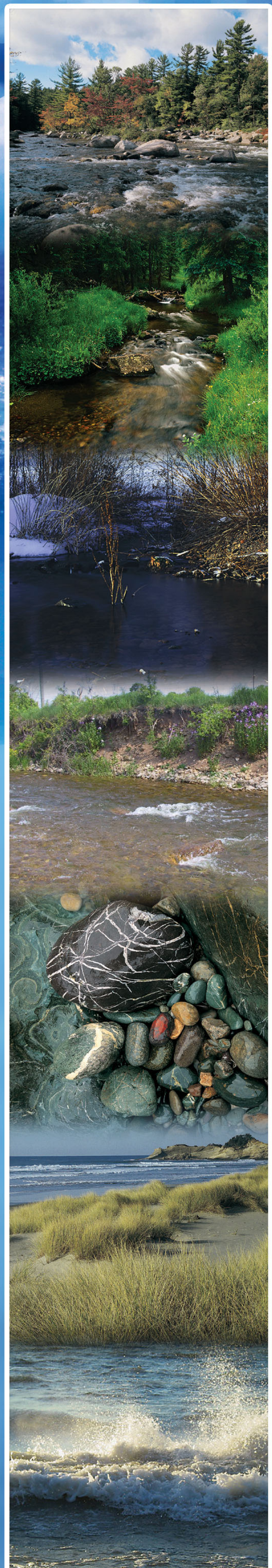

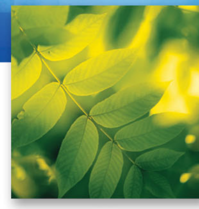

water's edge
ENVIRONMENTAL SOLUTIONS TEAM LTD.

Halton Hills

Fairy Lake Water Quality Study
WQ Modelling

January 31, 2023

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January 31, 2023
WE 21017

Ms. Lynette Renzetti, B.Ed., Hons. BSc.
LGL Limited Environmental Research Associates
445 Thompson Dr., Unit 2
Cambridge, Ontario
N1T 2K7

Dear Ms. Renzetti:

RE: Fairy Lake
Water Quality Modelling Study

1.INTRODUCTION

Water's Edge developed a hydrologic and water quality model of the Fairy Lake Watershed in the town of Acton (Halton Hills) following current design standards. Previously AECOM completed the Fairy Lake Water Quality Study in 2009 (AECOM, 2009). The past study analyzed the lake's water budget, water quality, sediments, vegetation, and waterfowl. This study takes a different approach in only analyzing water quality. Through classical hydrology and hydraulics modeling, the Fairy Lake water quality was analyzed to assess hydrologic factors affecting the water quality of the watershed and lake. Water's Edge used EPA SWMM to develop the hydrologic model. Phosphorus is a key indicator of lake health. This parameter is easy to model through runoff and in a rural setting is the key source for phosphorus loading into a lake (Dillon, 1975).This study focuses on rainfall inputs and assumes a baseflow. The model was run based on rainfall data from Georgetown and Acton from 2009-2022 as well as climate data from Guelph for the same time period. Additionally, phosphorous loads were estimated based on land use types from literature and other pre-existing models for similar watersheds. Model calibration was based on Water Quality tests sampled in Fairy Lake by LGL (see **APPENDIX A**)

This report includes background information on the watershed, detailed methodology for developing the model, and the results of the hydraulic analyses. Additionally, recommendations for managing phosphorous loads in Fairy Lake are presented.

2.BACKGROUND REVIEW

2.1 Data Sources

We have completed our assessment of the Fairy Lake in accordance with the approved project Terms of Reference. Data sources for the analysis include:

- Fairy Lake Water Quality Study AECOM 2009;
- Georgetown Rain Gauges; Acton Rain Gauge, (Gaps filled with Pearson Airport Data)
- Guelph Climate Gauges;
- Ontario Flow Assessment Tool (OFAT);
- Digital Elevation Model (Ontario GeoHub);
- Bathymetry from AECOM
- Water Quality Assessments from LGL
- Halton Region Flow Measurements
- Southern Ontario Land Resource Information System SOLRIS 3.0 2019 land use classification
- Phosphorus Budget Tool in Support of Sustainable Development for Lake Simcoe Watershed
- Discussions with LGL staff.

2.2 Watershed Characteristics

The Fairy Lake Watershed is at the headwaters of Black Creek, a tributary to the West Branch of the Credit River, and covers most of the urban area of Acton, ON. The Fairy Lake Watershed borders the Eramosa River Watershed in the west and north, the Sixteen Mile Creek Watershed in the South, and the Credit River system on the east. The watershed has an area of 20.24 km^2 according to the delineation in HEC-GeoHMS. See **Figure 1** for map of watershed.

Figure 1 Fairy Lake Watershed (Google Earth 2004)

The land use in the Fairy Lake Watershed is primarily undifferentiated rural area with built-up areas surrounding the lake and scattered wetlands throughout (SOLRIS). The average annual temperature in the region is 6.9 °C and the average annual precipitation is 901 mm according to the Ontario Flow Assessment Tool (OFAT) (MNRF, 2022). The watershed has been delineated into eight subcatchments. This is based on topography, land use, and the need to model inlets into Fairy Lake. Discretization based on land use areas allows for further analysis of phosphorus loading contributions. **Figure 2** shows the watersheds subcatchments used in EPA SWMM.

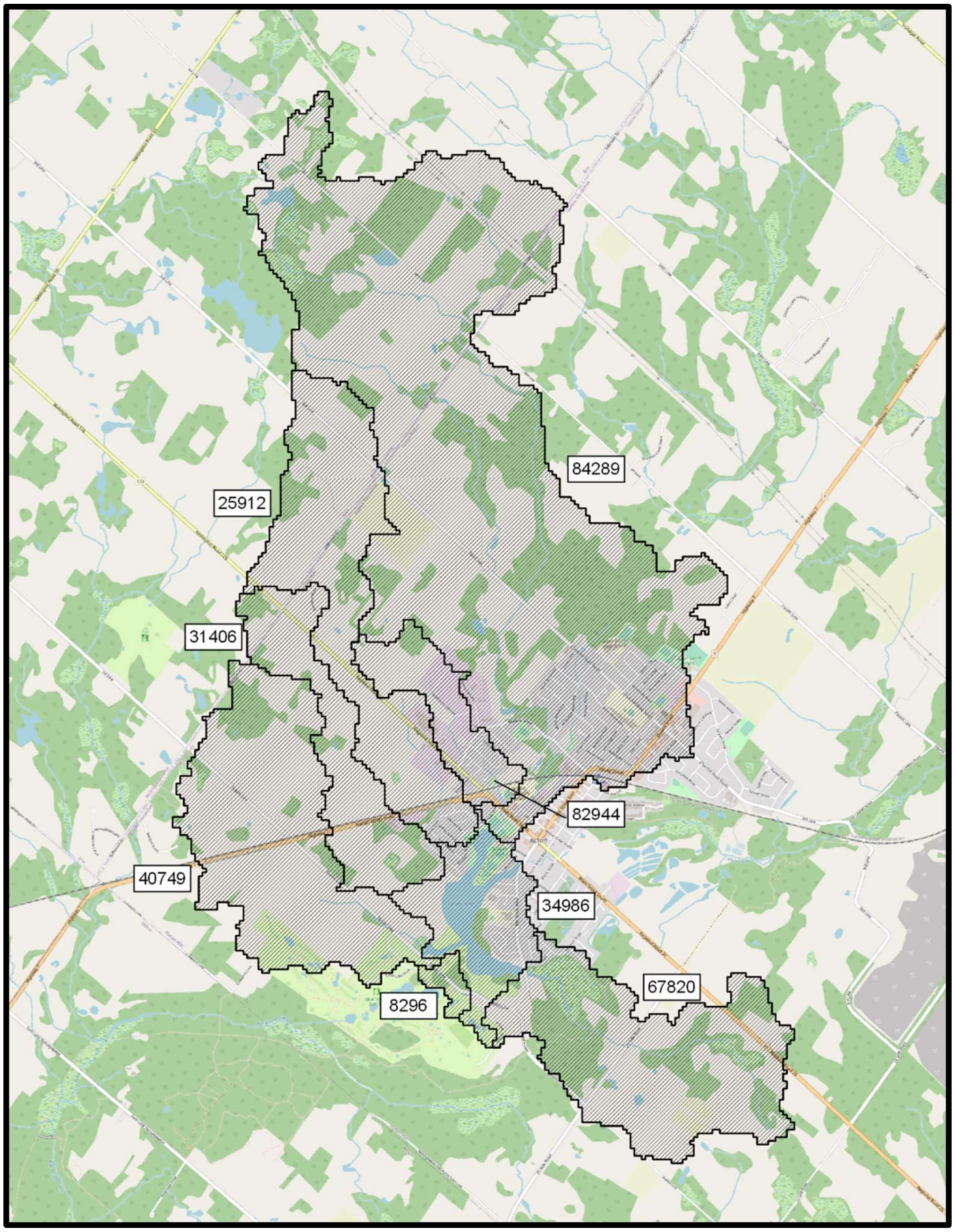

Figure 2 Watershed Delineated into Eight Subcatchments

2.3 Land Use

The catchments land uses were classified through SOLRIS. SOLRIS derived 16 land use classifications for the basin. Specific estimates of land use-specific phosphorus loading coefficients were determined based on loads previously calculated for the Lake Simcoe Watershed by Hutchinson (2012). As Fairy Lake has similar geography and climate to Lake Simcoe, these loadings were deemed to be comparable. Subsequently, the land uses were simplified from 16 categories to 7. **Table 1** shows how land use classifications were combined for use in the EPA SWMM model. See **Appendix B** for Land Use Calculations for each subcatchment.

Table 1 Land Use Classifications

SOLRIS Classification	Lake Simcoe Classification
Hedge Rows	Forest
Mixed Forest	Forest
Forest	Forest
Plantations - Tree Cultivated	Forest
Deciduous Forest	Forest
Coniferous Forest	Forest
Transportation	Residential
Built-Up Area - Impervious	Residential
Undifferentiated	Crop Land
Thicket Swamp	Wetland
Marsh	Wetland
Treed Swamp	Wetland
Thicket Swamp	Wetland
Built-Up Area - Pervious	Low intensity development
Tilled	Hay Pasture
Open Water	Open Water

Table 2 summarizes the land use phosphorus loading rates used in the EPA SWMM model derived in the Lake Simcoe study. A catchments land use map is displayed in **Figure 3**.

Table 2 Land Use Phosphorus Classification (Lake Simcoe Study Results)

Phosphorus Export per Land Use Classification (g/ha/day)						
Cropland	Hay-Pasture	Residential	Low Intensity Development	Forest	Wetland	Open Water
0.63	0.229	3.614	0.359142	0.167	0.164	0.712

To find Event Mean Concentrations for the EPA SWMM land uses, a data table from the Minnesota Pollution Control Agency was consulted (Minnesota Pollution Control Agency, 2021). In **Table 3** below, the determined mean concentrations are shown.

Table 3 Event Mean Concentrations of Phosphorus

Event Mean Concentrations (mg/L)						
Cropland	Hay-Pasture	Residential	Low Intensity Development	Forest	Wetland	Open Water
0.533	0.09	0.32	0.19	0.09	0.3	0.15

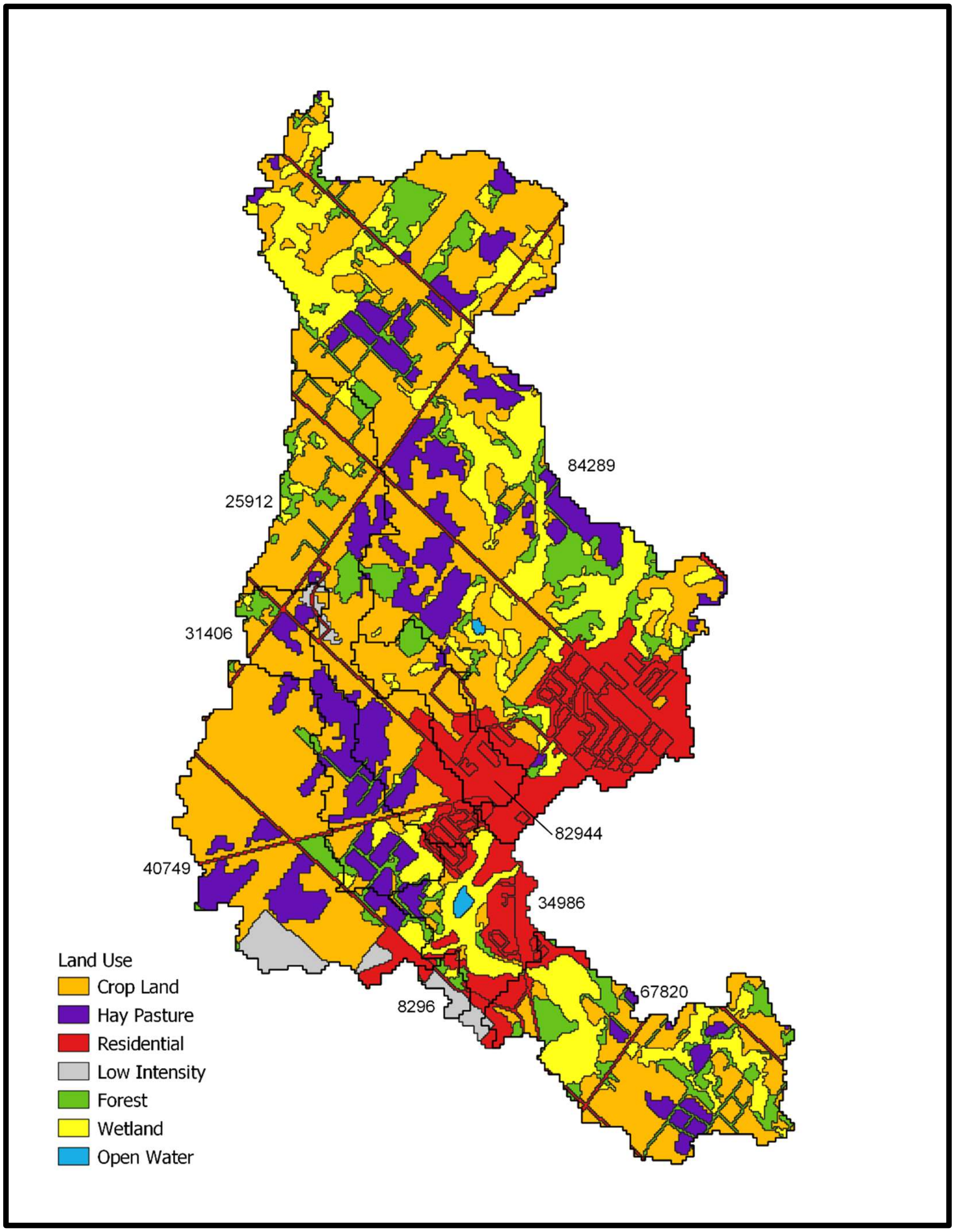

Figure 3 Land Use Classification

3. MODELLING

3.1 Methodology

A hydrologic model of the Fairy Lake Watershed was created in EPA-SWMM and run for the span of the climate data (13 years at a 24-hour time interval). This was based on rain gauge data from Georgetown. and available Acton Data. No flow gauges are present in the catchments, so a flood frequency analysis could not be conducted directly.

Provincial Water Quality Objectives state that phosphorus should be less than 0.02 mg/L in lakes and less than 0.03 mg/L in rivers.

3.2 Terrain Model Development

The terrain model was developed from Ontario GeoHub data. Imagery data was stitched together to cover the lake. The data was combined in AutoCAD with bathymetry data from LGL's April 2022 study to create a 3D Digital Terrain Model (DTM) of Fairy Lake as seen in **Figure 4**.

3.3 Terrain Pre-processing

Following the development of the DTM, additional manipulations were necessary to prepare the surface for use in the hydrologic model. HEC-GeoHMS version 10.1 was used for pre-processing and model development within ArcGIS. The first step was to ensure that flow paths were accurately represented in the DTM. The next step was to fill in depressions without apparent outlets. This step ensures that every cell within the watershed contributes flow to the outlet and there is no depression storage to attenuate peak flows, resulting in a more conservative representation of surface conditions. Following these steps, a linear workflow was followed that started with creating a flow direction raster that indicated which direction a given cell would drain to. Next, a flow accumulation raster was created that represented the number of upstream cells contributing to a given cell. A stream network was then defined based on a minimum number of contributing cells. The subcatchments were delineated based on the flow change locations. The catchment grid was converted into a polygon shapefile and metadata was added providing information on the connectivity of adjacent catchments.

