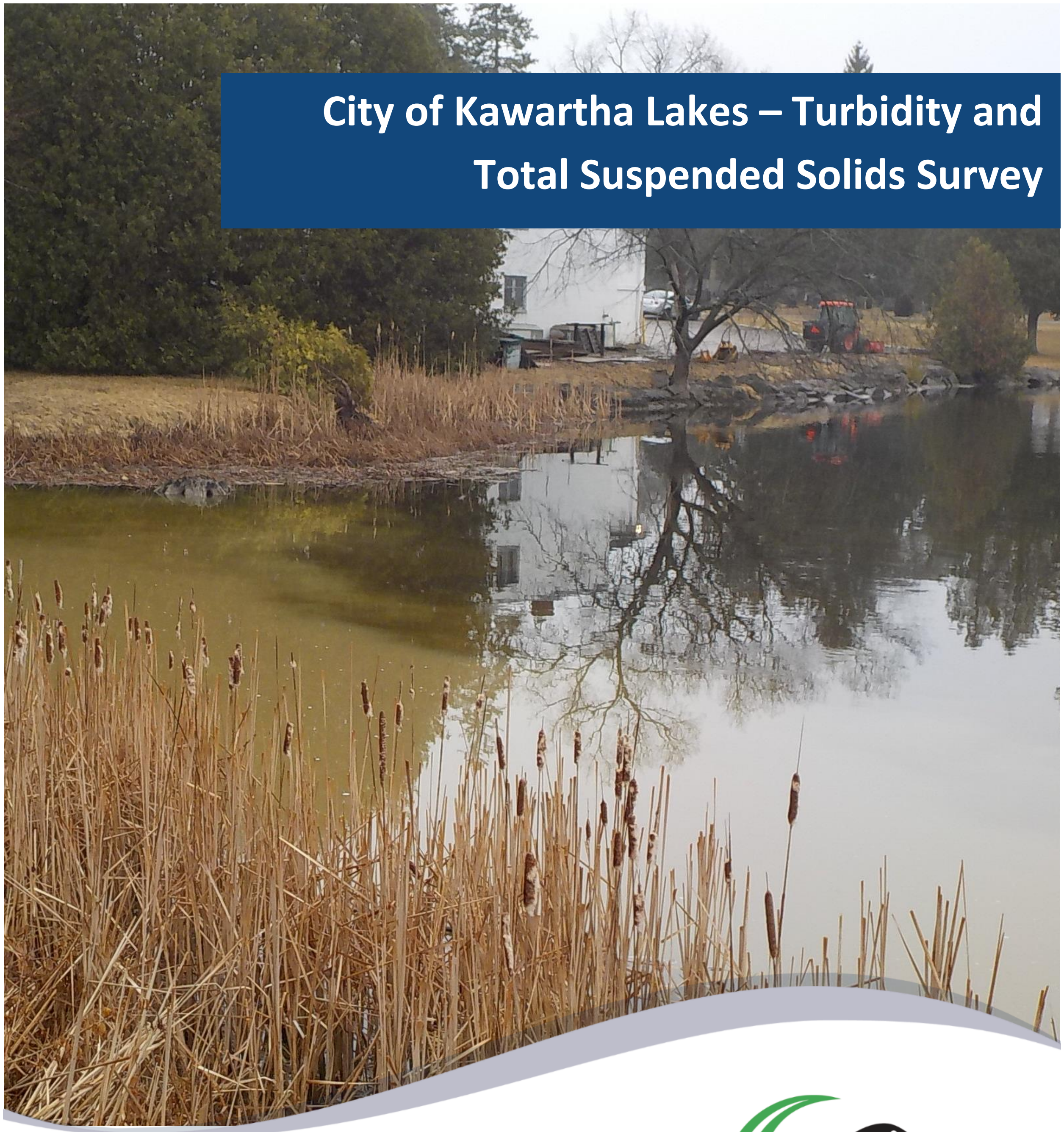

City of Kawartha Lakes – Turbidity and Total Suspended Solids Survey

KAWARTHA CONSERVATION

Discover · Protect · Restore

About Kawartha Conservation

Who we are
We are a watershed-based organization that uses planning, stewardship, science, and conservation lands management to protect and sustain outstanding water quality and quantity supported by healthy landscapes.

Why is watershed management important?
Abundant, clean water is the lifeblood of the Kawarthas. It is essential for our quality of life, health, and continued prosperity. It supplies our drinking water, maintains property values, sustains an agricultural industry, and contributes to a tourism-based economy that relies on recreational boating, fishing, and swimming. Our programs and services promote an integrated watershed approach that balance human, environmental, and economic needs.

The community we support
We focus our programs and services within the natural boundaries of the Kawartha watershed, which extend from Lake Scugog in the southwest and Pigeon Lake in the east, to Balsam Lake in the northwest and Crystal Lake in the northeast – a total of 2,563 square kilometers.

Our history and governance
In 1979, we were established by our municipal partners under the *Ontario Conservation Authorities Act*.

The natural boundaries of our watershed overlap the six municipalities that govern Kawartha Conservation through representation on our Board of Directors. Our municipal partners include the City of Kawartha Lakes, Region of Durham, Township of Scugog, Township of Brock, Municipality of Clarington, Municipality of Trent Lakes, and Township of Cavan Monaghan.

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Acknowledgements

We would like to acknowledge that many Indigenous Nations have longstanding relationships, both historic and modern, with the territories upon which we are located.

Today, this area is home to many Indigenous peoples from across Turtle Island. We acknowledge that our watershed forms a part of the treaty and traditional territory of the south-eastern Anishinaabeg.

It is on these ancestral and treaty lands that we live and work. To honour this legacy, we commit to being stewards of the natural environment and undertake to have a relationship of respect with our Treaty partners.

The region of Kawartha Lakes was referred to as *Gau-wautae-gummauh*, a glistening body of water, in anishinaabemowin. We are thankful to have an opportunity to work with Indigenous Peoples in the continued stewardship and care of this beautiful region.

This report was written by Tanner Liang, Water Quality Specialist, Kawartha Conservation. Others who have contributed to the development of this project include:

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Brett Tregunno, Aquatic Biologist	Kawartha Conservation

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Table of Contents

List of Figures

List of Tables

Abbreviations

%CV:	Coefficient of variation
%	Percentage
µS/cm:	Microsiemens per centimeter
^{o}C:	Degree Celsius
Cond:	Conductivity
CWQG:	Canadian Water Quality Guideline
DO:	Dissolved Oxygen
et al. :	*et al*ibī (latin phrase) meaning and other authors
FNU:	Formazin Nephelometric Unit
km^2:	Square kilometers
Hr(s):	Hour(s)
L	Liter
Log:	Logarithm
m:	Meter(s)
mg/L:	Milligram(s) per liter
mm:	Millimeter(s)
n:	Sample size
NTU:	Nephelometric Turbidity Unit
P:	Percentile
p:	p-value
PWQMN:	Provincial Water Quality Monitoring Network
Temp:	Temperature
TSS:	Total Suspended Solids
Turb:	Turbidity
ρ:	Spearman's Rho

Executive Summary

In this study, 84 sites were sampled across three major land covers; Urban (*n*=44), Natural (*n*=23), and Agricultural (*n*=17), to identify A) the variability of water clarity and suspended solids during a rain event, and B) any sites with concerning levels of turbidity or total suspended solids. During the time of the survey (October-November), daily precipitation ranged from 1.8-11 mm (average = 6.3 mm). All sites were located in the City of Kawartha Lakes region which is predominately used for agriculture. Patterns of total suspended solids and turbidity indicated that land cover type had some direct influence on concentrations, where Urban areas had higher levels of both parameters, followed by Agriculture and Natural land cover. Significant differences ($p<0.01$) were found between Urban and Natural land cover for both turbidity and total suspended solids. Using the Canadian Water Quality Guidelines for the Protection of Aquatic Life and values reported in the literature, we were able to estimate thresholds for total suspended solids (28.5 mg/L) and turbidity (10.25 FNU). When applied, there were 4 exceeded sites for total suspended solids and 20 exceeded sites for turbidity. Most of the exceeded sites were found in the Urban land cover. More exceeded site for turbidity may have been affected by smaller particles, natural dyes, or algae.

Introduction

The clarity of the water can impact the aesthetic of the waterbody and the organisms that live within it. Murky waters are often associated with increase in suspended solids that may originate from biotic (living; phytoplankton, algae) and abiotic (non-living; sand, silt, clay) sources. These particles can bind to organic and inorganic contaminants (Bodo, 1989) allowing them to travel up the food chain (via bioaccumulation and biomagnification) and travel vast distances from its original source. Inputs of particles from terrestrial source often occur during rain events (stormwater runoff), spring melts (meltwater) (Danz *et al.*, 2013), and human induced activities such as construction (Barton, 1977), agriculture (Rutledge and Chow-Fraser, 2019), and urbanization (Winter and Duthie, 1998).

