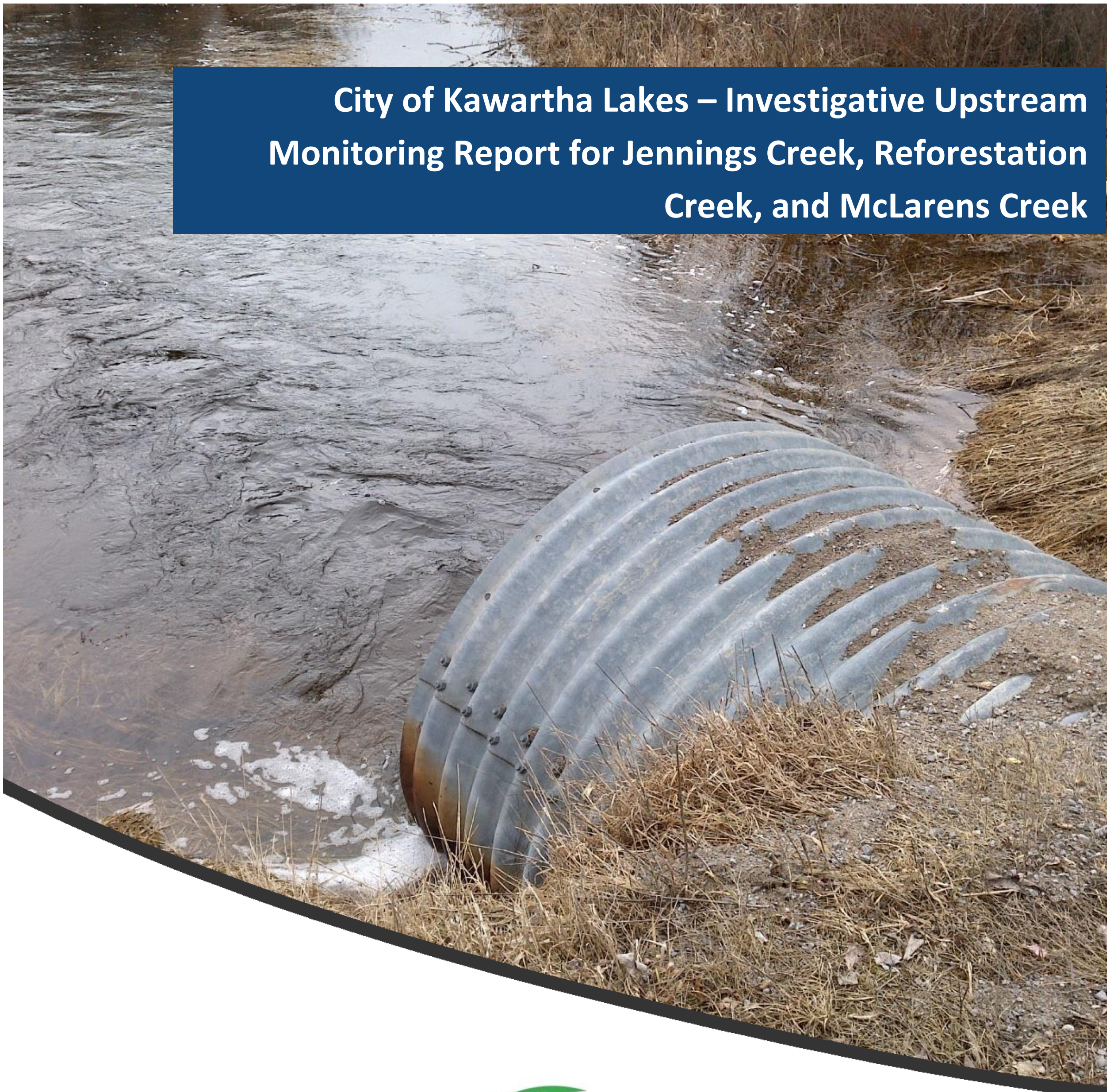

City of Kawartha Lakes – Investigative Upstream Monitoring Report for Jennings Creek, Reforestation Creek, and McLarens Creek

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.

Kawartha Conservation

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Kawartha Conservation. 2023. Investigative Upstream Monitoring Report for Jennings, McLarens, and Reforestation Creek

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 companion document was written by Tanner Liang, Water Quality Specialist. Peer editors include Ian McRae, Environmental Communications, Robert Stavinga, Watershed Resource Technician, and Nancy Aspden, Acting Manager, Integrated Watershed Management. Others who have contributed to the development of this project include:

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Abbreviations

%:	Percentage
%CV:	Coefficient of variation
µg/L:	Micrograms per liter
µS/cm:	Microsiemens per centimeter
^oC:	Degree Celsius
CCME:	Canadian Council of Ministers of the Environment
Cl:	Chloride
Cond:	Conductivity
CWQG:	Canadian Water Quality Guideline
DO:	Dissolved Oxygen
ERC:	Ecological Reference Condition
et al. :	*et al*ibī (latin phrase) meaning and other authors
FNU:	Formazin Nephelometric Unit
ha:	Hectare
kg:	Kilograms
km^2:	Square kilometers
m^3/s:	Cubic metre per second
mg/L:	Milligrams per liter
n:	Sample size
NH_3-N:	Ammonia-Nitrogen
NO_2-N:	Nitrite-Nitrogen
NO_3-N:	Nitrate-Nitrogen
NTU:	Nephelometric Turbidity Unit
p:	p-value
PRC:	Physical Reference Condition
PWQO:	Provincial Water Quality Objectives
r	Pearson's Correlation
Temp:	Temperature
TKN:	Total Kjeldahl Nitrogen
TN:	Total Nitrogen
TP:	Total Phosphorus
TSS:	Total suspended solids
Turb:	Turbidity
yr:	Year
ρ:	Spearman's rho

Executive Summary

From 2017 – 2019, the Investigative Upstream Monitoring project assessed 17 sites on three different tributaries of concern, including five sites for Jennings Creek, seven sites for McLarens Creek, and five sites for Reforestation Creek. The goal of this project was to identify potential areas of concern where excessive amounts of various compounds are observed. Within each tributary using upstream catchment area (ha), water quality (mg/L) and discharge measurements (m^3/s) were used to identify these hot spots. By identifying these hot spots, a more focused approach can be used for stewardship to help remediate areas with willing landowners that may be negatively impacted by surrounding activities. By remediating and restoring these areas, the water and habitat quality will dramatically improve, both locally and in the areas downstream.

Water quality results were compared against the Provincial Water Quality Objectives (PWQO) and the Canadian Water Quality Guidelines (CWQG) for the Protection of Aquatic Life. By using both the PWQO and CWQG we can ensure that water quality is satisfactory for the protection of aquatic life and for recreational use.

All parameters were found to be higher than those found in natural waterways, indicating that human influence is impacting these streams. Exceedances of nutrient parameters such as total phosphorus and nitrate were often associated with higher agricultural land cover while chloride was found to be associated with urban landcover and roadways.

Within the sampled tributaries, hot spots were found at the following sites: JEN1 and JEN3 on Jennings Creek, MCL5 on McLarens Creek, and REF2 on Reforestation Creek. All four sites should be of the highest priority for restoration and stewardship. Background concentrations of Total Suspended Solids (TSS) were also identified as a critical knowledge gap for better understanding patterns of suspended solids entering these streams.

Introduction

The Kawartha Conservation watershed covers over 2,500 km^2 (250,000 ha) and is primarily comprised of agricultural land cover (46%), with scattered population centers such as Lindsay (population = 22,367; Statistics Canada. 2022a), Bobcaygeon (3,576), Fenlon Falls (2,490), and Omemee (1,060) (Statistics Canada. 2022). The watershed also holds many freshwater systems such as creeks, rivers, and lakes, many of which are relied upon for tourism, recreation, and general well being.

Excessive nutrient input and poor land use practices have led to degradation of water and habitat quality, rapid eutrophication, and risk of harmful algae blooms (Thomas et al., 2018; Keatly et al., 2011). These types of conditions can negatively impact the health of our environment (Conley et al., 2009; Schindler et al., 2016), human health (Anderson et al., 2002), and the local economy (Dodds *et al.*, 2009). Thus, it is imperative to implement actions to reduce excessive nutrients from entering local waterbodies.

In a watershed, activities and behaviours on land have a great influence on water quality. Land use changes from a natural system to an agricultural system or from agricultural to urban systems can drastically elevate the inputs of contaminates such as chloride, heavy metals, and organic contaminants into waterbodies (Perera *et al.*, 2010; Howell *et al.*, 2012). This can negatively impact living organisms, such as benthic invertebrates and fish, as well as impact how humans can use these waterbodies. Implementing remediation actions can improve water and habitat quality by stabilizing eroded streambanks, increasing riparian zones, and segregating livestock pastures from natural bodies of water (Conley et al., 2009).

The goal of this project was to identify 'hotspots' within three tributaries of concern: Jennings Creek, McLarens Creek and Reforestation Creek. By identifying these hot spots, a focused stewardship approach can be used with willing landowners to alleviate human induced pressure and restore waterbodies to a more natural and usable state.

Methods

Study Area

All three tributaries, McLarens Creek, Jennings Creek, and Reforestation Creek, are located within the territory of the Michi Saagiig Nishnaabeg (Figure 1) and are covered under the Williams Treaties (1923) - Rice Lake Treaty No. 20 (1818). These tributaries are also located within the City of Kawartha Lakes Municipality in Central Ontario, which has a population of 79,247 (Statistic Canada, 2021).

These tributaries were each identified as a ‘tributary of concern’ through the Sturgeon and Pigeon Lake Management Plans (Kawartha Conservation 2014, 2018), where they often exceed the Provincial Water Quality Objectives (PWQO; OMEE, 1994) for phosphorus. Continued exceedance of the PWQO thresholds may lead to uncontrollable algae-blooms and degraded water quality.

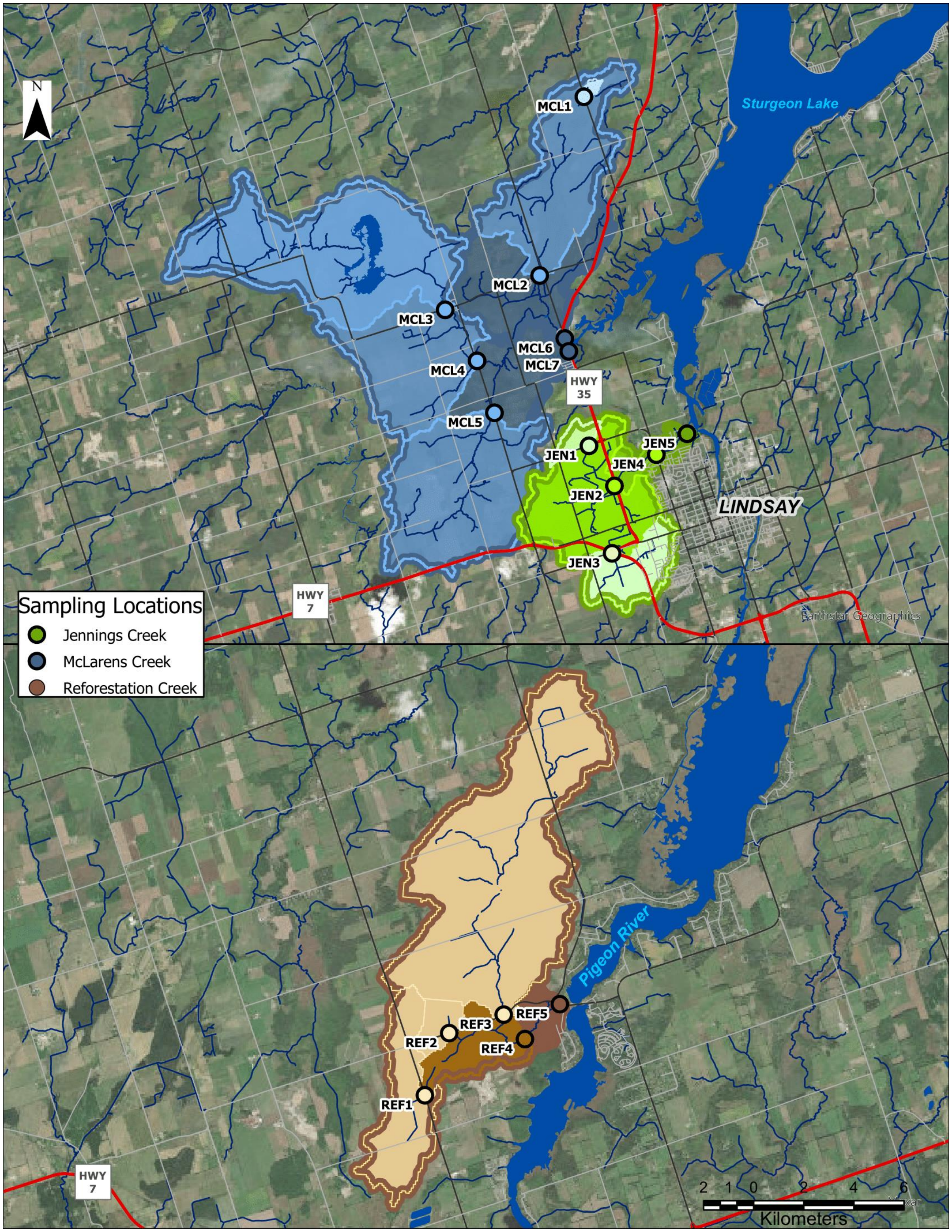


Figure 1. Locations and watersheds of each sampling site for Jennings (*n*=5), McLarens (*n*=7), and Reforestation Creek (*n*=5).

