be done without threat to the aquatic environment."*

This recommendation was accepted by the Town of Markham's advisor Jacques Whitford Environmental Limited[10] in 2003 which stated that:

> ***"As the contaminants identified are only slightly above the LEL (Low Effect Level of the MOE's Provincial Sediment Quality Guidelines), it is anticipated that there would be no detrimental effect and leaving the sediments in place would be acceptable."****[emphasis added]*

A "Risk Assessment for Block 9" report dated March 2006 by Water and Earth Sciences Associates Ltd ("WESA")[12] noted that relative to Provincial guidelines there was one Chemical of Concern (COCs) related to human health and six Chemicals of Concern related to aquatic life within Swan Lake.

The chemical analysis reported uranium concentrations between 20 – 32 µg/g, compared to expected background concentrations of up 10 µg/g however the report notes that the chemical analysis used is not an accredited method for uranium and that the laboratory had indicated that the results do not warrant a high level of confidence. The report notes that at the reported level if a person were to ingest and have dermal contact with the sediment on a daily basis that the estimated risks would still be well below the maximum acceptable levels for human health for the intended use as parkland.

The six Chemicals of Concern related to aquatic life were calcium, copper, sulphur, uranium, petroleum hydrocarbons (Fraction 3) and total organic carbon. The analysis involved comparing these levels to various standards, objectives and guidelines intended to be protective of ecological receptors as well as "background" concentrations of chemicals in the environment. The maximum measured concentrations were then compared to ecological toxicity reference values. The report concluded:

> *"This shows the risks due to copper are acceptable, there is no basis for assessing calcium, sulphur or uranium and impacts are possible for Fraction 3 but warrant a low degree of confidence, and impacts are possible for total organic carbon, but other data (notably dissolved oxygen levels) indicate that the organic carbon is not causing impacts at Swan Lake."*
>
> ***" The main finding of the risk assessment is that risk management measures are not needed to reduce potential health risks to human health or to ecological receptors. This is premised on Block 9 and the rest of Swan Lake continuing to be used as a visual amenity for the community and as a storm water management facility. If activities at the lake were to change and present the potential for materially greater exposures, then a new risk assessment might to required to determine the necessity to remove, treat or otherwise manage the sediment****.[emphasis added]*

The WESA report notes that if the sediment in Block 9 were to be removed, then those involved in such activity would have greater opportunities for exposure than those considered in the risk assessment. The report outlines a proposed three step risk management plan for the protection of workers and the safe management of the sediments.

2020 Assessment of Sediments

During the fall of 2020, additional samples of the sediments were taken and tested with a focus on phosphorus content in preparation for a planned second treatment of Phoslock. An initial treatment of Phoslock, which contains lanthanum was completed in 2013.

The samples were analysed by the Institut Dr. Nowak[13], and their report described the general sediment quality as:

> *3.1 General sediment quality*
>
> *The sediment samples were analyzed for general sediment characteristics such as the dry weight, the loss on ignition at 550°C, and their elemental composition.*
>
> *The sediment character was dominated by aluminosilicates with low organic content as indicated by the high dry weight percentages (average DS 52%) and low LOIs (average 3,6%). Metal concentrations of iron, manganese and calcium were comparably low (averages Fe 13500 mg/kg DW; Mn 335 mg/kg DW). Lanthanum concentrations were elevated (173 mg/kg DW), because of treatments with lanthanum modified bentonite in the past. Also sulfur concentrations were low, in line with the low LOI results.*

Phosphorus concentrations were moderate, with an average of 700 mg/kg DW, ranging from 1050 mg/kg DW (Site 10, 0-5 cm) up to 420 mg/kg DW (Site 10, 5-10 cm). Phosphorus concentrations seem to be correlated to LOI, which stands for the proportion of organic matter.

Updated Sediment Guidelines

In 2008, the Ontario government updated its sediment guidelines to be consistent with the Federal guidelines for the Great Lakes. The updated Ontario guidelines note that “sediment chemistry is often used only as an initial screening tool “ and that other tools “such as sediment bioassays, benthic community evaluation and biomagnification potential are crucial in the assessment of sediments for dredging, cleanup or monitoring.”

In 2020, Ontario released guidelines[17] called Rules for Soil Management and Excess Soil Quality Standards for the management of sediments.

If the Swan Lake sediments are to be disturbed, then a more comprehensive review of the sediments, particularly Block 9, will be required to determine whether there are any concerns under the new Ontario guidelines and a risk mitigation plan will be required for the safe management of the sediments.

Appendix F: Sediment Removal Options

Limitation of Cleaning or Drawing Down the Lake Water

Aquatic life is undermined by the excessive amount of chloride and the low levels of oxygen in the water. Industrial filtration of the lake water or the drawdown of the lake will have a significant impact on reducing chloride levels in the water and the restored water should have a higher oxygen content.

The significance of the sediments as a storage area for chloride is not known but the sediments are known to be an active storage facility for phosphorus and nitrogen and thus a significant continuing contributor of nutrients that will stimulate future algae growth. When the algae die in the fall, the process consumes oxygen thus unless the phosphorus and nitrogen are removed from the sediments, issues with algae and low oxygen levels can be expected to continue.

Recent research studies [A1, A2] have concluded that it is important to address both phosphorus and nitrogen.

The current chemical program readily impacts the phosphorus in the water column, but repeated treatments are required to neutralize the phosphorus within the sediments. The current long-term water quality plan assumes repeated chemical treatments over the next 25 years will be required just to maintain the lake at an oligotrophic level. A provision of $1.4 million has been included in the life-cycle reserve fund for chemical treatments.

Removal of the sediments would significantly reduce the challenges of restoring water quality in Swan Lake.

Efforts are underway to minimize the inflow of road salt by rerouting some of the stormwater flows away from the lake. Even if successful, inflows of road salt will be a long-term factor undermining the environmental health of the lake. Canada Geese will continue to contribute phosphorus and nitrogen to the lake. Even if the sediments are removed there may still be the need for future partial drawdowns of the water or continuing chemical treatments unless other programs such as oxygenation, restocking of algae eating fish and the restoration of aquatic plants prove to be effective management tools.

Quality of Sediments and Risk of Seepage

Appendix E provides a summary of the historical assessments of the sediments. An updated review of the Swan Lake sediments will be required to determine whether there are any concerns under the new Ontario guidelines that may impact the options outlined below.

Consideration will also have to be given the impact of Ontario's "Rules for Soil Management and Excess Soil Quality Standards" [17] on the management options outlined below.

In addition, the Swan Lake Long-Term Management Plan raised concerns about the potential for contaminants to seep into the lake from the various landfill sites along the shoreline. Options for storing sediments along the shoreline have the potential to help mitigate this potential risk.

Quantity of Sediments

Water filled the former gravel pit in the 1970's. It existed as a self-contained pond with no outlet until stormwater connections were added in the mid 1990's. Sediment has been building over its 50-year existence as a pond and chloride from road salt over the last 25 years.