Many water quality monitoring programs, such as the Provincial (Stream) Water Quality Monitoring Network (PWQMN), Lake Partner Program, Great Lakes Water Quality Monitoring Program, etc., have parameters that assess the clarity of the water. The Guidance Manual for Optimizing Water Quality Monitoring Program Design (CCME, 2015) recommends adding total suspended solids analysis for water quality programs that monitor for human health and human disturbance. When monitored for water quality, water clarity can be measured by the measuring the total suspended solids (TSS in milligrams per liter) in the laboratory or by measuring the amount of light that is deflected in the water. These two units are not the same but are generally used together to get a sense of water clarity.

When suspended solids enter the water, they can impact the gills of aquatic organism and macroinvertebrates, causing discomfort, change in behaviour, and possible death (Bash *et al.*, 2001; Kjelland *et al.*, 2015; Tuttle-Raycraft and Ackerman, 2019). When suspended solids settle out of the water column, these particles (when abundance) can cover/smother critical spawning nest or incubating eggs (Bash *et al.*, 2001). Depending on species, some species of fish can tolerate more murky (less clear) waters. For example, fish species such as Common Carp (*Cyprinus carpio*), Yellow Perch (*Perca flavescens),* Walleye (*Sander vitreus*), and Blue Gill (*Lepomis macrochirus*) are moderately/fully tolerant of turbid waters, some as high as >100 NTUs (Trebitz *et al.*, 2007). While others such as Muskellunge (*Esox masquinongy*) are intolerant of waters with >25 NTUs (Trebitz *et al.*, 2007; Ontario Ministry of Transportation, 2009). High turbidity from suspended solids have been recorded to affect the behaviour and performance of fish (Sweka and Hartman, 2011; Gary *et al.*, 2014), thus effective management of erosion and sediment control (especially in the long-term) can affect fish populations, and distribution and fate of pollutants.

The goal of this study was to survey 84 sites during precipitation events across the City of Kawartha Lakes region to:

1) Assess the variation of water clarity amongst different land uses (Natural, Urban, and Agricultural), and
2) Determine exceeded sites and highlight any streams in need for remediation.

Methods

Study Area

The City of Kawartha Lakes (previously known as Victory County) is a large (~3, 000 km^2) rural region of south-central Ontario with scatter population centers such as Lindsay (population = 22,367, Bobcaygeon (3,576), Fenelon Falls (2,490), and Omemee (1,060) (Statistics Canada. 2022) (**Figure 1**).

The region has deep glacial tills and limestone plains in the south and exposed granite bedrock to the north, which largely governs where agricultural lands occur and creates a mosaic of waterbodies with a variety of different water quality characteristics (Kawartha Conservation, 2010, 2014, 2015, 2018).

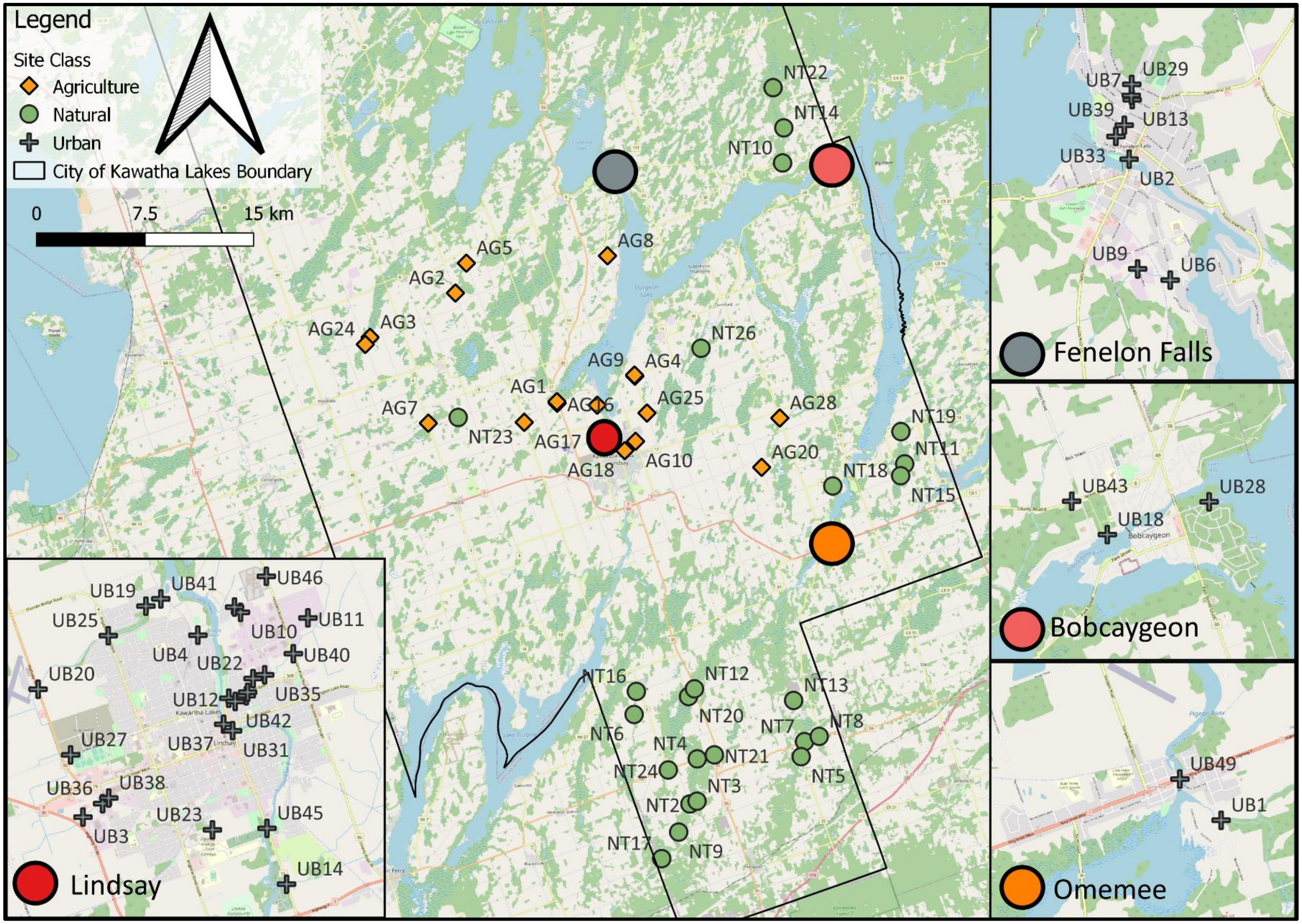


Figure 1. Locations of sampling sites in this study. Mini-maps depict Urban sites (Grey Cross) in Lindsay, Bobcaygeon, Fenelon Falls and Omemee. Orange Diamond = Agriculture sites and Green Circle = Natural sites.

Site Selection

A dataset of stream crossings was compiled for the region of City of Kawartha Lakes and were randomly stratified based on land cover, i.e., Urban, Agricultural, and Natural. A larger portion of sites were given to urban sites (*n*=50), where the remaining sites were split among agriculture (n=25) and natural (n=25) land cover. Urban sites were streams that were located within the official urban settlement boundaries of Lindsay, Bobcaygeon, Fenelon Fall, and Omemee.

Land cover and catchment characteristics for each site were obtained by the Southern Ontario Land Resource Information System (SOLRIS) through the Ontario Watershed Information Tool (OWIT; Government of Ontario, 2015). Sites with greater than 80% agricultural land cover were selected to represent the Agricultural land class while Natural sites were based on known sites which houses sensitive species such as Brook Trout (*Salvelinus fontinalis*) (Tregunno, personal communication, 2021).

Field and Laboratory Methods

At each site surface water was collected by first triple rinsing the collection jar with the targeted water, and then sampling the water at 0.15-0.3m depth. Field measurements of water temperature (Temp., ^{o}C), conductivity (Cond, µS/cm), dissolved oxygen (DO, mg/L), pH, and turbidity (Turb, FNU), were also taken in conjunction to the samples. Surface water samples were kept cool (<4^{o}C) and were sent to Caduceon Environmental Laboratories for total suspended solids (TSS) analysis.