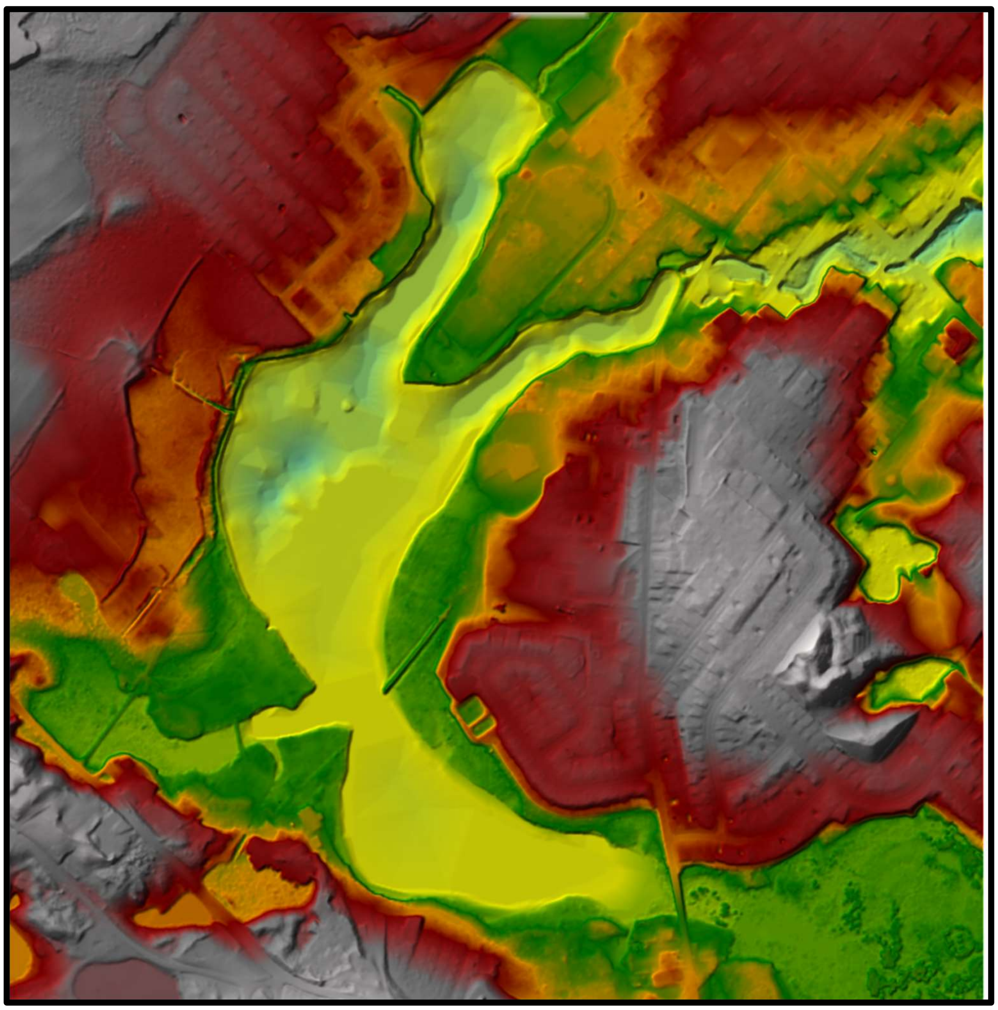

Figure 4 Digital Terrain Model with added LGL Bathymetry

3.4 Model Preparation

Once the subcatchments were satisfactory, several parameters were extracted based on the surface properties, listed below:

- Basin Area
- Basin Width (Function of Area and Longest Flowpath)
- Basin Slope
- Impervious Surface Area
- Land Uses
- Basin Curve Number (from Hydrologic Soil Groups)

3.4.1 Curve Number Grid

A Curve Number grid was created to assign each raster cell a Curve Number based on the soil and land use characteristics of that point. Curve Numbers were selected from the TR-55 document from the NRCS (NRCS, 1986). This ensures accurate geospatial representation of runoff characteristics. To produce the most accurate representation of current land use conditions in the watersheds, Ontario soil survey data were used to define soil characteristics and MNRF data were used for forest cover. A review of aerial imagery was undertaken to verify features. The land use categories were assigned based on the NRCS land use classifications to facilitate the assignment of Curve Numbers. Some assumptions were made based on the land use description and the information needed to assign a Curve Number in the NRCS document.

Following the preparation of the soil and land use data, layers were combined to include both land use and soil data. A lookup table was created to assign a Curve Number based on the land use and the hydrologic soil group (see **Table 4**). The output yielded a Curve Number raster that was used to determine a weighted-average Curve Number for each subcatchment, which was then recorded in the attribute table of the subcatchment shapefile.

Table 4 Curve Number Lookup Table

Land Use	Hydrologic Soil Group			
	A	B	C	D
Commercial	89	92	94	95
Industrial/Institutional	81	88	91	93
Open Space/Park	39	61	74	80
Residential	61	75	83	87
Rural	67	78	85	89
Water	100	100	100	100
Forest	30	55	70	77
Brush	30	48	65	73

3.5 EPA-SWMM Model

Following the model preparation in HEC-GeoHMS, the basin model was exported and then imported into ArcMap. A background image was created in order to redraw the subcatchments into EPA-SWMM. This step automatically assigned all data from the shapefile attribute tables to the appropriate locations in HEC-HMS.

The main components of the hydrologic model are the loss method and the routing method. Each of these components are discussed below.

3.5.1 Loss Method

The loss method selected was SCS Curve Number, due its relatively small data requirements and ease of calibration. In addition to the Curve Number and Percent Impervious determined previously, an Initial Abstraction was calculated automatically in HEC-HMS using the following SCS method (see **APPENDIX C** for results):

$$I_a = 0.2 * \frac{1000}{CN} - 10$$

3.5.2 Routing Method

The Kinematic Wave Method is used to estimate simplified 1D flow routing. It is an approximation commonly used for small catchment areas. This is because in small areas, inertial forces and differences in water pressure between elements are negligible, so a dynamic method is unnecessary. The routing method makes several assumptions to simplify the complexities of a natural watershed such as assuming there is no erosion or aggradation, that velocity is constant in a cross-section, and that flow is incompressible, among others. For the Kinematic Wave routing method, input parameters include an effective surface resistance N, the average slope of the flow element, and specifics of the channel geometry (USACE, 1993). The kinematic wave method takes into account Manning's equation and is useful in this application with larger time steps (EPA, 2015).

3.5.3 Detention Storage

Several storage areas are present in the Fairy Lake watershed, particularly natural ponds and commercial stormwater management (SWM) facilities. Much of the detention storage areas were deemed to be of little significance due to their location in a wetland and the lack of impacts to property. According to the MNRF Technical Guide on Flooding Hazard Limits, SWM facilities cannot be used to provide reduction in flood flows (MNRF, 2002). The guide also states that the unregulated flows should be used to determine the downstream flood hazard limit for minor reservoirs. Therefore, excluding these storage areas will not affect channel flows.

3.5.4 Precipitation Data

Once the basins had been set up in the model, precipitation data was entered. Georgetown rain gauge data, supplemented with Acton rain gauge data, were used for the 13-year simulation. Any gaps were filled with Toronto Airport precipitation data.

3.5.5 Baseflow Data

In order to simulate proper flows from each subcatchment, inflows were assigned to each outlet node. A minimal flow is desired as to not skew results. For the smallest subcatchment, a flow of 0.0001 m^3/s was given. Then for all other catchments, the value was scaled up based on relative area from the smallest as well as historical measurements through dry periods. The addition of these flows will ultimately reduce the "spikiness" of water quality data.

3.6 Sources of Phosphorous

Phosphorus is commonly sourced from agricultural fields, decaying organic matter, and urban non-point sources. In the model, phosphorus is dependent on land use. Comparing SOLRIS land use categories to those found in literature, several land use types were compared and merged to apply values properly. Using a Lake Simcoe phosphorus study as a base (Hutchinson, 2012), phosphorus buildup values for each land use type were created and applied. Values for the rainfall to wash the phosphorus off the land were sourced from the Minnesota Stormwater Manual (Minnesota Pollution Control Agency, 2021).

4. MODELLING RESULTS

4.1 Hydraulic Retention

Fairy Lake acts as a storage unit in the watershed. Outflow of the dam over long periods is considered to equal Inflow. Therefore, Fairy Lake is a storage facility that temporarily holds water rather than overflowing or completely draining. Evaporation is assumed to equal precipitation. In this model, phosphorous is added to the lake through runoff. The majority comes through the inlets into the lake. Phosphorous then either remains in the lake or flows out of the dam. From these assumptions, detention time and phosphorous loadings can be estimated for the lake.

The volume of Fairy Lake was calculated based on bathymetry data collected by LGL in April 2022. As a result, a linear stage storage relationship was developed.

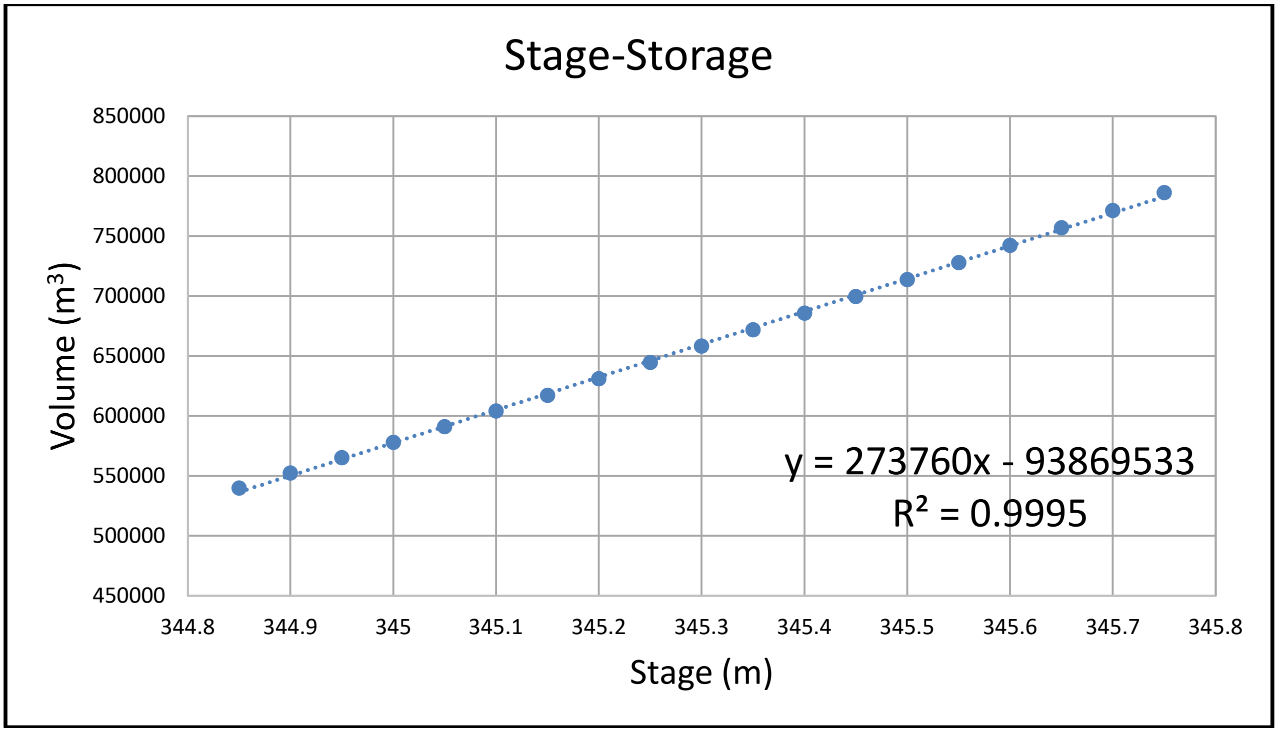

Figure 5 Stage Storage

The volume of Fairy Lake was calculated at stages from 344.85m to 345.75m to derive an average volume of 660,000 m^3. The inflow of Fairy Lake was modelled through *EPA SWMM* with precipitation inputs between 2009 and 2022. The annual inflow was then estimated to be about 3,000,000 m^3. From this, a retention time (τ_w) of 0.22 years was calculated for the lake. The average loading of phosphorous through runoff was modelled over 13 years at an average of 0.012 mg/L, obtained by dividing annual mass buildup by annual outflow volume.

4.2 Calibration

The model was calibrated based on LGL's water quality sampling results (see **APPENDIX A**) as well as Halton Region flow measurements. The model was first calibrated for discharge at the Library Inlet (WQ7-SW3) and for Dublin Line (WQ10-SW1). Following this the model was calibrated to the water quality samples at the same stations.

The model's initial empirical inputs for catchment attributes were then altered to match LGL's sampling results (see **Appendix C**).

For further calibration, continuous monitoring of the inlets could be implemented to capture flood events for both phosphorus and discharge. It was determined that the flow into Fairy Lake does not match empirical estimates from a hydrologic standpoint. This may be due to stormwater being captured in the Town's storm sewer system and discharged into Black Creek downstream of Fairy Lake. As a result, flow estimates were calibrated to match data.

It is noted that site measurements were point measurements while modelling was based on daily averages. These direct measurements are not always indicative of the daily average. Daily averages of precipitation were used to estimate flow and phosphorus concentrations but are being compared to these point measurements. It is possible that the timing of the water quality sampling could miss the daily flow peak. As a result, it is recommended that daily averages be compared to daily averages to have a more accurate calibration through the implementation of continuous monitoring of discharge and water quality.

4.3 Modelling Limitations

It is recommended that groundwater sources be incorporated into the model to estimate groundwater quality as the AECOM report states that groundwater accounts for 90% of the flow during droughts and 40% of the flow otherwise. As such, the current EPA SWMM model is simplified by assuming inflows. Though groundwater is not a significant factor for phosphorus loading, it is a factor for reducing the hydraulic retention time. If the phosphorus concentrations in groundwater are considered negligible then it is logical to assume that lake phosphorus concentrations would be reduced based on a simple mass balance approach. Therefore, future studies should consider updating the model to include groundwater inputs.

In this current model, Fairy Lake is assumed to act solely as sink for phosphorus. Further investigation is recommended to see if Fairy Lake is acting as also as a source of phosphorus. Downstream water quality samples would provide this understanding.

The AECOM report suggested that wildlife (primarily geese or dog) excretion along the waterfront was a factor for phosphorus. This was not modelled in the current EPA SWMM model but may be considered in future. Direct comparison water quality samples could be taken if excrement was removed prior to storms compared to existing conditions. LGL investigated geese populations in August 2022 and note that since over 13 years later from AECOM's report, that geese not only visit this site in migration, but also live here during summer periods (see **APPENDIX D**). It is recommended that phosphorus loads be further investigated from Geese.

Blue Springs Golf Club is geographically close to Fairy Lake. However, it lies outside the delineated catchment boundary based on topography. It is assumed that this golf course does not have any drainage into Fairy Lake as phosphorus export loads are high for golf courses (Hutchinson, 2012).

Lake Simcoe is estimated at having 27% of its phosphorus load from atmospheric sources (Ontario, 2010). Water's Edge EPA SWMM model estimated 120 kg of phosphorus per year from strictly runoff. By interpolation, and assuming that Fairy Lake has the same source distribution as Lake Simcoe, 47 kg a year of phosphorus can be estimated as an atmospheric loading. This has not been accounted for in the modelling.

In comparing the modeled phosphorus export from Fairy Lake to similar export values from Lake Simcoe it was determined that, if phosphorus loadings of Lake Simcoe were pro-rated to Fairy Lake based on watershed catchment sizes, Fairy Lake should have a phosphorus export of 175 kg per year (Ontario, 2010). This method takes all assumptions made when producing the loads for Lake Simcoe (rainfall based on Lake Simcoe, different time modelled, potentially different modelling software, etc.) and applies them to Fairy Lake. Considering the average outflow of the Fairy Lake Dam, that mass loading would present an average phosphorus concentration of 0.056 mg/L, which is close to the EPA SWMM value modelling results for Fairy Lake. The EPA SWMM calculated annual mass of 120 kg results in an average concentration of 0.038mg/L. This value is within the same order of magnitude of the pro-rated Lake Simcoe value, showing promise in the model's output. However, the modelled concentration is still greater than the MOE phosphorus water quality objective for lakes. The highest measured the sample value from LGL was 0.19 mg/L near a storm sewer outfall (See **Table 5** below for summary), but the average LGL lake samples were less than the PWQO. The model result concludes that with standard modelling, the samples would exceed the PWQO for Rivers. Since the Lake samples are lower than the PWQO, there are other factors that help reduce Phosphorus levels in Fairy Lake. These factors would be better understood through further monitoring as the data currently does not clearly provide enough information identify the discrepancy.

Table 5 Conditional Phosphorus Results

Specific Condition	Phosphorus Levels
MOE PWQO Phosphorus level for Lakes	0.02mg/L
EPA SWMM Modelled output	0.038mg/L
Pro-rated estimate from Lake Simcoe Model	0.056mg/L
Highest TP measured in 2021/2022 (Elmore Drive stormwater inlet)	0.19mg/L

Figure 6 Shows that the model has similar ranges of concentrations to LGL's samples. All of the modelled inlets are higher than MOE PWQO guidelines. Though there is a disparity between some of the modelled outputs and LGL's samples, this could be minimized by more sampling.

