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Environmental Sciences Ltd.

Jp2g Consultants Inc.

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Stormwater Assessment, Planning and Implementation of the Cobden Agriculture Area

Final Report

Prepared for: Township of Whitewater Region
Job #: J210005

March 18, 2022

March 18, 2022 HESL Job #: J210005

Ivan Burton
Planner/Economic Development Officer
Township of Whitewater Region
44 Main Street, P.O. Box 40
Cobden, ON K0J 1K0

Dear Mr. Burton:

Re: Stormwater Assessment, Planning and Implementation of the Cobden Agriculture Area – Background Review

The goal of this project is to characterize existing stormwater quality and stormwater management in Cobden's agricultural area and recommend mitigation measures to reduce nutrient loading to Provincially Significant Wetlands (PSWs) and Muskrat Lake. A background review was completed which included preliminary consultation with the agricultural community and environmental partners, characterization of existing stormwater management, identification of source areas of nutrient loss, evaluation of Cobden and Snake River Provincially Significant Wetland functions in relation to stormwater management (SWM), and identification of priority areas for management.

A variety of Best Management Practices (BMPs) were identified which could be utilized in the priority areas to reduce nutrient loading. Consultation was undertaken through a virtual public meeting and one-on-one interviews to determine which BMPs would be appropriate based on an evaluation of site conditions and feedback from local farmers and landowners. Priority areas were subsequently refined based on consultation and BMPs were shortlisted for future implementation. Descriptions of shortlisted BMPs and related nutrient reduction efficiencies associated with each refined priority area were developed to inform future implementation.

A series of recommendations were developed as outlined in an Action Plan that are intended to help implement BMPs that have been identified, apply a similar methodology and study to other jurisdictions in the Muskrat Lake Watershed, and investigate other means of reducing nutrient concentrations in Muskrat Lake.

Sincerely,
Per. Hutchinson Environmental Sciences Ltd.

Brent Parsons, M.Sc.
Principal and Senior Aquatic Scientist

Signatures

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Executive Summary

The goal of this project is to characterize existing stormwater quality and stormwater management in Cobden's agricultural area and local Provincially Significant Wetlands (PSWs), recommend and implement mitigation measures to reduce nutrient loading to PSWs and Muskrat Lake, develop information sharing amongst local and regional groups and residents, and develop lasting partnerships between the agricultural sector and regional organizations to help improve water quality in Muskrat Lake and the PSWs in both the short and long-term. The Muskrat Lake watershed encompasses several different municipalities but the study area and focus for this project has been defined as the Township of Whitewater Region (Figure 1).

The Muskrat Lake watershed has been very well studied in terms of water quality and land use, so a thorough background review was completed to set the stage for subsequent project tasks. The background was completed following five specific tasks:

1. Preliminary consultation with the agricultural community and environmental partners;
2. Characterization of existing stormwater management;
3. Identification of source areas of nutrient loss;
4. Evaluation of Cobden and Snake River Provincially Significant Wetland functions in relation to stormwater management (SWM); and
5. Preliminary identification of priority areas for management.

Nutrients in watercourses were similar or slightly higher than other agricultural-dominated watersheds in Ontario. Median TP and TN concentrations, as well as TP and TN loads/ha were all highest at SC-02 which was also the catchment with the highest percentage of agricultural lands and annual crop land within 1 km. The next most nutrient-enriched sites were MKR-03 and SNR-04.

The Cobden and Snake River PSWs both support a wide variety of natural heritage features and functions. The Snake River PSW consistently acts as a nutrient sink with the greatest nutrient retention occurring in the summer and fall. The Cobden PSW acts as a nutrient source but the assessment of TP retention in the Cobden PSW was limited because the downstream water sampling location was located in the middle of the wetland, thereby limiting the spatial assessment.

Three general priority areas were identified based on the results of the first phase of the study: SC-02 Catchment, Previously Flooded Areas and Muskrat Lake Riparian Lands. SC-02 contained the highest nutrient concentrations and loads, flooded areas result in significant nutrient loading to receiving waterbodies and poorly buffered agricultural lands along Muskrat Lake drain directly into the lake without being afforded TP retention in watercourses or wetlands

A variety of BMPs were identified which could be utilized in the priority areas to reduce nutrient loading. Consultation was undertaken through a virtual public meeting and one-on-one interviews to determine which BMPs would be appropriate based on an evaluation of site conditions and feedback from local farmers and landowners. Priority areas were refined based on consultation and BMPs were shortlisted for future implementation. Descriptions of shortlisted BMPs and related nutrient reduction efficiencies associated with each refined priority area were also presented to inform future implementation.

A series of recommendations were developed as outlined in an Action Plan that are intended to help implement BMPs that have been identified, apply a similar methodology and study to other jurisdictions in the Muskrat Lake Watershed, and investigate other means of reducing nutrient concentrations in Muskrat Lake.

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1. Introduction

Muskrat Lake is the drinking water source for the Cobden municipal drinking water system, it is nutrient-enriched, and concerns have arisen related to the formation of blue-green algal blooms. Blue-green algal blooms affect recreational opportunities but can also cause significant health effects. AECOM (2009) determined that algal toxins represent a high level of risk to the Cobden drinking water supply. A variety of different physical, chemical, and biological factors cause algal bloom formation, but lake and watershed managers often focus on nutrients during management as nutrients are generally the limiting factor for algal growth in freshwater ecosystems.

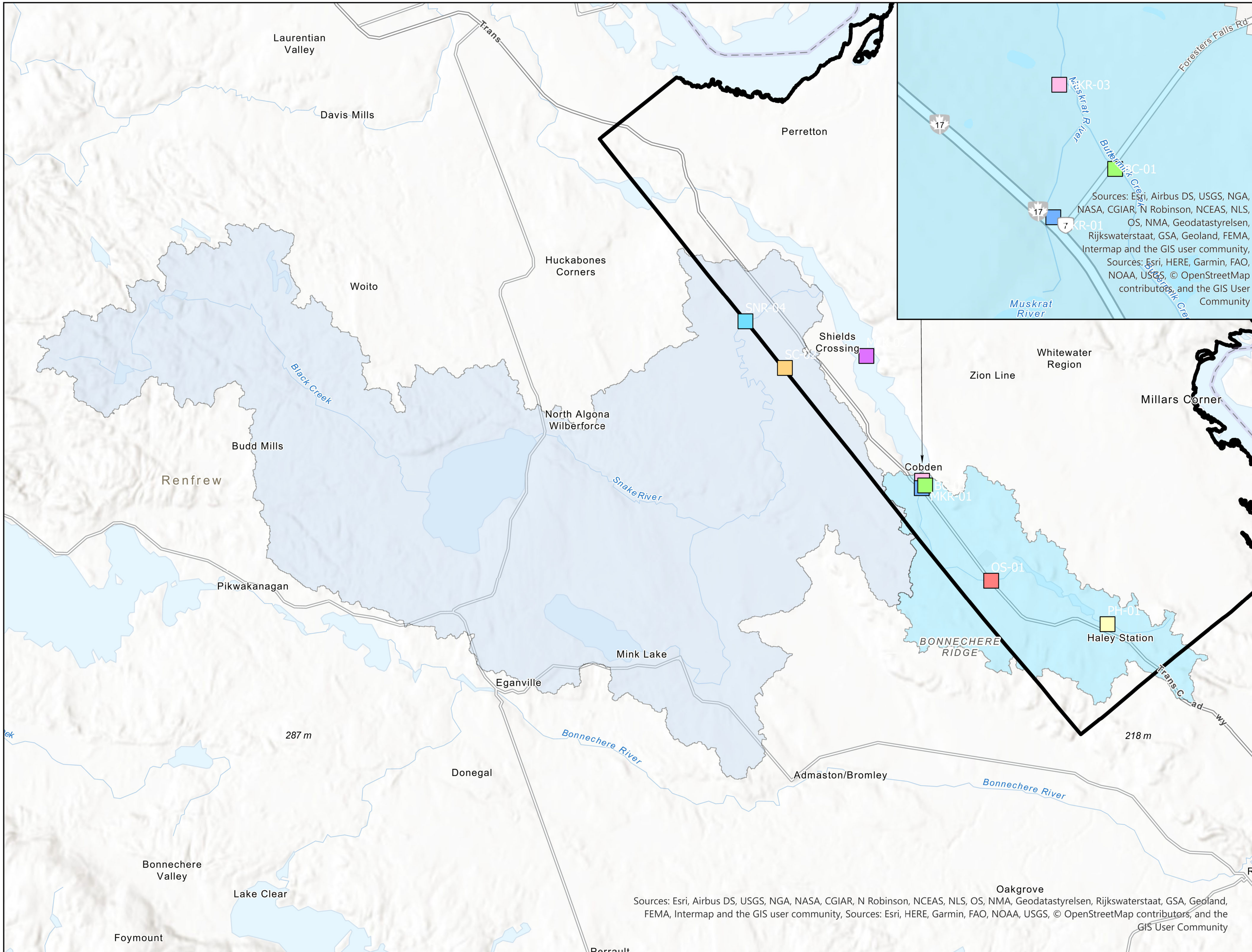
Data collected from water quality sampling locations established in the Muskrat Lake watershed have indicated that nutrient concentrations in inflowing tributaries are high, and in-stream concentrations of nutrients and suspended solids increase with increasing crop land and decrease with increasing natural habitat (Dalton 2019). Nutrient concentrations were typically elevated in watercourses adjacent to or downstream from agricultural operations due to runoff from fertilizers, decomposed crop residues, and manure. Dalton (2019) therefore recommended that improvements to water quality in Muskrat Lake should focus on reducing nutrient inputs from agricultural lands in the Muskrat Lake watershed.

The goal of this project is to characterize existing stormwater quality and stormwater management in Cobden's agricultural area and local Provincially Significant Wetlands (PSWs), recommend and implement mitigation measures to reduce nutrient loading to PSWs and Muskrat Lake, develop information sharing amongst local and regional groups and residents, and develop lasting partnerships between the agricultural sector and regional organizations to help improve water quality in Muskrat Lake and the PSWs in both the short and long-term. The Muskrat Lake watershed encompasses several different municipalities but the study area and focus for this project has been defined as the Township of Whitewater Region (Figure 1).

The Muskrat Lake watershed has been very well studied in terms of water quality and land use, so a thorough background review was completed to set the stage for subsequent project tasks. The background review is described herein and was completed following five specific tasks:

1. Preliminary consultation with the agricultural community and environmental partners;
2. Characterization of existing stormwater management;
3. Identification of source areas of nutrient loss;
4. Evaluation of Cobden and Snake River Provincially Significant Wetland functions in relation to stormwater management (SWM); and
5. Preliminary identification of priority areas for management.

Subsequent stages of the study included the Planning, Action and Public Education Phases. These phases focused on the identification of suitable agricultural BMPs, consultation with landowners to develop a short-list of BMPs which are suitable for application at a lot-level scale, and a discussion surrounding BMP considerations that should be considered during future planning and application such as nutrient reduction processes and efficiencies associated with each BMP.



Muskrat Lake Watershed Township of Whitewater Region

Boundaries and Water Quality Sampling Locations

Legend

- Snake River Watershed
- Muskrat Lake Watershed
- Township of Whitewater Region

Water Quality Sampling Locations

- BC-01
- MKR-01
- OS-01
- PH-01
- SC-02
- SNR-04
- MKR-03
- MLK-02

N

1:150,000

0 4 8 Km

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2. Methods

2.1 Consultation

Jp2g and HESL reached out to agricultural and environmental partners for the purposes of explaining the study program, data collection and establishing contacts to keep agricultural and environmental partners informed throughout the work program. A public and agency contact list was also developed for project notification for future stages of the project. A virtual public meeting was completed on December 8, 2021 and a number of one-on-one/small group meetings were also completed to ensure that information and insight from representatives from the farming community, property owners and interest groups was incorporated into the study.

2.2 Existing Agricultural SWM

Existing SWM for the Cobden and surrounding agricultural area was determined through local knowledge, background material, Google Earth, Ontario Flow Assessment Tool, the Township, and MTO Drainage Management Manual. Jp2g also completed field investigations to document SWM features. National Research Canada flood plan mapping was obtained from the County of Renfrew and reviewed to determine the areas and extent of flooding in the study area.

2.3 Source Areas of Nutrient Loss

Source areas of nutrient loss were identified through field investigations, evaluation of historical water quality data, review of land use and flood plain mapping. Source areas of nutrient loss were identified to focus future phases of the study on priority areas where the implementation of BMPs should be focused to generate the greatest benefit to downstream receiving water systems.

2.3.1 Water Quality

Twenty-two water quality sampling locations were sampled monthly from May to September 2014 – 2019 to characterize stormwater quality and to identify tributaries that are highly impacted by nutrients (Figure 1). The project was led by Algonquin College (Pembroke) and the Muskrat Watershed Council. Water quality parameters were analyzed by Ministry of Environment, Conservation and Parks (MECP) and reports were produced by Rebecca Dalton (Dalton 2015; Dalton 2019).

Water quality data from sampling stations located in the Township of Whitewater were analyzed through comparisons with Provincial Water Quality Objectives (PWQOs) and values reported in literature. Data were assessed spatially between sites and temporally over seasons. Sites included Muskrat River (PH-01), Muskrat River (OS-01), Muskrat River (MKR-01), Buttermilk Creek (BC-01), Cobden Wetland (MKR-03), Unnamed Creek (SC-02), Snake River (SNR-04) and Muskrat Lake (MLK-02; Table 1; Figure 1).

Nutrient loads were calculated to provide another means of identifying nutrient source areas. Loads for each site were calculated by multiplying median concentrations by the mean annual flow. Mean annual flows were estimated using the Ontario Flow Assessment Tool (Ministry of Natural Resources and Forestry 2020) and the built-in flow Mean Annual Flow Hydrology Model (Ministry of Natural Resources 2003).

Table 1. Descriptions of Water Quality Sampling Locations (Dalton 2019).

Site	Watercourse	Sub-Watershed	Easting	Northing	Rationale
PH-01	Muskrat River	Muskrat	362174	5047911	Most upstream site on Muskrat River
OS-01	Muskrat River		357146	5049780	This site reflects important land use changes from PH-01 (e.g. increased development and agriculture)
MKR-01	Muskrat River		354178	5053726	Upstream extent of Cobden PSW
BC-01	Buttermilk Creek		354318	5053859	Only site on tributary
MKR-03	Cobden Wetland/Muskrat River		354210	5053897	High phosphorus. This wetland warrants further study to assess the impact of the sewage treatment plant on export of phosphorus to Muskrat Lake.
SC-02	Unnamed Creek	Snake	348236	5058891	Existing highly impacted site. Only site on this tributary.
SNR-04	Snake River		346660	5060866	Existing, highly impacted, most downstream site.
MLK-02	Muskrat Lake	Lake	351810	5059377	Critical site for establishing long-term trends in nutrients within Muskrat Lake.

2.3.2 Land Use Mapping

Land use was determined to help identify source areas of nutrient loss at two different scales. Dalton (2019) characterized land use in a 1000 m x 200 m wide area (100 m on either stream/river bank) using 30 cm resolution satellite imagery data from Agriculture and Agri-food Canada's 2014 Crop Inventory. Percentages of annual crop land, pasture/forage land, natural habitat and developed land were calculated. Those numbers are reproduced here to inform the identification of nutrient source areas.

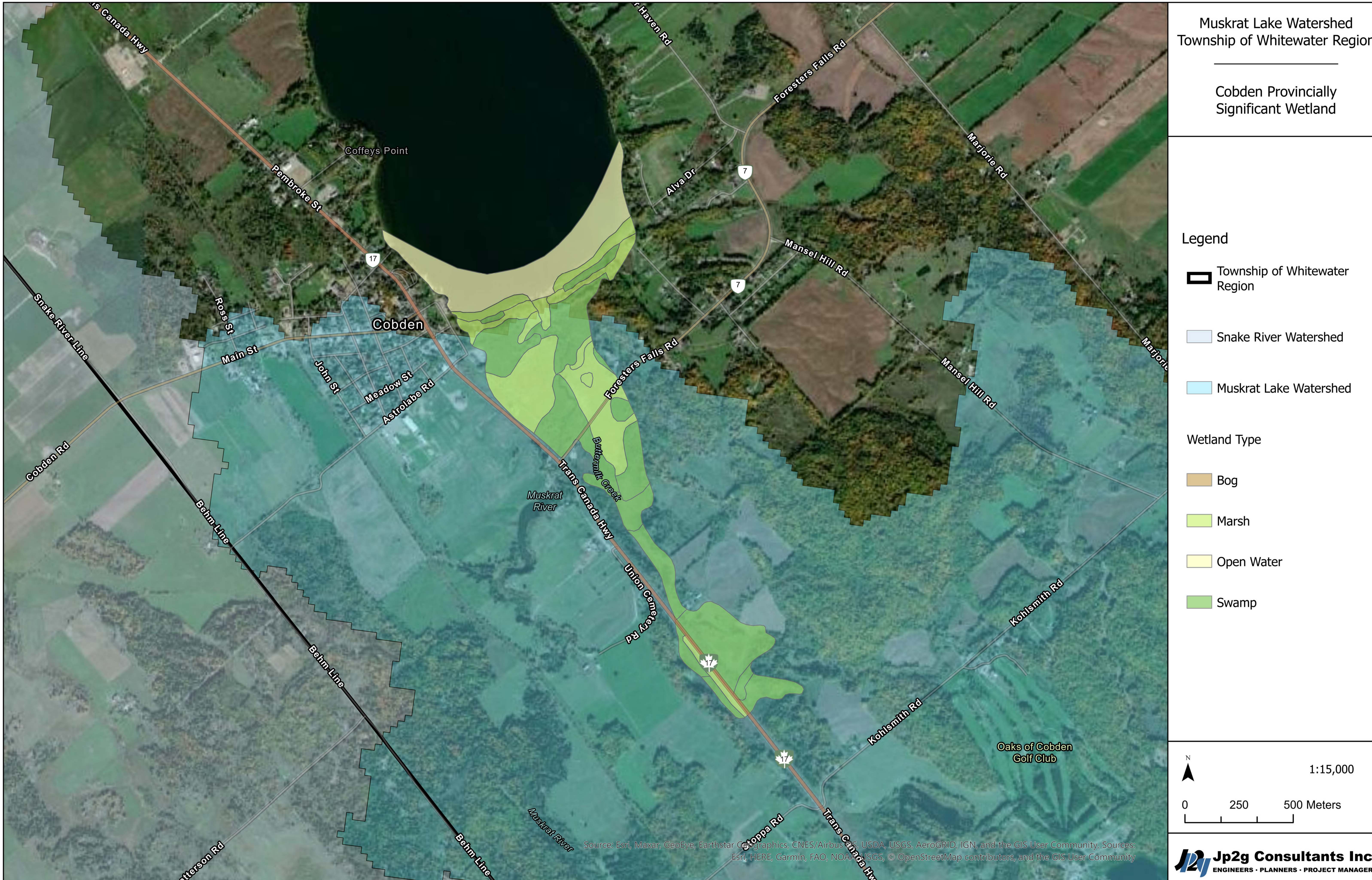
The agricultural area within the catchment for each water quality sampling location was calculated using the Ontario Flow Assessment Tool to provide an indication of land use at a larger scale. Land uses were used to inform the assessment through comparison with water quality data to help determine if there is a linkage between land use and water quality to define future priority areas.

2.4 Cobden and Snake River PSWs

The Cobden and Snake River PSWs are both located in the Muskrat Lake Watershed (Figure 2; Figure 3). The Ministry of Natural Resources and Forestry (MNRF) categorizes wetlands as Provincially Significant based on a science-based ranking system. We characterized the wetland features and functions of the Cobden and Snake River PSWs through review of the:

- Snake River Marsh Conservation Reserve Management Statement (Province of Ontario, 2019)
- Snake River Wetland Data Record (MNRF, undated)
- Cobden Wetland Data Record (MNRF, undated)
- Environmental Impact Study – Cobden Wastewater Treatment Plant Upgrades (Muncaster Environmental Planning and JP2G Consultants, 2016)

Features and functions of the PSWs were assessed in relation to natural heritage features to define the ecological sensitivities of these wetlands as receiving water systems of agricultural runoff. We also assessed the PSWs in terms of stormwater management through a review of water quality data at upstream and downstream sampling locations to determine when they act as sources or sinks for nutrients.


Muskrat Lake Watershed
Township of Whitewater Region
Cobden Provincially Significant Wetland
Legend
Township of Whitewater Region
Snake River Watershed
Muskrat Lake Watershed
Wetland Type
Bog
Marsh
Open Water
Swamp
N
1:15,000
0 250 500 Meters
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Coffeys Point
Cobden
Pembroke St
Main St
Ross St
John St
Meadow St
Astrolabe Rd
Cobden Rd
Snake River Line
Behm Line
Foresters Falls Rd
Alva Dr
Mansel Hill Rd
Marjorie Rd
Trans Canada Hwy
Union Cemetery Rd
Muskrat River
Kohlsmith Rd
Patterson Rd
Oaks of Cobden Golf Club
17
7
Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community, Sources: Esri, HERE, Garmin, FAO, NOAA, USGS, © OpenStreetMap contributors, and the GIS User Community

Township of Whitewater Region

Snake River Provincially Significant Wetlands

Legend

Township of Whitewater Region

Snake River Watershed

Wetland Type

Bog

Marsh

Open Water

Swamp

N

1:25,000

0 0.5 1 Kilometers

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3. Preliminary Consultation

A project kickoff meeting was completed on February 18, 2021, which included Karen Coulas from the Muskrat Watershed Council, Ivan burton and Lane Cleroux from the Township of Whitewater Region, Jp2g Consultants Inc. and HESL. The meeting included a review of project scope and deliverables, identification of background material, and establishment of lines of communication.

Preliminary background review and consultation included correspondence with MECP, Rebecca Dalton (author of the Muskrat Lake Watershed – 2017-2019 Water Quality Reports), Julie Sylvestre from Algonquin College, and the County of Renfrew to obtain Natural Resources Canada (NRCAN) mapping information for the 2019 flood.

Jp2g drafted a public and agency contact list for the purposes of project notification and the identification of individuals and groups interested in participating in the Action and Public Education Stages of the Study process (Appendix A). The draft public and agency contact list includes relevant Provincial agencies, local agricultural organizations, non-government organizations (NGO's), Algonquin College and the general public. A description of the "Purpose of Study" was also drafted for the project notification purposes.

This public and agency circulation list was reviewed with the Township and Muskrat Watershed Council prior to project notification. The form of consultation during the Action and Public Education Stages depended, in part, on the interested expressed by individuals and groups as per the direction of the Township. It is anticipated that public and agency consultation will consist of a combination of macro (broad-based public and agencies) focus group engagement and micro (individual/kitchen-table) level meetings. Options for public notification and participation during the Study process will be developed as per direction from the Township and include, but not be limited to the following:

1. Keeping interested individuals and organizations informed throughout the Study process.
2. General notifications (i.e. local newspapers; Township/MWC web-pages) regarding the Study and opportunities for participation during the Action and Public Education stages of the work plan.
3. Focus group session(s) with one or a combination of interested agricultural; agency, NGO and academic organizations.
4. Identification of individuals from the agricultural community for the purpose of obtaining input and buy-in on effective BMP's.
5. Preparation of information materials that can be circulated to individuals and the public.
6. Public meeting(s) (virtual or in public depending on COVID – 19) to present the study results and Action Plan moving forward.

4. Existing SWM

Existing SWM provided by natural systems and agricultural treatment in the study area was documented through background review and field investigations.

4.1 Natural SWM Features

4.1.1 Watercourses

The Muskrat and Snake Rivers drain into Muskrat Lake. The Muskrat River flows from Renfrew through a chain of small lakes into the Cobden PSW (Figure 4) and Muskrat Lake while the Snake River flows into Lake Dore before emptying into the Snake River PSW and Muskrat Lake.

Nutrient retention in riverine systems occurs through complex biogeochemical and physical processes that remove, delay or transform the nutrients. Factors affecting nutrient retention in watercourses include vegetation, hydrology, morphology, soil properties, water chemistry and groundwater supply. Floodplains, riparian buffers and in-stream processes combine to determine nutrient reduction efficiencies in watercourses, which may vary spatially and temporally in each of these interrelated environments. Lower uptake lengths[1] in first order streams suggests more efficient phosphorus retention driven by the inherent abiotic and biotic characteristics of those watercourse types (HESL 2017). Higher order and agricultural-influenced watercourses tend to retain less nutrients than more pristine or first order watercourses. Phosphorus retention efficiencies from various studies are presented in Table 2 and demonstrate the wide range of phosphorus reduction in watercourses due to site-specific factors.

Table 2. Phosphorus Reduction Efficiencies of Rivers from Various Studies

Total Phosphorus Reduction Efficiency	Primary Influencing Factors Investigated	Reference
28% after restoration	3 stage restoration including streams and wetlands	Richardson et al. 2011
Duffin Creek = 92%, Nottawasaga River = 44%	Seasonality, hydrology	Hill 1982
<10% - >30%	Flow conditions	House 2003
50% of SRP	Biological uptake during spring	
60%	Downstream of sewage treatment plant	Withers and Jarvie 2008

[1] *Uptake length is indicative of the phosphorus retention efficiency of a watercourse, lower uptake length suggests higher phosphorus-uptake efficiency and cycling*

Township of Whitewater Region
County of Renfrew

Waterbodies

Legend

Township of Whitewater Region

Watercourse

Muskrat River

Waterbody

1:60,000

N

0 0.5 1 2 Km

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4.1.2 Lakes

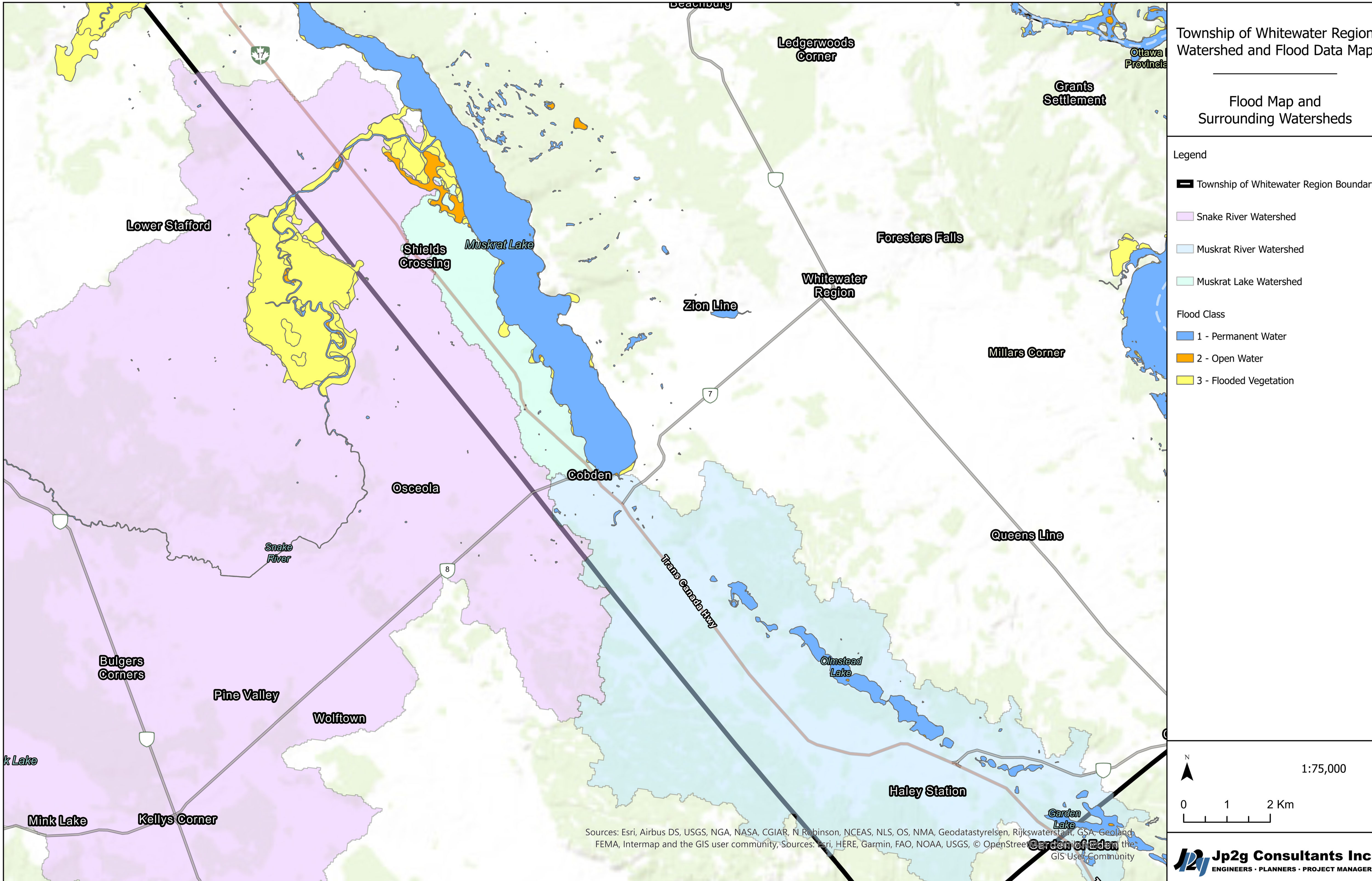
Nutrient retention rates in lakes are affected by a variety of different processes, the most important being water residence time as greater residence time increases settling and nutrient retention. Overland flow passes through a series of lakes in the Muskrat River watershed prior to draining into Muskrat Lake. The lakes include: Garden Lake, Edmunds Lake, Blanchards Lake, Smiths Lake, Galilee Lake, Dump Lake, Eadys Lake, Pumphouse Lake, Jeffreys Lake, Olmstead Lake, Round Lake, and Astrolabe Lake. These lakes all serve as storage and treatment opportunities for sediment prior to reaching Muskrat Lake.

4.1.3 Floodplains

Nutrient processing in floodplains largely dictates nutrient concentrations in adjacent watercourses by transforming nutrient forms and loads from upstream sources and from watercourses through complex biotic and abiotic processes. Hydrology shapes the physical and biological characteristics of floodplains and is therefore the key factor that regulates the transport of nutrients, including phosphorus, between floodplains and watercourses (Hoffmann et al. 2009, Richardson et al. 2011, Newcomer Johnson et al. 2016). Hydrological connectivity and the different flow paths that operate within floodplains determine how, when and where phosphorus interacts with soils and vegetation and are therefore key considerations for assessing the potential for phosphorus retention (Hoffmann et al. 2009.). Sedimentation, which occurs along many flow paths is the main removal process for phosphorus in floodplains.

Flooding can result in the export of nutrient-enriched stormwater from terrestrial lands to adjacent low-lying lands or watercourses. Figure 5 and Figure 6 show the National Research Canada (NRCan) flooding data from 2019. Figure 5 depicts the three classes of flooding: Class 1 represents permanent water bodies, Class 2 represents flood extents that can be directly observed by satellite observation, and Class 3 represents any flood which happens in flooded forest environment. Figure 6 depicts the extent of flooding on five separate days in April and May of 2019. In the Snake River Watershed, there are significant floodplains due to the flat surrounding areas between the Snake River PSW and Muskrat Lake. Large extents of flooding were evident throughout the spring of 2019 and designated as either “Class 2 – Open Water” or “Class 3 – Flooded Vegetation”.

Floodplain reconnection and flood loss reduction are potential BMPs to consider in future project phases. Floodplains have typically become disconnected to improve agricultural potential and for a host of other reasons. Areas that were cut-off by tile drains, or through channel straightening were historically included in the floodplain of a watercourse, greatly improving nutrient retention efficiencies of the riverine system as flows spread out, dissipate and deposited sediment. Flood loss reduction generally refers to improved drainage engineering where flooding is mitigated through improved drainage controls.