Data Analysis

All data analysis was performed with the statistical program, R (R Core Team, 2021). No observations were left as *NA*, while values below detection limits were addressed using the R package NADA (Lee, 2021) by following that of Huston and Juarez-Colunga (2009). Percent coefficient of variation (%CV) for pH followed that of Canchola *et al.*, (2017). Total suspended solid levels were compared against the Canadian Water Quality Guideline (CWQG) for the Protection of Aquatic Life (CCME, 2002).

Prior to any data analysis, the dataset was tested under certain condition to determine which type of test to use. Results indicated that non-parametric test should be used, i.e., Kruskal-Wallis, pairwise Wilcox, and Spearman's rank correlation.

Precipitation amount data were obtained through Kawartha Conservation's climate network, specifically from the following stations: Ken Reid Conservation Area, Indian Point Provincial Park, Pigeon River, Trent Lakes Municipal Office, and Emily Provincial Park. Precipitation amounts were taken on the day of sampling, 24hrs and 48 hrs prior.

Results

From the original 100 sites selected (see the Site Selection section), only 84 sites were visited, which 9 were found to be dry. This resulted in a total site sampled of 75 across all land cover; 17 on Agriculture, 23 on Natural, and 44 on Urban land cover.

During the time of the survey (October-November), daily precipitation ranged from 1.8-11 mm (average = 6.3 mm). Surprisingly, 9 sites were found to be dry and had no flow (**Appendix B Figure 1**) and were not sampled. Dry sites were mostly found under urban land cover (**Appendix B Figure 1**). Duplicate samples were taken at 4 sites and were found to be more variable (percent coefficient of variation >10%), thus were treated as single samples (Count in **Table 1**).

Sites classified as Natural were all found to be disturbed to some degree, i.e., having some agricultural areas present, and did not have a true 100% natural cover. Thus, "Natural" sites are more representative of "less impacted sites" and should not be used for background or baseline comparison. Most of these "Natural" sites were found within the Pigeon River and Fleetwood Creek watershed. Other watersheds that had a few Natural sites were Potash Creek and Martin Creek.

Table 1. Summary statistics [mean, median, %CV, Max, Min, 10th and 90th P (percentile)] of field (Temperature, Conductivity, pH, Dissolved Oxygen, and Turbidity) and chemical (Total Suspended Solids) parameters.

		Land Cover					Land Cover		
Parameter	**Statistics**	**AG**	**NT**	**UB**	**Parameter**	**Statistics**	**AG**	**NT**	**UB**
	Count	18	25	40		Count	18	25	40
Cond.	Mean	653.89	541.58	555.61	**Temp.**	Mean	7.82	4.43	8.26
µS/cm	Median	655	500.5	495	°C	Median	7.84	3.47	7.83
	%CV	47.49	24.08	53.55		%CV	10.98	49.29	20.04
	Max	1511	858	1330		Max	9.20	8.10	13.58
	Min	5.18	373	11.79		Min	6.14	1.57	5.11
	10th P.	403.1	395	258.1		10th P.	6.98	2.3	7.14
	90th P.	828.2	707.2	984.1		90th P.	9.08	7.48	9.63
Dissolved	Mean	7.89	9.62	8.61	**Total**	Mean	6.37	4.19	10.11
Oxygen	Median	8.48	10.70	9.04	**Suspended**	Median	5.00	3.50	6.00
	%CV	26.47	30.71	19.89	**Solids**	%CV	85.67	71.14	118.38
mg/L	Max	10.78	12.17	10.59	mg/L	Max	20.00	14.00	57.00
	Min	3.21	1.91	1.96		Min	0.79	0.92	1.25
	10th P.	4.62	4.34	6.81		10th P.	1.31	1.34	3.00
	90th P.	10.51	11.75	10.15		90th P.	13.8	7.00	20.1
pH	Mean	7.87	7.83	7.94	**Turbidity**	Mean	5.05	3.78	19.38
	Median	7.93	7.92	8.03	FNU	Median	3.40	1.70	8.25
	%CV*	3.70	134.29	440.52		%CV	107.59	210.15	152.41
	Max	8.23	8.11	8.30		Max	17.4	39.3	110
	Min	7.27	7.21	7.18		Min	0.00	0.00	0.00
	10th P.	7.52	7.46	7.49		10th P.	0.07	0.00	0.20
	90th P.	8.21	8.06	8.21		90th P.	10.77	6.90	59.57

*%CV calculations followed that of Canchola *et al.*, (2017).

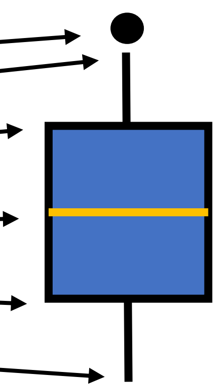
Total Suspended Solids

Fifteen (15) sites had total suspended solid concentrations below the detection limit of 3 mg/L and were addressed using the R package NADA (Lee, 2021). Levels of TSS found ranged from 0.79 to 57 mg/L and had a mean of 7.43 mg/L, and a median of 5.00 mg/L across all sites. Between land cover types, TSS were generally higher among Urban sites (mean = 10.11 mg/L, median = 6.00 mg/L), followed by Agriculture (mean = 6.37 mg/L, median = 5.00 mg/L), and last, Natural sites (mean = 4.19 mg/L, median = 3.50 mg/L) (**Table 1; Figure 2**).

How to read boxplots (Box and Wiskers)

A boxplot is a graph that shows the spread of the data, along with six key summary points:

1. Possible outliers
2. Maximum value
3. Upper quantile (75%)
4. Median (50%)
5. Lower quantile (25%)
6. Minimum value



Quantile is a cut-off point when the data is ordered largest to smallest.

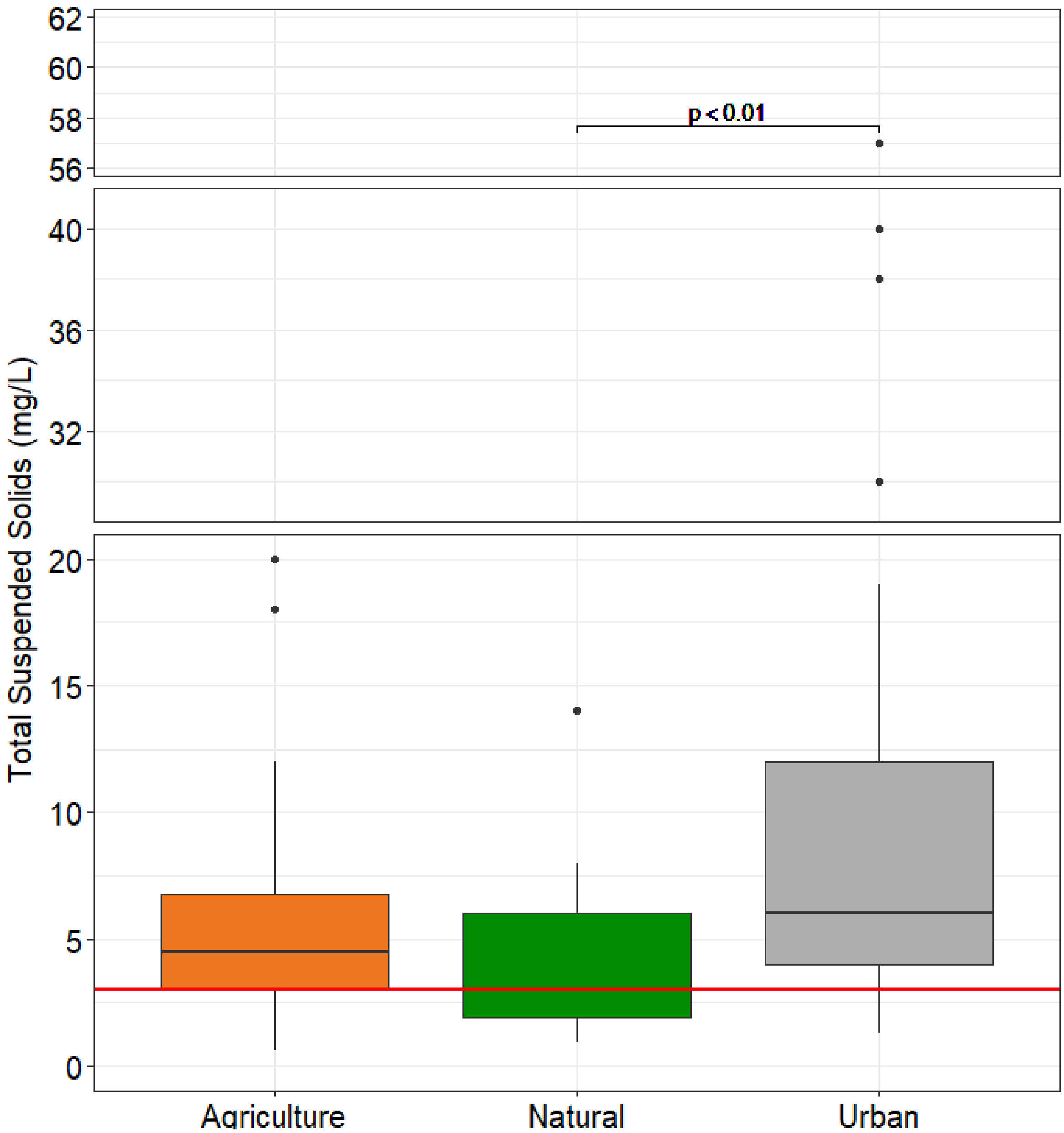


Figure 2. Total Suspended Solids concentrations across the three different land uses (Agriculture, Natural, and Urban). The red horizontal line indicates the detection limit, values below are modelled.