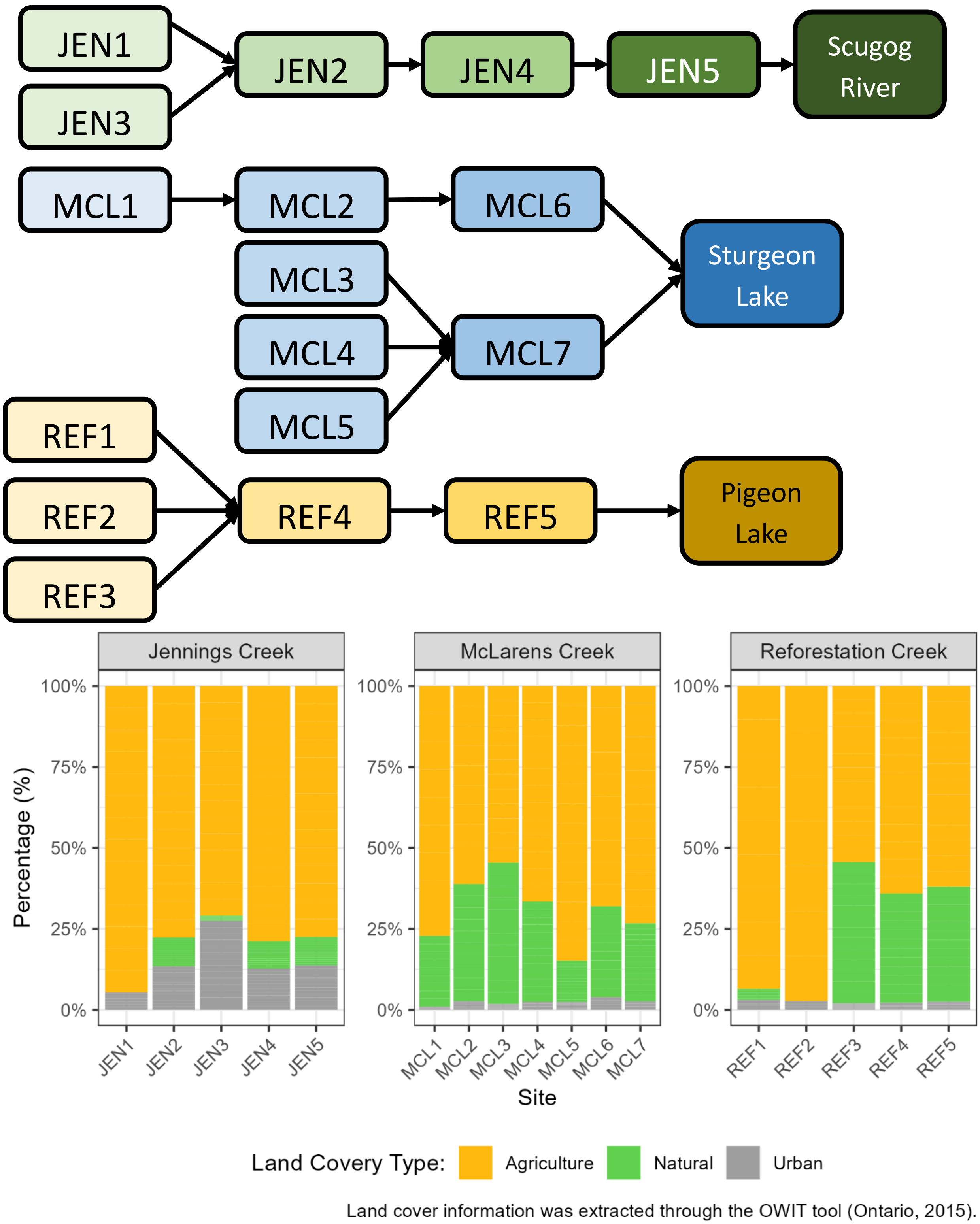


Figure 2 Conceptual diagram of the flow patterns (left) between sites for all tributaries. Percentage land cover (right) are shown per creek and site.

Field and Lab Methods

At each site, surface samples and discharge measurements were taken during ice-free periods from 2017 to 2019. All surface water sample containers were triplet-rinsed with the targeted water prior to sampling to help reduce the chances of contaminating the sample from external sources. The water samples were taken 0.15 – 0.3m below the surface of the water to ensure no surface debris was collected. Field parameters such as Water Temperature (Temp.), pH, Conductivity (Cond.), Dissolved Oxygen (DO), and Turbidity (Turb.) were measured in the field with a water quality meter. Samples were kept cool at less then 4°C during transportation and storage before being sent off to Caduceon Environmental Laboratories for chemical analysis, i.e., Chloride (Cl), Nitrite-N (NO_2-N), Nitrate-N (NO_3-N), Ammonia-N (NH_3-N), Total Kjeldahl Nitrogen (TKN), Total Phosphorus (TP) and Total Suspended Solids (TSS). Instant discharge measurements (m^3/s) were calculated by measuring the velocity and the cross-sectional area of the site using a Flow-tracker.

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) (Ontario, 2015).

Table 1. Site location and drainage area (ha) for all seventeen (17) sites assessed in this study.

Tributary	ID	Easting	Northing	Drainage Area* (ha)
Jennings Creek	JEN1	676513.5	4915736	0.77
	JEN2	677273.3	4914614	14.05
	JEN3	677257.6	4912695	3.90
	JEN4	678443.2	4915538	15.19
	JEN5	679308.3	4916155	15.88
McLarens Creek	MCL1	676100.0	4925657	0.18
	MCL2	674974.2	4920543	11.71
	MCL3	672302.3	4919494	20.52
	MCL4	673252.6	4918068	31.13
	MCL5	673787.5	4916603	15.29
	MCL6	675739.2	4918770	20.27
	MCL7	675864.6	4918409	52.60
	REF1	693502.7	4911244	2.27

Reforestation	REF2	693870	4912267	0.48
Creek	REF3	694751.5	4912594	10.28
	REF4	695110.1	4912207	14.42
	REF5	695663.0	4912792	14.98

By combining same-day water quality concentrations, area of the upstream catchment and discharge values, we can calculate loadings through the following equation:

$$Loading = \frac{(Concentration \times Discharge)}{Area}$$

Annual loading values are calculated through the sum of all daily discharge per year and are expressed in kg/ha/yr.

Data Analysis

Total nitrogen (TN) was calculated through the sum of Nitrite-N (NO_2-N), Nitrate-N (NO_3-N), and Total Kjeldahl Nitrogen (TKN). Water quality results were compared against the Ontario Provincial Water Quality Objectives (PWQO) (MOEE, 1994) and the Canadian Water Quality Guidelines (CWQG) for the Protection of Aquatic Life (CCME, 2002, 2004, 2010, 2012). By using both the PWQO and CWQG we can ensure that water quality is satisfactory for the protection of aquatic life and for recreational use.

All data analysis was performed with the statistical program known as R (R Core Team, 2021). Percent coefficient of variation (%CV) for pH followed that of Canchola *et al*., (2017). Areas where there were no observations were left as *NA*, while values below detection limits were addressed using the R package - NADA (Lopaka, 2020). Almost all parameters were significantly different than a normal distribution and did not fit the assumptions of linearity, thus non-parametric tests were used.

Results & Discussion

Three tributaries, Jennings Creek, McLarens Creek, and Reforestation Creek were monitored from 2017 to 2019 (Figure 1; Table 1). In total, there were 206 field observations and surface water samples collected. The raw data can be found in Appendix A – Table A.1, while additional figures of NO_2-N and TKN can be found in Appendix B – Figure A1 and A2.

Dissolved Oxygen

All aquatic organisms require dissolved oxygen (DO) to survive, however, some aquatic organisms can tolerate lower levels of DO than others. Warm water fish species such as Green Sunfish, Bluegill and the Common Carp can tolerate lower levels of DO, whereas other species such as Largemouth Bass, Northern Pike and Rainbow Trout require much more DO to survive (Tang *et al.*, 2020). All three tributaries are classified as warm water creeks that provide habitat for numerous warm water fish species: 16 species in Jennings Creek, 21 in McLarens Creek, (Kawartha Conservation 2014), and 11 in Reforestation Creek (Kawartha Conservation, 2018).

Across all sites, levels of dissolved oxygen ranged from 0.56 to 14.79 mg/L, with an average value of 8.85 and a median value of 9.26 mg/L (Table 2). Generally, Jennings Creek had higher DO concentrations, followed by McLarens Creek and Reforestation Creek (Table 2). As mentioned above, DO is critical for the survival of fish and prolonged low levels of DO can lead to the mortality of fish and other aquatic organisms. Furthermore, fish embryos require oxygen to incubate.

The Canadian Water Quality Guidelines (CWQG) for early life stages is a DO guideline that encompasses the oxygen demand for fish embryos, fish larvae, and the emergence of benthic macroinvertebrates (CCME, 1999). When compared to this guideline, the highest failure rate was 23.1% which occurred at MCL7, JEN1, JEN2, JEN3, JEN4, and JEN5, suggesting that most of Jennings Creek is of concern for dissolved oxygen levels.

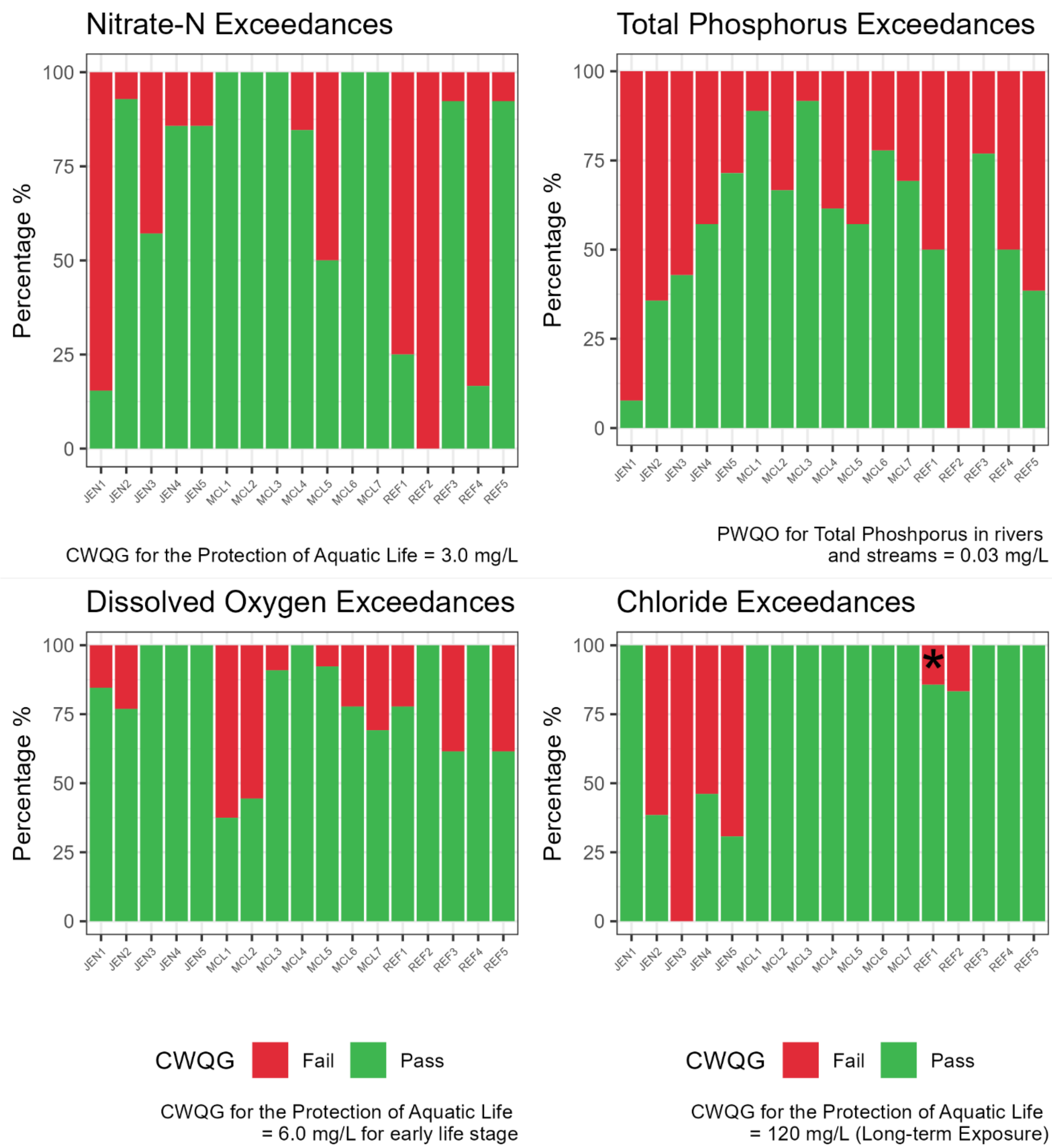


Figure 3. Percentage of exceeded observations per site for Nitrate-N, Total Phosphorus, Dissolved Oxygen, and Chloride when compared to the PWQO (OMEE, 1994) and the CWQG (CCEM, 1999, 2011, 2012) for the years 2017 to 2019. *Denotes exceedance of the short-term CWQG at 640 mg/L for chloride.

