Friends of Swan Lake Park

Focused on Rehabilitation of Swan Lake and Swan Lake Park

From this

to This

Markham Subcommittee

July 29, 2024

Request That The Committee:

1) Approve staff recommendations for continuing with current plan
2) Approve York U. CIFAL proposal for Citizen Science Lab
3) Follow through on TRCA's shoreline recommendations and community's request for $730,000 over the next 1-3 years for:
   a) Shoreline fencing ($125,000)
   b) Two recreational nodes with benches ($360,000)
   c) A new viewing location overlooking the western shoreline ($225,000)
   d) Six benches along southern and western shoreline ($20,000)
4) Support the community effort to raise $60,000 for research for the 2026 Lake Management Plan review by:
   a) Providing two tribute boards in Swan Lake Park
   b) Committing $15,000 in seed funding for lake management research
   c) Supporting staff and FOSLP pursuit of community, regional, provincial and federal funding

Partnering with the Markham Lions Club

April 2024: Lions and FOSLP Install 9 Birdhouses

May 2024: Mark Cullen donates tomatoes to Lions and FOSLP

Sustaining Biodiversity
First Residents: Tree Swallow

Thank you to Markham's park staff for installing the posts

Ongoing Park Improvements

- Children's Playground Upgraded 2023
- Brush cleared along shoreline (Mar 2024)
- Ongoing path and dock maintenance
- Bridge replacement underway
- Markham Lions Club reports Swan Lake Park to be one of cleanest parks they support

THANK YOU MARKHAM!

Discussion Outline

1) **Shoreline Enhancement**
2) 2024 Research Submissions
3) 2023 Water Quality Report
4) 2026 Swan Lake Plan Review

Primary Objective: Shoreline Enhancement

a) **Request $730,000 for Shoreline Enhancement**

More benches, two new recreational nodes, western viewing node, geese fencing

b) **Update David Plant: email May 7, 2024**

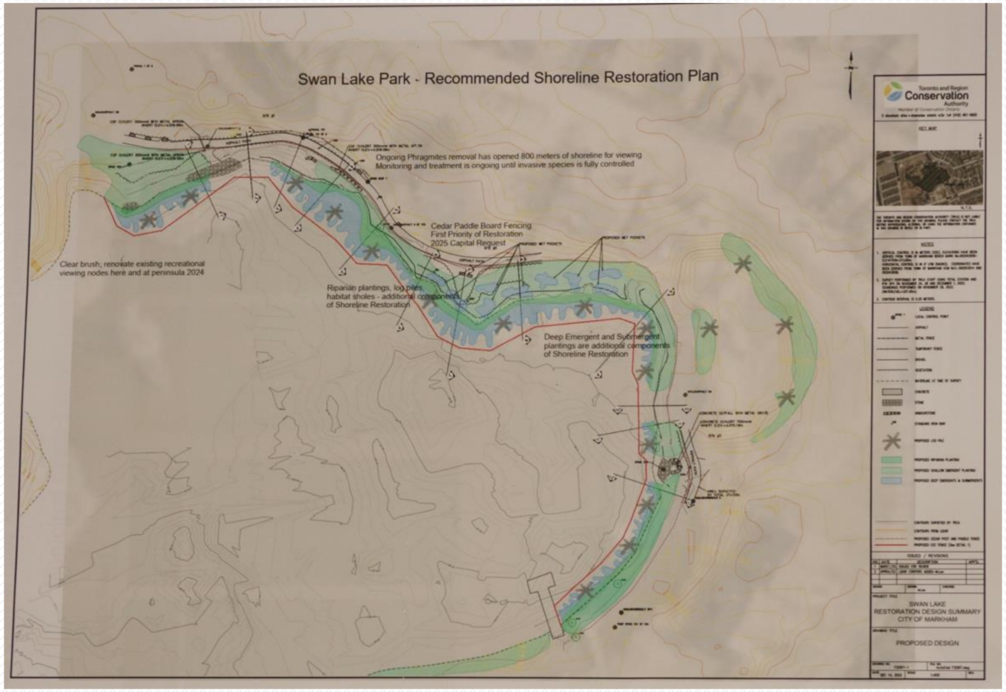
Given the number of areas to view the water compared to Toogood Pond staff do not support additional recreational nodes at Swan Lake.

1) Capital costs for TRCA style viewing nodes is $179,000
2) Will propose $125,000 fencing along eastern shoreline

SWAN LAKE 80% LARGER THAN TOOGOOD POND WITH VERY RESTRICTED VIEWING AREAS

Shoreline Restoration – Fencing ($125,000)

- TRCA had recommended use of stoneware along the eastern shoreline.
- Staff recommend lower cost fencing similar to Toogood Pond



TRCA's Shoreline Restoration Goals (2022)

√ Removal of invasive species (phragmites) **– almost completed**

√ Reducing waterfowl access to shoreline **- with fencing similar to Toogood**

X Improved shoreline access ("viewing & recreational nodes") **– not needed**

TRCA Recommendations (April 2022)

Recommended four new recreational nodes with benches for viewing

Two Benefits:

1) Increased water access for residents & fishers
2) Less conflict between fishers and residents on the dock

Markham staff:

Not needed, already have more viewing areas than Toogood Pond but doesn't resolve human conflict.

TRCA Example

Existing Swan Lake Dock A Popular Venue

For Marriage Proposals **And Sunsets**

Toogood Pond has 3 comparable lookout features

Existing Viewing Areas: Limited Visibility

E1: Existing Elevated Viewing (to be retrofitted)

- Not accessible, no benches

E2: Existing Elevated Viewing (to be retrofitted)

- Better accessibility

Upgrade Existing Recreational Node N1

- Primary access area
  - for fishing
  - land access point for geese
- Shoreline overgrown, poor viewing from benches on opposite side of path
- Needs TRCA style upgrade to support resident access

Existing Recreational Node N2

- Only Accessible Viewing Area Other Than Dock
- Traditionally overgrown, still needs improved viewing

Eastern Pathway/Bench Viewing Locations

Pathway Near Swan Club

Across from Recreational Node N2

New Features Proposed for Western Shoreline

New Recreational Node (N5) Near Amica & Townhomes

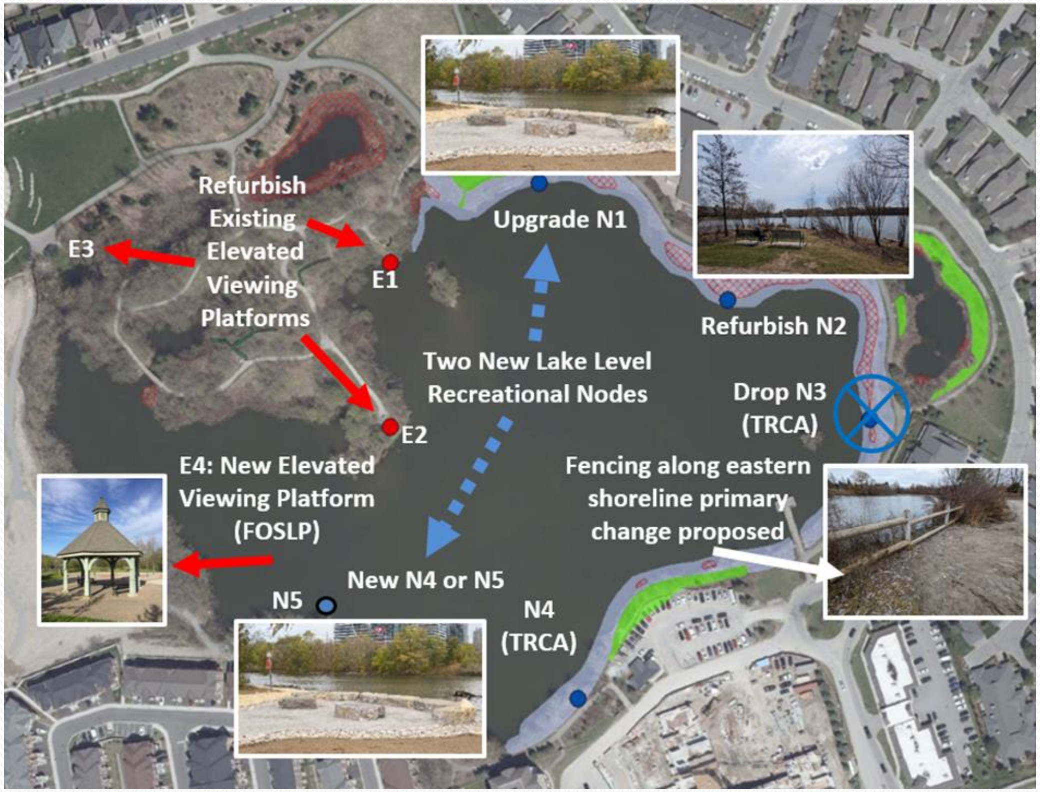
Original park plan recommended multiple points for fishing access along the shoreline

New Viewing Area (E4) Overlooking the Lake

Original park plan included recommendations for a dock along the western shoreline

FOSLP Proposed 2024 Recommendations

- Two new recreational nodes N1 & N5
  - Rather than 5
- Refurbish N2 – provide unrestricted views
- Add Gazebo (E4) as viewing area on western shoreline
- Install low-rise fencing provided it does not obstruct viewing areas



Swan Lake Shoreline Questionnaire

June 2024 124 Respondents

1) The invasive phragmites have been removed. (Choose 1)

96% I believe removing phragmites was an improvement for Swan Lake

4% I believe the phragmites should have been left alone

2) The TRCA recommended the use of stonework along the shoreline to restrain geese access to the shoreline. Markham staff is proposing lower cost fencing for geese restraint.

46% I support the use of stonework to restrain the geese (cost not known)

43% I support the use of lower cost fencing to restrain the geese. (cost estimate $125,000)

11% I believe there should be no effort to restrain the geese

Swan Lake Shoreline Questionnaire

3) In 2022, the TRCA recommended 4 new recreational nodes and FOSLP requested an additional node along the western shoreline. In 2024, FOSLP is recommending two new recreational nodes be added along the shoreline. (Choose 1)

19% I support the 2022 recommendations for installing 5 recreational nodes (cost estimate $900,000)

65% I support FOSLP's 2024 recommendations for installing 2 recreational nodes (cost estimate $360,000)

16% I support Markham staff recommendations that no new nodes be added (cost nil)

4) At present there is no view of the lake from the pathway along the western shoreline which is about 3-5 m above the water level. FOSLP recommends that a new elevated viewing area along the western pathway be added to provide residents on the western side of the park with a view of the lake. (Choose 1)

80% I support FOSLP's recommendation for a new elevated viewing platform on the western shoreline. (FOSLP cost estimate $225,000)

20% I do not support the installation of a new viewing platform on the western pathway.

Shoreline Enhancements: Capital Cost Estimates

	Additional Capital Cost Estimates		
	TRCA & FOSLP (April 2022)	**FOSLP** (June 2024)	**Markham Staff** (May 2024)
Shoreline Fencing for Geese	$125,000	$125,000	$125,000
Lakeside Viewing Nodes for the People	$900,000 (5)	$360,000 (2)	nil
Viewing Platform (Western Pathway)	$225,000	$225,000	nil
Six Pathway Benches	$0	$20,000	nil
Estimated Capital Cost *	**$1,250,000**	**$730,000**	**$125,000**

* Markham staff estimates. Excludes costs for improving existing sites

1) **Determine if development funds available**
2) **Please approve $730,000 to support the community's request for new access & viewing locations and more benches!**
   - **84% requested new recreational nodes**
   - **80% requested a western lookout**

Discussion Outline

1) Shoreline Enhancement
2) **2024 Research Submissions**
3) 2023 Water Quality Report
4) 2026 Swan Lake Plan Review

FOSLP Research Contributions

1) York U. research into biochar filtering underway
2) Four research initiatives in 2024
    i. York CIFAL: Swan Lake Citizen Lab
    ii. Benthic Invertebrate Monitoring
    iii. U of Toronto students' assessment of water quality options
    iv. McMaster University – alternative to PAC

CIFAL York Proposal

Swan Lake Citizen Science Lab (Drone Monitoring)

Project Leader: Professor Ali Asgary, Director CIFAL York
CIFAL York based in York Markham campus

York Region Involvement with CIFAL York

CIFAL York one of 31 UN approved training centres

1) Advisory Board Members from York Region
   - Wayne Emmerson, Chairman & CEO, York Region
   - James MacSween, Chief, York Region Police
   - Janel Smith, Program Manager, Community Investments, York Region

1) Several projects within York Region underway

Swan Lake Citizen Science Lab Objectives

1) **Citizen Science and Community Engagement Lab:**

   Empower the local community to participate in environmentally friendly activities and scientific drone-based data collection and AI-Based data analytics through creation of a Citizen Science & Community Engagement Lab Initiatives.

2) **Co-monitoring the Lake:**

   Utilize drone and AI technologies to monitor water levels, ecological changes, and water quality in Swan Lake, providing valuable continuous data to inform conservation efforts.

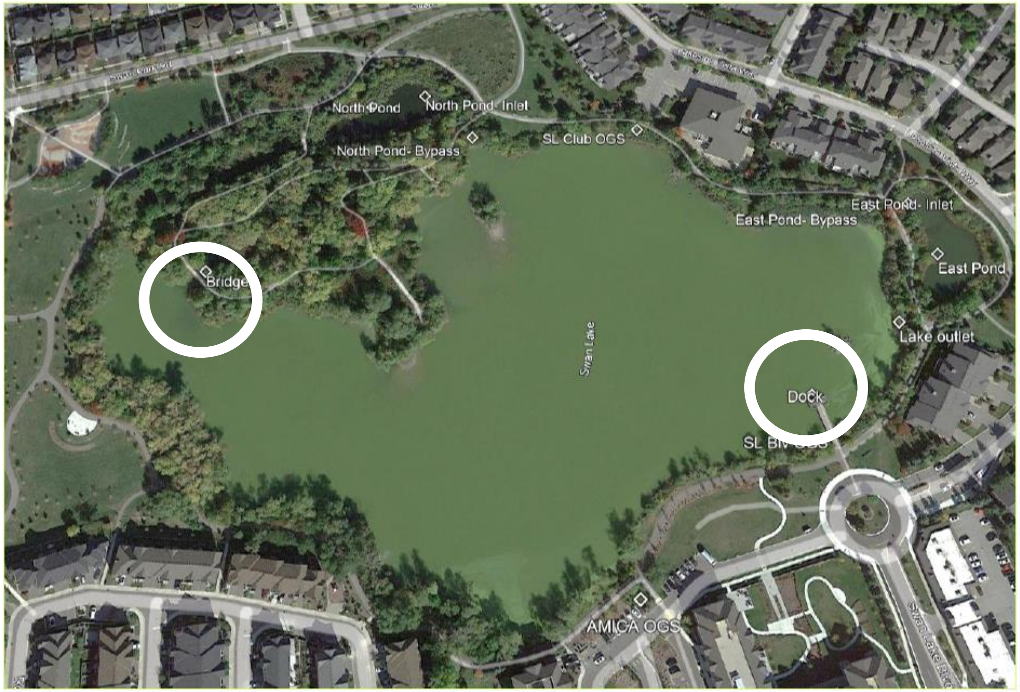
3) **Co-creating Documentary Films:**

   Create documentary films to raise awareness about the ecological importance of Swan Lake Park, the threats it faces, and the efforts to preserve and restore its wetlands.

Drones Will Provide More Extensive Testing

- Current testing for algae only at bridge & dock areas
- Testing for total algae content taken infrequently
- Drones can monitor the entire lake and report on algae levels by area and more frequently

Figure 1: Swan Lake and Runoff Monitoring Stations



Markham's Support for CIFAL Project

- FOSLP will assist with co-ordinating project discussions with Markham staff and CIFAL over the summer
- Markham requested to permit:
  1) Drone mapping by York U researchers
  2) Drone mapping by community volunteers
  3) Collection of water samples
  4) Release of information and images for public education and awareness
- Investigate potential use of information for Swan Lake rehabilitation plans
- No funding required
- Potential to incorporate other environmental elements

Swan Lake Benthic Invertebrate Monitoring

Chris Reeves
January 12, 2024

Commissioned by

Friends of Swan Lake Park

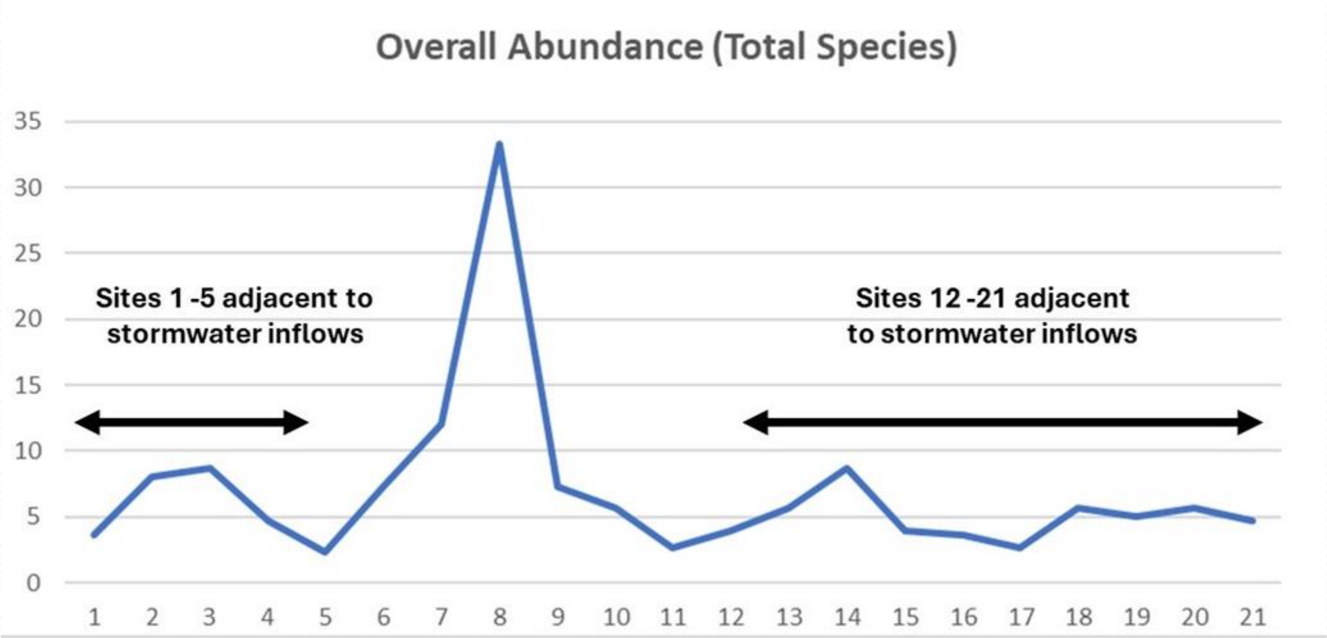
Summer 2023:

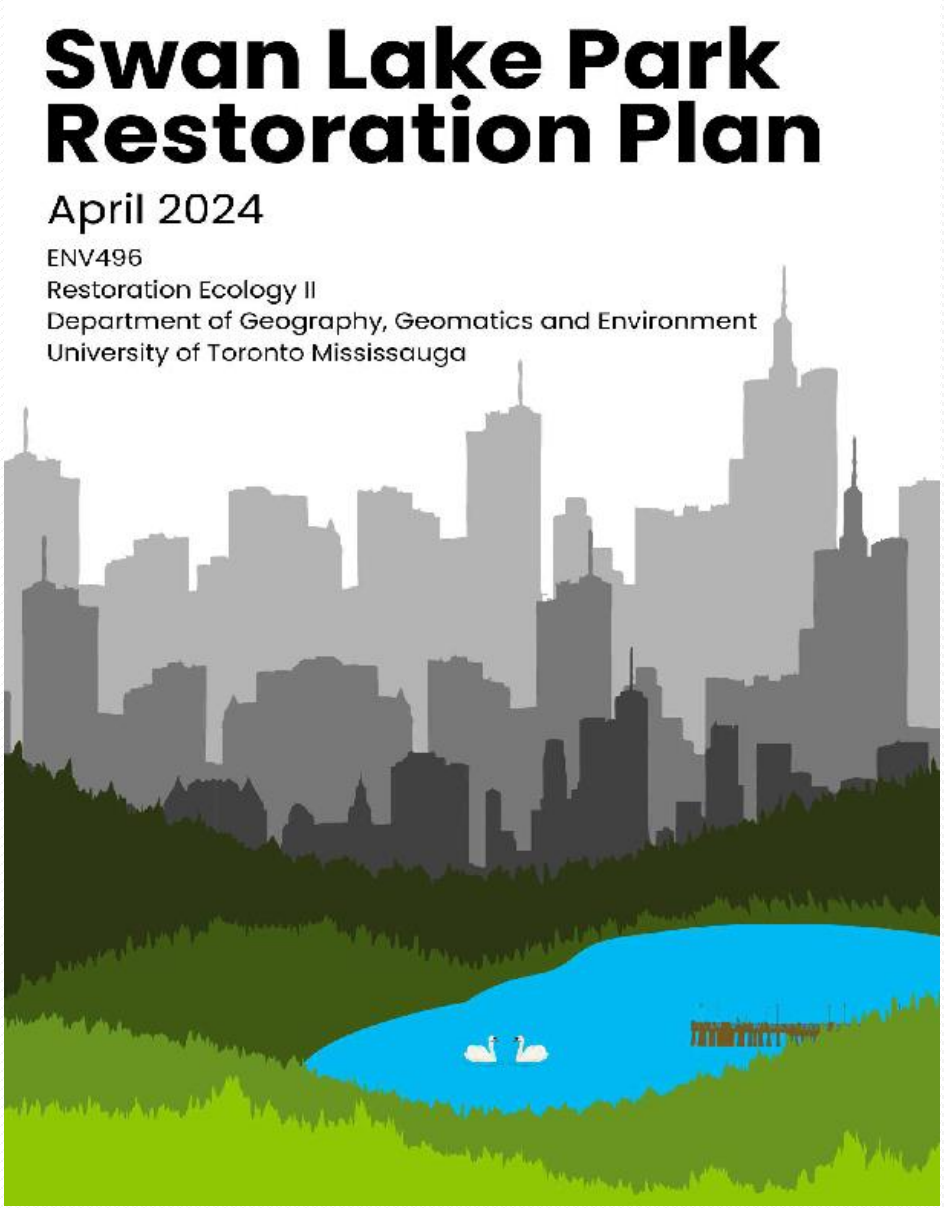
Benthic Invertebrate Monitoring: Chris Reeves

- Water quality is reflected in abundance and diversity of certain indicator species of insects.
- Provides an initial benchmark for monitoring improvement in water quality over time
- 16 taxonomic classes identified
  - 3 species indicators of “good” water quality
  - 4 species indicators of “fair” water quality
  - 6 species indicators of “poor or low” water quality
  - 3 other species associated with saline (chloride) rich environments

Chris Reeves' Conclusions:

- Overall abundance of species "rather low"
- Many sites had very few individuals, suggesting point sources of pollution
- Conclusion: indications of "intermediate or fair water quality"





Swan Lake Park Restoration Plan

April 2024

ENV496
Restoration Ecology II
Department of Geography, Geomatics and Environment
University of Toronto Mississauga

Winter 2024

University of Toronto – Student Assessment

1) Reviewed Markham's plan and FOSLP's 2023 recommendations in the context of current academic sources
2) Sponsor: Professor Monika Havelka, PhD
   - 4th Year Ecology Restoration Program
   - 36 students, four focused teams: 95-page report
     1) Chemical Treatment Options
     2) Shoreline Restoration
     3) Upland Terrestrial Ecosystem
     4) Community Engagement/ Awareness

U of T Student Assessment: April 2024

1) "**rehabilitation**" better term than "**restoration**" for framing the current and future interventions at Swan Lake Park
2) Current chemical treatments:
   - **Unlikely that this program is sufficient to <u>maintain</u> … interim target**"
3) **Water Quality:** Support FOSLP's call for investigation into additional options such as
   - sediment removal, additional chemical treatments, oxygenation, planting
4) **Community Engagement:** Support recommendations for new viewing platforms along shoreline

Discussion Outline

1) Shoreline Enhancement
2) 2024 Research Submissions
3) **2023 Water Quality Report**
4) 2026 Swan Lake Plan Review

2023 Water Quality Report

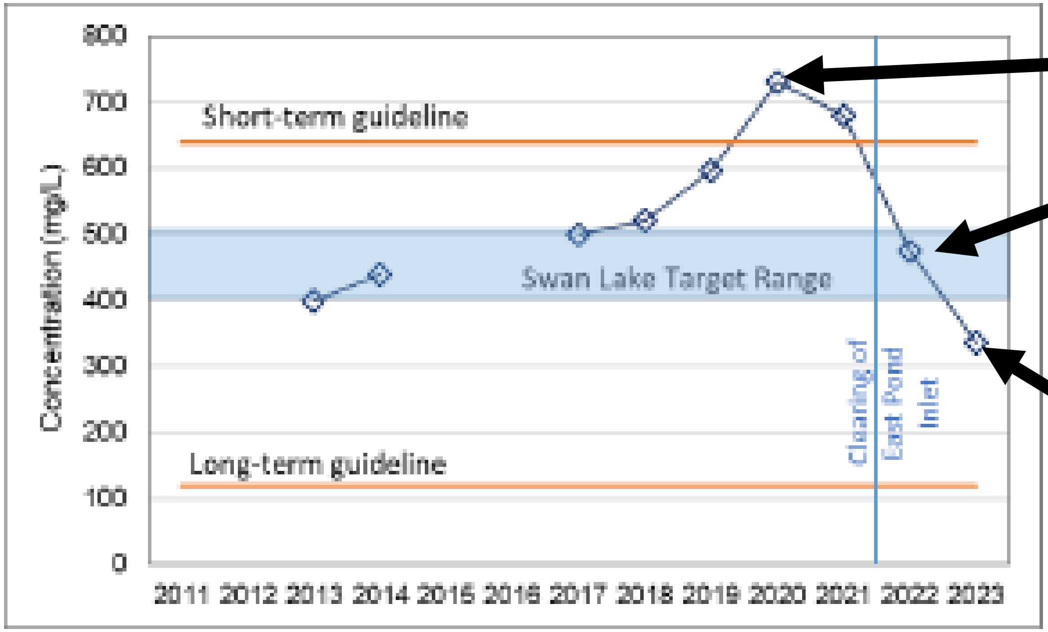
Positive But Unexpected Results

1) Drop in Chloride levels
2) Improvement in oxygen levels
3) Improvement in Phosphorus & Nitrogen
4) Static Aquatic Environment (Algae and Oxygen)

Raises questions about:

1) Impact of the aquifer
2) Impact of removal of phragmites
3) Disconnect between nutrient levels and algae levels

Significant Drop in Chloride Levels (2021-2023)



2020 55 tonnes

2022 39 tonnes (Reduction 16 tonnes or 29%)

2023 26 tonnes (Reduction 13 tonnes or 34%)

Where did chloride go? Dilution requires two step process:

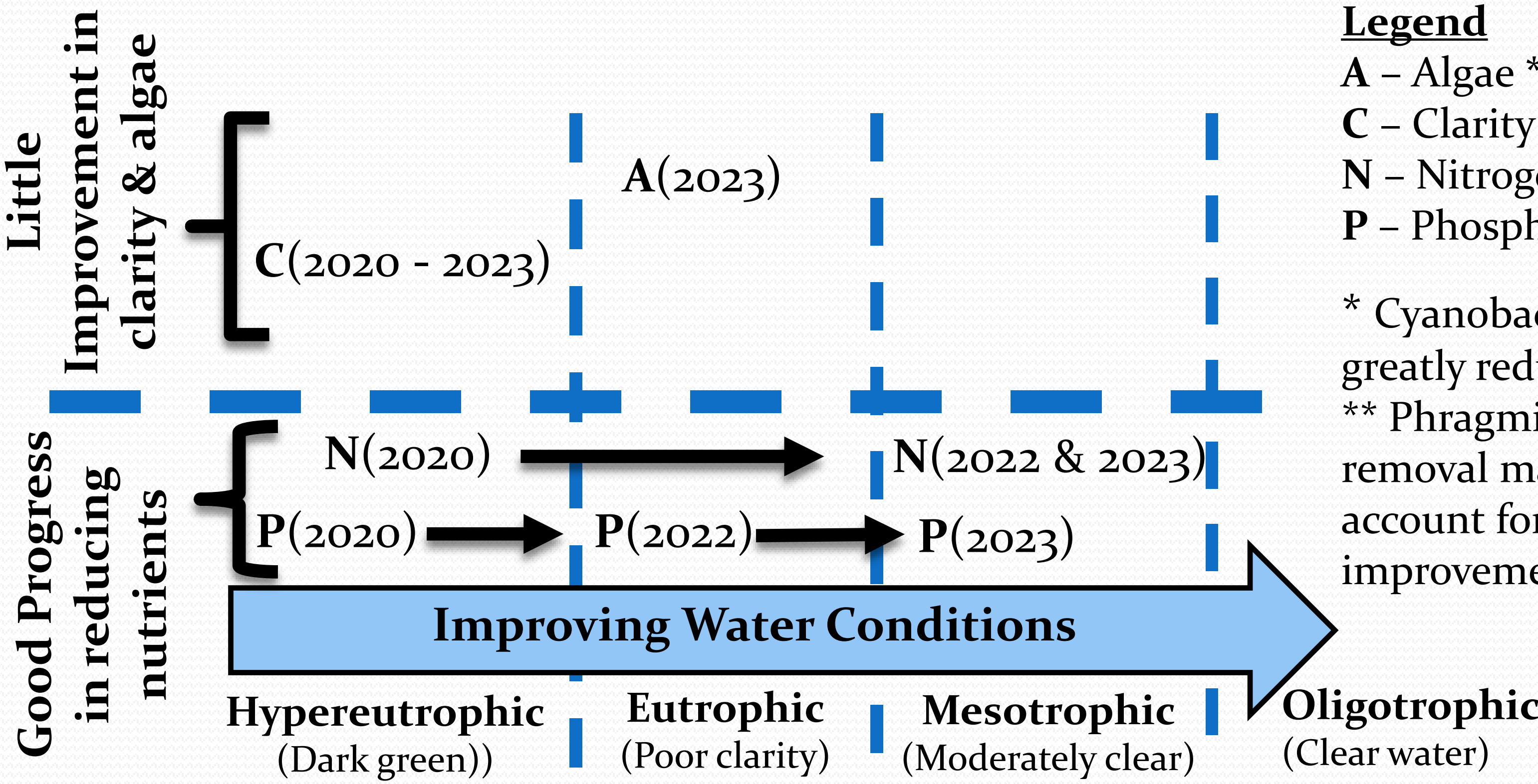
(1) Annual loss of 30%+ of chloride-laden water had to go somewhere - via lake outlet (not likely levels below outlet) or aquifer (most likely)

(2) Outflow replaced by fresh water – likely from aquifer (evaporation exceeds volume of precipitation)

Lower chloride levels may permit acceleration of aquatic planting

A Lag in Water Quality or a Disconnect?