Lake Parameters	Surface Area	Volume of Water
Maximum Elevation 209.2 m	5.48 ha (13.5 acres)	102,000 m3
Regulated Elevation 208.3 m	4.84 ha (11.9 acres)	80,000 m3

One early report on the sediments noted that sediment depth ranged from 0.15 m to 0.35 m. and that they were deeper along the southern shoreline due to prevailing wind action. The 2020 sediment analysis reported that the lakebed was hard, with limited amount of sediment to collect in most areas. For that analysis, samples were taken up to 10 cm.

The 2021 Swan Lake Long-term Plan provided data on the depth and volume of water in Swan Lake and the lakebed exposed at various depths. It is estimated that a drawdown of the lake to 207.0 m will remove 54% of the water and expose 59% of the lakebed. Additional efforts could be undertaken to pump water down to 206.0 m which removes 88% of the water and exposes 88% of the sediments. Full drainage would occur at 204.5 m.

Drawdown to	**207.0 m**	**206.0 m**	**204.5 m**
Volume of Water Removed (m3) *	44,000	70,000	80,000
Area of Lakebed Exposed (m2) *	28,000	43,000	48,000
% of Water Removed	54%	88%	100%
% of Lakebed Exposed	59%	88%	100%
Average Sediment Depth	**Sediment Volume (m3)**		
20 cm	5,600	8,600	9,600
35 cm	9,800	15,050	16,800
* Source: Swan Lake Long-term Plan November 2021, Page 5			

If the lake water is drawn down to 207.0 m., it is estimated that the volume of sediment exposed ranges between 5,600 m^3 (if sediment averages 20 cm deep) and 9,800 m^3 (if sediment averages 35 cm deep).

Drawing the water down to 206.0 m will expose 8,600 m^3 of sediment (if sediment is 20 cm deep) or 15,050 m^3 (if sediment is 35 cm deep). A full draw down would expose 9,600 – 16,800 m^3.

Four options were considered:

1) Do nothing, leave the sediments in place. Deal over time with the release of nutrients and other contaminants in the sediments.
2) Remove elements of concern onsite and return sediments to the lakebed.
3) Remove and truck the sediments to another site.
4) Remove the sediments and store them around the shoreline of Swan Lake.

Common project costs, which included collecting and drying of sediments and general management costs, were assumed to be $0.6 million for a drawdown to 207.0. For removal of additional water to 206.0 m, common project costs were increased to $0.8 million to reflect the need for pumps and additional challenges in dealing with irregular terrain on the lakebed surface. To fully drain the lake to 204.5 m, common project costs were assumed to be $1.0 million to address the additional challenges.

Storage and removal costs were added to the common project costs based on estimates of storage and removal costs and volume of sediments. The following summary illustrates the relative costs of the alternatives considered.

Option # 1: Leave Sediments in Place

Leaving the sediments in place is clearly the lowest cost short-term option but it would require continuation of the current chemical treatment program which is budgeted to be $1.4 million over the next 25 years. This option represents the least effective restoration technique because sediments are a known storage house for phosphorus, nitrogen and chloride but it provides a cost benchmark from which other alternatives can be assessed.

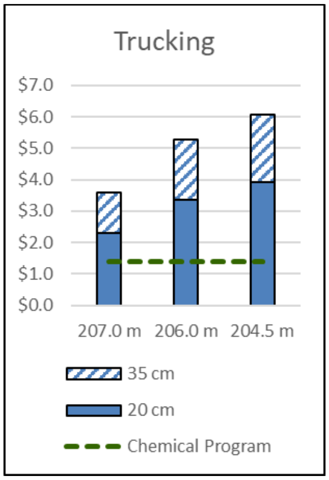
Option #2: Remove Contaminants and Return to Lakebed ("In situ" treatment)

It may be feasible to remove some of the contaminants on site and return the cleaned sediments to the lakebed. The effectiveness and the relative cost of this option would need to be determined and compared to the costs of the alternative solutions. A cost benchmark was not available, but it is assumed this approach will be more expensive than storing the sediments on site but cheaper than removal by truck.

Option #3: Truck Sediments to a Land-fill Location

Sediment removal and relocation is a relatively common practice when cleaning stormwater ponds. A 2016 guide prepared by the Toronto and Region Conservation Authority summarized the process and expected costs associated with cleaning stormwater ponds. Markham typically cleans 1 - 2 stormwater ponds per year and estimates removal costs of $300 per m^3 for projects of up to 2,000 m^3. The TRCA guide quotes on-site storage rates of $15 m^3. The amount of sediment in Swan Lake is more than 5x the typical volume removed from a stormwater pond so lower rates may be attainable. The following calculations used $300 per m^3 for trucking to an off-site landfill and $25 m^3 for onsite storage.

Removal to Offsite Storage							
Lake drawdown to		**207.0 m**		**206.0 m**		**204.5 m**	
Average Sediment Depth		**20 cm**	**35 cm**	**20 cm**	**35 cm**	**20 cm**	**35 cm**
Sediment Volume		5,600	9,800	8,600	15,050	9,600	16,800
# Truckloads @ 10 cu m		**560**	**980**	**860**	**1,505**	**960**	**1,680**
Project Costs		$0.6	$0.6	$0.8	$0.8	$1.0	$1.0
Removal Costs	$300.00	$1.7	$2.9	$2.6	$4.5	$2.9	$5.0
Total Cost		**$2.3**	**$3.5**	**$3.4**	**$5.3**	**$3.9**	**$6.0**



Utilizing dump trucks that can carry 10 m^3 of sediment to remove the sediment would require 560 – 1,680 truckloads depending on the extent of the drawdown and the depth of the sediments.

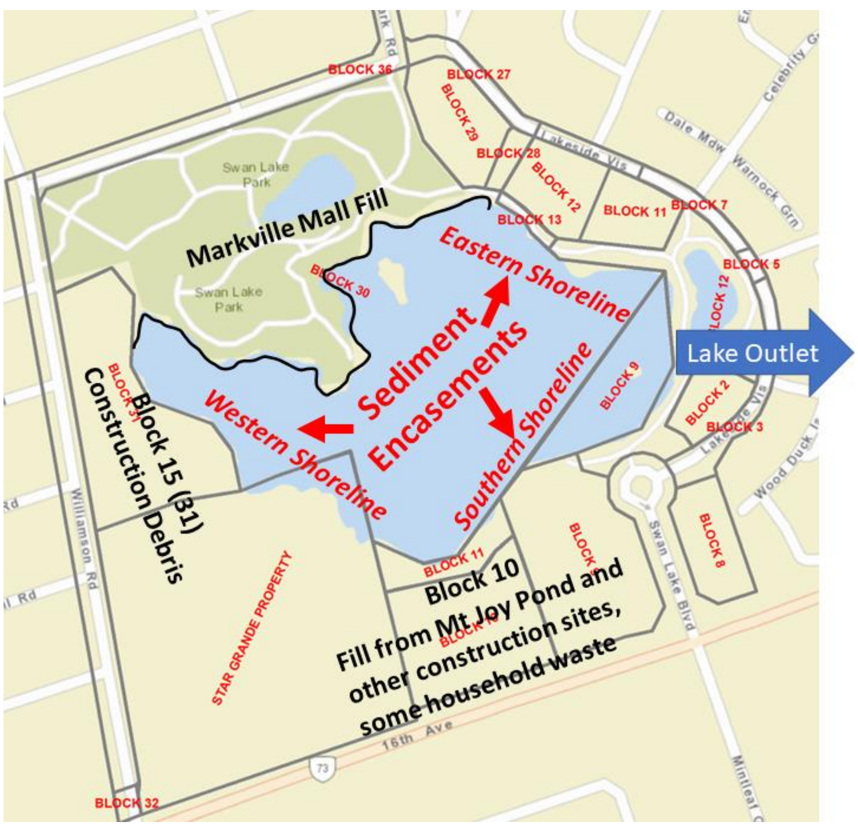
Assuming project management costs of $0.6 million and removal costs of $300 per m^3, the total project and removal costs could be in the range of $2.3 - $3.5 million if the lake is drawn down to 207.0 m which is above the $1.4 million budgeted for the chemical program.