Further suggestions for future modelling updates:

- Site specific phosphorus load exports
- Water Quality tests during flood events
- 2D hydraulics modelling
- Continuous flow gauges on Dam to calibrate discharge data
- Estimate of groundwater inputs into Fairy Lake
- Modelling of sedimentation of phosphorus in Fairy Lake

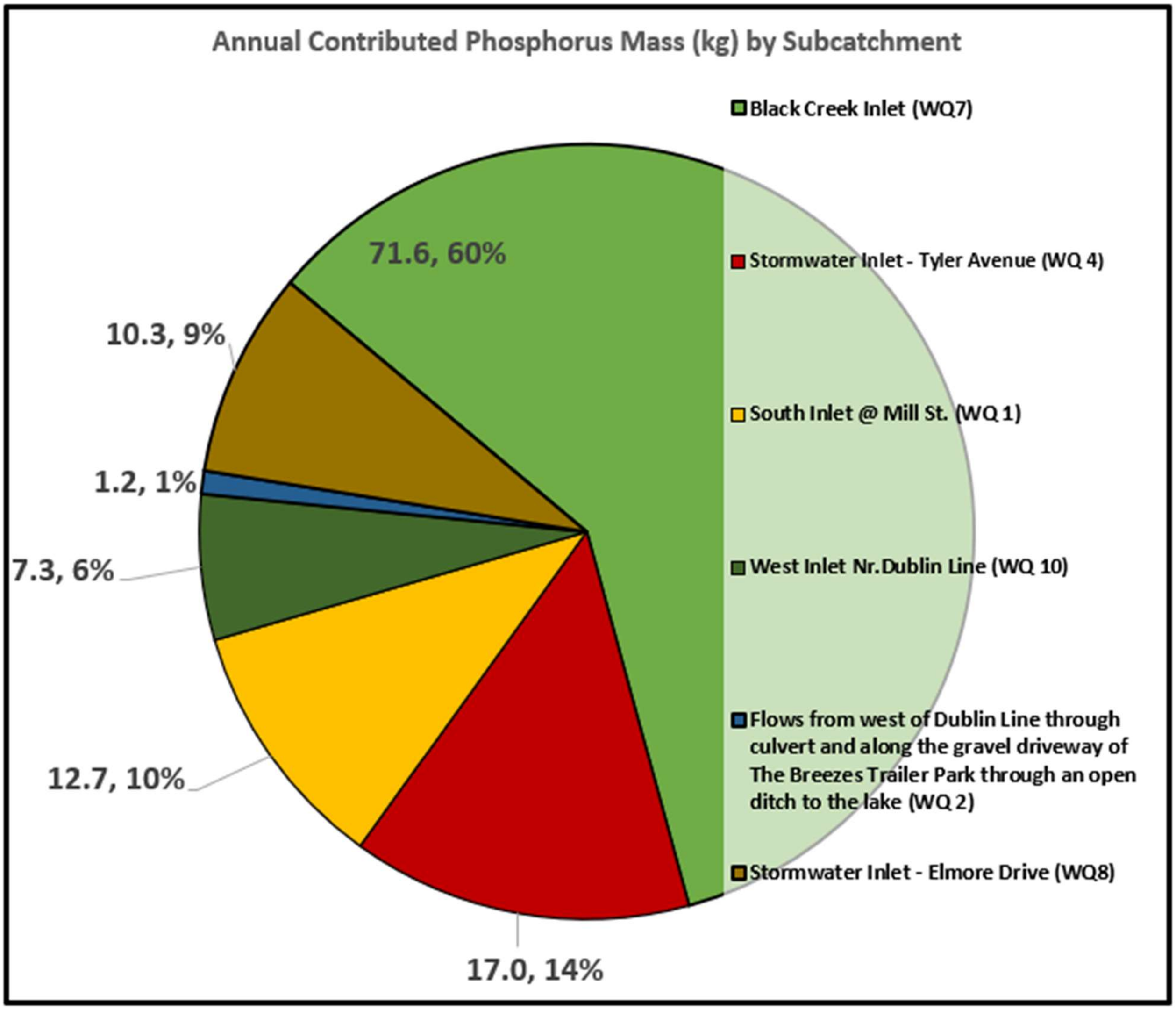

Figure 6 Annual Contributed Phosphorus Load (kg) by Subcatchment

5. DISCUSSION OF BEST MANAGEMENT PRACTICES

Six BMPs have been proposed for the implementation of phosphorus reduction in Fairy Lake. They are listed below:

1. Agricultural Tile Drainage
2. Oil and Grit Separators
3. Fairy Lake Maintenance
4. Natural Channel Design
5. Wetland Design
6. Monitoring Program

As a result, if the health of a lake is to be improved, there are broad approaches that can be implemented:

1. Decrease the phosphorous loading by phosphorus-reducing inputs into the watershed
2. Filter phosphorus out in the watershed
3. Increase the lake’s ability to process phosphorus intakes.

Further Benefit-Cost Analyses should be undertaken to estimate the optimal way of improving lake health as well as making sure that ecological factors are all considered. This processes briefly analyzes each BMP to help stakeholders decide to proceed going forward.

5.1 BMP Objectives

Water's Edge determined five objectives when considering BMPs. These were examined rationally and will be briefly described below. The ability for a BMP to meet an objective will determine whether it meets the needs for the Fairy Lake watershed. It is possible that stakeholders would have other objectives that could in the future be added to this analysis to weigh alternatives.

Effectiveness

- This is based on the ability of a BMP to eliminate Phosphorus from entering Fairy Lake. This would be weighing each alternative on the efficiency of installing this BMP compared to not. Some BMPs collect Phosphorus to be discarded, where others help prevent runoff. Thus, the BMPs are not completely comparable in this regard. It is important however to ensure that any recommended BMP is effective in the Fairy Lake setting so that is why this criteria is included.

Distribution:

- Each catchment has a different amount and potential source for phosphorus in the watershed. If one BMP is effective for a particular land use, but that land use is only represented in one catchment, then it may not be the most important BMP to focus on. The greater the number of catchments suited to the BMP, the higher the rating.

Low Maintenance Required

- If a BMP only has start-up costs than it would be rated higher than a long-term project that would require ongoing maintenance. This would prevent the Town of Halton Hills from having to implement new maintenance programs.

Cost:

- This criterion is basic and generalized. It ranks availability to funds. True costing would have to be done in a separate study. If private land is needed, then the scoring is lower. If known grants are already available, then scoring is higher. If the allocation of funding is unknown, then the rating would be in the middle. If able to be funded by a CA or Municipality rather than relying on Provincial or Federal Grants that currently are not designated, then the rating is higher.

Timeline Scoring:

- The shorter the time to implement, the higher the rating. This criteria focuses on the installation/start up of the BMP alone, and excludes consideration for permits/approvals or other factors.

5.2 Weighing the Objectives

All the objectives are important, but they are not equal. In order to evaluate the BMPs fairly, the weighting of objectives was done from a rationality method using a Pairwise Comparison Chart (See **Appendix F**). The results were then turned into percentages which could be used in the rating of each BMP.

Table 6 Weights

Rank	Objective	Weight Rating of Metric
1	Effectiveness	40%
2	Distribution	25%
3	Maintenance	20%
4	Cost	10%
5	Timeline	5%

5.3 BMP Descriptions

How each BMP fits with the objectives is described in **Appendix F**. Below is a description describing how each BMP works.

5.3.1 Agricultural Tile Drainage

Agricultural runoff accounts for a large proportion of phosphorus inputs into Fairy Lake.

Agricultural practices include the application of manure as well as fertilizers to arable lands. To minimize the runoff of nutrients from these landscapes, landowners should be encouraged to implement BMPs on agricultural lands. By providing education, incentives, or tools, famers could alter their land to minimize agricultural runoff especially during extreme events. This could minimize the loading into the contributing stream systems.

Agricultural tile drainage is a key method that is encouraged by government and agricultural bodies. As Phosphorus is directly proportional to runoff, reducing runoff volume and intensity will reduce runoff and thereby reduce phosphorus into Fairy Lake. The largest land use of Fairy Lake Watershed is agriculture. Therefore, implementing tile drainage will indeed have a positive impact. Phosphorus is needed for crop growth, and so reducing phosphorus is not as effective as reducing the wasting of phosphorus through excess runoff. Tile drainage prevents ponding, attenuates flow into rivers, improves crop yields, and minimizes storms from destroying crops.

Additional agricultural methods of reducing phosphorus runoff include:

- Vegetated field edges
- Separate applications of phosphorus (from other nutrients) so that it is applied when the plant needs it most.
- Improving soil moisture retention with additional organics

5.3.2 Oil Grit Separator

These are filters connected to storm sewer systems. They separate oil and grit from water, allowing water to flow downstream while detaining the solids. As phosphorus is contained in sediments, the more sediment that is prevented from flowing into Fairy Lake, the better.

The Town of Acton has put in place a small number of BMPs (e.g., oil-grit separators) to reduce the water quality impact of storm sewers from certain suburban neighborhoods. These measures should be expanded, especially to the areas which have outfalls directly into the lake rather than to a tributary. Effectively controlling the runoff quality from residential areas is important since it has the highest phosphorus export per land use area out of the land uses in the catchment (see **Table 2**).

5.3.3 Natural Channel Design

Rivers and streams can naturally improve water quality though natural stream functions of uptake and processing. The process of Natural Channel Design has the potential to provide significant phosphorus filtration as well as denitrification. While many river restorations do not include the use of a hyporheic zone for water quality improvements, natural rivers have hyporheic zones where subsurface zones mix with the groundwater. This zone acts to provide biotic life to the river by housing food sources, microorganisms, crustaceans, and bugs. This zone can also help to moderate the temperature in the river throughout the seasons. As watercourses and catchments have become urbanized; processes such as erosion, increased sedimentation, and aggregation can alter the bed of the river. The hyporheic zone can then be cut off from the river or the intermixing from it can be reduced. As a result, there are fewer chemical reactions, and the pollutants remain intact in their initial form. Restoring watercourses in the Fairy Lake Watershed with Natural Channel Design should consider restoring the hyporheic zone as well.

Natural channel designs can then be proposed for key locations and should include natural channel design components such as constructed riffles, increased meandering, J-hook and cross vanes, root wads, and toe wood structures. These structures can be used to encourage movement into the hyporheic zone where biochemical reactions can be activated and increase the lag time of pollutants into Fairy Lake. Designs should be supported by groundwater studies which would determine the effects of well water on the hyporheic zones. At this time, it is noted that there is a concrete channel on Bovis Creek between Division St. and Wallace St. that might benefit from natural channel design. The authors are not aware of any available groundwater study that could inform the natural channel design within this reach.

5.3.4 Fairy Lake Maintenance

The factors that affect lake health are noted as follows (Vollenweider, 1973):

Phosphorus Loading: Phosphorus has been a good indicator of lake health as lakes that have high nitrogen or chlorophyl levels most often have high phosphorus as well (Dillon, 1975). As a result, there is greater eutrophication with higher phosphorus. The key factor to phosphorus loading is through runoff or total inflow into Fairy Lake (AECOM, 2009).

Mean Depth $\bar{z}$: Dillon concludes that deeper lakes are less likely to have wind and waves disturbing phosphorus sediment. Further, lakes with larger mean depths have different biological processes due to stratification and having more volume per surface area. It is noted that Fairy Lake is a man made lake and so the mean depth may not be sufficient to provide proper lake health.

Retention time τ_w: Retention time, or hydraulic retention time, is defined as the time that water or dissolved substance will remain in the lake. The retention time of a lake is also described as the flushing rate. The better ability a lake has to flush itself, the lower concentration of phosphorous and thereby greater health to the lake. As stated in **4.1** the retention time is 0.22 years. This is assumed to be calculated as seen below:

$$\tau_w = \frac{Volume\ of\ Lake}{Total\ Inflow} = \frac{m^3}{\frac{m^3}{year}}$$

To decrease the retention time, the dam could be operated to flush the lake at key intervals in time.

The Fairy Lake Dam Repair and Leakage Mitigation in The Town of Halton Hills (Acton) report shows that there was significant sediment accumulation at the dam (See **Appendix E**). The removal of this sediment would decrease phosphorus concentrations in the lake as well as downstream of the outlet (Dillon, 1975). Further sedimentation samples could be collected at key points in the lake. This could be used to estimate the quantity of phosphorus in the bed of the lake. A Benefit-Cost Analysis could be calculated for this sediment removal. As this is an artificially created lake, it will have to be managed and maintained to provide optimal health for the lake and to encourage recreational uses to the community. It is recommended to consult all key stakeholders if this is pursued. At this time LGL is concerned how SAR would be affected by this and this idea should not be taken lightly.

5.3.5 Wetland Design

Wetlands are nature's way of filtering water. Studies have been completed showing that wetlands are more affordable than removing phosphorus or treating it (Land, 2016). Currently there is a wetland the southeast corner of Fairy Lake. In addition, there is wetland around WQ10. The success of reducing Total Phosphorus in the existing wetlands could be calculated by having multiple monitoring spots of the inlets.

Additionally micro wetlands could be designed at other inlets into Fairy Lake for instance (Tyler Ave, outfall, or Black Creek inlet). Currently these sites just have manicured outlets that have straight channels into Fairy Lake. It is possible that these could be engineered to act as a wetland while still allowing flow and preventing backwater in the inlets. One study estimated that 10g/(m^2year) of Phosphorus could be removed from a watershed (Land, 2016). For Tyler Ave. that would require 1,700m^2 of wetland to eliminate the estimated 17kg/year. Rotary Park was estimated at approximately 6900m^2. Black Creek would need 5,510m^2 at Prospect Park in order to hypothetically filter out the phosphorus.

Most likely, this would not fully eliminate phosphorus, but would be a relatively affordable method that requires little maintenance.

5.3.6 Monitoring Program

Though there have been past water quality studies, there has never been thorough monitoring to monitor trends in P over time to better understand how to prioritize BMPs. All the BMPs are recommended based on theoretical data and empirical data for other watersheds. Data from the 2021-2022 Fairy Lake Water Quality Study Update (LGL, 2023) demonstrated high TP concentrations in samples collected at inlets to the lake; however, TP concentrations within the lake and at the dam where flows report back to Black Creek were found at or below the PWQO for TP during all sampling events. Water quality is affected by a variety of factors including climate and flow conditions which vary year to year. A long-term water quality monitoring program would help the Town and other stakeholders to better understand the variation inherent within the water quality data so that trends over time could be better identified. This would allow for evidence based BMPs to be prioritized and implemented in and around Fairy Lake to result in the greatest possible benefit. In general, a consistent monitoring program is recommended to include more frequent sampling events or continuous automated sample collection for key constituents. As supporting studies are completed (e.g., the detailed multi-year study of HABs led by researchers from the University of Guelph), additional data collection (physical or chemical) relating to the identified drivers of HABs in Fairy Lake may be warranted as part of a long-term monitoring study. Specific ideas for a monitoring program are listed below:

- Continuous phosphorus water quality gauges at all inputs in and out of Fairy Lake.
- Continuous phosphorus monitoring upstream reaches to see how phosphorus levels change over time.
- Groundwater monitoring to estimate flow and impact of ground water into and out of Fairy Lake (municipal wells located at Prospect Park)
- Phosphorus monitoring upstream and downstream channelized concrete section of Bovis Creek.
- Identify additional key areas for monitoring based on stakeholder inputs.
- Complete sediment samples around Fairy Lake and specifically the dam. Depending on the results, initiate sediment sample program.
- Complete more samples around WQ2 near the trailer park to see what impact from the trailer park has.

6. RESULTS

The BMPs were analyzed against the objectives. The process is described in **Appendix F**. Efficacy ratings were multiplied by the weights of each objective from **Table 6.** The total scoring shows which BMPs are believed to be the most appropriate improvement to Fairy Lake. Land use and catchments were matched up to the most appropriate BMP.

Results are tabulated below in **Table 7**.

Table 7 BMP Ranking and Designations

BMPs	Scoring	Land Use Most Appropriate	Catchments Most Applicable
Agricultural Tile Drainage	**0.713**	Crop Land	WQ1, WQ4, WQ7
Oil Grit Separator	**0.32**	Residential	WQ2, WQ5
Natural Channel Design	**0.535**	Specific	WQ7
Fairy Lake maintenance	**0.545**	Open Water	WQ5
Wetland Design	**0.61**	Residential	WQ7, WQ4
Advanced Monitoring Program	**0.95**	All	All

7. SUMMARY

Fairy Lake in the Town of Halton Hills has been studied in the past to assess its water quality and water balance. As an update, Water's Edge has modelled phosphorus runoff inputs by creating a hydrologic and water quality model to simulate a 13-year continuous period of rainfall data. From the review of previous studies and the current modelling, and from current water quality sampling by LGL, it has been found that:

1. The Fairy Lake Water Quality Study in 2009 and current LGL water quality sampling show that the phosphorus loads are high coming into Fairy Lake and some inlets exceed PQWO at different times and locations;
2. Modelling results indicate there are currently high levels of phosphorus in Black Creek inlet NW of Fairy Lake;
3. The Fairy Lake modelling results were pro-rated to the phosphorus quality values of the Lake Simcoe study to ensure the results were reasonably accurate;
4. Total phosphorus has decreased in lake samples when strictly comparing LGL's 2021 & 2022 samples to the AECOM study, yet increased in storm water channels and Mill St. Wetland (WQ1)
5. Best Management Practices should be encouraged to control the runoff quality from agricultural fields and from residential areas;
6. Additional studies are required to determine what improvements in the hydraulic qualities of Fairy Lake could be implemented for Fairy Lake water quality to be within MOE PQWO guidelines for all inlets and within the lake;
7. Additional streamflow and water chemistry data would benefit the model and allow for more confident decisions and recommendations to be made.