Township of Whitewater Region
Watershed and Flood Data Map
Flood Map and
Surrounding Watersheds
Legend
Township of Whitewater Region Boundary
Snake River Watershed
Muskrat River Watershed
Muskrat Lake Watershed
Flood Class
1 - Permanent Water
2 - Open Water
3 - Flooded Vegetation
1:75,000
0 1 2 Km
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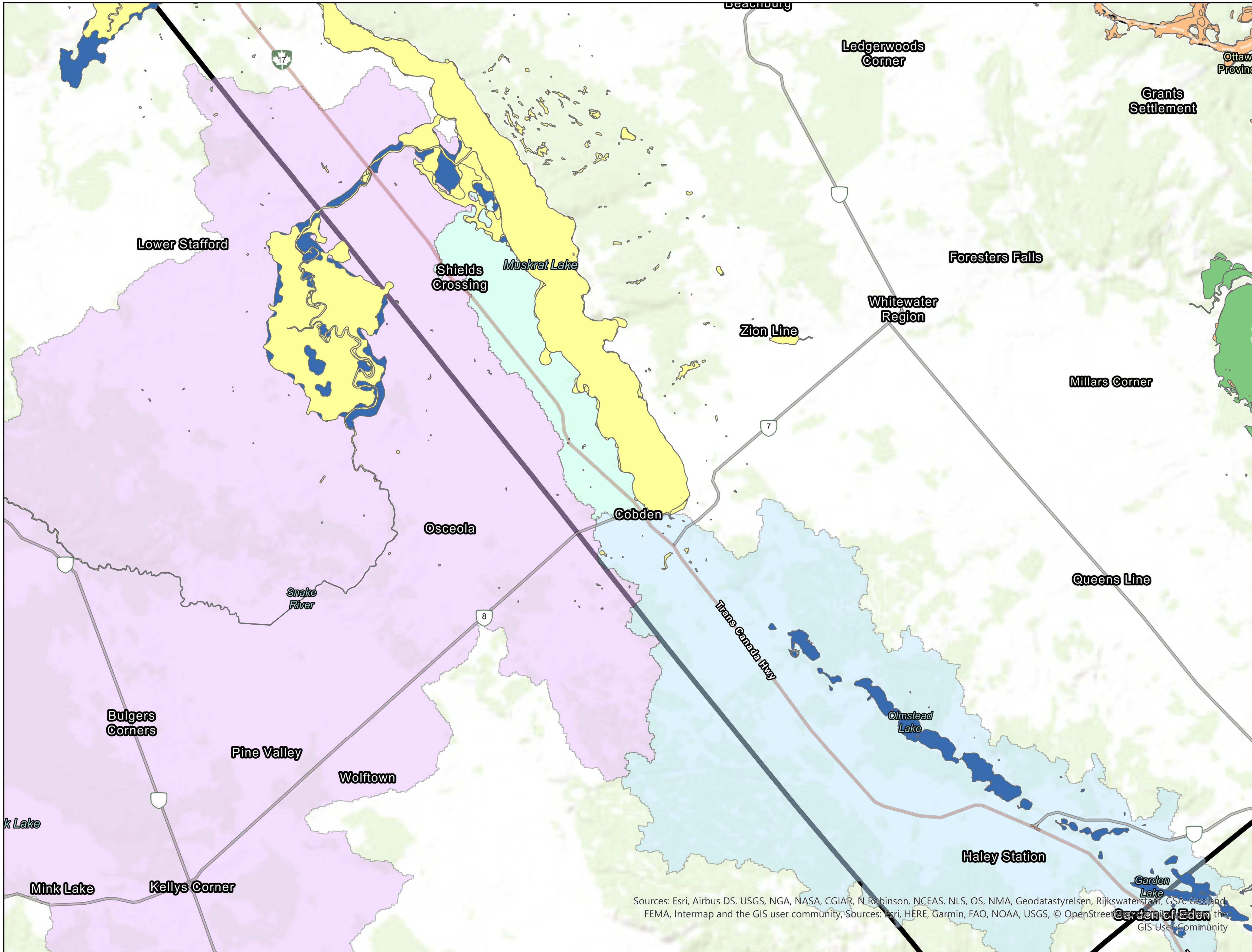
Ledgerwoods Corner
Grants Settlement
Lower Stafford
Shields Crossing
Muskrat Lake
Foresters Falls
Whitewater Region
Zion Line
Millars Corner
Cobden
Osceola
Queens Line
Snake River
Trans Canada Hwy
Olmstead Lake
Bulgers Corners
Pine Valley
Wolftown
Haley Station
Mink Lake
Kellys Corner
Garden Lake
Garden of Eden
Sources: Esri, Airbus DS, USGS, NGA, NASA, CGIAR, N Robinson, NCEAS, NLS, OS, NMA, Geodatastyrelsen, Rijkswaterstaat, GSA, Geoland, FEMA, Intermap and the GIS user community, Sources: Esri, HERE, Garmin, FAO, NOAA, USGS, © OpenStreetMap contributors, and the GIS User Community

Township of Whitewater Region Watershed and Flood Data Map

Flood Map and Surrounding Watersheds



Legend

- Township of Whitewater Region Boundary
- Snake River Watershed
- Muskrat River Watershed
- Muskrat Lake Watershed

Data Acquisition Date

- 4/22/2019
- 5/9/2019
- 5/10/2019
- 5/16/2019

N

1:75,000

0 1 2 Km

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4.1.4 Wetlands

The natural heritage features of the Cobden PSW and Snake River PSW and an evaluation of their status as nutrient sinks or sources was assessed in Section 5.0.

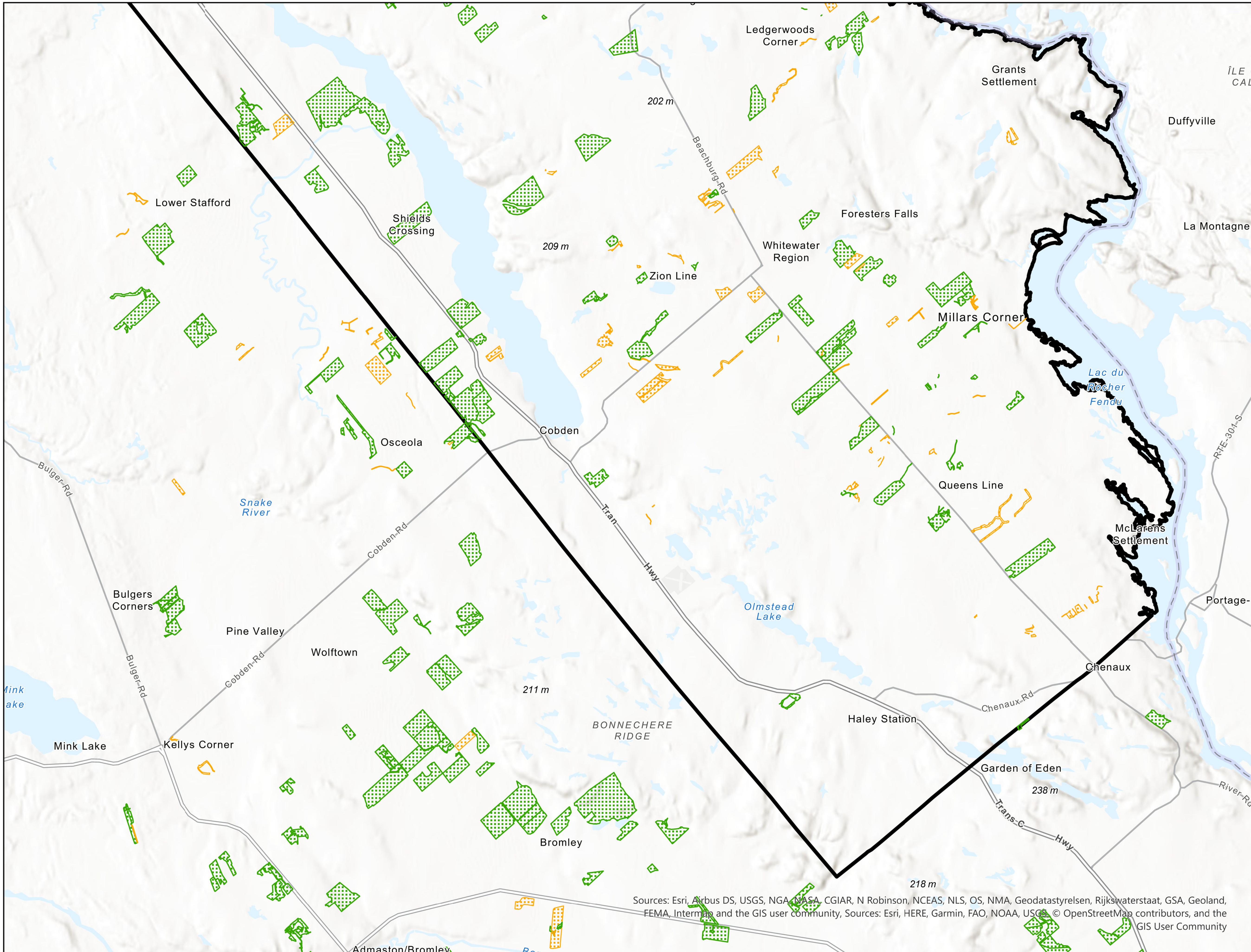
4.2 Artifical SWM Features

The locations of known tile drains and municipal drains are provided in Figure 7.

4.2.1 Tile Drainage

Phosphorus is transported from agricultural fields to adjacent watercourses via surface flow and subsurface flow, and much of the subsurface flow is conveyed by tile drains where they exist. Tile drains are designed to remove excess water quickly from below the soil surface to avoid crop damage and decreased yields. Tile drainage impacts hydrology substantially by increasing water output, reducing surface runoff and sedimentation, and eliminating saturated areas.

Dalton (2019) noted that two controlled tile draining structures were implemented and they reduced nitrate by 65% and phosphorus by 63% but there are variable results in scientific literature largely because of inconsistencies with nutrient retention processes that are impacted by soil characteristics, flow and season as discussed in Section 9.0. There are multiple tile drains in the study area, predominantly in the Snake River Watershed (Figure 7; Photographs 1-5). Tile drains are mapped as either "Systematic" where the drains have been installed in a crosshatched, regular pattern, or "Random" where tile drains have been installed where needed, for example to drain a wet spot in a field. Additional tile drains were identified through consultation but an accurate depiction of the locations of all tile drains, especially more recently installed drains was not available.



Muskrat Lake Watershed
Township of Whitewater Region

Tile and Municipal Drains

Legend

Township of Whitewater Region

Tile Drainage Areas

Tile System

Random

Systematic

N

1:88,891

0 0.5 1 2 Km

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Photograph 1. Tile Drain adjacent to Highway 17 - Snake River Watershed

Photograph 2. Drain Outlet - Snake River Watershed

Photograph 4. Drain Outlet - Snake River Watershed

Photograph 5. Tile Drain Astrolabe Road - Muskrat River Watershed

4.2.2 Municipal Drainage

Municipal drains are often implemented to improve drainage from agricultural lands in a similar manner as tile drains. Drains can influence nutrient retention when flow is diverted away from natural SWM features that provide TP attenuation such as wetlands. Based on the Artificial Drainage Mapping from the Ontario Ministry of Agriculture and Food, it was determined that there is one municipal drain in the Muskrat River Watershed, called the Haley Municipal Drain (Photographs 6 and 7). There are multiple municipal drains upstream of Whitewater Region as well which drain to the Snake River. A further discussion on historical drain implementation and related impacts on TP concentrations in Muskrat Lake is provided in Section 10.2.

Photograph 6. Haley Municipal Drain

Photograph 7. Outlet to Haley Municipal Drain

5. Source Areas of Nutrient Loss

Source areas of nutrient loss were identified through multiple lines of evidence. Information on water quality concentrations and loads were combined with information on land use (field investigations and review of mapping) to determine agricultural lands where BMP efforts should be focused. These areas represent source areas of nutrient loss and therefore implementation of BMPs will have the greatest benefit to downstream receiving water systems such as the Cobden PSW, Snake River PSW and Muskrat Lake.

5.1 Water Quality Results

Total phosphorus is generally the limiting nutrient for production of algae and macrophytes in freshwater environments. Various ratios such as Total Nitrogen (TN) to Total Phosphorus (TP) have been developed to define nitrogen-and phosphorus-limited conditions and systems. Guildford and Hecy (2000) found that nitrogen-deficient growth is found where TN:TP<20 and phosphorus-deficient growth is found where TN:TP>50. Schindler et al. (2008) however noted that reducing nitrogen inputs favored nitrogen fixing cyanobacteria and that nitrogen fixation was sufficient to allow for increased biomass in proportion to TP, indicating that lake and watershed management should be focused on TP.

Muskrat Lake data from 2014 – 2018 (MLK-02) were used to calculate the TN:TP molar ratio in Muskrat Lake. The TN:TP molar ratio ranged from 23.3 to 230, with a mean value of 23.3 indicating that Muskrat Lake is generally limited by phosphorus inputs (Table 3). Ratios indicated that the lake was phosphorus-limited on 15 out of 18 occasions according to ratios presented by Guildford and Hecky (2000).

We have focused on both TN and TP from watershed sampling locations to identify source areas of nutrient loss but nutrient removal efficiencies of BMPs were focused on TP because a) there is limited information on export coefficient modelling for TN or for TN-related reductions through BMP implementation, b) reductions in TN will not likely reduce algal biomass in downstream waterbodies because of nitrogen fixing cyanobacteria as noted by Schindler et al. (2008), and c) algal growth in Muskrat Lake is generally limited by phosphorus. Future BMPs will nonetheless improve TN as well as TP as the nutrients follow similar pathways.

Table 3. Total Phosphorus, Total Nitrogen and Total Nitrogen : Total Phosphorus at MLK-02.

Date	TP mol (mg/L)	TN mol (mg/L)	TN:TP molar ratio
2014-07-09	0.16	37.1	230
2015-06-15	0.45	23.6	52.1
2015-07-14	0.45	27.1	60.0
2015-08-11	0.65	35.7	55.3
2015-09-30	0.68	34.3	50.5
2016-05-24	0.58	33.5	57.7
2016-06-14	0.48	41.4	85.5
2016-07-12	0.58	34.3	58.9
2016-08-17	0.45	34.3	75.8
2016-10-03	0.32	32.1	99.5
2017-06-05	0.55	42.8	78.0
2017-07-10	0.90	32.8	36.3
2017-08-16	0.61	32.1	52.4
2017-09-20	0.58	30.7	52.8
2018-05-15	1.49	44.3	29.8
2018-06-19	0.39	27.8	71.8
2018-07-10	0.36	24.3	68.3
2018-08-13	1.16	27.1	23.3
		Minimum	23.3
		Maximum	230
		Mean	68.8

Total Suspended Solids (TSS) was also examined because nutrients are often elevated under high TSS conditions and TSS is often elevated because of sedimentation which is likely driven by agricultural runoff at the sampling locations.

5.1.1 Total Phosphorus

Median TP concentrations ranged from 0.011 mg/L (PH-01) and 0.012 mg/L (OS-01) to 0.178 mg/L (SC-02; Table 4). Between 2014 and 2019, sites with the greatest TP concentrations included SC-02 (median concentration of 0.178 mg/L), MKR-03 (median concentration of 0.120 mg/L) and SNR-04 (median concentration of 0.042 mg/L).

TP concentrations in the Whitewater Region in general, were highest in July or August (Figure 8). Monthly median TP concentrations were consistently greatest at SC-02 (a tributary that discharges to the Snake River PSW) ranging from 0.056 mg/L in April to 0.469 mg/L in July. Interpretation of monthly data should be viewed with caution due to differences in the number of samples available per site per month (Table 5).

Based on linear regression analysis TP concentrations were not statistically significantly related to total daily precipitation (Table 6).

Total phosphorus concentrations exceeded the PWQO and the threshold for stream impairment developed for Mixedwood Plains Ecozone of Ontario (Chambers et al., 2012) of 0.03 mg/L at all sites on various occasions. Percent exceedances (i.e. the % of samples that exceeded the guideline of 0.03 mg/L) ranged from 7% at PH-01 and OS-01 to 100% at SC-02 (Table 7).

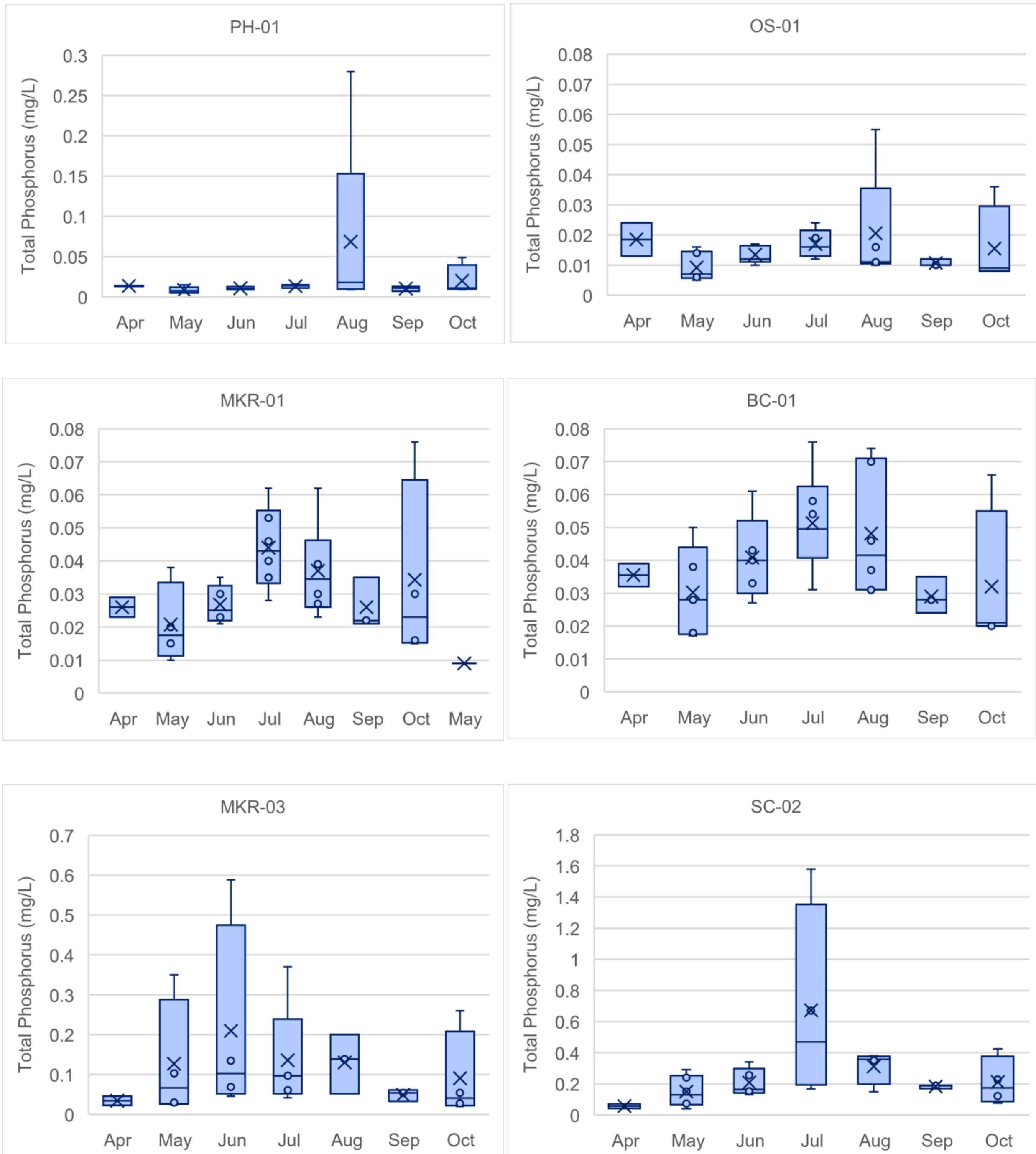
A review of 15 streams in agricultural watersheds in Southwestern Ontario between 2006 and 2009 found a range in TP concentrations between 0.002 to 0.129 mg/L (MOE 2012). The same study with an expanded dataset ranging from 2004 to 2009 found median concentrations ranging between 0.018 and 0.156 mg/L with median concentrations from 9 out of 15 streams exceeding the PWQO (MOE 2012). DeBues et al. (2019) noted mean TP concentrations of 0.01 to 0.044 mg/L in watersheds with 50% agricultural landcover between May and September in Lake Ontario tributaries.

Median TP concentrations measured in the Whitewater Region are similar to those found in Southern Ontario as reported by MOE (2012), while median concentrations at MKR-03 and SC-02 are higher than those presented in DeBues et al. (2019). The MOE (2012) study also found that TP concentrations were close to the annual average between July and September and high in October. This pattern is in contrast to what was observed in the Whitewater Region with low median October TP concentrations and high TP concentrations in July.

Table 4. Total Phosphorus Summary Stats for the Whitewater Region for April to October 2014 to 2019.

Total Phosphorus (mg/L)						
Sites	Mean	Median	Min	Max	Range	Number of Samples
PH-01	0.022	0.011	0.005	0.280	0.275	30
OS-01	0.015	0.012	0.005	0.055	0.050	30
MKR-01	0.032	0.029	0.009	0.076	0.067	31
BC-01	0.040	0.037	0.017	0.076	0.059	31
MKR-03	0.120	0.061	0.020	0.588	0.568	25
SC-02	0.263	0.178	0.039	1.580	1.541	28
SNR-04	0.050	0.042	0.017	0.264	0.247	32
SC-01	0.022	0.085	0.017	0.785	0.768	33
SNR-03	0.015	0.034	0.005	0.054	0.049	32

Figure 8. Monthly Total Phosphorus Concentrations in The Whitewater Region from April to October from 2014 to 2019.



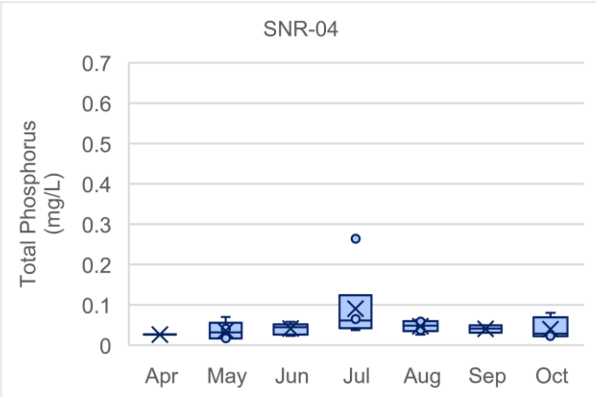


Table 5. Number of Monthly Samples Available per Site.

Site	April	May	June	July	August	September	October	Total
OS-01	2	6	5	5	5	3	4	30
MKR-01	2	5	5	6	6	3	4	31
BC-01	2	5	5	6	6	3	4	31
MKR-03	2	4	4	5	3	3	4	25
PH-01	2	6	5	5	5	3	4	30
SC-02	2	6	5	4	4	3	4	28
SNR-04	2	5	6	6	6	3	4	32

Table 6. Linear Regression Results for Total Phosphorus and Precipitation.

Site	r^2	P
PH-01	0.0048	0.732
OS-01	0.0008	0.890
MKR-01	0.0163	0.517
BC-01	0.0320	0.372
MKR-03	0.0386	0.393
SC-02	0.0001	0.955
SNR-04	0.0083	0.646

Table 7. Exceedance of PWQO and Threshold for Impairment for Phosphorus (0.030 mg/L) in the Whitewater Region.

Sites	Exceedance	Count	Percent Exceedance
PH-01	2	30	7%
OS-01	2	30	7%
MKR-01	12	31	39%
BC-01	22	31	71%
MKR-03	20	25	80%
SC-02	28	28	100%
SNR-04	23	32	72%
SC-01	31	34	91%
SNR-03	17	32	53%

5.1.2 Total Nitrogen

Median TN concentrations were similar at five of the seven sites and ranged from 0.31 mg/L (OS-01) to 0.48 mg/L (MKR-03), while median concentrations at SNR-04 (0.65 mg/L) and SC-02 (0.92 mg/L) were higher (Table 8). Median monthly TN concentrations at four (PH-01, MKR-01, SC-02, SNR-04) of the seven sites in the Whitewater Region were highest in October, and highest in May at OS-01, BC-01 and MKR-03 (Figure 9). As noted with TP monthly samples varied between sites, interpretation of monthly data should be viewed with caution due to differences in the number of samples available per site per month (Table 9).

TN concentrations were not statistically significantly related with total daily precipitation (Table 8).

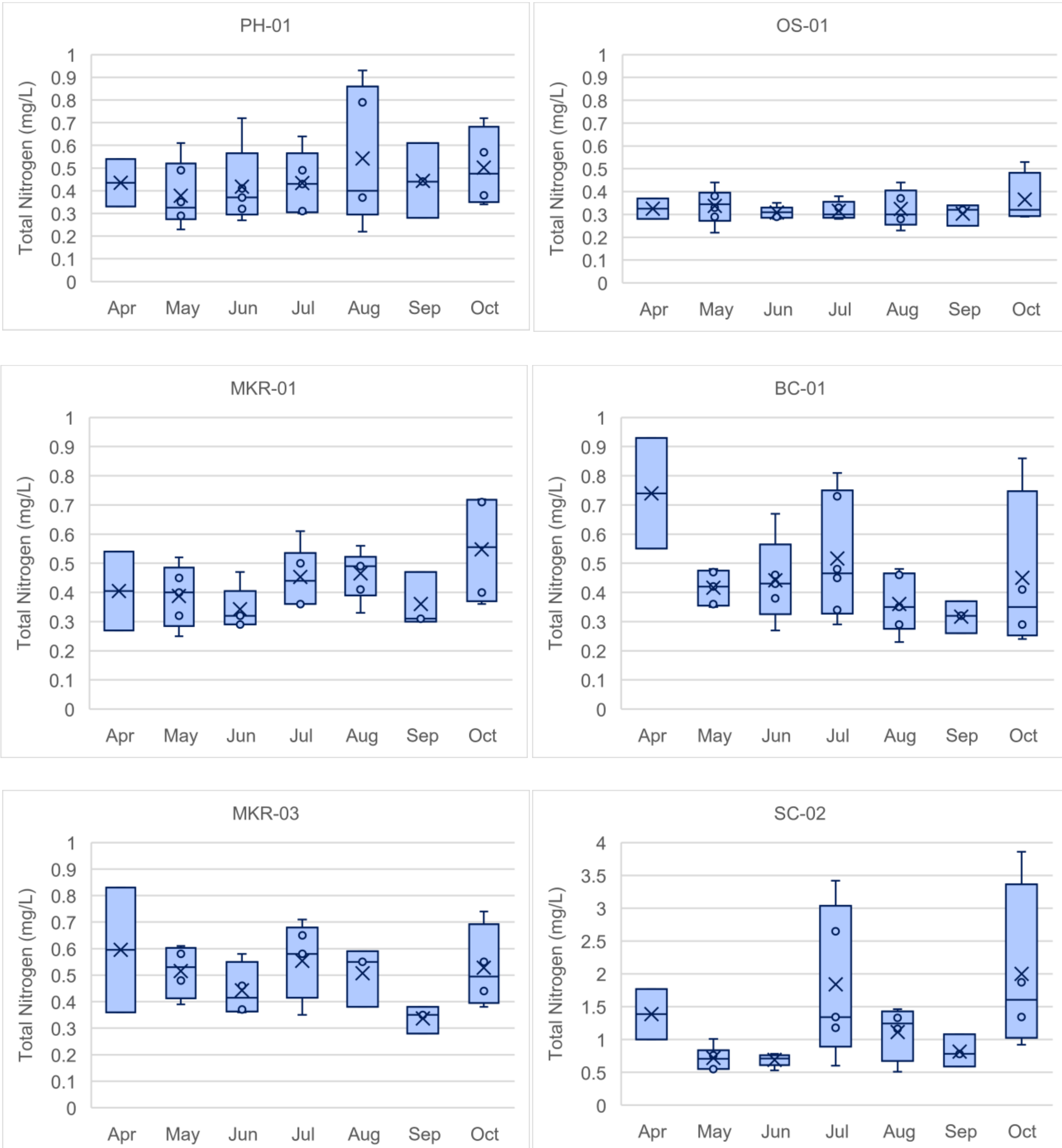
TN concentrations exceeded the threshold for stream impairment (1.10 mg/L) developed for the Mixedwood Plains Ecozone of Ontario (Chambers et al., 2012) at SC-02 (38% of samples) and SNR-04 (10% of samples, Table 11). SC-02, SNR-04 and MKR-03 had high concentrations of both TN and TP.

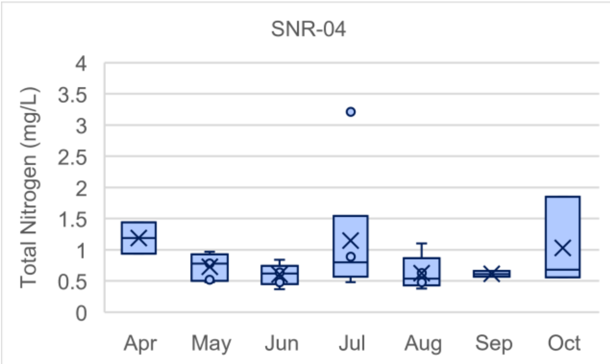
Between 1992-2001 the U.S. EPA (2007) investigated 133 streams in agricultural watersheds across the United States and found that 78% of streams had mean TN concentrations of 2 mg/L or greater during average flow conditions. Only one site in the Whitewater Region had a mean TN concentration greater than 2 mg/L suggesting concentrations in the area are relatively low compared to other agricultural watersheds in North America.

Table 8. Total Nitrogen Concentrations in the Whitewater Region from April to October from 2014 to 2019.

Site	Mean	Median	Min	Max	Range	Count
PH-01	0.45	0.39	0.22	0.93	0.71	30
OS-01	0.33	0.31	0.22	0.53	0.31	30
MKR-01	0.43	0.4	0.25	0.72	0.47	31
BC-01	0.45	0.41	0.23	0.93	0.7	31
MKR-03	0.50	0.48	0.28	0.83	0.55	25
SC-02	1.19	0.92	0.51	3.86	3.35	29
SNR-04	15.4	0.65	0.37	3.21	2.84	30

Figure 9. Monthly Total Nitrogen Concentrations in the Whitewater Region from 2014 to 2019.





Note: The y-axis scale was increased from 1.00 mg/L to 4.00 mg/L for SC-02 and SNR-04 to accommodate the higher monthly concentrations.

Table 9. Number of Monthly Samples Available per Site.

Site	April	May	June	July	August	September	October	Total
OS-01	2	6	5	5	5	3	4	30
MKR-01	2	5	5	6	6	3	4	31
BC-01	2	5	5	6	6	3	4	31
MKR-03	2	4	4	5	3	3	4	25
PH-01	2	6	5	5	5	3	4	30
SC-02	2	6	5	5	4	3	4	29
SNR-04	2	5	6	6	5	3	3	30

Table 10. Linear Regression Results for Total Nitrogen and Precipitation.

Site	r^2	P
PH-01	0.0163	0.525
OS-01	0.0088	0.648
MKR-01	0.0178	0.506
BC-01	0.0842	0.142
MKR-03	0.0201	0.539
SC-02	0.0060	0.713
SNR-04	0.0067	0.685

Table 11. Exceedance of Total Nitrogen Threshold for Stream Impairment (1.10 mg/L) in the Whitewater Region.