It should be noted that 36% of TSS observation for Natural sites had values below the detection limit, followed by 16% at the detection limit. This suggests that TSS levels in less impacted watersheds (where there were little impacts to aquatic organisms) in the Kawartha region are at and below 3.00 mg/L. This was similar to that found by Culp *et al.*, (2013) where a change-point of 2.60 mg/L of TSS was estimated using PWQMN data of Southern Ontario. At the change-point, a significant difference ($p < 0.05$) in relative abundance of EPT, *Ephemeroptera* (Mayflies), *Plecoptera* (Stoneflies), and *Trichoptera* (Caddisflies), sensitive benthic invertebrates that has been used as indicators of good water quality. Thus, suggest that sites used in this study for *Natural* land cover may hold sensitive EPT.

The Canadian Water Quality Guideline for the Protection of Aquatic Life for Total Particulate Matter aims to define a threshold that protects many aquatic biotas (fish and benthic invertebrates) of North America against impacts from suspended solids (CCME, 2002). The guideline suggests a max increase of 25 mg/L from background within a short-term period of 24 hrs (CCME, 2002). The term "background" concentration is considered to be those of that exist naturally due to natural processes and geological setting at a certain location (CCME, 2007). Currently, the "background" concentration of TSS have not been established in the Kawartha region. Thus, we used the Ecological Reference Condition (ERC) – the point where a significant change in abundance of sensitive benthic, from Culp *et al.* (2013) at 3.5 mg/L. When combined with the ERC from Culp *et al.*, (2013), we get a threshold of 28.5 mg/L. At this limit, only four sites exceeded (**Figure 3**), all of which were classified as Urban sites. These sites were located in Lindsay (n=3) and Fenelon Falls (n=1) (**Figure 3**). Since these sites were found to exceed during a smaller precipitation event, we can expect similar and worst results (higher TSS concentration) during a higher precipitation event, elevating the concern for these sites. When looking at all sites, the 90th percentile was found at 14.00 mg/L (**Table 1**), suggesting that 90% of TSS values found were well below the 28.5 mg/L limit, indicating that during this survey, many sites (except for the 4 exceeded sites) had limited risk for aquatic organism for suspended solids.

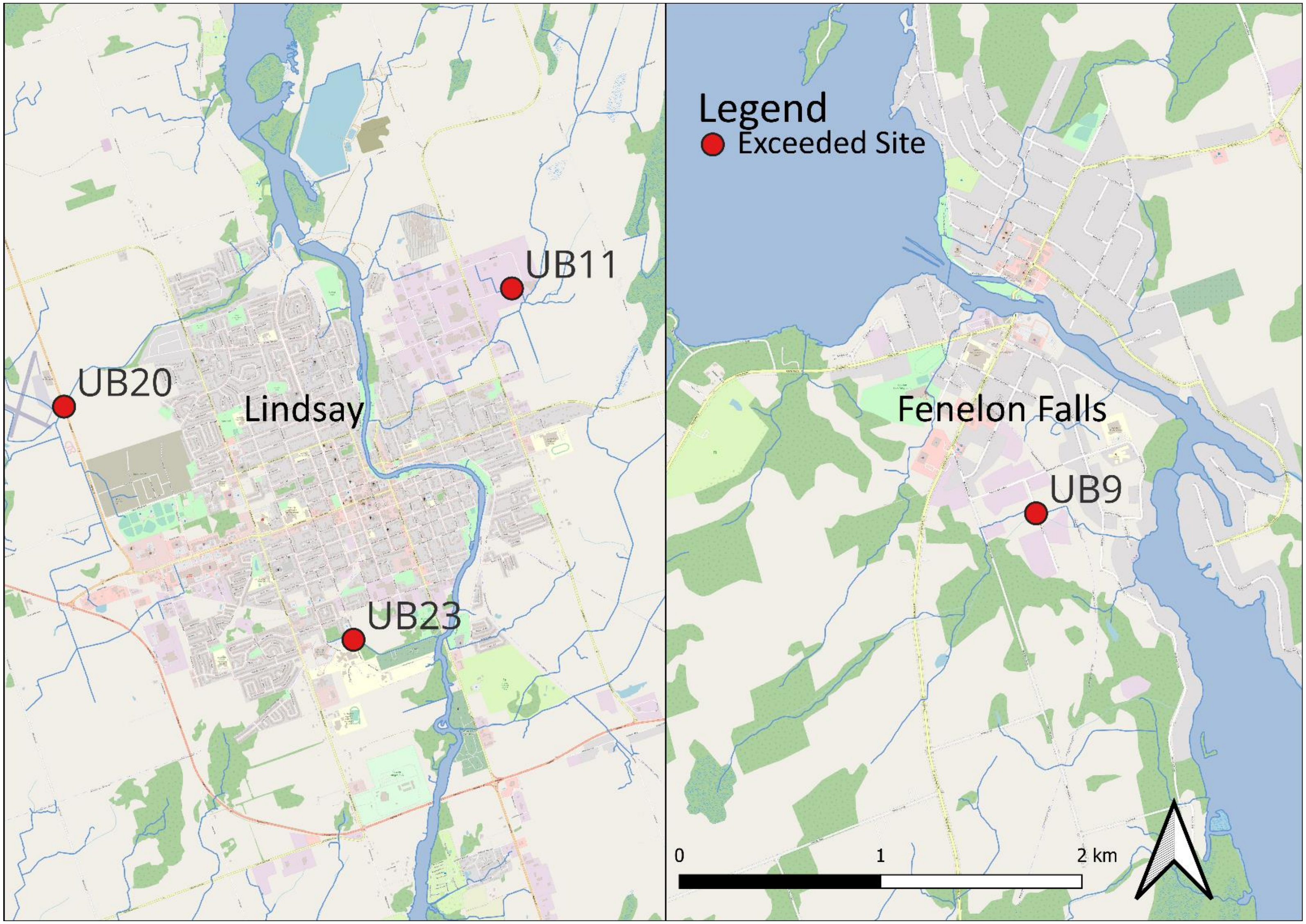


Figure 3. Location of all exceeded sites that had TSS levels greater than the threshold of 28.5 mg/L as per CWQG for the Protection of Aquatic Life.

Turbidity

Turbidity measurement followed that of TSS, where the highest measurement was found among Urban sites (mean = 19.38 FNU, median = 8.25 FNU) and lower among Agriculture (mean = 5.05 FNU, median = 3.40 FNU), and lowest among Natural sites (mean = 3.78 FNU, median = 1.70 FNU; **Table 2**; **Figure 4**). Across all sites, the minimum was found at 0.00 FNU and the maximum at 110 FNU (**Table 2**).

Guidelines for the Protection of Aquatic Life indicate a maximum increase of 8 NTUs within 24 hrs (CCME, 2002). Similar to TSS (above), there has not been a "background" (naturally concentrations) turbidity value established for the Kawartha Region. Thus, we used the median turbidity level of 2.25 FTU, which originated from 30 headwater streams in the Oak Ridge Moraine (Maude and Di Maio, 1996). Note that it is assumed that 1 NTU = 1 FNU = 1 FTU. When applied to the CWQG, it results in a threshold 10.25 FNU. At this level, we see that 20 sites exceeded this threshold, resulting in an increase of exceeded sites for turbidity when compared to TSS (**Figure 5**). This indicates that approximately 25% surveyed sites have been impacted to a degree that exceeds the short-term threshold for the protection of aquatic life. At a turbidity level of 10.25 FNU, turbidity intolerant (<10 NTU; Barbour *et al.*, 1999, Trebitz *et al.*, 2007) species that are generally, fall spawners (longer incubation period), depend on vision to hunt, and require high dissolved oxygen levels to be present. Between land cover types, there were 17 exceeded sites for Urban, 2 for Agriculture, and 1 for Natural. The single Natural site is located within the village of Bethany on the Provincial Highway 7A. This impervious roadway may be the result for its lack of clarity.