Respectfully submitted,

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REFERENCES

AECOM. (2009). *Fairy Lake Water Quality Study.* Town of Halton Hills: AECOM. Retrieved from https://www.haltonhills.ca/en/explore-and-play/resources/Documents/FairLakeWaterQualityStudy.pdf

Dillon, P. (1975). *The Application of the Phosphorus- Loading Concept.* Burlington: INLAND WATERS DIRECTORATE. CANADA CENTRE FOR INLAND WATERS. Retrieved from https://publications.gc.ca/collections/collection_2018/eccc/En36-502-46-eng.pdf

EPA. (2015). *Storm Water Management Model User's Manual Version 5.1.* Cincinnati: National Risk Management Research Laboratory. Retrieved from https://www.epa.gov/sites/default/files/2019-02/documents/epaswmm5_1_manual_master_8-2-15.pdf

Hutchinson. (2012). *Phosphorus Budget Tool in Support of Sustainable Development for the Lake Simcoe Watershed.* Aurora: Ontario Ministry of the Environment. Retrieved from https://www.aurora.ca/en/business-and-development/resources/Environment-and-Sustainability/Phosphorus-Budget-Guidance-Verison-2-1.pdf

Land, M. G. (2016). How effective are created or restored freshwater wetlands for nitrogen and phosphorus removal? A systematic review. *Environ Evid*, 5,9. Retrieved from https://doi.org/10.1186/s13750-016-0060-0

Minnesota Pollution Control Agency. (2021). *Event mean concentrations for total phosphorus.*

MNRF. (2002). *River & Stream Systems: Flooding Hadar Limit - Technical Guide.* Peterborough.

NRCS. (1986). *rban Hydrology for Small Watersheds TR-55.* USDA Natural Resources Conservation Services. Retrieved from https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1044171.pdf

Ontario. (2010, June). *Lake Simcoe phosphorus reduction strategy*. Retrieved from https://www.ontario.ca/page/lake-simcoe-phosphorus-reduction-strategy

USACE. (1993). *Introduction and Application of Kinematic Wave Routing Techniques Using HEC-1.* USACE Hydrologic Engineering Center.

Vollenweider. (1973). *Input-Output Models,.* Schweiz. Z. Hydro/.

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APPENDIX A:

Fairy Lake Water Quality Tests Results (LGL)

Appendix B Table 1: Fairy Lake Water Quality Data, 2021-2022

		Provincial Water Quality Objective (PWQO)	Canadian Council of Ministers of Environment (CCME)			WQ1 - South Basin Inlet at Mill St.							WQ2 - Stormwater Inlet at Trailer Park						WQ3 - Lake Central Basin							
Parameter	Unit	Aquatic Life	Aquatic Life		Livestock Health	2008 (AECOM)**	2021-08-03	2021-09-22	2022-04-20	Min	Max	Mean	2008 (AECOM)**	2021-09-22	2022-02-17	Min	Max	Mean	2008 (AECOM)**	2021-08-03	2021-09-22	2022-01-24	2022-04-20	Min	Max	Mean
			Acute	Chronic																						
Field Measured																										
Field Water Temperature	°C	-	-	-	-	-	16.4	16.5	3.5	3.50	16.50	12.13	-	16.4	0.1	0.1	16.4	8.3	-	22.2	20.3	3.2	7.5	3.2	22.2	13.3
Field Dissolved Oxygen	mg/L	>4.0	>5.5		-	-	0.59	1.40	8.13	0.59	8.13	3.37	-	7.16	11.87	7.16	11.87	9.52	-	7.62	7.53	8.23	11.43	7.53	11.43	8.70
Field Specific Conductivity	µS/cm	-	-	-	-	0.549	0.577	0.581	0.508	0.508	0.581	0.555	0.626	0.791	0.479	0.479	0.791	0.635	0.627	0.646	0.632	0.885	0.805	0.632	0.885	0.742
Field pH		6.5-8.5	-	6.5-9.0	-	8.10	6.99	7.49	7.47	6.99	7.49	7.32	8.10	7.48	7.57	7.48	7.57	7.53	8.40	8.14	7.93	7.56	8.00	7.56	8.14	7.91
General Chemistry																										
Total Ammonia-N	mg/L	-	-	-	-	0.05$^{(<RDL)}$	0.06	0.06	0.19	0.06	0.19	0.10	0.05$^{(<RDL)}$	0.27	0.54	0.27	0.54	0.41	0.73	0.04	0.05	0.09	0.22	0.04	0.22	0.10
Total Carbonaceous BOD	mg/L	-	-	-	-	2$^{(<RDL)}$	2$^{(<RDL)}$	2$^{(<RDL)}$	2$^{(<RDL)}$	<RDL	<RDL	<RDL	6	2$^{(<RDL)}$	4	<RDL	4	3	2$^{(<RDL)}$	2$^{(<RDL)}$	2$^{(<RDL)}$	2$^{(<RDL)}$	2$^{(<RDL)}$	<RDL	<RDL	<RDL
Total Dissolved Solids	mg/L	-	-	-	-	356	320	310	235	235	320	288	401	485	210	210	485	348	408	345	345	455	420	345	455	391
Total Nitrogen (N)	mg/L	-	-	-		1.21	0.83	1.3	0.46	0.46	1.30	0.86	1.11	1.5	4.3	1.5	4.3	2.9	1.61	0.5	0.68	1.3	1.2	0.50	1.30	0.92
Dissolved Organic Carbon	mg/L	-	-	-	-	-	15	13	6.7	6.7	15.0	11.6	-	22	11	11	22	17	-	5.8	5.9	7.1	4.0	4.0	7.1	5.7
Orthophosphate (P)	mg/L	-	-	-	-	0.02	0.0043	0.047	0.0044	0.0043	0.0470	0.0186	0.04	0.04	0.062	0.040	0.062	0.051	0.01$^{(<RDL)}$	0.0012	0.0013	0.0010$^{(<RDL)}$	0.0010$^{(<RDL)}$	<RDL	0.0013	0.0011
Dissolved Phosphorus	mg/L	-	-	-	-	0.032	0.018	0.065	0.009	0.009	0.065	0.031	0.048	0.052	0.066	0.052	0.066	0.059	0.009	0.007	0.007	0.005	0.005	0.005	0.007	0.006
Total Phosphorus	mg/L	0.020 lakes; 0.030 rivers	-	-	-	0.054	0.03	0.14	0.014	0.014	0.140	0.061	0.033	0.075	0.14	0.08	0.14	0.11	0.033	0.014	0.015	0.014	0.015	0.014	0.015	0.015
Total Suspended Solids	mg/L	-	-	-	-	2	3	7	1$^{(<RDL)}$	<RDL	7	4	13	3	28	3	28	16	3	3	3	2	2	2	3	3
Total Kjeldahl Nitrogen, calculated	mg/L	-	-	-	-	1.1	0.89	1.28	0.424	0.424	1.280	0.865	1	1.11	1.25	1.11	1.25	1.18	1	0.51	0.671	0.757	1.13	0.510	1.130	0.767
Alkalinity (Total as $CaCO_3$)	mg/L	-	-	-	-	229	250	170	200	170	250	207	236	250	100	100	250	175	202	170	170	260	220	170	260	205
Dissolved Chloride (Cl-)	mg/L	-	640	120		39	40	59	40	40	59	46	52	100	69	69	100	85	65	-	-	-	-	-	-	-
Nitrite (N)	mg/L	-	-	0.06	10	0.01$^{(<RDL)}$	0.0012	0.0032	0.004	0.0012	0.0040	0.0028	0.01$^{(<RDL)}$	0.0069	0.018	0.0069	0.0180	0.0125	0.01	0.0013	0.0022	0.0083	0.0040	0.0013	0.0083	0.0040
Nitrate (N)	mg/L	-	124	3.0	-	0.1$^{(<RDL)}$	0.0020$^{(<RDL)}$	0.011	0.002	<RDL	0.011	0.0051	0.1	0.39	3	0.39	3.00	1.70	0.6	0.0020$^{(<RDL)}$	0.012	0.51	0.029	<RDL	0.51	0.1383
Nitrite + Nitrate (N), calculated	mg/L	-	-	-	100	0.1$^{(<RDL)}$	0.0022$^{(<RDL)}$	0.014	0.033	<RDL	0.033	0.0164	0.1	0.4	3	0.4	3.0	1.7	0.6	0.0022$^{(<RDL)}$	0.014	0.52	0.033	<RDL	0.52	0.1433
Unionized Ammonia-N, calculated	µg N/L	16.5	16.0			-	0.2	0.6	0.6	0.2	0.6	0.5	-	2.4	1.7	1.7	2.4	2.1	-	2.4	1.7	0.3	3.3	0.3	3.3	1.9
Microbiology																										
Escherichia coli	CFU/100 ml	400 *E.coli* /100 mL (Ministry of Health)	-	-	-	-	100	**3500**	50	50	3500	1217	-	**3300**	80	80	3300	1690	-	10$^{(<RDL)}$	20	10$^{(<RDL)}$	10$^{(<RDL)}$	20	20	20
Metals																										
Total Aluminum (Al)	µg/L	15 (pH 4.5-5.5, clay free samples) 75 (pH 6.5-9.0, clay free samples)	100 (pH ≥6.5)		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Antimony (Sb)	µg/L	20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Arsenic (As)	µg/L	100		5	25	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Barium (Ba)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Beryllium (Be)	µg/L	11 ($CaCO_3$<75 mg/L); 1100 ($CaCO_3$>75 mg/L)	-	-	100	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Bismuth (Bi)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Boron (B)	µg/L	200	29000	1500	5000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Cadmium (Cd)	µg/L	0.2	a	a	80	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Chromium (Cr)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Cobalt (Co)	µg/L	0.9	-	-	1000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Copper (Cu)	µg/L	5	-	a	500-5000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Iron (Fe)	µg/L	300	-	300	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Lead (Pb)	µg/L	5 ($CaCO_3$<20 mg/L) 10 ($CaCO_3$=20-40 mg/L) 20 ($CaCO_3$ 40-80 mg/L) 25 ($CaCO_3$ >80 mg/L)	-	a	100	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Lithium (Li)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Manganese (Mn)	µg/L	-	b	b	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mercury (Hg), filtered sample	µg/L	0.2 (filtered sample)	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Molybdenum (Mo)	µg/L	40		73	500	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Nickel (Ni)	µg/L	25		65.8[a]	1000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Selenium (Se)	µg/L	100	-	1	50	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Silicon (Si)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Silver (Ag)	µg/L	0.1	-	0.25	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Strontium (Sr)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Thallium (Tl)	µg/L	0.3	-	0.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Tin (Sn)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Titanium (Ti)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Uranium (U)	µg/L	5	33	15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Vanadium (V)	µg/L	6	-	-	100	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Zinc (Zn)	µg/L	30	c	c	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Zirconium (Zr)	µg/L	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Sulphur (S)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

ID	Source	Conditions
a - calculated, specific to sampling event	CCME	used [$CaCO_3$] in CCME calculator to determin CWQG; available at: https://www.ccme.ca/en/current-activities/canadian-environmental-quality-guidelines
b - total manganese, calculated specific to sampling event	CCME	used CCME excel spreadsheet (available at: https://www.ccme.ca/en/current-activities/canadian-environmental-quality-guidelines) to calculate for each reported lab result
c - total zinc, calculated specific to sampling event	CCME 2018	acute: If hardness is 13.8>150.5 mg/L and dissolved organic carbon is 0.3>17.3 mg/L, use: (exp(0.833[ln(hardness)] + 0.240[ln(DOC)] + 0.526); chronic: If hardness is 23.4>399 mg/L, pH is 6.5>8.13 and dissolved organic carbon is 0.3>22.9 mg/L, use: (exp(0.947[ln(hardness)] – 0.815[pH] + 0.398[ln(DOC)] + 4.625)
RDL - reportable detection limit		
<RDL - result below RDL		
- no results available		
** Not included in min/max/mean calculations, represents average of 4 events as presented in AECOM (2009)		

Bold values exceed the Provincial Water Quality Objective

Appendix B Table 1: Fairy Lake Water Quality Data, 2021-2022

		Provincial Water Quality Objective (PWQO)	Canadian Council of Ministers of Environment (CCME)			WQ4 - Stormwater Inlet at Tyler Avenue						WQ5 - Prospect Park Beach							WQ6 - Fairy Lake Dam Outlet						
Parameter	Unit	Aquatic Life	Aquatic Life		Livestock Health	2008 (AECOM)**	2021-09-22	2022-02-17	Min	Max	Mean	2008 (AECOM)**	2021-08-03	2021-09-22	2022-04-20	Min	Max	Mean	2008 (AECOM)**	2021-08-03	2021-09-22	2022-02-17	Min	Max	Mean
			Acute	Chronic																					
Field Measured																									
Field Water Temperature	°C	-	-	-	-	-	16.8	0.4	0.4	16.8	8.6		22.5	20.3	7.6	7.6	22.5	16.8	-	23.7	20.4	2.3	2.3	23.7	15.5
Field Dissolved Oxygen	mg/L	>4.0	>5.5		-	-	8.03	13.69	8.03	13.69	10.86		6.95	7.82	11.65	6.95	11.65	8.81	-	7.62	8.47	7.56	7.56	8.47	7.88
Field Specific Conductivity	µS/cm	-	-	-	-	1.242	0.436	0.491	0.436	0.491	0.464	0.521	0.643	0.626	0.791	0.626	0.791	0.687	0.519	0.645	0.627	0.779	0.627	0.779	0.684
Field pH		6.5-8.5	-	6.5-9.0	-	8.30	7.92	8.14	7.92	8.14	8.03	8.40	8.02	8.05	7.99	7.99	8.05	8.02	8.40	8.18	8.12	7.60	7.60	8.18	7.97
General Chemistry																									
Total Ammonia-N	mg/L	-	-	-	-	0.05$^{(<RDL)}$	0.06	0.26	0.06	0.26	0.16	0.05$^{(<RDL)}$	0.04	0.03	0.06	0.03	0.06	0.04	0.05$^{(<RDL)}$	0.05	0.03	0.18	0.03	0.18	0.09
Total Carbonaceous BOD	mg/L	-	-	-	-	8	2$^{(<RDL)}$	3	<RDL	3	<RDL	3	2$^{(<RDL)}$	2$^{(<RDL)}$	2$^{(<RDL)}$	<RDL	<RDL	<RDL	3	2$^{(<RDL)}$	2$^{(<RDL)}$	2$^{(<RDL)}$	<RDL	<RDL	<RDL
Total Dissolved Solids	mg/L	-	-	-	-	805	255	195	195	255	225	339	365	330	350	330	365	348	340	380	345	355	345	380	360
Total Nitrogen (N)	mg/L	-	-	-		2.25	0.82	1.3	0.82	1.30	1.06	1.32	0.52	0.63	0.99	0.52	0.99	0.71	1.22	0.76	0.84	1.3	0.76	1.30	0.97
Dissolved Organic Carbon	mg/L	-	-	-	-	-	5.5	5.1	5.1	5.5	5.3		6.4	5.9	4.2	4.2	6.4	5.5	-	6	6.1	6.2	6.0	6.2	6.1
Orthophosphate (P)	mg/L	-	-	-	-	0.045	0.016	0.057	0.016	0.057	0.037	0.01$^{(<RDL)}$	0.0010$^{(<RDL)}$	0.0014	0.0010$^{(<RDL)}$	<RDL	0.0014	0.0011	0.01$^{(<RDL)}$	0.0026	0.0010$^{(<RDL)}$	0.0026	<RDL	0.0026	0.0021
Dissolved Phosphorus	mg/L	-	-	-	-	0.016	0.02	0.062	0.020	0.062	0.041	0.01	0.006	0.007	0.004	0.004	0.007	0.006	0.008	0.007	0.007	0.006	0.006	0.007	0.007
Total Phosphorus	mg/L	0.020 lakes; 0.030 rivers	-	-	-	0.058	0.052	0.15	0.052	0.150	0.101	0.021	0.013	0.013	0.010	0.010	0.013	0.012	0.019	0.014	0.021	0.019	0.014	0.021	0.018
Total Suspended Solids	mg/L	-	-	-	-	10	14	45	14	45	30	5	2	3	2	2	3	2	2	3	6	2	2	6	4
Total Kjeldahl Nitrogen, calculated	mg/L	-	-	-	-	0.9	0.466	0.83	0.466	0.830	0.648	0.8	0.55	0.624	0.321	0.321	0.624	0.498	0.8	0.55	0.816	0.692	0.550	0.816	0.686
Alkalinity (Total as $CaCO_3$)	mg/L	-	-	-	-	261	120	63	63	120	92	167	160	160	210	160	210	177	167	160	160	240	160	240	187
Dissolved Chloride (Cl-)	mg/L	-	640	120		223	56	100	56	100	78	52	-	-	-	-	-	-	53	-	-	-	-	-	-
Nitrite (N)	mg/L	-	-	0.06	10	0.05	0.0076	0.013	0.0076	0.0130	0.0103	0.02	0.0014	0.0014	0.0078	0.0014	0.0078	0.0035	0.02	0.0011	0.0019	0.012	0.0011	0.0120	0.0050
Nitrate (N)	mg/L	-	124	3.0	-	1.3	0.35	0.47	0.35	0.47	0.41	0.5	0.0044	0.0042	0.66	0.0042	0.6600	0.2229	0.4	0.0033	0.019	0.56	0.0033	0.5600	0.1941
Nitrite + Nitrate (N), calculated	mg/L	-	-	-	100	1.3	0.36	0.48	0.36	0.48	0.42	0.5	0.0058	0.0056	0.67	0.0056	0.6700	0.2271	0.4	0.0044	0.021	0.57	0.0044	0.5700	0.1985
Unionized Ammonia-N, calculated	µg N/L	16.5	16.0			-	1.5	5.5	1.5	5.5	3.5		1.9	1.3	0.9	0.9	1.9	1.4	-	3.6	1.5	0.7	0.7	3.6	2.0
Microbiology																									
Escherichia coli	CFU/100 ml	400 *E.coli* /100 mL (Ministry of Health)	-	-	-		9700	230	230	9700	4965		30	110	10$^{(<RDL)}$	<RDL	110	50		220	150	10$^{(<RDL)}$	<RDL	220	127
Metals																									
Total Aluminum (Al)	µg/L	15 (pH 4.5-5.5, clay free samples) 75 (pH 6.5-9.0, clay free samples)	100 (pH ≥6.5)		-	72	**285**	**987**	285	987	636	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Antimony (Sb)	µg/L	20	-	-	-	0.5$^{(<RDL)}$	0.175	0.272	0.175	0.272	0.224	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Arsenic (As)	µg/L	100		5	25	1	1.57	1.53	1.53	1.57	1.55	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Barium (Ba)	µg/L	-	-	-	-	59	31.7	18.8	18.8	31.70	25.25	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Beryllium (Be)	µg/L	11 ($CaCO_3$<75 mg/L); 1100 ($CaCO_3$>75 mg/L)	-	-	100	0.5$^{(<RDL)}$	0.016	0.065	0.016	0.065	0.041	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Bismuth (Bi)	µg/L	-	-	-	-	1$^{(<RDL)}$	0.013	0.028	0.013	0.028	0.021	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Boron (B)	µg/L	200	29000	1500	5000	30	20	14	14	20	17	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Cadmium (Cd)	µg/L	0.2	a	a	80	0.1$^{(<RDL)}$	0.0229	0.0597	0.0229	0.0597	0.0413	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Chromium (Cr)	µg/L	-	-	-	-	5$^{(<RDL)}$	1.45	2.38	1.45	2.38	1.92	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Cobalt (Co)	µg/L	0.9	-	-	1000	0.5$^{(<RDL)}$	0.195	0.663	0.195	0.663	0.429	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Copper (Cu)	µg/L	5	-	a	500-5000	4	2.97	**10.7**	2.97	10.70	6.84	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Iron (Fe)	µg/L	300	-	300	-	255	**517**	**1610**	517	1610	1064	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Lead (Pb)	µg/L	5 ($CaCO_3$<20 mg/L) 10 ($CaCO_3$=20-40 mg/L) 20 ($CaCO_3$ 40-80 mg/L) 25 ($CaCO_3$ >80 mg/L)	-	a	100	1	0.857	4.5	0.857	4.500	2.679	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Lithium (Li)	µg/L	-	-	-	-	5$^{(<RDL)}$	1.83	2.69	1.83	2.69	2.26	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Manganese (Mn)	µg/L	-	b	b	-	34	49.7	127	49.7	127.0	88.4	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mercury (Hg), filtered sample	µg/L	0.2 (filtered sample)	-	-	3	-	0.10$^{(<RDL)}$	0.10$^{(<RDL)}$	<RDL	<RDL	<RDL	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Molybdenum (Mo)	µg/L	40		73	500	-	0.669	0.658	0.658	0.669	0.664	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Nickel (Ni)	µg/L	25		65.8[a]	1000	1$^{(<RDL)}$	0.72	1.87	0.72	1.87	1.30	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Selenium (Se)	µg/L	100	-	1	50	2$^{(<RDL)}$	0.097	0.107	0.097	0.107	0.102	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Silicon (Si)	µg/L	-	-	-	-	3125	3070	2330	2330	3070	2700	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Silver (Ag)	µg/L	0.1	-	0.25	-	0.1$^{(<RDL)}$	0.010$^{(<RDL)}$	0.011	0.011	0.011	0.011	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Strontium (Sr)	µg/L	-	-	-	-	185	101	88.5	88.5	101.00	94.75	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Thallium (Tl)	µg/L	0.3	-	0.8	-	0	0.0066	0.0167	0.0066	0.0167	0.0117	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Tin (Sn)	µg/L	-	-	-	-	1$^{(<RDL)}$	0.20$^{(<RDL)}$	0.29	<RDL	0.29	<RDL	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Titanium (Ti)	µg/L	-	-	-	-	5$^{(<RDL)}$	8.6	32.2	8.6	32.2	20.4	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Uranium (U)	µg/L	5	33	15	-	1	0.196	0.138	0.138	0.196	0.167	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Vanadium (V)	µg/L	6	-	-	100	1	0.99	2.42	0.99	2.42	1.71	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Zinc (Zn)	µg/L	30	c	c	-	18	**32.9**	**40.1**	32.9	40.1	36.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Zirconium (Zr)	µg/L	4	-	-	-	1$^{(<RDL)}$	0.2	0.39	0.20	0.39	0.30	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Sulphur (S)	µg/L	-	-	-	-	-	6250	3620	3620	6250	4935	-	-	-	-	-	-	-	-	-	-	-	-	-	-