- Goal of phosphorus-focused program is to reduce algae
- Nutrient reduction not leading to improved water quality



Legend

A – Algae *
C – Clarity
N – Nitrogen **
P – Phosphorus**

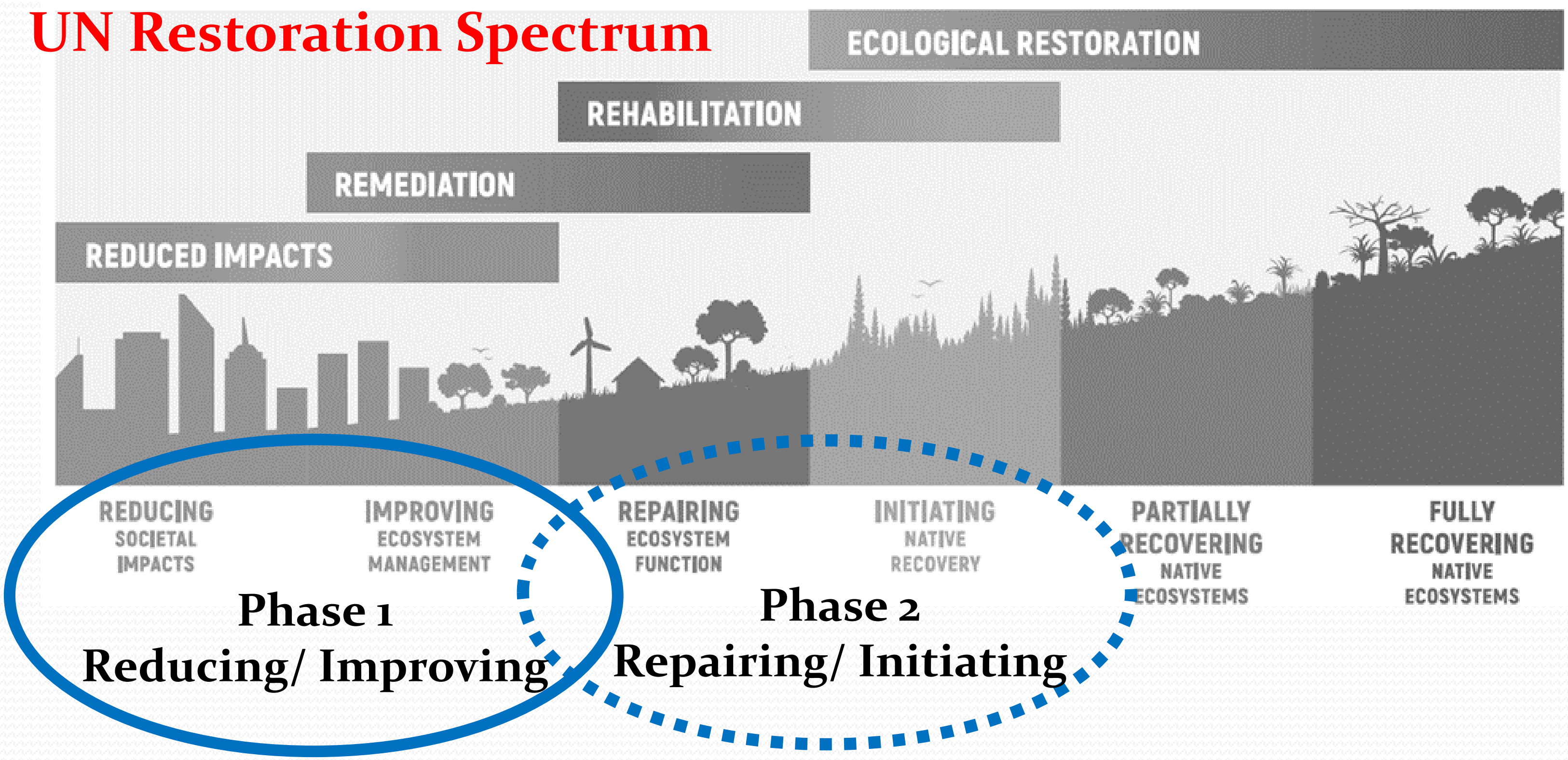
* Cyanobacteria greatly reduced
** Phragmites removal may account for 2023 improvements

Some academic researchers questioning effectiveness of phosphorus-centric programs

Discussion Outline

1) Shoreline Enhancement
2) 2024 Research Submissions
3) 2023 Water Quality Report
4) **2026 Swan Lake Plan Review**

Two Challenges: (1) Improving (2) Sustaining



2026 Plan Review: Inflection Point

- Transitioning from improving to sustainability
- What's desirable? What's attainable? What's sustainable?

Preparing for Phase 2 Review (2025)

OPTION #1: Independent but Collaboratively

- Markham staff and FOSLP each engage environmental consultants to work collaboratively during 2026 review

OPTION #2: Pooling of Resources

- Hire one environmental consultant reflecting perspectives of both Markham and community stakeholders
- Co-ordination on defining scope of assessment:
  a) Initial review of plan results and potential options
  b) Subsequent assessment(s) on selected topics
- Joint effort to identify funding for environmental consultants

Community Fundraising Goal: $60,000

1) **Community sources $30,000** (Timeline Fall 2024)
   a) **FOSLP**: $15,000 from Businesses, Organizations, Individuals
   b) **Markham's Contribution**
      i. Provide two "Tribute Boards" in Swan Lake Park to recognize community contributors
      ii. $15,000 – inspirational seed financing
2) **Foundations $30,000** (Timeline 2025)
   a) Lions International (active discussion/$30k matching basis)
   b) Federal Nature Smart Climate Solutions Fund (Fall 2024)
   c) Other Environmental Endowment Funds

2025

Ontario Great Lakes Local Action Fund ($1.8 m)

- Targeting “hands-on” Community projects
- Up to $50,000 for most projects

Eligibility:

- Municipalities and research groups that **partner with at least one community-based organization** involved in delivering the project (staff time, funding?)
- Applications by September 26, 2024

Two Swan Lake related examples cited:

1) Planting native species (aquatic plants?)
2) Mitigating the impacts of road salt (York U researchers)

Request That The Committee:

1) Approve staff recommendations for continuing with current plan
2) Approve York U. CIFAL proposal for Citizen Science Lab
3) Follow through on TRCA's shoreline recommendations and community's request for $730,000 over the next 1-3 years for:
   a) Shoreline fencing ($125,000)
   b) Two recreational nodes with benches ($360,000)
   c) A new viewing location overlooking the western shoreline ($225,000)
   d) Six benches along southern and western shoreline ($20,000)
4) Support the community effort to raise $60,000 for research for the 2026 Lake Management Plan review by:
   a) Providing two tribute boards in Swan Lake Park
   b) Committing $15,000 in seed funding for lake management research
   c) Supporting staff and FOSLP pursuit of community, regional, provincial and federal funding

Friends of Swan Lake Park

Focused on Rehabilitation of Swan Lake and Swan Lake Park

REHABILITATION PARTNER

UA LOCAL 46

SUPERIOR PIPING SKILLS SINCE 1890

SPONSOR

WALKER PARKER

REAL ESTATE

CONCEPT NOTE

PROGRAMME	**Swan Lake Citizen Science Lab** **Swan Lake Drone Monitoring, Mapping and Documentary Filming**
PURPOSE	The purpose of this concept note is to provide conceptual detail information about the proposed program.
Program Proponents	CIFAL York, One Water, Friends of Swan Lake Park
About CIFAL York	CIFAL York is a UNITAR affiliated international training center, serving as a hub for knowledge exchange and capacity building among government officials, private sector, academia, and civil society. CIFAL York was established in 2020 by **York University** as part of the global collaborative network of CIFAL training centers, in partnership with the **United Nations Institute for Training and Research (UNITAR)** and **York Region**. CIFAL York provides a range of training and research opportunities in key focus areas in alignment with the UN Sustainable Development Goals. CIFAL York permanent office is located in York Markham campus.
About One Water	One Water is a research centre at York University. One WATER aims to enhance our capacity to address the diverse aspects of the ongoing water sustainability crises, attract and train future leaders in the field, educate the public, innovate with industrial partners, and attract external competitive funding and endowments. One WATER engages in interdisciplinary world-class research on sourcing, Artificial Intelligence, Technologies, Education & Sustainability, Resource Recovery & Reuse as well as their environmental, educational, and societal implications.

About The Friends of Swan Lake Park ("FOSLP")	The Friends of Swan Lake Park ("FOSLP"), founded in 2019, is a group of Markham citizens committed to saving Swan Lake and Swan Lake Park through environmental best practices. The vision of the Friends of Swan Lake Park is to foster a sustainable level of biodiversity and public enjoyment of Swan Lake and Swan Lake Park, to facilitate public education opportunities and to encourage cooperation between the community, city leaders and staff.
BACKGROUND AND INTRODUCTION	Swan Lake Park, located in Markham, Ontario, is a vital natural resource that supports a rich diversity of flora and fauna, serving as a crucial wetland ecosystem. Over recent years, the lake and its surrounding wetlands have faced increasing threats and challenges from urbanization, pollution, and climate change. Recognizing the importance of protecting this valuable ecosystem, the proposed **Swan Lake Park Citizen Science Lab** program aims to empower the local community through *citizen science*, *ecosystem monitoring*, and *filming* to raise awareness utilizing drone and AI technologies for comprehensive environmental monitoring, mapping, and filming. By integrating these elements, the program seeks to foster a deeper connection between residents and their natural surroundings, encouraging sustainable practices and informed conservation efforts to ensure the longevity and health of Swan Lake Park. The use of drone technology for monitoring, mapping, and filming will help with community-based research, public education, and youth training on water levels, water quality, ecological changes, and addresses the need for innovative solutions in climate adaptation and resilience. Filming raises awareness and educates the public on the importance of wetland conservation, supporting efforts to halt biodiversity loss and sustain terrestrial ecosystems.

OBJECTIVES	**1.** Swan Lake Citizen Science and Community Engagement Lab: Empower the local community to participate in environmentally friendly activities and scientific drone-based data collection and AI-Based data analytics through creation of a Citizen Science & Community Engagement Lab Initiatives. **2.** Co-monitoring the Lake: Utilize drone and AI technologies to monitor water levels, ecological changes, and water quality in Swan Lake, providing valuable continuous data to inform conservation efforts. **3.** Co-creating Documentary Films: Create documentary films to raise awareness about the ecological importance of Swan Lake Park, the threats it faces, and the efforts to preserve and restore its wetlands.	
INTERNAL PARTNERS	One Water (York University)	
EXTERNAL PARTNERS	Friends of Swan Lake Park	
STAKEHOLDERS	City of Markham Markham Residents	
LOCATION	Swan Lake Park, Markham	
PROJECT SCHEDULE	Drone Mapping, Filming	Bi-Weekly/Monthly
	Community Engagement Workshops	Quarterly
	Documentary Films	Two documentaries every 6 months
	Community Screening	Annually
ROLES AND RESPONSIBILITIES	CIFAL York & One Water	Drone Mapping, Monitoring, and Filming

	One Water	Data Analytics
	Friends of Swan Lake Park	Facilitating Citizens'/Residents Engagement Advising the Research Team and Providing Feedback
	City of Markham (main stakeholder)	Permission for drone mapping (using under 25KG - RPAS) by certified drone pilots under York University Research Insurance coverage. Permission for community volunteers to participate in drone mapping. Permission to take water samples. Permission for public disclosure of information and images.
BUDGET, SPONSORSHIPS & FUNDING/COST SHARED	No direct costs are associated for the proposed program initial stages (Drone Mapping & Filming). We will use our internal resources (equipment, funds, students) to conduct these activities. However, the project will benefit from funding, and sponsorship. We will apply for appropriate funding to make the program more sustainable and expandable to other settings.	
INPUT	• Drone Footage: High-definition aerial shots to capture the vastness and beauty of Swan Lake and its wetlands. • Interviews: On-location interviews with experts, community members, and conservationists. • Workshops and Community Events: Filming of citizen science workshops and community engagement activities.	

	• Graphics and Infographics: To explain complex ecological processes, chemicals transport, citizen science data, and drone monitoring results.
PROGRAMME DIRECTORS	Ali Asgary, PhD, CIFAL York (director) & One Water (member) Satinder Kaur Brar, PhD, Director of One Water, York University Fred Peters, Founder and Volunteer at Friends of Swan Lake Park
SUPPORT STAFF	CIFAL York, One Water, Friends of Swan Lake Park
OUTPUTS/WAY FORWARD	• Time series drone monitoring data (orthomosaic maps, images, films, water level, ecological profile). The data will be available to the city. • Peer reviewed research articles. • Swan Lake Story Maps and Dashboard. • Community Engagement Events through community centres, public events. • Documentary films: Distribute through streaming services, social media, and environmental organization websites including COP conferences. • Educational and Training Outreach: For Schools, communities through libraries and Universities
OUTCOME	• Increased public awareness and understanding of the importance of Swan Lake and the role of citizen science. • Greater community engagement in environmental conservation/protection and data collection activities. • Improved data collection on water levels and contaminants, aiding in effective conservation planning.
INCLUSIVITY	Partners and researchers will make sure that in all aspects of this program from planning to outcomes inclusivity is followed to the highest level possible. This includes inclusion in the planning process,

	implementation of the mini-course, promotion of the mini-course, selection of any potential guest speakers, and making sure equal access to all interested target participants.
CONTACT PERSON (S)	Dr. Ali Asgary; asgary@yorku.ca Dr. Satinder Kaur Brar, skbrar@yorku.ca Fred Peters, fred.peters@rogers.com

Swan Lake Benthic Invertebrate Monitoring

Chris Reeves

January 12, 2024

Commissioned by

Friends of Swan Lake Park

Objective

Currently as there has been no benthic invertebrate sampling done in Swan Lake it is proposed that a total of 21 sites throughout the lake will be sampled with the purpose of providing a baseline for current water quality and lake health but also to provide an understanding of any improvements to water quality following future restoration efforts over the coming years.

Indicator species of water quality and lake health provide a basis for understanding the impacts development has had on the waterbody but also provide baseline for the improvement of lake health.

If overall water quality is improving in Swan Lake this will be reflected in changes of abundance, diversity, and the presence of certain indicator species. Low water quality will provide a different taxon than higher water quality, and thus monitoring of invertebrates is an effective way of establishing a baseline for ecosystem health. Presence of Ephemeroptera (Mayfly), Plecoptera (Stonefly) and Trichoptera (Caddisfly), or EPT, are indicators of good water quality and overall ecosystem health and can be considered a great benchmark for future years.

It is proposed that a range of habitat types will be assessed throughout the lake, however sampling will be conducted in-shore at depths of less than 3 feet, along 20 foot transects with use of dip net, and wash tray for identification purposes (Rosenberg, Davies, Cobb, and Wiens; 1997).

Results

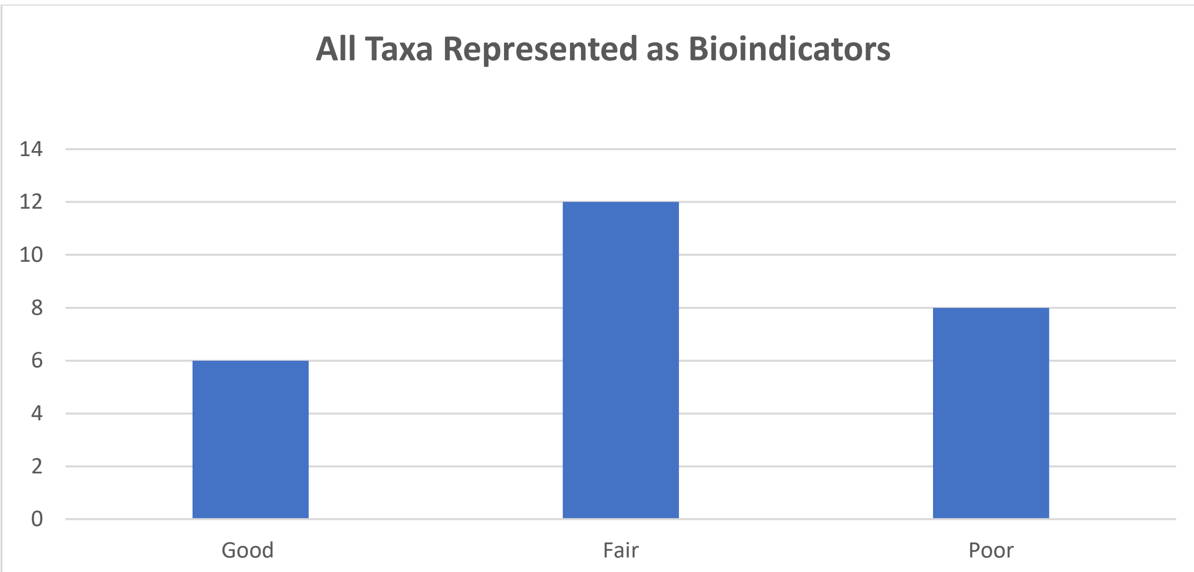
A total of 21 sites were sampled, over the course of 3 weeks. Sampling was conducted on days with no rainfall and very little cloud cover, days of sampling were July 22nd, July 30th, and August 5th.

Swan Lake is host to 16 taxonomic classes, these were categorized as good, fair or poor as bioindicators. Ephemeroptera (Mayflies), Trichoptera (Caddisflies), and Anisoptera (Dragonflies) were identified and categorized as bioindicators of good water quality. Gerridae (Water Strider), Zygoptera (Damselflies) Amiphipoda (scuds), Isopoda (Isopods) were categorized as fair water quality bioindicators. Diptera [this includes 2 species of Midge, as well as Aedes sp. (Mosquito)], Corixidae (Water Boatmen), Gastropods (Snails), and Nematoda sp. (Nematode worm) were categorized as poor or low water quality.

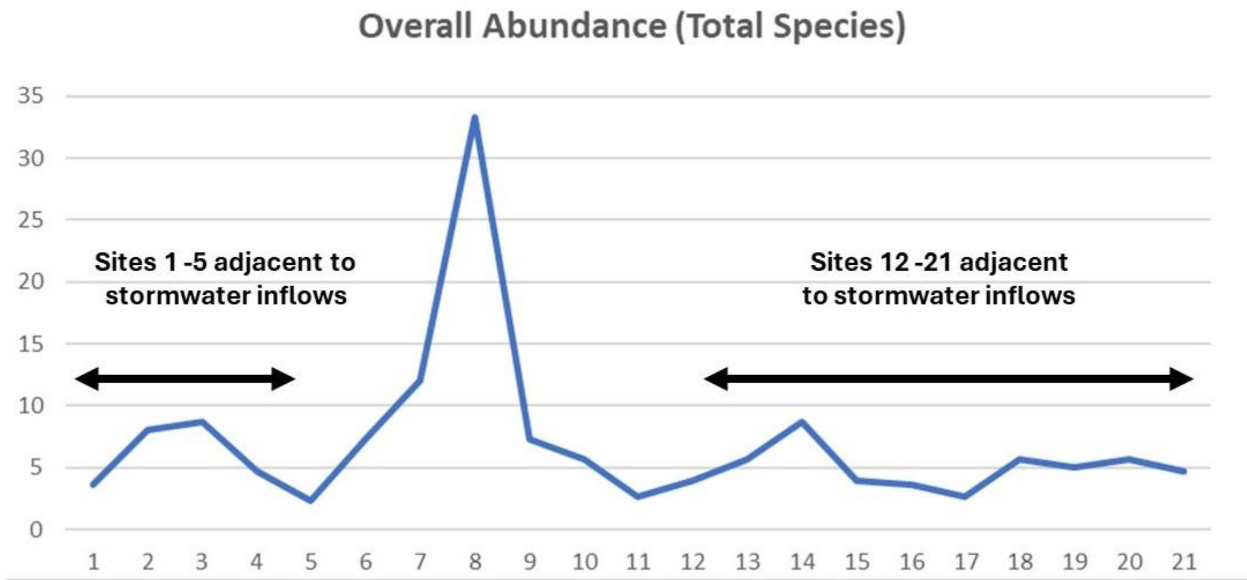
Species that could not be used as water quality bioindicators included Ranatra (Water scorpion), and Coleoptera (2 different species of Water Beetle). Although Ranatra and Coleoptera were removed as water quality indicators their presence has been associated with elevated levels of salinity, also water boatmen and water striders are also associated with saline rich environments. Also, there was a painted turtle observed at one site and a Common carp captured in the dipnet during the survey.

EPT as a percentage of all species sampled was found to be 12.5 % in respect to all taxonomic groups. Between 7% to 13% is typical of fair water quality (North Carolina Department of Environment, Health and Natural Resources; 1997).

Although EPT was found to be 48.96% of all individuals sampled in the survey. Mayflies are present at a few sites in high numbers, also some caddisflies were present, these species were found in less developed and more naturalized areas. Overall abundance in these areas was also high in comparison to other sites observed in the study. The total number of individuals according to EPT suggests good water quality, however given the diversity and types of species found overall the lake is found to be of fair or intermediate water quality.



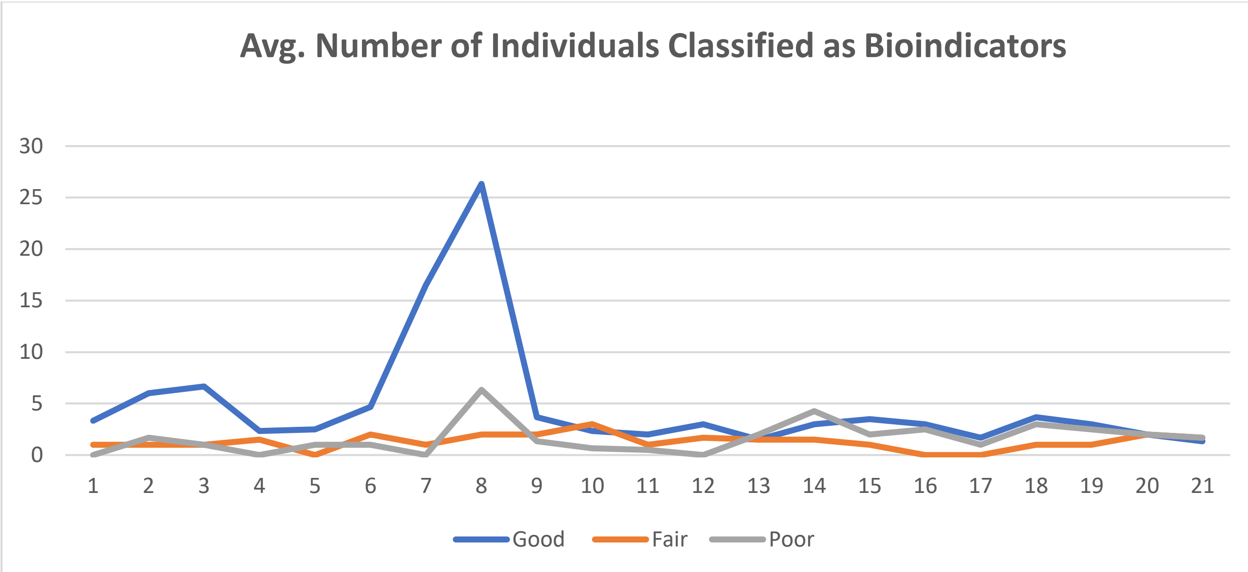
Given taxa categorized and given EPT percentage to total taxa, it is concluded that Swan Lake based off existing invertebrate populations sampled is of intermediate or fair water quality. Although the overall abundance seems rather low, the majority of sites had very few individuals. Considering the areas of little or no invertebrates may suggest point sources of pollution, this however would need to be correlated with additional water quality measures.



The purpose of this survey was to establish a baseline for water quality, if changes in the assemblage of bioindicators is observed in future years this will create a better understanding of improvements made in water quality. Also, the presence of water scorpions may be an indicator of higher-than-normal salinity. Elevated numbers of Hemiptera species would also be indicative of higher than usual salinity (Anufriyeva, Shadrin; 2016), also it is worth noting that water striders due to there presence on the surface are underrepresented in the surveyed benthic population, although Water Striders are still found in the survey it is most likely they are captured incidentally during the process of sampling (Spence, Anderson; 2003). The abundance of these species may be associated with road salt(s) run-off, however hydraulic conductivity data would be useful to gain a better understanding of this.

A lack of Oligochaete found in the survey seemed peculiar, it is difficult to say why this is the case as surficial sediment varied between sites sampled. Although it has been proposed that a Gerking sampler may be more effective at capturing sedentary species, this may be the reason for the lack of Oligochaete sp. as well as Leeches (Sychra, Zdeněk; 2010), also grab sampling may provide a better method for capturing these species (Rosenberg, Davies, Cobb, and Wiens; 1997).

In conclusion Swan Lake, given the taxa found and percentage of EPT, is currently of fair or intermediate water quality.



This report establishes a baseline for water quality. Changes in invertebrate populations in future years will establish a better understanding of either potential improvements or further degradation that may be occurring within the lake.