Costs for total drawdown and removal would range between $3.9 - $6.0 million.

Option #4: Encase the Sediments within Swan Lake

To avoid the costs of trucking and relocation of the sediments, a more cost-effective method would be to gather the sediments and encase the sediments along the shoreline of Swan Lake.

Design work on restoring the shoreline is already underway to curb the resident population of Canada Geese. Use of the shoreline for storage of sediments would need to incorporate the objectives of the shoreline restoration program but the costs outlined below may permit reduction in some of the costs planned for the shoreline restoration.



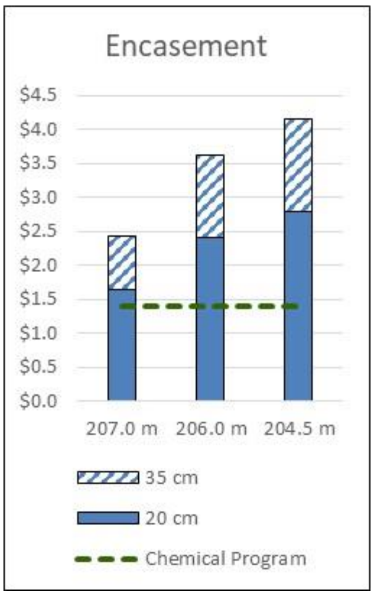
Enclosing the shoreline has a potential additional benefit.

Concern has been expressed about possible seepage from former dump sites around the lake. The impermeable seals or concrete encasements should minimize the chance of seepage of contaminants from the former sites and remove another possible complication.

Two possible approaches were considered for storing the sediments on site:

a) Concrete Encasement

Concrete Encasement Along Swan Lake Shoreline						
Lake drawdown to	**207.0 m**		**206.0 m**		**204.5 m**	
Average Sediment Depth	**20 cm**	**35 cm**	**20 cm**	**35 cm**	**20 cm**	**35 cm**
Sediment Volume	5,600	9,800	8,600	15,050	9,600	16,800
Project Costs	$0.6	$0.6	$0.8	$0.8	$1.0	$1.0
Removal Costs (50%) $300.00	$0.8	$1.5	$1.3	$2.3	$1.4	$2.5
Onsite Storage (50%) $75.00	$0.2	$0.4	$0.3	$0.6	$0.4	$0.6
Total Cost	**$1.7**	**$2.4**	**$2.4**	**$3.6**	**$2.8**	**$4.2**



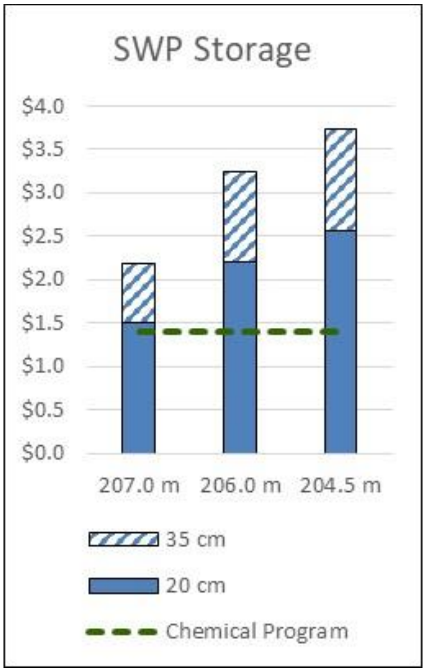
One option is to create concrete encasement areas as part of the shoreline to hold the sediments. Given the higher construction costs, we have assumed a cost equal to 25% of the removal costs ($75). We also assumed 50% onsite storage and 50% removal to a landfill site providing an estimate of $1.7 - $2.4 million for a drawdown to 207.0 m.

Depending on the extent of the drawdown, the costs are slightly or significantly greater than the costs of the planned chemical program. The additional costs of the concrete encasement may be justified if it is found to provide greater protection to seepage from former dump sites or provides some benefits to the shoreline restoration program.

b) Sediment Storage Using Stormwater Pond Techniques

Costs Using SWP Approach Along Swan Lake Shoreline						
Lake drawdown to	**207.0 m**		**206.0 m**		**204.5 m**	
Average Sediment Depth	**20 cm**	**35 cm**	**20 cm**	**35 cm**	**20 cm**	**35 cm**
Sediment Volume	5,600	9,800	8,600	15,050	9,600	16,800
Project Costs	$0.6	$0.6	$0.8	$0.8	$1.0	$1.0
Removal Costs (50%) $300.00	$0.8	$1.5	$1.3	$2.3	$1.4	$2.5
Onsite Storage (50%) $25.00	$0.1	$0.1	$0.1	$0.2	$0.1	$0.2
Total Cost	**$1.5**	**$2.2**	**$2.2**	**$3.2**	**$2.6**	**$3.7**

Another option is to use a process like that used to store stormwater pond sediments on site. A layer of impermeable plastic would be laid down and the sediments placed on top and then covered with another impermeable layer, providing a sealed container to minimize leeching. Alternatively, the sediment could be put into impermeable bags. Landscaping can then be added.



The TRCA guideline suggested \$15 per m^3 for onsite storage of sediments removed from a stormwater pond. For our analysis, we have assumed \$25 per m^3 for onsite storage and assumed 50% of the sediment must be removed to a landfill site at a cost of \$300 per m^3.

Costs are estimated to range from \$1.5 - \$3.7 million. Onsite storage is the lowest cost option. A removal of 50% of the sediment would provide a more comprehensive solution at costs equal to or slightly greater than the chemical program.

This analysis suggests that the lake could be drained down to 207.0 m (exposing 59% of the lakebed,) and all sediments stored for less than the cost of the chemical program. The limiting factor may be the ability to find sufficient storage along the shoreline so a full drawdown may require removal of some portion of the sediments.

If onsite storage can be found for 5,000 m^3, then 51% - 89% of the sediments exposed during a drawdown to 207.0 m could be stored onsite or 33% - 58% if the drawdown is to 206.0 m. Onsite storage of 8,000 m^3, would be sufficient to store 48% - 83% of the sediments for a drawdown to 204.5 m.

