Fairy Lake Long-term Monitoring Program

for:

TOWN OF HALTON HILLS

by:

Est. 1971 LGL LIMITED environmental research associates

LGL Limited
environmental research associates

May 2023
LGL File TA9122

prepared by:

Lynette Renzetti, B.Sc. Senior Ecologist

LGL Limited
environmental research associates
445 Thompson Drive, Unit 2
Cambridge, Ontario N1T 2K7
Tel: 519-622-3300 Fax: 519-622-3310
Email: cambridge@lgl.com
URL: LGL Limited

May 2023

LGL File TA9122

Table of Contents

1.0 Introduction

The Fairy Lake Water Quality Update (LGL, 2023) was conducted to document the current water quality conditions of Fairy Lake in the Town of Halton Hills and provide a comparison to the baseline water quality study completed previously (AECOM, 2009). LGL (2023) summarizes the results of several studies to include surface water quality, sediment quality, lake bathymetry, vegetation, and waterfowl use and provides recommendations to inform future management of the lake and its catchment. The recommendations include the design and implementation of a long-term monitoring program to track constituents of concern and apply adaptive management in future. A long-term monitoring program is integral to Fairy Lake in that it will provide data and critical information relating to:

- ecosystem change (e.g., analysis of climate change impacts);
- discovering emerging environmental issues;
- assessing whether an event/result is unusual or extreme;
- evaluating whether policies or management activities are having the intended effect; and,
- designing appropriate research experiments in future.

Surface water quality is impacted by changes in climate and local weather conditions within any given year. Therefore, a long-term routine monitoring program is recommended to track changes in water chemistry to understand variation in the dataset and improve upon the ability to accurately track trends over time. A water quality monitoring plan was one of the primary recommendations for the future management of Fairy Lake made to the Town of Halton Hills as a result of the Fairy Lake Water Quality Update Study completed in 2022 (LGL, 2023). This document summarizes the details of a proposed monitoring program.

2.0 Summary of Fairy Lake Water Quality Update Study (LGL, 2023)

The main conclusions resulting from the Fairy Lake Water Quality Update Study completed in 2022 (LGL, 2023) were that nutrient concentrations in the lake are influenced by surrounding land uses, both urban and rural. The bulk of the nutrient loading occurred during wet weather events (storms and spring melt). Specifically, phosphorus concentrations frequently exceeded provincial water quality objectives (PWQO) on a regular basis during wet weather events at creek and stormwater inlets to the lake, whereas lake samples generally met the PWQO throughout the 2021-2022 study. Total phosphorus in the lake was found in reduced concentrations compared to the baseline study (AECOM, 2009) but in increased concentrations at the stormwater and creek inlets. Particularly high concentrations of nitrogen containing compounds were found at Station WQ2 compared to other stations during the 2022 monitoring and compared to AECOM (2009) at that location. Overall, reduced chloride was found in stormwater flows in 2022 when compared to conditions recorded in previous monitoring. Sediment samples from the lakebed in 2021 demonstrated elevated concentrations of TKN at Stations SQ1 and SQ2 compared to AECOM (2009) and exceeded the provincial sediment quality guideline for TKN. These results and other recommendations made as part of the Fairy Lake Water Quality Study Update (LGL, 2023) provided the foundation for the water quality monitoring program that follows.

3.0 Recommendations for Long-term Monitoring Program

It is recommended that a long-term monitoring program be established to collect the data necessary to make science based decisions regarding the ongoing management of Fairy Lake. Laboratory analysis will represent a significant portion of the cost of implementation and for that reason costing as of May 2023, as secured from the Bureau Veritas accredited laboratory, is appended. The costing is provided on a per sample basis and as a total to reflect the recommendations made herein. To start, LGL recommends data collection on a biennial basis (once every two years). Once several years of data is in hand, the Town will have a better understanding of what frequency is best suited to the lake and/or the management practices that are being tracked.

3.1 Water Chemistry

Recommendations for Surface Water Quality are based on the 2022 findings and follow the same methods used in LGL (2023) so that future monitoring can compare results. Some additional stations and changes in sampling frequency are recommended. At minimum, it’s recommended that monitoring capture four wet weather (spring freshet and major storm events) and two dry weather events (summer/fall) as well as winter conditions within the lake stations to capture all seasonal conditions of nutrient loading, lake productivity and oxygen demand that influence surface water quality in the lake. Station locations are presented in **Figure 1**.