Table 2. Summary statistics of selective physical and chemical water quality parameters. The dataset used was modified with the NADA package for censored data.

Tributary	Statistic	°C Temp.	mg/L DO	µS/cm Cond	pH	NTU Turb	mg/L Cl	mg/L NO_2-N	mg/L NO_3-N	mg/L NH_3-N
Jennings Creek	Count	70	63	70	70	64	64	69	69	69
	Mean	12.18	9.94	996.00	7.64	7.79	160.26	0.02	2.81	0.07
	Median	10.80	10.17	1007.00	7.97	5.55	137.00	0.01	2.07	0.07
	%CV	57.38	24.53	25.79	10.20	149.24	47.03	159.80	92.45	59.11
	Min	1.90	3.27	9.23	8.53	0.21	52.80	0.00	0.03	0.01
	Max	27.70	14.79	1729.00	6.31	90.00	391.00	0.19	11.30	0.19
	10th	3.97	6.50	690.80	8.28	1.99	81.60	0.01	0.26	0.02
	90th	23.41	12.32	1309.70	7.52	14.77	274.90	0.04	6.80	0.12
	NAs	0	7	0	0	6	6	1	1	1
McLarens Creek	Count	82	74	82	82	74	72	79	79	79
	Mean	12.04	8.47	546.45	7.57	2.33	24.12	0.01	1.01	0.05
	Median	11.90	8.70	484.15	7.97	1.60	21.55	0.01	0.37	0.03
	%CV	60.19	40.50	71.21	15.13	119.36	63.04	81.57	163.74	97.25
	Min	0.80	1.50	104.60	9.16	0.00	1.40	0.00	0.00	0.00
	Max	24.60	14.74	3343.00	6.19	19.00	93.50	0.04	10.70	0.29
	10th	4.03	3.26	336.88	8.41	0.30	9.16	0.01	0.03	0.01
	90th	21.66	12.47	662.90	7.42	5.65	40.57	0.02	3.41	0.10
	NAs	0	8	0	0	8	10	3	3	3

Table 2. Continued

		°C	mg/L	µS/cm		NTU	mg/L	mg/L	mg/L	mg/L
Tributary	**Statistic**	**Temp.**	**DO**	**Cond**	**pH**	**Turb**	**Cl**	**NO_2-N**	**NO_3-N**	**NH_3-N**
Reforestation Creek	Count	54	53	54	54	35	48	53	53	53
	Mean	13.07	8.05	647.38	6.97	5.26	55.59	0.03	5.08	0.14
	Median	12.05	8.32	616.00	7.85	1.80	29.95	0.02	2.93	0.06
	%CV	104.23	34.60	32.46	27.16	341.35	267.58	115.97	118.23	212.51
	Min	2.50	0.56	336.50	8.88	0.40	11.90	0.00	0.03	0.01
	Max	104.00	12.53	1400.00	5.53	108.00	1050.00	0.15	25.70	1.71
	10th	4.70	3.96	445.26	8.34	0.71	14.17	0.01	0.82	0.02
	90th	18.75	11.94	903.20	7.04	4.17	62.79	0.08	14.36	0.24
	NAs	0	1	0	0	19	6	1	1	1

Table 2. Continued

Tributary	Statistic	mg/L TKN	mg/L TN	mg/L TP	mg/L TSS
Jennings Creek	Count	69	70	69	69
	Mean	0.68	3.46	0.04	8.51
	Median	0.70	2.63	0.03	7.00
	%CV	30.75	74.51	63.52	107.59
	Min	0.28	0.00	0.01	0.98
	Max	1.20	12.02	0.17	64.00
	10th	0.45	1.01	0.02	2.00
	90th	0.94	7.32	0.08	15.20
	NAs	1	0	1	1
McLarens Creek	Count	79	79	79	79
	Mean	0.68	1.70	0.03	6.42
	Median	0.69	1.18	0.02	4.00
	%CV	45.90	97.20	89.68	148.65
	Min	0.13	0.19	0.00	0.42
	Max	2.30	11.41	0.15	64.00
	10th	0.37	0.52	0.01	1.07
	90th	1.00	3.84	0.06	11.20
	NAs	3	3	3	3
Reforestation Creek	Count	53	53	53	53
	Mean	0.83	5.94	0.07	8.54
	Median	0.70	3.56	0.03	4.00
	%CV	72.47	100.58	184.35	273.63
	Min	0.31	0.87	0.01	0.43
	Max	3.88	26.42	0.80	172.00
	10th	0.40	1.72	0.01	0.96
	90th	1.20	14.79	0.08	12.00
	NAs	1	1	1	1

Total Phosphorus

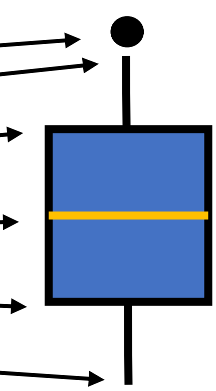
Phosphorus is a naturally occurring mineral, commonly found in sedimentary rocks such as limestone, mudstone, and sandstone. In the Kawarthas, the limestone geology that originated from historical ocean floors is a key component to providing this essential nutrient for the formation of DNA in all living organisms. Phosphorus containing bedrock in the Kawarthas has resulted in fertile lands, prime for agriculture. Due to its great ability to provide growth, especially in plants, too much phosphorus in aquatic ecosystems can result in large algae-blooms, which can degrade water quality, cause fish die-off, and reduce the overall aesthetic of the area. The PWQO for total phosphorus indicate an acceptable level no greater than 0.03 mg/L of phosphorus for the ice-free period in rivers and streams, which should eliminate excessive plant growth within these waterbodies (OMEE, 1994).

On average, Reforestation had the highest average level of 0.07 mg/L, followed by Jennings at 0.04 mg/L, and Reforestation Creek at 0.03 mg/L (Table 2). The top three concerning sites with high failure rates are: REF2 (100%), JEN1 (92.3%) and JEN2 (64.3%). Theses sites are regarded as hot spots for total phosphorus and should be focused upon for remediation with willing landowners.

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.

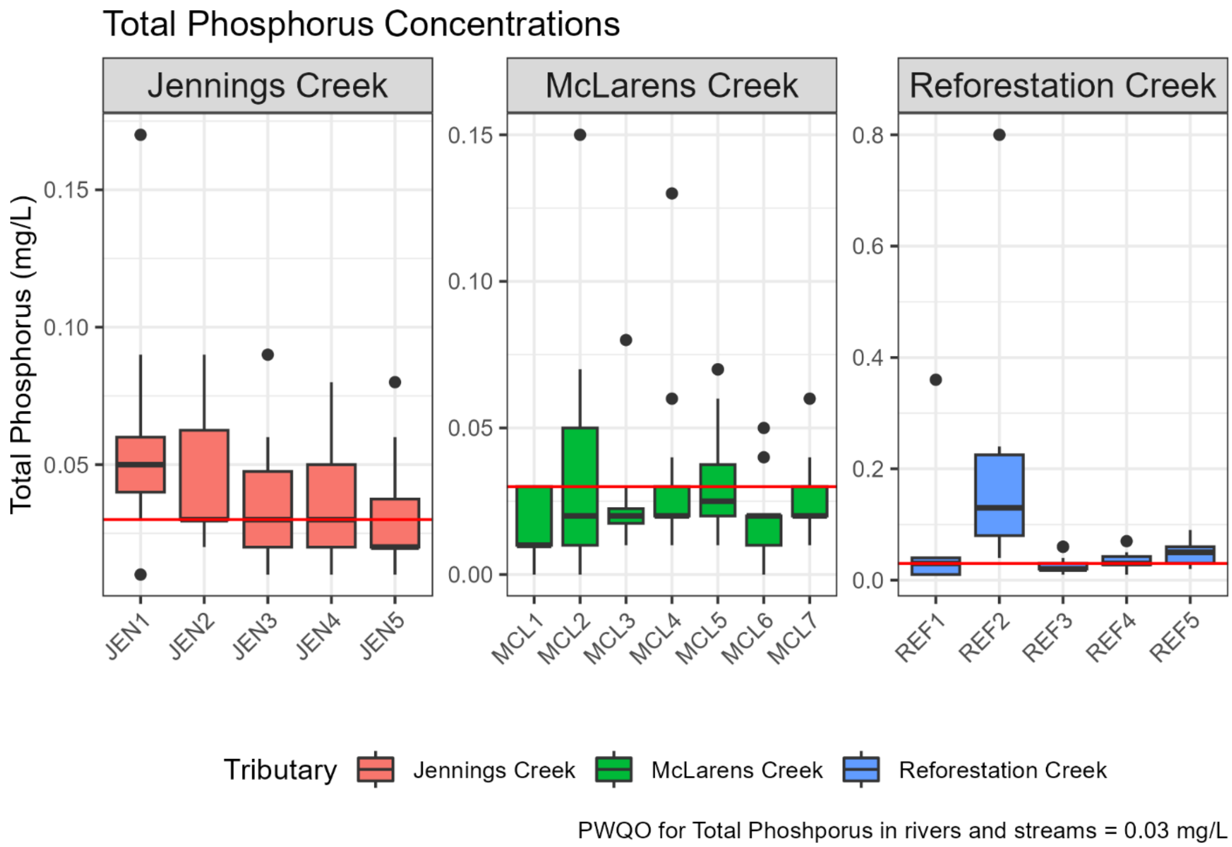


Figure 4. Total phosphorus (TP) concentrations across sites in Jennings, McLarens, and Reforestation Creek. The red horizontal line indicates the PWQO for TP in rivers and streams (0.03 mg/L; OMEE, 1994).

Nitrogen

For this study, we assess multiple forms of nitrogen including ammonia-nitrogen (NH_3-N), nitrite-nitrogen (NO_2-N), nitrate-nitrogen (NO_3-N) and total kjeldahl nitrogen (TKN). All forms of nitrogen in this study were found to have higher observations than those found in natural waterways (McNeely and Deyer 1979). Only ammonia and nitrate nitrogen levels will be presented.