References

Anufriyeva, Shadrin (2016); First record of Ranatra linearis (Hemiptera, Nepidae) in Hypersaline Water Bodies of Crimea; January 2016; Hydrobiological Journal 52(2):49-53

Dodson (2005); Introduction to Limnology; McGraw-Hill

North Carolina Department of Environment, Health and Natural Resources (1997); Standard operating procedures for biological monitoring; Environmental Sciences Branch Biological Assessment Group; Division of Water Quality. Water Quality Section

Rosenberg, Davies, Cobb, and Wiens (1997); Protocols for measuring biodiversity: Benthic Macroinvertebrates in Freshwater; Department of Fisheries and Oceans, Freshwater Institute,501 University Crescent, Winnipeg, Manitoba, R3T 2N6

Sychra, Zdeněk (2010); Sampling Efficiency of Gerking Sampler and Sweep Net in Pond Emergent Littoral Macrophyte Beds – a Pilot Study; Turkish Journal of Fisheries and Aquatic Sciences 10(2)

Spence, Anderson (2003) Biology of Water Striders: Interactions Between Systematics and Ecology; November 2003; Annual Review of Entomology 39(1):101-128

Testing Locations in Swan Lake, Markham

Summary of Site Visit Data – Summer 2023

species classified as total individual		Good	Fair	Poor
site visit 1	total n	155	16	46
site visit 2	total n	59	62	23
site visit 3	total n	757	25	60
total		971	103	129

Species Composition (classification as bioindicators)	Good	Fair	Poor
	2	4	4
	3	5	2
	1	3	2
total	6	12	8

Avg. Number of Categorized Species per Site Visit			
Site Number	Good	Fair	Poor
1	3.333333	1	0
2	6	1	1.666667
3	6.666667	1	1
4	2.333333	1.5	0
5	2.5	0	1
6	4.666667	2	1
7	16.5	1	0
8	26.33333	2	6.333333
9	3.666667	2	1.333333
10	2.333333	3	0.666667
11	2	1	0.5
12	3	1.666667	0
13	1.5	1.5	2
14	3	1.5	4.25
15	3.5	1	2
16	3	0	2.5
17	1.666667	0	1
18	3.666667	1	3
19	3	1	2.5
20	2	2	2
21	1.333333	1.666667	1.666667

Data: Site Visit 1 - July 22, 2023

			Good	Poor	Poor		Fair		Fair	Fair	Poor		Fair	Good	Poor	Fair		
Site	Depth	Coordinates	Mayflys	Water Boatmen	Midge Sp total	[redacted]	Damselfly	[redacted]	Water Beetle	Water Strider	Gastropod	isopod	Amphopodae	Caddisfly	Mosquito (Aedes sp.)	Isopod	Water Strider (2)	Nematoda
1	1	43.89694/-79.25047	4		0													
2	2	43.89762/-79.25072	3	1	3	1	1	2										
3	1	43.89764/-79.25107	12		1		1	1	1	1								
4	2.5	43.89805/-79.25193	4		0				1	2	2							
5	1	43.89809/-79.25209	4		1			1				1						
6	1	43.89775/-79.25326	12		1	1	2						1					
7	2.5	43.89745/-7925511	30		0		1				1							
8	2	43.89748/-79.2552	50	3	0									1				
9	2.5	43.89747/-79.25527	3	2	0					1								
10	2	43.89627/-79.25435	1		0				1									
11	1.5	43.89625/-79.25427	1		0		1								1			
12	1	43.89575/-792526	1		0						1							
13	1	43.89591/-79.25231	2		2			2								1		
14	2	43.89606/-79.25212	5		10	3		7									1	
15	2	43.89627/-79.25202	3		3	3												
16	2	43.89635/-79.25189	3		1	1												
17	2.5	43.89642/-79.25167	1		0													
18	2	43.8965/-79.25125	7		3	1	1	2										1
19	1.5	43.89652/-79.25108	4		4			4										
20	1	43.89655/-79.25095	2	1	1		1	1										
21	1	43.89663/-79.2508	2	1	3			3					2					
total			154	8	33	10	8	23	3	4	4	1	3	1	1	1	1	1

Data: Site Visit 2 - July 30, 2023

Site	Depth	Coordinates	Mayflys	Water Boatmen	Midge Sp total	[redacted]	Damselfly	[redacted]	Water Beetle	Water Strider	Gastropod	water beetle	Amphopodae	Caddisfly	Mosquito (Aedes sp.)	Isopod	Water Strider (2)	Nematoda	Dragonfly	water scorpian
1	1	43.89694/-79.25047	2							1									1	
2	2	43.89762/-79.25072	2																	
3	1	43.89764/-79.25107	2	1									1							
4	2.5	43.89805/-79.25193	1																	
5	1	43.89809/-79.25209																		
6	1	43.89775/-79.25326	1							3			2							
7	2.5	43.89745/-7925511	3				1													
8	2	43.89748/-79.2552	13							2										
9	2.5	43.89747/-79.25527	4	2						3										
10	2	43.89627/-79.25435	2	1												1				1
11	1.5	43.89625/-79.25427	3	1																
12	1	43.89575/-792526	5							2			2							
13	1	43.89591/-79.25231		1	1		2					2								
14	2	43.89606/-79.25212	1	1	1								1			2				
15	2	43.89627/-79.25202	4		1											1				
16	2	43.89635/-79.25189	3		4															
17	2.5	43.89642/-79.25167	3		2									1						
18	2	43.8965/-79.25125	2		3															
19	1.5	43.89652/-79.25108	3										1							
20	1	43.89655/-79.25095	2		4								4							
21	1	43.89663/-79.2508	1										2							
total			57	7	16	0	3	0	0	11	0	2	13	1	0	4	0	0	1	1

Data: Site Visit 3 – August 5, 2023

Site	Depth	Coordinates	Mayflys	Water Boatmen	Midge Sp total	[redacted]	Damselfly	[redacted]	Water Beetle	Water Strider	Gastropod	water beetle	Amphopodae	Caddisfly	Mosquito (Aedes sp.)	Isopod	water strider	Nematoda	Dragonfly	water scorpian
1	1	43.89694/-79.25047	3																	
2	2	43.89762/-79.25072	13	1			1													
3	1	43.89764/-79.25107	6				1													
4	2.5	43.89805/-79.25193	2							1								1		
5	1	43.89809/-79.25209	1																	
6	1	43.89775/-79.25326	1		1															
7	2.5	43.89745/-7925511					1													
8	2	43.89748/-79.2552	15		16															1?
9	2.5	43.89747/-79.25527	4							2								1		
10	2	43.89627/-79.25435	4		1					5										
11	1.5	43.89625/-79.25427										2								
12	1	43.89575/-792526								1										
13	1	43.89591/-79.25231	1		4															
14	2	43.89606/-79.25212			5															
15	2	43.89627/-79.25202																		
16	2	43.89635/-79.25189																		
17	2.5	43.89642/-79.25167	1																	
18	2	43.8965/-79.25125	2																	
19	1.5	43.89652/-79.25108	2		1															
20	1	43.89655/-79.25095								1								2		
21	1	43.89663/-79.2508	1		1					1										

Swan Lake Park Restoration Plan

April 2024

ENV496
Restoration Ecology II
Department of Geography, Geomatics and Environment
University of Toronto Mississauga

Table of Content

Restoration vs Rehabilitation: Understanding the Concept

UN Decade of Restoration

The year 2021 marked the beginning of what would be deemed the United Nations (UN) Decade on Ecosystem Restoration by the UN Environmental Programme and Agriculture Organization of the UN (United Nations, "About UN Decade"). Ending in 2030, the UN Decade represents a plea for the conservation and revitalization of global ecosystems for the betterment of society and the environment on which we rely (United Nations, "About UN Decade"). However what exactly does ecosystem restoration entail? The central tenet of ecosystem restoration involves aiding in the recovery of degraded, damaged, or destroyed ecosystems (Gann, 2019). Such ecosystems are often characterized by a loss of ecosystem health, function, and/or integrity as the result of direct or indirect effects from human activities and can manifest in a variety of ways depending on the system in question (Gann, 2019). A common misconception associated with the term 'restoration' is the belief that recovery must always refer to a return to an ecosystem's historic trajectory - that is, the ecosystem's structure, composition, and function prior to degradation, damage, or destruction (Gann, 2019). However, in some cases, the return to a historic trajectory may neither be feasible nor desirable. Rather, as a result of the highly dynamic nature of ecosystems and their ability to change, or even adapt, to varying environmental conditions, the recovery of an ecosystem may often involve a transition to an adjusted or alternative state (Gann, 2019); Crossman, 2017). Regardless of the specific goal of recovery, a restored ecosystem is characterized by resilience and self-sustainability so as to protect existing biodiversity, mitigate climate change, and enhance human livelihood via ecosystem services (United Nations, "What is Ecosystem Restoration"). With the goal of restoring 350 million hectares of degraded ecosystems by 2030, the continuum of restorative activities undertaken during the UN Decade could generate US$9 trillion in ecosystem services (United Nations, "What is Ecosystem Restoration").

Restorative Continuum

The actions associated with ecosystem restoration - not to be confused with ecological restoration - exist along a restorative continuum (Fig. 1) that provides a comprehensive approach to revitalizing ecosystems across the globe, allowing professionals to select the most appropriate plan of action based on the ecological, social, and economic opportunities and costs of the degraded site (Gann, 2019). The continuum is characterized by four categories of restorative action: 1) reduced impacts 2) remediation 3) rehabilitation and 4) ecological restoration (Gann, 2019). Determining which restorative activities to undertake ultimately depends on the specific attributes of the degraded ecosystem in question (Gann, 2019).

Of relevance to the current ecosystem at Swan Lake Park are the latter two categories of restorative interventions - that is, rehabilitation and ecological restoration. So far, the ethos of Swan Lake Park has focused on a call for the ecological restoration of the degraded ecosystem. Inherent to the term ‘ecological restoration’ is the idea that restorative actions are aimed explicitly at conserving biodiversity and improving ecological integrity, a metric that is often quantified based on the presence of species native to the historical reference ecosystem (Gann, 2019). However, a return to a historic native ecosystem may not always be desirable, as is the case for Swan Lake Park. Instead, we propose that restorative efforts at Swan Lake Park fall under the category of rehabilitation. The key distinction is that rehabilitation involves actions focused on improving ecosystem function for the purpose of boosting the provisioning of ecosystem services (Gann, 2019). Given that the primary goals of Friends of Swan Lake Park involves improving site conditions for the purpose of enhancing community engagement with the site , the term ‘rehabilitation’ would be best-suited for accurately framing the current and future interventions at Swan Lake Park.

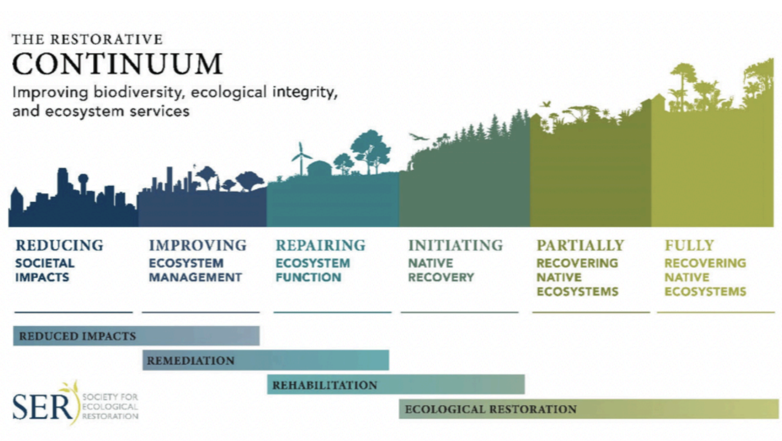


Figure 1. The Society for Ecological Restoration (SER) restorative continuum. As one moves from left to right along the continuum, the degree of degradation declines.

How Can Markham Contribute?

Green-Blue Spaces

When looking at both green and blue pieces of infrastructure they are designed to offer and enhance ecosystem services in developed areas. Thye enhance ecosystem services through various ways such as increased biodiversity, increased air quality, cooler temperatures, improved health, social interactions, and more.

Urbanization represents one of the leading causes of ecosystem degradation and the loss of ecosystem services associated with these natural environments (Cheng et al., 2023). The rapid expansion of urban areas, termed urban sprawl, is responsible for the conversion of natural permeable surfaces to impervious, built-up localities (Almaaitah et al., 2021). As a result, many of the ecosystem services associated with healthy, intact ecosystems have been disrupted (Cheng et al., 2023). In response to this, many cities have turned to the development of new green-blue spaces and/or the rehabilitation of existing blue-green spaces - that is, areas of vegetated land and water. Integrating green-blue spaces into increasingly urbanized areas has been shown to enhance a variety of regulating ecosystem services such as flood control, water and air purification, carbon storage, and climate regulation as well as several cultural ecosystem services including recreation, spiritual enrichment, social cohesion, and health (Pinto et al., 2022). Regarded as one of the fastest growing municipalities in Ontario, the City of Markham represents an ideal location for the establishment of functioning green-blue spaces (City of Markham, n.d.).

The Potential of Swan Lake

Swan Lake Park in Markham, Ontario is a community feature used by many of the local residents. Since the mid-1990s there has been growing concern over the continual degradation of park area as well as the lake (i.e., Swan Lake) in which it encompasses (Parhizgari & Muir, 2021). As one of the remaining areas of open land with a significant water body in a locality that is becoming increasingly urbanized, Swan Lake Park represents an ideal candidate for the rehabilitation of green-blue spaces within Markham, Ontario.

However, Swan Lake Park is unique in that it can be classified as a novel ecosystem (Fig. 2) - that is, a self-sustaining ecosystem that differs from what has historically existed in the area due extensive human influence (Hobbs et al., 2013). What once existed as an old gravel quarry has been transformed into a lake surrounded by an expanse of greenery filled with both native and exotic species. As such, with the goal of revitalizing one of Markham's green-blue spaces, the rehabilitation of Swan Lake Park to its historical ecosystem is neither feasible nor desirable. The long history of human intervention on site has led to landscape changes that are largely irreversible. Hence, the designation of Swan Lake Park as a novel ecosystem. Instead, the goal of rehabilitating this green-blue space is not to recover a native ecosystem that would have occupied this site in the past or to restore a historical ecosystem but rather to manage the unique ecosystem that currently exists so as to enhance the ecosystem services that have been degraded.

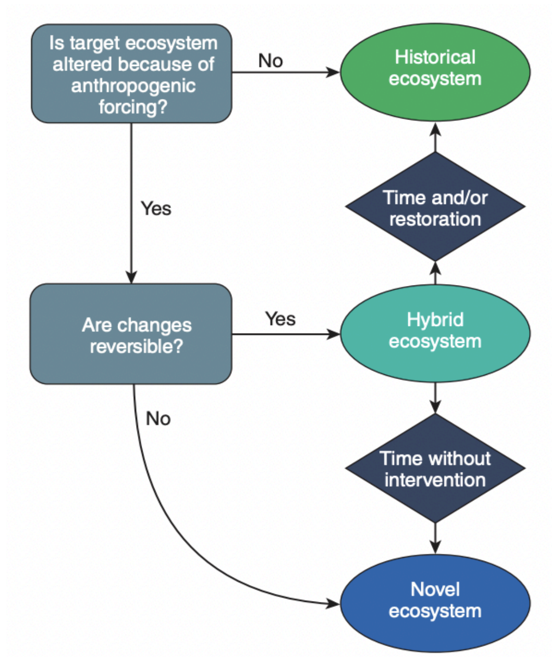


Figure 2. A simplified view of the definition that illustrates the relationship between historical, hybrid and novel ecosystems.

Background of Swan Lake Park

Figure 3. Display of a map of Swan Lake Park with images of local and native wildlife found throughout the park.

What is Swan Lake Park?

Swan Lake Park is a primarily retirement community with a large population of residents. The gravel pit on site was constructed via gravel quarrying during the 1850s. However, after operations ceased 1973, groundwater began to fill the pit leading to the formation of Swan Lake. The goal to transform Swan Lake into a diverse habitat for aquatic and terrestrial wildlife arose in 1993 (Cosburn Patterson Wardmand Limited et al., 1993) and has led to the formation of what Swan Lake Park is today. In 2010, residents of Swan Lake Park raised concerns over issues involving the water quality alongside high phosphorus levels, low dissolved oxygen, and overall degraded aquatic ecosystems. As a result, the city of Markham introduced the 2013 Phoslock treatment and Poly Aluminum Chloride (PAC) to gradually improve conditions and decrease phosphorus concentrations. The catchment of Swan Lake began as farmlands and then transitioned into a residential community.

In the early 1800s, the site where Swan Lake Park currently exists was occupied largely by vacant land and farmlands (Cosburn Patterson, 1993). However, upon the discovery of gravel deposits in the 1850s, the site swiftly transitioned into a gravel pit as a result of the intensive gravel quarrying operations (Cosburn Patterson, 1993). It was not until 1973 that excavation ceased and groundwater began to fill the gravel pit leading to the formation of Swan Lake (Cosburn Patterson, 1993). In addition to groundwater, since the early 1980s fill from surrounding construction sites at the time had been used to fill in the southern region of the gravel pit (Cosburn Patterson, 1993). While the fill consisted mostly of clean topsoil and sandy/clayey silt, the deposition of some construction debris led to the formation of areas with problematic fill (Cosburn Patterson, 1993). The current goal to transform Swan Lake into a diverse habitat for aquatic and terrestrial wildlife arose in 1993 and has led to the formation of what Swan Lake Park is today (Cosburn Patterson, 1993).

Figure 4. Different aerial photographs of Swan Lake Park. From Left to Right: Swan Lake in 1967, Swan Lake Park in 2002, Swan Lake Park in 2009, and lastly Swan Lake Park in 2023.

Located in the City of Markham, Swan Lake Park (43.8983°N, 79.2554°W, 210 m above mean sea level) is a beloved trail, park, and community feature utilized by the residents within the Markham area. Demographically, Swan Lake is primarily a retirement community with a vibrant populace of residents. Out of the three parks in Markham, Swan Lake Park is home to the second largest water body at approximately 5.4 hectares in size and 112,000 m^3 in volume. In its entirety, Swan Lake Park occupies 11 hectares of the 45 hectare catchment in which it resides (FOSLP, 2022b). Of the 45 hectares, 75% is composed of residences and infrastructure, 10% of tree canopy and park, and 15% of open water (Muir & Parhizgari, 2021). Swan Lake Park is one of the leading wildlife habitats in Markham providing habitat for over 155 species of birds, 12 species of mammals, 4 species of turtles, and 34 species of insects (FOSLP, 2022). It is not only rich in ecological value but also an important green/blue space for the local community.

The major threat to Swan Lake Park is the lack of environmental regulations or standards designated for the park. As indicated by Friends of Swan Lake Park (FOSLP, 2022b), Swan Lake is a “regulatory orphan”. That is, the lake is neither considered a part of the Rouge River watershed nor a municipal stormwater pond (FOSLP, 2022b). As a result, the management of the lake is often overlooked. This designation, or rather lack thereof, ultimately exacerbates the existing issues facing Swan Lake and the surrounding park.

Potential Goals for Rehabilitation

The primary goal proposed by Friends of Swan Lake Park (FOSLP) is to remove the lake’s role in stormwater management and establish an environmental plan to combat the threats and stressors facing the lake. In particular, FOSLP wishes to address the issues of water quality, wildlife habitat and invasive species, Canada goose (*Branta canadensis*) management, and public accessibility and engagement in the park.

In addition to their primary goal, FOSLP have also set out three long-term rehabilitation goals that we believe are crucial to restoring the park’s original glory. These long-term goals include: (1) a sustainable plan to help improve the quality of the water (2) a sustainable plan regarding the rehabilitation of aquatic- and land-based habitats and (3) an arrangement made by the City of Markham to develop a long-term stewardship plan for both Swan Lake and Swan Lake Park. The Friends of Swan Lake Park aims to establish better maintenance efforts including sediment and road salt pollution that may disrupt habitats, enhance the park's natural heritage, and improve the overall ecosystem (Friends of Swan Lake, 2022).

Stressors and Site Concerns

Hydrology

Swan Lake frequently switches between a hypereutrophic and eutrophic status, both of which are characterized by particularly poor water quality (FOSLP, 2023). As identified by Friends of Swan Lake Park, there exist three major contaminants of concern within Swan Lake including (1) phosphorus (2) nitrogen, and (3) chloride - all of which exist at undesirably high concentrations (FOSLP, 2023; Parhizgari & Muir, 2021). The primary sources of these contaminants are the inflows from the two stormwater ponds at the north and east end of the park, uncontrolled runoff from the surrounding catchment, and faecal matter from the abundant Canada goose (*Branta canadensis*) population (FOSLP, 2020a). As the aforementioned water quality parameters continue to deteriorate, aquatic plants and aquatic wildlife are both directly and indirectly negatively impacted. For instance, current chloride concentrations in Swan Lake are anywhere from four to six times the recommended federal guidelines which directly threatens the survival of low-level aquatic organisms such as zooplankton and small fish species (Li et al., 2022). However, high concentrations of nutrients within Swan Lake also indirectly affect aquatic animals by contributing to uncontrolled annual algal blooms that subsequently reduce dissolved oxygen levels available to life forms within the lake - which is another water quality concern at Swan Lake in and of itself. Thus, not only is the poor water quality an ongoing hazard to beneficial fauna and flora at Swan Lake Park, but it also hinders community engagement due to the low aesthetic appeal of the algae-laden water.

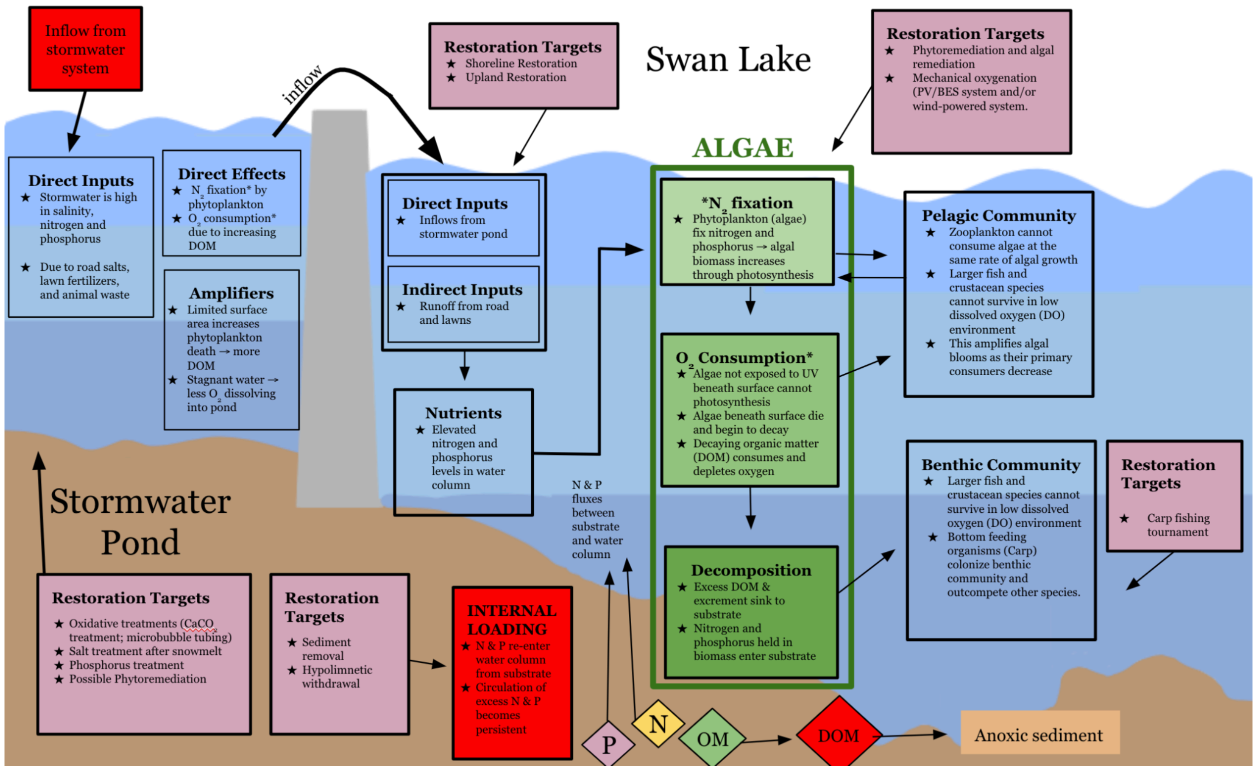


Figure 5. Box Model of Eutrophication in Swan Lake Park stormwater pond system.

So far, the long-term management plan approved by Markham Council in 2021 includes a chemical treatment program focused specifically on the reduction of phosphorus within Swan Lake. This program called for the application of either Phoslock or Poly Aluminium Chloride (PAC) in 2021 and 2024 with additional applications thereafter every three to five years (FOSLP, 2020a). However, treatment plans that address the unsustainably high nitrogen and chloride concentrations as well as the low DO levels in Swan Lake have yet to be established. While the current phosphorus treatments have seen some success in increasing the water quality to a eutrophic level, it is unlikely that this program is sufficient to maintain this interim goal. As such, of paramount importance to improving the water quality at Swan Lake is the development of a comprehensive management plan that addresses all four parameters of concern (i.e., phosphorus, nitrogen, chloride, and DO). This will not only require physical and chemical treatments that directly target existing water quality issues but will also necessitate mitigation mechanisms that reduce the abovementioned sources of phosphorus, nitrogen, and chloride to

Swan Lake (see **Appendix A**). Such mechanisms will be critical to preventing further declines in water quality at Swan Lake and aiding in the maintenance of desired water quality parameters once they are reached. Ultimately, combining chemical treatments with appropriate green infrastructure will facilitate a more holistic and adaptive approach for achieving the long-term sustainability of water quality at Swan Lake.

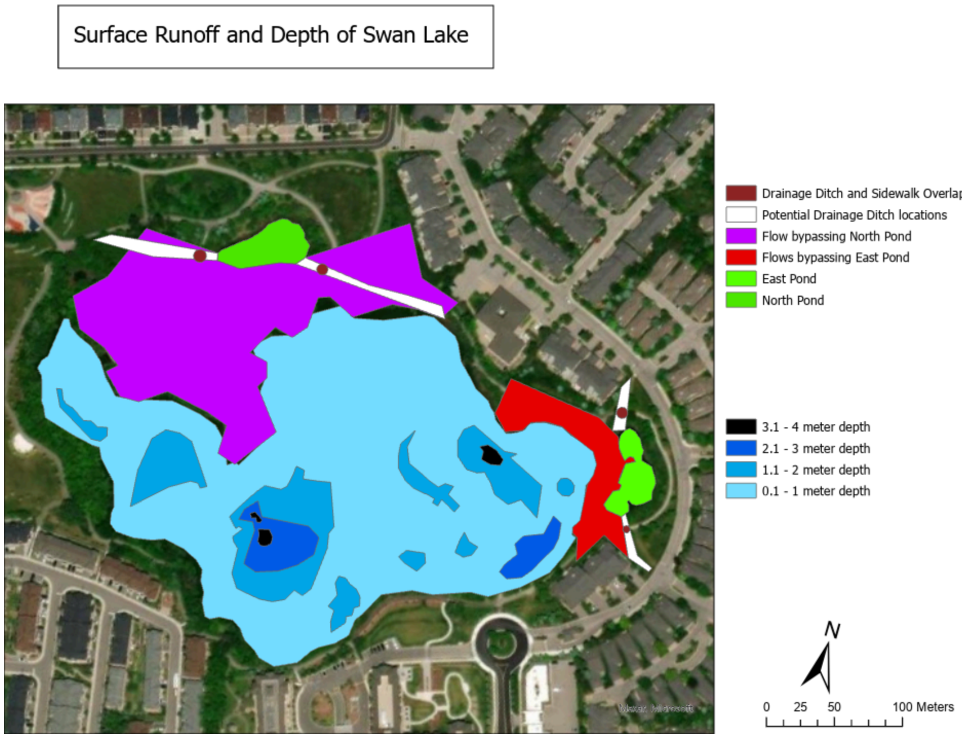


Figure 6. Map of Swan Lake that identifies the surface runoff regions bypassing the stormwater ponds and a potential position for drainage ditches. These ditches can redirect bypassing runoff into the stormwater ponds. The image includes regions of sidewalk overlap for the drainage ditch as well as depths of the Lake.

Biodiversity

Functional ecosystems require large amounts of biodiversity amongst them to function properly without the continuous interference of humans keeping natural processes in check. The balance of an ecosystem contributes to its resilience against pollutants and invasive species; the higher the resilience, then the more fortitude it has. As mentioned in the definition of restoration, it is crucial to return an ecosystem to the point where it can be self-sustaining. Biodiversity ultimately makes the world circulate and has benefits stretching to every part of human society. Therefore it is important to ensure even isolated ecosystems such as Swan Lake Park have biological diversity and can function on their own after rehabilitation efforts have ceased.