3.1.1 Field Measured Parameters

In-situ ambient conditions (water temperature, specific conductivity, dissolved oxygen [DO], and pH) should be recorded during each sampling event. Depth profiles of these parameters should also be collected under summer/high productivity, fall/high decomposition, and winter/ice covered conditions in the lake basins where water depths are greater than 1.5 metres.

3.1.2 Water Chemistry

Table 1 provides a list of the sampling stations, a brief description of each location and the timing and frequency of sample collection that’s recommended. Naming has been kept consistent with the stations monitored by AECOM (2009) and LGL (2023).

The analytes of interest chosen for the study are summarized in **Table 2** to include indicators of industrial and residential contaminant sources that align with the CVC's Integrated Watershed Monitoring Program for the Black Creek Watershed, and parameters linked to the stressors identified for Fairy Lake water quality in particular. Data are to be compared to PWQOs and where PWQOs are not available, Canadian Water Quality Guidelines (CWQGs) should be referenced.

3.1.3 Replicate Samples

It is recommended that a blind replicate (duplicate) sample be collected during each surface water sampling event to ascertain the precision of the sampling method and local heterogeneity of samples. To this end, the relative percent difference (RPD) between each replicate sample (R) and the corresponding original sample (O) would be calculated as a measure of precision using the following equation:

$$Relative\ Percent\ Difference\ (RPD) = \frac{ABS(R-O)}{(R+O)/2}\ x\ 100$$

Precision is influenced by how close an analytical value is to the laboratory detection limit for a given parameter. As a measured, analytical value approaches the detection limit, variability increases (precision decreases); thus, it is recommended that the use of the RPD be limited to values that are at least five times the detection limit of the analytical method (British Columbia Ministry of the Environment, 2003). For this reason, RPDs are only to be calculated for those samples where analytical values are detected at five times the detection limit for a given analyte.

For the Fairy Lake Water Quality Update Study (LGL, 2023) differences between concentrations in duplicate surface water samples were considered notable if the RPD was greater than 20%. Within station variability and field sampling precision were rated as:

- low variability and high precision if less than 10% of the parameters included in the duplicate sample analysis were notably different from one another;
- medium variability and precision if 10% - 30% of the parameters included in the duplicate sample analysis were notably different from one another; or,
- high variability and low precision if greater than 30% of the parameters included in the duplicate sample analysis were notably different from one another.

3.2 Sediment Chemistry

To characterize the sediment quality in the lakebed, grab samples of bottom sediments (top 15 cm) are recommended at four stations (SQ1 through SQ4 as shown **in Figure 1** and **Table 1**). Analytes of interest for sediment analysis are outlined in **Table 2**. Samples are to be collected in the fall to characterize the sediment quality in the lakebed during the period of the greatest decomposition and oxygen demand. Sediment quality data should be compared to available Provincial Sediment Quality Guidelines (PSQGs) set by the Ontario Ministry of Environment (OMOE, 1994) and where PSQGs are not available, Canadian Sediment Quality Guidelines (CSQG) should be referenced.

To better understand conditions at the sediment-water interface collection of redox potential (ORP) in mV should be included in routine in-situ data collection during all sampling events including when sediments are collected. This can be done using a handheld meter and would be a low cost method for considering changes in chemistry/oxidation at the water-sediment interface and how those conditions might relate to nutrient storage in, or release from, lakebed sediments. Low values of ORP generally indicate anaerobic conditions, therefore ORP can be used to detect anaerobic activity in the water column or bottom sediments. A number of research studies have reported that nutrient release (e.g., soluble reactive phosphorus, ammonium) and consumption (e.g., nitrate) rates in sediment are generally greater under anoxic conditions compared to well oxygenated environments (Fisher et al. 2005; Haggard et al. 2005; Small et al. 2014). The findings from these studies suggest that the cycling of nutrients (phosphorus and nitrogen) is aligned with DO conditions at the lakebed-water interface (Osaka et al., 2022). In particular, anoxic conditions were documented at some wetland influenced stations part of the Fairy Lake Water Quality Update Study (e.g., WQ1, WQ9). ORP and DO measurements will help to further the understanding of how prevalent anoxic conditions are and what effect they might have on nutrient concentrations in lake sediments. The next step, if the data warrants, would be to collect sediment cores and run lab analyses to quantify fluxes in nutrients from bottom sediments.