Among sites, we see that almost all Natural and Agriculture sites (90th percentile: Natural = 6.90 FNU, Agriculture = 10.77 FNU; **Table 2**) are found to be below this threshold. This may suggest that some turbidity sensitive fish may be found in agricultural dominated streams, but the author acknowledges that there are many other factors that govern the distribution of fish.

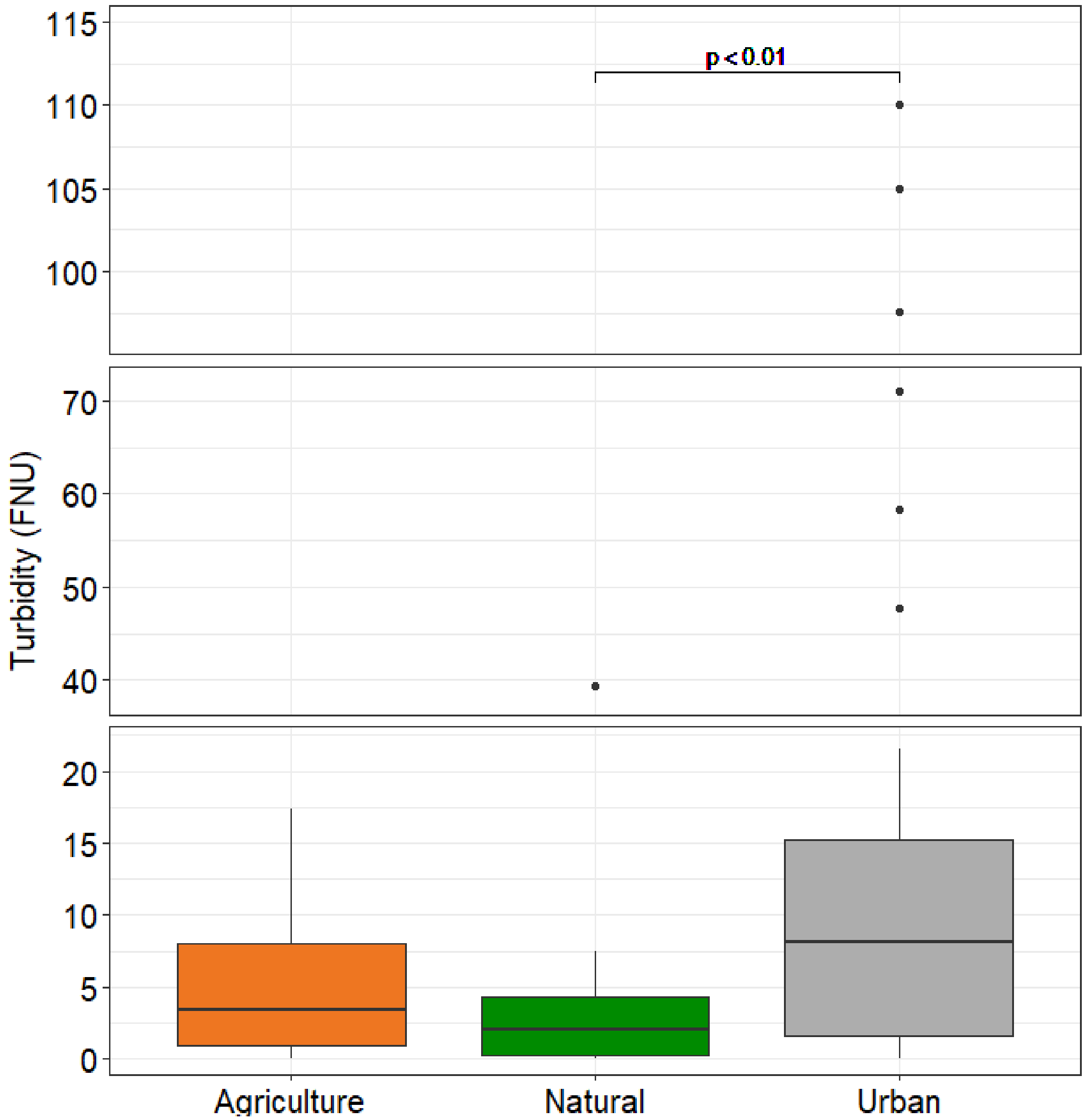


Figure 4. Turbidity measurements for 84 sites across Agriculture, Natural, and Urban land use.

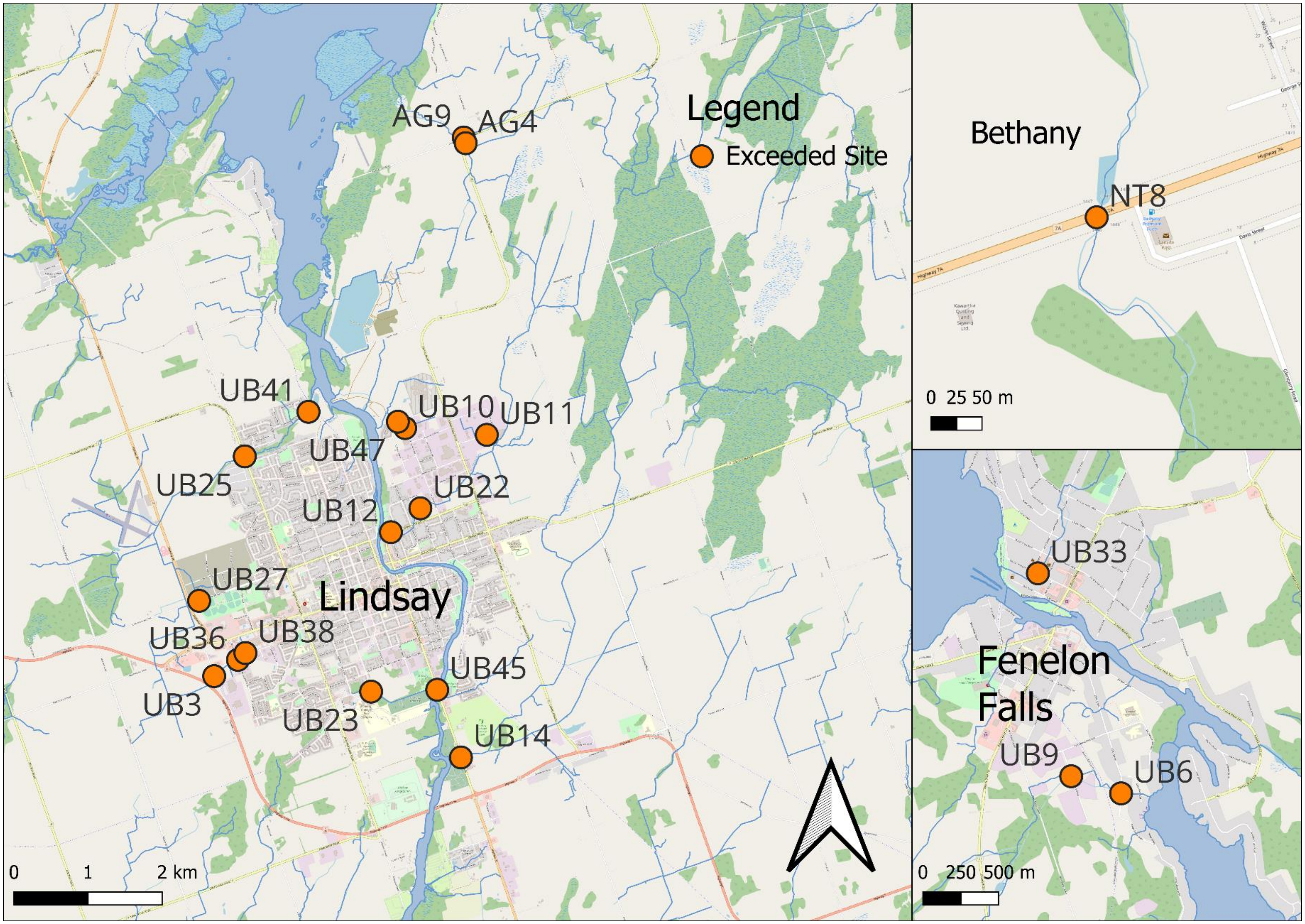


Figure 5. Location of all exceeded sites that had Turbidity levels greater than the threshold of 10.25 FNU as per CWQG for the Protection of Aquatic Life.