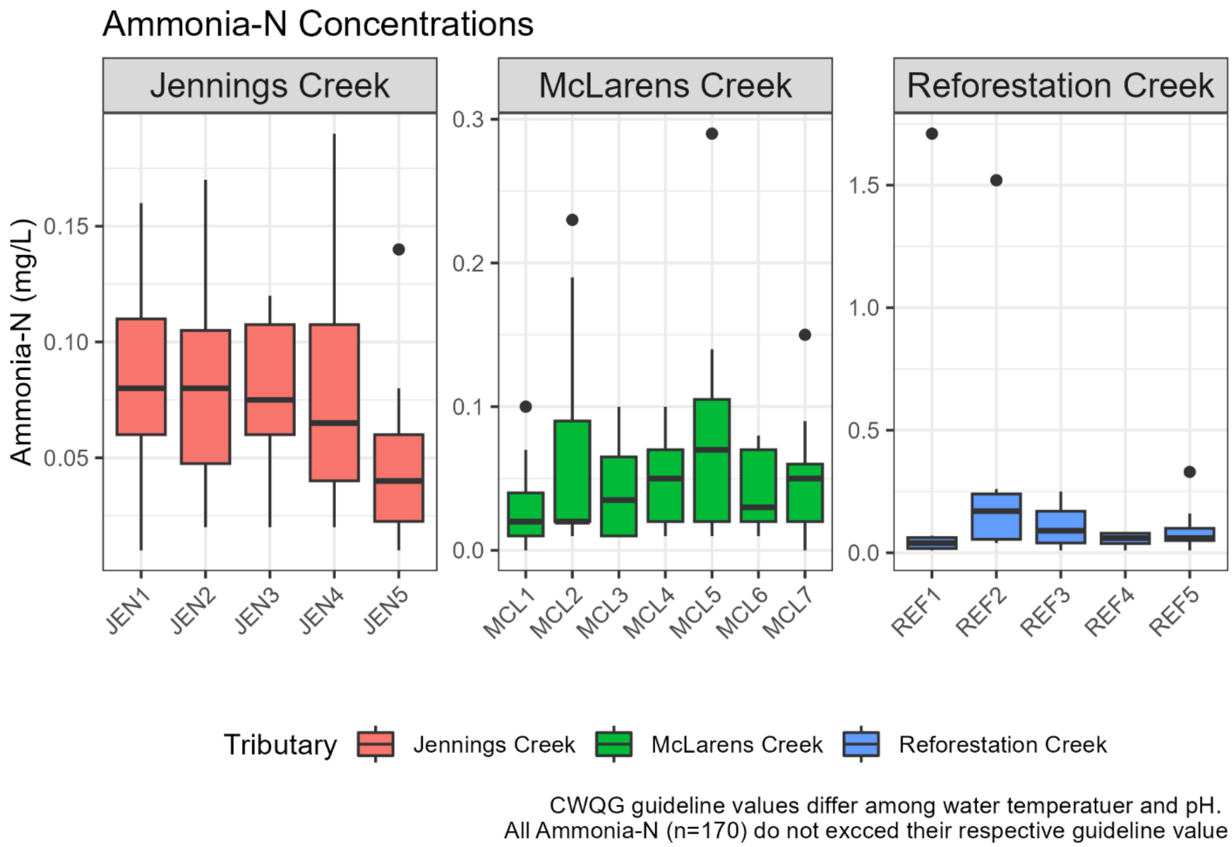


Figure 5. Ammonia-N concentrations across sites in Jennings, McLarens, and Reforestation Creek.

Ammonia is of importance as it causes direct impact on aquatic organisms. Elevated ammonia concentrations can prevent organisms from properly excreting toxins, resulting in a build-up of toxins. Ammonia can enter local waterbodies through animal and human waste, fertilizers, and the breakdown of organics. When comparing results between sites, Reforestation Creek had the highest average ammonia-N value of 0.14 mg/L in comparison to Jennings and McLarens Creek (Table 2). All observations of ammonia-N were below the CWQG (Figure 5; CCME, 2010). When compared to the PWQO, only one observation of JEN1 at one time was found to exceed the threshold (OMEE, 1994).

Through nitrification, ammonia is used by organisms and converted to nitrite where it is then rapidly converted to nitrate with the presence of oxygen. Higher nitrate values can often indicate exceeded use of fertilizers and uncontrolled inputs of human and animal waste. When compared to the CWQG for long-term exposure to aquatic life, JEN1, MCL5, REF1, and REF2 all exceed the guideline of 3.0 mg/L (CCME, 2012) ≥50% of the time (Figure 6) and should be an area of focus with willing landowners.

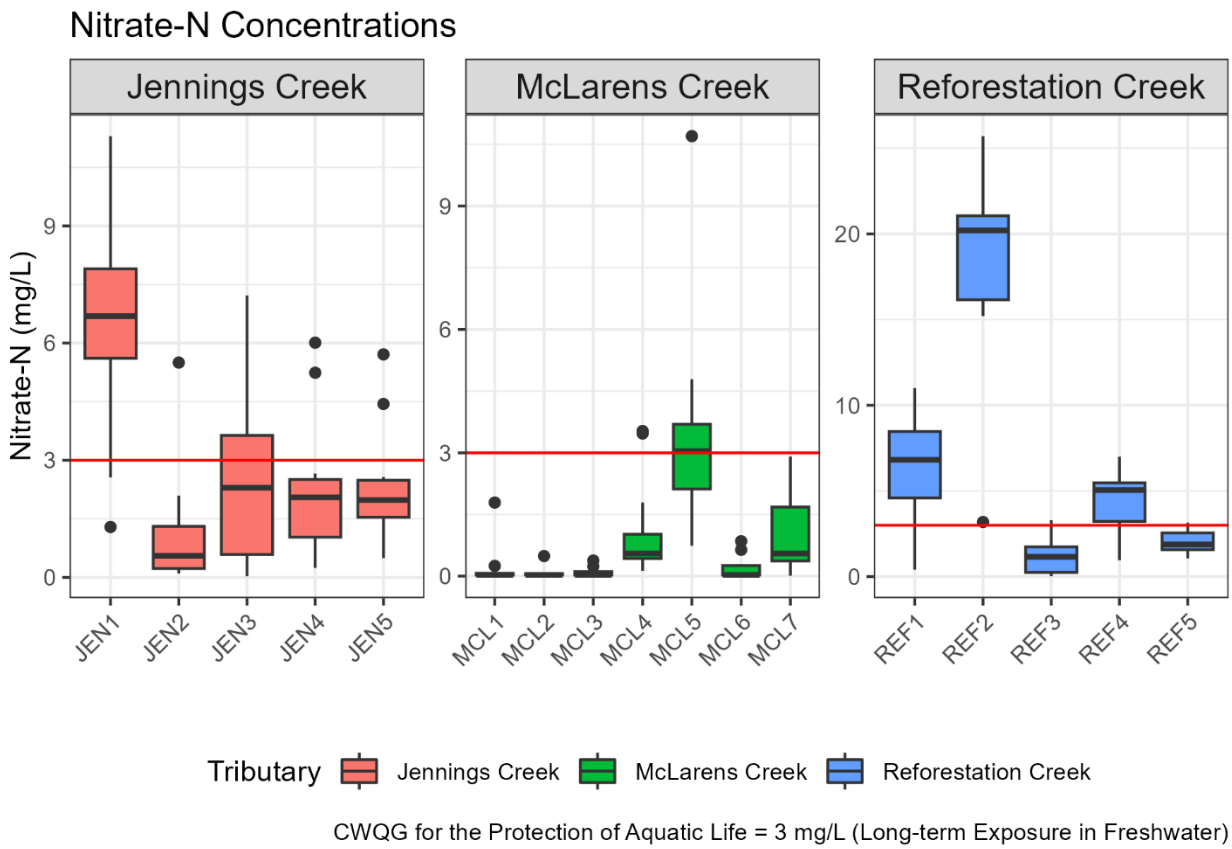


Figure 6. Nitrate-N concentrations across sites in Jennings, McLarens, and Reforestation Creek. The red horizontal line indicates the CWQG for nitrate-N in rivers and streams (0.03 mg/L; CCME, 2012).

Chloride

Chloride (Cl) is a naturally occurring element that occurs in seawater, inland salt lakes, salt wells, and chloride minerals originating from prehistoric dried-up oceans. It is hardly found in naturally occurring freshwater ecosystems (Nagpal *et al.*, 2003) and is often associated with human activities such as de-icing, wastewater treatment, and dust suppressants. Because of its rarity in the natural environment and its frequent use as an indicator of human disturbance and activities, elevated chloride levels in freshwater systems are a clear signal of human activity. Due to its chemical and physical properties, products containing Cl can easily dissolve in water and travel across different ecosystem components and geographic areas.

Chloride is an important element to measure in our freshwater streams because the aquatic life (fish, frogs, plants, etc.) have not evolved to tolerate it. For the protection of aquatic life, the CWQG for Cl is set at 120 mg/L for long-term exposure (CCME, 2011). At this level, the guideline aims to protect a variety of aquatic organisms such as fish, for an indefinite amount of time. Of the three tributaries, Jennings Creek had an average chloride concentration of 160.3 mg/L. This was higher than the CWQG and the average Cl levels found at McLarens (24.12 mg/L) and Reforestation Creek (55.6 mg/L) (Table 2, Figure 8). It should be noted that one observation for REF1, had a chloride concentration of 1050 mg/L (Table 2) which is higher than the short-term (640 mg/L) CWQG (CCME, 2011). Past this limit of 640 mg/L, harm can occur to aquatic organism in less than 96 hours (4 days). Although this observation is an outlier, it should serve as a warning, that if excessive road-salt use continues, chloride concentrations will continue to exceed the short-term threshold of 640 mg/L (CCME, 2011) and will render the area unhabitable for most aquatic organisms.

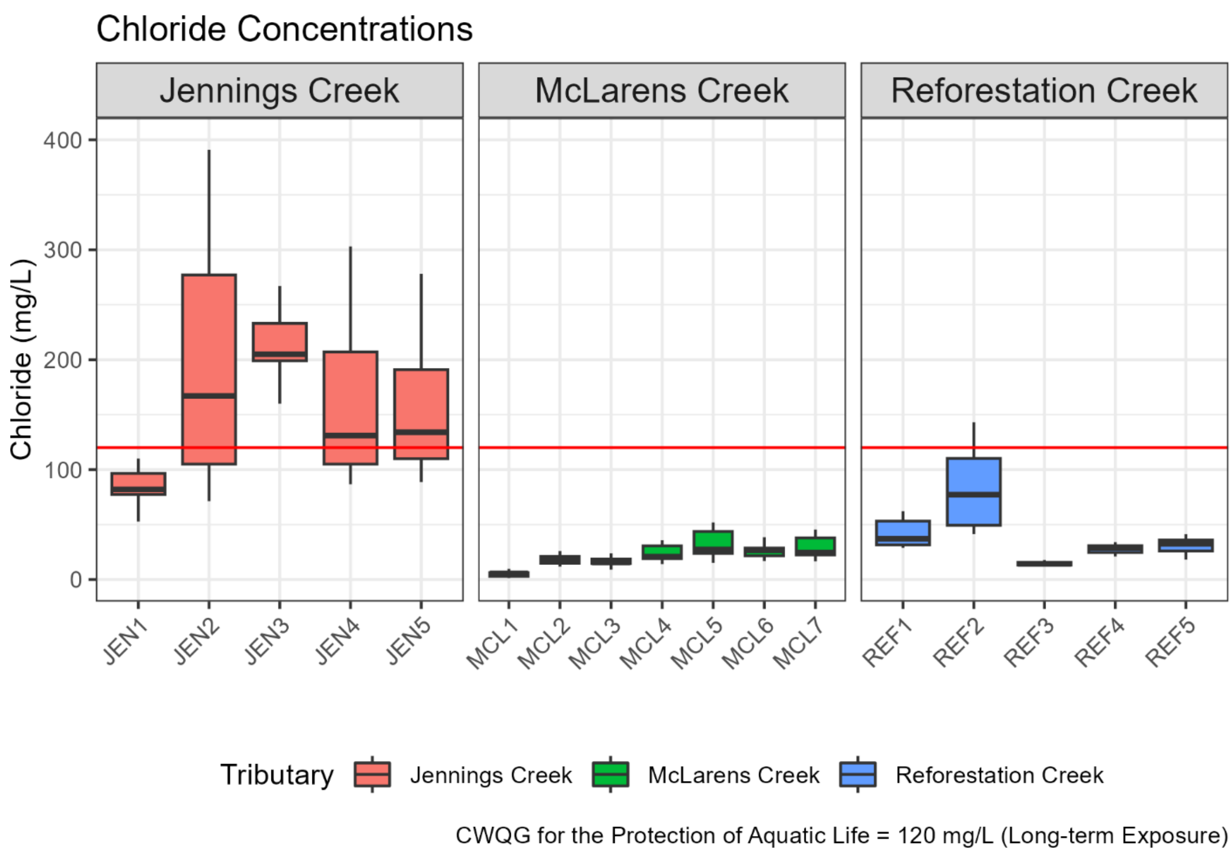


Figure 7. Chloride concentrations across sites in Jennings, McLarens, and Reforestation Creek. The red horizontal line indicates the long-term CWQG for Cl (120 mg/L CCME, 2011).

The top three sites that have the most concerning failure (of the CWQG) rates are: JEN3 (100% fail), JEN5 (69.2%), and JEN2 (61.5%) (Figure 3).