Table 1. Surface Water and Sediment Quality Sampling Locations (Figure 1)

Station ID	Station Description	Sampling Events	Analysis Type
WQ1	inlet from wetland at Mill Street	all	2
WQ2	inlet to lake from Breezes Trailer Park	when flowing	3
WQ3	lake - central basin	all, winter, profile, ORP	1
WQ4	stormwater flows from Tyler Ave. outfall	when flowing	3
WQ5	Prospect Park public beach	all, winter, profile, ORP	1
WQ6	outlet from Fairy Lake dam	all	1
WQ7	Black Creek inlet	all	3
WQ8	stormwater flows from Elmore Dr. outfall	when flowing	3
WQ9	lake - south basin	all, winter, profile, ORP	1
WQ10	inlet from wetland on west side of the lake	all	2
WQ11	lake - northwest basin	all, winter, profile, ORP	1
WQ12	stormwater flows from Cameron St. outfall	when flowing	3
WQ13	stormwater flows from Wright Ave. outfall	when flowing	3
WQ14	Culvert crossing of Dublin Line	when flowing	2
SQ1	at WQ11	fall	4
SQ2	at WQ9	fall	4
SQ3	at WQ3	fall	4
SQ4	near dam	fall	4

Table 1 Notes:
WQ = surface water quality   SQ = sediment quality
winter – winter, under ice water sample collection
all – spring, summer, fall surface water sample collection
fall – sediment collection to align with period of high decomposition
profile – DO, temperature, conductivity, and pH taken at 0.5 m intervals where depth > 1.5 m
1 = general, nutrients, *E.coli*; 2 = general, nutrients, *E.coli,* chloride; 3 = general, nutrients, *E.coli*, metals, chloride
4 = sediments - total organic carbon, total ammonia, total Kjeldahl nitrogen, nitrate, nitrite, total phosphorus (ORP, pH, and temperature at water-sediment interface)
Note: DO, temperature, conductivity, and pH are recorded during all sampling events

Table 2. Analytes of Interest, Fairly Lake Water Quality

Analyte Grouping	Analytes Included	Symbol	Units	Matrix	Data Source
General	Water temperature		°C	SW	Field
	Dissolved oxygen	DO	mg/L	SW	Field
	Specific conductivity		µS/cm	SW	Field
	pH		-	SW	Field
	ORP		mV	SW	Field
	Alkalinity (as CaCO3)		mg/L	SW	lab
	Dissolved Calcium	Ca	µg/L	SW	lab
	Dissolved Magnesium	Mg	µg/L	SW	lab
	Dissolved Organic Carbon	DOC	mg/L	SW	lab
	Total Carbonaceous BOD	BOD	mg/L	SW	lab
	Total Dissolved Solids	TDS	mg/L	SW	lab
	Total Suspended Solids	TSS	mg/L	SW	lab
Nutrients	Unionized Ammonia-N	UIA	µg/L	SW	calculated
	Total Ammonia-N	TAN	mg/L	SW	lab
	Total Nitrogen	N	mg/L	SW	lab
	Orthophosphate-P	Ortho-P	mg/L	SW	lab
	Dissolved Phosphorus		mg/L	SW	lab
	Total Phosphorus	TP	mg/L	SW	lab
	Total Kjeldahl Nitrogen	TKN	mg/L	SW	lab
	Nitrite-N	NO_2-N	mg/L	SW	lab
	Nitrate-N	NO_3-N	mg/L	SW	lab
	Nitrite+Nitrate	NO_2-N+NO_3-N	mg/L	SW	lab
Chloride	Dissolved Chloride	Cl-	mg/L	SW	lab
Microbiology	*Escherichia coli*	E.coli	CFU/100 ml	SW	lab
Metals	Total Aluminum	Al	µg/L, ug/g	SW, SED	lab
	Total Antimony	Sb	µg/L, ug/g	SW, SED	lab
	Total Arsenic	As	µg/L, ug/g	SW, SED	lab
	Total Barium	Ba	µg/L, ug/g	SW, SED	lab
	Total Beryllium	Be	µg/L, ug/g	SW, SED	lab
	Total Bismuth	Bi	µg/L, ug/g	SW, SED	lab
	Total Boron	B	µg/L, ug/g	SW, SED	lab
	Total Cadmium	Cd	µg/L, ug/g	SW, SED	lab
	Total Chromium	Cr	µg/L, ug/g	SW, SED	lab
	Total Cobalt	Co	µg/L, ug/g	SW, SED	lab
	Total Copper	Cu	µg/L, ug/g	SW, SED	lab
	Total Iron	Fe	µg/L, ug/g	SW, SED	lab
	Total Lead	Pb	µg/L, ug/g	SW, SED	lab
	Total Lithium	Li	µg/L, ug/g	SW, SED	lab