Under these turbidity levels, we find that only fishes that are intolerant of turbidity, require high dissolved oxygen, long egg incubations periods, and dependant on vision for hunting, i.e., Brook Trout (*Salvelinus fontinalis*), may occur in only Natural and some Agriculture sites.

For Urbanized sites, the 90th percentile was found to be 59.57 FNU (**Table 2**), fishes that are classified as moderately tolerant to tolerant, i.e., Common carp (*Cyprinus carpio*), Goldfish (*Carassius auratus*), Brown bullhead (*Ameiurus nebulosus*), or those that are non-guarding spring spawners and/or insectivores, may occur (Barbour *et al.*, 1999; Trebitz *et al.*, 2007; MTO, 2009b).

From the above, we see that there are higher rates of exceeded sites for turbidity than TSS. One possible reasoning is that particles affecting turbidity in water are much smaller than those filtered out for TSS analysis, where a common method is to weight the filter paper pre and post filtering of a sample. An abundant of smaller particles, i.e, clay/ algae/ dissolved organic matter in a water sample may yield low TSS concentration and high turbidity value.

Relationship between Turbidity and TSS

In this study, a very weak relationship between turbidity and TSS was found for Urban and Agricultural sites (**Figure 6**). No significant relationship was found for Natural Sites. For Urban and Agricultural sites, it is suggested that the resuspension or input of particles may affect the clarity of the water. Further monitoring is required to further dissect this relationship among streams in the region. Site specific relationships is encouraged to be explored as not all sites are created equal and other factors such as soil type and stream chemistry may affect the relationship. The creation of a turbidity and TSS curve by utilizing soils found upland of the waterbody may help determine exceedances quickly which can be applied in sensitive areas or areas that are under human development.

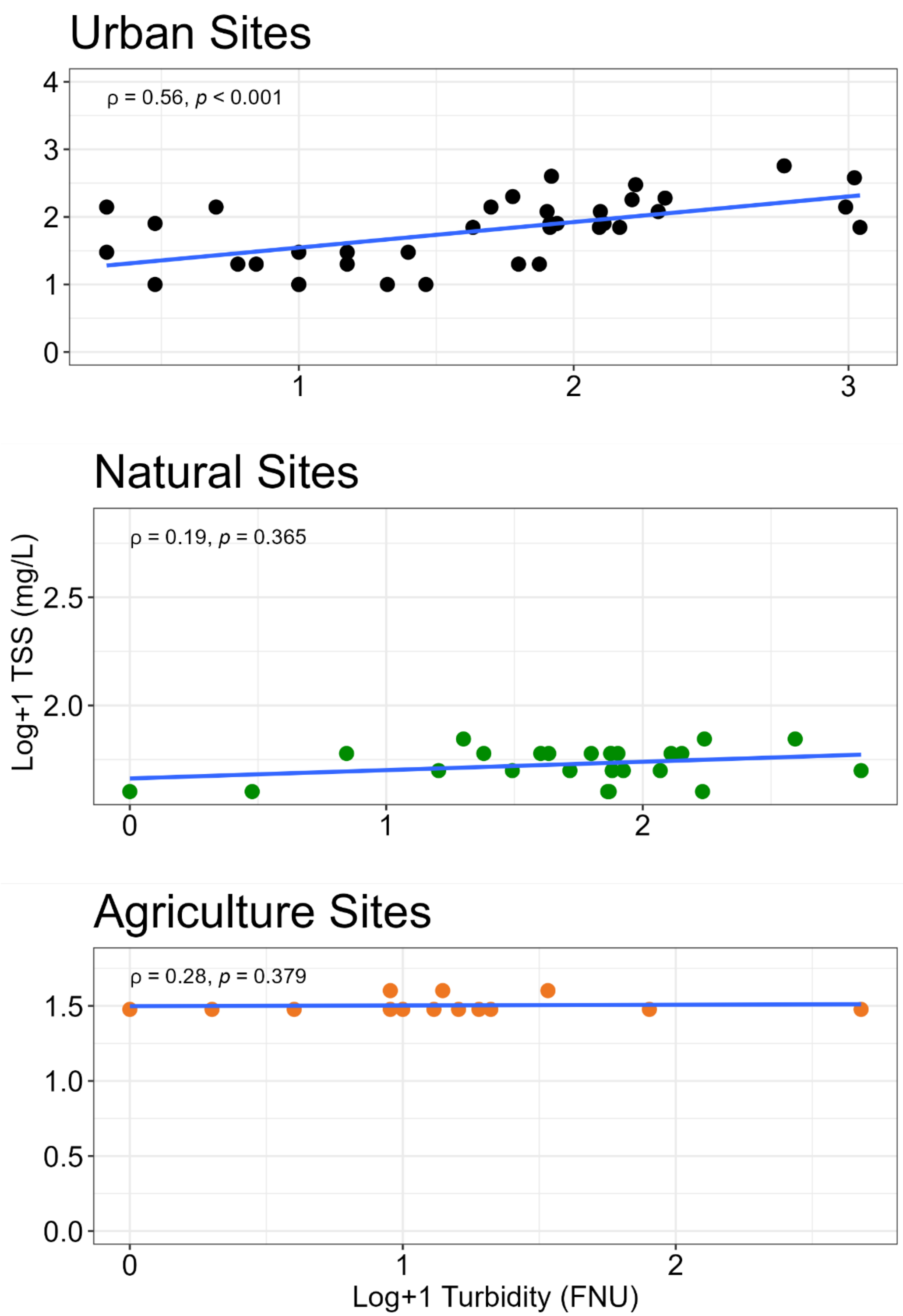


Figure 6. Relationship between transformed (Log+1) TSS and Turbity values for each of the three land cover types. Spearman's rho (ρ) and p-values are shown for land use type.

Conclusion and Recommendations

In this study we assessed sites for total suspended solids and turbidity across three major land covers, i.e., Urban, Natural, and Agriculture. We reported that there were significant differences between Urban and Natural sites, and that the Urban land cover hold many of the exceeded sites for TSS and turbidity when applying the CWQG limits with background levels from Culp *et al.*, (2013), Maude and Di Maio (1996).

Sources of TSS in urban areas include, but not limited to, wear from pavement, emissions, building and construction materials, soils material, plant litter, and others (Taylor and Owens, 2009). Urban areas tend to have large areas of impervious surfaces (concrete, roofs, asphalt) that concentrate pollutants and solids into pervious areas, i.e., green space. These green spaces are usually minuscule when compared to the overall urban space, which may result in a smaller buffer width for urban streams, overloading any natural process.

The recommended width of buffer is dependent on a variety of factors that include (but not limited): drainage area, slope, rainfall amount and intensity, soil type, pollutant type (MOE, 2003; Bentrup, 2008; CVC and TRCA, 2010). Thus, there are many different lengths and efficiencies reported in the literature, e.g., 16.4 m for 97% sediment removal (Lee *et al.* 2002), 20 m at 82% efficiency (Dun *et al.*, 2011), 3 m at 55% efficiency (Gharabaghi *et al.*, 2006). Through a literature review, it was pointed out by Sweeney and Newbold (2014) that narrow buffers (< 30 m) are only effective when runoff was lower and that they were not effective at trapping fine particles such as silts and clays. Thus, wider buffers should be implemented in exceeded site of turbidity.

However, it is generally agreed upon that narrow buffers in higher rainfall areas provide less sediment trapping (and other ecological and pollutant removal benefits) than those that are wider in lower rainfall events. When including benefits for reducing nutrients and fecal matter (Grismer 1981; Castelle *et al.* 1991), wildlife habitat (Roby *et al.* 1977; Hickman and Raleigh 1982), bank stabilization (Corbett and Lynch 1985), Environment and Climate Change Canada

(2013) has recommended **a minimum 30 m** for buffer width. The best approach would be to design the buffer for its specific drainage area, slope, rainfall amount and intensity, soil type, pollutant type (MOE, 2003; Bentrup, 2008; CVC and TRCA, 2010), with the addition of complex vegetation structure (include grasses, shrubs, and trees).

At the exceeded sites (**Figure 3 and 5**), restoration of proper buffer width with willing landowners should be priority. Alternatives and additions may include:

- Proper education, installation, monitoring and enforcement of sediment and erosion control measures.
- Implementing other stormwater technologies, such as sediment traps and/or basins, i.e., Oil-Grit Separators sized corrected, prior to it being released into waterways.