Site	Exceedance	Count	Percent Exceedance
PH-01	0	30	0%
OS-01	0	30	0%
MKR-01	0	31	0%
BC-01	0	31	0%
MKR-03	0	25	0%
SC-02	11	29	38%
SNR-04	3	30	10%

5.1.3 Total Suspended Solids

TSS concentrations in the Whitewater Region were variable ranging from 0.5 mg/L (PH-01, OS-01, MKR-03[2], SC-02) to 77.4 mg/L (SC-02, Table 12). Median suspended sediment concentrations were low and ranged from 1.3 mg/L (OS-01) to 5.3 mg/L (BC-01).

There was no month that consistently contained high suspended sediment concentrations in the Whitewater Region (Figure 10). As previously noted, number of monthly samples varied with site (Table 13). Suspended sediment concentrations were not statistically significantly related to total daily precipitation (Table 14).

Suspended solid concentrations had a positive and significant ($p<0.001$) relationship with TP concentrations at MKR-01 (Figure 11), BC-01 (Figure 12) and MKR-03 (Figure 13) while the relationship was close to statistical significance at SC-02 (Figure 14, $p = 0.05$). It should be noted that the significantly positive relationship between TSS and TP occurs at three sites in close proximity to one another suggesting there is a shared driver such as overland runoff. Strong positive relationships between TSS and TP frequently occur in agricultural areas however, pasture land use varies between the three sites and is limited at BC-01 (6.5% of upstream land use) and MKR-03 (4.8% of upstream land use, Section 5.2).

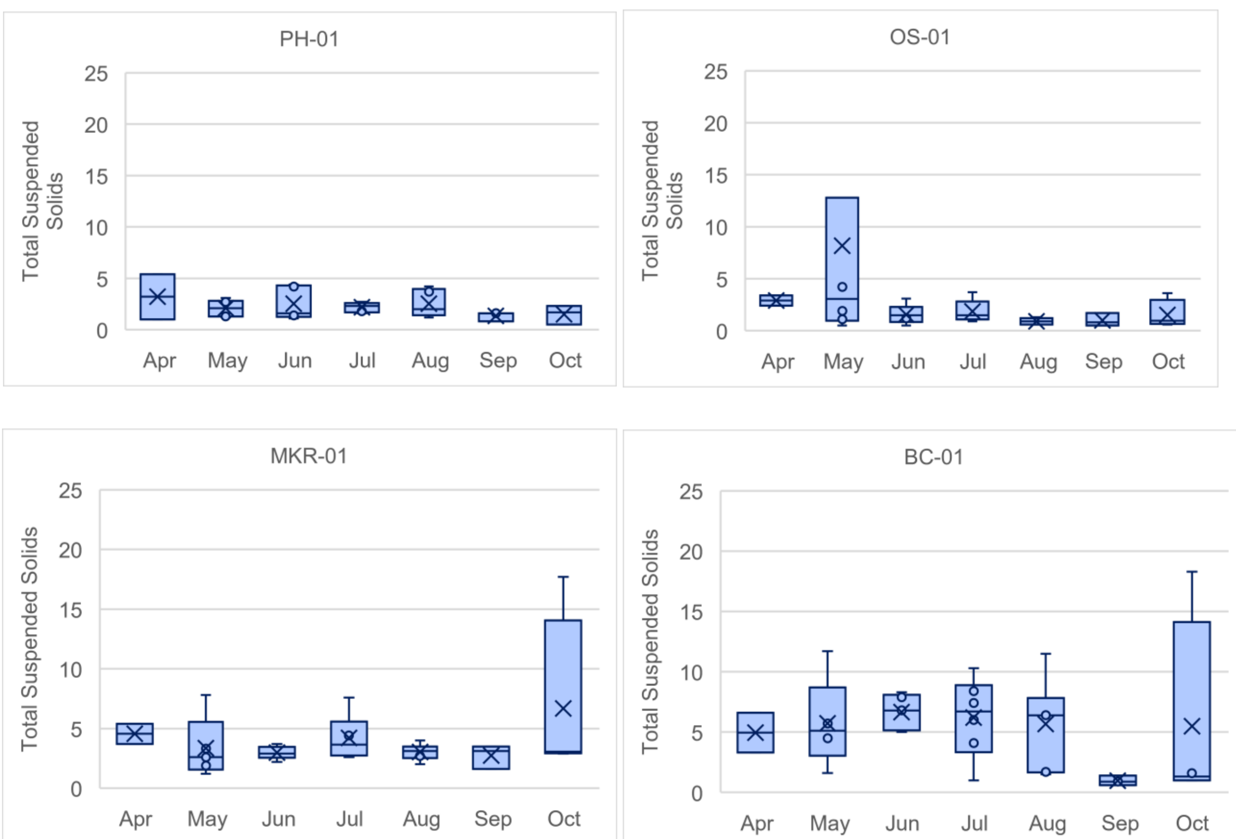
[2] *A TSS value at station MKR-03 collected in July 2015 (33.8 mg/L) was unusually high (greater than the mean plus three times the standard deviation, 23.6 mg/L) and therefore removed from analysis.*

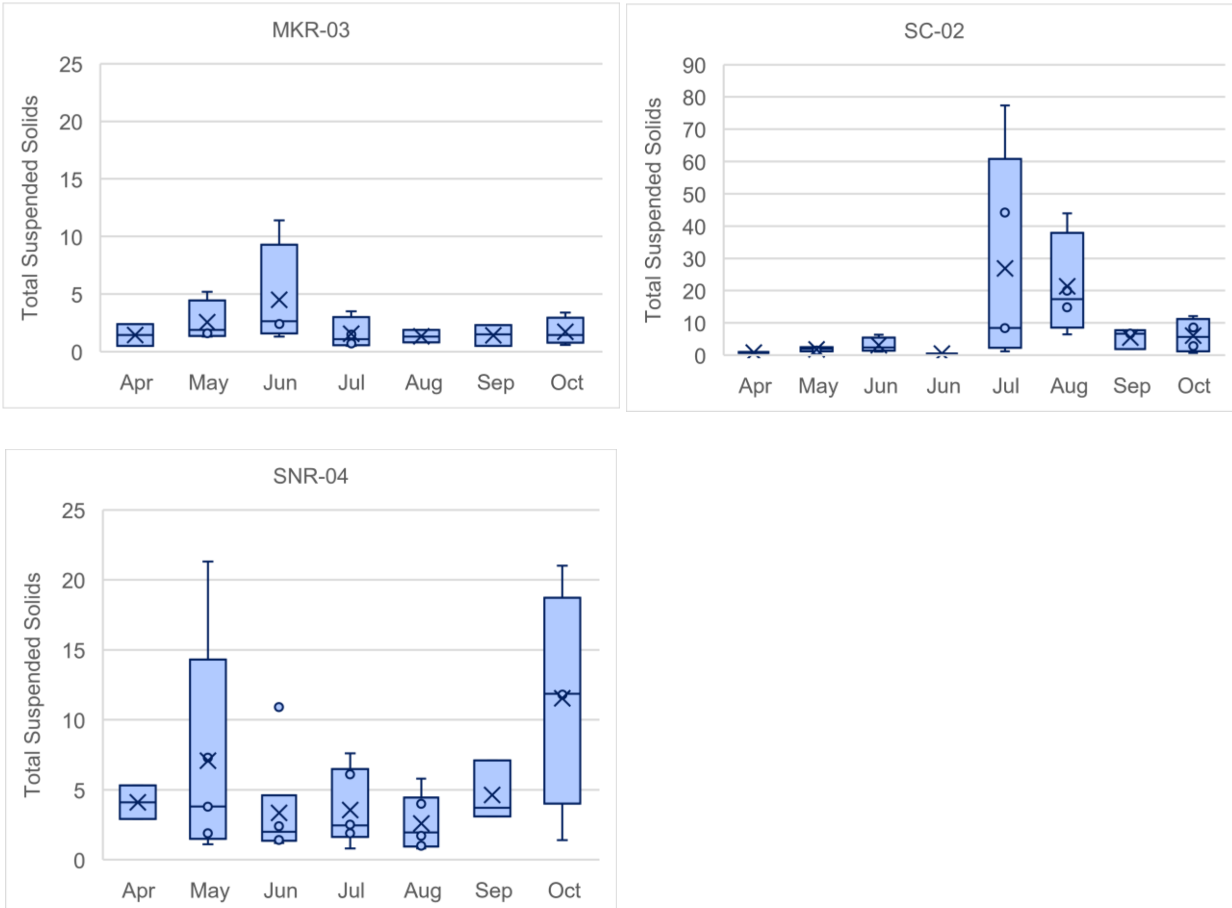
Table 12. Suspended Solids Concentrations in the Whitewater Region from April to October from 2014 to 2019.

Total Suspended Solids (mg/L)							
Site	Mean	Min	Max	Range	Median	Stdev	Count
PH-01	2.2	0.5	5.4	4.9	1.7	1.2	29
OS-01	2.9	0.5	36.5	36.0	1.3	6.5	30
MKR-01	3.8	1.2	17.7	16.5	3.1	2.9	31
BC-01	5.4	0.6	18.3	17.7	5.3	4.0	31
MKR-03	2.2	0.5	11.4	10.9	1.6	2.3	24
SC-02	9.9	0.5	77.4	76.9	2.6	17.1	29
SNR-04	5.0	0.8	21.3	20.5	2.7	5.3	32

Notes: Range is the maximum minus the minimum. StDev is the standard deviation.

Figure 10. Monthly Suspended Solids Concentrations in the Whitewater Region from 2014 to 2017.





Note: The y-axis scale was increased from 25 mg/L to 90 mg/L for SC-02 to accommodate the higher monthly concentrations.

Table 13. Number of Monthly Samples Available per Site.

Site	April	May	June	July	August	September	October	Total
OS-01	2	6	5	5	5	3	4	30
MKR-01	2	5	5	6	6	3	4	31
BC-01	2	5	5	6	6	3	4	31
MKR-03	2	4	4	4	3	3	4	24
PH-01	2	6	5	5	5	3	4	30
SC-02	2	6	5	5	4	3	4	29
SNR-04	2	5	6	6	6	3	4	32

Table 14. Linear Regression Results for Suspended Sediments and Precipitation.

Site	r^2	P
PH-01	0.0163	0.525
OS-01	0.0088	0.648
MKR-01	0.0178	0.506
BC-01	0.0842	0.142
MKR-03	0.0220	0.524
SC-02	0.0060	0.713
SNR-04	0.0067	0.685

Table 15. Linear Regression Results for Total Phosphorus and Suspended Solids.

Site	r^2	P
PH-01	0.0046	0.722
OS-01	0.0002	0.939
MKR-01	0.5080	<0.001
BC-01	0.5180	<0.001
MKR-03	0.6650	<0.001
SC-02	0.1400	0.05
SNR-04	0.0033	0.756

Figure 11. Total Suspended Solid vs. Total Phosphorus Concentrations at MKR-01.

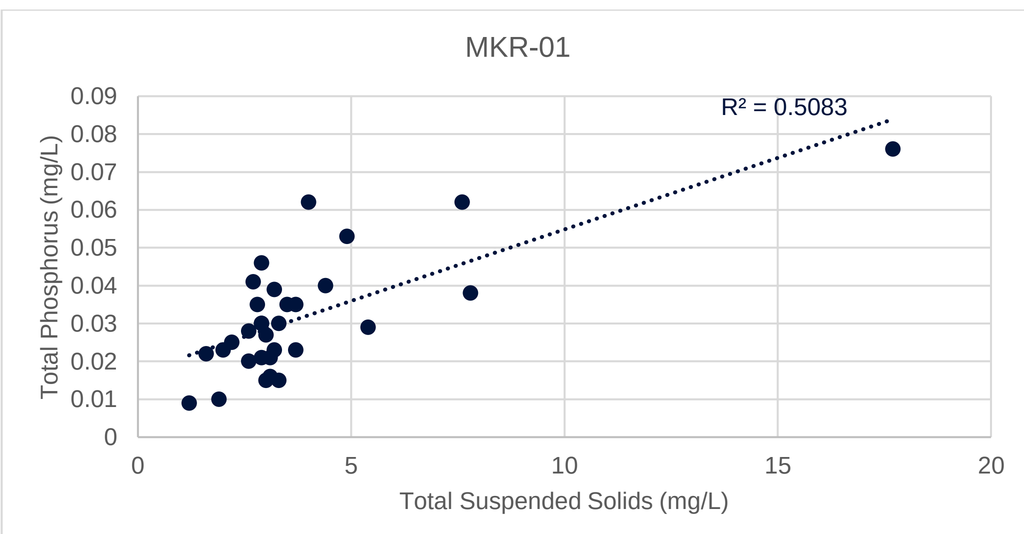


Figure 12. Total Suspended Solid vs. Total Phosphorus Concentrations at BC-01.

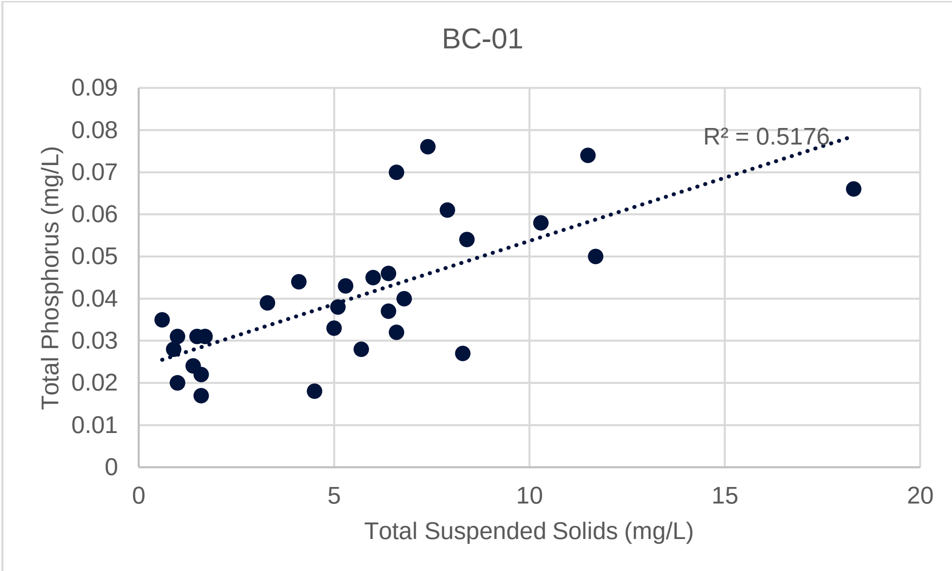


Figure 13. Total Suspended Solid vs. Total Phosphorus Concentrations at MKR-03.

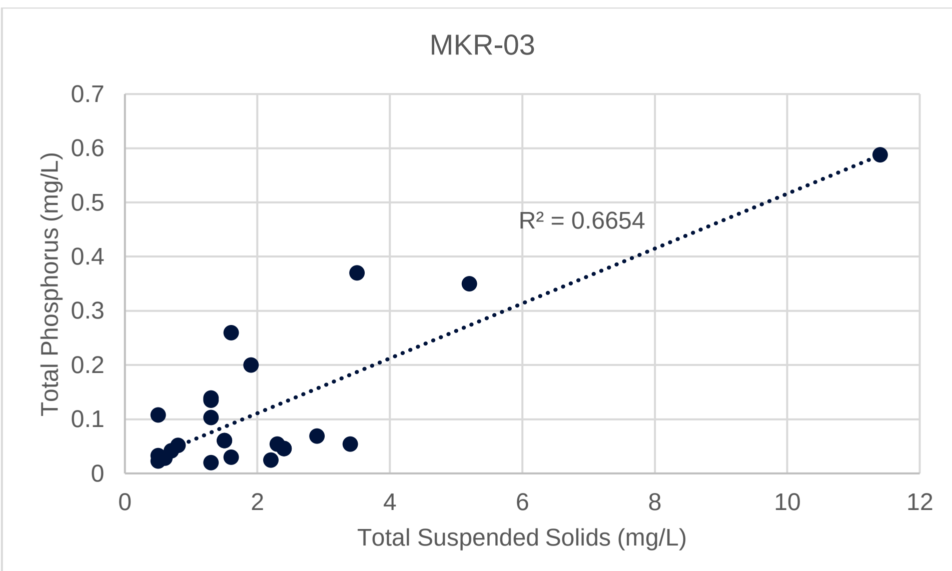
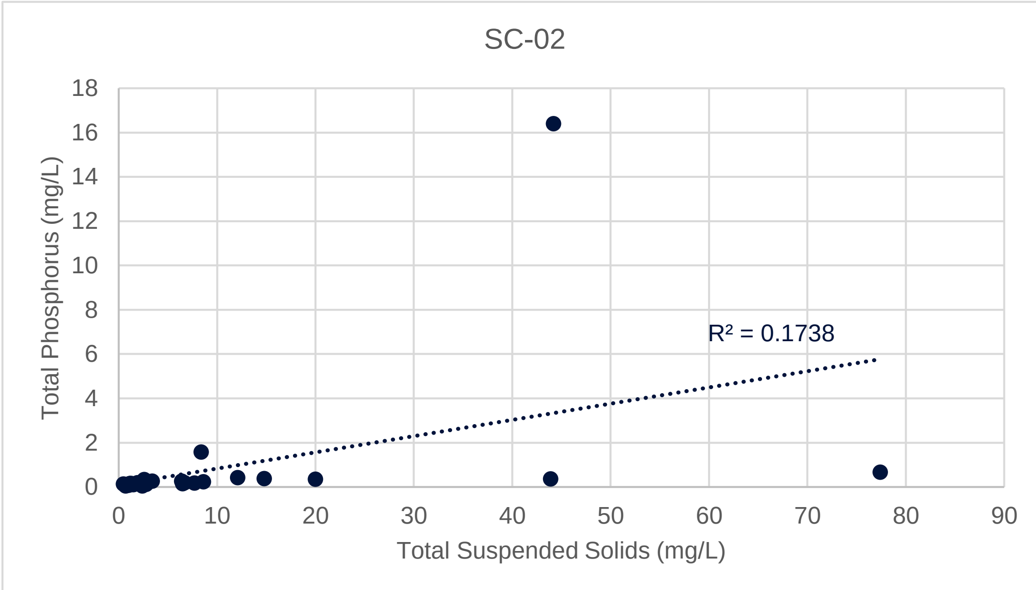


Figure 14. Total Suspended Solid vs. Total Phosphorus Concentrations at SC-02.



5.1.4 Nutrient Loads

5.1.4.1 Flow

The Ontario Flow Assessment Tool (OFAT) was used to calculate mean annual flows for each of the seven Whitewater Region sampling stations (Table 16). Catchment sizes ranged considerably from 1,030 ha (BC-01) to 37,980 ha (SNR-04; Table 16). Flows increased from upstream (e.g., PH-01 with a mean annual flow of 0.15 m^3/s) to downstream in the watershed (e.g., SNR-04 with a mean annual flow of 3.63 m^3/s).

Table 16. OFAT Mean Annual Flow Values at Water Quality Monitoring Sites within Whitewater Region.

Site	Catchment Size (ha)	Mean Annual Flow (m^3/s)
PH-01	1,350	0.15
OS-01	3,810	0.40
MKR-01	5,480	0.56
MKR-03	5,490	0.66
BC-01	1,030	0.10
SC-02	2,130	0.20
SNR-04	37,980	3.63

Annual TP and TN loads were calculated for the seven sites using the mean annual flows calculated using OFAT and site median concentrations.

5.1.4.2 Total Phosphorus Loads

TP loads ranged from 52 kg/year at PH-01 to 4,751 kg/year at SNR-04 while TP loads per ha ranged from 0.04 kg/ha/yr (PH-01 and OS-01) to 0.53 kg/ha/yr (SC-02). SNR-04 (4,751 kg/yr), MKR-03 (1,270 kg/year) and SC-02 (1,123 kg/year) had the largest annual TP loads (Table 17), and the highest median TP concentrations.

Table 17. Mean Annual Total Phosphorus Loads in the Whitewater Region.

Site	kg/year	kg/ha/yr
PH-01	52	0.04
OS-01	151	0.04
MKR-01	512	0.09
BC-01	117	0.11
MKR-03	1,270	0.23
SC-02	1,123	0.53
SNR-04	4,751	0.13

5.1.4.3 Total Nitrogen Loads

Total nitrogen loads ranged from 1,293 kg/year at BC-01 to 76,699 kg/year at SNR-04 and 1.03 kg/ha/yr (OS-01) to 2.72 kg/ha/yr (SC-02). Higher TN concentrations at SNR-04 (median concentration of 0.92 mg/L) in combination with high flows (3.63 m^3/s) resulted in the largest annual TN load calculated in the Whitewater Region (Table 8, Table 16, Table 18)

Table 18. Mean Annual Total Nitrogen Loads for the Whitewater Region.

Site	kg/year	kg/ha/yr
PH-01	1,845	1.37
OS-01	3,910	1.03
MKR-01	7,064	1.29
BC-01	1,293	1.26
MKR-03	9,991	1.82
SC-02	5,803	2.72
SNR-04	76,699	2.02

Median TP and TN concentrations, as well as TP and TN loads/ha were all highest at SC-02, the next most nutrient-enriched sites were MKR-03 and SNR-04 (Table 19).

Table 19. Priority Areas Based on Concentrations and Loads.

Sites	Median TP	TP Load/ha	Median TN	TN Load/ha
PH-01	0.011	0.04	0.39	1.37
OS-01	0.012	0.04	0.31	1.03
MKR-01	0.029	0.09	0.40	0.29
BC-01	0.037	0.11	0.41	1.26
MKR-03	0.061	0.23	0.48	1.82
SC-02	0.178	0.53	0.92	2.72
SNR-04	0.042	0.13	0.65	2.02

Note: *A green, yellow, red, colour scheme is used to designate sites as hot spots based on concentrations and loads. Sites with low concentrations or loads are highlighted in green, intermediate values are highlighted in yellow and the highest values are highlighted in red.*

5.2 Land Use

5.2.1 OFAT Mapping

The area of agricultural lands within the catchment of each water quality sampling location was calculated using the Ontario Flow Assessment Tool (Table 20). Corresponding figures are provided in Appendix B. The amount of agricultural land ranged from 4.07 km^2 (PH-01) to 126 km^2 (SNR-04). Percent of agricultural land within each catchment was similar for most sites (30.4% to 42%) and highest at SC-02 (67.8%).

Table 20. The Amount and Percentage of Agricultural (and undifferentiated) Land within the Catchment of each Water Sampling Location.

Site	Agriculture and Undifferentiated Rural Land Use (km^2)	
	km^2	%
BC-01	4.33	42.0
MKR-01	21.0	32.2
MKR-03	16.7	30.4
OS-01	12.0	31.5
PH-01	4.07	30.1
SC-02	14.5	67.8
SNR-04	126	33.1

5.2.2 Within 1 km of Water Quality Sampling Locations

Dalton (2019) characterized land use in a 1000 m x 200 m wide area (100 m on either stream/river bank) using satellite imagery data. Percentages of annual crop land (primarily corn and soybean crops), pasture/forage land (pasture land and land that is periodically cultivated with grasses and perennial crops such as alfalfa and clover for hay, pasture and seed), natural habitat and developed land (road, buildings, paved surfaced, urban/suburban areas and associated vegetation) were calculated and are presented in Table 21 and in Appendix C. Annual crop land adjacent to most sites was 0% except for SNR-04 (10.3%) and SC-02 (27.4%). Pasture/forage land ranged from 0% (SNR-04) to 24% (MKR-01).

Table 21. Land Uses Adjacent to Water Sampling Locations

Site	Annual Crop Land (%)	Natural (%)	Pasture/Forage (%)	Developed (%)
BC-01	0.0	90.4	3.2	6.4
OS-01	0.0	91.7	5.7	2.5
MKR-01	0.0	71.2	24.0	4.8
PH-01	0.0	90.9	3.5	5.6
MKR-03	0.0	91.1	0.7	8.3
SNR-04	10.3	87.7	0.0	2.1
SC-02	27.4	66.8	2.4	3.4

6. Cobden and Snake River Provincially Significant Wetlands

Wetlands are among the most productive and diverse habitats which provide a variety of social and economic needs in Ontario such as wildlife habitat, fish habitat, flood control, erosion reduction, groundwater recharge and discharge, climate change mitigation and resilience, recreation and tourism, food source and water quality improvement. Provincially Significant Wetlands have been determined by the Ministry of Natural Resources and Forestry as being the most valuable based on the Ontario Wetland Evaluation System and the standardized approach for evaluating the biological, social, hydrological and species features components of the wetlands.

A complex array of biogeochemical processes within wetlands act to trap and transform incoming nutrients, retaining them in the system for days to years, depending on biotic and abiotic conditions. Nutrient assimilation occurs through biological uptake, sedimentation, adsorption, precipitation and accumulation of organic matter. The functioning of wetlands as nutrient sinks is influenced by a wide variety of factors including vegetation, soil properties, wetland shape and size, hydrologic fluctuations, surrounding land uses, loading rates, hydraulic retention time, and seasonality.

Overall, phosphorus removal efficiencies vary tremendously. Some studies reported a net increase in total phosphorus export or no removal (Geosyntec Consultants, Inc. and Wright Water Engineers, Inc. 2014; Chouinard et al. 2015), while others documented removal efficiencies of over 90% (Reddy et al. 1999; Chouinard et al. 2015). The high variability in phosphorus removal efficiencies is consistent with the wide range of possible biotic and abiotic conditions that influence phosphorus cycling in different wetlands, the dynamic nature of those conditions, and the ability of monitoring programs to capture them (e.g., of sufficient frequency to capture seasonal changes, interannual variability in weather conditions and the full range of flow conditions including floods). TP and TN concentrations and loads upstream and downstream of the Cobden and Snake River PSWs were calculated on a seasonal and annual basis to determine if the two PSWs were sources or sinks of TP and TN.

6.1 Cobden PSW

The Cobden PSW is a combination of swamp (39%) and marsh (61%) occupying 91.5 hectares of land. The site is 70% riverine and 30% lacustrine (Buckland and Beaudette, 1985a). The catchment upgradient of the outflow is 54 km^2 and 50% of the wetland has organic soils (Buckland and Beaudette, 1985a). Blanding's Turtle (threatened) and Spiny Softshell (threatened) have been observed within the PSW and within 100 m of the site (Muncaster Environmental Planning and Jp2g Consultants Inc., 2016). The wetland serves as a breeding or feeding habitat for Black Tern, Northern Harrier, and Marsh Wren and Pintail, Wigeon use the wetland during migration (Buckland and Beaudette, 1985a) and it's a spawning ground for Northern Pike (Muncaster Environmental Planning and Jp2g Consultants Inc., 2016). In 1985 the site was considered moderately disturbed due to roads, drainage, filling and the discharge of treated effluent from the Cobden Waste Water Treatment Plant (WWTP (located on a separate tributary not monitored in this study), Buckland and Beaudette, 1985a). It should be noted that Jp2g Consultants Inc. (2015) recommended that tertiary treatment and sludge control be implemented during WWTP upgrades which would reduce the amount of overflow and bypass events during spring and heavy rainfall and provide tertiary treatment which would further reduce nutrient loading to Muskrat Lake.

6.1.1 Total Phosphorus

TP concentrations at MKR-01, a station located on the Muskrat River upstream of the Cobden PSW and the discharge of Buttermilk Creek, and MKR-03, a station within the wetland complex downstream of Buttermilk Creek and MKR-01, were compared to determine if the Cobden PSW was acting as a sink or source of TP and TN. In general, the Cobden PSW acted as a TP source. TP concentrations were higher at the downstream site (MKR-03) compared to the upstream site (MKR-01) on 23 out of 25 occasions (Figure 15).

The differences in event-based TP concentrations were calculated and the median value for each month is presented in Table 22. TP concentrations increased marginally in April and October (0.009 mg/L) with greater changes noted in September (0.026 mg/L), July (0.035 mg/L), May (0.052 mg/L), June (0.077 mg/L) and August (1.00 mg/L). Mean annual TP loads were also greater downstream of the PSW (1,270 kg/year) compared to upstream (512 kg/year). The Cobden WWTP discharges effluent into the Cobden PSW and could contribute to elevated nutrient concentrations at MKR-03 but it is challenging characterizing the flow path of the effluent in the PSW based on available information.

Figure 15. Total Phosphorus Concentrations Upstream and Downstream of the Cobden PSW between 2014 and 2019.

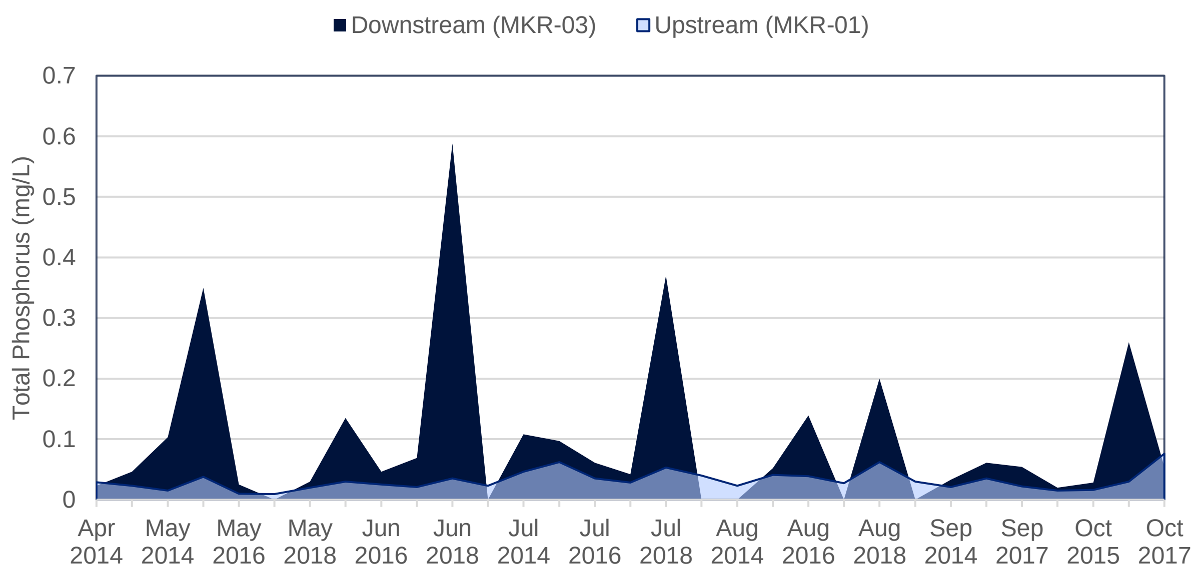


Table 22. Median Monthly Change in Phosphorus Concentrations in the Cobden PSW.

Month	Change in TP (mg/L)
April	+0.009
May	+0.052
June	+0.077

July	+0.035
August	+0.100
September	+0.026
October	+0.009

6.1.2 Total Nitrogen

Concentrations of TN were higher downstream at MKR-03 than MKR-01 on 18 out of 25 sampling occasions (Figure 15) indicating that the Cobden PSW generally acted as a source of TN. TN concentrations increased by 0.06 mg/L (August) to 0.19 mg/L (April), except in September when median concentrations decreased by 0.09 mg/L (Table 23, Figure 16). The mean annual TN load was also greater downstream (1,270 kg/yr) than upstream (512 kg/yr).

Figure 16. Total Nitrogen Concentrations Upstream and Downstream of the Cobden PSW between 2014 and 2019.