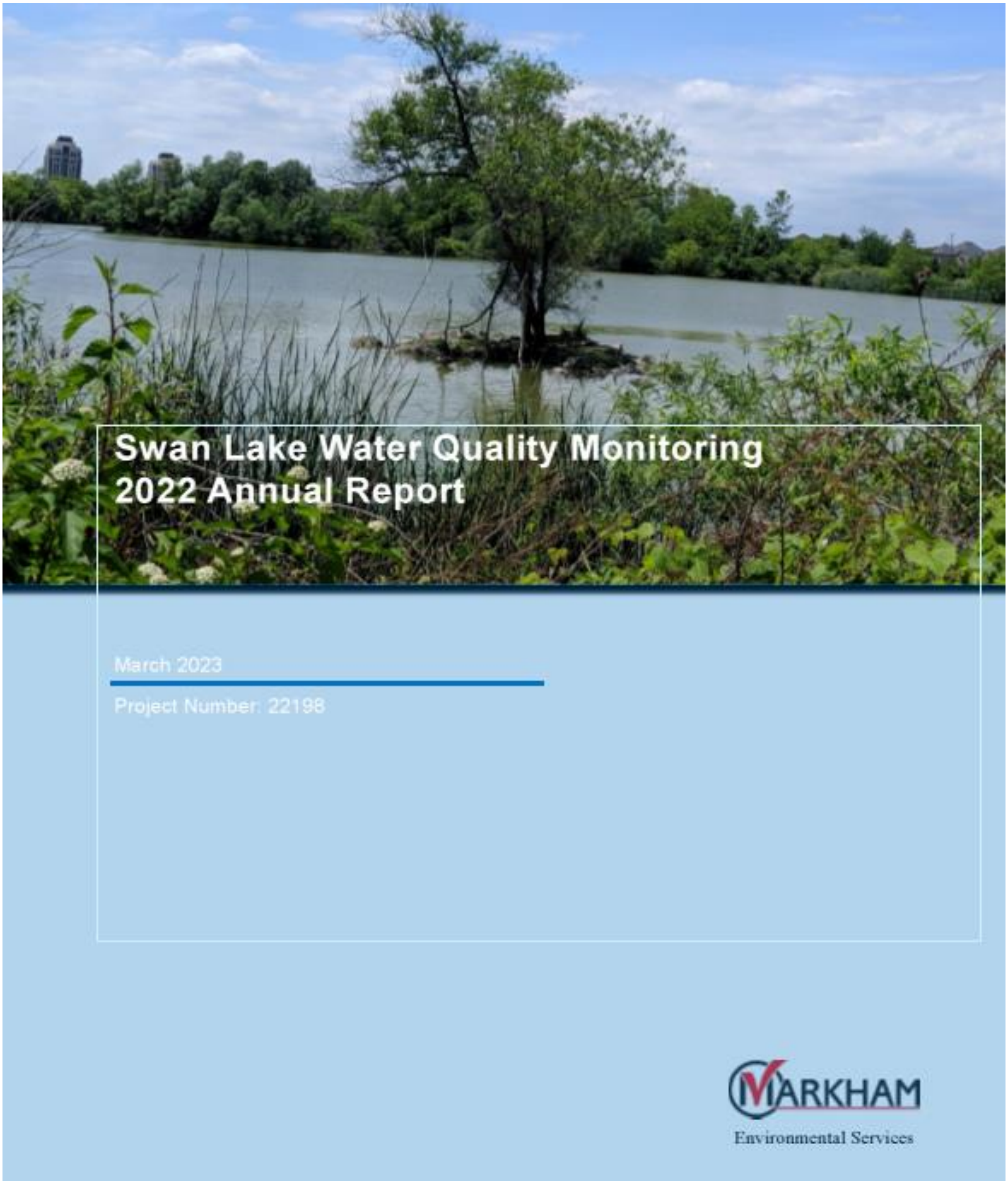
Estimate of Sediment Volume (M3)						
Lake drawdown to	**207.0 m**		**206.0 m**		**204.5 m**	
Lake Bed Exposure (m2)	28000		43000		48000	
Average Sediment Depth	**20 cm**	**35 cm**	**20 cm**	**35 cm**	**20 cm**	**35 cm**
Sediment Volume	5,600	9,800	8,600	15,050	9,600	16,800
Onsite Storage Capacity	**% Stored Onsite**					
5,000 m3	89%	51%	58%	33%	52%	30%
8,000 m3	143%	82%	93%	53%	83%	48%

Comparison of Options

The cost of having to remove or store the sediments must be considered in the context of whether the treatment would substantially displace the ongoing costs of the current chemical program. The sediments have built up over the 50-year history of Swan Lake. The core question becomes even if the option of removal or encasement of the sediments is more costly, would it provide a more sustainable solution over the next 25–50 years and provide the potential to maintain the lake at an improved and sustainable mesotrophic level.

Sediment Removal Options	**Nutrients** P	**Nutrients** N	**Cl**	**O**	**Factors Addressed**	**Restoration Timeframe**	**Costs**
a) Disposal Offsite (100%/0%)	1	1	1	1	4/11	1 year	\$2.3 - \$6.0 m
b) Concrete Encasement Onsite (50%/50%)	1	1	1	1	4/11	1 year	\$1.7 - \$4.2 m
c) SWM Storage Onsite (50%/50%)	1	1	1	1	4/11	1 year	\$1.5 - \$3.7 m

Appendix G: Executive Summary 2022 Water Quality Monitoring Report



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Executive Summary

Background

Swan Lake is situated in the City of Markham at the intersection of Sixteenth Avenue and Williamson Road. Swan Lake has an approximate area of 5.5 ha and a maximum water depth of 4.5 m (from the edge of the Lake at 210 MASL). A gravel pit in the 1960s and 1970s, Swan Lake is currently a community feature with multiple trails and urban development surrounding it.

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

In 2019, the City of Markham conducted a study to define a Water Quality Management Strategy for Swan Lake. The Strategy, finalized in July 2020, recommended a chemical treatment in 2021.

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

The Swan Lake Long-Term Management Plan was received by the Markham Sub Committee in November 2021 and approved by the Council in December 2021. It describes a phased adaptive approach, including provisions for chemical treatment every three years. Activities planned for 2022 included enhanced geese management, fish removal, water quality monitoring, and investigation of additional measures to improve water quality in the Lake.

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

In 2022, sampling for chloride measurement was also conducted at several locations to determine the relative contribution of each source to the Lake.

This report discusses observations at the monitored stations in the Lake and several runoff stations throughout 2022.

Results- Lake Water Quality

Water quality is regularly monitored at two shoreline sites: the Dock and the Bridge, on a bi-weekly basis (from April to November). Samples and measurements are taken at 0.5 m or 1m increments for the depth of the lake. A level logger is used to record the water level in the Lake.

The following paragraphs provide the monitoring results for the 2022 monitoring period, as well as annual summaries of available data from 2011 to 2022. The figures include plots of measured dissolved oxygen (DO), water clarity, phosphorus concentration, chloride concentration, and geese count.