In this study, we noted that all sites used for Natural Land Cover were not 100% pristine and had some level of human disturbance. Thus, values presented do not reflect that of background or baseline conditions. It is recommended that additional studies are needed to determine the background level of TSS and turbidity among streams in the Kawartha region. The purpose would be to:

- Provide a better understanding of 'background/ambient' conditions of TSS and turbidity in the Kawartha region to help with Canadian Water Quality Guideline application at a spatial and temporal scale.
- Establish a local/watershed/region level of TSS and turbidity relationships for practical application for sediment and erosion control compliance monitoring.

Following methods from CCME (2002), samples should be taken during clear flow events (not baseflow) and outside of the spring melt. Additionally, these proposed studies should assess streams across the landscape (different land cover types), flow periods, multi-year to capture both temporal and spatial variability. This information will greatly help understand the background concentration of TSS and turbidity in streams and will allow for a more accurate and precise assessment when monitoring the health of tributaries.

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Appendix A – Raw Data.

Table A1. Raw results for all surface water quality samples.

LandUse	UID	Easting	Northing	DateCollected	TSS_mgL	Temp_oC	pH	Cond_uScm	DO_mgL	DO_%	Turb_FNU
Urban	UB13	679807	4934490	2021-10-25	3.00	7.33	8.01	553.00	10.59	91.70	0.20
Urban	UB43	693982	4934960	2021-10-25	3.00	8.17	764.00	656.00	10.29	89.90	0.00
Urban	UB49	694993	4908090	2021-10-25	3.00	10.01	8.13	499.00	10.00	92.30	1.60
Urban	UB37	680335	4914100	2021-11-18	3.00	5.11	8.20	268.00	8.86	72.90	1.30
Urban	UB4	679912	4915560	2021-11-18	3.00	13.58	7.18	625.00	5.17	51.90	0.00
Urban	UB10	680607	4915940	2021-11-18	3.00	6.84	8.08	373.00	8.44	72.30	47.70
Urban	UB29	679808	4934640	2021-10-25	4.00	7.22	7.96	702.00	9.88	85.20	0.30
Urban	UB39	679726	4934230	2021-10-25	4.00	7.71	8.11	635.00	10.14	90.90	7.40
Urban	UB47	680508	4916020	2021-11-18	4.00	7.14	8.06	368.00	8.30	71.60	17.10
Urban	UB38	678456	4912900	2021-11-18	5.00	9.27	7.76	1330.00	7.49	68.20	11.70
Urban	UB40	681476	4915260	2021-11-18	5.00	7.62	7.94	444.00	9.31	81.40	7.60
Urban	UB42	680522	4914480	2021-11-18	5.00	8.01	8.27	250.00	9.46	83.60	3.10
Urban	UB12	680418	4914530	2021-11-18	5.00	7.90	8.30	452.00	9.23	81.50	71.00
Urban	UB3	678030	4912590	2021-11-18	6.00	7.91	7.75	12.36	8.92	78.90	14.20
Urban	UB30	680704	4914570	2021-11-18	6.00	8.01	8.22	452.00	9.56	84.40	8.00
Urban	UB31	680476	4914000	2021-11-18	6.00	8.97	8.14	259.00	9.15	74.90	2.40
Urban	UB34	680725	4914630	2021-11-18	6.00	8.02	8.22	453.00	9.47	83.70	7.50
Urban	UB22	680812	4914850	2021-11-18	6.00	7.29	7.34	491.00	8.55	74.00	12.90
Urban	UB19	679059	4916040	2021-11-18	6.00	7.59	8.15	532.00	8.59	74.80	7.50
Urban	UB6	680196	4932670	2021-10-25	7.00	8.39	7.49	971.00	1.96	61.70	110.00
Urban	UB36	678348	4912800	2021-11-18	7.00	7.55	8.04	1109.00	8.37	73.00	14.70
Urban	UB41	679305	4916160	2021-11-18	7.00	7.25	8.20	473.00	9.22	79.80	12.40
Urban	UB46	681030	4916530	2021-11-18	7.00	8.64	7.71	409.00	8.84	79.40	8.20
Urban	UB25	678440	4915550	2021-11-18	8.00	7.29	7.91	491.00	8.55	74.00	12.90
Urban	UB35	681007	4914910	2021-11-18	8.00	7.59	8.12	453.00	9.94	87.90	8.70
Urban	UB13-D	679807	4934490	2021-10-25	10.00	7.33	8.01	553.00	10.59	91.70	0.20
Urban	UB33	679643	4934120	2021-10-25	12.00	7.70	8.14	530.00	9.69	11.10	12.50
Urban	UB1-D	695402	4907680	2021-10-25	12.00	8.27	8.21	491.00	10.15	89.90	5.00

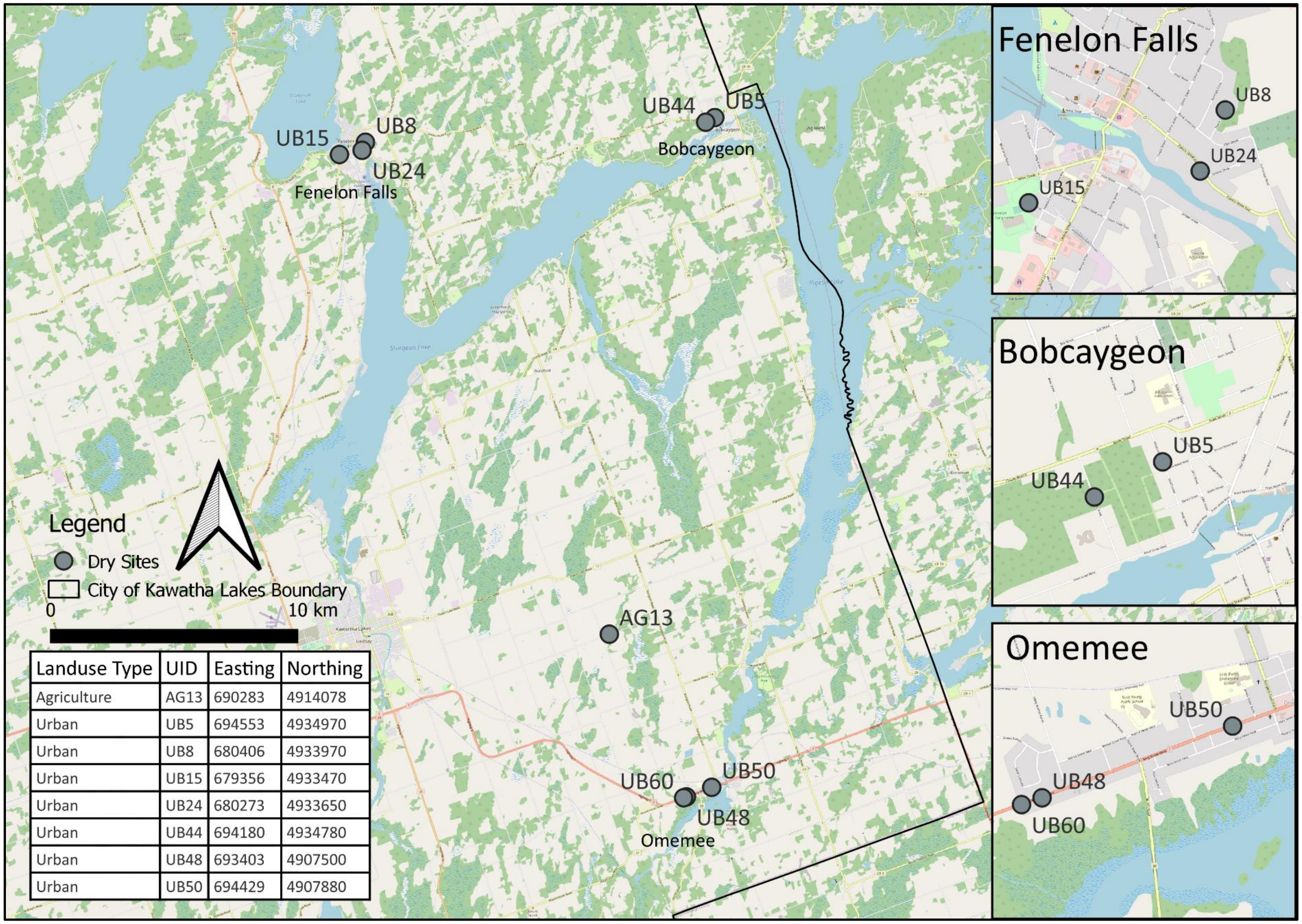
Table A1. Continued.