ID	Source	Conditions
a - calculated, specific to sampling event	CCME	used [$CaCO_3$] in CCME calculator to determin CWQG; available at: https://www.ccme.ca/en/current-activities/canadian-environmental-quality-
b - total manganese, calculated specific to sampling event	CCME	used CCME excel spreadsheet (available at: https://www.ccme.ca/en/current-activities/canadian-environmental-quality-guidelines) to calculate for each
c - total zinc, calculated specific to sampling event	CCME 2018	acute: If hardness is 13.8>150.5 mg/L and dissolved organic carbon is 0.3>17.3 mg/L, use: (exp(0.833[ln(hardness)] + 0.240[ln(DOC)] + 0.526); chronic: If
RDL - reportable detection limit		
<RDL - result below RDL		
- no results available		
** Not included in min/max/mean calculations, represents average of 4 events as presented in AECOM (2009)		

Bold values exceed the Provincial Water Quality Objective

Appendix B Table 1: Fairy Lake Water Quality Data, 2021-2022

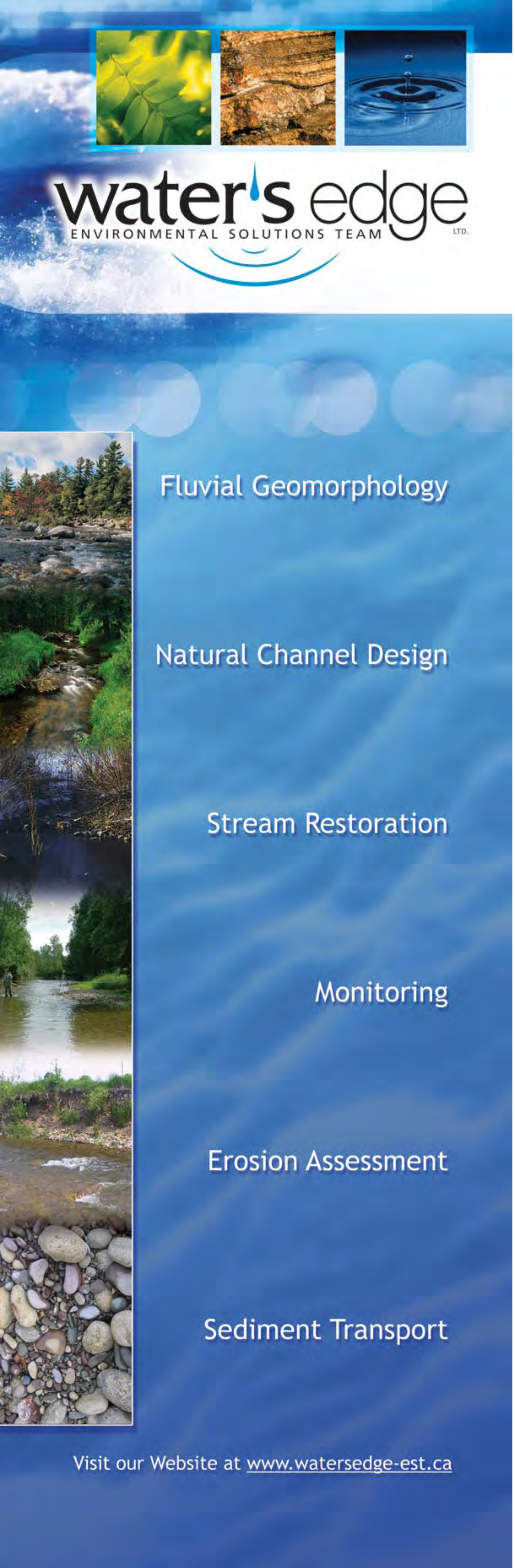
		Provincial Water Quality Objective (PWQO)	Canadian Council of Ministers of Environment (CCME)			WQ7 - Black Creek Inlet							WQ8 - Stormwater Inlet at Elmore Drive						WQ9 - Lake South Basin							
Parameter	Unit	Aquatic Life	Aquatic Life		Livestock Health	2008 (AECOM)**	2021-08-03	2021-09-22	2022-02-17	Min	Max	Mean	2008 (AECOM)**	2021-09-22	2022-02-17	Min	Max	Mean	2008 (AECOM)**	2021-08-03	2021-09-22	2022-01-24	2022-04-20	Min	Max	Mean
			Acute	Chronic																						
Field Measured																										
Field Water Temperature	°C	-	-	-	-	-	16.8	16.3	-0.1	-0.1	16.8	11.0	-	17.0	1.5	1.5	17.0	9.3	-	20.8	19.3	3.1	6.5	3.1	20.8	12.4
Field Dissolved Oxygen	mg/L	>4.0	>5.5		-	-	7.75	8.86	7.56	7.56	8.86	8.06	-	8.78	13.20	8.78	13.20	10.99	-	4.34	2.91	0.60	11.43	0.60	11.43	4.82
Field Specific Conductivity	µS/cm	-	-	-	-	-	0.685	0.468	0.617	0.468	0.685	0.590	-	0.131	0.495	0.131	0.495	0.313	-	0.655	0.639	0.769	0.691	0.639	0.769	0.689
Field pH		6.5-8.5	-	6.5-9.0	-	-	8.07	7.75	7.85	7.75	8.07	7.89	-	8.18	8.03	8.03	8.18	8.11	-	7.57	7.44	7.27	7.88	7.27	7.88	7.54
General Chemistry																										
Total Ammonia-N	mg/L	-	-	-	-	-	0.02	0.02	0.64	0.02	0.64	0.23	-	0.05	0.39	0.05	0.39	0.22	-	0.02	0.03	0.24	0.09	0.02	0.24	0.10
Total Carbonaceous BOD	mg/L	-	-	-	-	-	2(<RDL)	2(<RDL)	3	<RDL	3	2	-	2(<RDL)	3	<RDL	3	3	-	2(<RDL)	2(<RDL)	2(<RDL)	2(<RDL)	<RDL	<RDL	<RDL
Total Dissolved Solids	mg/L	-	-	-	-	-	350	280	295	280	350	308	-	95	170	95	170	133	-	380	365	415	330	330	415	373
Total Nitrogen (N)	mg/L	-	-	-		-	0.59	0.74	1.9	0.59	1.90	1.08	-	0.78	2	0.78	2.00	1.39	-	0.51	0.64	0.99	0.64	0.51	0.99	0.70
Dissolved Organic Carbon	mg/L	-	-	-	-	9	6.3	6.1	5.4	5.4	6.3	5.9	2	1.3	3.7	1.3	3.7	2.5	9	6.8	7.3	8	4.7	4.7	8.0	6.7
Orthophosphate (P)	mg/L	-	-	-	-	-	0.0018	0.035	0.033	0.0018	0.0350	0.0233	-	0.024	0.12	0.024	0.120	0.072	-	0.0012	0.0017	0.0013	0.0010(<RDL)	<RDL	0.0017	0.0013
Dissolved Phosphorus	mg/L	-	-	-	-	-	0.007	0.038	0.037	0.007	0.038	0.027	-	0.025	0.1	0.025	0.100	0.063	-	0.007	0.009	0.009	0.005	0.005	0.009	0.008
Total Phosphorus	mg/L	0.020 lakes; 0.030 rivers	-	-	-	0.019	0.02	0.086	0.093	0.020	0.093	0.066	0.034	0.04	0.19	0.04	0.19	0.12	0.053	0.014	0.017	0.023	0.012	0.012	0.023	0.017
Total Suspended Solids	mg/L	-	-	-	-	4	3	21	25	3	25	16	1(<RDL)	4	32	4	32	18	3	2	2	8	2	2	8	4
Total Kjeldahl Nitrogen, calculated	mg/L	-	-	-	-	0.8	0.56	0.519	1.17	0.519	1.170	0.750	1.6	0.202	1.19	0.202	1.190	0.696	0.8	-	0.635	0.886	0.371	0.371	0.886	0.631
Alkalinity (Total as $CaCO_3$)	mg/L	-	-	-	-	-	170	130	81	81	170	127	-	40	49	40	49	45	-	170	170	270	210	170	270	205
Dissolved Chloride (Cl-)	mg/L	-	640	120		-	95	58	130	58	130	94	-	20	110	20	110	65	-	0.53	-	-	-	0.53	0.53	0.53
Nitrite (N)	mg/L	-	-	0.06	10	-	0.0013	0.0042	0.017	0.0013	0.0170	0.0075	-	0.0056	0.012	0.0056	0.0120	0.0088	-	0.0010(<RDL)	0.0015	0.0083	0.0076	0.0015	0.0083	0.0058
Nitrate (N)	mg/L	-	124	3.0	-	-	0.0057	0.21	0.71	0.0057	0.7100	0.3086	-	0.57	0.76	0.57	0.76	0.67	-	0.0020(<RDL)	0.004	0.096	0.27	0.0040	0.2700	0.1233
Nitrite + Nitrate (N), calculated	mg/L	-	-	-	100	-	0.0070	0.22	0.72	0.0070	0.7200	0.3157	-	0.58	0.77	0.58	0.77	0.68	-	0.0022(<RDL)	0.0055	0.1	0.27	0.0055	0.2700	0.1252
Unionized Ammonia-N, calculated	µg N/L	16.5	16.0			-	0.7	0.3	3.7	0.3	3.7	1.6	-	2.3	3.9	2.3	3.9	3.1	-	0.3	0.3	0.5	0.9	0.3	0.9	0.5
Microbiology																										
Escherichia coli	CFU/100 ml	400 *E.coli* /100 mL (Ministry of Health)	-	-	-	-	10(<RDL)	**5600**	390	390	5600	2995	-	**3900**	**8600**	3900	8600	6250	-	10(<RDL)	30	10(<RDL)	30	30	30	30
Metals																										
Total Aluminum (Al)	µg/L	15 (pH 4.5-5.5, clay free samples) 75 (pH 6.5-9.0, clay free samples)	100 (pH ≥6.5)		-	-	n/a	**906**	**357**	357.0	906.0	631.5	-	76.5	**521**	76.5	521.0	298.8	-	-	-	-	-	-	-	-
Total Antimony (Sb)	µg/L	20	-	-	-	-	n/a	0.218	0.261	0.218	0.261	0.240	-	0.07	0.296	0.070	0.296	0.183	-	-	-	-	-	-	-	-
Total Arsenic (As)	µg/L	100		5	25	-	n/a	1.03	1.39	1.03	1.39	1.21	-	0.144	1.47	0.144	1.470	0.807	-	-	-	-	-	-	-	-
Total Barium (Ba)	µg/L	-	-	-	-	-	n/a	24	22.7	22.7	24.0	23.4	-	6.28	12	6.28	12.00	9.14	-	-	-	-	-	-	-	-
Total Beryllium (Be)	µg/L	11 ($CaCO_3$<75 mg/L); 1100 ($CaCO_3$>75 mg/L)	-	-	100	-	n/a	0.049	0.019	<RDL	0.049	<RDL	-	0.010(<RDL)	0.033	<RDL	0.033	<RDL	-	-	-	-	-	-	-	-
Total Bismuth (Bi)	µg/L	-	-	-	-	-	n/a	0.010(<RDL)	0.076	<RDL	0.076	<RDL	-	0.010(<RDL)	0.037	<RDL	0.037	<RDL	-	-	-	-	-	-	-	-
Total Boron (B)	µg/L	200	29000	1500	5000	-	n/a	44	12	12	44	28	-	10(<RDL)	10(<RDL)	<RDL	<RDL	<RDL	-	-	-	-	-	-	-	-
Total Cadmium (Cd)	µg/L	0.2	a	a	80	-	n/a	0.0295	0.0376	<RDL	0.0376	<RDL	-	0.0238	0.0403	0.0238	0.0403	0.0321	-	-	-	-	-	-	-	-
Total Chromium (Cr)	µg/L	-	-	-	-	-	n/a	1.54	2.87	<RDL	2.87	<RDL	-	0.35	3.72	0.35	3.72	2.04	-	-	-	-	-	-	-	-
Total Cobalt (Co)	µg/L	0.9	-	-	1000	-	n/a	0.476	0.317	<RDL	0.476	<RDL	-	0.054	0.509	0.054	0.509	0.282	-	-	-	-	-	-	-	-
Total Copper (Cu)	µg/L	5	-	a	500-5000	-	n/a	**6.24**	4.82	4.82	6.24	5.53	-	1.24	**8.66**	1.24	8.66	4.95	-	-	-	-	-	-	-	-
Total Iron (Fe)	µg/L	300	-	300	-	-	n/a	**1080**	**728**	728	1080	904	-	90.7	**1080**	90.7	1080.0	585.4	-	-	-	-	-	-	-	-
Total Lead (Pb)	µg/L	5 ($CaCO_3$<20 mg/L) 10 ($CaCO_3$=20-40 mg/L) 20 ($CaCO_3$ 40-80 mg/L) 25 ($CaCO_3$ >80 mg/L)	-	a	100	-	n/a	1.56	1.95	<RDL	1.95	<RDL	-	0.318	2.58	0.318	2.580	1.449	-	-	-	-	-	-	-	-
Total Lithium (Li)	µg/L	-	-	-	-	-	n/a	4.77	1.53	1.53	4.77	3.15	-	0.50(<RDL)	1.56	<RDL	1.56	<RDL	-	-	-	-	-	-	-	-
Total Manganese (Mn)	µg/L	-	b	b	-	-	n/a	48.5	84	48.5	84.0	66.3	-	8.49	72.4	8.49	72.40	40.45	-	-	-	-	-	-	-	-
Mercury (Hg), filtered sample	µg/L	0.2 (filtered sample)	-	-	3	-	0.10(<RDL)	0.10(<RDL)	0.10(<RDL)	<RDL	<RDL	<RDL	-	0.10(<RDL)	0.10(<RDL)	<RDL	<RDL	<RDL	-	-	-	-	-	-	-	-
Total Molybdenum (Mo)	µg/L	40		73	500	-	n/a	1.6	0.696	0.696	1.600	1.148	-	0.317	0.375	0.317	0.375	0.346	-	-	-	-	-	-	-	-
Total Nickel (Ni)	µg/L	25		65.8[a]	1000	-	n/a	1.28	1.04	1.04	1.28	1.16	-	0.24	1.26	0.24	1.26	0.75	-	-	-	-	-	-	-	-
Total Selenium (Se)	µg/L	100	-	1	50	-	n/a	0.098	0.114	<RDL	0.114	<RDL	-	0.04(<RDL)	0.095	<RDL	0.095	<RDL	-	-	-	-	-	-	-	-
Total Silicon (Si)	µg/L	-	-	-	-	-	n/a	4700	1700	1700	4700	3200	-	631	1200	631	1200	916	-	-	-	-	-	-	-	-
Total Silver (Ag)	µg/L	0.1	-	0.25	-	-	n/a	0.010(<RDL)	0.010(<RDL)	<RDL	<RDL	<RDL	-	0.010(<RDL)	0.010(<RDL)	<RDL	<RDL	<RDL	-	-	-	-	-	-	-	-
Total Strontium (Sr)	µg/L	-	-	-	-	-	n/a	180	95.3	95.3	180.0	137.7	-	24.6	64.5	24.6	64.5	44.6	-	-	-	-	-	-	-	-
Total Thallium (Tl)	µg/L	0.3	-	0.8	-	-	n/a	0.0125	0.0099	<RDL	0.0125	<RDL	-	0.0025	0.0123	0.0025	0.0123	0.0074	-	-	-	-	-	-	-	-
Total Tin (Sn)	µg/L	-	-	-	-	-	n/a	0.20(<RDL)	0.32	<RDL	0.32	<RDL	-	0.20(<RDL)	0.25	<RDL	0.25	<RDL	-	-	-	-	-	-	-	-
Total Titanium (Ti)	µg/L	-	-	-	-	-	n/a	26.5	13.7	<RDL	26.5	<RDL	-	2.0(<RDL)	16.5	<RDL	16.5	<RDL	-	-	-	-	-	-	-	-
Total Uranium (U)	µg/L	5	33	15	-	-	n/a	0.191	0.205	0.191	0.205	0.198	-	0.0686	0.107	0.0686	0.1070	0.0878	-	-	-	-	-	-	-	-
Total Vanadium (V)	µg/L	6	-	-	100	-	n/a	1.91	1.03	1.03	1.91	1.47	-	0.52	1.52	0.52	1.52	1.02	-	-	-	-	-	-	-	-
Total Zinc (Zn)	µg/L	30	c	c	-	-	n/a	10.8	**218**	10.8	218.0	114.4	-	7.4	**38.7**	7.4	38.7	23.1	-	-	-	-	-	-	-	-
Total Zirconium (Zr)	µg/L	4	-	-	-	-	n/a	0.76	0.29	<RDL	0.76	<RDL	-	0.10(<RDL)	0.47	<RDL	0.47	<RDL	-	-	-	-	-	-	-	-
Total Sulphur (S)	µg/L	-	-	-	-	-	n/a	6490	4220	4220	6490	5355	-	1570	3190	1570	3190	2380	-	-	-	-	-	-	-	-