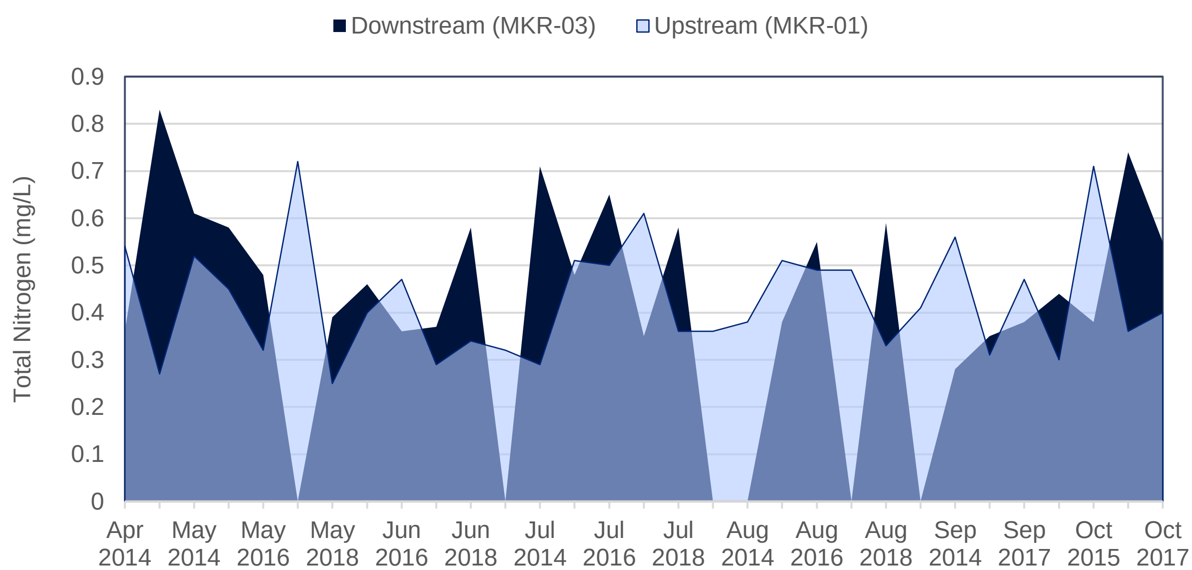


Table 23. Median Monthly Change in Total Nitrogen Concentrations Upstream and Downstream of the Cobden PSW.

Month	Change in TN (mg/L)
April	+0.19
May	+0.14
June	+0.07
July	+0.15
August	+0.06

September	-0.09
October	+0.15

6.2 Snake River PSW

The Snake River PSW is a mixture of deciduous swamp (84%) and marsh (16%) (MOE 2003) making up 879 hectares of land. The catchment basin above the wetland outflow is 302 km^2. The PSW is 95% riverine and 5% lacustrine at the river mouth. Soils in the wetland are a mixture of clays, loams or silts (35%), organic (55%) and undesignated (10%, Buckland and Beaudette 1985b).

Migratory birds, raptors, marsh wren and black-billed cuckoos frequent the PSW (MOE 2003) and it is a known nesting area for black tern (Buckland and Beaudette 1985b). The PSW is also known as critical spawning habitat for northern pike (Dillion 1995). It is susceptible to frequent flooding (MOE 2003) and has been disturbed by roads, drainage and railroad tracks (Buckland and Beaudette 1985b). MNR (2000) noted that the surrounding agricultural land use has impacted the nutrient status, plant diversity and abundance of the wetland.

6.2.1 Total Phosphorus

Several tributaries flow into the Snake River PSW. Water quality samples have been collected between April and October of 2014 and 2019 for three of these tributaries: SC-01, SC-02 and SNR-03. Water quality samples were also collected from the outlet of the Snake River PSW (SNR-04). Upstream concentrations were compared to downstream concentrations and upstream cumulative loads compared to downstream loads to evaluate if the Snake River PSW was a TP or TN sink between 2014 and 2019.

Average TP concentrations were greater upstream of the Snake River PSW compared to downstream on 31 out of 34 occasions indicating that the Snake River PSW was a sink for TP (Figure 17). The differences in event-based TP concentrations were calculated and the median value for each month is presented in Table 24. TP concentrations declined by 0.015 mg/L in April, 0.045 mg/L in May, 0.07 mg/L in June and between 0.102 mg/L and 0.135 mg/L in the remaining months.

The mean annual TP load downstream of the Snake River PSW (4,751kg/year) was slightly greater than the upstream load (4,589 kg/year). The greater load is due to the higher flow (3.63 m^3/s) downstream of the PSW compared to the three upstream sites (0.13 m^3/s at SC-01 + 0.2 m^3/s at SC-02 + 2.91 m^3/s at SNR-03 = 3.24 m^3/s). It should be noted that not all tributaries discharging to the Snake River PSW were monitored and therefore concentrations and flow entering the PSW were likely higher than those captured by the monitoring program and reported here. The Snake River PSW was a TP sink between 2014 and 2019 based on the decrease in TP concentrations downstream of the wetland.

Figure 17. Total Phosphorus Concentrations Upstream and Downstream of the Snake River PSW between 2014 and 2019.

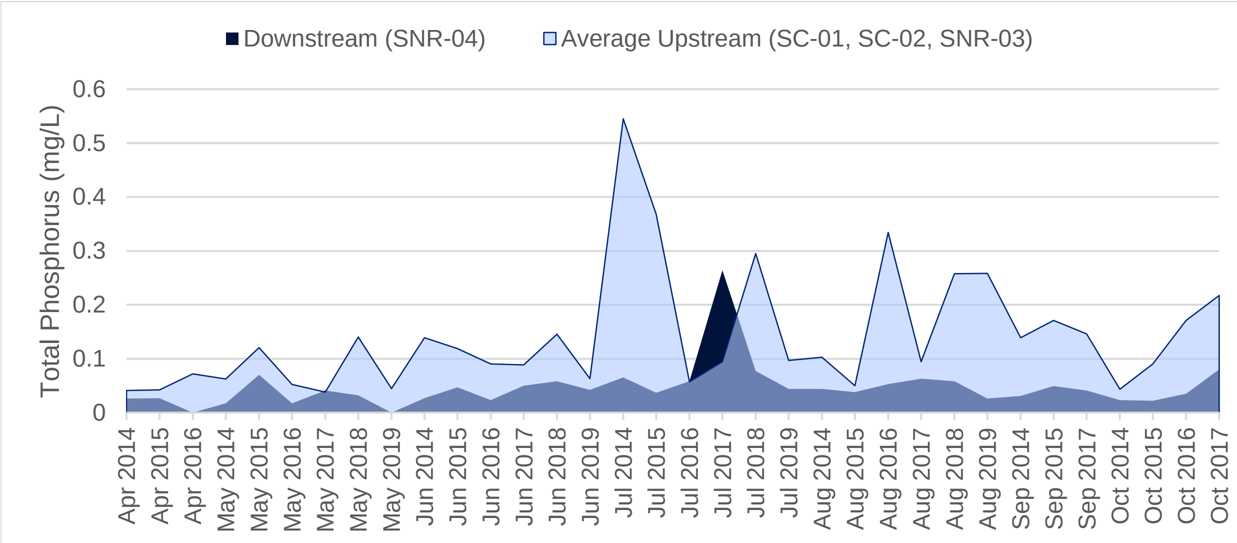


Table 24. Median Monthly Change in Phosphorus Concentrations Upstream and Downstream of the Snake River PSW.

Month	Change in TP (mg/L)
April	-0.015
May	-0.045
June	-0.070
July	-0.135
August	-0.129
September	-0.108
October	-0.102

6.2.2 Total Nitrogen

The Snake River PSW acted primarily as a sink for TN as average TN concentrations at the downstream sites were lower than the upstream site on 30 out of 34 sampling occasions (Figure 18). The differences in event-based TN concentrations were calculated and the median value for each month is presented in Table 25. Monthly median decreases in concentration from upstream to downstream ranged from 0.13 mg/L (May) to 0.80 mg/L (August, Table 25). The total upstream load (125,201 kg/yr) was substantially greater than the downstream load (76,699 kg/yr) providing further evidence that the Snake River PSW acted as a TN sink.

Figure 18. Total Nitrogen Concentrations Upstream and Downstream of the Snake River PSW between 2014 and 2019.

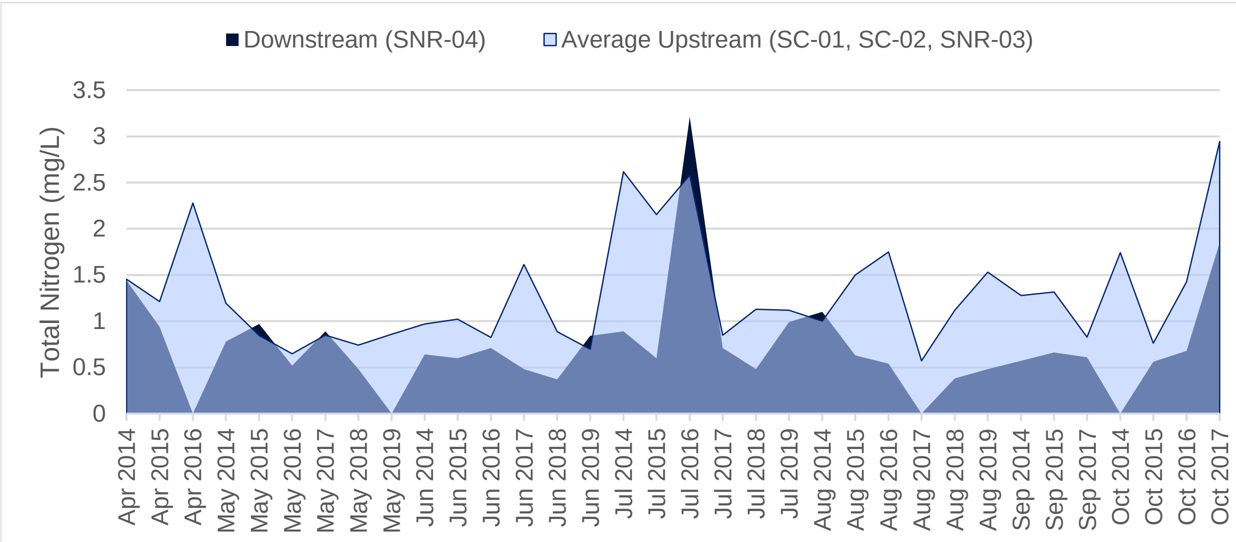


Table 25. Monthly Mean Total Nitrogen Concentrations Upstream and Downstream of the PSWs.

Month	Change in TN (mg/L)
April	+0.14
May	+0.13
June	+0.38
July	+0.40
August	+0.80
September	+0.66
October	+0.75

7. Identification of General Priority Areas

We identified the following general priority areas for future BMP implementation based on the results of the study (Figure 19):

1. SC-02 Catchment

Nutrient concentrations and loads/ha were the highest at SC-02 so future project phases should be focused in this area to reduce nutrient loading and nutrient concentrations in the Snake River PSW, Snake River and downstream Muskrat Lake. It should be noted however that the nutrients will be transformed in the PSW through a variety of biogeochemical processes and therefore a reduction in nutrient loads will not equal those that are displaced from Muskrat Lake.

2. Previously Flooded Areas

Flooding results in significant nutrient loading to downstream receiving waterbodies. Class two and three lands that flooded in the spring of 2019 should be assessed during future project phases in an attempt to lower nutrient loading from these areas and improve agricultural productivity. The majority of these previously flooded areas are located between the Snake River PSW and Muskrat Lake along the western shore of Muskrat Lake.

Prior to the virtual public meeting as described in Section 9.2, two property owners (Colin Fletcher and Doug Patterson) contacted the project team to identify an error in the mapping for Priority Area 2: Previously Flooded Areas for lands bounded by Highway No. 17, Poff Road and the Snake River Line. A site visit conducted on December 3rd, 2021, by a member of the project team confirmed that the elevation of farmland located within this area is much higher than flooded lands located along the Snake River, Snake River Wetland and Muskrat Lake. The data used to define the flooded lands included areal imagery of the 2019 spring flood prepared by NavCan. This NavCan information was provided to the Township through a data sharing agreement with the County of Renfrew. It was concluded that excessive amounts of water laying on croplands during the time period of the 2019 spring flood were interpreted by the areal imagery as flooded lands. A revised Priority Area 2 for flooded areas was prepared using the 124m contour elevation was prepared, circulated to Mr. Fletcher and Mr. Patterson for review and made available for review at the virtual public meeting and small group interview meetings. Based on input received from the public, there was general consensus that the revised Priority Area 2 mapping of flooded areas more accurately identifies the extent of flooded lands in the Study area.

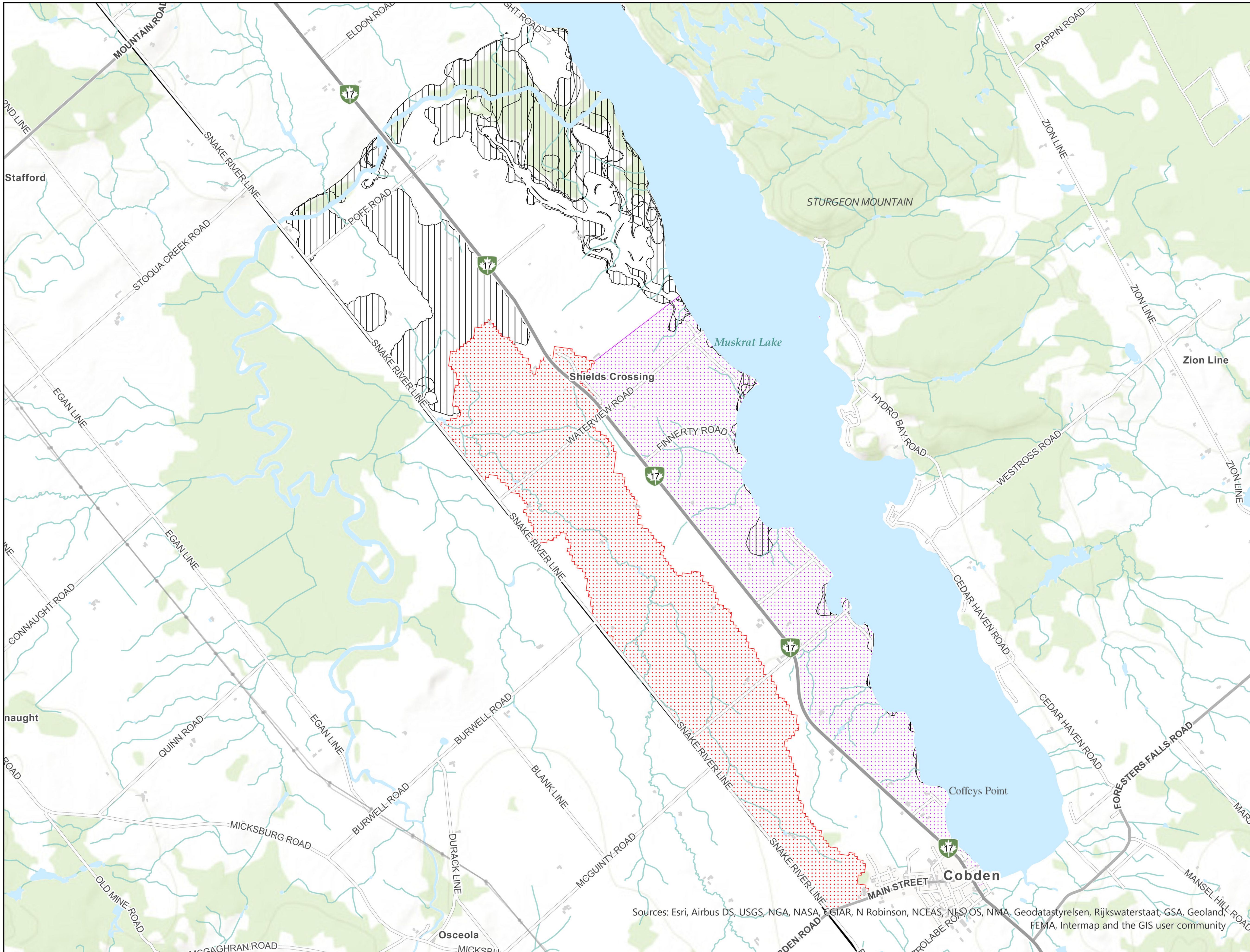
3. Muskrat Lake Riparian Lands

The Muskrat Lake watershed includes a number of agricultural lands that drain directly into the western shore of Muskrat Lake and runoff is not afforded phosphorus retention in watercourses, wetlands or other lakes. These lands should be examined as part of future project phases. Many of these agricultural operations appear to have little riparian buffer between cropland and the shoreline of Muskrat Lake.

Priority areas were further refined after consideration of agricultural BMPs and consultation; refined priority areas are discussed in Section 9.1.1 – 9.1.4.

Township of Whitewater Region
Watershed and Flood Data Map

Priority Areas for
Implementation of Future BMPs



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8. Agricultural BMPs

The intent of the agricultural treatment BMP's is to implement one or more options to provide a treatment train, which will capture and control sedimentation from agricultural areas prior to being discharged into the waterways, thereby ultimately reducing nutrient loading to downstream Muskrat Lake. The following treatment options are potentially in place but are not currently known or documented throughout the Muskrat River and Snake River Watersheds and could be implemented to improve water quality in the study area.

8.1 Stormwater Management Treatment Options

Stormwater Best Management Practices (SWM BMPs) can be implemented in three different zones: *At the Source* [where the rain lands], *Conveyance* [across the fields], and *End-of-Pipe* locations [immediately prior to discharge into the nearest waterway]. The following agricultural treatment BMPs were also considered: cattle exclusion fencing, milkhouse wastewater treatment, manure storage and clean water diversion.

8.1.1 End-of-Pipe Treatment

8.1.1.1 Wet Pond

According to the *Stormwater Management Planning and Design Manual* (MOE 2003), wet ponds are the most common end-of-pipe stormwater management facility employed in Ontario. They are less land-intensive than wetland systems and are normally reliable in operation, especially during adverse conditions (e.g., winter/spring). This reliability can be attributed to several factors:

- performance does not depend on soil characteristics;
- the permanent pool minimizes re-suspension;
- the permanent pool minimizes blockage of the outlet;
- biological removal of pollutants occurs; and
- the permanent pool provides extended settling.

Wet ponds can be designed to efficiently provide for water quality, erosion and quantity control, reducing the need for multiple end-of-pipe facilities. Wet ponds can be designed with extensive landscaping, contributing to the character of the agricultural setting.

8.1.1.2 Dry Pond

According to the *Stormwater Management Planning and Design Manual* (MOE 2003), dry ponds have no permanent pool of water. As such, while they can be effectively used for erosion control and flood control, the removal of stormwater contaminants in these facilities is purely a function of the detention time in the pond. For a 24-hour retention period, this normally means a lower contaminant removal (the inter-event settling time does not exist). While achieving this for smaller drainage areas can be difficult, the use of dry ponds in larger catchments may have greater potential than previously considered. However, there are no documented performance monitoring data for dry ponds with longer detention times and re-suspension of settled material remains a concern. As such, the use of dry ponds (for water quality improvement) remains largely restricted to retrofits, where temperature is an overriding concern, and situations where other more effective SWMP types are not feasible. Dry ponds may be used as part of an overall treatment train approach.

8.1.1.3 Hybrid Wetland

Hybrid wet pond/wetland systems consist simply of a wet pond element and a wetland element, connected in series (MOE, 2003). The system provides for the deep-water component which will be least impacted by winter/spring conditions and the wetland component which provides enhanced biological removal during the summer months. In terms of land requirements, it falls between the amounts needed for wet ponds and wetlands.

Hybrid systems present a more diverse range of opportunities to achieve aesthetic and ecological objectives since they afford greater design flexibility and a diversity of landscape elements.

The design of a hybrid system should be based on the guidance provided for each element (i.e., wet ponds (Section 4.6.2, MOE 2003) and wetlands (Section 4.6.3, MOE 2003)), with the following clarifications:

- Volumetric sizing of the permanent pool should be based on the Hybrid Wet Pond/ Wetland SWMP type as presented in Table 26. This assumes that the wet pond comprises 50% of the total permanent pool volume;
- A forebay is required for the wet pond (based on the size of the wet pond, not the entire system) but is not required for the wetland (the wet pond serves this purpose);
- Active storage depth restrictions for wetlands apply to the entire system, unless a terraced, overflow configuration is adopted;
- Detention time for the entire system should be targeted at 24 hours; and
- Length-to-width ratio for the wet pond element may be reduced to 2 to 1, although a higher ratio is encouraged.

Table 26. Water Quality Sizing (MOE 2003)

Protection Level	SWMP Type	Storage Volume (m^3/ha) for Imperviousness Level			
		35%	55%	70%	85%
Enhanced 80% long-term suspended solids removal	Infiltration	25	30	35	40
	Wetlands	80	105	120	140
	Hybrid Wet Pond/Wetland	110	150	175	195
	Wet Pond	140	190	225	250

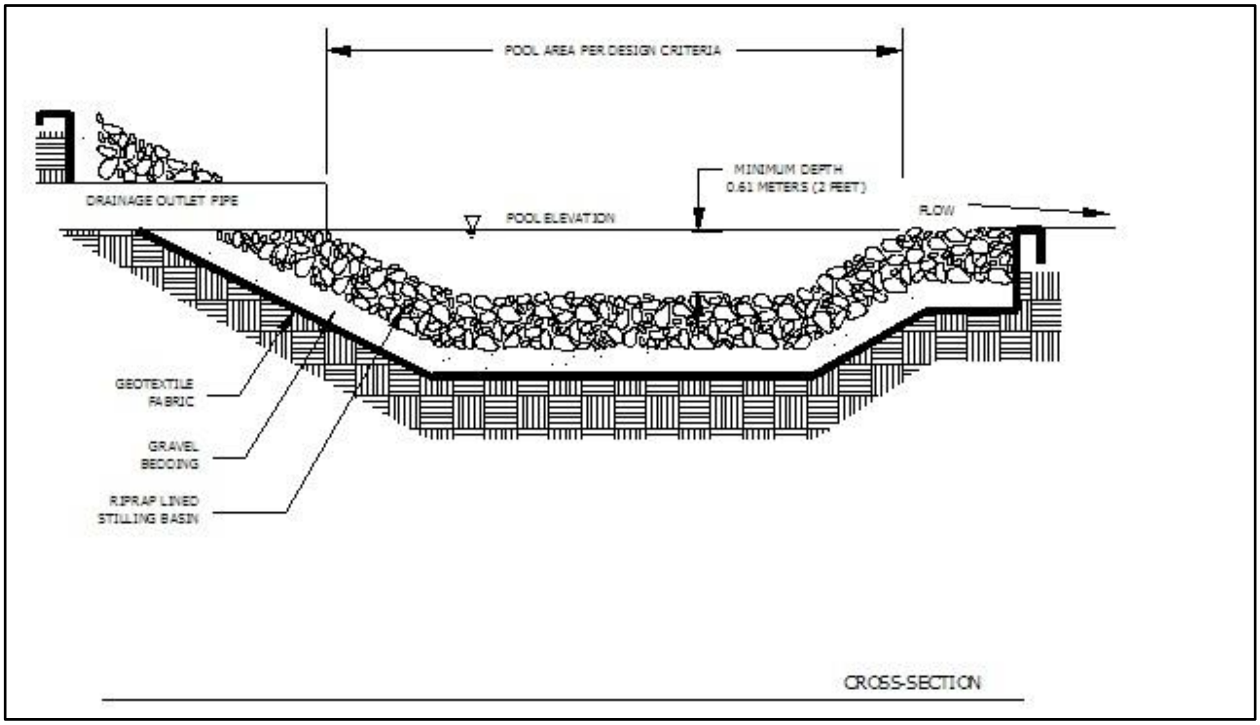
8.1.1.4 Plunge Pool

Plunge pools can be implemented along existing watercourses or drainage outlets to act as storage basins for runoff (Figure 20). A plunge pool functions to dissipate energy and moderate velocities which in turn aid in limiting the re-suspension of accumulated sediments. Plunge pools should be excavated to a greater depth than required and allowed to fill in and reshape to correspond with flow characteristics.

Once this evolution of form has taken place, the plunge pool will maintain itself at the required depth. An outlet weir can be used to control the water level in the plunge pool. Plant material interlaced with riverstone to create a weir that is resistant to breaching and will accumulate trash and other floatables, which will allow more efficient removal. Plunge pool energy dissipators are recommended to prevent scour and erosion at the point of discharge.

An outlet sediment trap is a small basin lined with riprap and located at the end of an outlet pipe, or channel outlet. It is designed similar to a plunge pool, to dissipate the energy of the incoming runoff. This device can be used where insufficient space is available.

Figure 20. Plunge Pool (Mass Highways 2004)

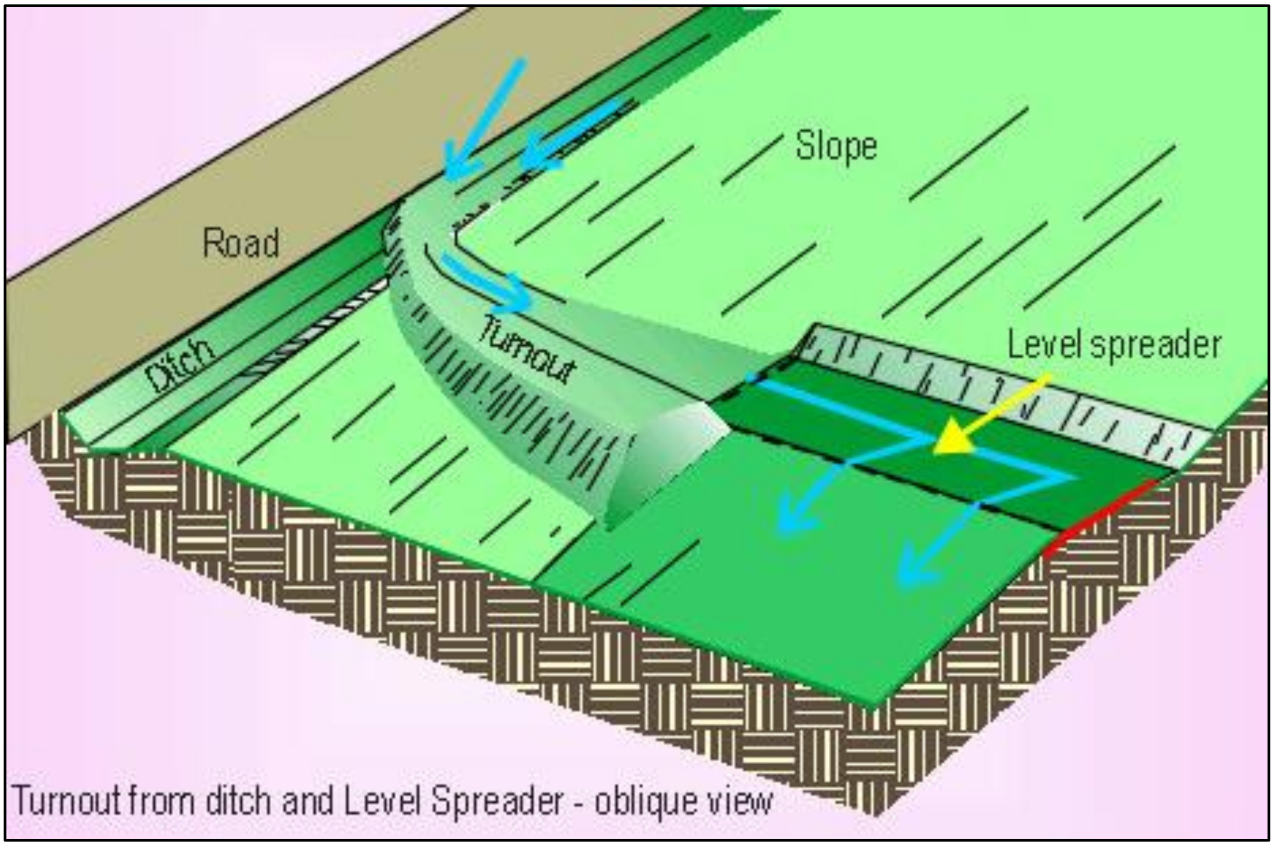


8.1.2 Conveyance Treatment

8.1.2.1 Flow Spreaders

Flow spreaders can reduce the velocity of flows by distributing runoff as sheet flow. This reduces the erosive potential of a concentrated stream. A level spreader consists of a raised weir constructed perpendicular to the direction of flow. Some common types of level spreader devices are pea gravel diaphragms and earthen berms. An example of a flow spreader is shown below in Figure 21.

Figure 21. Level Spreader Example (U.S. Army Corps of Engineers undated).



8.1.2.2 Vegetated Filter Strips

Vegetated filter strips are engineered stormwater conveyance systems which treat small drainage areas. Generally, a vegetated filter strip consists of a level spreader and planted vegetation. The level spreader ensures uniform flow over the vegetation which filters out pollutants and promotes infiltration of the stormwater.

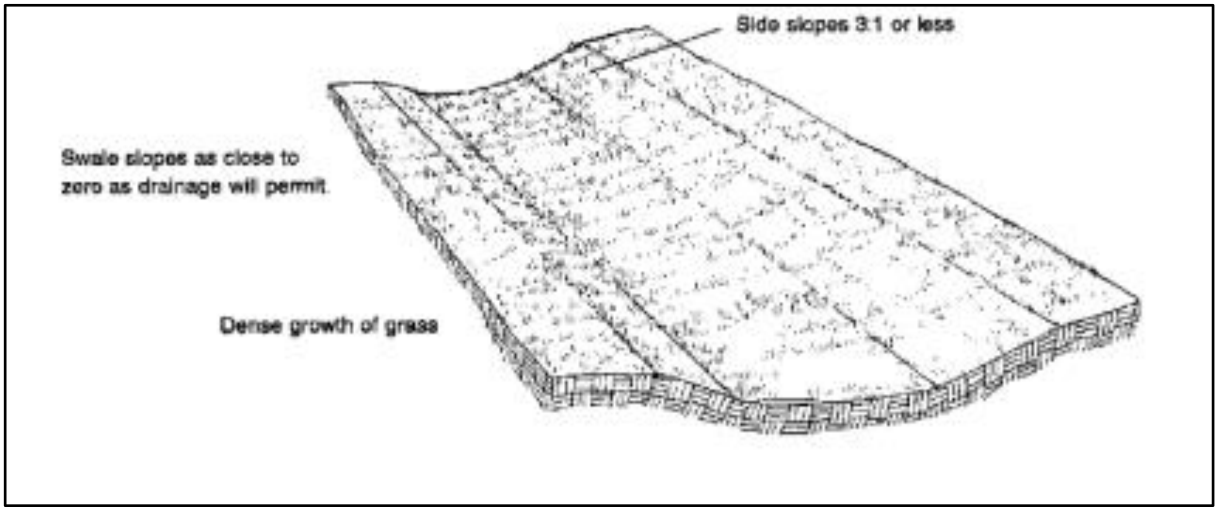
Vegetated filter strips are best utilized adjacent to a buffer strip, watercourse or drainage swale since the discharge will be in the form of sheet flow, making it difficult to convey the stormwater downstream in a normal conveyance system (swale or pipe).

8.1.2.3 Enhanced Grass Swale

Enhanced grass swales are vegetated open channels that convey, treat and attenuate stormwater runoff. Flat bottoms and vegetation in the swale decrease the velocity of the water, allowing for sedimentation, filtration through the root zone and soil, evapotranspiration, and infiltration into the underlying soil (CVC & TRCA, 2010). Check dams can also be added to grass swales to further reduce velocity and enhance infiltration. An enhanced grass swale is illustrated in Figure 22.