The missing appropriate vegetation and vegetation management has created a roadblock in the process of creating a diverse biological spectrum in Swan Lake Park. This can be partially correlated to high chemical levels which would have killed off sensitive plant life leaving only those who can tolerate these unnatural levels; it has created a survival of the fittest scenario which unfortunately has led to invasive helophytes taking over most of the wetland environment. Another scenario at Swan Lake is the ever invasive Carp that have beaten out native fish due to their tolerance to the pollutant-altered water quality. Therefore, as they have no predators, the carp have run rampant creating a single-sided aquatic system catered to their needs. The outlined management plan for these species is a crucial step in the right direction to bringing the biodiversity of Swan Lake back to where it needs to be in order for it to be a self-sufficient ecosystem with a strong resilience.

Nuisance Species

The area of Swan Lake Park is surrounded by large amounts of greenery, situated in a beautiful and scenic environment. Despite the Park's appearance, it is facing significant and serious concerns regarding uncontrolled growth of nuisance species. In particular, the species are disturbing both the physical and chemical properties in the ecosystem, which require attention and continuous management. Among these disturbances, the main nuisance species that are negatively impacting the ecosystem of Swan Lake Park are the high populations of Canadian geese, invasive carp, and invasive helophytes. Constant monitoring and proper management is important to address the main concerns which are impacting Swan Lake Park's ecological integrity, as well as its overall appeal to visitors and community members.

Canada Goose

Canadian Geese are a highly nuisance species that is present at Swan Lake Park, both at the park and in the lake. Canada geese like open, grassy areas and adapt eagerly in habitats of urban and suburban areas (Langdon, 2023), which explains why Swan Lake Park is a point of interest and "landing ground". In concern, the excess phosphorus levels in Swan Lake are partially due to the increase in large populations of migrating geese. According to FOSLP, geese that spend summers at Swan Lake not only account for 25% of the phosphorus loading in the lake but they also hinder community enjoyment of the park (FOSLP, 2020). In addition, about 70% of the phosphorus issue introduced by the geese is related to their fall migration where large populations stop at Swan Lake during their migration route south (FOSLP, 2020). Geese have significantly increased in population and their droppings combined with waterfowl has negatively impacted the water quality. Heavy concentrations of goose droppings consist of nitrogen, which results in eutrophication of ponds and lakes, which then leads to excessive algal growth (Istvanoics, 2009). Nutrient-rich fecal matter releases nutrients from the sediment, which causes nutrient levels in the lake to increase and the eutrophication to become more severe. In addition, geese that remain in the same area for long periods of time may overgraze the grass, causing large, dead spots on grass, as well as trample the soils, preventing vegetation growth, which can cause erosion and loss of habitat for other species. Geese are a nuisance for not only the ecosystem but for the community members as well.

To properly manage the increasing Canada Geese population at Swan Lake, various strategies and approaches need to be implemented. Briefly, planting native vegetation and other tall, dense and woody plant species (Ex., common cattail, red osier dogwood, tall Fescue grass) can help reduce open grazing areas, induce stress, block visibility, and disrupt geese. Limiting highly manicured lawns will also aid in reducing the hospitable area for goose population. For more detailed and in-depth information regarding these strategies and management plan for Swan Lake Park, please refer to page 29.

Carp

Invasive Carp has been reported to be an active species inhabiting and utilizing the lake in Swan Lake Park, and have been added to their list titled "invasive species affecting this lake". Carp in particular are a hardy species that can endure and inhabit in incredibly poor water conditions unlike many other species. In regard to Swan Lake Park, invasive Carp are a concern for the health and biodiversity of the lake, where it can greatly impact its levels and other species that are inhabitants there as well. The main issues they create are due to their feeding habitats and strong resilient characteristics. Carp are bottom feeders, which disturb clay sediments, contributing to the internal loading of phosphorus in the lakes. In addition, these fish species dig up the soil bed and muddy the water ways, which affect the reproduction and spawning of species such as Largemouth Bass and Sunfish. It is important to manage and remove these species as they are successful invaders that can replace native species in particular areas, can grow up to and more than 25 centimeters in the first year, and reproduce rapidly (Ministry of Natural Resource*s*, 2018).

Part of Swan Lake Park's Long-Term Management plan included a provision to manage bottom-feeder fish, and in addition, an inventory was implemented by the TRCA to capture and remove them. Common Carp (*Cyprinus carpio),* were among the species collected, which are a species that are considered to cause 86% of ecological effects (Badiou, 2011). Common carp can directly and indirectly negatively alter ecosystems by increasing total suspended sediments and erosion, increase water nutrient concentrations, and reduce the variety of native fish (Ministry of Natural Resources, 2018). More information on a suggested strategy to control and manage these fish species that are impacting the aquatic ecosystem at Swan Lake Park is detailed on page 31.

Invasive Helophytes

Helophytes are plants that are adapted to grow in wet environments, such as marshes, swamps, and rivers. Due to their high tolerance to biologically unfavorable environments, in polluted ponds they increase the competitiveness of the shoreline and aquatic ecosystem. Outcompeted indigenous species will eventually reduce in population or even be eliminated from the ecosystem. More specifically, Swan Lake Park has been struggling with the presence of invasive helophytes such as common reed, which is scientifically known as, *Phragmites australis*, along the shoreline of the lake. According to the June 2020 General Committee, Markham Council report, common reed grass is listed under the Ontario Invading Species Awareness Program (OISAP), as well as the TRCA (FOSLP, 2020). Invasive phragmites exhibit a vigorous competitive advantage, rapidly expanding and dominating native species in the means of accessing vital resources, particularly water and nutrients (FOSLP, 2020). In addition, these invasive plant species utilize allelopathic processes, releasing toxic compounds from their roots into soils, therefore inhibiting the growth of surrounding plant species, resulting in a decline.

In 2022, TRCA held a public meeting in response to their proposed methods of eradicating invasive helophytes such as herbicide applications, cutting and disposal, flooding, and spading. The management team later adopted the utilization of machinery harvesting in fall 2022 and herbicide treatment of imazapyr in winter 2023. Despite being a less harmful herbicide in comparison to the traditional herbicide glyphosate, it is still unknown of the potential damage it can cause to other living species in the ecosystem. While research suggests that some glyphosates could persist in soil or plant bodies for up to 79 days, the impacts of applying imazapyr are worrisomely inestimable (Hazelton et al, 2014). While imazapyr can be broken down through photodegradation, it relies on microbial breakdown upon permeating through the soil, which could take up to four years under conditional settings. Especially when 50% of the outflow is attributed to soil infiltration, these toxins could accumulate in the lake and soil causing further contamination. For more information regarding invasive helophytes and the proposed methods of removal and management, please refer to page 31.

Shoreline Erosion

A strong shoreline of any aquatic system is a necessity to the functionality of an ecosystem as a whole. These locations have a multitude of benefits to ecosystems such as being an organic buffer and water purifiers assisting in the trapping of sediments, nutrients and pollutants. It also creates another habitat for wildlife to live in and flourish but at the same time can prevent the nuisance of Geese. Increasing infiltration and the prevention of flooding are further benefits sourced from a strong shoreline area. Therefore the shoreline of Swan Lake requires attention in order to rehabilitate it and tap into all the benefits possible from it.

The continuous creation of informal access points by humans attempting to reach the water has contributed to the deterioration of shoreline. Coupling this with the detrimental surface runoff situation and the removal of non-native plant species that strengthened the shoreline, there is a large risk to the quality of the Swan Lake shoreline. The non-native species provided a strengthening characteristic to the shoreline through the means of rooting and slowing the erosion from runoff. The chemicalization of Swan Lake and the surrounding terrestrial regions have resulted in declining shoreline soil health and in turn causing further erosion for separate purposes than those mentioned previously (Litalien and Zeeb, 2020). This means the shoreline requires attention and effort to bring it back up to where it was.

Revitalization of Swan Lake's Shoreline

The construction of a riparian buffer zone with sections broken up by herbaceous plants that would flourish in these areas would be a strong point to start in the rehabilitation process. This not only would allow for some of the benefits to be accessed, but also pose competition for any lingering non-native species which may have been missed during a removal process. Furthermore it is recommended that a chain of floating islands just off the shoreline be implemented as a means of creating a secondary buffer zone in the lake. This concept came from a restoration plan proposal from UBC students and it aligns with goals of Friends of Swan Lake Park (Megan et al., 2020). Next, it is beneficial to consider and implement a raised boardwalk along shoreline locations. This would reduce the compaction of soil by preventing human and pet trampling. Alongside the boardwalk, viewing platforms should be installed to provide new locations to observe the natural beauty of the location. Lastly, vegetated rain gardens would be another structure that should be invested in. For a complete outline of benefits and construction of rain gardens, please reference the section dedicated to them titled *Rain Gardens*.

Proposed Management Plan for Swan Lake Rehabilitation

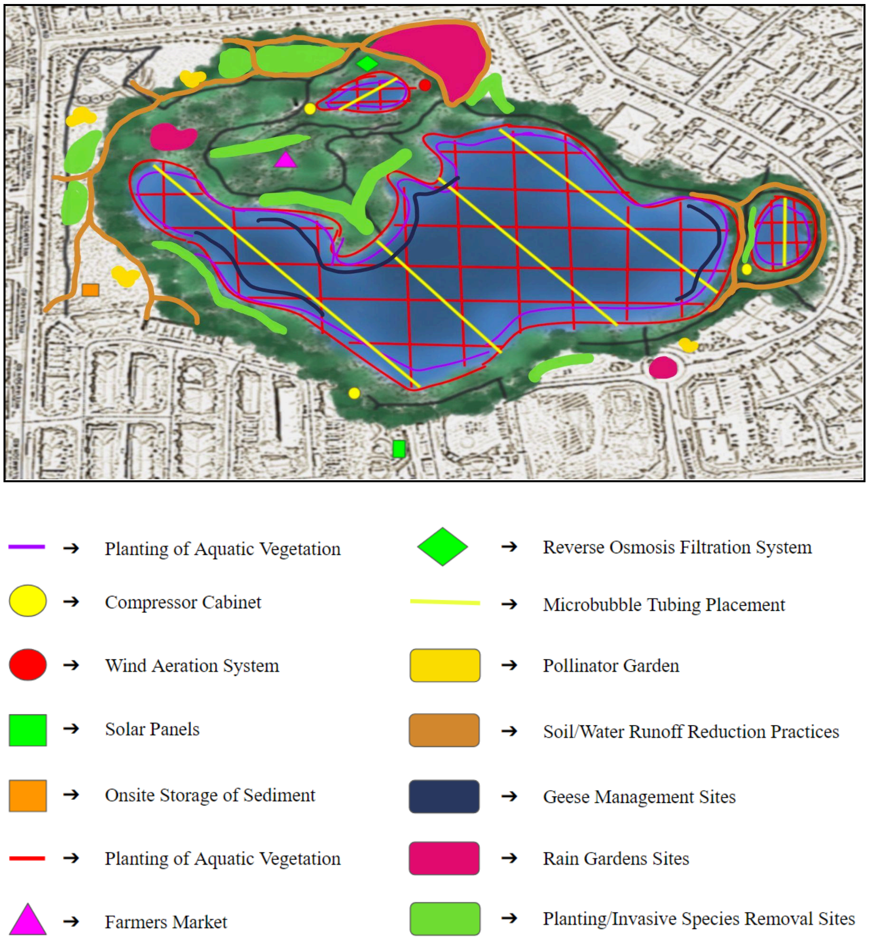


Figure 7. Conceptual Site model and legend of proposed treatment locations and pathways in Swan Lake Park

Hydrology

Eutrophic status represents the interim goal set out by Friends of Swan Lake Park, however, their aspiration goal is ultimately a mesotrophic status (FOSLP, 2023). Achieving either of these goals necessitates the development of a management plan that effectively addresses all four of the current water quality concerns. Recall that this includes (1) high phosphorus concentrations (2) high nitrogen concentrations (3) high chloride concentrations and (4) low dissolved oxygen (DO) levels. To improve the probability of the successful rehabilitation of the water quality at Swan Lake, we propose that physical and chemical treatment methods should be implemented throughout Swan Lake itself as well as the neighbouring stormwater ponds at the north and east end of the park. In addition, mitigation mechanisms established in the upland region around Swan Lake - such as rain gardens - that serve to reduce the input of the aforementioned contaminants of concern will be critical to maintaining desirable water quality levels once they are achieved.

Implementing some of the following management methods will not only improve water quality at Swan Lake but will also enhance biodiversity. In particular, improving water quality will allow aquatic plant and animal species that are more sensitive to poor water quality conditions to recolonize - or in the case of fish, to be reintroduced into - the lake, thereby contributing to the overall biodiversity of Swan Lake. The aesthetic value that arises from ameliorating water quality conditions and aquatic biodiversity will help to garner greater community engagement with the site and will, in turn, support a variety of cultural ecosystem services that will aid in revitalizing Swan Lake's status as Markham's crown jewel. These cultural services include recreation, spiritual enrichment, social cohesion, as well as physical and mental health.

Physical Site Alteration

Not only are there external sources of nutrients but there is also internal nutrient loading within the lake itself through the remobilization of phosphorus and nitrogen from the lake sediments. As a result, even when external sources of contamination are controlled, the internal source from the sediment will continue to contribute to eutrophication in the lake and hinder the rehabilitation process (Zhang et al., 2022). Hence, physical site alterations that remove nutrients from the water and sediment before further chemical and/or biological treatments are applied will be crucial to achieving successful results.

As previously identified by FOSLP, water withdrawal and dredging are appropriate steps required to remove the excess amount of nutrients and chloride in Swan Lake. Not only will this reduce the internal loading within the lake, but this will also decrease the dependency on future chemical treatments. However, prior to withdrawal and dredging we suggest conducting an environmental assessment of the water and the sediment in order to determine baseline conditions, namely chemical composition and benthic community composition. This data will serve as key indicators used to inform the most appropriate way to either store or recycle the water and the sediment removed from the lake. For the time being, it is not feasible to conduct physical site alterations at the two stormwater ponds adjacent to Swan Lake due to the limited capacity for sediment storage on site. Instead, the stormwater ponds can act as suitable intermittent storage sites for the water withdrawn from Swan Lake prior to recycling.

There are recommendations provided that fit together like pieces of a puzzle in terms of solutions for water quality and runoff. For example, french drains which are discussed in this paper, can force water to travel into the mentioned rain gardens for a natural filtration. At the same time, it was a recommendation by groups to look into the design and implementation of a Reverse Osmosis system that could also assist in the filtration of water before it reaches Swan Lake's water system. It is not the end of the water treatment plan if one of these pieces are missing, however they all healthily benefit one another and can create a well functioning process of water filtration.

For more detailed information regarding our recommendations for the environmental assessment, our proposed methods of physical alteration and their associated benefits, risks, and costs as well as our proposed options for sediment and water storage/recycling please refer to **Appendix A .**

Chemical Treatments

Following the physical alteration of Swan Lake, we recommend that practitioners resume chemical treatments. The current chemical treatment program is focused on removing phosphorus from the water and the lake sediments through the use of Phoslock or Poly Aluminium Chloride (CITE). While this program may remain in place, additional treatments are required to address the issues of nitrogen and chloride contamination in Swan Lake. Potential chemical treatments include:

- Iron-carbon composite with a photocatalytic film - filters out nitrogen and phosphorus
- Pond dyes - aids in the removal of chloride
- Ferric chloride - precipitates phosphorus out of the water
- Biochar - absorbs chloride and nutrients

For more detailed information regarding the function, benefits, and drawbacks associated with each of the aforementioned chemical treatments please refer to **Appendix A**. The additional chemical treatments to be implemented at Swan Lake will be up to the discretion of the practitioners involved in developing the rehabilitation plan. The above list is meant to provide various options from which these practitioners may choose from.

Plants for Bioremediation

As mentioned plants have many benefits to offer and be taken advantage of in an ecosystem. As a primary focus of Swan Lake's restoration revolves around the lake itself it is important to remember that aquatic plants can assist in the filtration of water pollutants in the long term. Reducing Phosphorus and Nitrogen levels in the lake can be done through phytoremediation. Two suggestions for this approach are Water Hyacinths (*Pontederia crassipes*) and Water Celery (*Oenanthe javanica*) both which are proven to uptake these pollutants and others which may be found in the lake. At the same time, the introduction of these plants will increase the biodiversity of the aquatic system and give aquatic wildlife, current and those introduced in the future, locations to breed and reproduce prolonging their existence in this isolated ecoregion.

Lake Oxygenation

While the above mentioned chemical treatments address the issue of high nitrogen and chloride concentration in Swan Lake, there remains the issue of low dissolved oxygen (DO) levels. Recall that DO is a measure of the concentration of oxygen that is dissolved in a water body and thus provides insight into the amount of oxygen available to aquatic organisms. As such, DO is a critical metric used to measure the health of an aquatic ecosystem. Currently, only the most tolerant taxa of fish can survive at such low levels of DO in Swan Lake. Thus, improving DO levels in Swan Lake will not only improve water quality conditions overall but it will allow Swan Lake to potentially support a greater variety of fish and other aquatic species. In order to increase oxygenation within Swan Lake there are two types of treatments available, chemical and mechanical.

The chemical treatment we propose involves the application of calcium peroxide (CaO_2) - an alkaline metal peroxide. Not only has CaO_2 been shown to increase and maintain stable levels of DO within water bodies due to its slow and prolonged release of oxygen (O_2) over time, but $CaCO_2$ also reduces the release of nitrogen and phosphorus from lake sediments thereby improving the nutrient-holding capacity of the sediment. Thus, the use of $CaCO_2$ will help to improve oxygenation within Swan Lake while also reducing internal nutrient loading.

In contrast, there are also mechanical methods of aeration that employ the use of technology to improve DO levels by enhancing water circulation. Potential mechanical methods of aeration include:

- Microbubbling

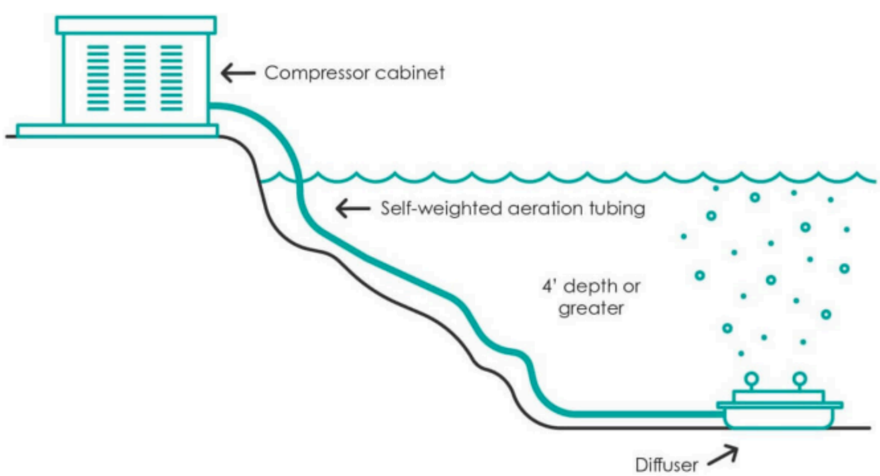


Figure 8. Microbubble tubing using an air diffuser that produces tiny bubbles for the efficient transfer of oxygen.*(Aquagenix Aquatics, 2024).https://aquagenixaquatics.com/aeration-systems/*

- Photovoltaic (PV)/Battery Energy Storage (BES) system - uses solar panels installed on floating installations to power a paddlewheel aeration system; battery energy storage provides back-up power during variable weather
- Wind powered system - uses wind to power a paddlewheel aeration system

For more information on the abovementioned aeration methods please refer to **Appendix A**.

Rain Gardens

Rain gardens, also called bioretention systems, are landscaped depressions with loose, deep soil that collects and absorbs stormwater runoff from impervious surfaces including compacted lawns, roofs, driveways, walkways, and roadways (Johnston et al., 2019; Malaviya et al., 2019). In comparison to a conventional lawn, a rain garden can improve water infiltration by 30% (Toronto and Region Conservation Authority, 2019).

This type of green infrastructure should not be confused with bioswales. Bioswales tend to be more heavily engineered with the purpose of conveying stormwater run-off to an alternative location from where it is currently concentrated (Johnston et al., 2019). In contrast, simple rain gardens are designed to capture, and subsequently absorb, the majority of the water it collects (Johnston et al., 2019).

In using rain gardens as a stormwater management tool, the ultimate goal is to reduce both the total contaminant-laden runoff volume as well as the peak runoff (Johnston et al., 2019; Malaviya et al., 2019). As such, there are three key features of rain gardens that improve their retention and infiltration abilities thereby distinguishing them from regular landscaped gardens. These features include a:

1. Ponding area - a naturally or artificially modified depression in the ground that allows stormwater runoff to be collected and stored for a short period. This aboveground storage zone is what allows for the infiltration and reduction of stormwater runoff.
2. Inflow structure - funnels stormwater runoff from surrounding impervious surfaces into the ponding area.
3. Outflow structure - directs overflowing water from the ponding area to an alternative location, usually the sewer network.

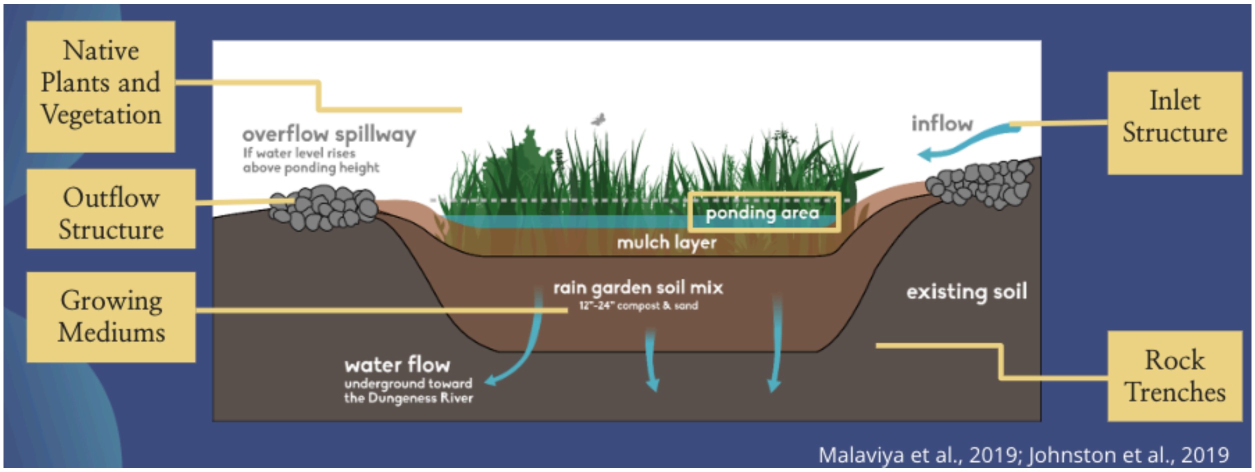


Figure 9. Proposed rain garden structure to be implemented in the upland region in Swan Lake Park.

Within the ponding area, the depression should be filled with appropriate growing medium(s) and native vegetation (Johnston et al., 2019). Choosing one or more suitable growing media helps to support plant growth, maximize the soil water holding capacity (i.e., the soil field capacity), and filter out pollutants (Johnston et al., 2019). Moreover, the vegetation planted within these media aids in maintaining the infiltration surface - that is, the soil surface where stormwater runoff enters the soil profile - as well as facilitates reductions in stormwater volumes via evaporation and transpiration (Johnston et al., 2019).

In addition to the above mentioned features, rock trenches and/or an underdrain system may be present beneath the rain garden depression (Johnston et al., 2019). These features are optional in highly permeable soils but are recommended in areas with poor soil drainage (Johnston et al., 2019; Prince George's County, n.d.). Rock trenches aid the infiltration and subsequent release of stormwater into the soils following rainfall events (Johnston et al., 2019). Furthermore, an underdrain system that consists of a perforated pipe not only helps to convey excess stormwater runoff to storm drain systems but also benefits plants growing in the medium above by preventing plant roots from flooding and maintaining oxygen levels in the soil (Johnston et al., 2019; Prince George's County, n.d.). Depending on the soil texture present around Swan Lake in Swan Lake Park, rock trenches and/or an underdrain system may be necessary.

When deciding on what vegetation to plant within the rain garden there are several factors to consider. One factor that is arguably the most pertinent to the success of the rain garden is plant tolerances, including light-, salt-, water-, and drought tolerance. The location of the rain garden and the surrounding canopy cover will affect light exposure in the area, thus influencing whether plants requiring partial or full sun exposure for adequate growth and survival are to be planted in the garden. On a smaller scale, light conditions will also be influenced by neighboring plants, hence the height and width of full-grown plants should be considered when selecting which species to plant and where to plant them within the rain garden. Moreover, given that the rain garden will be intercepting and assimilating stormwater runoff containing chloride ions from road salt, the plants selected should exhibit some degree of salt tolerance to be able to successfully establish, grow, and propagate in the rain garden. Furthermore, the rain garden should be sowed with plants that are tolerant of both inundation and drought conditions as the garden will periodically flood and dry out. Ideally, plants with the greatest tolerance of inundation should be concentrated in the interior of the rain garden as the center where the depression is lowest is ultimately the most prone to flooding (Prince George's County, n.d.). In contrast, the edge of the rain garden is most susceptible to dry conditions (Prince George's County, n.d.). As such, planting plans should focus on establishing drought-tolerant plants around the perimeter of the rain garden.

In addition to the aforementioned plant tolerances, when designing the rain garden it will be equally important to consider how the garden will contribute to biodiversity in the surrounding ecosystem at Swan Lake. Thus, plants should be selected based on the desired wildlife and insect species we wish to attract to the rain garden while also considering the continuity with the existing landscape (Prince George's County, n.d.).

Keeping the above mentioned factors in mind, rain gardens are typically planted with a variety of ornamental grasses, perennial flowers, and woody shrubs. For a suggested list of suitable plant species for the rain garden please reference **Appendix G**.

French Drains

A solution to runoff and permeability of soil is a common residential landscaping technique to move water away from a foundation or structure to another desired location without adjusting the grade of the landscape. French drains involve excavating locations in the ground and digging a trench to wherever the designated catchment location is on a very slight slope. While the work can be disruptive and noisy, the only damage is truly to the top layers of soil and grass which can easily recover or be fixed with seeding. At the same time, it may help to till some of these soils to increase permeability too. French drains being under the ground are completely invisible to visitors so they are not an eye-sore, they do not take long to install and nor are they expensive to install. The benefits they can provide by directing water away from locations to others means runoff can be controlled and forced to a location, such as an oil-grit separator or rain garden designed to slow and filter the water. With the lasting benefits of a french drain, and the simplicity to install, it is a strong contender to assist in controlling runoff and infiltration. Reference **Appendix E** for a breakdown on french drains and their design.

Biodiversity

Pollinator Gardens

Pollinator gardens are human-managed habitats, which are created specifically to attract and support pollinating insects, for example, bees and butterflies. Langellotta et al. explains that stressors such as habitat loss and fragmentation, and pesticide exposure have been highlighted as drivers of the global bee decline (Langellotta et al., 2018), so it is important that we protect these species as they are vital in our ecosystems. These unique gardens consist of a variety of flowering plant species that provide resources such as nectar, pollen, a form of habitat for pollinator species, as well as a place for reproduction, such as nesting boxes, and host plants (Majewska et al., 2018). The main purpose and goal for pollinator gardens is to create an environment that supports sustainability as well as promotes the health and overall well-being of important species. They promote the importance of habitat restoration and ultimately support biodiversity.