Conductivity (Cond) is the measure of water's ability to pass an electrical current through the water. Higher conductivity measurements indicate that the water contains higher amounts of dissolved salts which allow for a stronger electrical flow. In this study, we used a correlation assessment to help distinguish if there is a relationship between conductivity readings and Cl concentrations (Figure 9). The results showed that there was a significantly positive relationship between higher conductivity readings and increased concentrations of Cl within Jennings Creek (Figure 9).

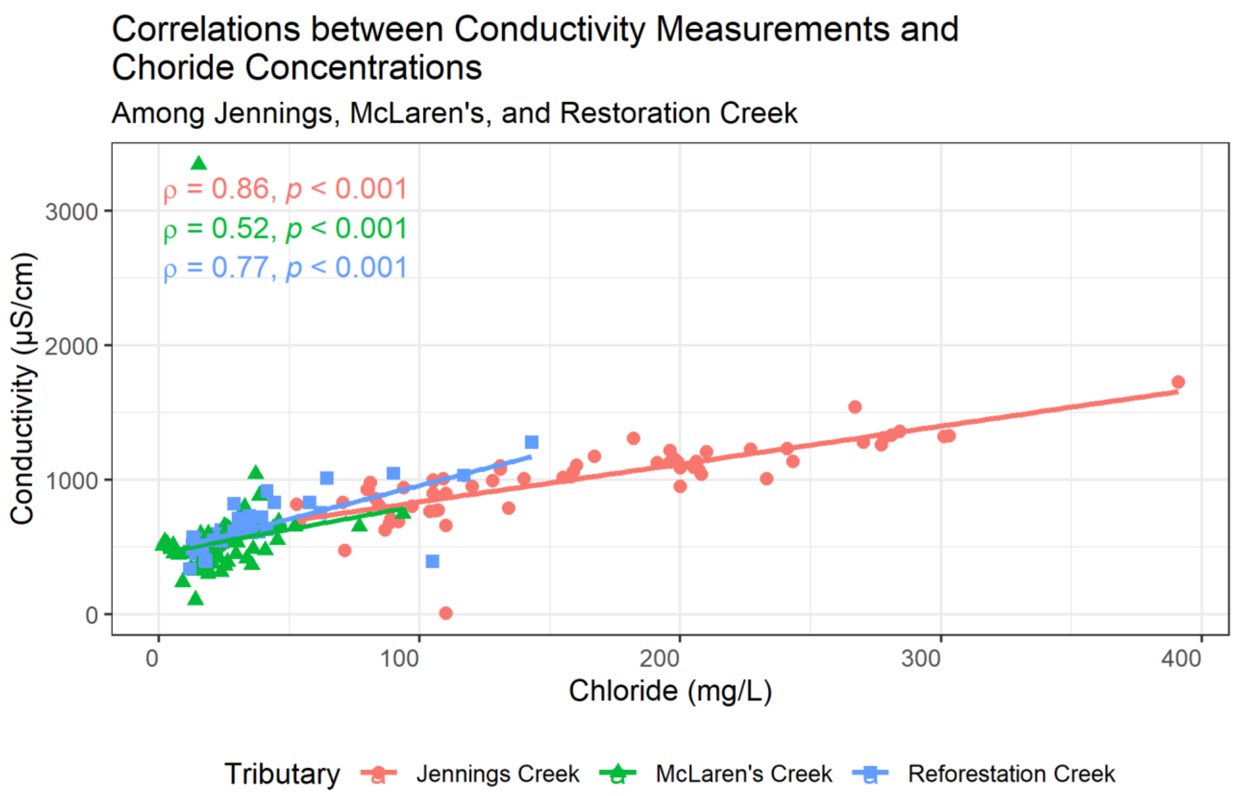


Figure 8. Linear regression between conductivity measurements and Cl concentrations across Jennings, McLarens, and Reforestation Creek. Trendlines and spearman's correlation coefficient with p-values are tributary specific and colour-coded.

This was expected for Jennings Creek as it has a much higher amount of urban land cover within the surrounding area (Figure 2). Within these urban areas, impermeable surfaces such as asphalt and concrete concentrate stormwater and pollutants by reducing where it can be treated or infiltrated into the ground. Areas that do have infiltration treatment capabilities (greenspaces and green technologies) are then forced to address a greater load of pollutants.

Surprisingly, a positive relationship was found for Reforestation Creek, where it has some of the highest natural land cover with little to no urban cover (Figure 2). Generally, agricultural landcover are mostly fields and thus are permeable. The positive relationship between Cond and Cl found in the Reforestation Creek watershed may suggest that roadways and other impermeable transportation surface can contribute to higher inputs of dissolved salts and can act as large source of Cl. Of the three streams, it is recommended that stewardship activities should focus on all failing sites on Jennings Creek, i.e., JEN2-JEN5.

Total Suspended Solids

The lack of clarity caused by excessive suspended solids in water can have harmful impacts on aquatic organisms. Long-term exposure to higher amounts of suspended solids can impact the gills of fish (Herbert and Merkens, 1961). When deposited, solids and particles can smoothen important fish spawning grounds, reduce the available oxygen for egg incubation, and/or expose eggs to predation (Bash *et al.*, 2001). Managing the amount of runoff, as well as decreasing erosion along creeks and streams, can help reduce the total amount of suspended solids entering a waterbody.

The Canadian Council of Ministers of the Environment guidelines (CCME, 2002) for TSS is: A maximum increase of 25 mg/L for short term exposure (24 hrs) from background levels or a maximum increase of 5 mg/L from background levels for longer term exposures. For background levels, we used the Ecological Reference Condition (ERC) guideline of 3.5 mg/L (Culp *et al*., 2013).

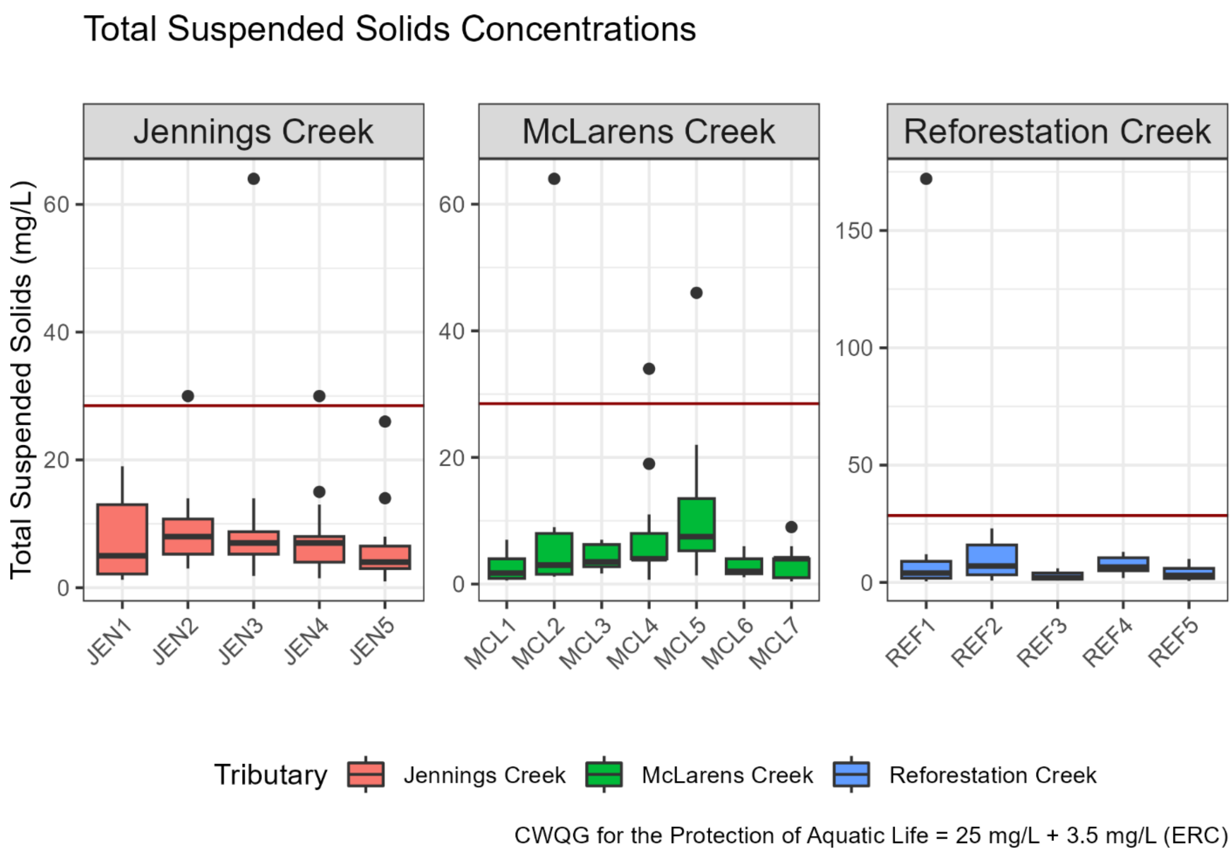


Figure 9. Total suspended solid concentrations across sites in Jennings, McLarens, and Reforestation Creek. The red line indicates the CWQG limit with the Ecological Reference Condition.

When compared to the estimated CWQG for TSS (28.5 mg/L), only seven observations failed.

All failed observations were found on different sites at one time suggesting all three tributaries have good water quality, with TSS below the harmful limit of 28.5mg/L. However, continued efforts to implement good erosion control and natural riparian areas will ensure that these tributaries continue to have excellent water quality.

Loadings

Loading is an important measure of how much of a specific compound is flowing through the stream within a given amount of time, e.g., Kilograms per Hectare per Year. To achieve targets that would align with provincial objectives (PWQO) and

CWQG limits, the reduction targets in kilograms were calculated for chloride and phosphorus (Table 4).

Table 3. Reduction targets (kg/yr) for chloride (Cl) and phosphorus (TP) for selective sites.

Tributary	Site	TP	Cl
McLarens Creek	MCL5	0.0004	
Jennings Creek	JEN1	0.0013	
	JEN2	0.0004	
	JEN3	0.0002	**2.54**
	JEN4	0.0003	
	JEN5		0.19
Reforestation Creek	REF1	0.000001	
	REF2	**0.0027**	
	REF4	0.0004	
	REF5	0.0004	

At these levels, excessive plant growth should be eliminated, and the long-term protection of aquatic life is ensured. As seen in Table 3, reduction targets for chloride are much higher than those of phosphorus (Table 3), even those among heavy urbanized sites (Figure 2). The largest target for phosphorus was found to be REF2 (Table 3) with 0.0027 kg/yr. For Chloride, reduction targets were needed for Jennings Creek, specifically for JEN3 and JEN5 (Table 3). For example, at JEN3, approximately 2.54 kg of chloride is needed to be reduced annually to prevent harmful impacts to aquatic organisms such as fish.

Recommendations

Stewardship

Elevated concentrations of certain chemical parameters have been identified for at least one (1) hot spot site among each of the three tributaries. Some sites have multiple concerns indicating that they should be a priority for stewardship remediation activities. Using all the information gathered and presented above, we recommended that the following sites be a priority for stewardship activity:

- Jennings Creek – JEN1 and JEN3
- McLarens Creek – MCL5
- Reforestation Creek – REF2

Please refer to Table 1 for the coordinates of the sites mentioned above.

Monitoring

Continued monitoring of each tributary should take place in conjunction with stewardship activities. In fact, monitoring should continue post-restoration to track the effectiveness of the remedial activity. Background concentrations of turbidity and TSS should be assessed to understand the baseline variation for the Kawartha Conservation administration area. Knowledge of baseline levels of turbidity and TSS can be used with existing guidelines to better understand impacts and acceptable limits. Remedial actions for total suspended solids and turbidity will enhance local biotic habitat for fish and benthic organisms.

Furthermore, the relationship between higher conductivity readings and higher Chloride concentrations was found to be greatest among urbanized watersheds. Additional data could be used to model Cl concentrations, i.e., using a continuous conductivity logger to model chloride concentrations over great temporal scales. Further studies are needed to validate this relationship.