Analyte Grouping	Analytes Included	Symbol	Units	Matrix	Data Source
	Total Magnesium	Mg	ug/g	SED	lab
	Total Manganese	Mn	µg/L, ug/g	SW, SED	lab
	Mercury (low level)	Hg	µg/L, ug/g	SW, SED	lab
	Total Molybdenum	Mo	µg/L, ug/g	SW, SED	lab
	Total Nickel	Ni	µg/L, ug/g	SW, SED	lab
	Total Phosphorus	P	µg/L, ug/g	SW, SED	lab
	Total Potassium	K	ug/g	SED	lab
	Total Selenium	Se	µg/L, ug/g	SW, SED	lab
	Total Silicon	Si	µg/L	SW	lab
	Total Silver	Ag	µg/L, ug/g	SW, SED	lab
	Total Sodium	Na	ug/g	SED	lab
	Total Strontium	Sr	µg/L, ug/g	SW, SED	lab
	Total Thallium	Tl	µg/L, ug/g	SW, SED	lab
	Total Tin	Sn	µg/L, ug/g	SW, SED	lab
	Total Titanium	Ti	µg/L, ug/g	SW, SED	lab
	Total Uranium	U	µg/L, ug/g	SW, SED	lab
	Total Vanadium	V	µg/L, ug/g	SW, SED	lab
	Total Zinc	Zn	µg/L, ug/g	SW, SED	lab
	Total Zirconium	Zr	µg/L	SW	lab
	Total Sulphur	S	µg/L	SW	lab

Table 2 Notes
SW – surface water
SED – lake sediments
Metals - ICPMS low level analysis for surface water, Acid extractable for sediments

4.0 Data Storage

Creation of a database to house all raw data and associated metadata is crucial to tracking changes in and around Fairy Lake over time, particularly where data is being conducted by various parties (e.g., university research studies, Town, CVC). This cost is not estimated at this time but this effort would allow for data analysis in future studies to be completed in a more cost efficient manner and would support a standardized approach to data collection and storage (e.g., ensure data is presented using the same units so that no conversion is necessary during analysis).

5.0 Conclusion

The Fairy Lake Water Quality Update Study (LGL, 2023) identified the key water quality stressors in Fairy Lake and recommended a standardized long-term monitoring program to track conditions over time and allow for adaptive management with the goal of maintaining recreational uses and the ecological function of the lake. The program should include sediment and surface water sample collection for laboratory analysis and documentation of field measured parameters following the methods employed for the Fairy Lake Water Quality Study Update. Existing data should be moved into a relational database to standardize results and allow for more efficient analysis and comparison to past conditions. Through additional monitoring, there is potential to improve the understanding of the Fairy Lake ecosystem, track changes over time and allow for science-based decision making so that the most appropriate management practices are employed in an effort to reduce nutrient loading to the lake.

6.0 References

AECOM. 2009. Town of Halton Hills Fairy Lake Water Quality Study.

Anthony, J.L., Lewis, W.M. 2012. Low boundary layer response and temperature dependence of nitrogen and phosphorus releases from oxic sediments of an oligotrophic lake. Aquatic Sciences 74, 611–617. https://doi.org/10.1007/s00027-012-0255-6

Canadian Council of Ministers of the Environment (CCME). 2012. Water Quality Guidelines for the Protection of Aquatic Life. Retrieved from Canadian Council of Ministers of the Environment (ccme.ca)

Canadian Council of Ministers of the Environment (CCME). Sediment Quality Guidelines for the Protection of Aquatic Life. Retrieved from https://ccme.ca/en/resources#

Fisher, M.B, Reddy, K. R. Thomas James, R. 2005. Internal Nutrient Loads from Sediments in a Shallow, Subtropical Lake, Lake and Reservoir Management, 21:3, 338-349, DOI: 10.1080/07438140509354439

Haggard, B.E., Moore, P.A., Jr. and DeLaune, P.B. 2005. Phosphorus Flux from Bottom Sediments in Lake Eucha, Oklahoma. Journal of Environmental Quality, 34: 724-728. https://doi.org/10.2134/jeq2005.0724