Check dams and vegetation in the swale slows the water to allow sedimentation, filtration through the root zone and soil matrix, evapotranspiration, and infiltration into the underlying native soil. Simple grass channels or ditches have long been used for stormwater conveyance, particularly for roadway drainage. Enhanced grass swales incorporate design features such as modified geometry and check dams that improve the contaminant removal and runoff reduction functions of simple grass channel. A dry swale is a design variation that incorporates an engineered soil media bed and optional perforated pipe underdrain system. Enhanced grass swales are not capable of providing the same water balance and water quality benefits as dry swales, as they lack the engineered soil media and storage capacity of that best management practice.

Figure 22. Enhanced Grass Swale (CVC and TRCA 2010).



8.1.2.4 Field Contouring

Fields within the watersheds can be re-contoured to promote infiltration or re-direct stormwater runoff to another treatment option. Field contouring construction is an extension of the practice of plowing fields at a right angle to the slope. The contour ditches are dug along a hillside in such a way that they follow a contour and run perpendicular to the flow of water. The soil excavated from the ditch is used to form a berm (a narrow shelf) on the downhill edge of the ditch. The berm can be planted with permanent vegetation (native grasses, legumes) to stabilize the soil and for the roots and foliage in order to trap any sediment that would overflow from the trench in heavy rainfall events.

8.1.2.5 Earth Dams/Berms

Dams or berms can be constructed in areas where the stormwater runoff is problematic. The dams or berms can retain the runoff and act as a level spreader. A weir can be constructed at the top of the berm to convey flows.

The California Stormwater Quality Association Stormwater BMP Handbook (2003) considers a check dam to be a small barrier constructed of rock, gravel bags, sandbags, fibre rolls, or reusable products placed across a constructed swale or drainage ditch. Check dams reduce the effective slope of the channel thus reducing the velocity of the surface water runoff, which enhances sedimentation and reduces erosion. It is important to note that check dams will reduce the capacity of the swale. Therefore, extra storage and/or conveyance may be required in order to restore the hydraulic capacity. This can be accomplished by increasing the size – depth and/or width – of the swale.

8.1.2.6 Minor Vegetative Buffers

Buffer strips are simply natural areas between development and the receiving waters. There are two broad resource management objectives associated with buffer strips:

- The protection of the stream and valley corridor system to ensure their continued ecological form and functions; and
- The protection of vegetated riparian buffer areas within the valley system to minimize the impact of development on the stream itself (filter pollutants, provide shade and bank stability, reduce the velocity of overland flow).

Although both types of buffers provide only limited benefits in terms of stormwater management, they are an integral part of overall environmental management for sustainable development. The protection of stream and valley corridors provides significant benefits in terms of sustaining wildlife migration corridors, terrestrial and aquatic species food sources, terrestrial habitat, and linkages between natural areas. Given the larger scale natural system benefits provided by stream and valley corridors, the required width of this type of buffer is best defined at the sub-watershed plan level. Individual conservation authorities and municipalities have developed their own guidelines for buffer areas. The designer should confirm local requirements with the applicable authority.

8.1.2.7 Major Vegetative Buffers

Vegetative buffers can be implemented in areas adjacent to existing watercourses. As mentioned above, there are existing vegetative buffers at some locations throughout the watersheds draining to Muskrat Lake. Multiple vegetative species can be planted along the embankments or adjacent to the watercourse for optimal sediment removal. Vegetative buffers can provide bank stability, filter pollutants, and reduce the velocity of overland flow.

8.1.3 At the Source

8.1.3.1 Tile Drainage

Tile drains are designed to remove excess water quickly from below the soil surface to avoid crop damage and decreased yields. Tile drainage impacts hydrology substantially by increasing water output, reducing surface runoff and sedimentation, and eliminating saturated areas.

8.1.3.2 Soakaways and Infiltration Trenches

On sites suitable for underground stormwater infiltration practices, there are a variety of facility design options to consider, such as soakaways, infiltration trenches and infiltration chambers.

Soakaways are rectangular or circular excavations lined with geotextile fabric and filled with clean granular stone or other void forming material, that receive runoff from a perforated pipe inlet and allow it to infiltrate into the native soil. They typically service individual lots and receive only roof and walkway runoff (MOE, 2003) but can also be designed to receive overflows from rainwater harvesting systems. Soakaways can also be referred to as infiltration galleries, dry wells, or soakaway pits.

Infiltration trenches are rectangular trenches lined with geotextile fabric and filled with clean granular stone or other void forming material. Like soakaways, they typically service an individual lot and receive only roof and walkway runoff. This design variation on soakaways is well suited to sites where available space for infiltration is limited to narrow strips of land between buildings or properties, or along road rights-of-way. They can also be referred to as infiltration galleries or linear soakaways.

8.1.3.3 Hickenbottom

Hickenbottoms are drain inlets that can be utilized in a variety of agricultural applications (Figure 23). Each hickenbottom inlet is made of high-density polyethylene insuring the longevity and durability of the product. The inlet area is greater than the restricted outlet, eliminating suction and trash plug-ups. A special inlet riser may be installed to maintain ponding at a certain level improving water filtration in semi-arid regions. Hickenbottoms are also known as vertical drains (EMCO Waterworks undated), primarily serving to collect water retained in low-lying agricultural land. Hickenbottoms allow some soil particles and pollutants to settle out.

Figure 23. A view of a hickenbottom installed in an agricultural setting (Soleno 2021).

8.1.4 Agricultural Treatment

8.1.4.1 Cattle Exclusion Fencing/Livestock Restriction

"*Fencing can be repaired or installed to restrict livestock access to watercourses to reduce the potential for contamination and to reduce stream bank erosion*" (Cole Engineering 2016). According to the United States

Department of Agriculture (USDA), "*A Livestock Exclusion System means a system of permanent fencing (board, barbed, high tensile or electric wire) installed to exclude livestock from streams and critical areas not intended for grazing to improve water quality. Benefits may include reduced soil erosion, sedimentation, pathogen contamination and pollution from dissolved, particulate, and sediment-attached substances*" (North Carolina Department of Agriculture & Consumer Services undated).

Based on the *Streamside Livestock Exclusion* study, "Even a small separation of livestock and their manure from the stream can significantly reduce the contribution of manure-borne bacteria to the stream." Streamside fencing can reduce negative water quality impacts by excluding livestock from the stream. Streambanks become more stable, and the diversity and abundance of riparian vegetation is improved (Zeckoski et al. 2012).

8.1.4.2 Milkhouse Wastewater Treatment

"*Milkhouse wastewater refers to wastewater generated from cleaning milking equipment, pipeline, bulk tank, and milk parlour floor which can contain manure, bedding, and feed. The wastewater not only includes phosphorus from milk proteins, fat, bedding, feed, and manure, but also from the detergents and acid rinses used in the cleaning procedures. Milkhouse wastewater can be treated by constructing or expanding a nutrient storage facility for dairy operations. It holds the waste for several days to allow settling. A treatment facility can also be constructed that may included a flocculator to enhance settling, vegetated filter strips, constructed wetlands, lagoons, or ponds.*

The siting or type of milkhouse wastewater treatment structures can be limited by setbacks to surface water, wells, field drains, proximity to nearby neighbouring dwellings, topography, floodplain restrictions, soil type, and depth to water table and bedrock. The structure must comply with the Canadian Farm Building Code, Nutrient Management Act, and Ontario Water Resources Act. It may also require approval under the Environmental Protection Act.

Maintenance of the system can include inspection, addition of chemicals (if using a flocculator system), and removal of sediment and debris. Maintenance costs vary depending on the system in place" (Cole Engineering 2016).

In New Brunswick, an innovative technology was introduced involving flocculators to remove the majority of phosphates and suspended solids from the milkhouse effluent. The effluent and a proportionate amount of hydrated lime sits undisturbed for two hours to encourage settling and then the clarified liquid is discharged to a tile field while the sludge is sent to the manure storage (Government of New Brunswick undated).

8.1.4.3 Manure Storage

"*A manure storage structure is constructed or repaired to provide proper manure storage that will not be carried away during a storm event. A berm, settling basin, and/or buffer strip can also be used for control of manure. These measures are implemented to replace a stacked manure pile.*

These structures are limited by setbacks to surface water, wells, field drains, proximity to nearby neighbouring dwellings, topography, floodplain restrictions, soil type, and depth to water table and bedrock. The structure must comply with the Canadian Farm Building Code and Nutrient Management Act (NMA). Manure storage has a potential benefit of odour reduction and control and can also contain bacteria which would otherwise be transported in runoff. It has a high TP removal capability, The amount of TP removed can be calculated based on the number of farm animals, type of animal, and type of farm (feedlot or dairy). Operations and maintenance costs depend on the type of storage cover and structure" (Cole Engineering 2016).

Ontario Soil and Crop states that "proper manure storage is an important factor in protecting water resources in close proximity to livestock facilities." The size of the storage facility is very important since it determines how much manure can be stored and how often and how much manure is spread (OMAFRA and MOE 2005) so that the producer can find the optimum time to apply manure that balances environmental risks with their crop rotation and, equipment and labour availability. These types of BMP projects help reduce the quantity of manure and nutrients potentially entering waterways through potential runoff (Cole Engineering 2016).

8.1.4.4 Clean Water Diversion

"*Clean water diversion structures can be installed to direct clean water away from barnyards and other sources of contamination. Structures can include eavestroughs, berms, or ditches. This method is physically constrained primarily by topography and proximity to any permanent nutrient storage facilities. Maintenance activities may include inspection, repairs due to erosion, and cleaning debris*." (Cole Engineering 2016).

9. Public and Agency Consultation

9.1 Purpose and Approach

The purpose of the public and agency consultations was to obtain public input from farmers, property owners and interest groups on the BMP's that would be best suited within the priority areas for reducing nutrient loading on wetlands and Muskrat Lake. The interviews also assisted in defining the revised priority areas for future BMP implementation.

Public and agency consultation included a virtual public meeting followed by small group meetings (interviews) with farmers, property owners and NGO's. The virtual public meeting was held on Wednesday, December 8, 2021, and the interviews with farmers, property owners and NGO's were held on December 9th and 14th, 2021 and January 6th, 2022.

9.2 Virtual Public Meeting

In advance of the detailed consultations, an "Invitation for Public and Agency Consultation" in the form of a newsletter was circulated to all property owners and farmers within the three (3) general priority study areas identified in the Planning Phase of the Study as well as to all individuals and organizations listed in the public and agency contact list which is attached in Appendix A. The newsletter invited all farmers, property owners and organizations to attend the public meeting on December 8th and/or participate in the one-on-one/small group meetings (2-3 people) on December 9th. Information on the location of the general priority study areas, a Draft of the Study up to and including the Background and Planning Phases were available on the Township's website, as well as information on Next Steps for the Study. A copy of the newsletter and list of public and agency contacts is contained in Appendix A.

At the virtual public meeting on December 8th, 2021, the project team made a formal presentation to approximately 12 individuals and NGO representatives. This presentation included:

- An explanation of the purpose of the Study to identify general priority areas for the implementation of BMP's for reducing nutrient loading to wetlands and Muskrat Lake;

- The scientific approach used to determine general priority areas for the implementation of BMP's.

- An overview of the types of BMP's for:
    - At-the-Source Treatment: where the rain lands;
    - Conveyance Treatment: across the fields;
    - End-of-Pipe Treatment: immediately prior to discharge into the nearest waterway; and
    - Agricultural Treatment.

- Next steps including:
    - One-on-one and/or small group meetings to discuss BMP's;
    - Identification of most suitable BMP's within Priority Areas;
    - Assessment of net costs and environmental benefits of BMP's; and
    - Preparation and Implementation of an Action Plan.

Discussions following the project team presentation included general discussions about BMPs, the scientific approach used to define the Priority Study Areas, the desire by some participants to participate in one-on-one meetings and a concern from a property owner about the impacts of surface drainage from "Priority Area 1: SC-02 Catchment" on farmlands located outside of project study area in the adjacent Municipality of Admaston Bromley. All property owners and NGO representatives attending the virtual public meeting were encouraged to attend the one-on-one meetings (interviews), including the property owner located adjacent to the Study Area in Admaston Bromley.

9.3 One-on-one/Small Group Meetings (Interviews)

The interview approach and general comments arising from the one-on-one/small group meetings are summarized in the following sections.

8.3.1 Survey Approach

A total of six (6) in person interviews, two (2) virtual interviews and one (1) telephone interview were conducted with farmers and representatives from the Muskrat Lake Association, Muskrat Watershed Council and the Renfrew County Federation of Agriculture. Five (5) of the farmers and NGO representatives who participated in the on-on-one/small group meetings also participated in the virtual public meeting. The interviews were conducted by planning and drainage engineering staff from Jp2g Consultants Inc., with the assistance of the Township's Planner/Economic Development Officer and Manager of Community

Development. Aerial imagery maps showing the location of the Study priority areas, property fabric and the 124m contour for the estimated 2019 flood elevation were available for review with each interviewee.

A list of the persons interviewed is attached in Appendix D and a plan showing the location of their properties is attached in Appendix E. Participation included representation from farmers owning and farming lands located within all three general priority areas defined in the Planning Phase of the Study. It is estimated that the total area of land owned by farmers participating in the interviews represents approximately 50% of the total farmlands with the priority study areas.

Each meeting was scheduled to take approximately one (1) hour and included a semi-structured interview process designed to:

- Confirm the purpose of the Study and detailed consultations;
- Review the priority study areas, including amendments to Priority Area 2: Previously Flooded Lands;
- A review of the location and description of their property or properties within the study area in relation to the priority study areas and general discussions on site features, drainage and farming practices;
- General discussion on BMPs and specific discussions with property owners on BMPs that would be most suitable for the property or properties owned by the farmer.

8.3.2 General Comments

It was determined from the interviews that tile drainage is extensively used throughout the study area. Most of the landowners use no-till farming and produce cash crops. The landowners participating in the interviews were generally interested in implementation of BMPs on their properties.

Many residents were interested in the implementation of berms and/or flow spreaders on the edge of their properties. Flow spreaders would ensure that the agricultural runoff would remain on the field to a certain flooding depth. Minor and/or major vegetative buffers were also widely received within the study area, for implementation between fields and adjacent waterways. As there are many small tributaries within the study area, there is an opportunity to implement buffers. This could include the addition of trees and shrubs between agricultural land and waterways.

A few of the landowners were interested in end-of-pipe treatment, including a dry pond, plunge pool, and wetland or wet pond. End-of-pipe treatment can be implemented at the outlet of the Unnamed Creek or any outlet prior to entering Snake River or Muskrat Lake. Favourable conditions for end-of-pipe treatments include at least 2 hectares of contributing land, land contoured towards the low area, and a watercourse nearby to connect to the outlet. Plunge pools can be used for small area outlets.

Representatives from the Muskrat Watershed Council (MWC) provided valuable information based on their local knowledge of agricultural land and the community within the study area. This includes recent trends toward farmland purchases for cash cropping purposes and a significant increase in the installation of tile drainage in recent years. The MWC also shared their experiences with the implementation of BMP initiatives including a tree planting program and controlled tile drainage which have been implemented by the Muskrat watershed.

Input from the Muskrat Lake Association (MLA) included concerns about the impacts of municipal drains (e.g. Harris Drain) and nutrient loading on Muskrat Lake and the importance of farming best management practices including the use of cover crops for minimizing the flow of nutrients and sediments during spring flooding events. Follow-up correspondence received from the MLA supports a recommended approach advanced in Great Lakes Water Quality (International Joint Commission [IJC] 2017). The IJC Report describes the limited success in implementing BMPs for achieving reduced phosphorous loading targets for the western Lake Erie basin and recommends “enforceable standards and regulatory actions” for the implementation of domestic action plans (BMPs) that include timelines for the implementation of actions, project leads, or teams responsible for expected deliverables and outcomes and quantifiable performance metrics in order to ensure accountability.

Representatives from the farming community interviewed were advised by Township Staff and the Consultants that the terms of reference for this Study is intended for the preparation of education materials and the development of partnerships for the implementation of BMPs within the defined priority areas.

10. BMP Implementation Strategy

BMPs should be selected and implemented depending on physical conditions such as soil type, bedrock location, maintenance requirements, field slopes, water table, property limits, and accessibility. Favourable conditions associated with the various BMPs presented in Section 8.1 are summarized in Table 27. Suitable conditions were discussed with farmers and landowners, and used to determine appropriate BMPs for implementation as presented in Sections 10.1.1 – 10.1.4.

Table 27. Agricultural BMPs and Favourable Conditions for Implementation.

BMP	Favourable Conditions
Wet Pond	• Greater than 5 hectares of contributing land • Land contoured towards low area • Low infiltration rate of existing soil keeping water within the pond • Pond accessible for routine maintenance • Watercourse nearby to connect pond outlet
Dry Pond	• Greater than 2 hectares of contributing land • Land contoured towards low area • Low to high infiltration rate of existing soil acceptable • Pond accessible for routine maintenance • Watercourse nearby to connect pond outlet
Hybrid Wetland	• Greater than 5 hectares of contributing land • Land contoured towards low area • Low infiltration rate of existing soil acceptable maintaining permanent water • Wetland/watercourse nearby to connect outlet.
Plunge Pool	• Small area outlets (i.e. field ditch or tile drain outlet) • Outside of tilled areas (rocks may get in machinery)

	• Easy access for maintenance (sediment removals) • Can be in series or in parallel, supporting multiple outlets • Areas that see steady flow, but not flooding.
Flow Spreaders	• Areas with concentrated flow • Along a watercourse, tree line, or vegetive buffer • Outside of tilled areas • Accessible for sediment removals • Generally flat lands to ensure flows don't erode berm and berm can be constructed at straight elevation
Vegetated Filter Strips	• Outside of tilled areas, providing separation between fields, watercourses, or other vegetation • Low slope, promoting sediment trapping/removal and infiltration
Enhanced Grass Swales	• Outside of tilled areas, providing separation between fields, watercourses, or other vegetation • Connection to watercourses • Low slope, promoting sediment trapping/removal and infiltration • Sufficient depth to allow for ponding/flooding • Minimal grass cutting to promote taller growth within the swale
Field Contouring	• Fields with mild to moderate slopes • Within the tilled areas • Moderate to high infiltration rates of existing soils
Earth Dams/Berms	• Similar to the flow spreader, but requires more area available for storage/flooding due to the larger size • Best used along a watercourse to prevent flooding/erosion of a field
Minor Vegetative Buffer	• Along a swale/ditch/watercourse or property limit • Outside of tilled areas • Low slope, promoting sediment trapping/removal and infiltration
Major Vegetative Buffer	• Along a swale/ditch/watercourse or property limit • Outside of tilled areas • Low slope, promoting sediment trapping/removal and infiltration • Larger buffer limits
Tile Drainage	• Within the tilled areas • Low slope within the fields • Sufficient depth on the outlet ditch/watercourse for tile outlets • Moderate to high infiltration rates of existing soils • Low groundwater table
Soakaways, Infiltration, Trenches	• Outside of tilled areas and watercourse flooding • Low groundwater table • high infiltration rates of existing soils
Hickenbottom	• Outside of tilled areas and watercourse flooding • Low groundwater table • High infiltration rates of existing soils
Cattle Exclusion Fencing/Livestock Restriction	• Fencing limits free of obstructions (i.e. trees, sharp drop-offs, easements, etc.) • Exterior access not required (or gates installed) • Land mildly sloped at limits of the fence

	• Treatment BMP's (such as vegetated filter strips or vegetated buffers) located around the exterior perimeter of the fence
Milkhouse Wastewater Treatment	• Available capacity in existing nutrient storage systems • Grade separation sufficient to outlet nutrient storage tank liquids • Available space to install nutrient storage system
Manure Storage	• Available capacity in existing storage system • Available space to install manure storage system • Large separation distances to living spaces • Separation fencing or walls to prevent accidental animal falls into the space
Clean Water Diversion	• Moderate to high infiltration rates of existing soils • Land sloping contoured to separate nutrient area and clean water flows or can be graded to establish separation.

Consultation was undertaken with landowners in the priority areas both as part of project presentations and one-on-one meetings. Through consultation and an examination of site-specific features and conditions such as those discussed in Table 27, priority areas were refined to focus on specific features and several BMPs were shortlisted for each priority area. Descriptions of shortlisted BMPs and related nutrient reduction efficiencies associated with each refined priority area are provided in the following paragraphs.

Tile drains were also discussed with landowners as tile drains are commonly implemented to improve agricultural productivity and provide pathways for nutrient reduction as they reduce surface runoff and provide additional capacity for infiltration. Tile drains were previously installed as part of pilot projects in the Muskrat Lake watershed (Dalton 2019) as substantial nutrient reductions efficiencies for nitrate (65%) and phosphorus (63%) have been reported (Agriculture and Agri-Food Canada 2010). Based on a review of recent peer-reviewed literature, it appears that nutrient reduction associated with tile drains is less certain and is dependant on soil characteristics, flow and seasonality. Moore (2016) noted highly variable results in literature that range from nutrient loads that are two orders of magnitude lower to loads that are higher after installation of tile drains. Klaiber et al. (2020) found that tile drainage substantially reduces surface runoff, total suspended solids and soluble reactive phosphorus but it doesn't impact TP exports. Tile drain installation and calculations of related nutrient reduction should be completed as part of site-specific applications where an accurate depiction of site conditions and the SWM treatment train can be properly assessed.

10.1.1 Refined Priority Area #1a – Unnamed Creek within SC-02 Catchment

Priority Area 1 includes surface drainage farmlands that flow into a watercourse called the "Unnamed Creek" that drains into a low-lying area where pooled water is pumped into a culvert (Photograph 8) along the Snake River Line, Snake River PSW and adjacent farmlands in the geographic township of Bromley (Figure 24).

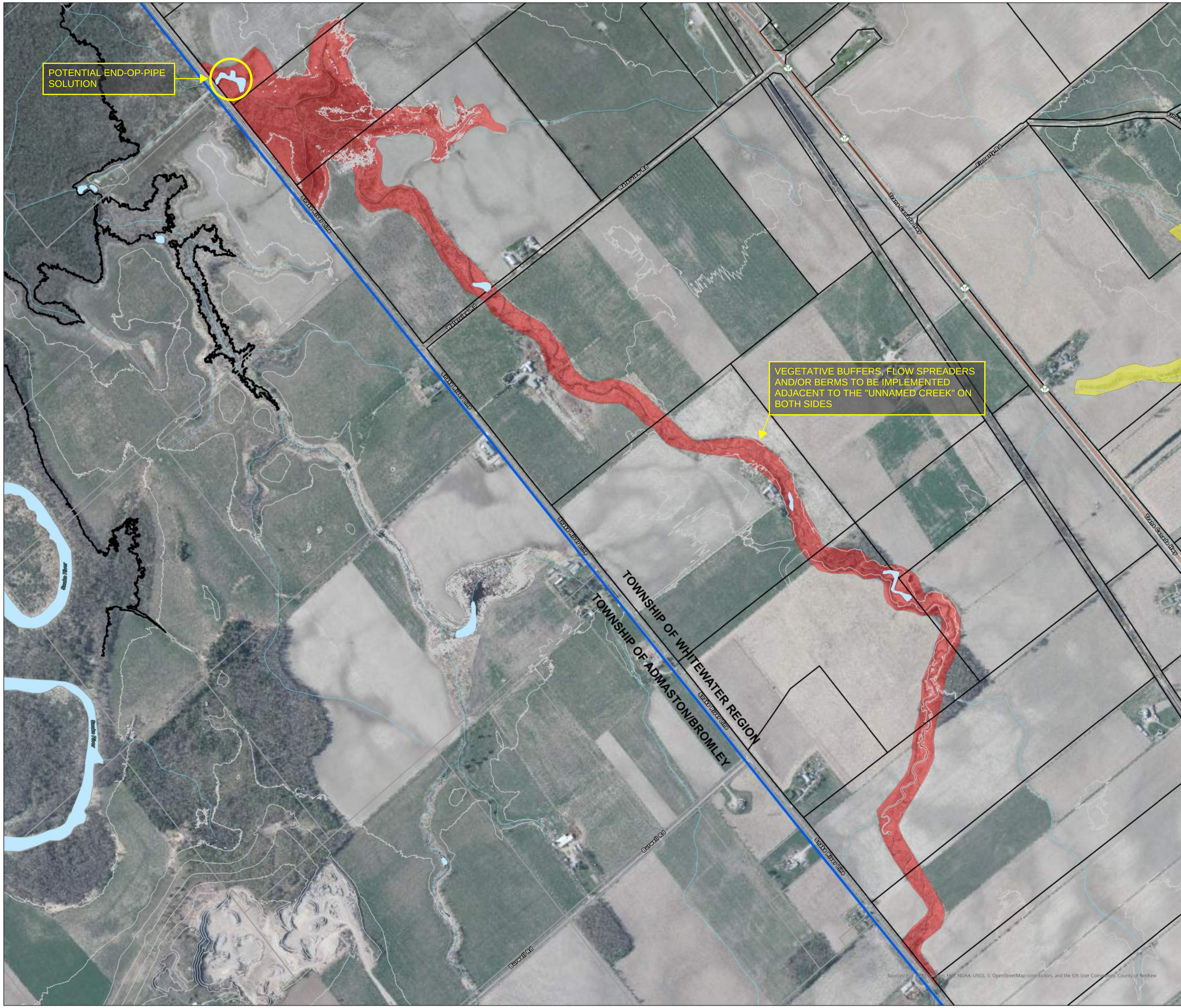
The unnamed creek is surrounded by agricultural lands and vegetative buffers are limited throughout much of the reach indicating that nutrient-rich, agricultural run-off flows into the unnamed creek which empties into the Snake River PSW and ultimately, Muskrat Lake. Based on interview discussions, it is concluded that there is an opportunity to work with farmers to implement buffers, berms and/or flow spreaders along the edge of Unnamed Creek. Vegetative buffers primarily reduce nutrient loads through filtering, infiltration and nutrient uptake (Table 28). Nutrient reduction effectiveness is determined by buffer width and vegetation type as well as site conditions such as slope and soil type that in turn influence the type of stormwater flow (i.e. sheet flow vs concentrated flow). Flow spreaders and berms are generally used in a treatment train approach to promote sheet flow to appropriate areas such as vegetated buffers.

Farmers expressed an interest in these options as they would keep nutrients on their farmlands and excavate nutrient rich silt deposits that would accumulate for spreading on farmlands at a later date. Since these BMP's would be located near the edge of the Unnamed Creek, it is concluded that future BMP implementation within Priority Area 1a should be further defined to focus along the pathway of the Unnamed Creek as shown on Figure 24.

Information provided during the interviews indicates that there has been extensive tile drainage work carried out within Priority Area 1a in recent years. Increased surface water drainage flows in recent years has increased surface water flows onto downstream properties owned by Ron McCoy resulting in prolonged spring flooding and late planting for cash crops. The outlet to Priority Area 1a is located on the Harrison Farm along the Snake River Line as shown on Figure 24. The Harrison's have implemented a "crock" system at this outlet that pumps ponded water on their farmland from well tiles into the drain that flows under the Snake River Line and into adjacent farmlands and the Snake River Wetland (Photograph 8). Mr. Harrison has expressed an interest in working with the Township on initiatives for improving drainage in the Study area. Potential end-of-pipe treatment options include a plunge pool, hybrid wetland or wet pond which reduce nutrient loading through sedimentation and a variety of biotic and abiotic processes (Table 28). A reliable reduction efficiency for plunge pools was not found because of the importance of site-specific factors in application but wet ponds and wetlands are capable of reducing TP loads substantially, 63% and 77%, respectively.

COBDEN AGRICULTURAL AREA STUDY

MAP 3a:
PRIORITY AREA 1a (SCOPED) (1/2)



Legend

- Waterbody
- Watercourse
- 5m Contours
- 124m Contour Elevation
- Township of Whitewater Region Boundary
- Township of Whitewater Region Property Fabric
- Township of Admaston/Bromley Property Fabric

Priority Areas

- Priority Area #1 (Scoped)
- Priority Area #2 (Scoped)
- Priority Area #3 (Scoped)

Scale: 1:5,000

0 0.25 0.5 Kilometers

Maps are not intended to be used for legal purposes or to identify exact locations of map elements. Verification and survey of existing conditions is required to confirm actual location of existing conditions and/or proposed elements.

Photograph 8. A view of pumping systems designed to remove excess water from the unnamed creek to Snake River PSW.

Table 28. A Description of Nutrient Reduction Processes, TP Reduction Efficiencies and Considerations associated with Shortlisted BMPs

Shortlisted BMPs	Nutrient Reduction Process	TP Reduction	Considerations
Vegetative Buffer	Filtering of nutrients and sediments Promotes infiltration Nutrient uptake by vegetation	5m buffer or more = 56% reduction 6 – 10m buffer = 67% reduction 11m or more = 74% reduction (Allaway 2010)	Effectiveness dependent on slope and soil type of the source area Effectiveness dependent on vegetation type and width More effective filtering sheet flow than concentrated flow
Flow Spreader	Promotes sheet flow to allow for filtering and settling of suspended solids and uptake of related nutrients by vegetation/crops Filtration, sedimentation, plant uptake, adsorption and possibly biological treatment (NC State University, 2010). Primarily sedimentation	32% to 48% (NC State University, 2010) but studies combined flow spreaders with filter strips	Often located upstream of vegetative buffers as part of a treatment train approach Effectiveness dependent on slope and soil type in area of application
Berm	Redirects channelized or sheet flow to promote filtration, sedimentation and plant uptake	Depends on application	Often located upstream of vegetative buffers as part of a treatment train approach Effectiveness dependent on slope, soil type and drainage in area of application

Tile Drains	Reduces surface runoff Provides more capacity for infiltration	63% (Agriculture and Agri-Food Canada, 2000) Variable results in literature (Moore 2016)): Two order of magnitude lower or higher Tile drainage substantially reduced surface runoff, TSS and SRP exports while having no impact on TP exports (Klaiber et al. 2020)	Effectiveness depends on soil characteristics Varies in flow and season. Most comes from surface runoff during the non-growing season
Plunge Pool	Absorbs impact of discharge preventing additional erosion Allows for sedimentation Reduces downstream flow velocities Promotes infiltration	Depends on application	Effectiveness depends primarily on site topography and the contributing drainage area
Wet Pond	Chemical precipitation, dilution and biological uptake	Wet Detention Pond 63% (HESL 2014)	Effectiveness depends on location and loading from influent stormwater runoff, water temperature (Ryan 2008)
Dry Pond	Primarily sedimentation	Dry Detention Pond 10% (HESL 2014)	Soil characteristics, depth to bedrock and depth to bedrock

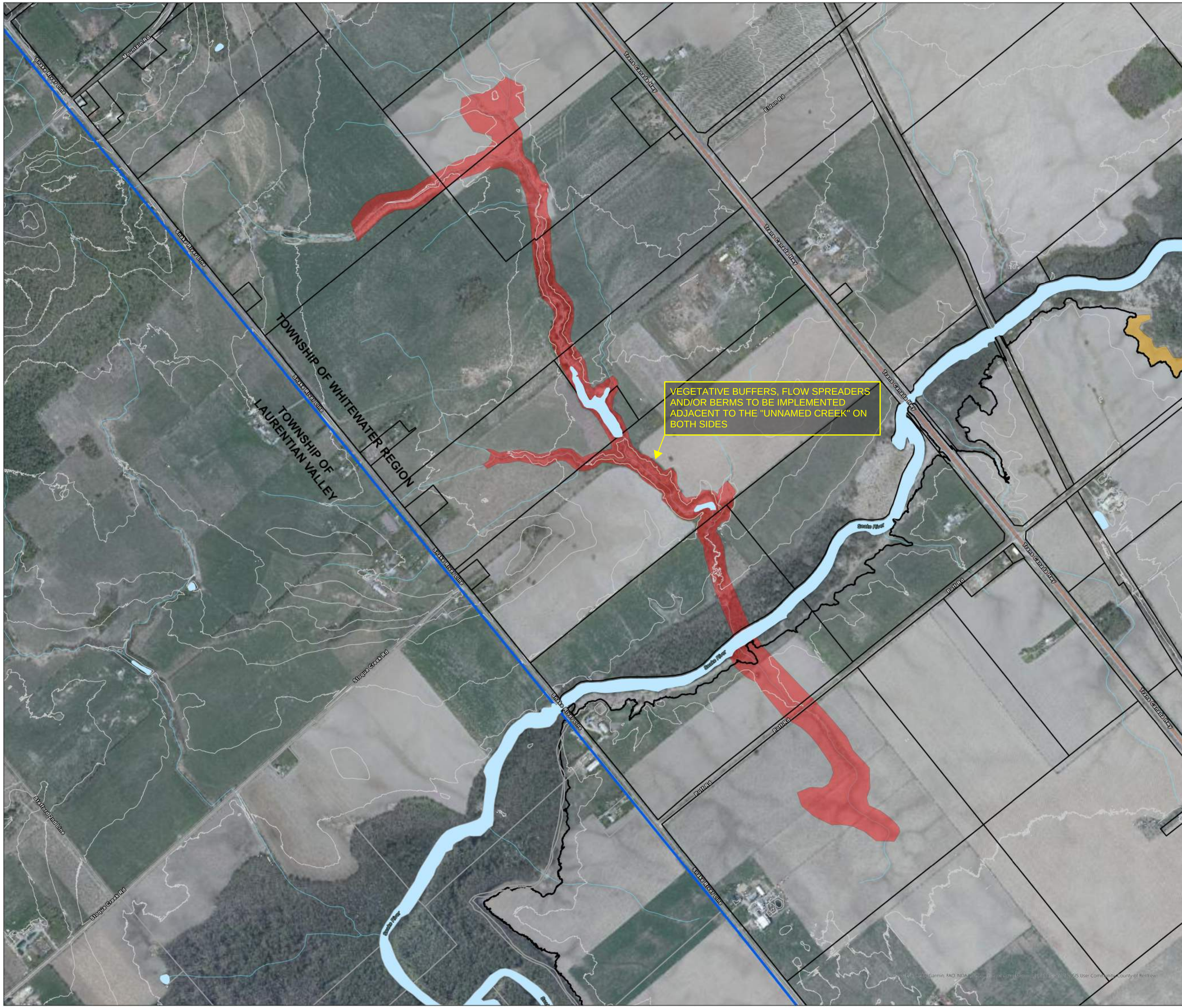
Hybrid Wetland	Biological uptake, sedimentation, adsorption, precipitation and accretion of organic matter	Constructed wetland (77%) (HESL 2014)	Vegetation, soil properties, wetland shape and size, hydrologic fluctuations, surround land use and TP loading rate, hydraulic retention time, seasonality.