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Appendix

Appendix A – Raw Data

Table A1. Water quality and water quantity results

		°C	mg/L	µS/cm		NTU	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	m^3/s
Site ID	**Date Collected**	**Temp.**	**DO**	**Cond**	**pH**	**Turb**	**NO_2-N**	**NO_3-N**	**NH_3-N**	**TKN**	**TN**	**TP**	**TSS**	**Discharge**
JEN1	2017-03-29	4	10.46	814	8.11	7.9	0.009	1.29	0.06	0.46	1.759	0.055	< 3	0.0238
JEN2	2017-03-29	2.3	13.41	843	7.98	2.8	0.006	2.09	< 0.01	0.52	2.616	0.018	4	0.2931
JEN3	2017-03-29	4.5	14.65	1148	7.98	3.7	0.008	3.59	< 0.01	0.47	4.068	0.02	6	0.0933
JEN4	2017-03-30	1.9	11.77	888	7.98	3.7	0.008	2.19	< 0.01	0.48	2.678	0.013	4	0.2401
JEN5	2017-03-30	2.2	14.24	887	7.81	2.3	0.006	1.18	< 0.01	0.46	1.646	0.013	5	n/a
JEN1	2017-06-15	12.2	10.17	813	7.73	17	0.037	9.1	0.03	0.47	9.607	0.046	< 3	0.0141
JEN2	2017-06-15	15.9	5.47	951	7.82	30	0.031	0.21	0.08	0.94	1.181	0.028	4	0.0399
JEN3	2017-06-15	15.9	9.26	1110	7.79	6.7	0.07	2.52	0.03	0.57	3.16	0.024	< 3	0.0059
JEN4	2017-06-15	15.8	7.91	900	7.97	4.1	0.041	2.66	0.06	0.95	3.651	0.027	8	0.0384
JEN5	2017-06-15	14.7	10.76	9.23	8.14	2.2	0.015	2.44	< 0.01	0.66	3.115	0.023	< 3	n/a
JEN1	2017-09-14	13.6	6.65	937	8.27	1.2	0.006	8.05	0.01	0.37	8.426	0.034	19	0.0056
JEN2	2017-09-14	13.4	5.54	1174	8.18	11.8	0.012	0.27	0.04	0.86	1.142	0.043	11	0.0966
JEN3	2017-09-14	15.9	10.32	1544	8.04	16	0.018	0.74	0.06	0.51	1.268	0.038	5	0.0084
JEN4	2017-09-14	14.2	9.53	1082	8.2	4.6	0.017	5.24	0.02	0.72	5.977	0.02	8	0.0150
JEN5	2017-09-14	14	11.29	993	8.19	2.1	0.005	4.44	0.01	0.52	4.965	0.011	4	n/a
JEN1	2017-10-31	10.9	6.59	981	7.88	7.8	0.005	6.44	< 0.01	0.38	6.825	0.038	17	0.0054
JEN2	2017-10-31	4.7	10.01	997	8	7.9	0.011	0.44	0.04	1.01	1.461	0.025	7	0.0242
JEN3	2017-10-31	5.3	11.54	1309	7.99	5.6	0.015	2.06	0.06	0.56	2.635	0.029	3	0.0060
JEN4	2017-10-31	5.7	11.9	1034	8.19	10.4	0.008	1.36	0.04	0.79	2.158	0.019	8	0.0295
JEN5	2017-10-31	5.9	12.3	1104	8.05	3.6	0.006	1.72	< 0.01	0.61	2.336	0.015	5	n/a
JEN1	2018-04-24	5.50	n/a	674.00	8.35	1.50	0.009	6.690	0.080	0.570	7.269	0.042	< 2	0.0054
JEN2	2018-04-24	9.10	n/a	691.00	8.26	4.20	0.007	1.370	0.030	0.500	1.877	0.019	3.000	0.4873
JEN3	2018-04-24	9.40	n/a	1088.00	8.03	7.10	0.005	3.650	0.060	0.400	4.055	0.055	6.000	0.1218
JEN4	2018-04-24	9.30	n/a	679.00	8.51	3.60	0.007	1.910	0.020	0.450	2.367	0.016	< 2	0.4621

Site ID	Date Collected	°C Temp.	mg/L DO	µS/cm Cond	pH	NTU Turb	mg/L NO_2-N	mg/L NO_3-N	mg/L NH_3-N	mg/L TKN	mg/L TN	mg/L TP	mg/L TSS	m^3/s Discharge
JEN5	2018-04-24	9.30	n/a	689.00	8.41	5.20	0.007	1.970	0.050	0.450	2.427	0.023	7.000	n/a
JEN1	2018-06-13	12.30	7.96	940.00	7.24	0.21	0.007	7.880	0.060	0.280	8.167	0.014	13.000	0.0054
JEN2	2018-06-13	24.50	14.79	1360.00	8.52	5.50	0.035	0.750	0.070	0.810	1.595	0.033	12.000	0.0094
JEN3	2018-06-13	26.80	19.76	1233.00	8.34	5.08	0.038	3.070	0.070	0.520	3.628	0.013	7.000	0.0074
JEN4	2018-06-13	23.50	9.37	1042.00	8.15	6.34	0.018	1.680	0.080	0.760	2.458	0.024	13.000	0.0081
JEN5	2018-06-13	20.20	9.62	1150.00	8.14	5.60	0.005	1.990	0.040	0.590	2.585	0.022	8.000	n/a
JEN1	2018-08-20	17.20	6.48	819.00	7.30	10.00	0.194	3.160	0.120	0.900	4.254	0.169	16.000	0.0002
JEN2	2018-08-20	20.70	7.18	1334.00	7.54	6.20	0.034	0.100	0.110	1.100	1.234	0.069	10.000	0.0048
JEN3	2018-08-20	26.40	9.64	1228.00	7.74	7.01	0.007	0.025	0.100	0.700	0.732	0.046	10.000	0.0066
JEN4	2018-08-20	20.80	10.32	1075.00	7.82	2.30	0.006	0.240	0.040	0.900	1.146	0.045	3.000	0.0225
JEN5	2018-08-20	19.90	11.27	1126.00	7.88	1.94	0.007	1.480	0.040	0.700	2.187	0.028	4.000	n/a
JEN1	2018-10-29	9.90	9.44	1007.00	7.80	2.16	0.004	7.280	0.070	0.500	7.784	0.031	5.000	0.0023
JEN2	2018-10-29	5.10	10.77	1261.00	7.91	6.20	0.002	0.370	0.090	0.500	0.872	0.032	5.000	0.0690
JEN3	2018-10-29	6.70	11.56	952.00	8.02	8.48	0.003	0.530	0.120	0.500	1.033	0.034	8.000	0.0441
JEN4	2018-10-29	4.70	9.30	1137.00	8.06	8.07	0.004	0.920	0.100	0.500	1.424	0.030	7.000	0.0089
JEN5	2018-10-29	5.20	11.99	1282.00	8.08	7.42	0.003	1.220	0.070	0.400	1.623	0.023	3.000	0.0369
JEN1	2019-04-17	3.3	5.51	860	7.78	1.84	0.019	5.61	0.11	0.8	6.429	0.058	3	0.0421
JEN2	2019-04-17	2.4	10.32	769	7.75	7.01	0.007	1.46	0.07	0.8	2.267	0.024	6	0.0311
JEN3	2019-04-17	3.7	12.25	1211	8.03	5.27	0.007	4.06	0.06	0.8	4.867	0.037	7	0.0941
JEN4	2019-04-17	3.2	12.2	765	8.06	4.36	0.007	2.54	0.05	0.6	3.147	0.029	< 3	2.0980
JEN5	2019-04-17	4	12.91	776	8.1	4.46	0.006	2.5	0.03	0.7	3.206	0.029	< 3	n/a
JEN1	2019-06-05	9.9	5.99	929	7.05	0.63	0.018	6.54	0.16	0.6	7.158	0.063	3	0.0247
JEN2	2019-06-05	14.4	10.19	804	7.82	1.91	0.014	1.11	0.08	0.8	1.924	0.035	7	0.2260
JEN3	2019-06-05	14.6	13.74	1216	7.98	11.9	0.034	4.05	0.12	0.7	4.784	0.031	64	0.2123
JEN4	2019-06-05	13.8	10.52	629	7.9	90	0.014	2.29	0.19	1.1	3.404	0.079	7	0.4650
JEN5	2019-06-05	13.2	9.46	709	7.83	18.4	0.012	2.13	0.14	0.8	2.942	0.079	26	n/a
JEN1	2019-07-02	13.4	7.09	989	7.14	16.1	0.03	7.9	0.14	0.6	8.53	0.052	9	0.0099
JEN2	2019-07-02	24.1	8.1	1134	7.92	16.54	0.061	0.66	0.17	1.2	1.921	0.084	30	0.0300
JEN3	2019-07-02	27.7	26.56	1321	8.36	4.93	0.191	2.07	0.1	0.8	3.061	0.024	7	0.0142

Site ID	Date Collected	°C Temp.	mg/L DO	µS/cm Cond	pH	NTU Turb	mg/L NO_2^-	mg/L NO_3^-	mg/L NH_3-N	mg/L TKN	mg/L TN	mg/L TP	mg/L TSS	m^3/s Discharge
JEN4	2019-07-02	23.7	9.87	1008	7.98	8.44	0.062	2.41	0.12	1.1	3.572	0.06	15	0.0264
JEN5	2019-07-03	16.6	7.51	1061	8.05	n/a	0.015	2.57	0.08	0.9	3.485	0.056	14	0.0722
JEN1	2019-08-07	18.4	12.13	815	8.14	n/a	n/a	n/a	n/a	n/a	0	n/a	n/a	n/a
JEN2	2019-08-07	20	3.27	1729	8.53	n/a	0.01	0.16	0.11	0.9	1.07	0.085	14	0.0114
JEN3	2019-08-07	23.4	12.12	1007	7.35	n/a	0.009	0.025	0.08	0.9	0.934	0.085	14	n/a
JEN4	2019-08-07	21.2	8.76	1328	7.14	n/a	0.008	0.49	0.16	0.7	1.198	0.054	30	0.0165
JEN5	2019-08-08	15.7	9.9	1316	6.31	n/a	0.008	1.77	0.06	0.4	2.178	0.046	3	0.0107
JEN1	2019-10-23	10.7	9.88	833	7.76	3.95	0.041	2.56	0.11	0.9	3.501	0.085	7	0.0027
JEN2	2019-10-23	10.2	6.02	474	7.79	10.5	0.008	0.14	0.08	0.5	0.648	0.074	10	0.5054
JEN3	2019-10-23	10.2	11.61	1092	7.75	7.22	0.011	0.3	0.12	0.7	1.011	0.055	3	0.0123
JEN4	2019-10-23	9.4	8.69	659	7.79	8.1	0.008	0.28	0.07	0.6	0.888	0.057	7	0.1056
JEN5	2019-10-23	9.2	10.97	789	7.78	5.9	0.009	0.49	0.03	0.5	0.999	0.044	4	n/a
JEN1	2019-11-05	9.1	9.46	900	7.57	2.1	0.02	11.3	0.1	0.7	12.02	0.05	< 3	0.0108
JEN2	2019-11-05	6.2	9.45	1138	7.61	2.91	0.017	5.5	0.12	1	6.517	0.034	9	0.1448
JEN3	2019-11-05	8.1	12.32	1133	7.78	5.81	0.022	7.22	0.11	0.8	8.042	0.024	9	0.0085
JEN4	2019-11-05	6.4	11.05	1024	7.77	2.33	0.016	6.01	0.11	0.8	6.826	0.023	4	0.0649
JEN5	2019-11-05	6.7	11.78	1017	7.85	2.34	0.013	5.71	0.06	0.7	6.423	0.019	< 3	n/a
MCL1	2017-03-28	2.4	10.4	457.8	8.16	1.7	0.006	1.79	< 0.01	0.19	1.986	0.008	< 3	0.0141
MCL2	2017-03-28	1	10.56	381	8.15	1.6	0.006	0.49	< 0.01	0.38	0.876	0.009	< 3	0.5728
MCL3	2017-03-28	1.6	12.56	310.9	7.89	1.3	0.004	0.38	0.01	0.39	0.774	0.016	3	0.7104
MCL4	2017-03-28	5.2	16.28	526	8.31	2.3	0.01	1.79	< 0.01	0.48	2.28	0.02	4	0.5757
MCL5	2017-03-28	4	14.37	385.7	8.35	1.4	0.008	2.09	< 0.01	0.43	2.528	0.017	3	0.7423
MCL6	2017-03-28	4.3	12.57	420	8.1	2.4	0.007	0.26	< 0.01	0.44	0.707	0.013	4	n/a
MCL7	2017-03-28	5.3	14.11	448.5	8.11	1.8	0.009	2.09	< 0.01	0.52	2.619	0.021	< 3	n/a
MCL1	2017-06-19	17.9	3.15	496	8.02	0.3	0.005	< 0.02	< 0.01	0.56	0.575	0.022	< 3	0.0106
MCL2	2017-06-19	18	3.5	519	7.85	0.1	0.008	< 0.02	0.02	1.06	1.078	0.027	< 3	0.1881
MCL3	2017-06-19	20.8	7.21	344.9	7.94	2.3	0.007	< 0.02	< 0.01	0.81	0.827	0.026	4	0.4350
MCL4	2017-06-19	20.7	8.29	419.4	8.12	3.4	0.022	3.47	0.03	0.86	4.352	0.04	7	0.1690
MCL5	2017-06-19	20.1	8.56	600	8.15	5.8	0.008	1.32	< 0.01	0.89	2.218	0.043	6	0.5764