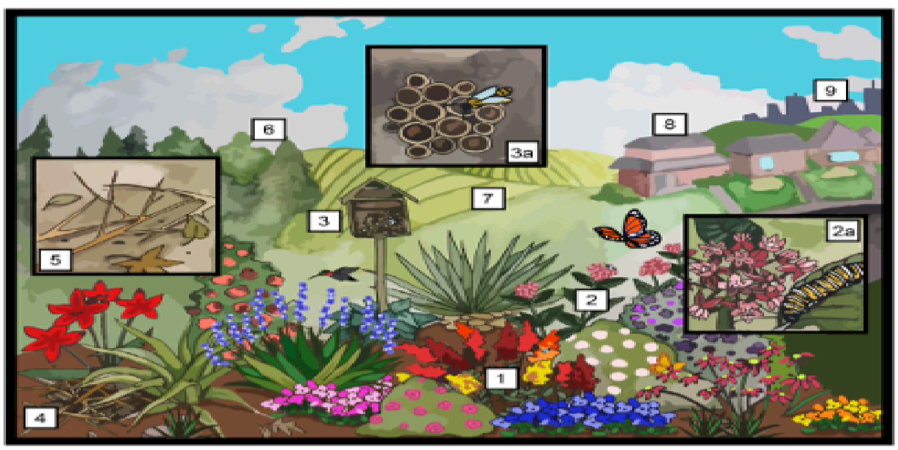


Figure 10. Representation of key features that make up a pollinator garden; taken directly from, Majewska et al., 2018. Planting gardens to support insect pollinators. Conservation Biology, 34(1), 15-25. DOI: 10.1111/cobi.13271

Some key features of pollinator gardens can be seen in Figure 10. Majewska et al., explain in this figure what features of a pollinator garden make it successful. They encourage individuals to follow gardening for pollinator books and guides to understand what is needed to create a successful and well-operating garden. The figure highlights the implementation of planting a variety of colorful flowering plants that provide nectar and pollen (Figure 10; 1); planting host plants and offering nesting boxes (Figure 10; 2,3,3a); brush piles which will assist in nesting and protection from weather conditions (Figure 10; 4); bare patches of soil to allow for ground pollinator species (Figure 10; 5); and lastly, presence of natural or native plants/trees (Figure 10; 6) (Majewska et al., 2018). Pollinator gardens function as important havens that are rich in nutrients, shelter, and nesting areas which are necessary for supporting the health of pollinating insects and furthering biodiversity. They enhance outdoor sites while simultaneously strengthening environmental sustainability.

Design and Plant Species

Friends of Swan Lake Park have large areas of open green space where these pollinator gardens could be built. Some examples of what these gardens could look like are seen in Figure 11 below. The structures will hold multiple plant species that are selected to attract insect pollinators and will be a great visual aspect of the park as well. Essentially, pollinator gardens could be placed in designated areas around the park, or a whole section could be created specifically for them.

Figure 11. Example design of pollinator gardens that could be implemented in areas in Swan Lake Park, DeJohn, S. (2023, July 26). *Garden design: Pollinator garden plan for bees | Gardener's supply*.https://www.gardeners.com/how-to/pollinator-garden-design-for-bees/9144.html

According to Toronto Master Gardeners, pollinators are searching for three main sources of food, nectar for a source of energy, pollen as a source of protein, and a host plant to consume and lay larvae in (*Toronto Master Gardeners,* n.d.). Pollinator gardens need to consist of specific flowering species that attract and cater to pollinator insects. For more information regarding examples of plant species that could be planted, as well as pros and cons of pollinator gardens, please refer to **Appendix G**.

Reference the Riverwood Conservatory website following this link for further information regarding a local highly successful pollinator garden for tips regarding construction, maintenance, and vegetation selection.

Trees & Vegetation Planting

A recommended planting plan has been derived to outline what research indicates would be the best means of implementing vegetation to Swan Lake Park, as well as leaving vegetation some may deem questionable with facts to back up the reasoning. Firstly, it makes sense to discuss what is already present in Swan Lake Park so the start of this section will focus on the current tree populations. As much as there is a concern for certain tree species found in Swan lake, there are proven benefits and reasons their survival should be considered in Swan Lake. For many non-native species that appear unwanted there is a concern of these becoming invasive species to other ecological regions. However, due to the isolation of Swan Lake Park from any other ecosystem areas, and the lack of an ecological corridor connecting it to any other locations the risk of spread is extremely low. Coupling this with the benefits these species can provide at the certain time and place Swan Lake is in in the rehabilitation process, they should be considered.

Tree Life

Starting with the Black Locust (*Robinia pseudoacacia*) tree which has been left with a poor assessment of what its benefits can be for Swan Lake. In previous case studies the negative effect of this tree's presence has resulted in its culling from locations. However, research does indicate it can be used as a nitrogen sink which happens to be a main focus of Swan Lake Park due to the increased nitrogen levels found throughout the park (Xiao-rong et al., 2010). If the trees can be used and maintained so that the leaves it sheds are raked and removed, so as to not release nitrogen back into the soil, then it can have an ultimately positive impact on the park. Not to mention if the plan does not work as intended, or the successful reduction of nitrogen has occurred, the trees can be harvested for lumber and replaced with other, more desired, tree types.

Secondly, the Manitoba Maple (*Acer negundo)* tree has also been misjudged through the label as an invasive species. While the title may be true, it does not have the negative effects on Swan Lake Park as it would to a wild forest in Southern Ontario. The Manitoba Maple provides a lengthy list of benefits similar to other tree species such as being windbreaks, creating habitat, and providing food for birds and squirrels. They also tend to absorb large amounts of water, which if infiltration can be improved, could be a very beneficial thing for Swan Lake as it would prevent more runoff with pollutants potentially entering the waterway. With proper care and maintenance, the Manitoba Maple could end up being a positive introduction to Swan Lake Park.

The concern with these two tree species is their competitiveness and strength compared to other species; eventually there is a risk of a monoculture developing of just Manitoba Maple or Black Locust. This is why the recommendations provided have been assessed as vegetation that not only provides benefits with the goals of FOSLP in mind, but also general ecological benefits. The first recommendation being the species of Norway Spruce (*Picea abies*) trees which are found throughout Southern Ontario. These trees help to prevent soil erosion with their extensive root networks and add extra food sources through cones for wildlife within the park (Caledon Tree land, 2023). Blue Spruce (*Picea pungens*) trees are another option with very similar characteristics to the Norway Spruce, the Blue spruce however has extremely thick foliage providing strong habitat locations for animals. Oak trees (*Quercus*) are another of the recommended options providing the same ecosystem services as previously mentioned except the food source comes from acorns. Their ability to grow near one hundred feet in height provides shaded cover for persons in the summer, and can be a goose deterrent.

Vegetation Species

Moving along to other vegetation species besides trees, a large portion of the rehabilitation can be rested on the shoulders of plant life. There are many ecological services the recommended plants can provide, and they also can bring a sense of natural beauty to the Park if they produce colorful flowers. The first category of vegetation derived are those that will contribute to the filtering of water and increasing soil permeability for the purpose of infiltration. The first recommended species is the Purple Coneflower (*Enchinacea purpurea*)which is a perennial bloomer designed to attract pollinators and survive in dry or saturated settings (Neal and Lewis, 2013). This would be best implemented near the flowing of water, along a shoreline, or in the rain gardens mentioned in this document. The next recommendation is Butterfly Weed (*Asclepias tuberosa)* which is also a perennial flower a part of the Milkweed family creating the possibility of attracting large amounts of butterfly species (Neal and Lewis, 2013). It is also a very bushy plant which contributes to the plan to deter geese from visiting the park while also being a visually appealing plant to individuals visiting the park (Cooper, 1998).

On the topic of Canadian Geese (*Branta canadensis*) deterrence, part of the research effort was focused on finding plants that would make locations less attractive to this specific animal. The Big Bluestem (*Andropogon gerardii)* was already discussed in the Goose Management section of this document, but to recap briefly, it is capable of growing to seven feet tall and can block access to grazing locations. The other previously mentioned plant was Tall Fescue Grass (*Festuca arundinacea*) which is the most common natural grass in Southern Ontario (Cooper, 1998). These grasses will prevent runoff and increase the amount of water absorbed by vegetation as more of it is planted.

With the question of how to make the shoreline of Swan Lake more resilient, plants are a main component of the solution. Once the removal of the invasive helophytes are complete, there will be a requirement to fill the voids of these plants in the water. The best choice appears to be native plant species found in marsh and pond environments like cattails (*Typha*) or bulrushes

(*Scirpoides holoschoenus*) to prevent the reinvasion of helophytes. During the removal of the invasive Helophytes, the replacement of them with native species should occur simultaneously. Native Eastern Flowering Dogwood (*Cornus florida*) is another strong contender for shoreline stabilization. Not only does it live and thrive along the shores of water systems, it also flowers adding a visual appeal and attraction to pollinators. On top of this, it is an endangered species in Ontario since 2009 via the provincial government website. The isolation of Swan Lake could provide a location for the plant to continue to exist and survive. There are a multitude of other vegetative types that can be implemented and used, it is recommended to reference different organizations documents which can be found online for planting lists and the drawbacks associated with specific plant species.

No Mow

The No Mow strategy was developed in efforts to allow natural grasses to grow as opposed to planting species. This way it promotes natural biodiversity and prevents having to add new plant species into the ecosystem. The way it works is preventing the mowing of lawns and grasses allowing them to grow. Beyond simply allowing natural grasses to the landscape to grow, it will also act as a geese deterrent since they will not be able to see over the height of the grasses and be intimidated due to the lingering threat of predators. At the same time, they also will be prevented from feeding on the grasses and low vegetation once they grow to a certain height (Conover, 1991). While this strategy may not be the most visibly appealing or pleasing to visitors, it is recommended to implement as a cheap alternative to some of the other options. It is not the recommendation that the mowing of all grasses be stopped, but just in key areas where it may benefit the ecosystem as a whole. In the worst case scenario that the No Mow does not provide the desired results, mowing can begin once more. It is recommended to try this strategy in an isolated area and gather a species list of what sprouts up from the soil in order to determine if there are desired plants being suppressed by the mowing and maintenance of the Park.

Nuisance Species

To tackle the problem brought up by nuisance species and minimize their adverse effects to the ecosystem, below are a series of measures for each aforementioned species.

Canada Goose Management

As excessive Canada geese have flooded the lake and park, measures for tackling the problem will mainly focus on reducing their quantity. Geese that utilize both the lake and open grass area here at Swan Lake Park are considered to be 18-20% of the overall problem (FOSLP, 2020). Through the implementation of tall grasses and vegetation, Swan Lake Park could eventually see minor changes, for example, higher rates in biodiversity and ultimately, a reduction in geese population. Plants such as Tall Fescue grass (*Festuca arundinacea*), and Big bluestem (*Andropogon gerardi*i) which can grow up to 7 ft, are species that will help to impede access to grazing sites, induce unnecessary stress, and deter geese altogether. In addition, plant species such as common cattail, red osier dogwood, willow and bulrushes are other candidates to further block visibility, and disturb sight lines, limiting the attractiveness to geese. Geese prefer large, unobstructed open grassy areas that give them views and strong sight lines of any potential predators (Conover, 1991). Therefore, the presence of these plants and other vegetation will primarily reduce open space for Canada geese to reside, as well as provide areas for potential predators.

Geese preferentially consume short grasses, such as Kentucky Bluegrass (*Poa pratensis)*, which is a dominant grass in the majority of lawns (Conover, 1991). Essentially, shorter, freshly manicured lawns will attract an increased geese population due to the higher palatable vegetation that is easily accessible. Therefore, another proposed management strategy will involve the implementation of a no-mow program. This plan would restrict the place that is allocated for carefully manicured lawns, which is consequently decreasing the hospitable habitat for the rising geese population. A no-mow program would typically involve implementing regulations or specific guidelines regarding the reduction of regular lawn mowing in particular areas of the park. Instead of frequently cutting the grass in certain areas of the park, the chosen sites will grow naturally and will need minimal maintenance. Ultimately, these areas will help to support biodiversity, conserve resources, and promote a more environmentally friendly and sustainable green space.

For more information regarding the specified plant species and vegetation mentioned above, please refer to page 26; *Trees and Vegetation Planting*

Carp

Being classified as invasive bottom-feeders in Swan Lake, carp are a concern to the health and biodiversity of the ecosystem due to their endurance to inhabit in poor aquatic conditions and disturbance to the soils, nutrients, and native species. Proper management is needed to successfully remove or reduce the amount of Carp in the lake, which requires a multifaceted approach. The combination of both manual and mechanical extraction, as well as exploitative fishing strategies are suggested ways of removal.

Manual and Mechanical Extraction:

- Electrofishing
- Gillnetting and seining

Exploitative Fishing Strategies

- Sanctioning commercial exploitation
- Incentivized recreational angling

Incorporating the combination of manual and mechanical extraction methods accompanied by exploitative fishing strategies could successfully aid in the removal and reduction of invasive carp. Methods including electrofishing, gill netting, seingin, and fish trapping are implemented for their recognized effectiveness in catching carp while minimizing any impacts that will affect non-target species and surrounding environments. These techniques can be modified to accommodate various lake conditions and carp behaviors, which are accessible and feasible for a wide range of stakeholders. The combined action supports long-term sustainability by sustaining continuous pressure on carp populations and limiting their reoccurance, essentially repairing the environmental strength of the ecosystem of the lake.

For more information regarding the function of manual and mechanical extraction as well as exploitative fishing strategies, please refer to **Appendix D**.

Invasive Helophytes

The TRCA have suggested methods such as herbicide application, cutting and disposal, as well as flooding and spading, in order to successfully remove and reduce invasive helophytes. Risk of potential harm, it is not suggested to apply any common herbicides such as glyphosate as there are unpredictable impacts that could be associated with the utilization of them. A comprehensive report which summarized 40-year trials and outcomes regarding various techniques for eradicating phragmites in the United States explains that particular glyphosate-based herbicides could persist in the soil or plant body for up to 79 days (Hazelton et al., 2014). In addition, multiple applications of these herbicides are needed to be implemented over several years in order to see results and change. Therefore, apart from the approach of utilizing herbicides, spading and plantation of new vegetation can be implemented.

In replacement of herbicide application, depending on the targeted area, implementing manual removal techniques on invasive phragmites is both feasible and more controllable. Executing the "cut-to-drown" technique is an effective method to control and manage invasive phragmites (Great Lakes Phragmites, n.d). This would involve cutting phragmites below water surface, which is effectively drowning the plant by removing its oxygen supply (*Great Lakes Phragmites*, n.d). In addition, for any helophytes that are above water (occupying terrestrial areas), spading is the technique that would be situated. This technique involves severing the stem at a 45 degree angle beneath the soil surface, removing the main shoot and the newest bud of the species (*Great Lakes Phragmites*, n.d). Utilizing these techniques multiple times throughout the season will essentially reduce the amount of phragmites, as well as free up space for the implementation of other vegetation. Refer to page 26, *Trees and Vegetation Planting*, regarding specific plant species that could be implemented.

Risk Management & Long-Term Monitoring

For the purpose of cleanliness and design, risk management and long-term monitoring were established in four groups to divide data based on category. They were categorized as Chemical Treatment, Shoreline Restoration, Upland Restoration, and Education and Outreach. In **Appendix F** is each of these groups and their deliverables divided by subheadings with charts correlating to their data. The purpose of this section is to outline data which is required to begin any of the ideas mentioned in this document. It also provides a risk assessment chart to outline where ideas could go wrong, and how detrimental it would be to the rehabilitation effort as a whole.

<u>Risk Assessment for Hydrology (Table 1A and 1B)</u>

Physical Lake Alterations for Restoration: Need to Knows

This phase focuses on conducting physical alterations to Swan Lake. This includes a hypolimnetic withdrawal which will help to reduce the nutrient and salt loading within the water. This will in turn improve the water quality and reduce the need for excessive amounts of chemical treatments in the future. The later half of this restoration step includes mechanically dredging the lake in order to reduce the nutrient loading in the sediment. This will prevent release of excess nutrients such as phosphorus from the lake sediment into the water. Additionally, this will aid in making a more heterogeneous bed which in turn will improve the biodiversity of the lake. With these steps in mind, we need to know several things in order to proceed and the associated risks:

- Need to know the level of contamination present in the water in order to determine where to store and recycle the withdrawn water.
- Need to know if the lake will recharge and the water will rise again to the level it is currently at. If the lake does not fully recharge, this could lead to a cascade of effects on the local environment and biological communities.
- Need to know if the aquifer can be withdrawn from to aid with re-establishing the water levels following withdrawal.
- Need to know the sediment type and contamination level in order to determine the safest storage technique and if it can be recycled.
- Need to know the current benthic conditions, such as communities and hyporheic exchange conditions. Dredging may permanently alter these conditions, therefore we need to establish a starting baseline to see whether these functions are also restored.

Fortunately, dredging often aids in improving hyporheic exchange which further aids in nutrient cycling upon restoration.

- Need to know what are best practices to do while conducting this step in the restoration phase. For example, dredging can lead to erosion, and cause substantial suspension of sediment into the water. It is important to know if there are any available devices or techniques to help mitigate these impacts.
- Dredging will cause substantial disturbance to the shore and uplands as well due to the machinery, we need to know if fencing off as designated area may be helpful in reducing the size of the disturbance.

Chemical and Biological Treatments: Need to Knows

The second phase of the restoration plan features the proposed use of multiple chemical and biological treatments yet to be explored at Swan Lake. This includes pond dyes, ferric chloride, biochar, and the introduction of remediating plants and organisms. These treatments aim to reduce levels of phosphorus, nitrogen, and chloride in the lake, and some have additional benefits for increasing dissolved oxygen as well. There is a need to know some chemical characteristics such as pH, dissolved oxygen levels, nutrient concentrations (especially nitrogen and phosphorus), and turbidity of Swan Lake and the two stormwater ponds. Since the use of appropriately dosed chemical treatments based on the above information would prevent further pollution and damage to the lake as a result of overdosing, we need to establish reasonable dose ranges after weighing effectiveness and hazards and strictly adhere to these ranges during the implementation of chemical treatments.

- Need to know the aquatic environment such as the composition of species (plants, algae, fish, and other organisms) and to determine how those chemical treatments may affect their food webs, quality of habitats, and interactions.
- Need to know what are better practices instead of leaving the native species in the lake to suffer and even die from the chemical treatments. For example, it is better to know if other places and management plans can support these aquatic species provisionally.

Lake Oxygenation: Need to Knows

In the final phase of the chemical treatment restoration plan, we propose introducing a new aeration mechanism along with remedial treatments using calcium peroxide. This phase aims to increase the dissolved oxygen (DO) levels in the lake to reduce eutrophication and prevent algae blooms in the future. This will also aid in improving the biodiversity of the lake via the increased oxygen and overall increase in the activity of microbial communities. Nonetheless, there are several need-to-knows to consider for this phase.

Both the wind-powered and PV/BEV systems are susceptible to mechanical failure due to general environmental degradation over time. This may eventually damage the generators and power systems relying on the windmills or solar panels. We need to know what the best practices are for maintaining these systems in order to ensure their longevity. We need to know whether these machines are at risk of theft or damage by the public and if so, how to protect them from such. This will likely require anchoring them to the lake bed and keeping them away from the shore. A structural feature of these instruments are the paddles which create turbulence, subsequently increasing the DO. These may cause habitat disturbances and potentially damage aquatic plants and life. Additionally, they may contribute to upturning and resuspending sediment, thereby decreasing the clarity of the water. We need to know what the best locations in the lake for these devices are to avoid interfering with aquatic plants and sediment.

As for the bubble tubing, it requires an onshore pumphouse to create the bubbles. We need to know whether there are locations available to install one of these pump houses. Additionally, similar to the other techniques, the tubing may become degraded over time. Therefore, an understanding of the best practices to maintain and protect it from damage is crucial as any damage to the tubing may affect its delivery of oxygen to the lake.

Risk Assessment for the Upland Region

Upland Restoration: Need to Knows

The upland restoration phase includes several steps, such as geese and invasive species management, soil amendment to improve permeability, along with proposed planting like rain gardens and additional native species throughout the site. The addition of plants and improved soil quality will aid in slowing run-off into the lake, thereby reducing external loading of phosphorus and chloride. Managing geese populations will further aid in reducing eutrophication and the high nutrient contents of the lake. With this in mind, there are multiple need-to-knows to take into consideration.

It is a necessary need to know the current soil quality and permeability prior to soil treatment and restoration. This will also aid in gauging soil conditions for planting. We need to know the public attitude toward the project of deterring geese in a non-lethal way. This can be achieved using a survey method. Another need-to-know the current population of invasive species in the upland area and areas of higher concentrations in order to document how they are affected by our methods in the future. It is necessary to understand what environmental conditions are required for the proposed planting of vegetation and their sensitivity to pollutants, especially those selected to be a part of the bioremediation plan.

Risk Assessment for the Shoreline Restoration

Shoreline Restoration: Need to Knows

The shoreline restoration phase tackles issues such as the invasive carp and plant species, run-off and subsequent salination of Swan Lake, and erosion along the banks. In order to restore the lake to what it once was, these issues need to be dealt with using appropriate invasive species control, run-off redirection techniques, reverse osmosis for desalination, and erosion control. As with the other restoration phases, this phase involves several need-to-knows:

- Need to know what kind of turn out to expect for a fishing event as a large number of people visiting the lake at once may impose indirect effects on the environment.
- Need to know the population of carp following the mass fishing in order to determine its effectiveness based on the starting population.
- Need to know current plant population numbers of invasive plant species and areas with higher concentration. It would be useful to know a list of native species as well in order to determine current community composition.
- By extension of the previous point, we need to know soil quality (i.e. permeability, conductivity, organic matter composition, nutrient composition) in order to determine environmental conditions and how they fit those required for the native species.

<u>Risk Assessment for Outreach and Education</u>

The community outreach and education plans for this restoration project will outline the potential opportunities for involvement by the local community. Currently, there is a lack of resident involvement in sustainability frameworks as well as a lack of community education regarding issues with Swan Lake Park. The aim with regard to the community is to increase levels of engagement through the notion to implement a farmers market. In addition, the further implementation of educational programs through local schools will not only inform students about methods regarding sustainability and ecological restoration, but will also edify the local community. To carry forward with these processes, there are a few need-to-knows:

Educational programs: Need to Knows

- Need to know the level of interest of the local schools to create and implement new ecological programs involving the park into the curriculum
- Need to know the accessibility regarding student participation in monitoring, planting, digging, etc. at the park
    - I.e. permissions needed by the school, parents/guardians, and the city

Farmers Market: Need to Knows

- Need to know the percentage of residents interested in having a farmers market and if they would attend
- Need to know what permits must be obtained for hosting the market at the park and the cost for the permit
- Need to know the costs associated with staff required to operate the market (i.e. volunteers, paid employees, outside agency, etc.):
    - Cleaners for the market area before, during, and after each event
    - Security for the farmers market to ensure appropriate conduct during the market by vendors and visitors

Community Impact of Rehabilitation Efforts

When looking at ways in which we can involve the community with rehabilitation efforts a couple that stick out to us are educational programs, farmers market, Indigenous acknowledgement, and recreational activities.

Educational Programs

Creating student programs through local schools to address the importance of the local species of the lake to the rest of the neighborhood ecosystem is a great way of raising knowledge. We need to evaluate the description of YDSB/YCDSB and local private school board curriculums about subjects of ecology, animal physiology, botany, and chemistry and see how we can improve it. Overall, educating students on the importance of promoting a healthy ecosystem will allow them to understand the problems within Swan Lake and get them more engaged with building the resilience of the park Some list of schools and the respective principals/teachers within a 10 km range of the park include Greensborough Public School, St. Julia Billiart Catholic School, St. Brother Andre Catholic High School, Marander Montessori School. Additionally, we can reach out to camp directors at Mt. Joy Community Center to propose nature walks to Swan Lake Park for the children. This also can be used to provide volunteer opportunities for students (make volunteer programs count toward volunteer hours required for secondary school graduation in Ontario or for resume/school application reasons).

Farmer's Market

Figure 12. Proposed image of what a farmers market could look like at Swan Lake Park (AI imagery).

There are currently events in Markham that exist similar to those of a farmers market that could exist in Swan Lake Park. The City of Markham hosts 2 weekly farmer's markets from

May to October in the BIA areas of Markham Village and Unionville. They also have music festivals with vendors that are held throughout the spring, summer, and fall. Promoting and hosting more farmers markets can create opportunities for local businesses to sell goods at the park once monthly, potentially advertised as a farmer's market. It can include an information booth about Swan Lake Park initiatives to educate the community on new rehabilitation projects and collect donations. It can also include a list of local businesses that have an interest in vending at the park. This can include reaching out to local business owners with flyers potentially with a QR code linking them to a poll/survey. Alternatively, we can contact businesses by phone, email, or social media and inquire about their interest in the idea and how they plan to participate. We can also find a list of companies that will provide staff for set-up and clean-up of the park before, during, and after operational hours of the market.

Indigenous Acknowledgment - Artwork

Additionally we can encourage members of the Indigenous community to use the park for gatherings/events and allow expression of these communities. That will allow them to feel included with the community and be part of the rehabilitation of the park and community goals. We aim to look at the demographic of the local Indigenous community (number of people, and specific denominations) within a 15 km - 20 km range of the park; to provide a space that is accommodating to their type of gatherings. It would be worthwhile to create a list of local indigenous artists who might be open to donate art to the park and provide the written context of the piece to be displayed together. This will allow them to feel like their expressions and beliefs are welcomed and valued in the rehabilitation of Swan Lake Park.

Recreational Activities

Additionally the restoration of Swan Lake Park can create opportunities for recreational activities such as fishing and canoeing/kayaking on the lake. Friends of Swan Lake can generate a list of local businesses that have rental programs for fishing and canoeing/kayaking materials who are interested in collaborating with the park. This will allow community members and residents of Swan Lake Park to have access to the resources that are necessary to partake in the recreational activities and provide a clear list of the steps individuals can take to be engaged in them. These activities can also be advertised through the Lake website to create more awareness of what Swan Lake offers as well as spread that sense of interest.

Grants & Scholarships

When looking at grants and scholarships there are a few that have been a missed opportunity by Friends of Swan Lake that should be looked at for future use that will better help with the restoration of the park and aid in achieving the goals we have in place.

The first one is the Markham Environmental Sustainability Fund Program, but more specifically the Markham Environmental Sustainability Fund. This fund provides financial support for projects within Markham that deliver demonstrable, widespread, environmental benefits to the Markham community. In order to receive this grant you must meet at least one learning objective. These learning objectives are leading environmental innovation, promoting education, understanding and participation in environmental sustainability in Markham, supporting Markham's environmental policies and strategic plans for example Building Markham's Future Together (BMFT) and enhancing the health, resilience and sustainability of our ecosystem and natural environment. There are also various criterias listed for these grants:

- Projects must be within the City of Markham and initiated by members of the Markham community or a community group in Markham,
- Applicants can request a maximum of $10,000 from the Markham Environmental Sustainability Fund per project per year
- Applicants may only apply once a year for projects that will be completed within that same one-year time frame (12 months from issuance of cheque)
- Only materials and equipment costs are eligible for funding from the Markham Environmental Sustainability Fund (consulting services are not eligible)
- Project must demonstrate measurable results
- Project must be demonstrable, widespread and lasting environmental benefits for the Markham community
- Groups that received funding for projects which have not been completed and reported on are not eligible for future funding
- Funding will not be granted where projects have been commenced

Another one is the Ontario Community Environment Fund Program. This is when you receive direct funds from environmental penalties to important, community-based activities like shoreline cleanups, habitat restoration and tree planting. Funding is available for two categories. The first one is funding for environmental restoration and remediation activities that repair environmental harm (stabilizing stream banks, tree planting). The second one is funding for resilient communities and local solutions to environmental issues (environmental monitoring that provides data to understand and support the protection and conservation of the natural environment). The deadline for this grant is May 30th, 2023.