10.1.2 Refined Priority Area #1b – Unnamed Creek flowing Into the Snake River

An unnamed creek was identified which drains agricultural lands into the Snake River (Figure 25). As discussed similarly in Section 8.3.1, the creek is not well buffered in reaches. Based on consultations with Colin Fletcher, who's father owns a 98 acre parcel of farmland on either side of this watercourse, there is an opportunity to implement berms and/or flow spreaders on the edge of this watercourse in a similar matter to the Unnamed Creek in Priority Area 1a shown on Map 3a. There is also an opportunity to implement a vegetative buffer, and possibly a dry pond at the outlet of the watercourse prior to the Snake River.

COBDEN AGRICULTURAL AREA STUDY

MAP 3b:
PRIORITY AREA 1b (SCOPED) (2/2)



Legend

- Waterbody
- Watercourse
- 5m Contours
- 124m Contour Elevation
- Township of Whitewater Region Boundary
- Township of Whitewater Region Property Fabric
- Township of Admaston/Bromley Property Fabric

Priority Areas

- Priority Area #1 (Scoped)
- Priority Area #2 (Scoped)
- Priority Area #3 (Scoped)

Scale: 1:5,000

0 0.25 0.5 Kilometers

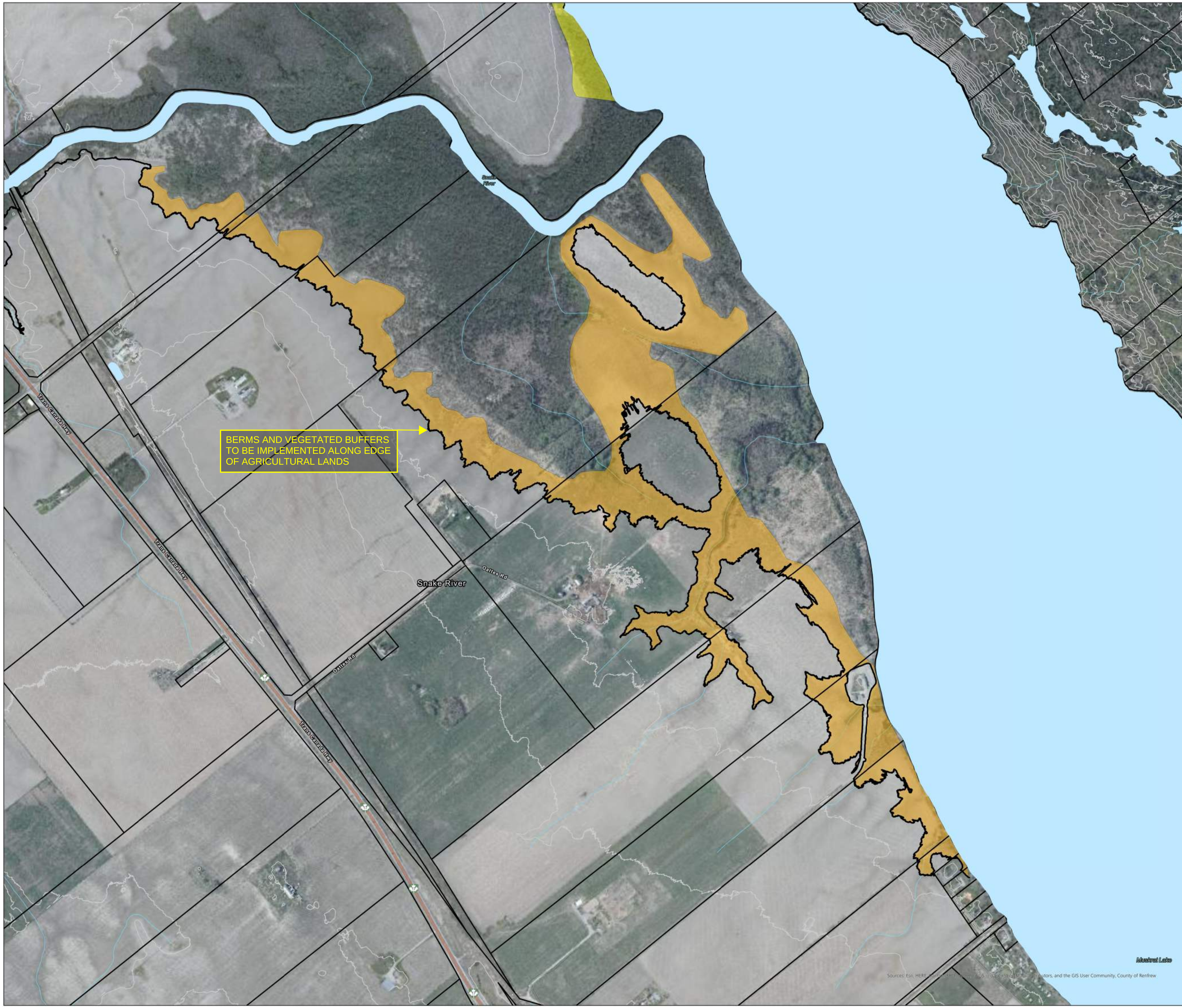
N W E S

Maps are not intended to be used for legal purposes or to identify exact locations of map elements. Verification and survey of existing conditions is required to confirm actual location of existing conditions and/or proposed elements.

10.1.3 Refined Priority Area #2 – Previously Flooded Areas

A considerable amount of agricultural land in the Muskrat Lake watershed has become seasonally flooded in recent years, with a substantial portion of that land located between the Snake River PSW and Muskrat Lake. The flooded lands in 2019 generally corresponded to the 124m contour elevation, which is shown on Figure 26. Flooding results in substantial nutrient loading and it is recommended that areas receiving frequent flooding should be established into wetlands with a vegetative buffer and flow spreader surrounding the wetland as a part of a treatment train approach. Dennis Harrison had planned to re-do an existing berm at the edge of his property, which extends to the Snake River. Ian Byce, who owns a parcel that is adjacent to the Snake River and Muskrat Lake, was interested in implementing vegetative buffers adjacent to all watercourses on his property. As seen on Figure 26, there are two raised areas on Mr. Byce's property, so runoff cannot be collected easily and implementing a flow spreader or berm would not be very beneficial.

A flow spreader promotes sheet flow and vegetative buffers would reduce nutrient loading through filtration, sedimentation, plant uptake and biological treatment. Phosphorus assimilation in wetlands occurs over the short-term through biological uptake by vegetation, periphyton, plankton and microorganisms. Longer term assimilation occurs through abiotic processes, such as sedimentation, adsorption to sediments, chemical precipitation, and accretion of organic matter (Reddy et al. 1999; Fisher and Acreman 2004). The functioning of wetlands as phosphorus sinks is influenced by a wide variety of factors, including seasonality, soil physicochemical properties, velocity of water flow, hydraulic retention time, wetland shape and size, water depth, phosphorus loading, and hydrologic fluctuations (Land et al. 2016).



COBDEN AGRICULTURAL AREA STUDY

MAP 4: PRIORITY AREA 2 (SCOPED)

Legend

- Waterbody
- Watercourse
- 5m Contours
- 124m Contour Elevation
- Township of Whitewater Region Boundary
- Township of Whitewater Region Property Fabric
- Township of Admaston/Bromley Property Fabric

Priority Areas

- Priority Area #1 (Scoped)
- Priority Area #2 (Scoped)
- Priority Area #3 (Scoped)

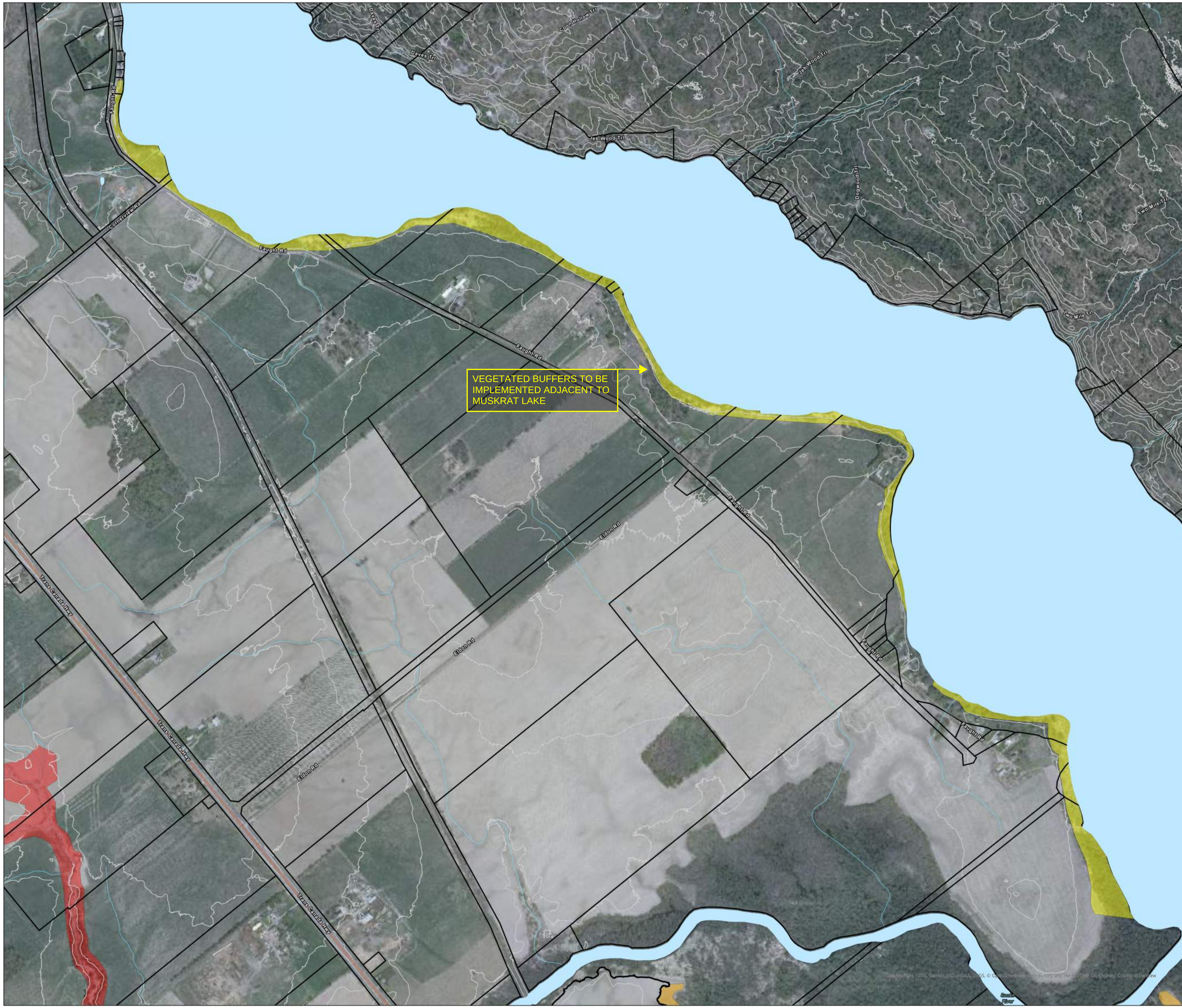
Scale: 1:5,000

0 0.25 0.5 Kilometers

Maps are not intended to be used for legal purposes or to identify exact locations of map elements. Verification and survey of existing conditions is required to confirm actual location of existing conditions and/or proposed elements.

10.1.4 Refined Priority Area #3 – Muskrat Lake Riparian Lands

Agricultural lands are located along the western shoreline of Muskrat Lake. Many areas are poorly buffered from the shoreline so there is limited TP retention for nutrient-rich agricultural runoff by natural heritage SWM features such as watercourses, floodplains or wetlands (Figure 27 and Figure 28). It is recommended that vegetative buffers be implemented in these priority areas to reduce nutrient loading to Muskrat Lake.



COBDEN AGRICULTURAL AREA STUDY

MAP 5a:
PRIORITY AREA 3a (SCOPED) (1/2)

Legend

- Waterbody
- Watercourse
- 5m Contours
- 124m Contour Elevation
- Township of Whitewater Region Boundary
- Township of Whitewater Region Property Fabric
- Township of Admaston/Bromley Property Fabric

Priority Areas

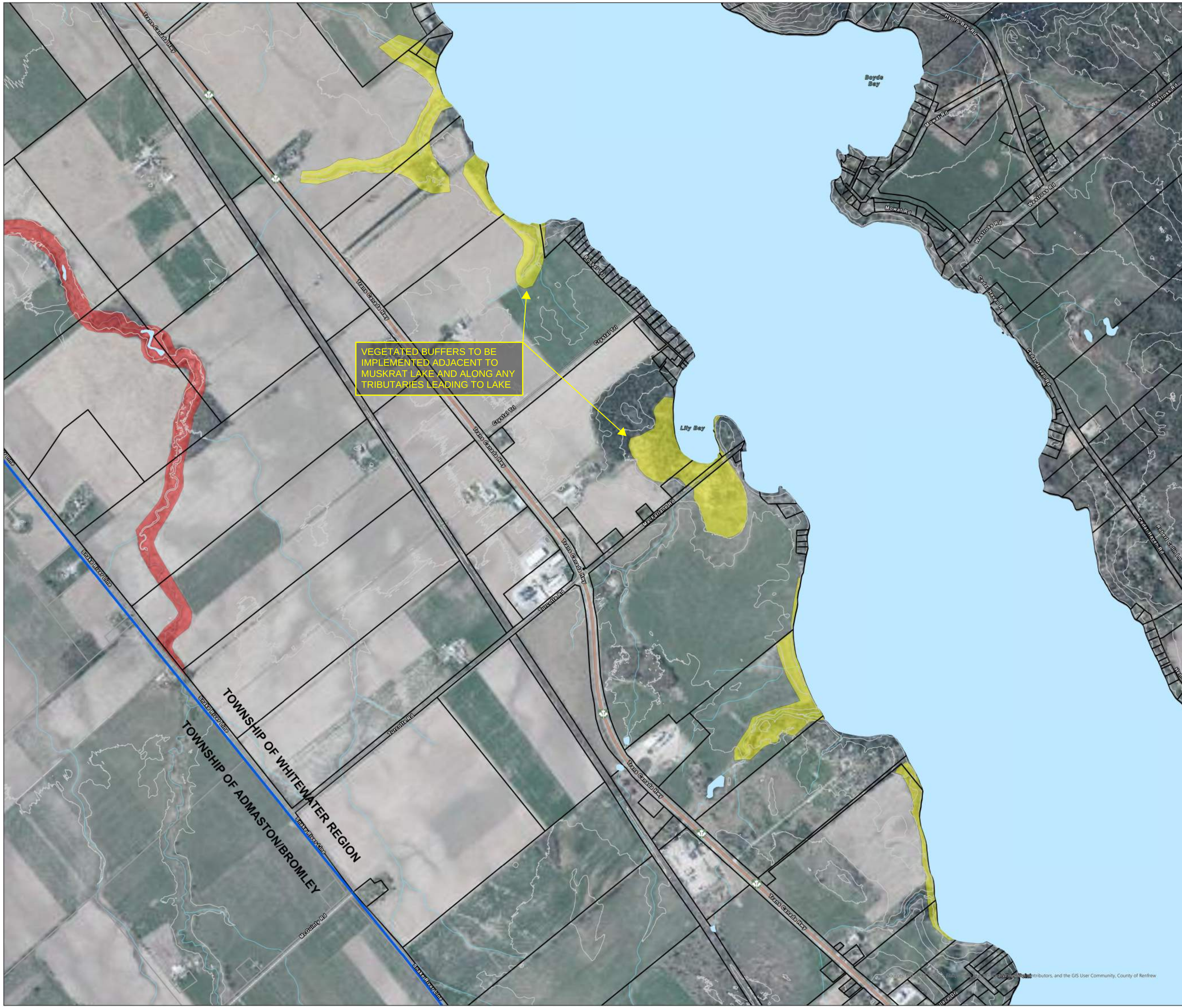
- Priority Area #1 (Scoped)
- Priority Area #2 (Scoped)
- Priority Area #3 (Scoped)

Scale: 1:5,000

0 0.25 0.5 Kilometers

N W E S

Maps are not intended to be used for legal purposes or to identify exact locations of map elements. Verification and survey of existing conditions is required to confirm actual location of existing conditions and/or proposed elements.



COBDEN AGRICULTURAL AREA STUDY

MAP 5b:
PRIORITY AREA 3 (SCOPED) (2/2)

Legend

- Waterbody
- Watercourse
- 5m Contours
- 124m Contour Elevation
- Township of Whitewater Region Boundary
- Township of Whitewater Region Property Fabric
- Township of Admaston/Bromley Property Fabric

Priority Areas

- Priority Area #1 (Scoped)
- Priority Area #2 (Scoped)
- Priority Area #3 (Scoped)

Scale: 1:6,000

0 0.25 0.5 Kilometers

Maps are not intended to be used for legal purposes or to identify exact locations of map elements. Verification and survey of existing conditions is required to confirm actual location of existing conditions and/or proposed elements.

11. Other Considerations

11.1 Muskrat Lake TP Budget and Internal Loading

Muskrat Lake is nutrient-enriched and although agricultural runoff was the focus of this study, it is not the only source of nutrients in the lake. MECP completed a nutrient budget for the Snake River and Muskrat River watersheds through the utilization of a variety of methods including the Lakeshore Capacity Model, GIS, coefficients and formulas, runoff according to land use and soil type and WPCP loadings from 2012 and 2013. Nutrient runoff from agriculture lands, defined as both pasture/cleared land and cropland, constituted:

- Snake River = Pasture/cleared (24%) + Crops (22%) = 46% (Figure 29)

- Muskrat River = Pasture/cleared (17%) + Crops (4%) = 21% (Figure 30)

The Snake River and Muskrat River contribute 61% and 9% of the TP load to Muskrat Lake, respectively. The next highest load of nutrients comes from internal loading of nutrients from the sediments due to prolonged anoxia in the bottom waters. AECOM (2009) reported TP concentrations >200 µgL at a water depth of 50 m. Alum and Phoslock have both been commonly implemented to reduce internal loading of phosphorus through application to surface waters of lakes. Brattebo et al. (2015) noted that there have been over 250 documented treatments of alum in the world and internal loading was subsequently reduced by 70% - 80%. In-lake treatments to reduce TP loading from internal loading should be completed alongside watershed improvements such as agricultural BMPs to ensure that meaningful improvements in lake water quality are completed.

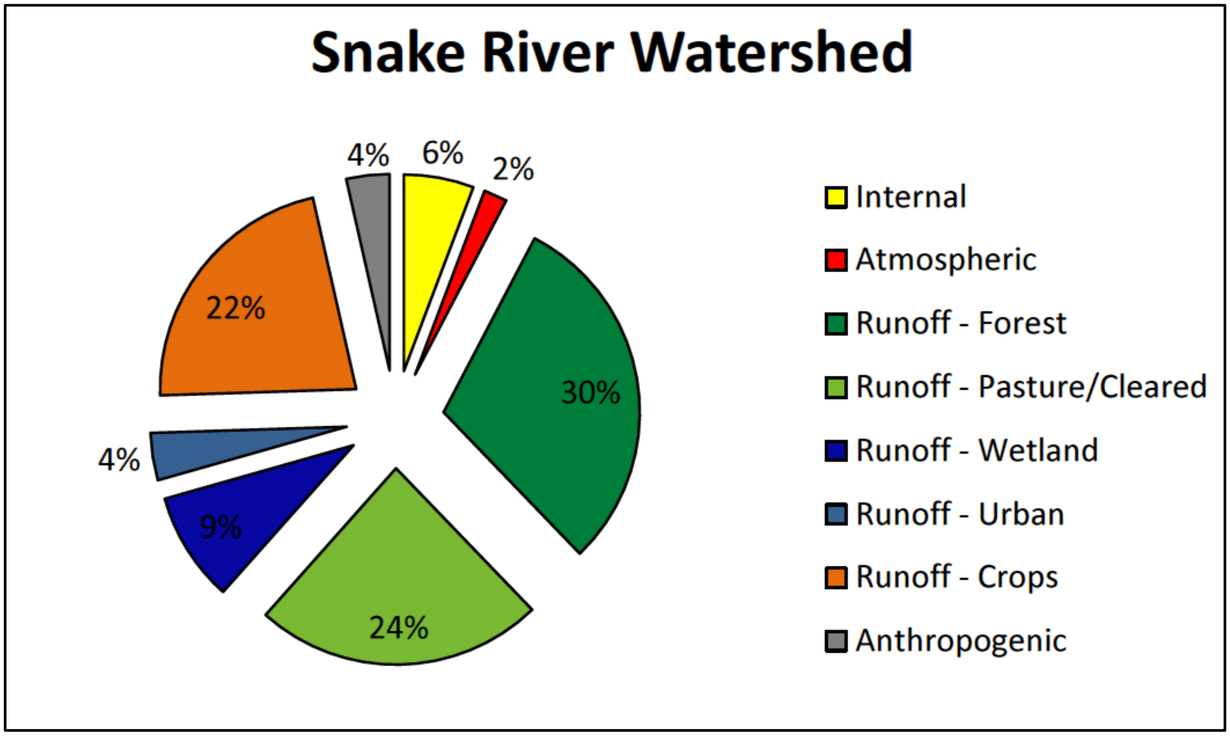


Figure 29. TP Budget for the Snake River Watershed.

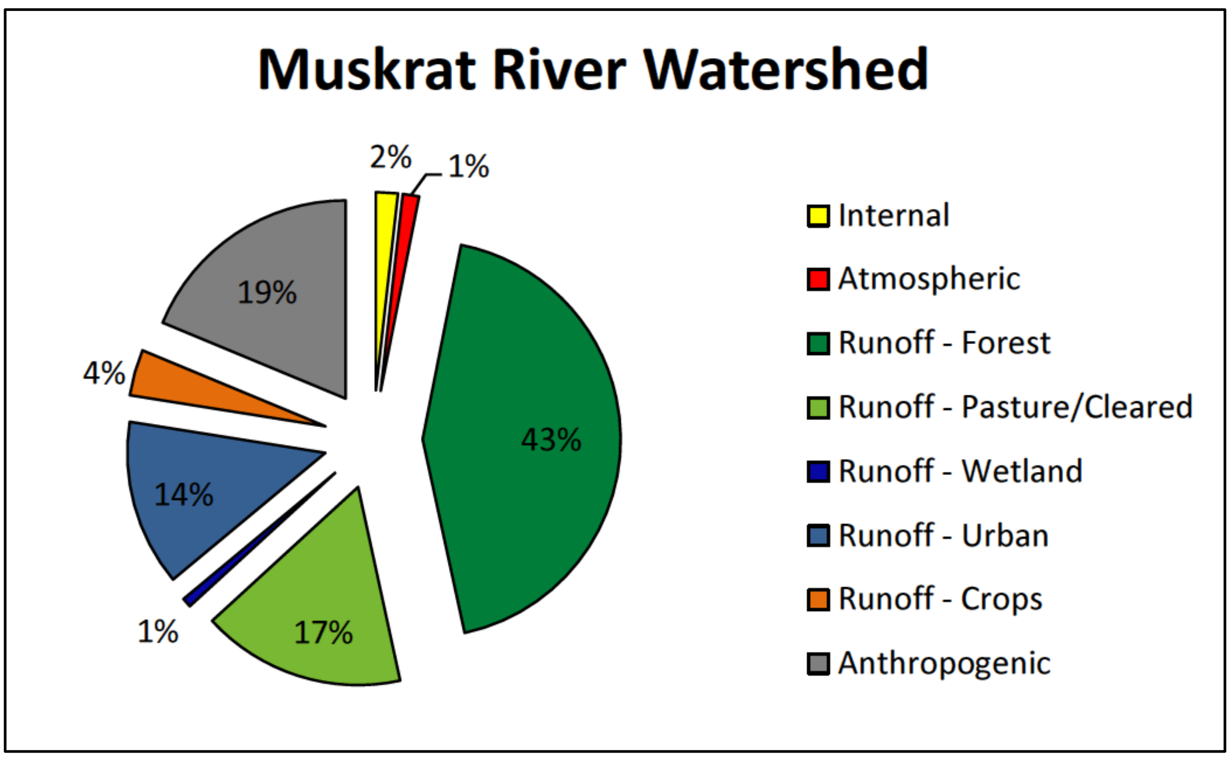


Figure 30. TP Budget for the Muskrat River Watershed.

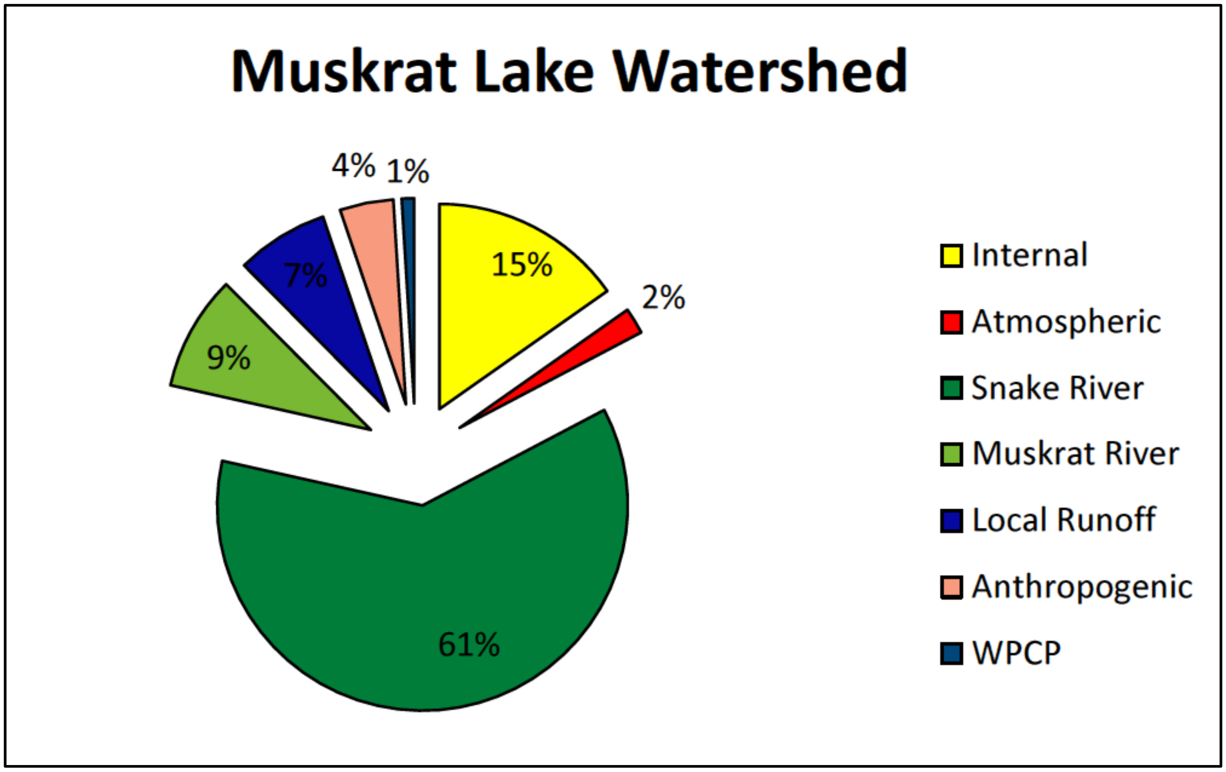


Figure 31. TP Budget for the Muskrat Lake Watershed

11.2 Historical Alteration to Agricultural Drains

The natural drainage patterns in the Muskrat Lake watershed have been altered in the past to improve agricultural productivity and these alterations have increased TP loading to Muskrat Lake due to increased nutrient concentrations from agricultural lands and the fact that flow has been diverted away from natural SWM features that would provide TP attenuation, such as wetlands. The Harris Drain was constructed in 1968 which drains a portion of Harris Creek into the Snake River instead of flowing into the Bonnechere River (Greer, Galloway and Associated Limited 1981). Additional drainage works have also been completed, including a number of projects approved in 1982 such as deepening of the Snake River from Osceola back to the Mink Drain, lowering of the Upper Harris Drain, and construction of the Agnew Angus drain which empties into the Upper Harris Drain, all of which allowed for more farms to drain into the Upper Harris Drain.