LandUse	UID	Easting	Northing	DateCollected	TSS_mgL	Temp_oC	pH	Cond_uScm	DO_mgL	DO_%	Turb_FNU
Urban	UB45	681040	4912400	2021-11-18	12.00	7.42	8.01	691.00	8.52	73.80	20.30
Urban	UB1	695402	4907680	2021-10-25	14.00	8.27	8.21	491.00	10.15	89.90	5.00
Urban	UB18	694486	4934490	2021-10-25	14.00	9.57	7.78	520.00	7.37	67.30	0.50
Urban	UB27	677824	4913600	2021-11-18	14.00	9.27	7.34	1182.00	6.18	56.30	97.60
Urban	UB14	681360	4911490	2021-11-18	19.00	7.75	8.17	862.00	9.49	82.80	21.50
Urban	UB11	681710	4915840	2021-11-18	30.00	7.10	7.79	518.00	8.15	70.50	16.80
Urban	UB9	679868	4932780	2021-10-25	38.00	8.12	7.48	799.00	6.88	60.80	105.00
Urban	UB20	677292	4914680	2021-11-18	40.00	6.64	7.93	11.79	9.37	80.00	8.30
Urban	UB23	680151	4912380	2021-11-18	57.00	9.59	7.81	1102.00	8.42	76.90	58.30
Urban	UB2	679779	4933890	2021-10-25	< 3	13.57	8.09	141.00	9.76	97.70	1.50
Urban	UB7	679802	4934530	2021-10-25	< 3	7.31	8.01	712.00	10.02	86.80	0.60
Urban	UB28	695935	4934960	2021-10-25	< 3	11.24	7.94	293.00	4.92	45.50	0.20
Natural	NT10	691642	4934513	2021-10-25	3.00	7.33	8.04	489.00	10.39	9.00	0.00
Natural	NT22	690981	4939720	2021-10-25	3.00	8.10	78.80	500.00	10.33	91.20	0.00
Natural	NT20	685134	4897644	2021-11-26	3.00	2.35	7.73	476.00	9.31	71.40	2.10
Natural	NT6	681377	4896405	2021-11-26	3.00	3.19	8.02	439.00	11.67	91.50	0.90
Natural	NT19	699826	4915956	2021-10-25	4.00	6.92	7.41	642.00	4.24	36.10	0.10
Natural	NT21	686922	4893612	2021-11-26	4.00	3.91	7.98	858.00	11.19	89.90	7.30
Natural	NT4	685739	4893335	2021-11-26	4.00	3.50	7.99	417.00	11.50	90.50	0.90
Natural	NT12	685545	4898171	2021-11-26	4.00	2.27	7.67	501.00	9.53	73.00	1.40
Natural	NT24	683739	4892567	2021-11-26	5.00	3.79	8.03	590.00	11.82	94.30	5.20
Natural	NT2	685231	4890224	2021-11-26	6.00	3.70	8.06	404.00	11.62	92.50	6.30
Natural	NT7	693160	4894528	2021-11-26	6.00	3.43	8.11	389.00	11.75	93.10	4.30
Natural	NT5	692924	4893486	2021-11-26	7.00	1.57	7.89	512.00	11.38	85.60	2.00
Natural	NT8	694173	4894887	2021-11-26	7.00	2.85	7.95	531.00	11.27	87.70	39.30
Natural	NT9	684454	4888272	2021-11-26	7.00	3.43	8.11	389.00	11.75	93.10	4.30
Natural	NT15	699808	4912904	2021-10-25	8.00	7.86	7.21	749.00	3.40	29.60	0.30
Natural	NT23	669208	4916926	2021-10-25	14.00	7.58	7.95	681.00	9.42	81.90	0.20

Table A1. Continued.

LandUse	UID	Easting	Northing	DateCollected	TSS_mgL	Temp_oC	pH	Cond_uScm	DO_mgL	DO_%	Turb_FNU
Urban	UB45	681040	4912400	2021-11-18	12.00	7.42	8.01	691.00	8.52	73.80	20.30
Urban	UB1	695402	4907680	2021-10-25	14.00	8.27	8.21	491.00	10.15	89.90	5.00
Urban	UB18	694486	4934490	2021-10-25	14.00	9.57	7.78	520.00	7.37	67.30	0.50
Urban	UB27	677824	4913600	2021-11-18	14.00	9.27	7.34	1182.00	6.18	56.30	97.60
Urban	UB14	681360	4911490	2021-11-18	19.00	7.75	8.17	862.00	9.49	82.80	21.50
Urban	UB11	681710	4915840	2021-11-18	30.00	7.10	7.79	518.00	8.15	70.50	16.80
Urban	UB9	679868	4932780	2021-10-25	38.00	8.12	7.48	799.00	6.88	60.80	105.00
Urban	UB20	677292	4914680	2021-11-18	40.00	6.64	7.93	11.79	9.37	80.00	8.30
Urban	UB23	680151	4912380	2021-11-18	57.00	9.59	7.81	1102.00	8.42	76.90	58.30
Urban	UB2	679779	4933890	2021-10-25	< 3	13.57	8.09	141.00	9.76	97.70	1.50
Urban	UB7	679802	4934530	2021-10-25	< 3	7.31	8.01	712.00	10.02	86.80	0.60
Urban	UB28	695935	4934960	2021-10-25	< 3	11.24	7.94	293.00	4.92	45.50	0.20
Natural	NT10	691642	4934513	2021-10-25	3.00	7.33	8.04	489.00	10.39	9.00	0.00
Natural	NT22	690981	4939720	2021-10-25	3.00	8.10	78.80	500.00	10.33	91.20	0.00
Natural	NT20	685134	4897644	2021-11-26	3.00	2.35	7.73	476.00	9.31	71.40	2.10
Natural	NT6	681377	4896405	2021-11-26	3.00	3.19	8.02	439.00	11.67	91.50	0.90
Natural	NT19	699826	4915956	2021-10-25	4.00	6.92	7.41	642.00	4.24	36.10	0.10
Natural	NT21	686922	4893612	2021-11-26	4.00	3.91	7.98	858.00	11.19	89.90	7.30
Natural	NT4	685739	4893335	2021-11-26	4.00	3.50	7.99	417.00	11.50	90.50	0.90
Natural	NT12	685545	4898171	2021-11-26	4.00	2.27	7.67	501.00	9.53	73.00	1.40
Natural	NT24	683739	4892567	2021-11-26	5.00	3.79	8.03	590.00	11.82	94.30	5.20
Natural	NT2	685231	4890224	2021-11-26	6.00	3.70	8.06	404.00	11.62	92.50	6.30
Natural	NT7	693160	4894528	2021-11-26	6.00	3.43	8.11	389.00	11.75	93.10	4.30
Natural	NT5	692924	4893486	2021-11-26	7.00	1.57	7.89	512.00	11.38	85.60	2.00
Natural	NT8	694173	4894887	2021-11-26	7.00	2.85	7.95	531.00	11.27	87.70	39.30
Natural	NT9	684454	4888272	2021-11-26	7.00	3.43	8.11	389.00	11.75	93.10	4.30
Natural	NT15	699808	4912904	2021-10-25	8.00	7.86	7.21	749.00	3.40	29.60	0.30
Natural	NT23	669208	4916926	2021-10-25	14.00	7.58	7.95	681.00	9.42	81.90	0.20

Appendix B – Additional Figure.



Landuse Type	UID	Easting	Northing
Agriculture	AG13	690283	4914078
Urban	UB5	694553	4934970
Urban	UB8	680406	4933970
Urban	UB15	679356	4933470
Urban	UB24	680273	4933650
Urban	UB44	694180	4934780
Urban	UB48	693403	4907500
Urban	UB50	694429	4907880

Figure B1. Locations of site that were found to be dry during the survey.

Appendix C – Coordinates of Exceeded Sites.

Table A2. Coordinates of exceeded sites for Turbidity and Total Suspended Solids.

Parameter	UID	Easting	Northing	Result
Turbidity (FNU)	UB6	680196	4932670	110
	UB9	679868	4932780	105
	UB27	677824	4913600	97.6
	UB12	680418	4914530	71
	UB23	680151	4912380	58.3
	UB10	680607	4915940	47.7
	NT8	694173	4894887	39.3
	UB14	681360	4911490	21.5
	UB45	681040	4912400	20.3
	AG9	681404	4919854	17.4
	UB47	680508	4916020	17.1
	UB11	681710	4915840	16.8
	AG4	681429	4919778	16.3
	UB36	678348	4912800	14.7
	UB3	678030	4912590	14.2
	UB25	678440	4915550	12.9
	UB22	680812	4914850	12.9
	UB33	679643	4934120	12.5
	UB41	679305	4916160	12.4
	UB38	678456	4912900	11.7
Total Suspended Solids (mg/L)	UB23	680151	4912380	57
	UB20	677292	4914680	40
	UB9	679868	4932780	38
	UB11	681710	4915840	30