Li, J., Zhang, Y. and Katsev, S. 2018. Phosphorus recycling in deeply oxygenated sediments in Lake Superior controlled by organic matter mineralization.Limnology and Oceanography, 63: 1372-1385. https://doi.org/10.1002/lno.10778

LGL Limited. 2023. Fairy Lake Water Quality Update Report, 2021-2022. May 2023

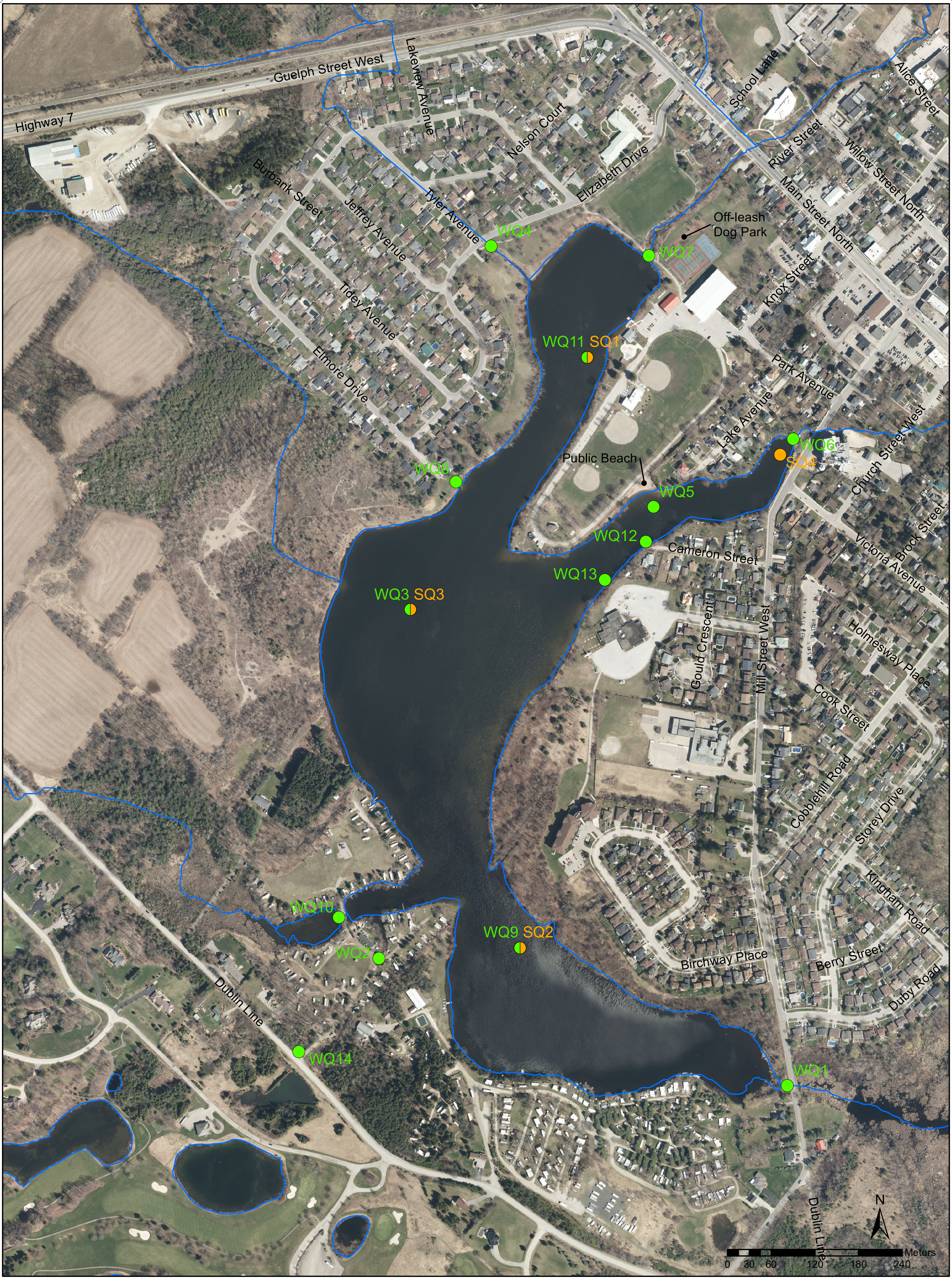
Lovett G. M., Burns D.A. and C.T. Driscoll. 2007. Who needs environmental monitoring? In Frontiers in Ecology and the Environment 5, pp. 253–260.