ID	Source	Conditions
a - calculated, specific to sampling event	CCME	used [$CaCO_3$] in CCME calculator to determin CWQG; available at: https://www.ccme.ca/en/current-activities/canadian-environmental-quality-
b - total manganese, calculated specific to sampling event	CCME	used CCME excel spreadsheet (available at: https://www.ccme.ca/en/current-activities/canadian-environmental-quality-guidelines) to calculate for each
c - total zinc, calculated specific to sampling event	CCME 2018	acute: If hardness is 13.8>150.5 mg/L and dissolved organic carbon is 0.3>17.3 mg/L, use: (exp(0.833[ln(hardness)] + 0.240[ln(DOC)] + 0.526); chronic: If
RDL - reportable detection limit		
<RDL - result below RDL		
- no results available		
** Not included in min/max/mean calculations, represents average of 4 events as presented in AECOM (2009)		

Appendix B Table 1: Fairy Lake Water Quality Data, 2021-2022

		Provincial Water Quality Objective (PWQO)	Canadian Council of Ministers of Environment (CCME)			WQ10 - West Arm Inlet							WQ11 - Lake North Basin			
Parameter	Unit	Aquatic Life	Aquatic Life		Livestock Health	2008 (AECOM)**	2021-08-03	2021-09-22	2022-02-17	Min	Max	Mean	2022-01-24	Min	Max	Mean
			Acute	Chronic												
Field Measured																
Field Water Temperature	°C	-	-	-	-	-	25.2	19.2	0.6	0.6	25.2	15.0	1.8	1.8	1.8	1.8
Field Dissolved Oxygen	mg/L	>4.0	>5.5		-	-	12.11	4.44	2.77	2.77	12.11	6.44	11.81	11.81	11.81	11.81
Field Specific Conductivity	µS/cm	-	-	-	-	-	0.422	0.553	0.795	0.422	0.795	0.590	0.949	0.949	0.949	0.949
Field pH		6.5-8.5	-	6.5-9.0	-	-	8.90	7.73	7.32	7.32	8.90	7.98	7.93	7.93	7.93	7.93
General Chemistry																
Total Ammonia-N	mg/L	-	-	-	-	-	0.03	0.12	0.4	0	0	0	0.05	0.05	0.05	0.05
Total Carbonaceous BOD	mg/L	-	-	-	-	-	2	2[<RDL]	2[<RDL]	<RDL	2	2	2[<RDL]	<RDL	<RDL	<RDL
Total Dissolved Solids	mg/L	-	-	-	-	-	265	310	340	265	340	305	465	465	465	465
Total Nitrogen (N)	mg/L	-	-	-		-	0.91	0.89	1.1	0.89	1.10	0.97	1.7	1.7	1.7	1.7
Dissolved Organic Carbon	mg/L	-	-	-	-	8.5	11	8	7.8	7.8	11.0	8.9	6.2	6.2	6.2	6.2
Orthophosphate (P)	mg/L	-	-	-	-	-	0.0024	0.0013	0.0036	0.0013	0.0036	0.0024	0.0010[<RDL]	<RDL	<RDL	<RDL
Dissolved Phosphorus	mg/L	-	-	-	-	-	0.009	0.01	0.012	0.009	0.012	0.010	0.005	0.005	0.005	0.005
Total Phosphorus	mg/L	0.020 lakes; 0.030 rivers	-	-	-	0.049	0.021	0.03	0.034	0.021	0.034	0.028	0.015	0.015	0.015	0.015
Total Suspended Solids	mg/L	-	-	-	-	2	3	4	3	3	4	3	2	2	2	2
Total Kjeldahl Nitrogen, calculated	mg/L	-	-	-	-	0.6	0.87	0.869	1.06	0.869	1.060	0.933	0.699	0.699	0.699	0.699
Alkalinity (Total as $CaCO_3$)	mg/L	-	-	-	-	-	150	170	280	150	280	200	270	270	270	270
Dissolved Chloride (Cl-)	mg/L	-	640	120		-	45	74	76	45	76	65	-	-	-	-
Nitrite (N)	mg/L	-	-	0.06	10	-	0.0014	0.0016	0.0063	0.0014	0.0063	0.0031	0.0087	0.0087	0.0087	0.0087
Nitrate (N)	mg/L	-	124	3.0	-	-	0.01	0.016	0.023	0.010	0.023	0.016	1	1	1	1
Nitrite + Nitrate (N), calculated	mg/L	-	-	-	100	-	0.011	0.017	0.03	0.011	0.030	0.019	1	1	1	1
Unionized Ammonia-N, calculated	µg N/L	16.5	16.0			-	9.4	2.4	0.7	0.7	9.4	4.2	0.4	0.4	0.4	0.4
Microbiology																
Escherichia coli	CFU/100 ml	400 *E.coli* /100 mL (Ministry of Health)	-	-	-	-	10	**460**	10[<RDL]	<RDL	460	<RDL	10[<RDL]	<RDL	<RDL	<RDL
Metals																
Total Aluminum (Al)	µg/L	15 (pH 4.5-5.5, clay free samples) 75 (pH 6.5-9.0, clay free samples)	100 (pH ≥6.5)		-	-	-	-	-	-	-	-	-	-	-	-
Total Antimony (Sb)	µg/L	20	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Arsenic (As)	µg/L	100		5	25	-	-	-	-	-	-	-	-	-	-	-
Total Barium (Ba)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Beryllium (Be)	µg/L	11 ($CaCO_3$<75 mg/L); 1100 ($CaCO_3$>75 mg/L)	-	-	100	-	-	-	-	-	-	-	-	-	-	-
Total Bismuth (Bi)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Boron (B)	µg/L	200	29000	1500	5000	-	-	-	-	-	-	-	-	-	-	-
Total Cadmium (Cd)	µg/L	0.2	a	a	80	-	-	-	-	-	-	-	-	-	-	-
Total Chromium (Cr)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Cobalt (Co)	µg/L	0.9	-	-	1000	-	-	-	-	-	-	-	-	-	-	-
Total Copper (Cu)	µg/L	5	-	a	500-5000	-	-	-	-	-	-	-	-	-	-	-
Total Iron (Fe)	µg/L	300	-	300	-	-	-	-	-	-	-	-	-	-	-	-
Total Lead (Pb)	µg/L	5 ($CaCO_3$<20 mg/L) 10 ($CaCO_3$=20-40 mg/L) 20 ($CaCO_3$ 40-80 mg/L) 25 ($CaCO_3$ >80 mg/L)	-	a	100	-	-	-	-	-	-	-	-	-	-	-
Total Lithium (Li)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Manganese (Mn)	µg/L	-	b	b	-	-	-	-	-	-	-	-	-	-	-	-
Mercury (Hg), filtered sample	µg/L	0.2 (filtered sample)	-	-	3	-	-	-	-	-	-	-	-	-	-	-
Total Molybdenum (Mo)	µg/L	40		73	500	-	-	-	-	-	-	-	-	-	-	-
Total Nickel (Ni)	µg/L	25		65.8[a]	1000	-	-	-	-	-	-	-	-	-	-	-
Total Selenium (Se)	µg/L	100	-	1	50	-	-	-	-	-	-	-	-	-	-	-
Total Silicon (Si)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Silver (Ag)	µg/L	0.1	-	0.25	-	-	-	-	-	-	-	-	-	-	-	-
Total Strontium (Sr)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Thallium (Tl)	µg/L	0.3	-	0.8	-	-	-	-	-	-	-	-	-	-	-	-
Total Tin (Sn)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Titanium (Ti)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Uranium (U)	µg/L	5	33	15	-	-	-	-	-	-	-	-	-	-	-	-
Total Vanadium (V)	µg/L	6	-	-	100	-	-	-	-	-	-	-	-	-	-	-
Total Zinc (Zn)	µg/L	30	c	c	-	-	-	-	-	-	-	-	-	-	-	-
Total Zirconium (Zr)	µg/L	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Sulphur (S)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

ID	Source	Conditions
a - calculated, specific to sampling event	CCME	used [$CaCO_3$] in CCME calculator to determin CWQG; available at: https://www.ccme.ca/en/current-activities/canadian-environmental-quality-
b - total manganese, calculated specific to sampling event	CCME	used CCME excel spreadsheet (available at: https://www.ccme.ca/en/current-activities/canadian-environmental-quality-guidelines) to calculate for each
c - total zinc, calculated specific to sampling event	CCME 2018	acute: If hardness is 13.8>150.5 mg/L and dissolved organic carbon is 0.3>17.3 mg/L, use: (exp(0.833[ln(hardness)] + 0.240[ln(DOC)] + 0.526); chronic: If
RDL - reportable detection limit		
<RDL - result below RDL		



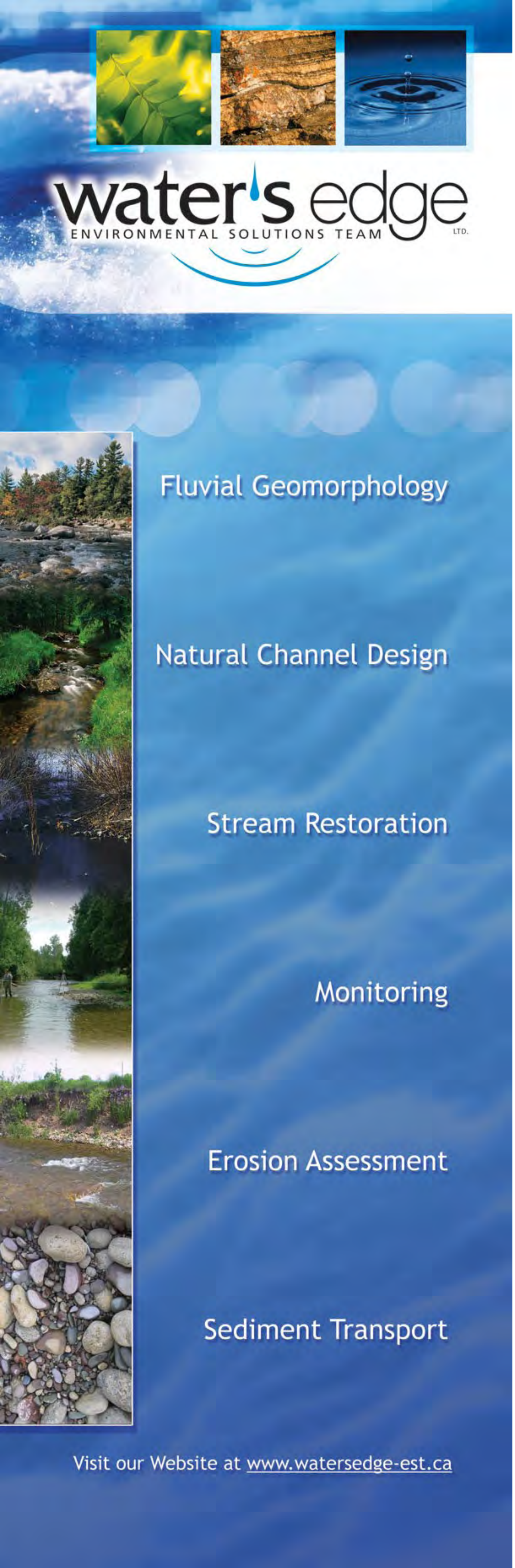
APPENDIX B:

Fairy Lake Land Use Calculations

APPENDIX B: Fairy Lake Land Use

OFAT Watershed ID	Area (m^2)	Land Use	Percent Land Use
8296	1125	Crop Land	0.9%
	11925	Wetland	9.2%
	17325	Forest	13.3%
	20475	Residential	15.8%
	24300	Residential	18.7%
	54450	Low Intensity	41.9%
25912	22950	Low Intensity	1.0%
	85950	Wetland	3.7%
	110925	Residential	4.8%
	229275	Residential	9.9%
	229500	Forest	9.9%
	281025	Hay Pasture	12.1%
	1365975	Crop Land	58.7%
31406	13950	Residential	1.1%
	22950	Low Intensity	1.8%
	50175	Residential	4.0%
	125550	Wetland	9.9%
	131850	Forest	10.4%
	455625	Crop Land	36.0%
	466200	Hay Pasture	36.8%
40749	7650	Residential	0.3%
	49500	Wetland	1.8%
	110025	Forest	4.0%
	175050	Residential	6.3%
	227475	Low Intensity	8.2%
	423900	Hay Pasture	15.3%
	1776600	Crop Land	64.1%
67820	5850	Low Intensity	0.2%
	44325	Residential	1.8%
	166050	Residential	6.7%
	175500	Hay Pasture	7.1%
	452925	Forest	18.2%
	601875	Wetland	24.2%
	1038375	Crop Land	41.8%