Site ID	Date Collected	°C Temp.	mg/L DO	µS/cm Cond	pH	NTU Turb	mg/L NO_2-N	mg/L NO_3-N	mg/L NH_3-N	mg/L TKN	mg/L TN	mg/L TP	mg/L TSS	m^3/s Discharge
MCL6	2017-06-19	22	8.61	501	8.11	1.3	0.021	0.64	0.04	0.82	1.481	0.039	< 3	2.1381
MCL7	2017-06-19	22.5	6.38	595	8.02	0.4	0.007	< 0.02	0.02	1.03	1.047	0.033	< 3	0.4210
MCL1	2017-09-13	11.5	4.71	522	8.62	0	0.004	0.025	< 0.01	0.5	0.529	0.014	7	0.0007
MCL2	2017-09-13	13.3	2.28	798	7.83	6.3	0.008	0.025	0.19	2.3	2.333	0.148	64	0.0015
MCL3	2017-09-13	16.1	9.07	360	8.23	1.2	0.005	0.025	0.01	0.83	0.86	0.016	7	0.0687
MCL4	2017-09-13	16	9.84	423.7	8.61	2.3	0.005	0.37	< 0.01	0.67	1.045	0.019	11	0.0450
MCL5	2017-09-13	15.6	11.34	667	8.38	3.3	0.008	3.64	0.02	0.63	4.278	0.02	< 3	0.0151
MCL6	2017-09-13	13.9	6.4	882	8.18	0	0.005	0.025	0.02	1.19	1.22	0.016	< 3	0.0411
MCL7	2017-09-13	15.4	7	523	8.31	1.74	0.008	0.37	0.05	0.66	1.038	0.016	3	0.0619
MCL1	2017-11-02	5.9	6.85	449.3	8.3	2.7	0.005	0.025	< 0.01	0.34	0.37	0.012	< 3	0.0005
MCL2	2017-11-02	6.3	7.21	561	7.99	3.9	0.005	0.025	< 0.01	1.1	1.13	0.021	9	0.0314
MCL3	2017-11-02	5.5	12.13	339.4	7.95	1.6	0.007	0.025	< 0.01	0.56	0.592	0.007	< 3	0.1913
MCL4	2017-11-02	6.5	12.25	429	7.88	2.3	0.011	0.54	< 0.01	0.69	1.241	0.015	3	0.2239
MCL5	2017-11-02	7.4	11.23	653	7.91	8.4	0.007	2.21	0.02	0.76	2.977	0.034	14	0.0756
MCL6	2017-11-02	6	9.78	501	7.83	4	0.006	0.85	0.07	0.69	1.546	0.016	6	0.4811
MCL7	2017-11-02	6	5.78	1041	7.47	1.3	0.006	0.025	< 0.01	0.93	0.961	0.009	< 3	0.1442
MCL1	2018-04-23	5.00	n/a	446.90	9.16	0.30	0.004	0.060	0.040	0.130	0.194	0.002	< 2	0.0231
MCL2	2018-04-23	4.30	n/a	327.20	8.54	0.60	0.005	0.025	0.020	0.290	0.32	0.004	< 2	1.0740
MCL3	2018-04-23	7.60	n/a	296.60	8.37	0.60	0.005	0.240	0.030	0.340	0.585	0.008	< 2	1.2915
MCL4	2018-04-23	7.90	n/a	496.20	8.72	3.30	0.006	3.530	0.020	0.460	3.996	0.012	3.000	0.3348
MCL5	2018-04-23	7.90	n/a	3343.00	8.43	5.20	0.006	0.740	0.020	0.430	1.176	0.028	11.000	1.1446
MCL6	2018-04-23	8.50	n/a	375.70	8.37	0.30	0.006	0.025	0.030	0.290	0.321	0.003	< 2	n/a
MCL7	2018-04-23	8.70	n/a	399.50	8.66	2.70	0.005	1.570	0.020	0.650	2.225	0.021	6.000	n/a
MCL1	2018-06-13	16.70	2.95	506.00	7.52	n/a	0.004	0.025	0.020	0.300	0.329	0.027	4.000	0.0001
MCL2	2018-06-13	15.40	2.42	647.00	7.59	n/a	0.008	0.060	0.230	1.530	1.598	0.068	8.000	0.0388
MCL3	2018-06-13	21.30	8.38	324.60	8.21	0.13	0.005	0.025	0.030	0.610	0.64	0.014	< 2	0.0458
MCL4	2018-06-13	20.00	8.98	393.70	8.46	3.94	0.006	0.550	0.060	0.760	1.316	0.032	7.000	0.0413
MCL5	2018-06-13	19.00	10.66	606.00	8.41	6.42	0.019	4.330	0.070	0.630	4.979	0.018	12.000	0.0257
MCL6	2018-06-13	20.30	6.02	620.00	7.81	0.22	0.007	0.025	0.030	1.210	1.242	0.017	2.000	0.0132

Site ID	Date Collected	°C Temp.	mg/L DO	µS/cm Cond	pH	NTU Turb	mg/L NO_2-N	mg/L NO_3-N	mg/L NH_3-N	mg/L TKN	mg/L TN	mg/L TP	mg/L TSS	m^3/s Discharge
MCL7	2018-06-13	22.50	7.06	485.20	7.85	0.40	0.012	0.520	0.050	0.840	1.372	0.017	5.000	0.1290
MCL5	2018-08-20	17.20	5.16	649.00	7.60	7.78	0.030	0.920	0.290	0.900	1.85	0.063	15.000	n/a
MCL7	2018-08-20	22.10	4.68	649.00	7.33	1.60	0.008	0.025	0.020	0.900	0.933	0.055	9.000	0.0039
MCL3	2018-10-29	4.00	12.24	360.90	8.31	6.17	0.002	0.025	0.090	0.800	0.827	0.029	7.000	0.0830
MCL4	2018-10-29	4.50	13.16	412.00	8.35	1.27	0.003	0.130	0.070	0.700	0.833	0.015	4.000	0.0639
MCL5	2018-10-29	5.20	12.12	664.00	8.20	5.30	0.003	3.400	0.090	0.400	3.803	0.019	4.000	0.0160
MCL7	2018-10-29	4.40	11.87	483.10	8.28	1.98	0.006	0.550	0.090	0.700	1.256	0.016	4.000	0.0757
MCL1	2019-04-16	1.2	9.14	441	8.14	1.46	0.005	0.25	0.02	0.3	0.555	0.01	3	0.0134
MCL2	2019-04-16	0.8	10.18	337.6	7.89	1.7	0.005	0.06	0.02	0.4	0.465	0.01	< 3	0.3758
MCL3	2019-04-16	1.7	11.91	238.2	7.86	0.99	0.005	0.025	0.04	0.5	0.53	0.016	6	1.5553
MCL4	2019-04-16	3	13.16	104.6	7.83	1.47	0.005	1.02	0.03	0.5	1.525	0.022	8	1.3458
MCL5	2019-04-16	5.1	14.74	526	7.91	2.44	0.006	3.68	0.02	0.6	4.286	0.022	7	0.2277
MCL6	2019-04-16	4.7	12.27	388.6	8.02	0.66	0.005	0.07	0.02	0.5	0.575	0.01	< 3	1.2379
MCL7	2019-04-16	5	13.51	387.8	8.04	1.66	0.005	1.95	0.03	0.5	2.455	0.018	4	1.6280
MCL1	2019-06-05	12.7	5.76	510	7.38	0.27	0.005	0.025	0.07	0.4	0.43	0.031	< 3	0.0066
MCL2	2019-06-05	12.3	6.03	453	7.5	0.31	0.006	0.025	0.07	0.7	0.731	0.052	4	0.1201
MCL3	2019-06-05	12.9	9.08	334.1	7.51	0.41	0.005	0.025	0.06	0.5	0.53	0.02	3	0.2849
MCL4	2019-06-05	14.4	10.42	415.4	8.31	0.78	0.007	0.96	0.06	0.5	1.467	0.029	4	0.4746
MCL5	2019-06-05	13.9	11.29	594	8.19	1.92	0.014	3.7	0.07	0.5	4.214	0.014	8	0.1174
MCL6	2019-06-05	12.7	6.68	534	7.58	0.33	0.006	0.025	0.07	0.7	0.731	0.01	3	0.5452
MCL7	2019-06-05	11.5	8.71	506	7.76	0.45	0.013	1.68	0.06	0.5	2.193	0.01	4	0.5569
MCL1	2019-07-02	19	1.82	543	7.65	0.82	0.005	0.07	0.1	0.4	0.475	0.026	4	0.0012
MCL2	2019-07-02	18	5.66	599	7.64	0	0.007	0.025	0.09	1	1.032	0.019	3	0.0185
MCL3	2019-07-02	23.1	7.81	366	7.96	1.03	0.006	0.08	0.06	0.7	0.786	0.023	7	0.0280
MCL4	2019-07-02	24.6	8.68	415.8	8.35	7.05	0.017	0.45	0.07	0.9	1.367	0.061	19	0.0767
MCL5	2019-07-02	21.7	9.69	635	8.25	19	0.042	4.79	0.11	0.7	5.532	0.071	46	0.7960
MCL6	2019-07-02	22.7	5.37	631	8.01	1.25	0.007	0.025	0.08	0.9	0.932	0.05	5	0.0103
MCL7	2019-07-02	22.6	4.1	537	7.78	1.88	0.04	0.73	0.15	0.9	1.67	0.041	4	0.2075
MCL2	2019-08-07	20.7	2.99	2136	6.82	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

Site ID	Date Collected	°C Temp.	mg/L DO	µS/cm Cond	pH	NTU Turb	mg/L NO_2-N	mg/L NO_3-N	mg/L NH_3-N	mg/L TKN	mg/L TN	mg/L TP	mg/L TSS	m^3/s Discharge
MCL3	2019-08-07	21	5.68	336.8	6.9	n/a	0.008	0.2	0.1	0.8	1.008	0.078	5	0.0019
MCL4	2019-08-07	20.3	7.03	448.1	7.13	n/a	0.007	0.43	0.07	1	1.437	0.131	34	0.0058
MCL5	2019-08-07	20.6	6.9	638	7.87	n/a	0.022	2.68	0.11	0.7	3.402	0.071	22	0.0029
MCL6	2019-08-07	21	1.5	446.2	6.67	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
MCL7	2019-08-07	20.9	2.16	482.1	6.19	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
MCL4	2019-10-23	7.2	10.82	747	7.83	1.21	0.007	0.16	0.1	0.7	0.867	0.032	< 3	0.0038
MCL5	2019-10-23	7.4	8.72	690	7.85	4.09	0.023	2.33	0.14	0.6	2.953	0.034	7	0.0034
MCL7	2019-10-23	9.1	678	552	7.42	0.96	0.017	0.55	0.08	0.8	1.367	0.035	< 3	0.1220
MCL3	2019-11-05	4.6	11.88	311.9	7.12	2.22	0.008	< 0.05	0.08	0.7	0.733	0.016	3	0.3363
MCL4	2019-11-05	4.9	12.18	363.5	7.63	1.28	0.008	0.73	0.05	0.7	1.438	0.019	4	0.2778
MCL5	2019-11-05	6.5	11.65	645	7.75	1.86	0.011	10.7	0.08	0.7	11.411	0.015	5	0.0560
MCL7	2019-11-05	5.5	10.66	475	7.78	1.29	0.013	2.91	0.06	0.7	3.623	0.017	< 3	0.3947
REF1	2017-04-05	2.8	12.44	716	7.74	1.8	0.002	2.3	< 0.01	0.61	2.912	0.016	4	0.0313
REF2	2017-04-05	2.9	12.17	878	7.74	9.2	0.112	3.19	1.52	3.88	7.182	0.803	7	0.0041
REF3	2017-04-05	5	10	378.3	8.88	1.3	0.011	1.74	< 0.01	0.72	2.471	0.018	< 3	0.8848
REF4	2017-04-06	4.7	12.53	504	7.92	3	0.005	0.96	0.06	0.98	1.945	0.066	4	0.3777
REF5	2017-04-06	5.1	10.42	444.3	8.13	3.6	0.017	1.58	< 0.01	0.85	2.447	0.028	3	0.4038
REF1	2017-06-14	11.4	8.28	820	7.19	1.2	0.004	11	< 0.01	0.34	11.344	0.007	< 3	0.0024
REF2	2017-06-14	12.6	7.78	1012	7.4	0.4	0.033	21	0.04	0.54	21.573	0.08	< 3	0.0017
REF3	2017-06-14	19.4	4.66	513	7.69	0.4	0.097	0.78	0.25	1.28	2.157	0.025	4	0.1387
REF4	2017-06-14	16.8	8.4	592	8.02	2.8	0.061	2.96	< 0.01	0.88	3.901	0.036	9	0.0555
REF5	2017-06-14	16.8	7.25	592	7.86	0.9	0.033	1.42	0.05	0.78	2.233	0.049	< 3	0.0206
REF3	2017-09-11	12.5	7.6	506	8.35	1.3	0.018	2.08	0.04	0.93	3.028	0.014	< 3	0.0087
REF4	2017-09-11	11	9.73	620	8.01	3.8	0.005	5.37	0.01	0.56	5.935	0.027	7	0.0316
REF5	2017-09-11	11.1	7.15	621	8.38	1.4	0.016	2.93	0.04	0.43	3.376	0.028	< 3	0.0109
REF3	2017-10-30	6.1	6.75	573	8.26	1.7	0.054	3.29	0.18	1.11	4.454	0.018	6	0.0451
REF4	2017-10-30	7.7	9.42	627	7.96	2.9	0.005	5.15	0.04	0.48	5.635	0.014	13	0.0658
REF5	2017-10-30	6.4	5.54	635	8.09	4.2	0.009	2.76	0.06	0.62	3.389	0.027	6	0.0456
REF1	2018-05-09	6.10	11.99	729.00	8.01	n/a	0.007	8.860	0.030	0.410	9.277	0.007	< 2	0.0069