Ontario Ministry of Environment (OMOE). 1994. Water management: policies, guidelines, provincial water quality objectives. Queen's Printer for Ontario. ISBN 0-7778-8473-9.

Osaka, K., Yokoyama, R., Ishibashi, T. and Goto, N. 2022. Effect of dissolved oxygen on nitrogen and phosphorus fluxes from lake sediments and their thresholds based on incubation using a simple and stable dissolved oxygen control method. Limnology Oceanography Methods, 20: 1-14. https://doi.org/10.1002/lom3.10466

Small, G.E., Cotner, J.B., Finlay, J.C. et al. 2014. Nitrogen transformations at the sediment–water interface across redox gradients in the Laurentian Great Lakes. Hydrobiologia 731, 95–108.https://doi.org/10.1007/s10750-013-1569-7

Figures



Fairy Lake Water Quality Study

Station Locations

- Sediment Quality (SQ) Station (LGL)
- Water Quality (WQ) Station (LGL)
- Watercourse (LIO)
- Waterbody (LIO)

Water / Sediment Quality Station (LGL)

WQ1:	south basin - inlet at Mill St
WQ2:	stormwater inlet at trailer park
WQ3 SQ3:	central basin
WQ4:	stormwater outlet - Tyler Avenue
WQ5:	old beach
WQ6:	Fairy Lake dam
WQ7:	Black Creek inlet
WQ8:	stormwater outlet - Elmore Drive
WQ9 SQ2:	south basin
WQ10:	west inlet
WQ11 SQ1:	northwest basin
WQ12:	stormwater outlet at end of Cameron St
WQ13:	stormwater outlet at end of Wright Ave
WQ14:	NW side of Dublin Line at culvert
SQ4:	upstream of dam

LGL LIMITED environmental research associates Est. 1971

Project	BDON1381	Figure	1
Date	May 2023	Prepared By	KC
Scale	1:5,000	Verified By	LKR

Costs for Laboratory Analysis

Laboratory Costs associated with analysis recommended for Fairy Lake Long-term Monitoring Program, May 2023

Station ID	Station Description	Sampling Events	Analysis Type	Assumed # samples	Lab Cost
WQ1	inlet from wetland at Mill Street	all	2	6	$2,002.02
WQ2	inlet to lake from Breezes Trailer Park	when flowing	3	4	$1,670.68
WQ3	lake - central basin	all, winter, profile, ORP	1	7	$2,188.69
WQ4	stormwater flows from Tyler Ave. outfall	when flowing	3	4	$1,670.68
WQ5	Prospect Park public beach	all, winter, profile, ORP	1	7	$2,188.69
WQ6	outlet from Fairy Lake dam	all	1	6	$1,876.02
WQ7	Black Creek inlet	all	3	6	$2,506.02
WQ8	stormwater flows from Elmore Dr. outfall	when flowing	3	4	$1,670.68
WQ9	lake - south basin	all, winter, profile, ORP	1	7	$2,188.69
WQ10	inlet from wetland on west side of the lake	all	2	6	$2,002.02
WQ11	lake - northwest basin	all, winter, profile, ORP	1	7	$2,188.69
WQ12	stormwater flows from Cameron St. outfall	when flowing	3	4	$1,670.68
WQ13	stormwater flows from Wright Ave. outfall	when flowing	3	4	$1,670.68
WQ14	Culvert crossing of Dublin Line	when flowing	2	4	$1,334.68
SQ1	at WQ11	fall	4	1	$108.40
SQ2	at WQ9	fall	4	1	$108.40
SQ3	at WQ3	fall	4	1	$108.40
SQ4	near dam	fall	4	1	$108.40
Replicate Samples (assumes general & nutrient analysis and one sample per event)				7	$1,982.19
				TOTAL COST	$29,244.71

Type of Analysis:	Cost per sample
1 = general, nutrients, *E.coli* ;	$312.67
2 = general, nutrients, *E.coli,* chloride;	$333.67
3 = general, nutrients, *E.coli* , metals, chloride	$417.67
4 = sediments - total organic carbon, total ammonia, total Kjeldahl nitrogen, nitrate, nitrite, total phosphorus (ORP, pH, and temperature at water-sediment interface)	$108.40