The Muskrat Lake Association has been focused on describing these drainage alterations and identifying remedial measures to improve nutrient concentrations in Muskrat Lake such as re-routing Spence Drain and Upper Harris Drain to the Bonnechere River and in-lake treatments such as those discussed in Section 9.1. Greer, Galloway and Associates (1981) noted that diverting the Harris Creek to the Bonnechere River would cause TP concentrations in Muskrat Lake to decrease approximately ~2.7 µg/L (30.4 µg/L to 27.7 µg/L) as diversion would reduce the size of the Muskrat Lake's watershed and related TP loads associated with different land/soil types. A reduction in TP concentration of ~2.7 µg/L in Muskrat Lake is substantial and therefore drainage alterations should be considered moving forward alongside agricultural BMPs and in-lake treatment to help make meaningful improve water quality conditions in Muskrat Lake.

12. Action Plan

For this Study, one-on-one and/or small group meetings have proven to be an effective method for communicating with the farming community about the benefits of implementing BMPs for the improvement of drainage and the reduction of nutrient loss from farmlands. There are opportunities to work with farmers to implement BMPs within the identified priority areas. Recommended action items for implementation of the recommended BMPs within the identified priority areas as well as other recommendations for the ongoing communication, education and funding of BMP initiatives include the following:

1. The methodology, consultation program and the recommended action plan for the implementation of BMPs within defined priority areas identified by the Study be presented to Council of the Township of Whitewater Region for review and endorsement.

2. Property owners within the Study be notified about the results of this Study, including the BMPs that have been identified as best suited for the defined priority areas.

3. The results of this Study be circulated to the Muskrat Watershed Council, the Muskrat Lake Association and other interested individuals and agencies on the agency contact list to obtain their support of initiatives for the implementation of BMPs within defined priority areas.

4. That Dennis and Spencer Harrison be contacted to confirm their interest in partnering with the Township of Whitewater Region on funding applications for the implementation of end-of-pipe treatment options such a dry pond, plunge pool, wetland or wet pond at the outlet of the Unnamed Creek at the Snake River Line (Photograph 8). The purpose of these end-of-pipe solutions would be to provide treatment for reducing nutrient loading from the Unnamed Creek and controlling surface water flows into downstream properties and the Snake River Wetland.

5. An ongoing communication plan be implemented which includes:

    - Descriptions and schematics of BMPs that have been deemed suitable, such berms, flow spreaders and/or vegetated buffer areas, be provided to relevant landowners in priority areas.

    - Follow-up meetings continue to be held with additional members of the farming community not interviewed during this Study for the purpose assessing site specific BMP's that can be considered for their farm properties. These meetings would be coordinated by the Township, with assistance from Agricultural Committee representatives from the Muskrat Watershed Council and technical engineering support, as necessary, to assess existing conditions and proposed BMP implementation plans.

    - Maintaining an inventory or list of farmers that would be interesting in partnering with the Township, NGO's and other interested farming organizations on applications for funding to implement BMPs within defined priority areas.

    - Notifications to the farming community on funding opportunities that arise for the implementation of BMPs within the defined priority areas.

6. That the Township monitor and apply for funding programs with regional, provincial and/or federal organizations for the purpose of partnering with farmers on the implementation of BMPs within priority areas identified by this Study.

7. That the Township consider amending their Community Improvement Plan (CIP) for the purpose of adding berms, flow spreaders and/or vegetated buffer areas at the edge of their properties along watercourses including the Unnamed Creek in Priority Area 1a and 1b; flooded areas along the Snake River and Muskrat Lake in Priority Area 2 and along the riparian shoreline and smaller drainage courses flowing into the of Muskrat Lake in Priority Area 3.

8. Neighbouring municipalities within the Muskrat Lake Watershed should be contacted to share the Study methodology and results in hopes that similar efforts can be applied to identify priority areas and BMPs in other jurisdictions, and ultimately make a larger impact on improved water quality in PSWs and Muskrat Lake.

9. Active in-lake management and engineered drain alterations should be pursued in tandem with Agricultural BMPs in hopes of making a meaningful difference in water quality in the face of climate change.

13. Conclusions

Nutrients in watercourses were similar or slightly higher than other agricultural-dominated watersheds in Ontario. Phosphorus concentrations were highest in the summer, TN was highest in the spring and fall, and neither nutrient concentration was statistically significantly related to precipitation. Total suspended solid concentrations were low and significantly related to TP at the three sites located in the Cobden PSW which could be driven by upstream overland runoff.

Median TP and TN concentrations, as well as TP and TN loads/ha were all highest at SC-02 which was also the catchment with the highest percentage of agricultural lands and annual crop land within 1 km. The next most nutrient-enriched sites were MKR-03 and SNR-04.

The Cobden and Snake River PSWs both support a wide variety of natural heritage features and functions. The Snake River PSW consistently acts as a nutrient sink with the greatest nutrient retention occurring in the summer and fall. The Cobden PSW acts as a nutrient source but the assessment of TP retention in the Cobden PSW was limited because the downstream water sampling location was located in the middle of the wetland, thereby limiting the spatial assessment.

Three general priority areas were identified based on the results of the first phase of the study: SC-02 Catchment, Previously Flooded Areas and Muskrat Lake Riparian Lands. SC-02 contained the highest nutrient concentrations and loads, flooded areas result in significant nutrient loading to receiving waterbodies and poorly buffered agricultural lands along Muskrat Lake drain directly into the lake without being afforded TP retention in watercourses or wetlands

A variety of BMPs were identified which could be utilized in the priority areas to reduce nutrient loading. Consultation was undertaken through a virtual public meeting and one-on-one interviews to determine which BMPs would be appropriate based on site conditions and feedback from local farmers and landowners. Priority areas were refined based on consultation and BMPs were shortlisted for future implementation. Descriptions of shortlisted BMPs and related nutrient reduction efficiencies associated with each refined priority area were also presented to inform future implementation.

A series of recommendations were developed as outlined in an Action Plan that are intended to help implement BMPs that have been identified, apply a similar methodology and study to other jurisdictions in the Muskrat Lake Watershed, and investigate other means of reducing nutrient concentrations in Muskrat Lake.

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Appendix A. Stormwater Assessment, Planning and Implementation Contact List and Invitation for Public and Agency Consultation Newsletter

Township of Whitewater Region
Stormwater Assessment, Planning and Implementation of Cobden Agricultural Area
Contact List: Public, Agencies, Agricultural Organizations & Other NGO's

Agencies:

1. MECP: Victor Castro Victor.Castro@ontario.ca
2. OMAFRA: Peter Doris or designate
3. MNRF: Corrie Bourgoin (Tech/Pembroke Office) or Scott Smithers (Kemptville) scott.smithers@ontario.ca
4. MTO: Stephen Kapusta, MCIP, RPP Stephen.Kapusta@ontario.ca
5. County of Renfrew:
   - Paul Moreau, CAO
   - Craig Kelley, Director of Property and Development; and
   - Bruce Howarth, Manager of Planning Services.

Agricultural Organizations:

1. Renfrew County Federation of Agriculture: Filed Letter of Support for Study – Contact on file: Reuben Stone
2. Renfrew County Soil and Crop Improvement Association: Filed Letter of Support for Study– Contact on file: Jennifer Doleman
3. Natural Farmers Union - Renfrew County: Filed Letter of Support for Study
4. Ontario Federation of Agriculture (Renfrew County): Filed Letter of Support for Study
5. Renfrew County Beef: Contact on file: David McGonegal
6. Christian Farmers: Contact on file: Gerry Rook
7. Renfrew South District Women's Institute: Lillian Collins
8. Renfrew County Stewardship Council: Eric Smith

NGO's

1. Muskrat Watershed Council:
   - Karen and Rene Coulas;
   - Jim Lawrence and others.
2. Muskrat Lake Association:
   - Donald Deer
   - Gary Younghusband
   - Hugh Mitchell
3. Renfrew County Water Quality Leadership Group
   - Evelyn St. Amour (Muskrat Watershed Council)
   - Lynn Clelland (Agriculture)
   - Gerry Richards (Agriculture)
   - John Almstedt (Lake Clear)
   - Eric Smith (Agriculture)
   - Jennifer Doleman (Agriculture)
   - Kathryn Lindsay (Bonnechere Watershed Project)
   - Ole Hendrickson (Ottawa River Institute)
4. Ottawa River Keeper
   - Meagan Murphy

5. Ottawa River Institute
   - Ole Hendrickson
6. Bonnechere River Project
   - Kathryn Lindsay

Colleges and Universities:

1. Algonquin College
   - Sarah Hall
   - Julie Sylvestre

General Public:

- Discussions with interested property owners, open house meetings etc. regarding best management practices and mitigation measures.
- Circulation list to be provided by the Township.

Purpose of Study:

To prepare an action plan for the purpose of implementing best management practices to reduce nutrient loss for agricultural produces and improve water quality of Muskrat Lake and the Cobden and Snake River Provincially Significant Wetlands (PSWs).

This project will characterize existing stormwater management in Cobden's agricultural area and water quality in adjacent watercourses, recommend and implement mitigation measures to reduce nutrient loading to PSWs and Muskrat Lake, develop information sharing amongst local and regional groups and residents, and develop partnerships between the agricultural sector and other local and regional organizations to help improve water quality in Muskrat Lake and the PSWs in both the short and long-term.

The project will provide a better understanding of the sources of nutrients/phosphorous loading from Cobden area agricultural producers leading to water quality deterioration of Muskrat Lake and the Cobden and Snake River Provincially Significant Wetlands. It will also quantify the amount of nutrients that can be reduced through implementation of best management practices and stewardship activities.

Hutchinson Environmental Sciences Ltd. and Jp2g are reaching out to agricultural, environmental, academic and agency partners for the purposes of explaining the study and establishing contacts for the purpose of keeping agricultural, environment partners and the public informed about and engaged in the work program.

Credit: Xiaoqiang Liu, Food, Agricultural and Biological Engineering - The Ohio State University

WHITEWATER REGION STORMWATER ASSESSMENT, PLANNING AND IMPLEMENTATION OF THE COBDEN AGRICULTURAL AREA

WHITEWATER REGION

Muskrat Watershed Council

Hutchinson Environmental Sciences Ltd

Invitation for Public & Agency Consultation

The Township of Whitewater Region invite you to participate in the consultation program for the "Cobden Agricultural Area Study". You are receiving this Newsletter and invitation because:

1. You are a property owner or farmer within one of the Cobden Agricultural Study priority areas for Best Management Practices (BMP) implementation, which includes the areas shown on the attached Map.
2. You are a member of the public that is interested in the learning about Best Management Practices (BMP's) for reducing nutrient loading to Significant Wetlands and Muskrat Lake in the Study Area.
3. You are part of a government or non-government organization that is interested in the protection of Significant Wetlands and the improvement of water quality of Muskrat Lake.

Virtual Public Meeting: Wednesday, December 8th, 2021

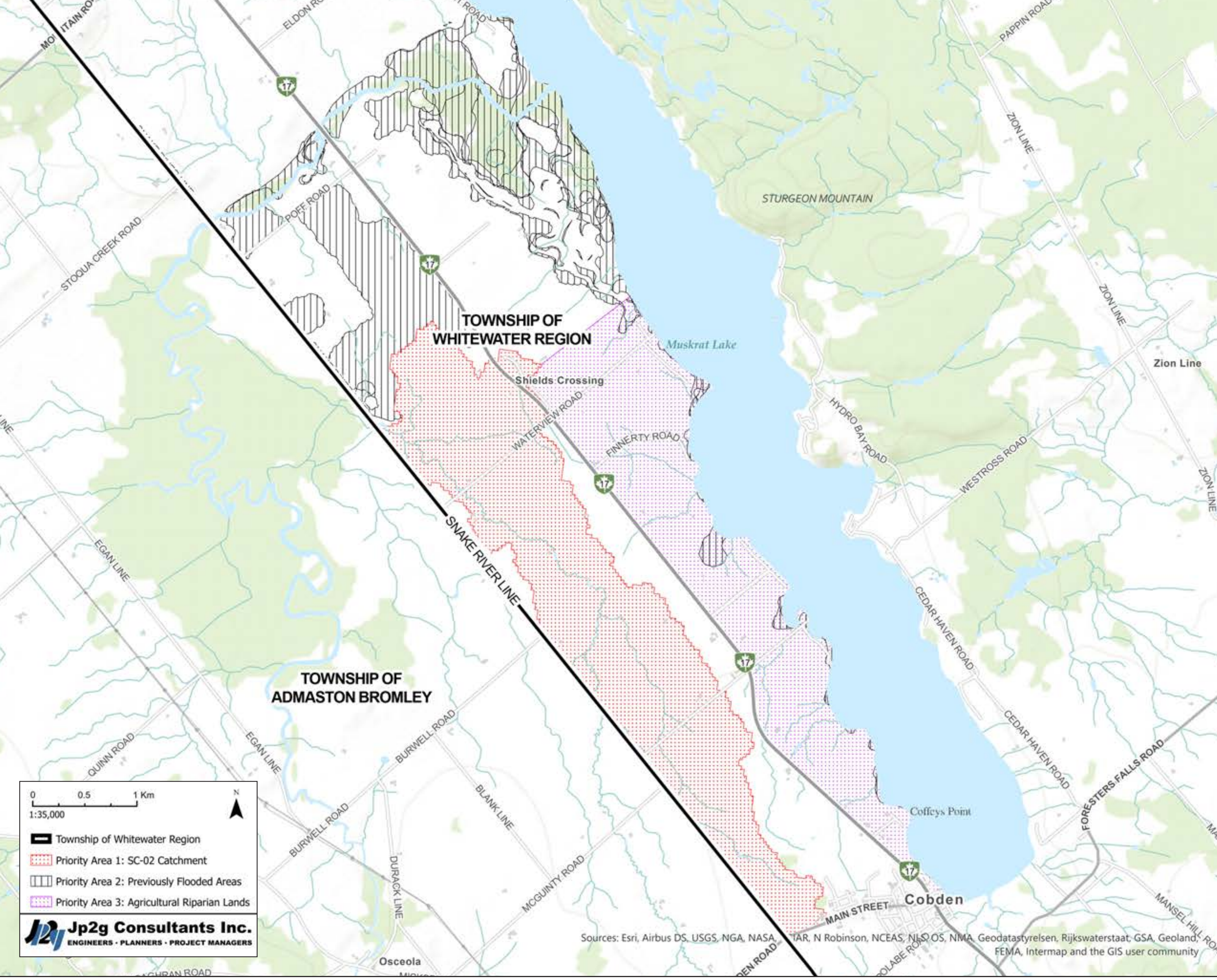
A Virtual Public Meeting will be held on Wednesday, December 8th at 6:30 pm. This meeting will include a brief presentation by the Consulting Team followed by a question and answer. Members of the public will be encouraged to provide comments on the options for Best Management Practices in the Study Area.

Participation in this virtual Public Meeting can be accessed using the following link: *https://us02web.zoom.us/j/86906368984* (zoom). Should you prefer to receive Zoom Meeting Invitation by e-mail, please contact: Carmen Miller *cmiller@whitewaterregion.ca*

One-on-One / Small Group (2-3 People) Meetings: Thursday, December 9th, 2021

Farm owners, interested individuals and organizations are also invited to participate in one-on-one or small group meetings for further consultation. The purpose of these meetings will be to discuss best management for mitigating nutrient loading that would be most suitable for specific agricultural properties or generally within the Study Area.

These meetings will be held by in the basement meeting room at the Whitewater Region Municipal Offices or by a virtual Zoom meeting, upon request. Please contact Andrea Bishop (*andreab@jp2g.com*) to schedule a meeting (in-person or virtual). Standard COVID-19 protocols for all in-person meetings.



Additional Information and Next Steps:

A Draft of the Study up to and including the Background and Planning Phases of this Study work program is available for review on the Township of Whitewater Region's website, under "Projects". The Planning Phase identifies source areas of nutrient loss and includes potential best management practices (BMPs).

The public consultation program will assist the project team in assessing BMP's that will be best suited for reducing nutrient loading and help improve water quality in Muskrat Lake and the PSWs in both the short and long-term. The Final Report will include an action plan to implement best management practices (BMPs) to reduce nutrient loss for agricultural practices.

Contact information

Jp2g Consultants

Andrea Bishop, Civil Engineer

andreab@jp2g.com

613-282-6464

Township of Whitewater Region

Ivan Burton, Manager/Planner/EDO

iburton@whitewaterregion.ca

613-646-2282

Virtual Public Meeting

December 8th, from 6:30 to 8:30 p.m.

Meeting ID: 869 0636 8984

1-587-328-1099 or 1-647-374-4685

Appendix B. Agricultural Lands within Catchments of Water Quality Sampling Locations

Muskrat Lake Watershed
Township of Whitewater Region

Agricultural Land Use
within the Catchment Areas

Legend

Township of Whitewater Region

Water Sampling Location

BC-01

Catchment Areas

BC-01 Catchment Area

Land Cover Classification

Agriculture and Undifferentiated Lands

N

1:20,000

0 0.5 1 Km

Jp2g Consultants Inc.
ENGINEERS · PLANNERS · PROJECT MANAGERS

Muskrat Lake Watershed
Township of Whitewater Region

Agricultural Land Use within the Catchment Areas

Legend

Township of Whitewater Region

Water Sampling Location

MKR-01

Catchment Areas

MKR-01 Catchment Area

Land Cover Classification

Agriculture and Undifferentiated Lands

N

1:45,000

0 1 2 Km

Jp2g Consultants Inc.
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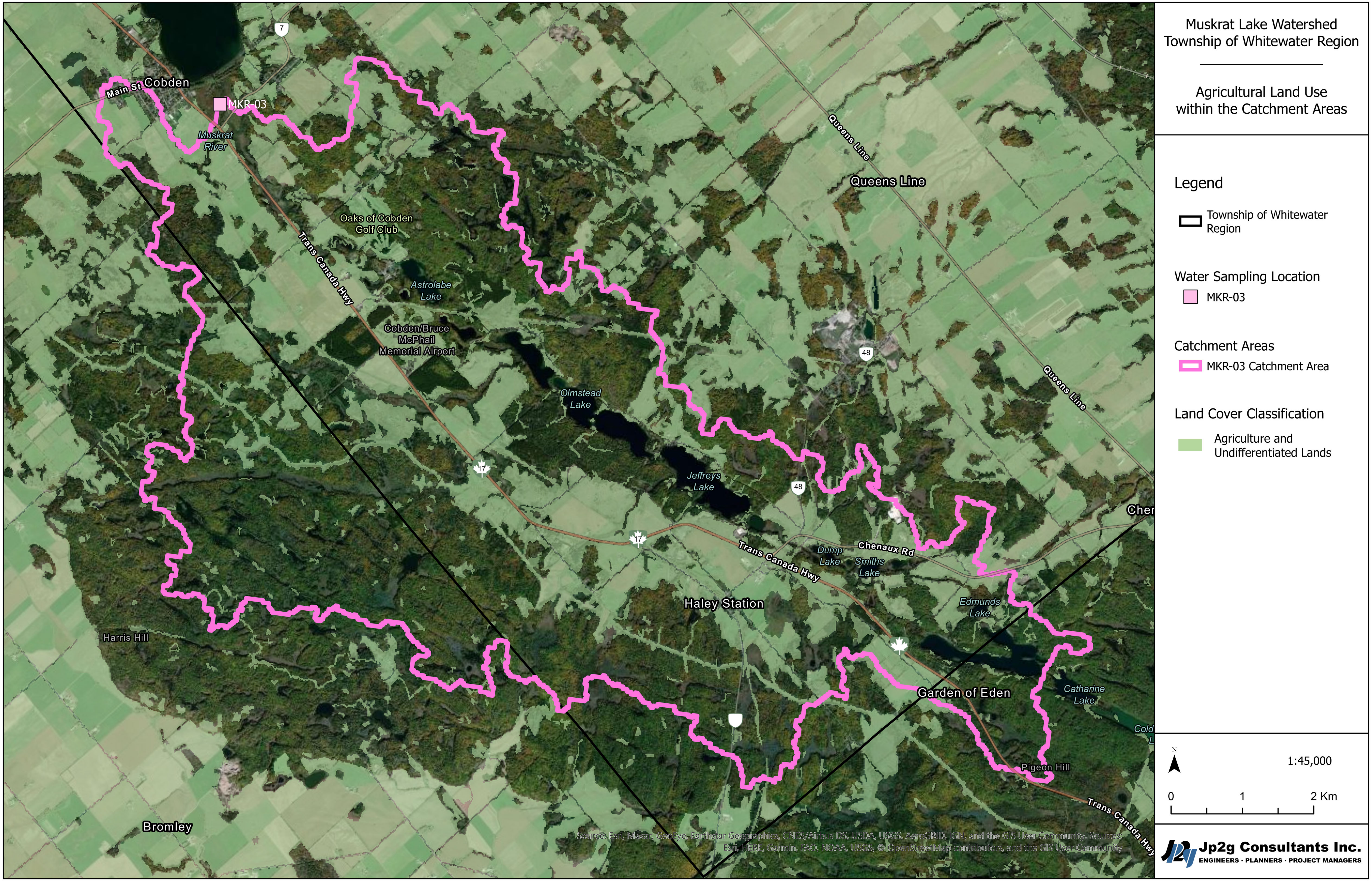
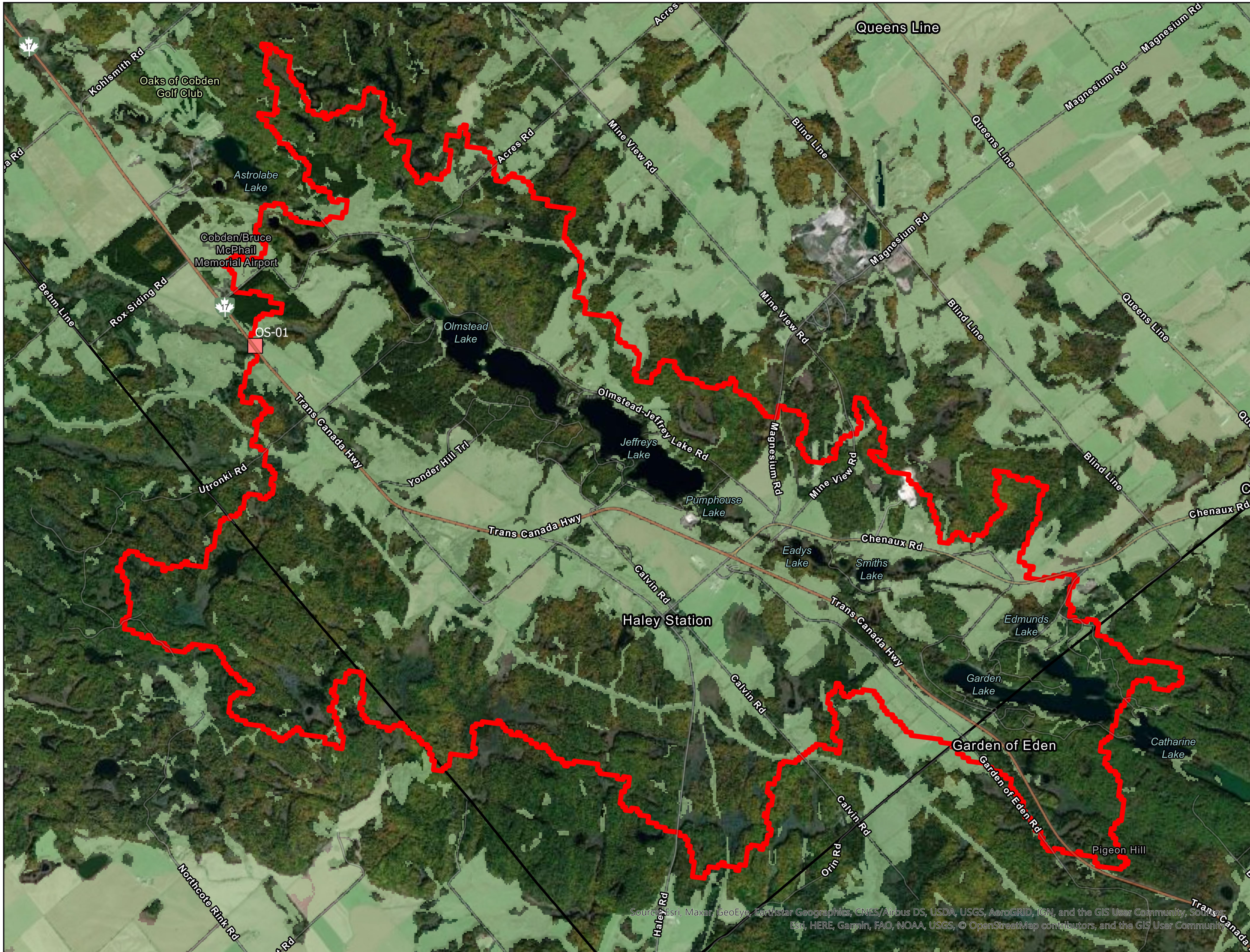
Muskrat Lake Watershed
Township of Whitewater Region

Agricultural Land Use
within the Catchment Areas



Muskrat Lake Watershed
Township of Whitewater Region

Agricultural Land Use
within the Catchment Areas



Legend

Township of Whitewater Region

Water Sampling Location

OS-01

Catchment Areas

OS-01 Catchment Area

Land Cover Classification

Agriculture and Undifferentiated Lands

N

1:35,000

0 0.75 1.5 Km

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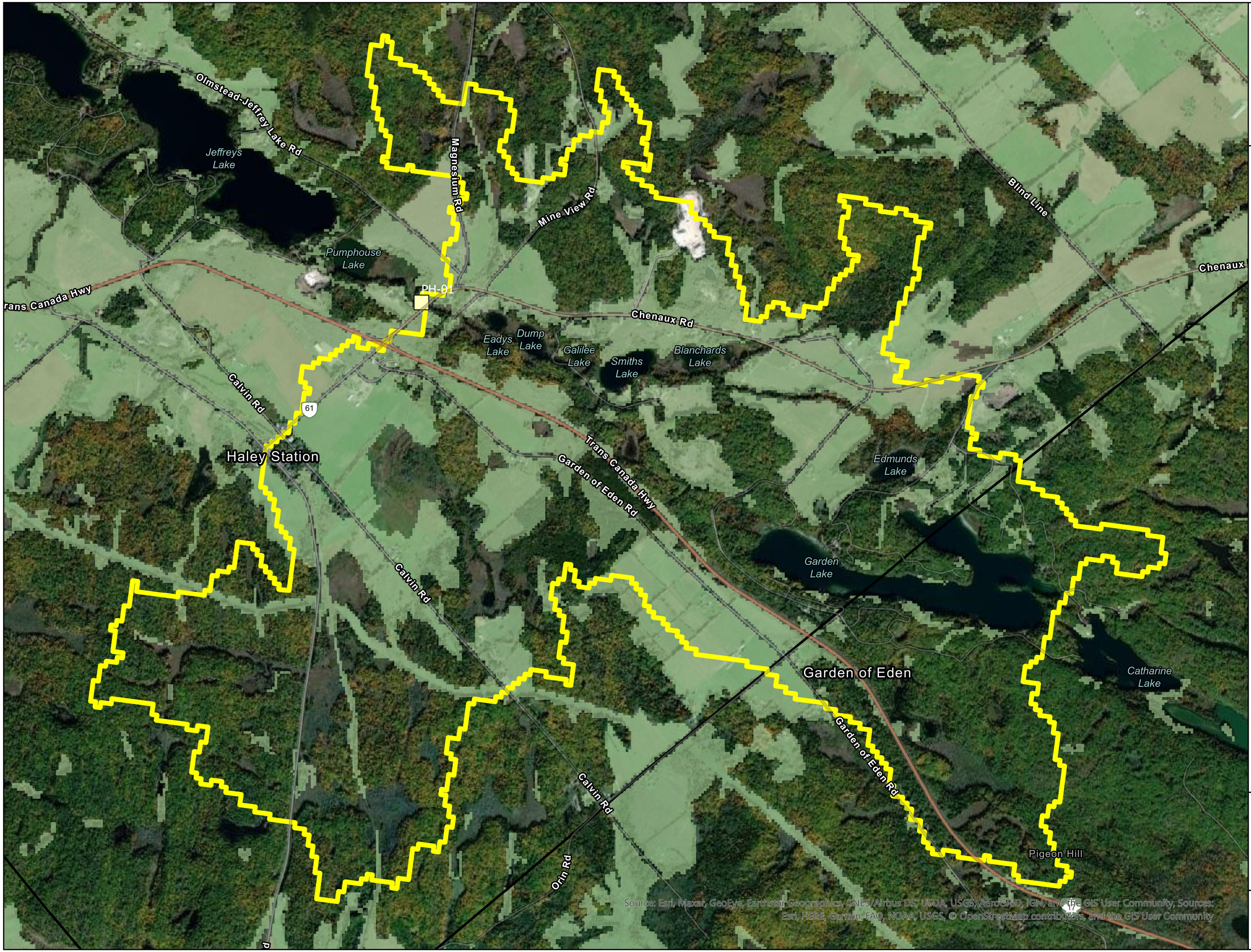

Muskrat Lake Watershed
Township of Whitewater Region

Agricultural Land Use
within the Catchment Areas

Legend

Township of Whitewater Region

Water Sampling Location

PH-01

Catchment Areas

PH-01 Catchment Area

Land Cover Classification

Agriculture and Undifferentiated Lands

N

1:20,000

0 0.5 1 Km

Jp2g Consultants Inc.
ENGINEERS · PLANNERS · PROJECT MANAGERS

Muskrat Lake Watershed
Township of Whitewater Region

Agricultural Land Use
within the Catchment Areas

Legend

Township of Whitewater Region

Water Sampling Location

SC-02

Catchment Areas

SC-02 Catchment Area

Land Cover Classification

Agriculture and Undifferentiated Lands

N

1:45,000

0 1 2 Km

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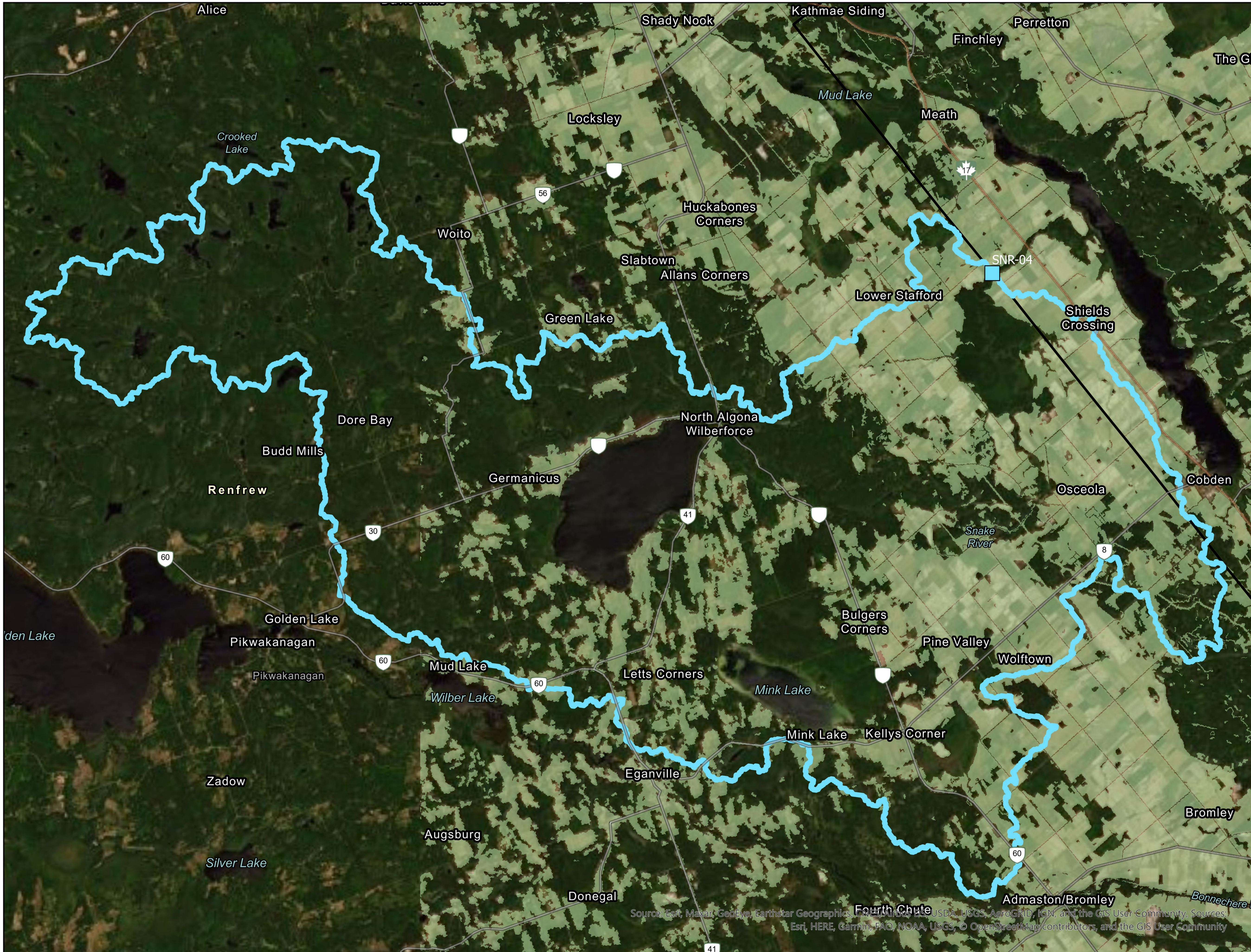
Muskrat Lake Watershed
Township of Whitewater Region