OFAT Watershed ID	Area (m^2)	Land Use	Percent Land Use
73159	25425	Open Water	2.6%
	34200	Low Intensity	3.5%
	38475	Hay Pasture	4.0%
	54450	Forest	5.6%
	64125	Crop Land	6.6%
	236700	Residential	24.4%
	244350	Residential	25.2%
	271575	Wetland	28.0%
82944	7425	Hay Pasture	1.04%
	22275	Wetland	3.12%
	47475	Forest	6.66%
	115425	Residential	16.19%
	209025	Residential	29.32%
	311175	Crop Land	43.64%
84289	1350	Low Intensity	0.0%
	9900	Open Water	0.1%
	615825	Residential	6.3%
	1016100	Residential	10.4%
	1066050	Forest	10.9%
	1193850	Hay Pasture	12.2%
	2080350	Wetland	21.2%
	3821175	Crop Land	39.0%



APPENDIX C:

Fairy Lake Curve Numbers

APPENDIX C: Fairy Lake Curve Numbers

Land Use	Hydrologic Soil Group	OFAT Watershed ID	Area	Curve Number	Weighted Curve Number
Crop Land	B	8296	1125	78	0.68
Forest	A	8296	7395	30	1.71
Forest	B	8296	9930	55	4.21
Low Intensity	A	8296	44490	39	13.39
Low Intensity	B	8296	9960	61	4.69
Residential	A	8296	16930	61	7.97
Residential	A	8296	2700	61	1.27
Residential	B	8296	7370	75	4.26
Residential	B	8296	15686	75	9.08
Residential	N	8296	2089	100	1.61
Wetland	B	8296	9447	78	5.69
Wetland	N	8296	2478	100	1.91
				Watershed Curve Number:	56.47

Crop Land	A	25912	1172924	67	33.82
Crop Land	B	25912	185359	78	6.22
Crop Land	N	25912	7693	100	0.33
Forest	A	25912	177275	30	2.29
Forest	B	25912	49342	55	1.17
Forest	N	25912	2882	100	0.12
Hay Pasture	A	25912	228701	30	2.95
Hay Pasture	B	25912	52284	48	1.08
Hay Pasture	N	25912	40	100	0.00
Low Intensity	A	25912	22950	39	0.39
Residential	A	25912	84980	61	2.23
Residential	B	25912	11505	75	0.37
Residential	N	25912	132790	100	5.71
Residential	N	25912	109279	100	4.70
Wetland	A	25912	77952	67	2.25
Wetland	B	25912	7178	78	0.24
Wetland	N	25912	819	100	0.04
				Watershed Curve Number:	63.91

Land Use	Hydrologic Soil Group	OFAT Watershed ID	Area	Curve Number	Weighted Curve Number
Crop Land	A	31406	454456	67	24.05
Crop Land	D	31406	1169	89	0.08
Forest	A	31406	131557	30	3.12
Forest	D	31406	293	77	0.02
Hay Pasture	A	31406	452323	30	10.72
Hay Pasture	D	31406	13877	73	0.80
Low Intensity	A	31406	22950	39	0.71
Residential	A	31406	45900	61	2.21
Residential	N	31406	4275	100	0.34
Residential	N	31406	13571	100	1.07
Wetland	A	31406	61281	67	3.24
Wetland	D	31406	61562	89	4.33
Wetland	N	31406	2707	100	0.21
				Watershed Curve Number:	50.90
Crop Land	A	40749	1754837	67	42.44
Crop Land	B	40749	21763	78	0.61
Forest	A	40749	81298	30	0.88
Forest	B	40749	28727	55	0.57
Hay Pasture	A	40749	407375	30	4.41
Hay Pasture	B	40749	16525	48	0.29
Low Intensity	A	40749	227475	39	3.20
Residential	A	40749	158291	61	3.49
Residential	A	40749	4307	61	0.09
Residential	B	40749	16759	75	0.45
Residential	B	40749	3343	75	0.09
Wetland	A	40749	5071	67	0.12
Wetland	B	40749	44429	78	1.25
				Watershed Curve Number:	57.90
				Calibrated Curve Number:	56.00

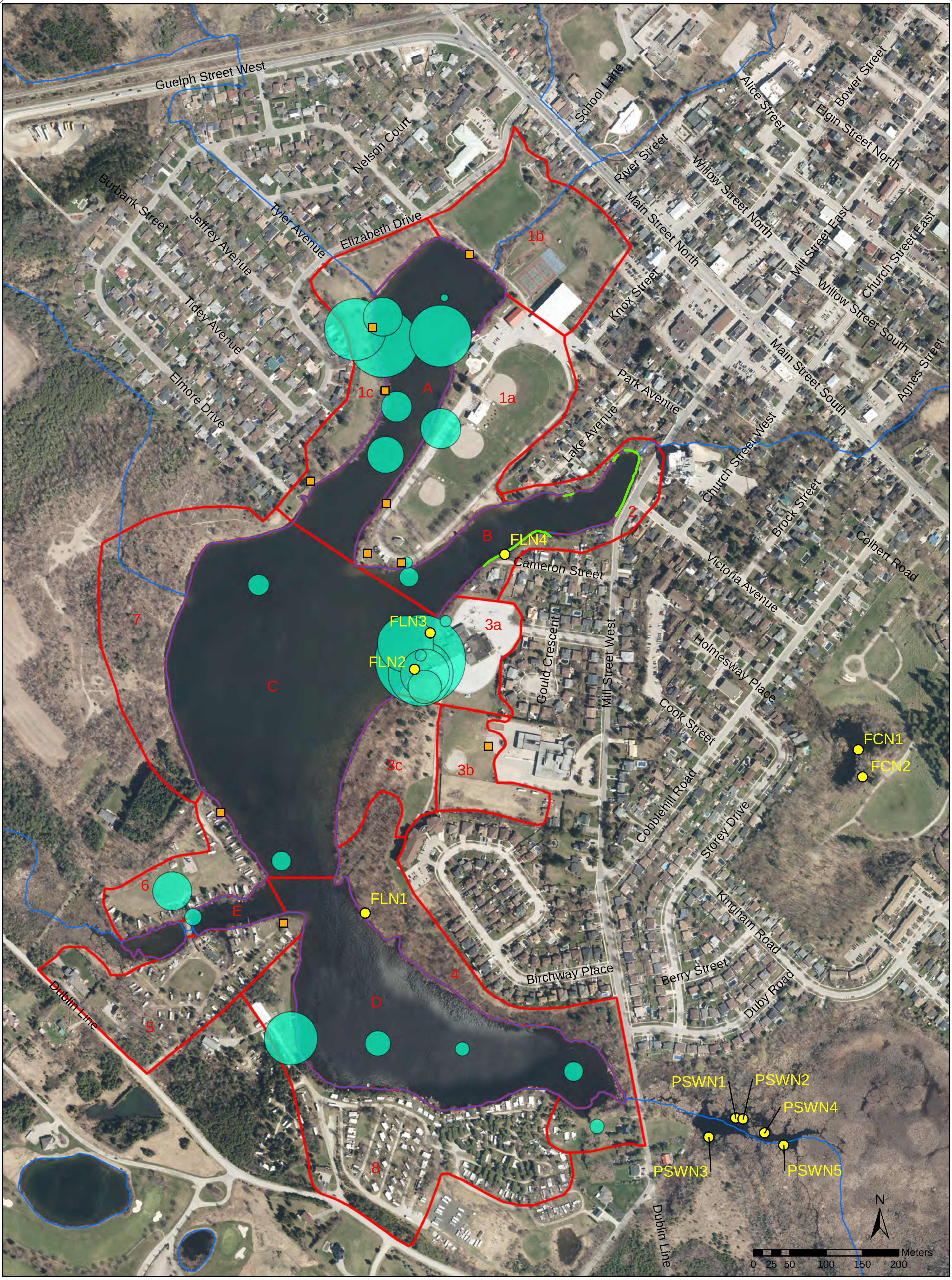
Land Use	Hydrologic Soil Group	OFAT Watershed ID	Area	Curve Number	Weighted Curve Number
Crop Land	A	67820	719566	67	19.40
Crop Land	B	67820	290306	78	9.11
Crop Land	D	67820	28503	89	1.02
Forest	A	67820	174012	30	2.10
Forest	B	67820	240392	55	5.32
Forest	D	67820	35545	77	1.10
Forest	N	67820	2976	100	0.12
Hay Pasture	A	67820	127928	30	1.54
Hay Pasture	B	67820	44429	48	0.86
Hay Pasture	D	67820	3143	73	0.09
Low Intensity	A	67820	5850	39	0.09
Residential	A	67820	73244	61	1.80
Residential	A	67820	9003	61	0.22
Residential	B	67820	44980	75	1.36
Residential	B	67820	29697	75	0.90
Residential	N	67820	47826	100	1.92
Residential	N	67820	5625	100	0.23
Wetland	A	67820	119105	67	3.21
Wetland	B	67820	461906	78	14.50
Wetland	D	67820	19595	89	0.70
Wetland	N	67820	1269	100	0.05
				Watershed Curve Number:	65.65

Land Use	Hydrologic Soil Group	OFAT Watershed ID	Area	Curve Number	Weighted Curve Number
Crop Land	A	73159	24565	67	1.70
Crop Land	B	73159	8348	78	0.67
Crop Land	D	73159	6102	89	0.56
Crop Land	N	73159	25110	100	2.59
Forest	A	73159	29230	30	0.90
Forest	B	73159	13338	55	0.76
Forest	N	73159	11882	100	1.23
Hay Pasture	A	73159	36216	30	1.12
Hay Pasture	B	73159	2259	48	0.11
Low Intensity	A	73159	34200	39	1.38
Open Water	N	73159	25425	100	2.62
Residential	A	73159	27900	61	1.76
Residential	A	73159	28886	61	1.82
Residential	B	73159	7923	75	0.61
Residential	B	73159	30168	75	2.33
Residential	D	73159	16	87	0.00
Residential	D	73159	1242	87	0.11
Residential	N	73159	200862	100	20.72
Residential	N	73159	184054	100	18.99
Wetland	A	73159	15391	67	1.06
Wetland	B	73159	20035	78	1.61
Wetland	D	73159	819	89	0.08
Wetland	N	73159	235329	100	24.28
				Watershed Curve Number:	87.01
				Calibrated Curve Number:	65.65
Crop Land	A	82944	224452	67	21.14
Crop Land	B	82944	1350	78	0.15
Crop Land	N	82944	85373	100	12.00
Forest	A	82944	43343	30	1.83
Forest	B	82944	2107	55	0.16
Forest	N	82944	2025	100	0.28
Hay Pasture	A	82944	249	30	0.01
Hay Pasture	N	82944	7176	100	1.01
Residential	A	82944	4358	61	0.37
Residential	N	82944	204667	100	28.77
Residential	N	82944	114048	100	16.03
Wetland	A	82944	21158	67	1.99
Wetland	N	82944	1117	100	0.16
				Watershed Curve Number:	83.90
				Calibrated Curve Number:	45.00

Land Use	Hydrologic Soil Group	OFAT Watershed ID	Area	Curve Number	Weighted Curve Number
Crop Land	A	84289	1606641	67	10.98
Crop Land	B	84289	1841568	78	14.65
Crop Land	D	84289	281441	89	2.55
Crop Land	N	84289	91525	100	0.93
Forest	A	84289	416584	30	1.27
Forest	B	84289	462210	55	2.59
Forest	D	84289	178549	77	1.40
Forest	N	84289	8707	100	0.09
Hay Pasture	A	84289	692684	30	2.12
Hay Pasture	B	84289	485750	48	2.38
Hay Pasture	D	84289	11009	73	0.08
Hay Pasture	N	84289	4407	100	0.04
Low Intensity	A	84289	1347	39	0.01
Low Intensity	N	84289	3	100	0.00
Open Water	A	84289	1574	100	0.02
Open Water	B	84289	8326	100	0.08
Residential	A	84289	67911	61	0.42
Residential	A	84289	638	61	0.00
Residential	B	84289	65659	75	0.50
Residential	B	84289	1805	75	0.01
Residential	D	84289	34248	87	0.30
Residential	D	84289	0	87	0.00
Residential	N	84289	848283	100	8.65
Residential	N	84289	613382	100	6.26
Wetland	A	84289	810472	67	5.54
Wetland	B	84289	613655	78	4.88
Wetland	D	84289	631073	89	5.73
Wetland	N	84289	25151	100	0.26
				Watershed Curve Number:	71.77
				Calibrated Curve Number:	45

APPENDIX D:

LGL GEESE STUDY



Fairy Lake Water Quality Study

Goose Survey Results

- Nest Location (2022)
- Goose Monitoring Area
- Watercourse (LIO)
- Waterbody (LIO)
- Hardened Shoreline
- Geese Activity - Indirect Evidence (scat, feathers)

Geese Activity - Number of Individuals

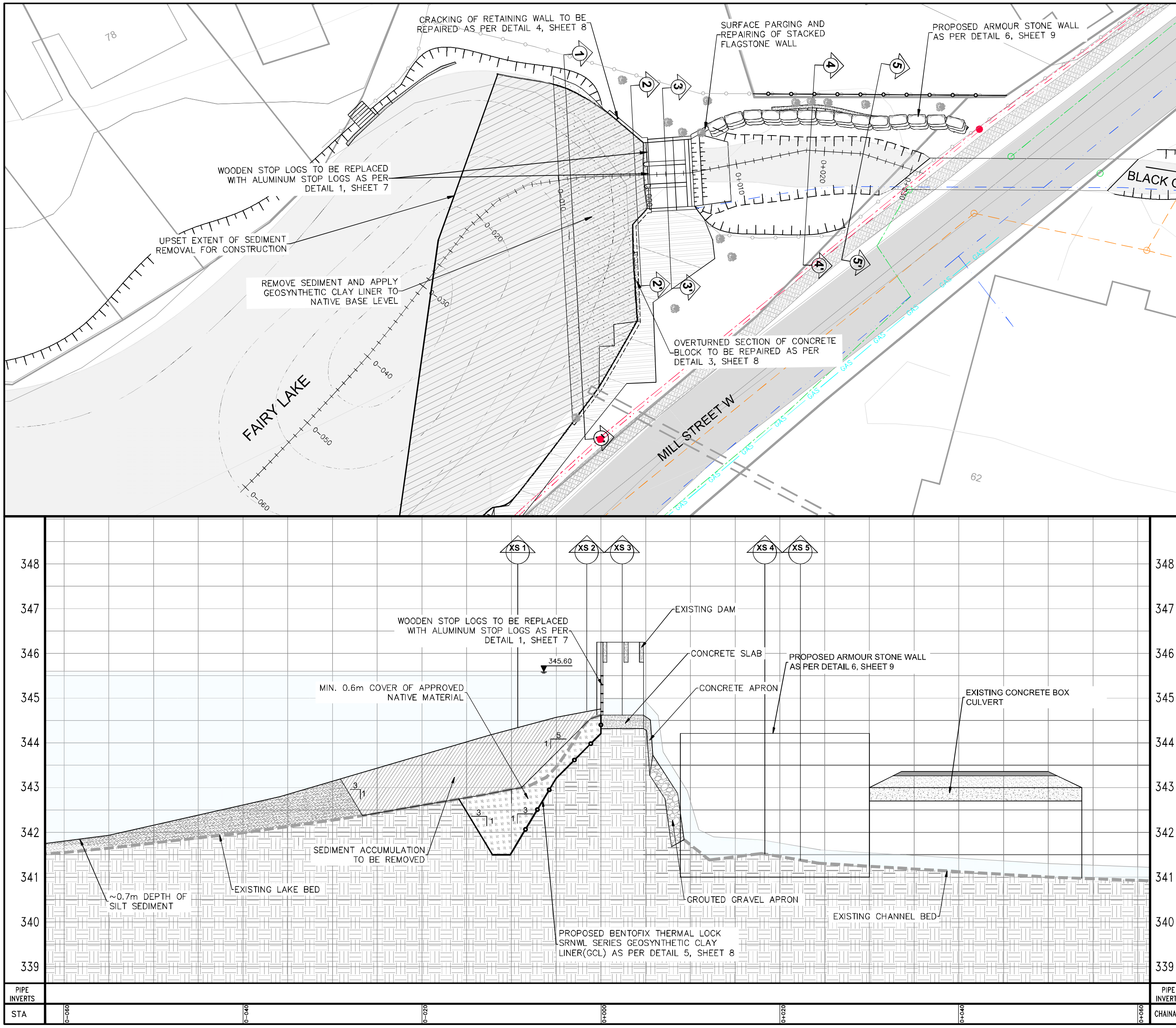
- 1
- 10

LGL LIMITED
Est. 1971
environmental research associates

Project	TA9122	Figure	9
Date	September 2022	Prepared By	KC
Scale	1:5,000	Verified By	LKR

APPENDIX E:

Fairy Lake Dam with Sediment Removal



LEGEND

- TOP OF SLOPE
- TOP OF BANK
- EXISTING CONTOUR
- PROPERTY LINE
- EXISTING TREES
- EXISTING TC LINE
- EXISTING FENCING/RAILING
- EXISTING SANITARY SEWER
- EXISTING STORM SEWER
- EXISTING WATERMAIN
- EXISTING SANITARY MANHOLE
- EXISTING STORM MANHOLE
- EXISTING HYDRO LINE
- EXISTING UNION GAS LINE
- EXISTING HYDRO POLE

NOTICE TO CONTRACTORS

48 HRS PRIOR TO COMMENCING WORK NOTIFY THE FOLLOWING

THE REGIONAL MUNICIPALITY OF HALTON PUBLIC WORKS DEPT.
HALTON HILLS HYDRO
UNION GAS COMPANY
THE TOWN OF HALTON HILLS ENGINEERING DEPT.
COGECO CABLE SYSTEMS
BELL TELEPHONE COMPANY