Targets

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

Dissolved Oxygen (DO), Temperature, and pH

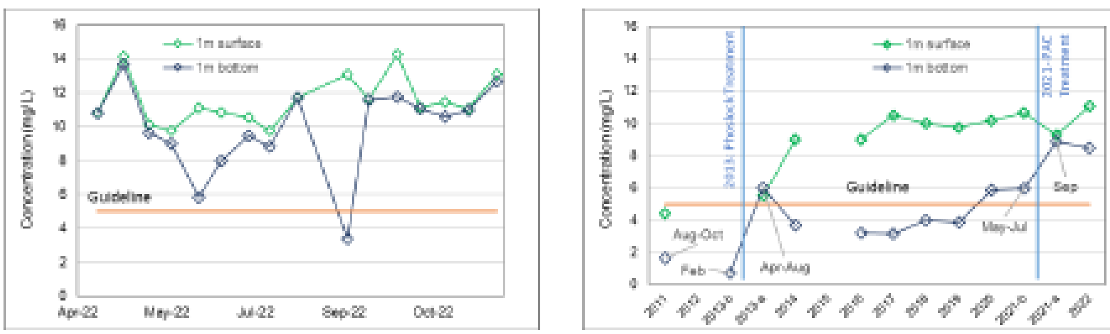
The minimum dissolved oxygen concentration required for the protection of warm water fish is 5 mg/L for water temperatures up to 20 °C, and 4 mg/L for temperatures above 20 °C. DO concentrations for the 1m from the surface and 1m from the bottom layers are shown below.

Measured day-time surface concentrations were above the DO guideline throughout 2022 (above 9.5 mg/L). DO concentration at the bottom layer was also above the guideline, except for two measurements at 2.2 and 3.4 mg/L, which occurred on dates when the water column was thermally stratified.

Lower DO concentrations could have lethal or sub-lethal (physiological and behavioral) effects on fish; however, some fish can acclimate to lower oxygen levels and survive concentrations between 1 and 3 mg/L.

Although measured DO levels did not indicate anoxia during the sampling events, its decline at the bottom of the water column could suggest that if the stratification persisted, it could have led to anoxic episodes (at night when respiration occurs), contributing to the release of nutrients from the sediments. Such potential occurrence would, however, be less severe than pre-treatment conditions as implied from the annual trend of day-time surface and bottom concentrations.

Figure ES-2: 2022 Monitoring Results and 2011-2022 Annual Results- Dissolved Oxygen



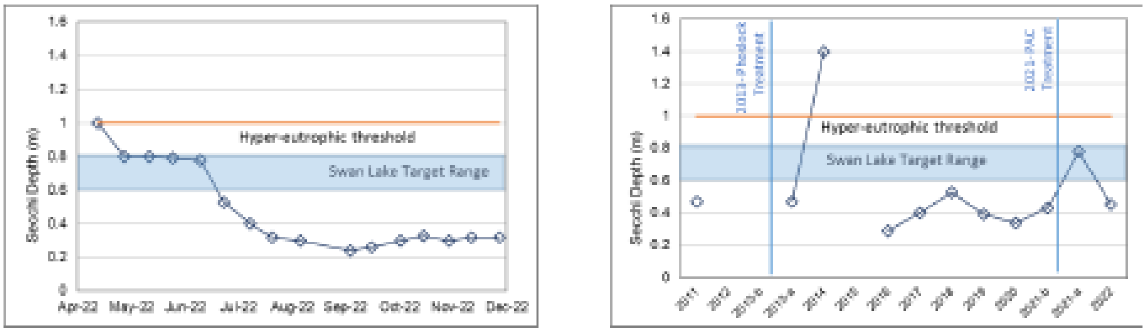
Note 1: DO concentrations are shown at 1 m from the surface (average of 0.5 and 1 m) and 1 m from the bottom (average of two bottom depths).
Note 2: Historical data are shown for the average growing period (June-Sep) unless otherwise indicated.

pH measured at the lab ranged from 7.5 to 9.4 throughout the year. High pH is consistent with high levels of algae. Algae take up carbon dioxide, a weak acid, from the water for photosynthesis, causing the water to become more basic (higher pH).

Water Transparency (Secchi Depth)

Secchi depth represents water transparency, which declines when the algae level increases. In the trophic state classification scheme, growing period average water clarity of under 1 m is the threshold for a hyper-eutrophic condition. The proposed interim target for Swan Lake is 0.6-0.8 m based on correlation with the phosphorus target. In 2022, water clarity was above 0.5 m until the end of June but dropped to below 0.4 m for the remainder of the monitoring period.

Figure ES-3: 2022 Monitoring Results and 2011-2022 Annual Results- Secchi Depth

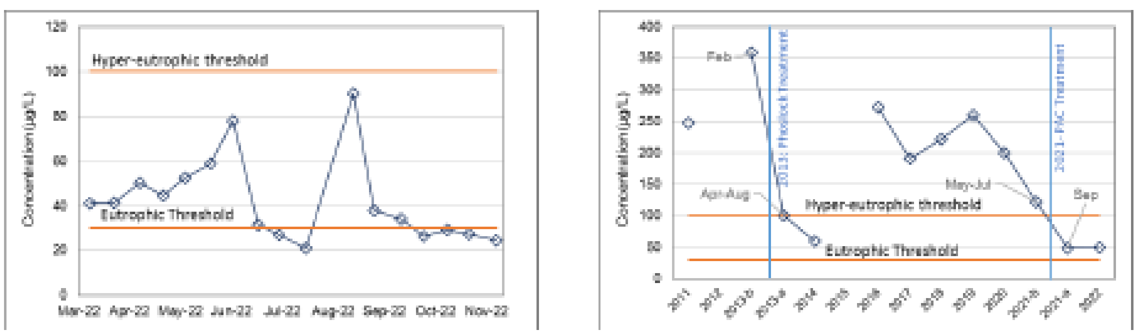


Phosphorus and Nitrogen Concentrations

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

Phosphorus concentrations above 100 µg/L represent a hyper-eutrophic condition, which lead to high algae concentrations. Total phosphorus concentration in the top 0.5 and 1.5 m depths averaged under 50 µg/L during the growing season (under the 100 µg/L threshold for a hyper-eutrophic condition, and below the interim target of 50-100 µg/L). There was significant improvement in phosphorus concentrations after treatment by Phoslock and PAC.

Figure ES-1: 2022 Monitoring Results and 2011-2022 Annual Results- Total Phosphorus



Note 1: The 2022 values are averages of samples collected at 0.5 and 1.5 m from the surface.
Note 2: Annual concentrations are summaries of the growing period (June-Sep) unless otherwise indicated.

Total nitrogen concentrations over the growing season averaged about 0.60 mg/L (below the 1.2 mg/L threshold for a hyper-eutrophic condition). In 2022, ammonia and nitrate concentrations (the forms available for uptake by biota) were generally very low (except in April), and nitrogen was mainly present as organic matter.