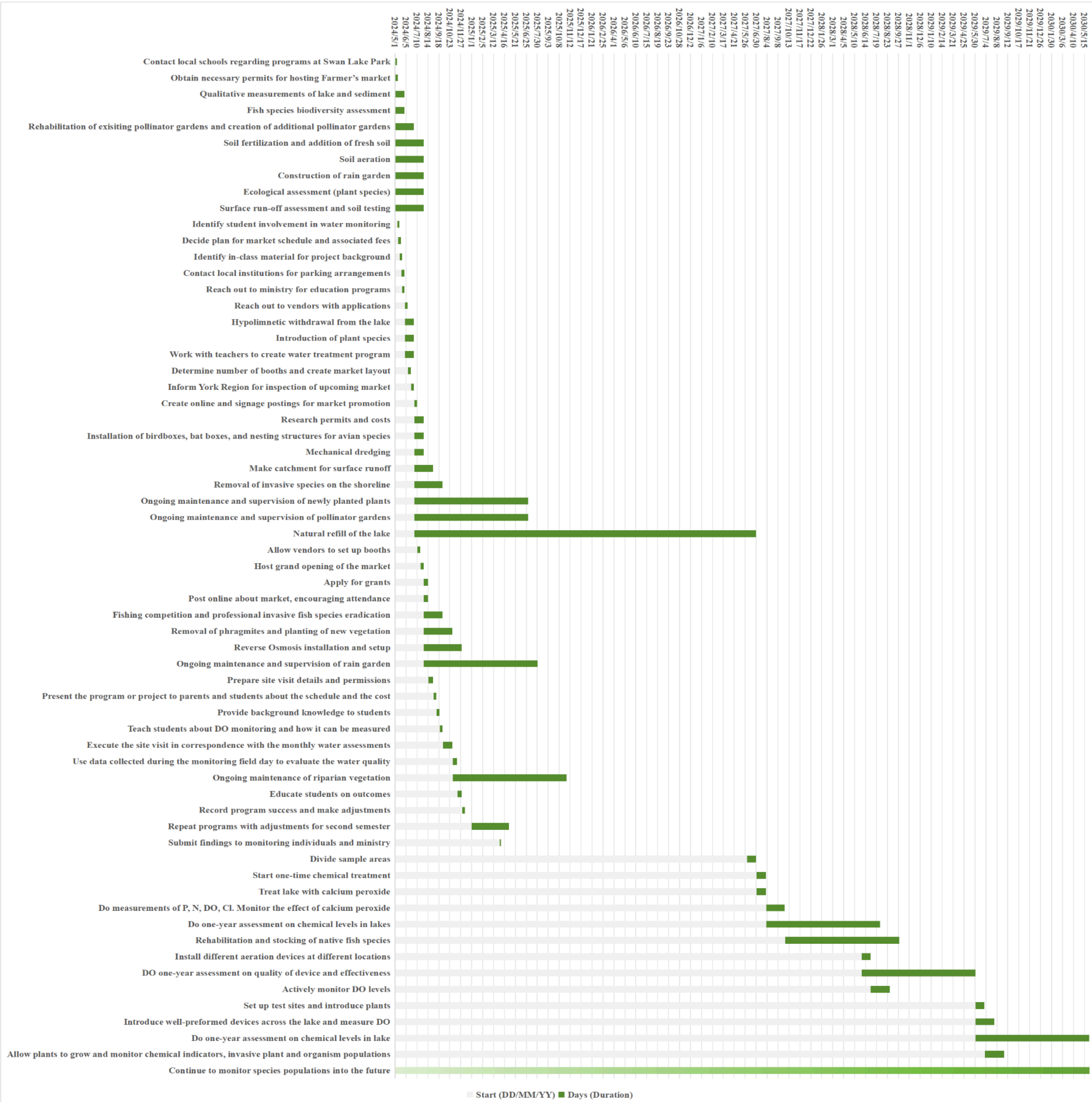
A third one is the TD Park People Grant. This grant provides grassroots for community groups with $2,000 to support their vision for environmental education, sustainability and stewardship programs that help connect people to their local parks and green spaces. This grant can cover any event expense, including, but not limited to, honoraria for volunteers, event materials, supplies, and equipment, and printing of promotional materials.

StoryMaps

ArcGIS StoryMaps, provided by ESRI, is a tool that allows users to create stories by blending maps, multimedia, and text. It's easy to use interface and customizable templates enable individuals to mix maps, images, videos, and storytelling components to develop captivating narratives about locations, events, or topics. The platform's adaptable design ensures accessibility on devices. Additionally features such as collaboration tools and simple sharing options support teamwork and widespread sharing of projects. Two StoryMaps were created using this software to highlight the hydrology of Swan Lake Park and the proposed Green Blue Infrastructure project.

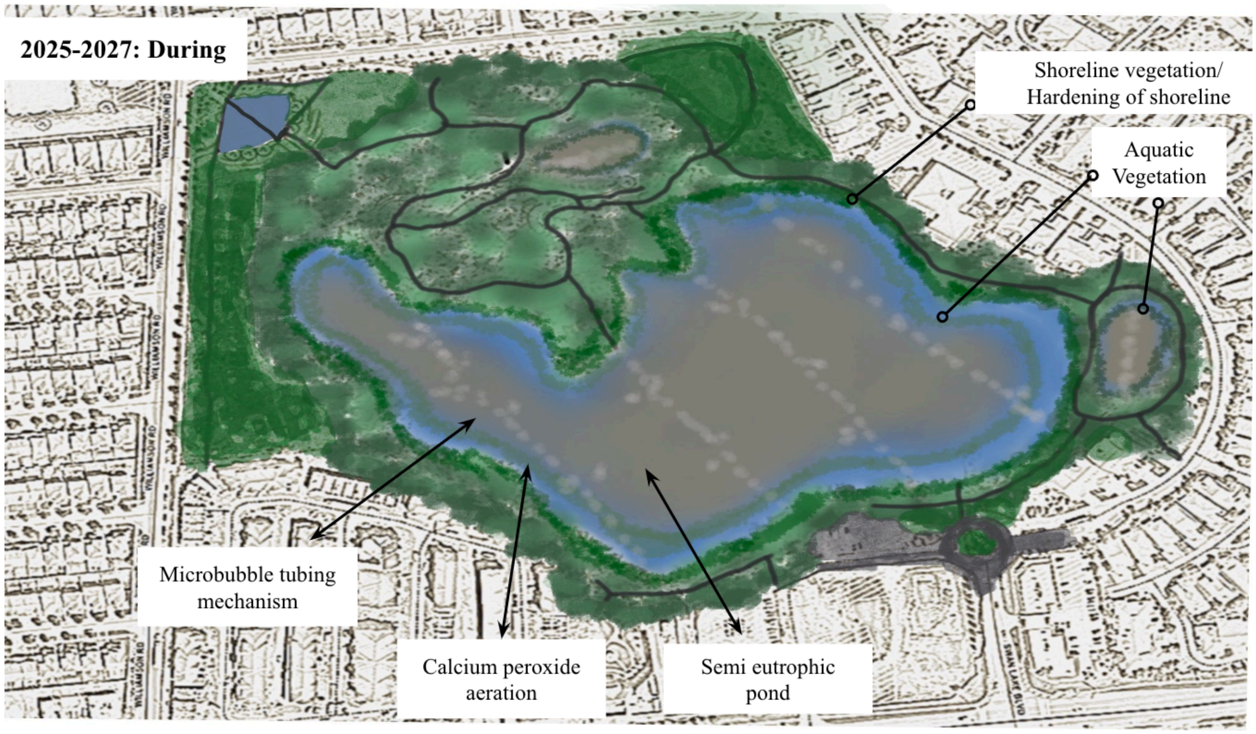
ENV496 Swan Lake StoryMap
https://storymaps.arcgis.com/stories/a4ecf33096c2420f96c89e2f4a14a4d1

Gantt Chart


2024/5/1
2024/6/5
2024/7/10
2024/8/14
2024/9/18
2024/10/23
2024/11/27
2025/1/1
2025/2/5
2025/3/12
2025/4/16
2025/5/21
2025/6/25
2025/7/30
2025/9/3
2025/10/8
2025/11/12
2025/12/17
2026/1/21
2026/2/25
2026/4/1
2026/5/6
2026/6/10
2026/7/15
2026/8/19
2026/9/23
2026/10/28
2026/12/2
2027/1/6
2027/2/10
2027/3/17
2027/4/21
2027/5/26
2027/6/30
2027/8/4
2027/9/8
2027/10/13
2027/11/17
2027/12/22
2028/1/26
2028/3/1
2028/4/5
2028/5/10
2028/6/14
2028/7/19
2028/8/23
2028/9/27
2028/11/1
2028/12/6
2029/1/10
2029/2/14
2029/3/21
2029/4/25
2029/5/30
2029/7/4
2029/8/8
2029/9/12
2029/10/17
2029/11/21
2029/12/26
2030/1/30
2030/3/6
2030/4/10
2030/5/15
Contact local schools regarding programs at Swan Lake Park
Obtain necessary permits for hosting Farmer's market
Qualitative measurements of lake and sediment
Fish species biodiversity assessment
Rehabilitation of exisiting pollinator gardens and creation of additional pollinator gardens
Soil fertilization and addition of fresh soil
Soil aeration
Construction of rain garden
Ecological assessment (plant species)
Surface run-off assessment and soil testing
Identify student involvement in water monitoring
Decide plan for market schedule and associated fees
Identify in-class material for project background
Contact local institutions for parking arrangements
Reach out to ministry for education programs
Reach out to vendors with applications
Hypolimnetic withdrawal from the lake
Introduction of plant species
Work with teachers to create water treatment program
Determine number of booths and create market layout
Inform York Region for inspection of upcoming market
Create online and signage postings for market promotion
Research permits and costs
Installation of birdboxes, bat boxes, and nesting structures for avian species
Mechanical dredging
Make catchment for surface runoff
Removal of invasive species on the shoreline
Ongoing maintenance and supervision of newly planted plants
Ongoing maintenance and supervision of pollinator gardens
Natural refill of the lake
Allow vendors to set up booths
Host grand opening of the market
Apply for grants
Post online about market, encouraging attendance
Fishing competition and professional invasive fish species eradication
Removal of phragmites and planting of new vegetation
Reverse Osmosis installation and setup
Ongoing maintenance and supervision of rain garden
Prepare site visit details and permissions
Present the program or project to parents and students about the schedule and the cost
Provide background knowledge to students
Teach students about DO monitoring and how it can be measured
Execute the site visit in correspondence with the monthly water assessments
Use data collected during the monitoring field day to evaluate the water quality
Ongoing maintenance of riparian vegetation
Educate students on outcomes
Record program success and make adjustments
Repeat programs with adjustments for second semester
Submit findings to monitoring individuals and ministry
Divide sample areas
Start one-time chemical treatment
Treat lake with calcium peroxide
Do measurements of P, N, DO, Cl. Monitor the effect of calcium peroxide
Do one-year assessment on chemical levels in lakes
Rehabilitation and stocking of native fish species
Install different aeration devices at different locations
DO one-year assessment on quality of device and effectiveness
Actively monitor DO levels
Set up test sites and introduce plants
Introduce well-preformed devices across the lake and measure DO
Do one-year assessment on chemical levels in lake
Allow plants to grow and monitor chemical indicators, invasive plant and organism populations
Continue to monitor species populations into the future
Start (DD/MM/YY)
Days (Duration)

Conclusion

This document intended to provide research and ideas from a four month long research class designated at solving some of the Swan Lake Park problems outlined by the Friends of Swan Lake Park organization. While parts of this research are preliminary and have left more questions, there has also been the design of a strong plan to outline future options. Swan Lake Park has the opportunity to return to a beautiful space to be enjoyed by the people who visit it and provide ecological services irreplaceable anywhere else around. By referencing Figure 13 one can observe a projected conceptual site model for Swan Lake Park. The quickest action to be taken would be removal of outlined invasive species and the replacement with strong, suitable native species that provide ecological services favored by park visitors and increase the well-being of this ecosystem. At the same time, any tests needed to be done should be done as soon as possible so the results required to use things such as chemicals can be done at the earliest time possible. This way there is an avoidance of an extreme delay in the execution in some of the recommended remedies found in this document. The intended impact of our work is to have long-lasting improvements on the health of Swan Lake Park's ecosystem and answer the requests of those members of Friends of Swan Lake Park.



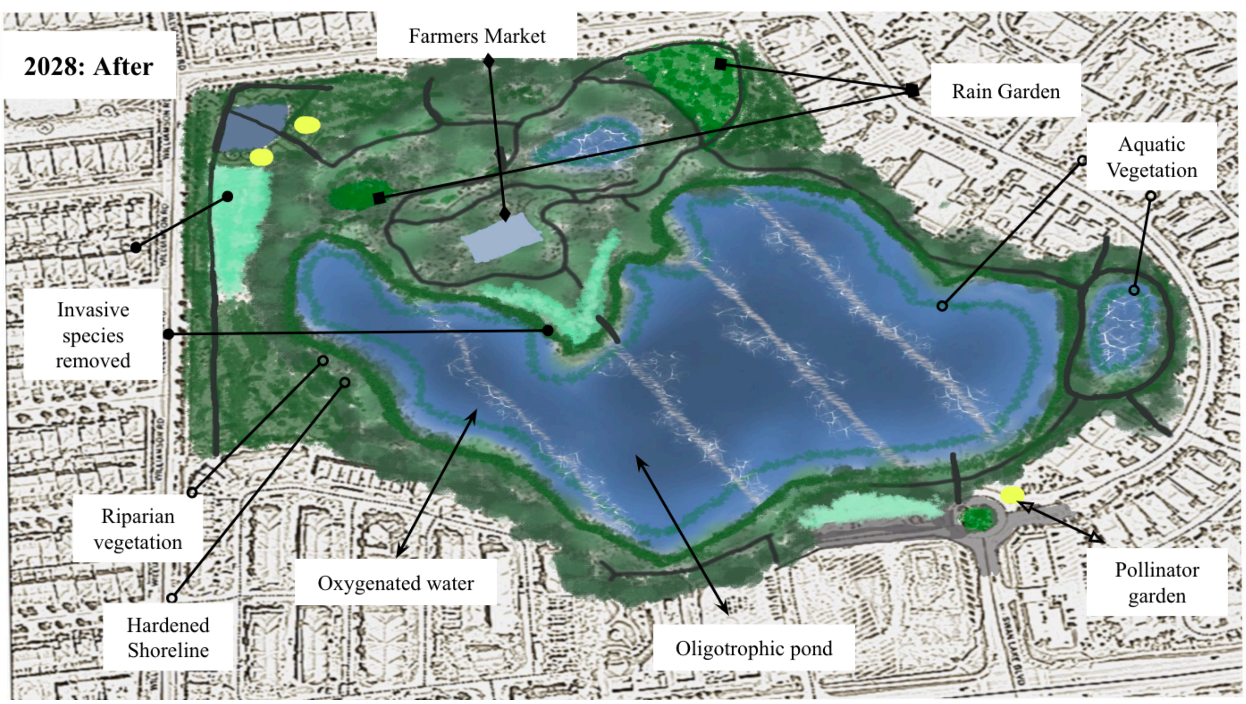


Figure 13. Conceptual Site Model of the current condition of Swan Lake Park in Markham, ON. Followed by two further images indicating a time scale in the top left corner for predicted changes and what the outcomes would appear to be like.

Glossary of Terms

Biodiversity: the variety and variability of life in an ecosystem required for it to function. Can be on a large scale like all of Earth or a small location such as a park.
Environmental Remediation: Cleanup of hazardous substances dealing with removal, treatment of pollution or contaminants which negatively affect an ecosystem through soil, water, and sediment.
Eutrophication: the accumulation of nutrients in a body of water resulting in the depletion of oxygen in the water and the increased development of microorganisms.
Exotic: A plant or animal species that is non-native. They are normally introduced in an area where they do not naturally occur.
Hypereutrophic: a classification of a body of water given when there are extremely heightened nutrient levels that result in the body of water having frequent and nuisance algae blooms.
Invasive: A species that is not indigenous or native to a particular area. Invasive species can cause great economic and environmental harm, damaging local ecosystems. They are considered an extreme threat to animal and plant life, especially here in Canada.
Native: A species that is found in a certain ecosystem related to a natural process such as natural distribution
Non-native: Species that are found in an area where they do not naturally exist. Oftentimes this occurs through accidental or intentional introduction by humans like livestock or ornamental plants.
Restoration ecology: Revitalizing environments to increase its ecological functions and restore it to the way it was meant to be, but also improving the impact on humanity these sites can have.
Rehabilitation: Management actions that aim to reinstate a level of ecosystem functioning on degraded sites, where the goal is renewed and ongoing provision of ecosystem services rather than the biodiversity and integrity of a designated native reference ecosystem.
Restorative continuum: The restorative continuum offers a holistic approach to repairing the world's ecosystems, enabling practitioners to apply the most appropriate and effective treatment given the ecological, social, and financial conditions.
Riparian Zone: The joining area between land and a river or stream, similar to a river bank but can be between different types of water bodies including a river.
Stakeholders: an individual or group with a particular vested interest in an ecosystem or location with ecosystem services.

NBS Framework - Theory of Change

Table 1. outlines and explains the NBS Framework for the target objectives identified in the restoration plan

MAIN OBJECTIVES	NBS ACTIONS	EXPECTED IMPACTS
Improve the water quality of Swan Lake	Dewater and dredge the lake. Chemically treat the water using phoslock, ferric chloride, ferrous sulfate, biochar, pond dye, etc. Use calcium peroxide treatment to increase dissolved oxygen content. Aeration of the pond with new technology and decommissioning of the old fountain. Long term treatments after initial treatments (Aquatic plants, mollusks, diatom algae introduction).	Decreased salt and phosphorus levels, increased dissolved oxygen Foster better conditions for rehabilitating native species.
Aquatic invasive plant control and introduction of native plants	Use herbicides or pesticides particularly for controlling invasive plants. Manual removal or burning. Changing the condition of the lake might also be helpful for invasive species control. Introduce native aquatic plants such as water hyacinths, duckweed, and water stargrass.	Reduce invasive plant populations and promote native species that can help improve water quality. Re-introducing historical functions with suitable conditions to support native species.
Stormwater management and pollution control	Alter the surface soils to funnel stormwater by creating rain gardens and french drains to increase runoff absorption and filter out pollutants. Potentially build a filtration system that can perform reverse osmosis to desalinate runoff water near shoreline before it enters the lake.	Reduces runoff and pollutants from getting into the lake creating cleaner lake water. Improves conditions for aquatic and semi-aquatic organisms to live in.

	Redesign the upland region to divert stormwater through the cleaning process.	
Terrestrial invasive species control and native species protection/introduction	Manual removal or use of bioherbicides like BioChon (*Chondosterum purperum*) which use bacteria to kill weeds and invasive plants. Inhibit geese by planting geese deterrents, modifying habitat by manually planting trees, tall grasses, and other woody vegetation species, decoy deployment, and fence barrier. Install artificial habitats such as bird boxes, bat boxes and nest boxes. Development of ecological corridor	Reduces invasive plant populations. Increases population of native plant species Improves biotic resistance through increased competition and less space/resources for invasive plants. Reduces the number of geese by reducing habitat geese can occupy. Improves habitat heterogeneity and greater animal species richness by preventing monocultures.
Stabilize the banks of Swan Lake	Bioengineering of soil. Addition of water-edge vegetation to increase root presence. Addition of sediment to the bank area.	Reduces soil erosion which improves surface run-off quality. Improves bank stability. Decreases undercutting and degradation of shoreline habitat.
Invasive carp control in the lake	Mass fishing event or tournament with local fishers.	Reduces suspended solids in the lake and aquatic vegetation destruction as carp uproot plants and disturb sediment as they feed. Allows native species to thrive.
Develop recreational activities, educational and community engagement opportunities for the city of Markham	Implement more community pollinator gardens within the park (possibly in areas around the existing windmill). Plant native wildflower species include, but are not limited to Black-eyed Susan, Canada goldenrod, purple-stemmed aster, Swamp milkweed, and more (Suzuki, 2023). Develop recreational access points for on-water activities (ex. fishing, paddle sports).	Increases community contact with nature and supports physical and mental health and strong social ties. Increases accessibility of Swan Lake and Swan Lake Park for the community. Increase in property value for commercial/residential areas around the park. Increases environmental awareness.

	Create recreational opportunities, such as fishing and canoeing/kayaking. Engage school children in supporting the pollinator gardens through volunteer opportunities, class field trips. Create a monthly farmers market at Swan Lake Park to support local businesses. Allow citizens in the community to voice their opinions by engaging them in park restoration activities.	
Represent past Indigenous communities and involve present Indigenous communities.	Dedicate space in Swan Lake Park for Indigenous community members looking to host ceremonies, events, and gatherings. Display art by local Indigenous artists within Swan Lake Park.	Involvement of Indigenous community. Representation of Indigenous communities' art and culture.
Change the designation of Swan Lake and Swan Lake Park as Natural Heritage Network Lands	Follow up with Markham Council about the proposal FOSLP submitted in June 2022. Involve Markham residents in petitioning for the change in designation.	Provides Swan Lake Park with environmental protection.

Table 2. The second part of our Theory of Change with the corresponding objective number listed in the far left column. This table includes the unexpected impacts, synergies, and trade-offs that are hypothesized to occur upon completion of our objectives.

MAIN OBJECTIVE	UNINTENDED IMPACTS	SYNERGIES	TRADE-OFFS
Improve the water quality of Swan Lake	Disruption of the natural environment, potentially altering and displacing existing biological communities and hydrological regimes. Some treatments may have unknown toxic effects. Risk introducing foreign contaminants and creating new issues with lake health. Introduction of invasive species that affect species composition and the establishment of native species ex: mollusk. Although unlikely as oxygen is released from CaO_2 slowly. Excessive oxygen levels that could kill species through hypoxia.	Decrease in excess nutrient levels will allow for native species' habitats to thrive. Influence of various frequent chemical treatments which are beneficial to the water chemistry and health of the pond and aquatic life and can reduce dangerous aerosols. Introduced biotic phytoremediation initiatives that will improve the health of the lake's water and lower the amount of volatile cyanobacteria. Aquatic plants help to increase habitat heterogeneity. enhanced lake water quality because of the chemical treatment's non-toxic nature, which won't endanger	Dredging of sediments can lead to more construction in the park and can deter terrestrial organisms from returning and equipment can temporarily increase air pollution. Enhancing the lake's aesthetics and biodiversity could increase foot traffic and disturb the local ecological communities, leading to gentrification. As the lake water gets healthier it can boost the number of terrestrial and aquatic species but also draw invasive or highly adapted to urban environments species, like Canada geese or common carp, which can eventually drive out the target native species. The aeration system might detract from the lake's natural beauty and have an impact on upcoming water-based activities.

	failure of aeration to raise DO levels and potential disturbance of the lake's fauna. Increasing oxygen will decrease algae growth and increase biodiversity.	aquatic biodiversity and is also cost-efficient	
Aquatic invasive plant control and introduction of native plants	Improper or ineffective removal could lead to failure to remove invasive species causing them to spread more or re-establish. Improper use of pesticides could cause harm to native species, soil quality, and water quality.	Intentionally planting native plant species and removing invasive species can help other native species spread out. The detrimental effects of invading plant species can be mitigated by native species. They might, for example, aid with improving water quality. More vegetation can increase biodiversity by giving some animal species new habitats.	Pesticides used to remove invasive plant species could potentially harm water quality, pollute lake sediment, and harm native species.
Stormwater management and pollution control	Increased riparian zones created could increase the number of bugs such as mosquitos and water borne diseases/illnesses	Riparian zones can be integrated to improve stormwater management, lessening the strain on traditional drainage systems, and offering wildlife habitat.	Reserving land for riparian zones could result in a reduction of available area for construction or cultivation. For the local population's economic and social requirements to be met, ecological benefits must be balanced.

Terrestrial invasive species control and native species protection/introduction	Removal methods may be ineffective and invasive species could re-establish. Improper or inappropriate removal could fail to remove invasive species causing them to spread more. Broad-spectrum herbicides can harm beneficial native plants. Reduction of open space because of planted vegetation overgrowth regarding Geese deterrence. Fence barriers will take up more space and might not be able to stop flying birds	Native plants may draw a wider variety of pollinators and other animal species, improving Swan Lake Park's overall biodiversity. Intentionally planting native plant species and removing invasive species can help other native species spread out. The detrimental effects of invading plant species can be mitigated by native species. They might, for example, aid with improving soil conditions. More vegetation can increase biodiversity by giving some animal species new habitats. Increasing the number of trees and vegetation surrounding the lake can help with shade and water temperature regulation.	Removal of invasive plants can create gaps that allow geese to enter the lake until native plants are planted and regrown. Without proper tools or technology native plants can become nutrients for invasive plants Swan Lake Park may be less suitable for hosting events if there is less open area.

Stabilize the banks of Swan Lake	Sediment strengthening vegetation is eaten by wildlife	Improved riparian plants that are established along the banks. Improved plant root absorption of toxic nutrients to lessen the effect of contaminated runoff on Swan Lake.	Eutrophic sediments may harm wildlife.
Invasive carp control in the lake	Pollution from the fishing tournament or fishermen	Organizing a fishing event that unites the community and emphasizes the significance of managing invasive species. Collaborating with Fish and Wildlife enforcement organizations to investigate and/or put an end to the invasive carp species. Removing carp's impact on vegetation can improve water habitats for native fish and aquatic plant species.	Catch-and-release fishing competitions may raise the risk of native fish species that are important to the ecosystem dying out of carelessness or poor technique.
Develop recreational activities, educational and community engagement opportunities for the city of Markham	Negative environmental effects because of excessive lake and park use. Not enough community	Improving the relationships between plants and pollinators can increase the park's overall biodiversity.	Aids in gentrification and certain groups' exclusion. A lack of sense of obligation for garden maintenance.

	involvement in the preservation and care of pollinator gardens and other park amenities. When community involvement in the park is improved, the surrounding homes' property values rise.	Increasing the park's recreational opportunities will further highlight the significance of Swan Lake.	Plants that are not able to take root and develop to draw pollinators into the garden. The affordability of living in this area is impacted by rising property values. Who has access to and the chance to live in these spaces?
Represent past Indigenous communities and involve present Indigenous communities.	May not be possible to find artist to display art or Indigenous communities may not want use Swan Lake over other areas for event and ceremonies	Increased community involvement with Swan Lake Park is another benefit of Indigenous representation in the park.	N/A
Change the designation of Swan Lake and Swan Lake Park as Natural Heritage Network Lands	Unable to receive designation	Helps to protect the lake and its species	May make it more difficult to host farmers markets.

Table 3: Table outlining the Challenges and Key Indicators for the Swan Lake restoration plan.

CHALLENGES	KEY INDICATORS
Climate Resilience	- Total carbon removed and stored in vegetation and soil. - Daily average and maximum temperatures at Swan Lake
Water Management	- Surface runoff relative to the amount of precipitation - Runoff/stormwater absorption rate - Water quality: dissolved oxygen content, phosphorus levels, heavy metal levels, salt levels, total suspended solids

Biodiversity Enhancement	- Number of invasive species - Number of native species - Pollinator presence - Number of different species
Knowledge and Social Capability Building for Sustainable Urban Transformation	- Rise in environmental awareness - Educational learning with children
Participatory Planning and Governance	- Engagement of citizens in park restoration activities. - Consultation with stakeholders (local community, indigenous, etc.)
Natural and Climate Hazards	- Flood Excess Volume (FEV) - Peak flow variation - Rainfall storage - Potential population vulnerable to risk - Flood peak reduction and delay
Health and Wellbeing	- Self-reported mental health and wellbeing - Improved feeling of connection to nature in Swan Lake community
New Economic Opportunities and Green Jobs	- Environmental testing jobs created to monitor Swan Lake conditions. - Farmers markets create a place for local farmers to sell their produce and goods.

Works Cited

Almaaitah, T., Appleby, M., Rosenblat, H., Drake, J., & Joksimovic D. (2021). The potential of Blue-Green infrastructure as a climate adaptation strategy: a systematic literature review. *Green-Blue Systems*. 3(1). 223-248. https://doi.org/10.2166/bgs.2021.016

Badiou, P & Goldsborough, L. (2011). Impacts of the carbon carp on freshwater ecosystems: A Literature Review. *Carp: Habitat, Management and Diseases.* https://www.researchgate.net/publication/288110284_Impacts_of_the_common_carp_Cyprinus_carpio_on_freshwater_ecosystems_A_review

Balch, G., Broadbent, H., Wootton, B., & Collins, S. (2013). Phosphorus removal performance of bioretention soil mix amended with Imbrium® Systems Sorbtive® Media. In *Centre for Alternative Wastewater Treatment* (Vol. 2013, Issue 19, pp. 143–161). https://www.imbriumsystems.com/Portals/0/documents/sm/technical_docs/Fleming%20College%20CAWT%20Report%20on%20Sorbtive%20Media%20Performance.pdf

Caledon Tree Land. (2023). Norway Spruce Trees in Ontario: The benefits of growing them. https://treeland.ca/norway-spruce-trees-in-ontario-the-benefits-of-growing-them/#:~:text=Environmental%20Benefits&text=One%20of%20the%20primary%20benefits,excellent%20at%20preventing%20soil%20erosion.

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

Canadian Pond. (n.d.). Bubble tubing, fine bubble linear diffuser. https://shop.canadianpond.ca/products/bubble-tubing-linear-diffuser?_ga=2.237864576.1020307750.1707246546-239094323.1707246546&_gl=1*ter846*_ga*MjM5MDk0MzIzLjE3MDcyNDY1NDY.*_ga_E775MWYPLP*MTcwNzI2MDk5OC4yLjEuMTcwNzI2MTI5Ny41OC4wLjA.