NO.	DATE	BY.	REVISIONS
6	28/07/20	RA/OC	ISSUED FOR CONSTRUCTION
5	25/03/20	RA/OC	REISSUED FOR CVC PERMIT
4	18/02/20	RA/OC	ISSUED FOR TENDER
3	29/05/19	RA/OC	ISSUED FOR CVC PERMIT
2	22/04/19	RA/OC	90% DESIGN FOR REVIEW
1	06/02/19	RA/OC	FOR MNRF-LRIA SCOPING

DESIGN	R.A	CHECKED	R.A	SCALE
DRAWN	O.C	CHECKED	R.A	HORIZ.– 1:200 VERT.– 1:40
DATE DRAWN	2020.07.28			

APPROVALS

MUNICIPAL — Signed ______ Dated ______ Transportation and Public Works — STAMP

REGIONAL — STAMP: R.A.AMOS, JUL.28.2020, REGISTERED PROFESSIONAL ENGINEER, PROVINCE OF ONTARIO

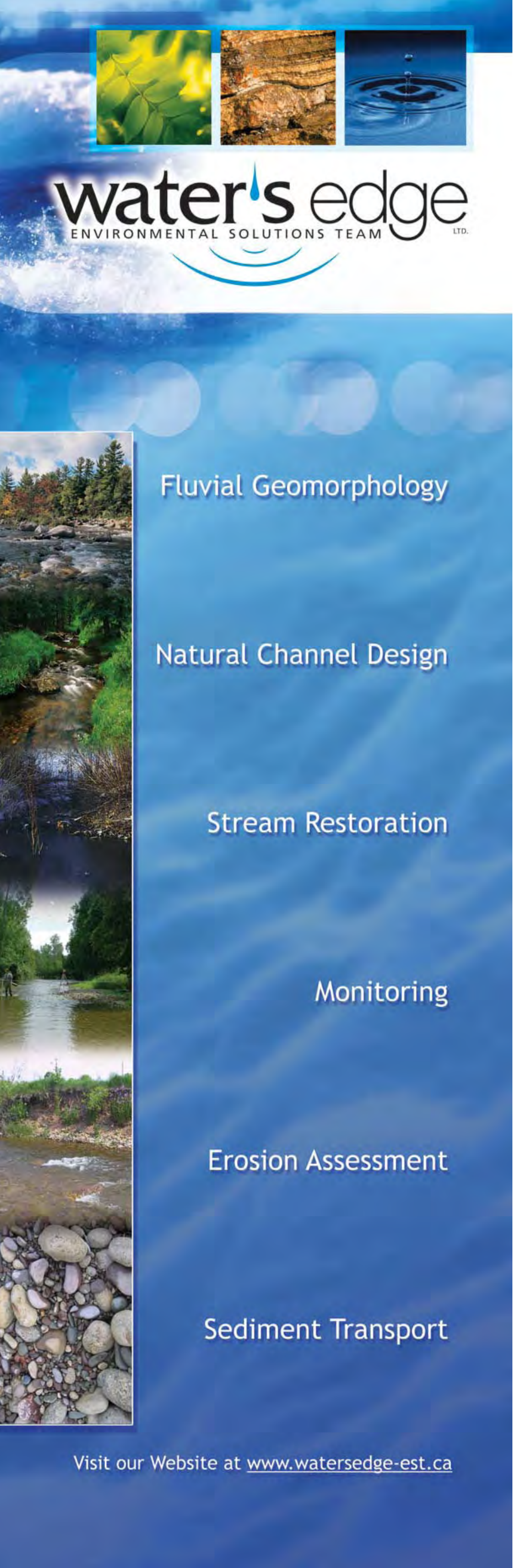
CONSULTANT: Aquafor Beech Limited

MUNICIPALITY: TOWN OF HALTON HILLS — TRANSPORTATION AND PUBLIC WORKS

TITLE: PLAN AND PROFILE
FAIRY LAKE DAM REPAIR AND LEAKAGE MITIGATION

MUNICIPAL DRAWING NO. | REGIONAL DRAWING NO.

CONTRACT NO. T–003–20 | SHEET 3 OF 13



APPENDIX F:

BMP Examination and Decision Process

Table C Scoring of the BMPs

	Effectiveness		Distribution		Maintenance		Cost		Timeline		Total
BMPs:	Wgt (%)	Efct.	Wgt (%)	Efct	Wgt (%)	Efct.	Wgt (%)	Efct	Wgt (%)	Efct	
Agricultural Tile Drainage	40	0.7	25	1.0	20	0.6	10	0.5	5	0.25	0.71
Oil Grit Separator	40	0.4	25	0.4	20	0.1	10	0.3	5	0.2	0.32
Natural Channel Design	40	0.7	25	0.2	20	0.8	10	0.3	5	0.3	0.54
Fairy Lake maintenance	40	0.6	25	1.0	20	0.1	10	0.3	5	0.1	0.55
Wetland Design	40	0.8	25	0.2	20	0.7	10	0.6	5	0.8	0.61
Advanced Monitoring Program	40	1.0	25	1.0	20	0.8	10	0.9	5	1.0	0.95

Table D BMP Ranking and Designations

BMPs	Scoring	Land Use Most Appropriate	Watersheds Most Applicable
Agricultural Tile Drainage	0.713	Crop Land	WQ1, WQ4, WQ7
Oil Grit Separator	0.32	Residential	WQ2, WQ5
Natural Channel Design	0.535	Specific	WQ7
Fairy Lake Maintenance	0.545	Open Water	WQ5
Wetland Design	0.61	Residential	WQ7, WQ4
Advanced Monitoring Program	0.95	All	WQ1, WQ2, WQ3, WQ4, WQ5, WQ7, WQ10,

A Decision Process

The process for deciding what BMPs to implement where is explained below.

B Objectives

Water's Edge determined five objectives when considering BMPs. These were examined rationally and will be briefly described below. The ability for a BMP to meet an objective will determine whether it meets the needs for the Fairy Lake Watershed. It is possible that stakeholders would have other objectives that could in the future be added to this analysis to weigh alternatives.

Effectiveness

- This is based on the ability of a BMP to eliminate Phosphorus from entering Fairy Lake. This would be weighing each alternative on the efficiency of installing this BMP compared to not. Some BMPs collect Phosphorus to be discarded, where others help prevent runoff. Thus, the BMPs are not completely comparable in this regard. It is important however to ensure that any recommended BMP is effective in the Fairy Lake setting so that is why this criteria is included.

Distribution:

- Each catchment has a different amount and potential source for phosphorus in the watershed. If one BMP is effective for a particular land use, but that land use is only represented in one catchment, then it may not be the most important BMP to focus on. The greater the number of catchments suited to the BMP, the higher the rating.

Low Maintenance Required

- If a BMP only has start-up costs than it would be rated higher than a long-term project that would require ongoing maintenance. This would prevent the Town of Halton Hills from having to implement new maintenance programs.

Cost:

- This criterion is basic and generalized. It ranks availability to funds. True costing would have to be done in a separate study. If private land is needed, then the scoring is lower. If known grants are already available, then scoring is higher. If the allocation of funding is unknown, then the rating would be in the middle. If able to be funded by a CA or Municipality rather than relying on Provincial or Federal Grants that currently are not designated, then the rating is higher.

Timeline Scoring:

- The shorter the time to implement, the higher the rating. This criteria focuses on the installation/start up of the BMP alone, and excludes consideration for permits/approvals or other factors.

C Weighting the Objectives.

All the objectives are important, but they are not equal. In order to evaluate the BMPs fairly, the weighting of objectives was done below from a rationality method using a Pairwise Comparison Chart. Each objective is compared with each other. If the row objective is more important than the column objective it gets a 1, if it is equally important it receives a 0.5 and if it is less important it gets a 0 designation. The rows are tallied in **Table A** below and then given a percentage weight based of that seen in **Table A.**

Table A: Pairwise Comparison of Objectives

	Timeline	Cost	Effectiveness	Distribution	Maintenance	Total
Timeline		0	0	0.5	0	0.5
Cost	1		0	0	0	1
Effectiveness	1	1		1	1	4

Distribution	0.5	1	0		1	2.5
Maintenance	1	1	0	0		2

Table B: Weights

Rank	Objective	Weight Rating of Metric
1	Effectiveness	40%
2	Distribution	25%
3	Maintenance	20%
4	Cost	10%
5	Timeline	5%

D BMPs:

Waters' Edge has determined six BMPs that are to be considered for the implementation into the Fairy Lake watershed. Each one is discussed in how it fits the objectives.

Advanced Monitoring Program

Effectiveness: Good data, will help make sound decisions to accurately implement the right program, to create actual results.

Timeline: Low time to implement. Program length would be long term even after other BMPs have been implemented, to determine effectiveness.

Cost: Would be funded by municipality funded or by the CA. Data loggers, technicians, and data management would be apart of the costing.

Maintenance: Site visits would be required.

Distribution: This can be implanted in all the inlets of Fairy Lake, and at significant points in the watershed.

Agricultural Tile Drainage

Effectiveness: Agricultural practices include the application of manure as well as fertilizers to arable lands. To minimize the runoff of nutrients from these landscapes, landowners should be encouraged to implement BMPs on agricultural lands. By providing new or improving existing education, incentives, or tools, famers could alter their land to minimize agricultural runoff, especially during extreme events. This could minimize the loading into the contributing stream systems. Phosphorus is directly linked to runoff. If tile drainage drains water into the soil effectively instead of into the streams, this will prevent phosphorus from running into the rivers.

Timeline: Long term implementation will be created. This can be implemented with one field at a time. This BMP is labor and material intensive.

Cost:

- Loans to farmers: OMAFRA
- Grants: NOHFC

- Initial expensive cost: $1000/acre

Maintenance: Low maintenance is involved. Once installed, these are permanent structures that do not have any moving parts.

Distribution: Can be implemented in key locations (near creeks), can be implemented in all catchments that have crop land. Encourage farmers to choose their own methods (i.e. winter cover crops, buffer strips around fields, sediment ponds, terrace farming are additional methods used to mitigate agricultural runoff). Education for farmers on need to reduce runoff on farms is important as they must want to buy into the idea and see the benefits for their own properties.

Oil Grit Separator

Effectiveness: Though, this has not been seen to be successful currently in the Town of Halton hills, there are multiple studies showings that OGS can be effective. However, OGS can only filter so much water at a time; during peak flows of storms, water is often diverted which would miss large amounts of Phosphorus. These units if placed in key locations around inputs into Fairy Lake, will operate 24/7 to remove phosphorus.

Timeline: This must be installed properly and at the right locations. If municipal workers are installing it, they must be trained in how to properly install. This BMP can be installed incrementally throughout the watershed.

Cost: Low relative unit costs. Not any known grants or funding for OGS. Would be funded by Municipality. Maintenance costs would be taken on by municipality.

Maintenance: Maintenance would be needed to clean out and dispose of the sediment in OGS. As OGS are already in place there would be maintenance program existing that could be expanded.

Distribution: The Town of Acton has put in place a small number of BMPs (e.g., oil-grit separators) to reduce the water quality impact of storm sewers from certain suburban neighborhoods. These measures should be expanded, especially to the areas which have outfalls directly into the lake rather than a tributary. Effectively controlling the runoff quality from residential areas is important since it has the highest phosphorus export per land use area out of the land uses in the watershed. There are multiple municipal inputs into Fairy Lake, i.e. Tyler Ave. outfall. OGS could be installed as a part of this outfall.

Natural Channel Design

Effectiveness: Rivers and stream can naturally improve water quality though natural stream functions of uptake and processing. The process of Natural Channel Design (NCD) has the potential to provide significant denitrification. While many river restorations do not include the use of a hyporheic zone for water quality improvements, natural rivers have hyporheic zones where subsurface zones mix with the groundwater. This zone acts to provide biotic life to the river by housing food sources, microorganisms, crustaceans, and bugs. This zone can also help to moderate the temperature in the river throughout the seasons. As watercourses and watersheds have become urbanized; processes such as erosion, increased sedimentation, and aggregation can alter the bed of the river. The hyporheic zone can then be cut off from the river or the intermixing from it can be reduced. As a result, there are fewer chemical reactions, and the pollutants remain intact in their initial form. Restoring watercourses in the Fairy Lake Watershed with Natural Channel Design should consider restoring the hyporheic zone as well.

Timeline: This would require permits and construction during specific times periods. NCD is a relatively quick process to implement.

Cost: This option is not seen to be the most expensive option. It is presumed that this would be Conservation Authority/Municipally Funded. Disposal of existing concrete would be a significant cost in the project.

Maintenance: Low maintenance costs are expected as this is revitalizing a reach of river and NCD rivers rarely require maintenance cost when functioning as designed.

Distribution: Natural channel designs can then be proposed for key locations and should include natural channel design components such as constructed riffles, increased meandering, J-hook and cross vanes, root wads, and toe wood structures. These structures can be used to encourage movement into the hyporheic zone where biochemical reactions can be activated and increase the lag time of pollutants into Fairy Lake. designs should be supported by groundwater studies which would determine the effects of well water on the hyporheic zones. At this time, it is noted that there is a concrete channel on Black Creek between Division St. and McDonald Blvd. There are no ground water studies associated with this reach for this purpose at this time.

This BMP is recommended to be implemented in whole reaches at a time in order to be working efficiently.

Fairy Lake Maintenance

Effectiveness: The Fairy Lake Dam Repair and Leakage Mitigation in The Town of Halton Hills (Acton) report shows that there was significant sediment accumulation at the dam (See APPENDIX E). The removal of this sediment would have decreased phosphorus concentrations in the lake as well as downstream of the outlet. Further sedimentation samples could be collected at key points in the lake. This could be used to estimate the quantity of phosphorus in the bed of the lake. A Benefit-Cost Analysis could be calculated for this sediment removal. As this is an artificially created lake, it will have to be managed and maintained to provide optimal health for the lake and to encourage recreational uses to the community. It is recommended to consult key stakeholders if this is pursued.

Flushing of the lake could also dilute the phosphorus levels in the lake. Though the inputs into Fairy Lake, have high levels of phosphorus, if a quantity of the lake is flushed, then their will not be as much build up of phosphorus.

Timeline: The time to implement sediment sample most likely would happen during open water months.

Cost: Depending on the_on how much or often the maintenance is completed, would determine the cost. It is estimated that if large scale dredging was completed, then there would be high costs, but would then no longer have to be spent on a regular basis.

Flushing of the lake is estimated to not have a high cost assuming that it can be done through the existing dam or bypass pipeline.

This would be funded by the CA, Municipality, and possibly other stakeholders.

Sediment samples are needed (low costs)

Maintenance: This BMP is a maintenance item. Depending on the effectiveness of this, it would not have to happen regularly (i.e. every 15 years). In this study, it is estimated that it would have to occur more than once, so it was rated lower. As sediment has already been removed from the dam, it shows that there is a need to complete maintenance on the lake. This should be continued.

Distribution: This is impacted by all catchments. Instead of adjusting phosphorus at the source, this is trying to dilute it at the sink. This method prescribes that instead of the watershed being the problem, the lakes ability to deal with phosphorus is the problem.
Sediment samples around the lake would identify which areas of sediment have the most phosphorus. This would help know which areas would need to be dredged

Wetland Design

Effectiveness: Wetlands are natures way of filtering water. Studies have been completed showing that wetlands are more affordable than removing, phosphorus, or from treating it (Land, 2016). Currently there is a Provincially Significant Wetland on the southeast corner of Fairy Lake. In addition, there is wetland around WQ10. The success of reducing phosphorus in the existing wetlands could be calculated by having multiple monitoring spots of the inlets.

Timeline: These could be implemented relatively quickly but would require permits.

Cost: There is a low relative cost estimated for this BMP. This would be funded by the CA or Municipality.

Maintenance: Little to no maintenance is estimated for this BMP, however further geese deterrents may be required if more nesting grounds are created.

Distribution: Two inlets have been identified as possible locations of implementation. This is a small location in the whole watershed to have impact. Additionally micro wetlands could be designed at other inlets into Fairy Lake for instance (Tyler Ave, outfall, or Black Creek outlet). Currently these outlets just have manicured outlets that have straight channels into Fairy Lake. It is possible that these could be engineered to act as a wetland while still allowing flow and preventing backwater in the inlets. Land's study estimated that 10g/(m^2year) of Phosphorus could be removed from a watershed (Land, 2016). For Tyler Ave. that would need to be 1700m^2 of wetland to eliminate 17kg/year. Rotary Park was estimated at approximately 6900m^2. Black Creek would need 5510m^2 to hypothetically remove all the annual phosphorus that runs into Fairy Lake.

If two wetlands were designed, it would not completely eliminate phosphorus, but would be a relatively affordable method that requires little maintenance.

E Weighing the BMPS

As per **Table C**, effectiveness ratings (Efct.) based on the descriptions of the BMPs and how they meet their objectives above were given to each BMP. The scale of 0-1 was given. If the BMP met the objective, it would receive a '1.0'. If the BMP did not, then it would receive '0'. These ratings were based on reasonable judgment. Effectiveness ratings were multiplied by the weights of each objective from **Table A**. The total of each row shows which BMPs are believed to be the most appropriate to be used for the improvement to Fairy Lake.

Table D shows the scoring of each BMP and recommendation of which subwatersheds the BMPs would be applied to.

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