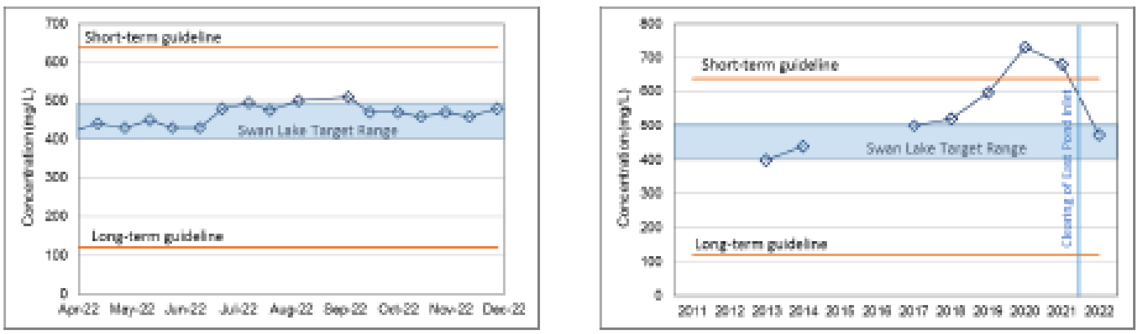
Chloride Concentration

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

Chloride guidelines developed for generic environmental data include a long-term guideline (120 mg/L) and a short-term guideline (640 mg/L). The long-term guideline has been developed to protect all organisms (present in Canadian aquatic systems) against negative effects during chronic indefinite exposure. The short-term guideline aims to protect most species against lethality during a sudden hike in chloride concentration for an acute short period (24-96 hrs). These guidelines may be over-protective for areas with an elevated concentration of chloride and associated adapted ecological community. For such circumstances, it has been suggested that site-specific (higher) targets be derived considering local conditions such as water chemistry, background concentrations, and aquatic community structure. The interim target for chloride is 400-500 mg/L consistent with 2013-2014 values.

In 2022, chloride levels reduced considerably compared to 2021, likely due to clearing the blockage at the East Pond inlet, which resulted in lower catchment flows from the inlet bypass to the Lake. The lower water level in the summer may have resulted in more concentrated amount of chloride starting from end of June.

Figure ES-4: 2022 Monitoring Results and 2011-2022 Annual Results- Chloride



In 2022, water samples were collected from various inlets to the Lake and analyzed for chloride. The mass balance established using these data is documented in a separate report.

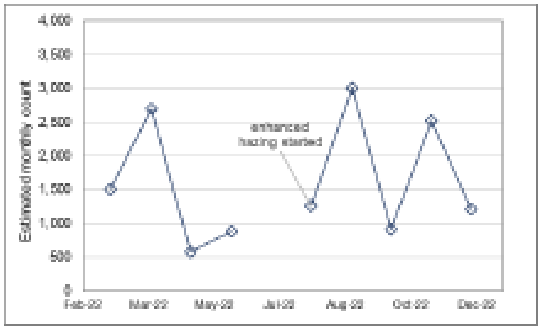
Geese Count

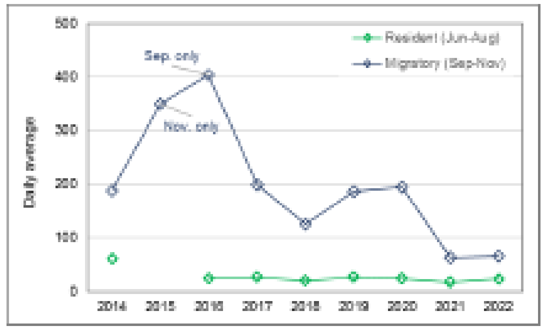
Geese are the primary external source of nutrients in the Lake. Therefore, active geese management is completed annually. The geese control program started in 2014, focusing on resident geese. The program extended to the management of migratory geese in 2016.

The 2022 program included a hazing program in the Spring, with an expanded version starting in mid-August to mid-December, nest management and geese relocation, the installation of nine strobe lights on the Lake and adjacent stormwater ponds, and geese count program.

In 2022, the increased hazing efforts were very effective in reducing the number of migratory geese visiting the Lake, similar to those achieved in 2021 when the extended program started. The strobe lights did not have any noticeable impact on the counts. The geese count data helped provide more certainty in the results, and were used to more effectively schedule hazing efforts.

Figure ES-5: 2022 Monitoring Results and 2011-2022 Annual Results- Geese Count





Note 1: 2022 data are the sum of counts in each month, compensated for days with no count.
Note 2: Annual trends are shown as daily averages of counts over June-August and September to November, representing resident and migratory geese, respectively.

Other management activities completed in 2022 included a fish inventory, the removal of bottom-dwelling fish to reduce sediment disturbance, and Phragmites management through spraying and physical removal.

Algal Growth

In 2022, limited surface scums were observed along the shoreline around the Dock, as well as in the northern bay at the Bridge site. While the Lake was dominated by phytoplankton from late June, surface scums were not widespread.

Samples were collected and sent to the laboratory for phytoplankton and cyanobacteria. Test results showed lower diversity and higher total counts compared to 2021.

Several algal blooms with potentially toxic cyanobacteria were observed in years before 2011; however, testing completed before 2011 and following treatment (2013-2016) did not detect any Microcystin in the water. In 2016, a bloom was tested and resulted in a Microcystin concentration of 73 µg/L. Extended blooms were observed at several sites in 2018; however, cell density was at half of WHO's threshold for significantly increased human health risk. These results suggest that in most years, toxin-producing cyanobacteria are not the dominant form of phytoplankton in Swan Lake. In recent years, Abraxis tests have resulted in Microcystin levels below the recreational limit (20 µg/L, recently updated to 10 µg/L).

Summary and Recommendations

Overall, the management activities in 2021/2022 that focused on the significant nutrient loadings identified in the water quality improvement study (i.e., chemical treatment and fish management to reduce internal loads and geese management to reduce external loads), were effective at improving water quality in the Lake as shown in reduced phosphorus concentrations and improved dissolved oxygen levels. These improvements represent a positive step towards improving the aquatic habitat in the Lake and meeting the long-term water quality goals.

In 2022, chloride levels decreased considerably compared to 2021, likely due to clearing the blockage at the East Pond inlet, which resulted in lower catchment flows from the inlet bypass to the Lake.

While internal and external source controls successfully reduced nutrient concentrations, the Lake was dominated by phytoplankton, and water clarity did not improve. This could be partly due to the absence of submerged aquatic vegetation (SAV), which has been replaced by phytoplankton (algae) due to low water clarity.

The 2023 monitoring program will follow the recommendation of the Long-Term Management Plan. Additional measures will be investigated for the return of SAVs to the Lake, as well as strategies to reduce chloride concentration in the Lake.

Appendix H: Summary of Swan Lake Long-term Management Plan (2021)

In December 2021, Markham Council approved a Long-term Water Management Plan (the "Plan") for Swan Lake. The Plan is based on an evolving "adaptive" management approach and focuses on the reduction of algae through actions to reduce phosphorus as the critical nutrient spurring the algal growth. Following are extracts and summaries of the long-term plan.

6.3 Goal Statement and Level of Service

Based on the review of applicable policies and strategies, as well as input received from stakeholders, a narrative was developed as a goal statement for water quality management in Swan Lake, as follows:

To improve the overall health of Swan Lake, which will provide opportunities for no-contact activities for the enjoyment of the community.

Numerical values were developed as interim targets in 2019 (Freshwater Research, July 2020). The targets are further improved through the recent analysis of treatment scenarios (Freshwater Research, August 2021) and considering the Lake and watershed characteristics and beneficial uses that are practically achievable.