Site ID	Date Collected	°C Temp.	mg/L DO	µS/cm Cond	pH	NTU Turb	mg/L NO_2^-	mg/L NO_3^-	mg/L NH_3-N	mg/L TKN	mg/L TN	mg/L TP	mg/L TSS	m^3/s Discharge
REF2	2018-05-09	8.70	11.75	1032.00	8.09	n/a	0.048	15.200	0.070	0.400	15.648	0.035	14.000	0.0023
REF3	2018-05-09	13.10	5.88	447.50	8.58	n/a	0.023	1.160	0.050	0.800	1.983	0.012	< 2	0.2511
REF4	2018-05-09	12.60	10.18	546.50	8.32	n/a	0.018	3.100	0.050	0.690	3.808	0.015	< 2	0.1053
REF5	2018-05-09	12.50	5.18	542.20	8.26	n/a	0.022	1.770	0.050	0.560	2.352	0.015	4.000	0.0438
REF1	2018-06-04	11.40	8.93	712.00	8.19	n/a	0.006	8.340	0.020	0.310	8.656	0.011	4.000	0.0020
REF2	2018-06-04	12.30	9.74	1047.00	8.28	n/a	0.010	25.700	0.040	0.710	26.42	0.130	23.000	0.0005
REF3	2018-06-04	15.10	3.78	551.60	8.36	n/a	0.018	0.080	0.120	1.220	1.318	0.027	< 2	0.0726
REF4	2018-06-04	13.10	9.15	642.70	8.27	n/a	0.013	4.310	0.060	0.700	5.023	0.027	6.000	0.0377
REF5	2018-06-04	14.40	6.04	630.00	8.10	n/a	0.012	1.570	0.090	0.600	2.182	0.040	3.000	0.0773
REF3	2018-08-21	19.30	3.91	458.80	7.31	1.70	0.006	0.025	0.040	0.900	0.931	0.064	3.000	0.0740
REF4	2018-08-21	12.20	7.16	618.00	7.42	2.71	0.036	4.960	0.030	0.400	5.396	0.028	5.000	0.0244
REF5	2018-08-21	16.40	3.89	620.00	7.40	0.82	0.033	1.880	0.060	0.500	2.413	0.064	< 2	0.0124
REF3	2018-10-29	4.40	11.72	596.00	8.43	0.52	0.009	2.180	0.170	0.700	2.889	0.015	2.000	n/a
REF4	2018-10-29	7.00	8.78	610.00	7.83	3.03	0.003	5.640	0.080	0.400	6.043	0.022	5.000	0.0309
REF5	2018-10-29	4.90	6.76	609.00	8.04	1.61	0.005	3.150	0.100	0.400	3.555	0.027	3.000	0.0374
REF1	2019-04-17	2.5	8.32	755	7.84	1.83	0.008	5.36	0.05	0.7	6.068	0.044	< 3	0.0298
REF2	2019-04-17	4.7	12.3	830	7.53	2.2	0.151	20.2	0.17	1	21.351	0.076	< 3	0.0094
REF3	2019-04-17	4.7	11.3	336.5	8.21	0.95	0.006	0.96	0.03	0.7	1.666	0.017	< 3	0.8185
REF5	2019-04-17	6.5	106.8	390.6	7.85	1.25	0.007	1.89	0.04	0.6	2.497	0.049	< 3	0.5396
REF1	2019-06-06	9.9	7.58	829	7.03	2.11	0.007	7.89	0.07	0.7	8.597	0.037	8	0.0311
REF2	2019-06-06	10.9	9.15	914	7.41	4.12	0.044	21.1	0.26	1.4	22.544	0.242	5	0.0037
REF3	2019-06-06	14.1	9.12	488	7.72	0.63	0.014	1.62	0.07	0.8	2.434	0.019	5	0.5160
REF4	2019-06-06	14.3	9.36	550	7.88	2.53	0.015	3.26	0.08	0.9	4.175	0.052	12	0.3751
REF5	2019-06-06	14.5	7.97	542	7.79	1.08	0.024	2.55	0.08	0.9	3.474	0.057	10	0.4104
REF1	2019-07-03	13.3	8.42	721	6.95	n/a	0.01	5.74	0.06	0.6	6.35	0.039	12	n/a
REF2	2019-07-03	15.8	7.71	1277	7.22	n/a	0.129	17.1	0.22	0.9	18.129	0.214	18	0.0001
REF3	2019-07-03	24.1	7.57	481.1	7.73	n/a	0.071	0.25	0.16	1.2	1.521	0.026	4	0.0505
REF4	2019-07-03	16.8	8.42	619	7.91	n/a	0.024	5.51	0.08	0.7	6.234	0.032	10	0.0307
REF5	2019-07-03	21.1	4.17	631	7.11	n/a	0.057	1.55	0.16	0.8	2.407	0.078	7	0.0579

Site ID	Date Collected	°C Temp.	mg/L DO	µS/cm Cond	pH	NTU Turb	mg/L NO_2^-	mg/L NO_3^-	mg/L NH_3-N	mg/L TKN	mg/L TN	mg/L TP	mg/L TSS	m^3/s Discharge
REF1	2019-08-06	16.8	0.56	1400	6.68	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
REF3	2019-08-06	19.2	3.87	402.5	6.1	n/a	0.006	0.06	0.09	0.8	0.866	0.043	5	0.0070
REF4	2019-08-06	11.9	9.77	619.7	6.15	n/a	0.012	7	0.06	0.5	7.512	0.049	12	0.0235
REF5	2019-08-06	17.7	2.99	627	5.53	n/a	0.035	1.06	0.33	0.5	1.595	0.085	10	0.0715
REF1	2019-10-23	9.1	4.44	392.3	7.07	108	0.122	0.41	1.71	3.2	3.732	0.363	172	0.0005
REF3	2019-10-23	104	12.31	511	8.01	5.05	0.086	1.54	0.24	1.2	2.826	0.064	< 3	0.0020
REF4	2019-10-23	9.1	9.73	614	7.54	2.65	0.013	5.46	0.08	0.6	6.073	0.03	6	0.0200
REF5	2019-10-23	8.8	6.59	604	7.34	1.42	0.031	2.41	0.13	0.6	3.041	0.049	< 3	0.0879

Appendix A – Additional Figures

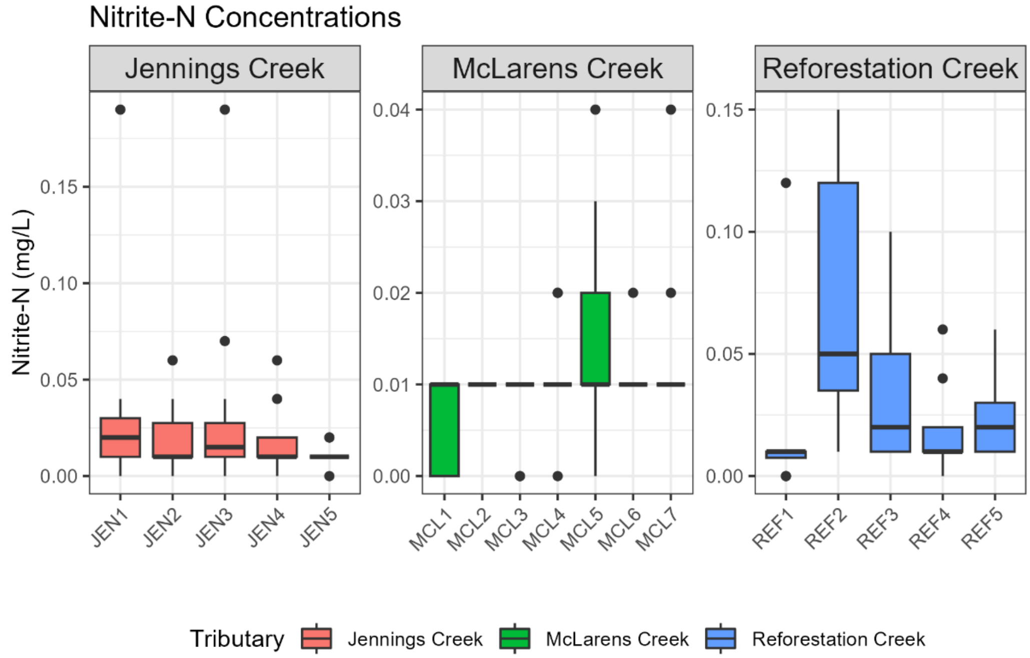

Figure A1. Nitrite-N concentrations per site for all three tributaries.

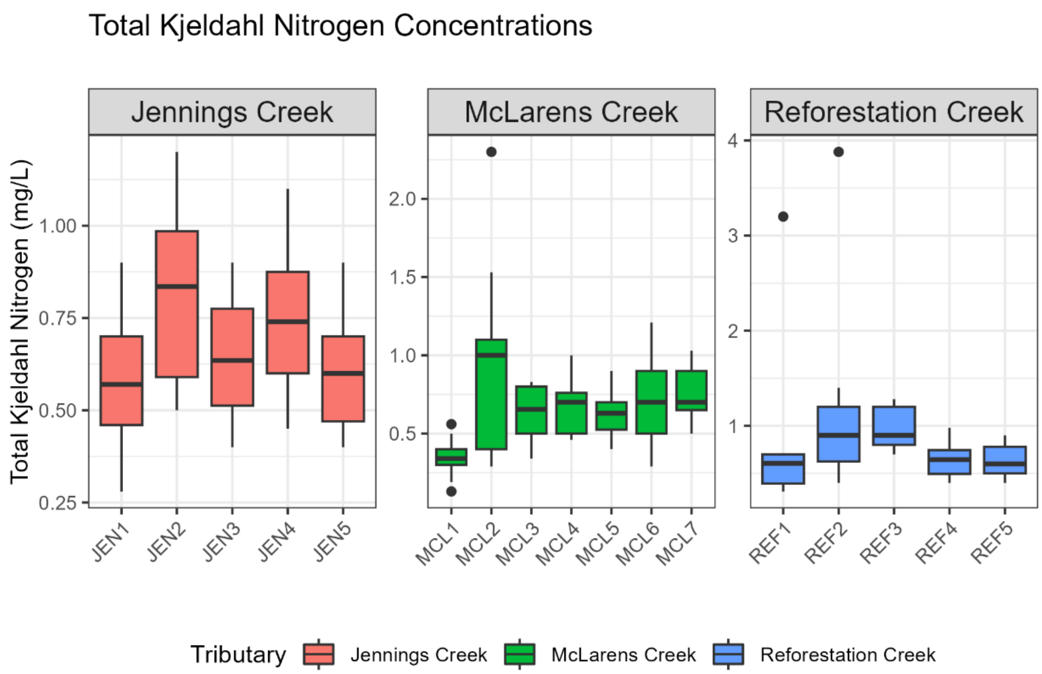

Figure A2. Total Kjeldahl Nitrogen concentrations per site for all three tributaries.