Cheng, Y., Kang, Q., Liu, K., Cui, P., Zhao, K., Li, J., Ma, X., & Ni, Q. (2023). Impact of Urbanization on Ecosystem Service Value from the Perspective of Spatio-Temporal Heterogeneity: A case study from the Yellow River Basin. *Land*. 12(7). https://doi.org/10.3390/land12071301

Chorabik, S. (2023). Native Ontario Plants for Pollinators. *Ontario Honey Creations*. https://www.ontariohoneycreations.com/blogs/ohc-blogs/native-ontario-plants-for-pollina tors

City of Markham. (n.d). Major City Projects. https://www.markham.ca/wps/portal/home/about/city-hall/city-projects-initiatives/city-projects-initiatives

City of Markham. (n.d). Sustainable Neighbourhood Small Grant. https://www.markham.ca/wps/portal/home/about/city-hall/awards-grants-funding/sustainable-neighbourhood-small-grant/sustainable-neighbourhood-small-grant

City of Markham. (2021). Sustainable Neighbourhood Small Grant Pollinator Garden Guidelines. https://www.markham.ca/wps/wcm/connect/markham/97f3d13c-1157-4f0b-9dd9-29ed127826aa/Pollinator+Garden+Guidelines.pdf?MOD=AJPERES&CONVERT_TO=url&CACHEID=ROOTWORKSPACE.Z18_2QD4H901OGV160QC8BLCRJ1001-97f3d13c-1157-4f0b-9dd9-29ed127826aa-nFp5RsS

Cooper, J. A. (1998). The potential for managing urban Canada geese by modifying habitat. In R. O. Baker & A. C. Crabb (Eds.), *Proceedings of the Eighteenth Vertebrate Pest Conference (1998)*. University of Nebraska-Lincoln. https://core.ac.uk/download/pdf/19727598.pdf

Cosburn Patterson Wardman, Cosburn Giberson Landscape Architects, & Michael Michalski Associates. (1993). The Swan Lake Community Environmental Management Study. In *Town of Markham* (No. 87464). https://friendsofswanlakepark.ca/wp-content/uploads/2020/05/Swan-Lake-Environmental-Management-Study_Dec-1993.pdf

Conover, M. R. (1991). Herbivory by Canada geese: Diet selection and effect on lawns. *Ecological Applications, 1*(2), 231-236. https://doi.org/10.2307/1941816

Credit Valley Conservation. (n.d.). Native Plants for Pollinators. https://files.cvc.ca/cvc/uploads/2017/04/17-uo-nativeplantsforpollinators-booklet-v8-web.pdf

Erickson, A. J., Gulliver, J. S., & Weiss, P. T. (2012). Capturing phosphates with iron enhanced sand filtration. *Water Research*, *46*(9), 3032–3042. https://doi.org/10.1016/j.watres.2012.03.009

Friends of Swan Lake Park (2020). We want to go back to the future. https://pub-markham.escribemeetings.com/filestream.ashx?DocumentId=29162

Friends of Swan Lake Park. (2020a). *A Pathway to Sustainable Water Quality for Swan Lake.* https://friendsofswanlakepark.ca/wp-content/uploads/2020/12/Pathway-to-Sustainable-Water-Quality-in-Swan-Lake_-Dec-15-2020-1.pdf

Friends of Swan Lake Park. (2020b). *Enhanced Goose Management Plan*. https://friendsofswanlakepark.ca/enhanced-goose-management-plan-proposed-august-2020/

Friends of Swan Lake Park. (2020c). *Invasive Species*. https://friendsofswanlakepark.ca/resources/invasive-species/

Friends of Swan Lake Park. (2023). *Towards a Comprehensive Restoration Plan.* https://friendsofswanlakepark.ca/wp-content/uploads/2023/06/Torwards-a-Comprehensive-Restoration-Plan__May-2023_Final.pdf

Gann, G. D., McDonald, T., Walder, B., Aronson, J., Nelson, C. R., Jonson, J., Hallett, J. G., Eisenberg, C., Guariguata, M. R., Liu, J., Hua, F., Echeverría, C., Gonzales, E., Shaw, N., Decleer, K., & Dixon, K. W. (2019). International principles and standards for the practice of ecological restoration: Second edition. Restoration Ecology, 27(S1), S1-S46. https://doi.org/10.1111/rec.13035

Government of Canada. (2022). *Guidelines for Canadian Drinking Water Quality - Summary Tables*. https://www.canada.ca/en/health-canada/services/environmental-workplace-health/reports-publications/water-quality/guidelines-canadian-drinking-water-quality-summary-table.html

Greats Lakes of Phragmites Collaborative. (n.d.). Management Techniques. https://www.greatlakesphragmites.net/management/techniques/

Hazelton, E., Mozdzer, T., Burdick D., Kettenring., K & Whingham., D. (2014). *Phragmites australis* management in the United States: 40 yeast of method and outcomes. *AoB Plants*. https://doi.org/10.1093/aobpla/plu001

Hobbs, R., Higgs, E., & Hall, C. (n.d.). Defining Novel Ecosystems. 1-3. https://onlinelibrary-wiley-com.myaccess.library.utoronto.ca/doi/pdf/10.1002/9781118354186.ch6

Huang, Y., Yuan, D., Ma, J., Zhang, M., & Chen, G. (2009). Rapid speciation of trace iron in rainwater by reverse flow injection analysis coupled to a long path length liquid waveguide capillary cell and spectrophotometric detection. *Mikrochimica Acta*, *166*(3–4), 221–228. https://doi.org/10.1007/s00604-009-0193-8

Istvánovics, V. (2009). Eutrophication of Lakes and Reservoirs. Gene E. Likens (Eds.), *Encyclopedia of Inland Waters.* (pp. 157-165). Elsevier Inc.

Jamroen, C. (2022). Optimal techno-economic sizing of a standalone floating photovoltaic/battery energy storage system to power an aquaculture aeration and monitoring system. *Sustainable Energy Technologies and Assessments*. 50, 101862.

Johnston, C., Lee, D., Kipkie, C., Zabil, D., & Carter, J. (2019). Rain Gardens: Design, Implementation, and Maintenance Considerations. In *Kerr Wood Leidal*. Kerr Wood Leidal Associates Ltd. https://www.kwl.ca/wp-content/uploads/2019/07/8-1a.pdf

Kiani, M., Tammeorg, P., Niemistö, J., Simojoki, A., & Tammeorg, O. (2020). Internal phosphorus loading in a small shallow Lake: Response after sediment removal. *Science of The Total Environment*, *725*, 138279. https://doi.org/10.1016/j.scitotenv.2020.138279

Lake Erie Lowlands. (n.d.). Selecting Plants for Pollinators. https://www.pollinator.org/pollinator.org/assets/generalFiles/LakeErieLowlands.2017.pdf

Langdon, C. (2023). Deterring Canada geese. Haliburton County Master Gardeners. https://www.haliburtonmastergardener.ca/resource-category/native-plants-for-your-property-including-shorelines/

Langellotto, A., Melathopoulos, A., Messer, I., Anderson, A., McClintock, N., & Costner, L. (2018). Garden Pollinators and the Potential for Ecosystem Service Flow to Urban and Peri-Urban Agriculture. S*ustainability*. https://mdpi-res.com/sustainability/sustainability-10-02047/article_deploy/sustainability-10-02047.pdf?version=1529132283

Lewtas, K., Paterson M., Venema, H. and Roy, D. (2015) Manitoba Prairie Lakes: Eutrophication and In-Lake Remediation Treatments. International Institute for Sustainable Development. https://www.iisd.org/system/files/publications/manitoba-prairie-lakes-remediation-literature-review.pdf

Li, Y., Yang, Z., Yang, K., Wei, J., Li, Z., Ma, C., Yang, X., Wang, T., Zeng, G., Yu, G., Yu, Z., & Zhang, C. (2022). Removal of chloride from water and wastewater: Removal mechanisms and recent trends. *The Science of the total environment*, *821*, 153174. https://doi.org/10.1016/j.scitotenv.2022.153174

Litalien, A., & Zeeb, B. (2020). Curing the earth: A review of anthropogenic soil salinization and plant-based strategies for sustainable mitigation. *The Science of the Total Environment*, *698*, 134235–134235. https://doi.org/10.1016/j.scitotenv.2019.134235

Ma , Z., Ge, Z., Liu, K., Wang , C., Wu, T., & Zhang, J. (2023, September). Application of calcium peroxide for efficient treatment of surface water turbidity: Mechanisms and Microbial Community responses. *Journal of Environmental Chemical Engineering*. 11 (5), 110905.

Majewska, A. A., & Altizer, S. (2019). Planting gardens to support insect pollinators. *Conservation Biology*, *34*(1), 15-25. https://doi.org/10.1111/cobi.13271

Malaviya, P., Sharma, R., & Sharma, P. K. (2019). Rain gardens as a stormwater management tool. In *Springer eBooks* (pp. 141–166). https://doi.org/10.1007/978-981-13-2772-8_7

Ministry of Natural Resources. (2018). Invasive Carps. https://www.ontario.ca/page/invasive-carps

Ministry of Ontario. (2016). Ontario Community Environment Fund application Guide. https://www.ontario.ca/page/ontario-community-environment-fund-application-guide

Mobile Water Quality Colorimeter. (2023). Conduct Science. https://conductscience.com/lab/portable-spectrophotometer-water-quality-analyzer/

Nagul, E. A., McKelvie, I. D., Worsfold, P., & Kolev, S. D. (2015). The molybdenum blue reaction for the determination of Orthophosphate Revisited: Opening the Black Box. *Analytica Chimica Acta*, *890*, 60–82. https://doi.org/10.1016/j.aca.2015.07.030

Neal, Catherine & P. Lewis. (2013). *Native Plant Selection for Biofilters and Rain Gardens*. Rain Gardens, Stormwater Management, Ecological Landscape Alliance. https://www.ecolandscaping.org/12/managing-water-in-the-landscape/stormwater-management/native-plant-selection-biofilters-rain-gardens/

Not so Hallow. (n.d.). Monarchs Need Milkweed. https://notsohollowfarm.ca/got-milkweed/

Nürnberg, G. K. (2020). Hypolimnetic withdrawal as a lake restoration technique: determination of feasibility and continued benefits. *Hydrobiologia*, *847*(21), 4487–4501. https://doi.org/10.1007/s10750-019-04094-z

Nykänen , A., Kontio, H., Klutas, O., Penttinen, O.-P., Kostia, S., Mikola, J., & Romantschuk, M. (2012). Increasing lake water and sediment oxygen levels using slow release peroxide. *Science of the Total Environment.* 429, 317-324.

Parhizgari, Z, & Muir, R. (2021). *Swan Lake Water Quality Management Plan.* City of Markham. https://pub-markham.escribemeetings.com/filestream.ashx?DocumentId=46635
Park People (n.d). TD Park People Grants. https://parkpeople.ca/opportunity/td-park-people-grants/

Pereira, A. C., & Mulligan, C. N. (2023). Practices for eutrophic shallow lake water remediation and restoration: A critical literature review. *Water*, *15*(12), 2270. https://doi.org/10.3390/w15122270

Pinto, L., Inacio, M., Ferreria, C., Ferreria, A., & Periera P. (2022). Ecosystem Services and Well-being dimensions related to urban green spaces - A Systematic Review. *Sustainable Cities and City. https://doi.org/10.1016/j.scs.2022.104072*

Pratap, T., Patal, M., Pittman, C. U., Nguyen, T. A., & Mohan, D. (2021). Nanobiochar: A sustainable solution for agricultural and environmental applications. In *Nanomaterials for Soil Remediation* (pp. 501-519). Elsevier. https://doi.org/10.1016/B978-0-12-822891-3.00028-1

Prince George's County Department of the Environment. (n.d.) *Rain Garden Fact Sheet*. Chesapeake Bay Trust. https://cbtrust.org/wp-content/uploads/Fact-Sheet-and-Guidelines_Rain-Garden_042120.pdf

Pulichara, R., & Brar, S. (2022). Research into the removal of nutrients and chloride from Swan Lake. *University of York.* https://friendsofswanlakepark.ca/wp-content/uploads/2024/02/York-University_Swan-Lake_May-2-2022.pdf

Šarko, J., & Mažeikienė, A. (2020). Investigation of sorbents for phosphorus removal. *The 11th International Conference ENVIRONMENTAL ENGINEERING 11th ICEE SELECTED PAPERS*. https://doi.org/10.3846/enviro.2020.620

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

Singh, N. K., Van Meter, K. J., & Basu, N. B. (2023). Widespread increases in soluble phosphorus concentrations in streams across the transboundary Great Lakes Basin. *Nature Geoscience, 16,* 893-900. https://doi.org/10.1038/s41561-023-01257-5

Smith, A., Craven, S., & Curtis P. (n.d.) Managing Canada Geese in Urban Environement. https://ecommons.cornell.edu/server/api/core/bitstreams/918dbe4e-6a34-4eef-beb4-5818e59e762b/content

Smith, N. (2021). Urban Blue spaces and human health: A systematic review and meta-analysis of quantitive studies. *Cities*. https://doi.org/10.1016/j.cities.2021.103413

SOLitude Lake Management. (n.d.). Debris and Sediment Removal. SOLitude Lake Management. https://www.solitudelakemanagement.com/dredging-sediment-removal-option-best-lake-pond-waterway/#:~:text=There%20are%20several%20methods%20of,%2C%20budget%2C%20and%20disposal%20considerations.

Tammeorg, O., Chorus, I., Spears, B., Nõges, P., Nürnberg, G. K., Tammeorg, P., Søndergaard, M., Jeppesen, E., Paerl, H., Huser, B., Horppila, J., Jilbert, T., Budzyńska, A., Dondajewska‐Pielka, R., Gołdyn, R., Haasler, S., Hellsten, S., Härkönen, L. H., Kiani, M., … Lürling, M. (2023). Sustainable lake restoration: From challenges to solutions. *WIREs Water*. https://doi.org/10.1002/wat2.1689

Thistleton, J., Berry, T. A., Pearce, P., & Parsons, S. A. (2002). Mechanisms of chemical phosphorus removal II: Iron (III) salts. *Process Safety and Environmental Protection, 80*(5), 265-269. https://doi.org/10.1205/095758202762277623

Toronto Master Gardeners (n.d.). Gardeners Guides. https://www.torontomastergardeners.ca/gardeningguides/pollinator-garden-a-toronto-master-gardeners-guide/

Toronto and Region Conservation Authority. (2016). Town of Ajax Rain Gardens Retrofit: Case study. In *Sustainable Technologies Evaluation Program*. https://sustainabletechnologies.ca/app/uploads/2016/06/Ajax-Rain-Gardens.pdf

Toronto and Region Conservation Authority. (2019). *Rain Gardens*. https://trcaca.s3.ca-central-1.amazonaws.com/app/uploads/2019/02/11103208/2138_Healthy-Yards_Rain-Gardens_2019_FA_web.pdf

Toronto Zoo. (n.d). Pollinator Plant Guide. https://www.torontozoo.com/pollinators/Pollinator%20Plant%20Guide.pdf

UC Davis. (n.d.). Spectrophotometric Determination of Phosphates in Water. UC Davis Engineering.

https://mse.engineering.ucdavis.edu/sites/g/files/dgvnsk4451/files/inline-files/GAANN-exp-9-Spectr ophotometric-Determination-Phosphates-Water.pdf

United Nations Ecosystem Program (n.d.) What is Ecosystem Restoration? https://www.decadeonrestoration.org/what-ecosystem-restoration

United Nations Ecosystem Program (n.d). About UN Decade. https://www.decadeonrestoration.org/about-un-decade

United Nations Ecosystem Program (n.d.) Preventing, Halting, and Reserving Loss of Nature. https://www.decadeonrestoration.org/

Wang, W., Wang, Y., Fan, P., Chen, L., Chai, B., Zhao, J., & Sun, L. (2019). *Environmental Pollution*. 248. 18-27. https://doi.org/10.1016/j.envpol.2018.11.0690269-7491

Wang, Y., Wang, W.-H., Yan, F.-L., Ding, Z., Feng, L.-L., & Zhao, J.-C. (2019). Effects and mechanisms of calcium peroxide on purification of severely eutrophic water. *Science of The Total Environment*, *650*, 2796–2806. https://doi.org/10.1016/j.scitotenv.2018.10.040

Wright, A. (2020). *Photothermal enhancement of saline water evaporation using organic dyes* (Publication No. 28001143) [Master's thesis, New Mexico Institute of Mining and Technology]. https://www.proquest.com/docview/2451115770/fulltextPDF/706F3AFEDF7346D9PQ/1?%20Theses&accountid=14771&sourcetype=Dissertations%20

Xiao-rong, W, Ming-an, S, Xing-chang, Z, Hong-bo, S. (2010). Landform affects on profile distribution of soil properties in black locust (*Robinia pseudoacacia* L.) land in loessial gully region of the Chinese Loess Plateau and its implications for vegetation restoration. *African Journal of Biotechnology*, 8, 13.

Ye, M., Pan, W., Dai, W. (2023). Composite iron-carbon constructed wetland combined with photocatalytic film to restore eutrophic water body and the hydraulic performance of constructed wetland. *Journal of Water Process Engineering, 53*, 103590. https://doi.org/10.1016/j.jwpe.2023.103590

Zhang, Y., Hu, Y., Peng, Z., Hu, W & Zhu J. (2022). Environmental Mechinisams of Capturing Nutreint Rich particles by lake bottom trap in a large shallow lake. *Chemosphere*. https://doi.org/10.1016/j.chemosphere.2022.136081

Zhou, S., Marcelino, K.R., Wongkiew, S., Sun, L., Guo, W., Khanal, S.K., & Lu, H. (2022) Untapped Potential: Applying Microbubble and Nanobubble Technology in Water and

Wastewater Treatment and Ecological Restoration. *ACS EST Engg.* 2 (9), 1558-1573. doi: 10.1021/acsenstengg.2c00117

Appendix A: Details on Hydrology Management

Environmental Assessment Recommendations

Prior to water withdrawal and dredging, it is imperative to conduct chemical tests of the lake water and sediments in order to determine their chemical composition and level of contamination. Swan Lake can be divided into 10 m transets traveling north to south, and east to west. Each intersection along the transects can be marked as a sampling area. Taking samples in this manner will improve the heterogeneity of the samples and give a more comprehensive estimate of water quality across the entire lake. At each sampling location, two water samples should be collected, one just above the maximum depth within 1 m of the lake bed and another within 1 m of the water surface. This will give an idea of the water conditions both at depth and at the surface of Swan Lake. In addition, sediment cores at each location should also be sampled to at least 35 cm (as proposed in FOSLP). The sediment cores can be further divided into 5 cm horizons to examine the stratification of chemical concentrations within the sediment. Based on where contamination is the highest, this will aid in determining the volume of sediment to be removed in the dredging process. Furthermore, sediment samples can be used to assess the benthic community composition within Swan Lake that, in turn, can be used as an indicator of water quality conditions. For example, the presence or absence of sensitive, tolerant, and/or resistant taxa often correlates to the degree of contamination on site. Typically, the greater the contamination and degradation of the site, the smaller the proportion of environmentally sensitive species and the larger the proportion of resistant species.

Fortunately, the Government of Ontario has a Lake Partner Program that provides sampling guidelines for lake water testing. Friends of Swan Lake Park (FOSLP) could utilize this program and collaborate with volunteers to have the water quality tested at Swan Lake. As opposed to being a one-time procedure, this program involves long-term water quality testing.

As such, the Lake Partner Program may provide a way for FOSLP to continually monitor water quality at Swan Lake. Once samples are collected by volunteers, they are subsequently tested at the Dorset Environmental Science Center to determine if provincial water quality guidelines are met.

The results of the sediment samples acquired from Swan Lake can then be compared to the Provincial Sediment Quality Guidelines in order to determine the level of contamination and thus the next steps in terms of sediment disposal and recycling post-dredging. The Guidelines for Identifying, Assessing and Managing Contaminated Sediments in Ontario provides a breakdown of contaminants and what concentrations are considered dangerous. These guidelines also provide information on different permits and approvals that may be required prior to dredging.

Table 1. Reports the water quality parameters to be measured and monitored at Swan Lake, the methods of measurement, as well as the provincial benchmarks.

Parameter	Methods/Instrumentation	Benchmarks and Goals
Phosphorus levels	Samples collected from the lake can be tested for phosphorus concentration using a UV-Vis and a standard calibration curve ● See UC Davis (n.d.) and Nagul et al. (2015) for experimental details and sample preparation ● The referenced article details how orthophosphate can be directly measured via a portable spectrophotometer, as these compounds contain a reactive form of phosphate found in water bodies (Nagul et al., 2015). ● Spectrophotometry can show the concentration of phosphorus in a sample by measuring the unique amount of light that is absorbed by the sample when light is shone through it (Singh, 2023).	Phosphorus levels should be monitored after the chosen chemical treatment has been applied at regular intervals for signs of improvement, and then annually once targets have been met. Phosphorus levels should be kept between 10 and 50 $\mu g \cdot L^{-1}$, where eutrophic conditions are considered to be above 30 $\mu g \cdot L^{-1}$ (Canadian Council of Ministers of the Environment, 2004).

	For the purposes of Swan Lake, a portable UV-VIS spectrophotometer should therefore be used. These instruments can cost up to \$700, but can afford measurements of additional parameters with this extra cost such as pH, turbidity, total chlorine, free chlorine, nitrate, nitrite, and ammonia among several others ("Mobile Water Quality Colorimeter", 2023). ● Orthophosphates can also be measured using simple portable colorimeters as well, but these are less precise, and can be just as expensive or more for reliable instrumentation (Singh, 2023).	
Nitrogen levels	The portable UV-Vis spectrophotometer mentioned for phosphorus testing can also be used with great accuracy for nitrogen concentration measurements	A maximum concentration of $45 \mu g \cdot L^{-1}$ as nitrate is recommended in Canada, and for nitrite, $3 \mu g \cdot L^{-1}$ (Government of Canada, 2022).
Turbidity	Turbidity of the water can be measured using the appropriate probe or benchtop turbidity meter, and these work via assessing how much light is reflected back from the instrument light according to product-included instructions A more inexpensive option uses a Secchi Disc	Turbidity is measured in Nephelometric Turbidity Units (NTU), where higher turbidity corresponds to higher values A turbidity level of 1.0 NTU or less is is desirable
Dissolved Oxygen (DO)	Dissolved oxygen levels can be easily measured using DO probes similar to those used for turbidity	A DO level of > 6 mg/L is considered healthy However, DO levels of 4-5 mg/L are acceptable for warm water fish which are the species of fish most common in Swan Lake (Parhizgari & Muir, 2021)
Salinity	Salinity can be measured using a conductivity probe ● This measures the conductivity of a water sample, which can be correlated	Freshwater salinity should ideally be below 1000 ppm

	with the dissolved ion concentration (such as chloride) Laboratory quality calibrating probes can be purchased online for up to $1000 and results can be seen immediately	

Physical Site Alteration Recommendations

Physical site alterations have already been proposed by Friends of Swan Lake Park as a way to address the internal nutrient loading within Swan Lake. The following table outlines the methods proposed as well as their respective costs, benefits, and risks.

Table 2. Summary of the proposed physical site alterations along with their associated costs, benefits, and risks.

Method	Process	Limitations	Risk	Benefits	Reference
Mechanical Sediment Removal	Mechanical dredging utilizes machinery like excavators to remove nutrient-rich sediment from lakes. This is particularly useful for coarse sediment types.	Expensive if there is no dump site nearby. Requires sediment analysis to ensure there are no toxic contaminants in the sediment before dumping.	Damage to benthic environments (disrupting habitats for fish and invertebrates) and permanent alteration to lake bed bathymetry. Mechanical dredging stirs up sediment. Risk of erosion.	Mechanical dredging can be used for coarser sediments. Sediments can be repurposed as fertilizers on the site. Effectively reduced phosphorus and other contaminants in lakes.	Tammeorg et al., 2023 Kiani et al., 2020 Solitude Lake Manageme nt, n.d.
Hypolimnetic Withdrawal	Selectively removes phosphorus-ri ch water from lakes using an	Low-cost if gravity-based , and more expensive if pumping is	A decrease in water level can affect established communities.	An effective method for reducing phosphorus loading in	(Tammeorg et al., 2023) (Nürnburg, 2020) (Silvonen

	Olszewski Pipe. This is often employed when nutrient levels are the highest in the lake. Involves the epilimnion water layer mixing with the deeper anoxic waters to encourage oligotrophication. Occurs in either a closed precipitation system with sorptive filtration for removal or an open system diversion.	required to remove water. $80 000-$600 000. This is an average range and includes installation and annual operation of the pipe.	Need to ensure water levels will rise afterwards. Diversion of contaminated discharge may cause issues downstream/upl and if not disposed of properly.	lakes, especially in the hypolimnion. Water can be repurposed and used elsewhere.	et al., 2022) (Pereira and Mulligan, 2023) (Lewtas et al., 2015).

<u>Sediment and Water Storage/Recycling Options</u>

Whether practitioners decide to dredge Swan Lake or undertake hypolimnetic withdrawal, the sediment and/or water that is removed must be stored, recycled, or disposed of. The following table summarizes these options and their associated costs.

Table 3. Potential options for sediment and water storage, reuse, and disposal.

Options	Process	Volume	Cost
On-site storage	*Depends on results from testing and the level of contamination* For low-levels of contamination:	Swan Lake can accommodate between 5000-8000m^3 of	$1.5-3.7 mil → includes cost for potential

	- Evacuate the pit on site, and line it with clay soil to reduce leaching. Dump sediment and cover with fresh soil and grass. This space can serve as an additional area for planting. For high-levels of contamination: - Consider either treating the sediment prior to dumping, or line the pit with a low-permeability landfill liner to prevent leaching. Dump sediment and cover with fresh soil.	sediment. Variable, depends on how much is removed from lake and stormwater ponds based on chemical tests.	transport if necessary Price will vary depending on the amount of sediment removed. $34-$1 409 per m^3 to remove contaminated sediment (Lewtas et al., 2015).
Sediment Recycling	*Depends on results from testing and level of contamination* Dredged sediment can be recycled and repurposed for agriculture and general gardening on site. Collaborate with the community and farmers in the area to organize either delivery or pick-up. High fertilizing ability, can also be repurposed on site to aid with planning on shoreline and upland regions. Reduces the focus on storage and more towards redistribution.	This would reduce the amount of sediment stored on site and help the surrounding community. Contributes to a circular economy.	Potential cost of transport accounted for above.
Water Recycling	*Depends on results from testing and level of contamination* Water pumped out of the lake and stormwater ponds can be recycled and reused for agriculture (irrigation), as well as cooling in	Predicted volume is 44 000 m^3	Installation and maintenance fees for the pump are around $80,000-$400,

	buildings. Generally, water would be sent downstream or to another reservoir. Either the water can be temporarily redistributed to the stormwater ponds or another nearby water source before recycling. Water can also be used to aid with planting projects in the shoreline and upland regions.		000 (Lewtas et al., 2015)

Chemical Treatments

After the physical site alterations, practitioners should resume chemical treatments. While Phoslock and Poly Aluminium Chloride are already in use at Swan Lake, additional chemical treatments that address the high nitrogen and chloride concentrations should be considered. See Table 4 for a list of applicable chemical treatments.