Table 8 lists the proposed interim targets. These targets are proposed to be achieved within the next five years after which the management plan will be reviewed and updated.

Table 8: Proposed Interim Targets for Swan Lake for the next five years

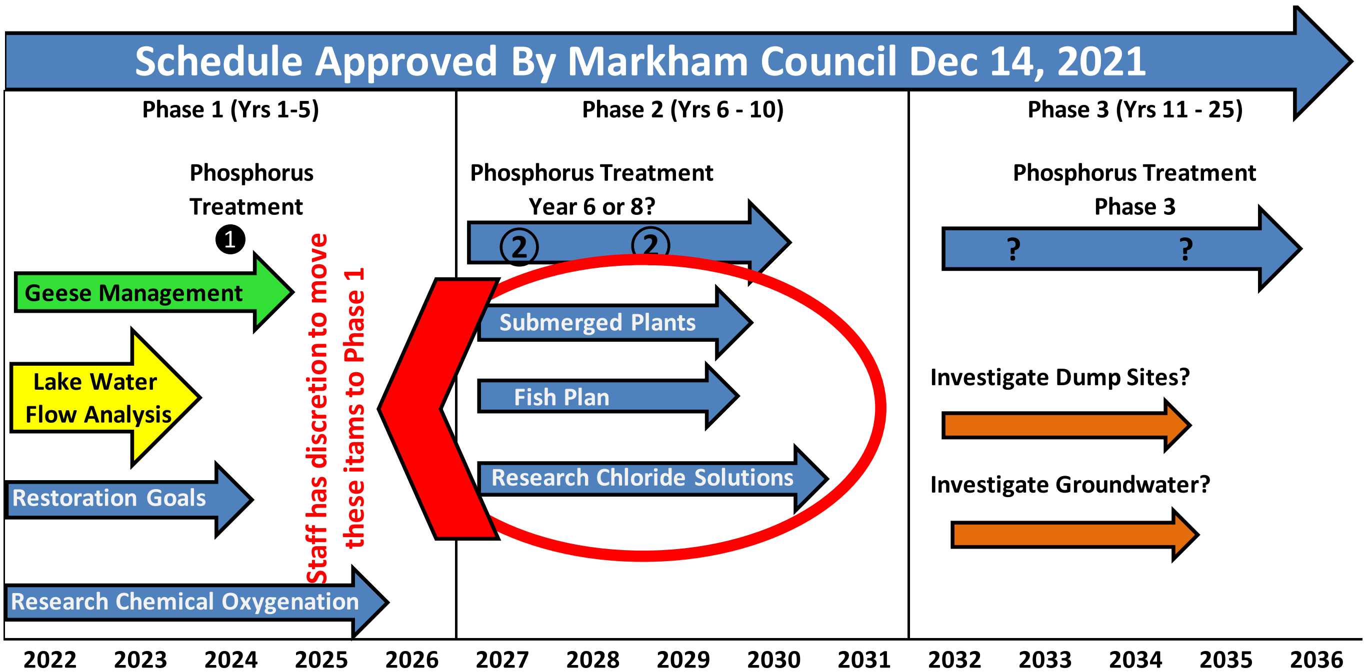
Parameter	Current Values	Interim Target	Objective and Rationale
Total phosphorus (µg/L)	>200	50–100	Current value: the average of growing season TP values in the period since 2016 has been 200. Interim target: will provide a low eutrophic condition in the first year after treatment increasing to eutrophic in year three
Secchi Transparency (m)	<0.5 m	0.6-0.8 m	Based on correlation with the phosphorus target. Secchi is also a substitute for Chlorophyll a.
Chloride Concentration (mg/L)	700	400-500	Chronic guideline for the protection of aquatic life (120 mg/L) is not achievable at this time. Target: to remain below acute guideline (640 mg/L) and close to 2013-2014 values of about 400 mg/L.
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 concentration target (see above)
External phosphorus load (kg/yr)	30	15	

8.1 Summary of Evaluation of Optional Measures

Table 9 provides a summary of measures evaluated in Section 7 for feasibility, effectiveness, and costs over 25 years. Costs include projects completed in 2021.

Table 9: Evaluation of Optional Measures

Issue	Measure No.	Description	Technical Feasibility and Effectiveness	Unit Cost
Internal Load	IL1	Chemical Treatment for Phosphorus Control	Feasible; lowers nutrient input from the most significant and bioavailable source and hence the most immediate and effective solution.	$150,000 per full application (three-year intervals)
	IL2	Bottom-Dwelling Fish Management	Feasible; lowers internal load release.	$18,000 initial $5000 annually
	IL3	Nitrogen Control (by pumping & treatment or artificial wetlands)	Water pumping and treatment will result in increased water temperature, and significant disturbance of the area. Artificial wetlands provide geese habitat and promote settling of solids beneath the mats. Nitrogen will be controlled by lowering productivity through other management measures, and does not need targeted treatment.	Significant
External Load	EL1	Geese Management (including Toogood Pond)	Feasible; lowers nutrient input from the most significant external source.	Existing measures: $27,000 annually New measures: $40,000 annually
	EL2	Stormwater Management Ponds Maintenance (2 wet ponds)	Feasible; lowers nutrient input; currently maintained by the developers and, once ponds are assumed, by the City.	$1500 annually $500,000 cleanout ($33,000 annualized)
	EL3	Shoreline Planting/ Improvements	Feasible; lowers nutrient input by blocking geese access to the Lake, intercepts nutrient runoff	$35,000 design $125,000 implementation
	EL4	Groundwater and historic dumping areas	Groundwater requires extensive investigation. A study of the dumping areas will involve the developers and private owners; low priority	Significant
Oxygen Level	OL1	Mechanical or chemical oxygenation	Mechanical circulation will have negative impacts because of sediment disturbance and nutrient release. Calcium peroxide may be used in a pilot project.	Pilot project TBD through a research institute
Chloride Level	CL1	Winter Maintenance on Private Land	Stakeholder engagement for snow and salt management will help reduce chloride concentration.	Privately funded
	CL2	Physical or Biological Treatment	Existing methods are not very effective; New technologies may be considered when proven effective.	TBD
	CL3	Redirecting Stormwater	Involves private landowners and York Region and detailed study to assess impacts/feasibility, and chloride levels may not impact desired aquatic biota; low priority.	Significant
Natural Features	NF1	Shoreline Planting/ Improvements	Feasible; will provide fish habitat	See EL3
	NF2	Planting of Submerged Water Plants	Feasible; will help solidify sediment and provide fish habitat	TBD
	NF3	Fish Management Plan and Fish Stocking	Feasible; once water quality improves.	TBD for the Plan MNDMNRF for Fish Culture program



Review #1 (Year 2 - 3)

1) Monitor success of 2021 treatment
2) Decision on Lake Flow Analysis
3) Decision on "Restoration" goals
4) Decision on oxygenation options
5) Decision on timing of next treatment