Agricultural Land Use within the Catchment Areas



Legend

Township of Whitewater Region

Water Sampling Location

SNR-04

Catchment Areas

SNR-04 Catchment Area

Land Cover Classification

Agriculture and Undifferentiated Lands

N

1:110,000

0 2.5 5 Km

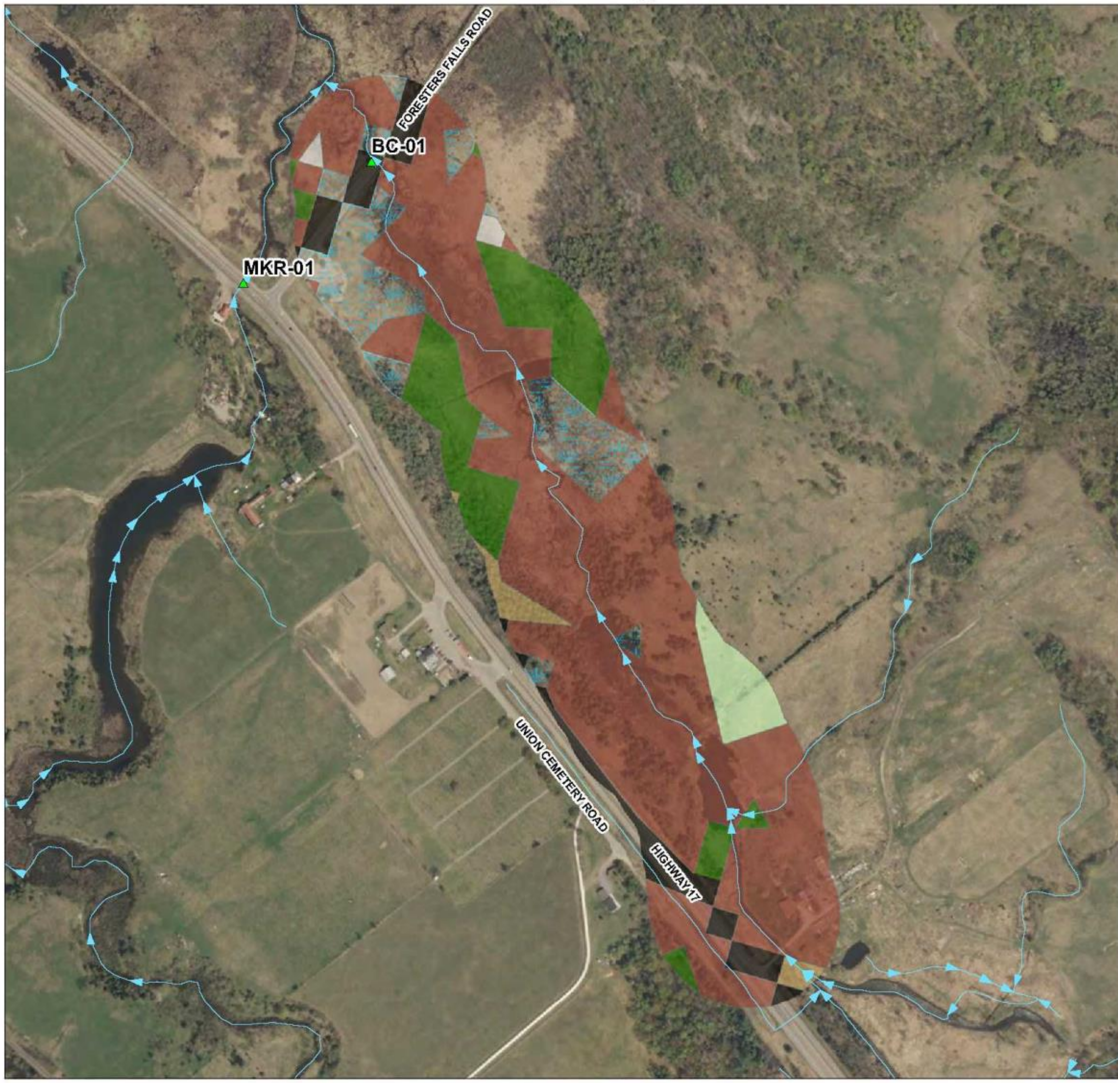
Jp2g Consultants Inc.
ENGINEERS · PLANNERS · PROJECT MANAGERS

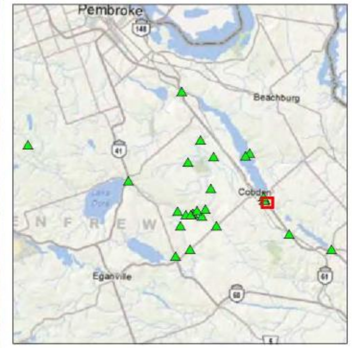
Appendix C. Land Uses within 1 km of Water Quality Sampling Locations (Dalton, 2019)

Ontario

Sampling Location: BC-01

Ministry of the Environment and Climate Change





Legend

SampleSites — Flow Direction

AAFC Data Categories

Label

N/A	Mixedwood
Barley	Nursery
Berries	Oats
Broadleaf	Other Grains
Canola/Rapeseed	Pasture/Forages
Coniferous	Shrubland
Corn	Soybeans
Exposed landBarren	Urban/Developed
Grassland	Water
Hemp	Wetland
	Wheat

**Note: not all AAFC classes are present at each sampling site

N W E S

0 25 50 100 150 200 Meters

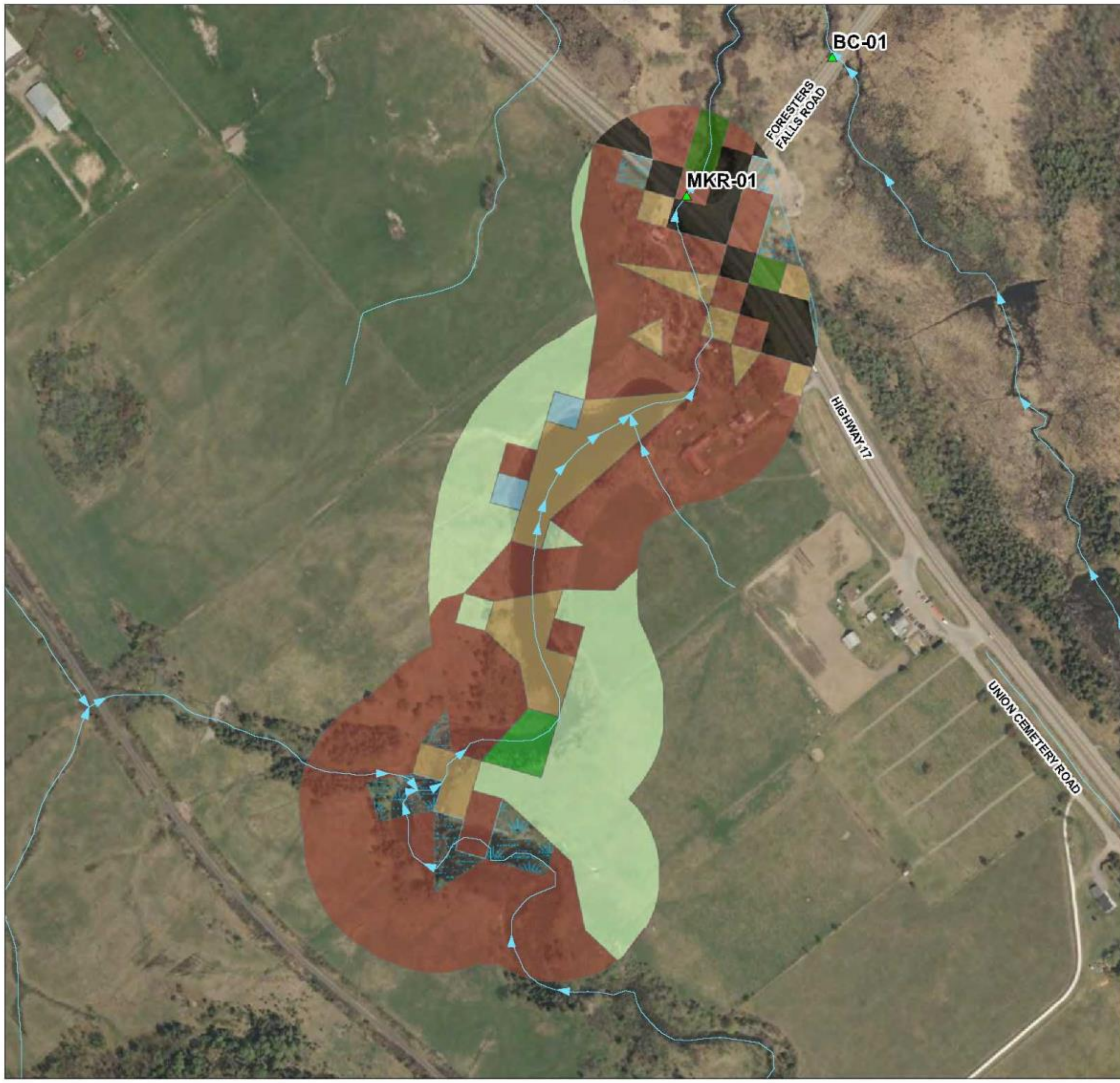
UTM Zone 18 (NAD 1983)
Information Provided by: Ministry of Natural Resources and Forestry, Ministry of the Environment and Climate Change, Ministry of Municipal Affairs and Housing, Agriculture and Agri-Food Canada (AAFC) Annual Crop Inventory 2014
Imagery Provided by Land Information Ontario

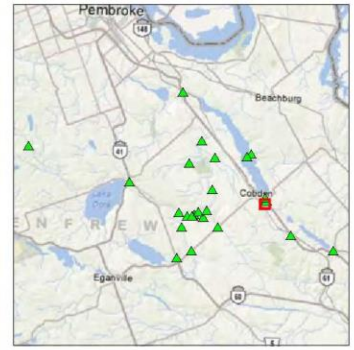
Published 2015

Ontario

Sampling Location: MKR-01

Ministry of the Environment and Climate Change





Legend

- SampleSites
- Flow Direction

AAFC Data Categories

Label

N/A	Mixedwood
Barley	Nursery
Berries	Oats
Broadleaf	Other Grains
Canola/Rapeseed	Pasture/Forages
Coniferous	Shrubland
Corn	Soybeans
Exposed landBarren	Urban/Developed
Grassland	Water
Hemp	Wetland
	Wheat

**Note: not all AAFC classes are present at each sampling site

N W E S

0 25 50 100 150 200 Meters

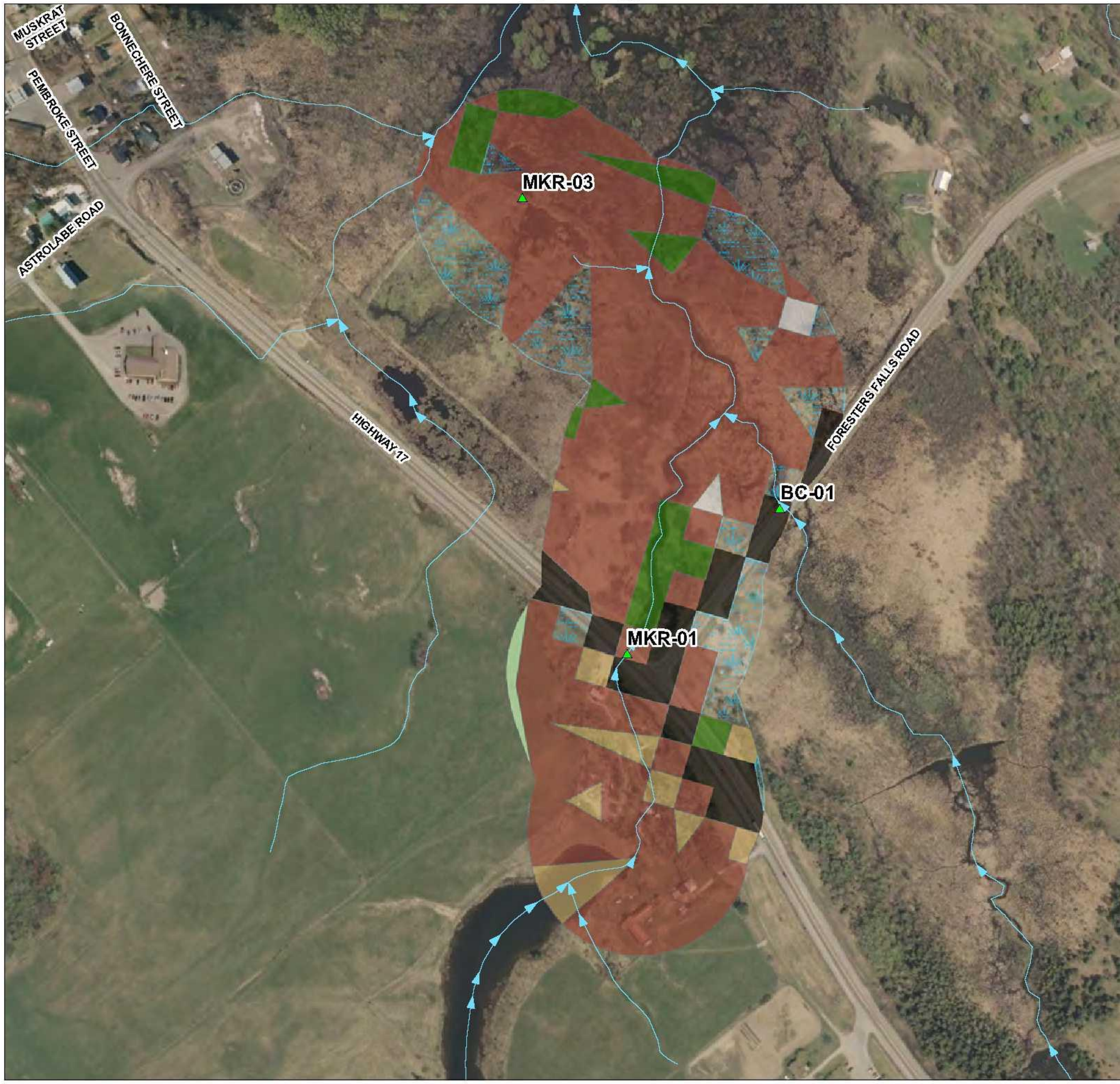
UTM Zone 18 (NAD 1983)
Information Provided by: Ministry of Natural Resources and Forestry, Ministry of the Environment and Climate Change, Ministry of Municipal Affairs and Housing, Agriculture and Agri-Food Canada (AAFC) Annual Crop Inventory 2014
Imagery Provided by Land Information Ontario

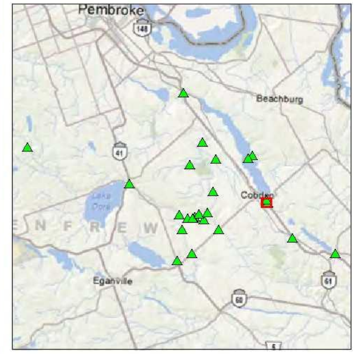
Published 2015

Sampling Location: MKR-03

Ontario

Ministry of the Environment and Climate Change





Legend

SampleSites
Flow Direction

AAFC Data Categories

Label

N/A	Mixedwood
Barley	Nursery
Berries	Oats
Broadleaf	Other Grains
Canola/Rapeseed	Pasture/Forages
Coniferous	Shrubland
Corn	Soybeans
Exposed landBarren	Urban/Developed
Grassland	Water
Hemp	Wetland
	Wheat

**Note: not all AAFC classes are present at each sampling site

N W E S

0 20 40 80 120 160 Meters

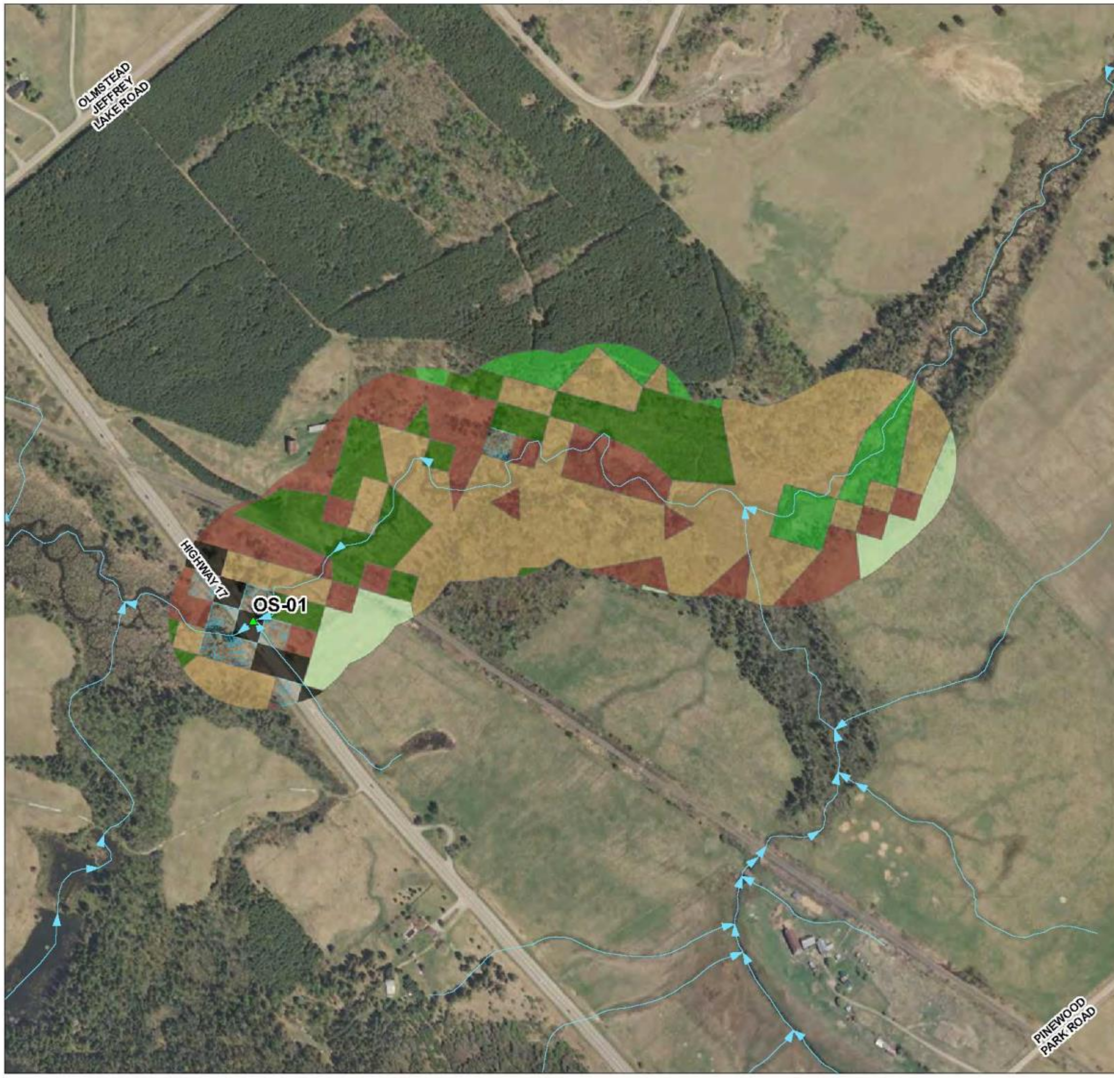
UTM Zone 18 (NAD 1983)
Information Provided by: Ministry of Natural Resources and Forestry, Ministry of the Environment and Climate Change, Ministry of Municipal Affairs and Housing, Agriculture and Agri-Food Canada (AAFC) Annual Crop Inventory 2014
Imagery Provided by Land Information Ontario

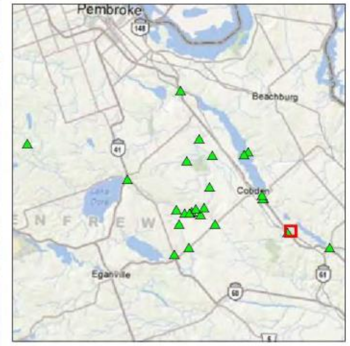
Published 2015

Ontario

Sampling Location: OS-01

Ministry of the Environment and Climate Change





Legend

- SampleSites
- Flow Direction

AAFC Data Categories

Label

- N/A
- Barley
- Berries
- Broadleaf
- Canola/Rapeseed
- Coniferous
- Corn
- Exposed land/Barren
- Grassland
- Hemp
- Mixedwood
- Nursery
- Oats
- Other Grains
- Pasture/Forages
- Shrubland
- Soybeans
- Urban/Developed
- Water
- Wetland
- Wheat

**Note: not all AAFC classes are present at each sampling site

N W E S

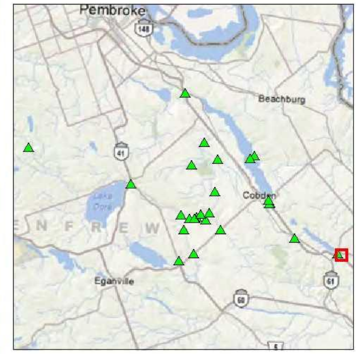
0 25 50 100 150 200 Meters

UTM Zone 18 (NAD 1983)
Information Provided by: Ministry of Natural Resources and Forestry, Ministry of the Environment and Climate Change, Ministry of Municipal Affairs and Housing, Agriculture and Agri-Food Canada (AAFC) Annual Crop Inventory 2014
Imagery Provided by Land Information Ontario

Sampling Location: PH-01

Ontario

Ministry of the Environment and Climate Change



Legend

SampleSites
Flow Direction

AAFC Data Categories

Label

- N/A
- Barley
- Berries
- Broadleaf
- Canola/Rapeseed
- Coniferous
- Corn
- Exposed landBaren
- Grassland
- Hemp
- Mixedwood
- Nursery
- Oats
- Other Grains
- Pasture/Forages
- Shrubland
- Soybeans
- Urban/Developed
- Water
- Wetland
- Wheat

**Note: not all AAFC classes are present at each sampling site

N W E S

0 25 50 100 150 200 Meters

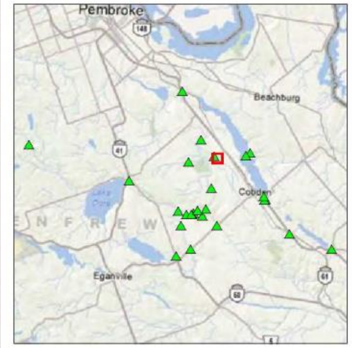
UTM Zone 18 (NAD 1983)
Information Provided by: Ministry of Natural Resources and Forestry, Ministry of the Environment and Climate Change, Ministry of Municipal Affairs and Housing, Agriculture and Agri-Food Canada (AAFC) Annual Crop Inventory 2014
Imagery Provided by Land Information Ontario

Published 2015

Ontario

Sampling Location: SC-02

Ministry of the Environment and Climate Change



Legend

SampleSites	Flow Direction	

AAFC Data Categories

Label	
N/A	Mixedwood
Barley	Nursery
Berries	Oats
Broadleaf	Other Grains
Canola/Rapeseed	Pasture/Forages
Coniferous	Shrubland
Corn	Soybeans
Exposed land/Baren	Urban/Developed
Grassland	Water
Hemp	Wetland
	Wheat

**Note: not all AAFC classes are present at each sampling site

N W E S

0 25 50 100 150 200 Meters

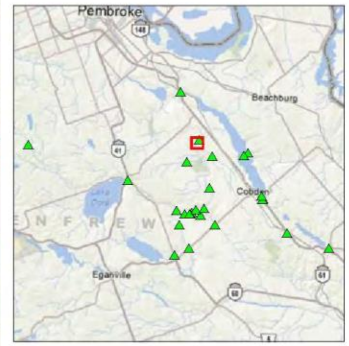
UTM Zone 18 (NAD 1983)
Information Provided by: Ministry of Natural Resources and Forestry, Ministry of the Environment and Climate Change, Ministry of Municipal Affairs and Housing, Agriculture and Agri-Food Canada (AAFC) Annual Crop Inventory 2014
Imagery Provided by Land Information Ontario

Published 2015

Ontario

Sampling Location: SNR-04

Ministry of the Environment and Climate Change



Legend

SampleSites
Flow Direction

AAFC Data Categories

Label

- N/A
- Barley
- Berries
- Broadleaf
- Canola/Rapeseed
- Coniferous
- Corn
- Exposed landBaren
- Grassland
- Hemp
- Mixedwood
- Nursery
- Oats
- Other Grains
- Pasture/Forages
- Shrubland
- Soybeans
- Urban/Developed
- Water
- Wetland
- Wheat

**Note: not all AAFC classes are present at each sampling site

N
W E
S

0 30 60 120 180 240 Meters

UTM Zone 18 (NAD 1983)
Information Provided by: Ministry of Natural Resources and Forestry, Ministry of the Environment and Climate Change, Ministry of Municipal Affairs and Housing, Agriculture and Agri-Food Canada (AAFC) Annual Crop Inventory 2014
Imagery Provided by Land Information Ontario

Published 2015

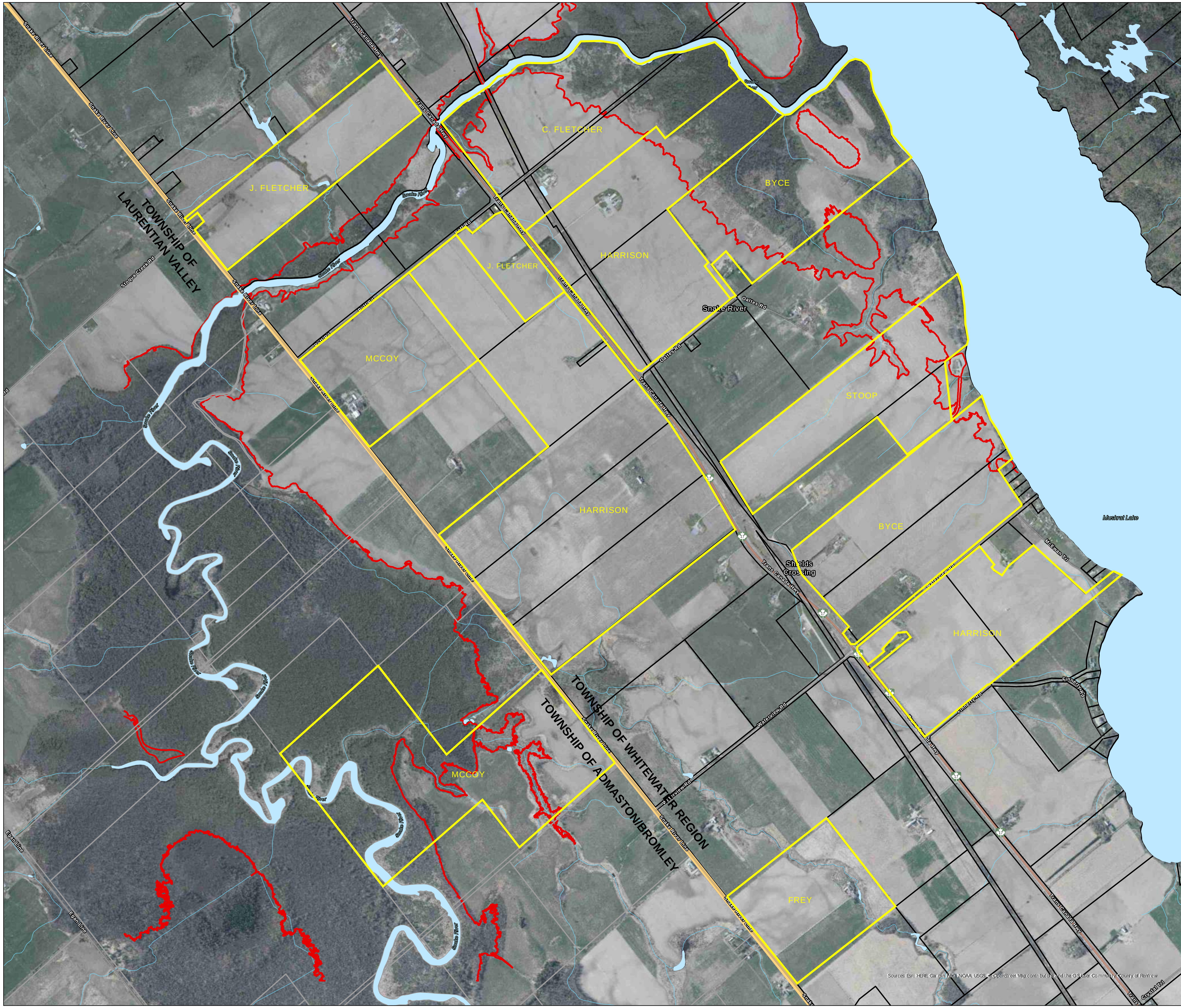
Appendix D. One-on-One Meeting Participants

Appendix D

Participants in the one-on-one/small group meetings (interviews) is summarized below. The location of the farmlands of participating farmers is shown on the map attached in Appendix E.

1. Colin Fletcher, Farmer
2. Donald Deer, Muskrat Lake Association
3. Karen Coulas, Muskrat Watershed Council
4. Rene Coulas, Muskrat Watershed Council
5. Bill Stoop, Farmer
6. Dennis Harrison, and Spencer Harrison, Farmers
7. Reuben Stone, Formerly with the Renfrew County Federation of Agriculture
8. Ron McCoy & Michael Lott, Farmers
9. Kevin Frey, Farmer

Appendix E. Property Owners in Priority Areas that Attended Consultation



COBDEN AGRICULTURAL AREA STUDY

MAP 1: PROPERTY OWNER MAP

Legend

- Waterbody
- Watercourse
- 124 m Contour Elevation
- Township of Whitewater Region
- Township of Whitewater Region Property Fabric
- Township of Admaston/Bromley Property Fabric

Scale: 1:9,000

0 0.5 1 Kilometers

Maps are not intended to be used for legal purposes or to identify exact locations of map elements. Verification and survey of existing conditions is required to confirm actual location of existing conditions and/or proposed elements.