Table 4. Pros and cons of proposed chemical treatments for Swan Lake and the surrounding stormwater ponds

Treatment	Function	Benefits	Limitations	Reference
Iron-Carbon Composite with a Photocatalytic Film	The iron-carbon composite can be introduced along the shoreline and in the shallow depths of the lake sediment. This composite acts as a filter for nitrogen and phosphorus, as well as a few micromolecular compounds. The photocatalytic film is	This method is effective at removing nitrogen and phosphorus, as well as chlorophyll. Studies have also shown that this approach increases DO in water as well.	The composite can remain part of the lake into the future as an active filter, although the photocatalytic film covers the surface which is not ideal in the long run. Photocatalytic films are expensive, and based on the size of	Ye et al., 2023

	placed along the surface of the lake and breaks down contaminants in the water through oxidation-reduction.		the lake, we need to consider the cost.	
Pond Dyes	Organic dyes act as photothermal agents that absorb solar energy to mediate the evaporation of saline water.	Aids in the removal of salt from water. Non-toxic and low-cost Small molecular size makes them readily dispersible in water and non-invasive, yet efficient.	Become photo-bleached over time, meaning they lose their photothermal effect.	Wright, 2020
Ferric chloride	Ferric chloride is added to water bodies, as the iron (III) salt readily reacts with phosphate to form solid iron-phosphorus complexes, thereby precipitating phosphorus from the water.	Been shown to be effective at removing up to 80% - 90% of total phosphorus from the water using a stoichiometric excess of the ferric chloride salt.	Have to ensure an excess of the iron salt, as there is a competitive alternative reaction with the hydroxide, forming metal hydroxide complexes in water.	Thistleton et al., 2002
Biochar	Biochar is a carbon-based material from biomass that acts as a filter for pollutants and nutrients.	Effective for removing salt and excess nutrients from water, it has also been shown to remove heavy metals from soil.	Since this is a solid material, introducing it into the water directly may create a suspension. Hence, we should consider applying this directly to the sediment or test on a smaller scale how it settles in	Pratap et al., 2021 Pulicharla and Brar, 2022

			water.	
Calcium Peroxide	Calcium Peroxide is a tasteless and odourless alkaline metal peroxide, which slowly releases oxygen and has been shown to reduce pollution in wastewater treatment	Increases phosphorus sediment capacity Reduces the release of nitrogen and phosphorus from sediment Increases DO in water and maintains stable levels due to slow prolonged O_2 release. Increases microbial diversity, which aids in future nutrient cycling Increases oxidation-reduction potential of water Further algae removal will prevent the breakdown of organic matter and consumption of oxygen, enhancing the quality of this chemical treatment.	Alters microbial communities which may be part of a larger system. This could have effects on the natural state of the ecosystem. Wang et al. used up to 75 kg for a 30m x 10m plot of water. We need to consider how much will be required for Swan Lake.	Wang et al., 2019

<u>Aeration Methods</u>

Calcium Peroxide

One mg of calcium peroxide releases 0.22 mg of oxygen. Moreover, due to the low solubility of the compound, it will settle on the bottom of the lake and continue to release oxygen into the environment (Ma et al., 2023). The reaction of the calcium peroxide compound with water creates calcium hydroxide that increases the pH levels of water. However, the calcium hydroxide subsequently reacts with carbon dioxide in the water column resulting in the formation of bicarbonate. This bicarbonate compound limits the rising pH levels in the water system thereby neutralizing the pH of the water (Ma et al., 2023).

Application method:

The proposed application method for this chemical aerator needs humans to execute the dispersal of this chemical into stormwater inlets and ponds. The process includes the use of a rowboat to travel along the water bodies and drop the material into the water column. There would be no need to mix the granulated chemical compound in the area as the chemical will sink through the strata of the water column and subsequently settle at the bottom of the pond (Nykanen et al., 2012). It is in this area where the recommended 10 mg/L (Ma et al., 2023) of granulated calcium peroxide will then mix with the lake sediments and be released over a period of 5 to 7 months in order to gradually increase dissolved oxygen levels in the lake (Nykanen et al., 2012).

Cost: $60 to $200 CAD

Microbubble tubing

Mechanical aeration via microbubble tubing involves tubes carrying pressurized air from a diaphragm compressor to the bottom of a water body (Canadian Pond, n.d.). This produces microbubbles, which have a diameter under 200 μm. This gives them a slower ascension rate in comparison to larger bubbles thereby increasing the dissolved oxygen content across different depths. This technology requires an on-shore pump and air compressor, as well as a power source.

Application method:

Installing transects of microbubble tubing across the whole lake would be logistically challenging, especially considering the variable depth of the lake and the bottom-feeding carp. While this may not translate to higher DO in the lake itself, it will likely aid in removing harmful nitrates and phosphorus from the stormwater ponds before circulating into the lake.

The installation of microbubble tubing should happen after the calcium peroxide treatment, with enough time to monitor water chemistry changes after the treatment is completed. Given that CaO_2 takes about 5-7 months to release, no mechanical alterations should be made to the ponds for at least 9 months after the treatment.

Cost: $429.00 CAD per Stormwater Pond

PV/BES system

Floating photovoltaic (PV) /Battery energy storage (BES) systems are floating installations that use solar panels to power a paddle system. These paddles increase turbidity as the floating system moves across the surface. The BES system allows surplus energy from sunny days to be stored so the system can continue running during overcast conditions.

Application method:

Within this aeration system, voltage and current sensors would be needed to ensure the system is functioning properly and efficiently using energy (Jamroen, 2022). In addition, a DO sensor would be needed to monitor the oxygen concentration of the stormwater ponds and main lake regions to ensure DO levels are appropriate and the system is functioning efficiently.

As with the microbubble tubing system, we recommend that this physical system not be installed until after a round of CaO_2 treatment has been completed and DO profiles have been monitored.

Wind-powered system

Similar to the floating PV/BES systems, a wind-powered system would power a paddle wheel using wind. This generates turbidity at the surface, increasing the DO as the water mixes.

Table 5. Summary of the benefits, limitations, and feasibility of various aeration methods.

Methods	Benefits	Limitations	Feasibility in Swan Lake/ Stormwater Ponds?	Mechanisms for Success
Calcium peroxide	Increases phosphorus sediment capacity as CaO_2 reduces the release of nitrogen and phosphorus from sediment. (Wang et al., 2019) Increases the DO levels throughout the water column and helps to maintain stable DO levels due to the prolonged release of oxygen (O_2) as the calcium peroxide sits on the lake bed (Wang et al., 2019).	This chemical aerator method can alter the pond's microbial communities which may be part of a larger system. This could have effects on the natural state of the ecosystem. As Wang et al. discuss, they used up to 75 kg for a 30m x 10m plot of water. We need to consider how much will be required for Swan Lake.	This chemical method may not be feasible within the winter season. Rather, application should occur during the warmer months.	Consistent, regular applications of the calcium peroxide

	Increases microbial diversity that will, in turn, aid in future nutrient cycling (Wang et al., 2019).			
Microbubble tubing	Microbubbles produced continuously treat the DO levels in the stormwater ponds. This is an efficient way to increase DO throughout all depths. Not necessary to retrieve the tubing in the winter, it can simply be turned off. Flow rate and pressure of bubbles may be altered to achieve the desired results (Canadian pond, n.d.) Can also effectively reduce contaminants and nutrient excesses in stormwater (Zhou et al., 2022)	Not feasible in the winter, as microbubbles disturb the lake freezing processes. Requires a power source to continuously run. If there are carp in the stormwater ponds, they could easily disturb the system due to their bottom-feeding behaviors. Outside of the stormwater ponds, the amount of tubing required to achieve adequate spatial coverage would be high in cost due to the large quantities of PVC required.	Microbubble tubing in the stormwater ponds may increase DO in the ponds themselves, but is less feasible than chemical oxygenation for circulating DO throughout the lake. Increases in DO from microbubbles may also assist in reducing harmful nitrates and phosphorus in stormwater before it enters the lake This system would not be feasible in shallow zones of the pond, specifically where the depth of the pond is less than 3 meters as bubbles would rise quickly and would not have enough time to infiltrate into the water column. Due to the large size of Swan Lake, installing micro bubble tubing in the stormwater ponds is more feasible than across the lake itself.	To install microbubble tubing, Swan Lake Park would need a compressor cabinet installed at the shore. There would also need to be an electrical source, such as an outlet or a battery to connect the system and get it running.

PV/BES system	PV/BES systems use solar panels to generate power and a battery to store power surplus. Thus, additional power sources are not required. Cost-effective considering the size of Swan Lake Park, running at just over 10 cents/kWh.	Not feasible in the winter while the lake is frozen, and therefore would need to be retrieved and stored over the season. Paddles generate turbidity at the surface, which may not correspond to increases in DO at lower depths.	These systems are not feasible in stormwater ponds, as they need space to generate turbidity. We suggest either of these systems be installed in the lake itself.	Both the PV/BES and wind powered systems run the risk of running into shore and the subsequent risk of theft or vandalism. So, these systems would likely need a buoy gate mechanism to keep the system from running into shore. There would also need to be a place to store both systems in the winter months.
Wind Powered System	Like the PV/BES system, wind powered systems also benefit from not needing an electric source. The wheel powered by the wind-system is shown to be especially effective in larger water bodies like Swan Lake Park, as it achieves adequate spatial coverage.	Similar to the PV/BES system, this wind powered system would need to be removed and stored over the winter months. Paddles generate turbidity at the surface, which may not correspond to increases in DO at lower depths.		

Appendix B: Rain Gardens

Below is a table consisting of the advantages and disadvantages associated with the rain gardens.

Advantages	Disadvantages
Reduced stormwater runoff and peak flow	Requires large land area
Reduced pollutant load in nearby waterways	Only applicable in certain locations; specific criteria for implementation (see *Rain Gardens* section)
Enhanced groundwater recharge	Public concern about mosquitoes
Relatively low maintenance once established	Public concern about drowning hazard
Aesthetically pleasing and functional	
Minimal cost difference compared to other landscaped areas	
Attracts pollinating insects and contributes to biodiversity	

A Case Study: The Town of Ajax Rain Garden Retrofit

The Town of Ajax's Rain Garden Retrofit project's objective is to improve water quality for Ajax by intercepting and treating stormwater runoff while also enhancing the surrounding landscape and improving aesthetics. The objectives of the Town of Ajax align with the objectives and goals of Friends of Swan Lake Park in regard to treating water quality to maintain natural aquatic ecosystems and improve the aesthetics of the park. Rain gardens are relatively small-scale stormwater management solutions that are more feasible in smaller and already developed sites in comparison to implementing wet ponds or bioswales. Rain gardens are low-impact development solutions (LID) that are the most viable in existing developed areas, areas of potential redevelopment, and new development areas. The implementation of a rain garden similar to the Town of Ajax could be applicable in Swan Lake Park.

Engineered Soil Mix Options (Biomedia)

Biomedia Type	Description	Pros	Cons
Typical media bed	Mix of course-fine	Easy to implement	Shortcomings in the

mix	sand and leaf-organic compost which is responsible for runoff reduction.	and is the most common engineered soil mix type. Responsible for reducing runoff through infiltration and supports the growth of plants within the rain garden	ability of a typical media bed mix to effectively filter out pollutants like phosphorus, suspended solids and E.coli.
Sorbtive media (aluminum oxide)	Sorbitive additives (Imbrium Systems Sorbtive Media) blended into soil mixtures at a 3-5% volume basis are found to be more effective for removing phosphorus. The sorbtive media consists of an engineered mixture of aluminum oxide and iron oxide.	Highly effective for improving phosphorus removal due to its chemical and physical properties. Characteristics such as electrical conductivity, mineral composition, cation and anion exchange capacity (Šarko & Mažeikienė, 2020)	No notable disadvantages in the literature in regard to the application of sorbtive media
Iron fillings additives	Also known as the “Minnesota Filter” (Iron enhanced sand filters) consists of a 5% iron filling mixed into sand filters to improve the performance of sand filters.	This mixture was successful at capturing at least 88% of phosphate at a depth of 200m. Adding iron filling to sand filters can effectively capture 35-93% of dissolved phosphorus depending on the fraction used. (Erickson et al., 2011).	The use of iron filling can interact negatively with other metals which can deteriorate water quality (Huang et al., 2009) and potentially affect plant life growing in the medium.

Appendix C: Pollinator Gardens

Below, is a table consisting of plant species corresponding with which pollinator insect it attracts. (*CVC,* n.d.; *Toronto Zoo,* n.d.; Allinson Chorabik, 2023).

Plant Name	Annual or Perennial	Bloom Time	Sun Cover	Pollinator
Black-eyed Susan	Perennial	Summer-early fall	Full sun	Long-horned Bees, Mining Bees, Tiger Swallowtail Butterfly
Swamp, Common, and Butterfly Milkweed	Perennial	Mid-season	Full-part sun	Monarch Butterfly, Cuckoo Bees, Leafcutter Bees
Sunflower	Annual	Late summer-early fall	Full Sun	Sweet Bees, Long-horned Bees
Aster	Perennial	Summer-frost	Full/part sun	Long-horned bees, bumble bees, Common Buckeye Butterfly
Canada Goldenrod	Perennial	Mid-early fall	Full Sun	Mining Bees, Cellophane Bees, Pearl Crescent Butterfly

PROS	CONS
• Promote biodiversity and sustainability	• Needs maintenance
• Supports insect pollinators and pollination of plants and other flowering species	• Associated costs
• Contributes to a visually appealing environment	• May attract unwanted wildlife/rodents
• Reduces geese population by occupying open grass areas	• Requires monitoring
• Creates educational opportunities	

Appendix E: Carp Management Strategies

Manual and Mechanical Extraction

Electrofishing

Electrofishing is the implementation of using electricity and probes or nets wired to an electric current to stun or euthanize the fish upon contact. There are professional corporations and even researchers who do this sort of work, however it is indiscriminate. This means not only Carp will be affected by this, but any other surviving aquatic species. There is no way around this, and it may be a requirement for this treatment to work.

Gillnetting and seining

This strategy involves the use of woven nets to entrap and entangle fish in order to extract them. As previously mentioned in electrofishing, this is also indiscriminate however there is no real harm to the fish. If there are professionals such as Ministry of Natural Resources employees there who can readily identify fish species, those not intended to be targets of this strategy can be returned to the lake. The effectiveness of this strategy comes down to how mobile the fish are. There is also the concern of stirring up sediment from in the lake

Exploitative Fishing Strategies

Sanctioning commercial exploitation

Corporations have been developed which specialize in the removal of designated species such as the removal of invasive fish. Essentially a corporation would be brought in to fish out and remove the invasive Carp. The downside to this option is it is expensive and can come with public disapproval.

Incentivizing recreation angling

Recreational angling is the cheapest of all these options and uses community involvement in the Park to remove the invasive Carp species. There can be arranged fishing tournaments, or signs posted that if Carp are caught, they are not to be returned into the water. There would need to be a professional or volunteer capable of identifying Carp and disposing of them once caught. This option could bring around public awareness and a sense of responsibility amongst the visitors and anglers of Swan Lake Park.

Appendix E : French Drains

French drains are normally found in use around residential structures to prevent flooding of basements or movement of soil due to freeze-thaw dynamics causing shifting of landscape interlocking and putting extra strain on building materials like concrete pads. They can be implemented in Swan Lake Park to direct water away from the Lake before it has a chance to be cleaned by the many recommended systems (rain gardens, oil-grit separators). Their design and building is relatively simple. It truly would only require a crew of one or two individuals over the span of a few days and maybe a landscape remediation group to fix soil and grass damaged by the required excavator and skid steer construction machines.

When it comes to the actual materials required, gravel, perforated pipe, and topsoil. The perforated pipe is required as the carrier of water and as it is perforated it prevents clogging from sediment but allows water to seep in. A trench needs to be dug with an extra six inches wide on each side to incorporate the size of the pipe and then gravel to secure it from moving. The trench goes from a location on a slight slope, to inhibit water flow downhill, to the selected catchment system. A layer of, recommended half inch clean cut, gravel then is put into the trench along the whole way, ensuring to keep the degree of slope. This gravel acts as a permeable surface for any water which does not enter the drain, and prevents the drain from sinking into the soil and pooling of water if the slope is lost. The pipe is then inserted and any connections needed are made with coupling connectors. Gravel needs to then be placed around the sides of the pipe to prevent shifting, and over top to increase infiltration. Topsoil can then be added and a choice of seeding or sod to replace the grass removed for access to the designated trenching location. What is left behind is a functioning French drain system promoting infiltration and runoff control, with no maintenance or concern for years to come.

Appendix F: Risk Matrices

Table 1A: Risk Matrix for Chemical Remediation of Swan Lake

Action	Potential Risk	Impact (1-5)	Probability (1-5)	Score
Hypolimnetic withdrawal	Water is highly contaminated and cannot be recycled.	4	2	8
	Lake does not recharge in predicted timeframe (1-3 seasons)	5	3	15
Mechanical Dredging	Sediment is highly contaminated, making it difficult to store/recycle.	5	2	10
	Damage to benthic communities	3	4	12
	Negative impacts on hyporheic exchange	5	3	15
	Erosion and sediment suspension.	3	5	15
	Disturbance to terrestrial land	4	5	20

Use of Pond Dyes	Alter the aquatic environment by reducing light availability	4	2	8
Use of Ferric Chloride	Decrease in lake pH	4	2	8
Use of Biochar	P, N release back to the lake	5	2	10
Species Introduction (mollusks and water hyacinths)	Disrupt ecological processes	5	3	15
	Loss of native species	5	3	15
Wind-powered and PV/BEV aeration systems	Mechanical failure from degradation	5	3	15
	Theft and damage from humans	3	4	12
	Habitat disturbance	5	1	5
	Sediment resuspension	5	1	5
Microbubble tubing	No space on the shore for the pump house.	4	2	8

	Damage and degradation of the bubble tubing.	5	3	15

Table 1B: Potential Risks and Strategies for proposed chemical remediation strategies

Potential Risk	Strategy
Lake does not recharge in the predicted timeframe and/or does not recover to its original water level.	● As mentioned in FOSLP, with permission, water from the aquifer can be pumped into the lake to aid with regeneration. ● Water catchment on nearby infrastructure to collect rainwater.
Dredging damages benthic communities	● Prior to dredging, conduct benthic tests to determine the current distribution and diversity in order to set a baseline to compare to following restoration. This will indicate whether or not diversity and conditions have improved (certain benthic organisms can be used as indicators for environmental conditions)
Negative impacts to hyporheic exchange	● Pre- and post-restoration measurements on hyporheic exchange. This can be modeled by measuring water exchange in and out of the bed (install piezometers and take hydraulic head measurements) and nutrient distribution between the bed and water (ex. Use phosphorus as measure). These can be used to determine the relative magnitude of flow and exchange between the bed and water.

	• Introduce conductive soils like gravel following dredging to improve water exchange.
Erosion and sediment suspension	• Implement erosion control along the shoreline prior to dredging, such as live stakes and geotextiles. • Use best practices to avoid disturbing lake water that remains following withdrawal.
Disturbance of terrestrial land	• Begin dredging after the summer when plants are no longer growing. • Fence off area for machinery to move through as to avoid large-scale disturbance across the site. Essentially, try to limit disturbance to only a small space.
Disruption of ecological processes	• Conduct simulation tests prior to the introduction of species and develop response plans based on the results. • Conduct regular and long-term monitoring of ecosystems and ecological processes in the lake/stormwater pods and determine the quality of the water through some warning indicators such as turbidity and DO.
Loss of native species	• Although the introduction of invasive species can be devastating to native species, regular measurements of species composition and rapid response may be able to help keep native species from being eliminated • Species that will be affected by our introduced species can be ranked in terms of their vulnerability and

	different levels of protection can be established for them.
Mechanical failure and degradation of the different aeration systems.	• Yearly maintenance of the wind-powered and PV/BEV systems, and microbubble tubing. During the winter months, before the lake freezes, bring them to shore and maintain any damage. Keep in storage until the lake is no longer frozen.
Theft and damage from humans.	• While in operation, anchor the floating aeration systems to the lake bed. • Keep these systems farther from the shore so they're difficult to reach, there by deterring people.

Table 2A: Risk Matrix for Upland Restoration

Action	Potential Risk	Impact	Probability	Score
Geese management	Geese persist, and eutrophication persists as a result, further affecting fish populations and water quality.	4	4	16
	Geese continue to degrade upland vegetation and soil, perpetuating run-off.	5	5	25
	Public outcry and discontent, preventing geese management.	4	2	8

	Deterring plants become invasive/compete with other plant species.	4	2	8
Invasive species removal	Invasive species persist.	5	4	20
	Invasive species alter site conditions, preventing the establishment of new plants.	3	3	9
Rain gardens and planting.	New plants do not establish due to poor environmental conditions.	5	2	10
	Roots are slow to establish, therefore may not aid in stabilizing soil and contribute to erosion.	4	3	12
	Visitors to the park interfere with new plants.	3	2	6

Table 2B: Potential Risks and Strategies for Upland Restoration region

Potential Risk	Strategy

Geese persist, leading to continued eutrophication and fish die-offs.	● Adopt new management strategies such as frightening devices. ● Physical barriers, like fences and stones. ● Counter the impacts of geese by improving water quality management through chemical and biological treatments, and improved barriers to run-off on terrestrial land (as proposed in several sections).
Geese degrade the environment and soil, perpetuating erosion and poor environmental quality.	● Like previous strategy, introduce new forms of deterrents. ● Implement more soil amendments to counter the damage from the geese.
Invasive species persist.	● Try other methods than manual removal, such as solarization or smothering. ● Solarization will aid in removing other invasive species identified in the park.
New plants do not establish due to poor environmental quality.	● Take baseline soil quality measurements (porosity, organic matter, nutrient and moisture content) prior to planting in order to gauge the conditions following previous soil alterations (i.e. fertilization and aeration). ● Based on these results, soil may require additional amendments like organic mulch, to aid with establishing the new plants.
Roots are slow to establish, leading to poor soil stabilization and continued erosion.	● Implement intermediate erosion control measures such as geotextiles and live stakes. These can be removed once plants have effectively established.

Table 3A: Risk Matrix for Shoreline Restoration

Actions	**Potential Risk**	**Impact (1-5)**	**Probability (1-5)**	**Score**
Mass fishing to remove invasive carp species	If the fishing method is not selective, leads to unintended capture of other species.	4	2	8
	Human-led degradation of park due to the high volume of people.	3	3	9
	Carp still persist.	4	3	12
Installation of filtration system for reverse osmosis	Can lead to terrestrial habitat destruction/interference during construction and establishment.	4	2	8
	Human damage to system/degradation overtime.	3	4	12
Bioswales	destroy/degrade habitat for installation.	5	1	5
Removal of invasive species	Proposed techniques are not effective and invasive species persist.	5	3	15

	Active removal techniques disperse seeds, causing increased growth.	5	3	15
	Might require herbicides.	4	2	8
	Not enough sun for solarization to be effective.	3	4	12
Introduce native species, specifically along shore to aid with sediment stabilization.	Native species do not establish themselves effectively due to inadequate environmental conditions.	5	3	15
	Native species do not stabilize soil immediately, leading to erosion.	5	3	15
	If invasive species persist, this creates competition.	5	4	20

Table 3B: Potential Risks and Strategies for Shoreline Restoration

Potential Risk	**Strategy**
Carp still persist.	• Water withdrawal will alter the environmental conditions, which may aid in reducing the carp population. • Yearly fishing to slowly lower the population. Likely cannot be completed in one season, requires persistent fishing.

Human damage to RO system/degradation overtime.	● Fence off the area with the piping, filters and other mechanical pieces in order to deter people from interfering. ● Hide or naturalize with vegetation. ● Maintain and preform upkeep on the filters and solar panels, check pipes regularly to make sure nothing is damaged.
Invasive species persist due to resistance against removal techniques. This ultimately has negative impacts on future native assemblages.	● Frequent management and removal of invasive species. Much like the carp, this will likely take seasonal treatment and upkeep in order to maintain manageable invasive populations. ● Try new techniques, like smothering with ragweed.
Active removal techniques increase seed dispersal of invasive plant species.	● Make sure that the best practices are being used and disposal of the invasive species is done properly. ● Conduct removal after seeds have been dispersed or prior to seed development.
Infrequent sun for solarization.	● Conduct solarization during the summer months when the sun is more consistent (June-August).

Inadequate environmental conditions prevent establishment of native species.	• Refer to information on native assemblages and required environmental conditions to sustain their growth. • Conduct environmental assessments on soil quality such as permeability, conductivity, water content, organic matter composition, and nutrient concentration. Based on these assessments and the results, this will indicate whether prior soil amendments are required to aid with plant growth.
Slow soil stabilization by native species.	• Use intermediate erosion control techniques like live stakes and geotextiles. Dogwood and willow stakes survive the best and establish quickly. • Once soil stabilized, this may help with native species establishment.

Table 4A: Risk Matrix for the Education Programs

Actions	**Potential Risk**	**Impact (1-5)**	**Probability (1-5)**	**Score**
Contacting local schools to participate in educational programs	Participation delay results in missed opportunities for learning during the processes.	**2**	**3**	**6**
	Participation denial: schools refusing educational program proposals.	**5**	**2**	**10**

Planning the programs	Scheduling conflicts: unable to coordinate between mitigation processes and program meet times.	**2**	**4**	**8**
	Student-supervisor ratio not adequate	**3**	**3**	**9**
Accessibility	Park not accessible to all students	**3**	**3**	**9**
Weather conditions	Extreme weather can impact activities of students	**5**	**1**	**10**
	Extreme weather can impact safety of students	**5**	**3**	**15**
Program involvement	Low attendance	**4**	**3**	**12**
Safety concerns	Water, wildlife, uneven terrain may pose safety risks to children if not managed properly or supervised	**5**	**3**	**15**
Educational Effectiveness	Low educational effectiveness: Impact of program may vary depending on the program and engagement	**3**	**3**	**9**

Table 4B: Potential Risks and Strategies for Education and Outreach.

Potential Risk	Strategy

Extreme weather can impact safety of students	● Coordinate student visits according to the weather, reschedule if necessary.
Safety concerns related to water, wildlife, uneven terrain may pose safety risks to children if not managed properly or supervised	● Stress the importance of staying on the path when in the park, can use signs to aid with reminding. ● Introduce additional barriers, either fencing or plants to encourage people to stay on paths.
Permit approval delay for the farmers market	● Apply for the permit early, well in advance of the farmers market so that delays do not impact its establishment.
Seasonal conditions for the farmers market	● Consider adding temporary tents depending on the weather. ● Possibly can add heaters for cold weather ● Creating temporary platforms that can be removed after each event to account for flooding, mud, ice, etc.
Brochures are ineffective for communication	● Implement QR codes in addition to brochures. ● Place brochures in community centres and other central areas to increase communication with the public.
Budget constraints for brochures	● Again, potentially switch to QR codes that direct people to the website. This may be a cheaper option since the website is already established.
Low attendance to educational workshops and educational programs.	● Ensure that the educational workshops are relevant to the community and their interests. Potentially consider making a survey to see what kind of workshops people would be interested in attending.

	● Make workshops engaging and hands-on.
Parking congestion and limited parking spaces	● Coordinate with other community members and consider parking implementing parking spots along streets. ● Encourage different forms to transport, like busing or cycling, to help reduce traffic (i.e. through signs, paid parking, rack for locking bikes)

Appendix G: Species List

Table 1A: Species list with associated growing conditions.

Plant Name	Species Name	Annual or Perennial	Bloom Time	Sun Cover	Pollinator
Black-eyed Susan	*Rudbeckia hirta*	Perennial	Summer-early fall	Full sun	Long-horned Bees, Mining Bees, Tiger Swallowtail Butterfly
Swamp, Common, and Butterfly Milkweed	*Asclepias incarnata, Asclepias syriaca, Asclepias tuberosa*	Perennial	Mid-season	Full-part sun	Monarch Butterfly, Cuckoo Bees, Leafcutter Bees
Sunflower	*Helianthus annuus*	Annual	Late summer-early fall	Full Sun	Sweet Bees, Long-horned Bees
Aster	*Aster*	Perennial	Summer-frost	Full/part sun	Long-horned bees, bumble bees, Common Buckeye Butterfly
Canada Goldenrod	*Solidago canadensis*	Perennial	Mid-early fall	Full Sun	Mining Bees, Cellophane Bees, Pearl Crescent Butterfly
Water hyacinth	*Pontederia crassipes*	Perennial	Late summer-early fall	Full sun	Insects or wind.
Duckweed	*Lemnoideae*	Perennial	summer	Full sun to full shade.	Bees and other insects.
Stargrass	*Heteranthera zosterifolia*	Perennial	Summer to fall	Full sun-part shade.	n/a (aquatic)

Manna Grass	*Glyceria*	Perennial	Summer to fall	Full sun	Bees and other insects.
Canary Grass	*Phalaris canariensis*	Perennial	Early spring	Full sun	Bees and other insects.
Tulips	*Tulipa*	Perennial	Spring	Full sun	Bees, butterflies, other insects.
Oak	*Quercus*	Annual	New germination in spring.	Full sun-shade	Bees, butterflies, other insects
Blue spruce	*Picea pungens*	Annual	year-round	Full sun-shade	Bees, butterflies, other insects
Red-oiser dogwood	*Cornus sericea*	Perennial	June-August	Full sun-part shade	Bees, butterflies, other insects
Heath Aster	*Symphyotrichum ericoides*	Perennial	Summer-Autumn	Full sun	Bees, butterflies, other insects
Big bluestem	*Andropogon gerardii*	Perennial	April	Partial sun-full sun	Bees, butterflies, other insects