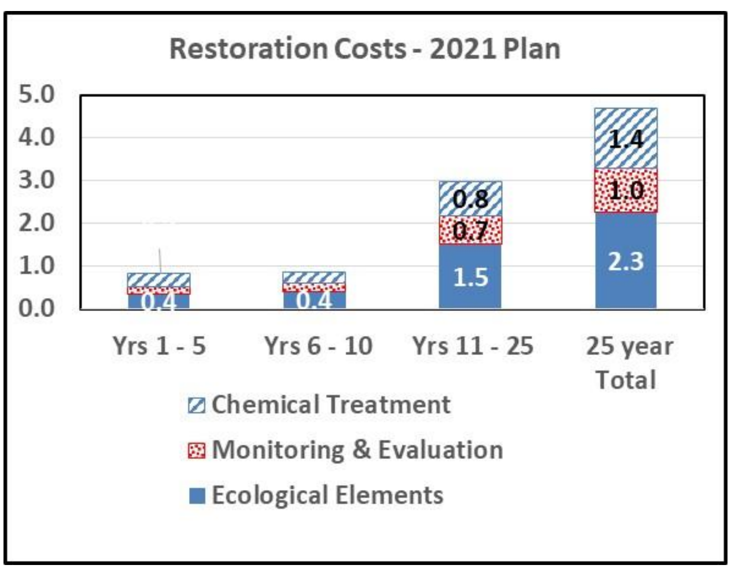
Review #2 (Year 5 - 6)

1) Assess targets and program
2) Decision on plants, fish
3) Decision on chloride options

Review #3 (Year 10)

1) Assess targets and program
2) Decision on Dump Sites
3) Decision on Groundwater

Restoration Costs



The Plan provides for $4.7 million for water quality restoration over the next 25 years.

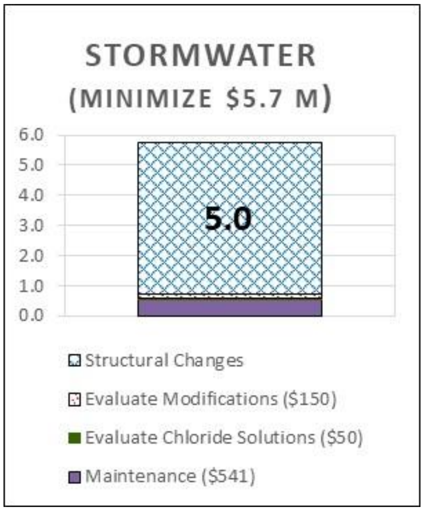
The budget provision in Markham's Life-Cycle Reserve Fund includes $2.3 million (49%) for Ecological Elements including geese management and restoration of fish and aquatic plants.

Another $1.0 million (22%) is provided for water quality monitoring and site testing and $1.4 million (29%) for ongoing chemical treatment program for phosphorus.

The current plan does not include estimates of the costs for restoring the shoreline but provides an outline of potential additional costs related to rerouting stormwater flows and addressing potential issues related to former dump sites.

Stormwater Management Costs

In addition to the water quality program, the long-term budget includes $541,000 for future stormwater pond management and $50,000 for investigation into options for removal of chloride.

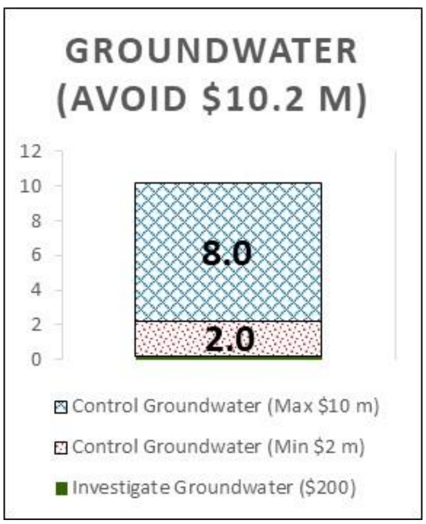


Finding a cost-effective approach for reducing stormwater inflows is an essential component of a restoration program.

Markham Council recently approved $150,000 for investigation into the feasibility of rerouting the stormwater away from the lake. Results are expected in 2024.

The long-term plan indicates a potential cost of $5 million for rerouting stormwater flows. It is expected that the technical investigation underway will provide a refinement to this estimate in 2024.

Potential Dump Site Related Costs



If it is determined that seepage from the old dump sites is undermining restoration success, the plan has indicated that costs for addressing groundwater issues could be in the range of $2.0 - $10.0 million.

Development of a comprehensive plan for restoration should endeavour to minimize or avoid issues that may trigger costs related to the dump sites. Storage of sediments along the shoreline near the dump sites could possibly reduce the risk of seepage from the dump sites.

The following table outlines the specific budget allocations in the life-cycle fund.

Table 10: Life-Cycle Cost Estimate (Assuming 2% Annual Inflation)

Some future costs are included as nominal values for perspective- see footnotes.

Core

Complementary

Alternative

Measure	Phase 1	Phase 2	Phase 3	Total	Current Life-Cycle (2021)	Increase Over Current Life-Cycle
Continue water quality monitoring	$149,356	$ 164,901	$ 605,013	$ 919,270	$ 87,095	$ 832,175
Continue geese management and enhanced	$275,037	$ 383,582	$ 1,407,339	$ 2,065,958		
Remove benthic-dwelling fish	$ 38,608	$ 28,165	$ 103,336	$ 170,109	$1,017,325	$ 1,218,742
Maintenance of stormwater management	$ 4,591	$ 8,284	$ 528,374	$ 541,249	$ -	$ 541,249
Chemical treatment with adjusted frequency	$309,181	$ 261,141	$ 806,227	$ 1,376,549	$1,763,350	$ (386,801)
Fish management plan and fish stocking **	$ -	$ 20,000	$ -	$ 20,000	$ -	$ 20,000
Planting of submerged plants **	$ -	$ 20,000	$ -	$ 20,000	$ -	$ 20,000
New technologies for chloride treatment **	$ -	$ 50,000	$ -	$ 50,000	$ -	$ 50,000
Investigate dumping areas	$ -	$ -	$ 20,000	$ 20,000	$ -	$ 20,000
Investigate groundwater **	$ -	$ -	$ 200,000	$ 200,000	$ -	$ 200,000
Control groundwater loading**	$ -	$ -	$ 2,000,000 to $10,000,000	$ 2,000,000 to $10,000,000	$ - $ -	$ 2,000,000 to $10,000,000
Evaluate structural modifications **	$ -	$ -	$ 200,000	$ 200,000	$ -	$ 200,000
Implement structural modifications **	$ -	$ -	$ 5,000,000	$ 5,000,000	$ -	$ 5,000,000
Evaluate measures	$ 25,000	$ 27,602	$ 33,647	$ 86,249	$ -	$ 86,249
Option 2 - 25-year cost with Alternative Measures	$801,772	$ 963,675	$10,903,936 to $18,903,936	$12,669,383 to $20,669,383	$2,867,770	$ 9,801,613 to $17,801,613
Recommended Option 1 - 25-year cost without Alternative Measures			$ 3,450,289	**$ 5,215,736**		**$ 2,347,967**

Notes:
* Assumed 25% decrease in five years and 25% in 10 years (not reduced from Phase 2 due to climate change impact).
** Values are order of magnitude and are rough estimates for perspective.
Assume pond cleanout/retrofit during the period.