Optimizing Water Quality Sampling Through Application Of Real Time Ionic Concentration Regression Models

Real-Time Water Quality Monitoring Workshop, 2018

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Overview

- Purpose
- Traditional Grab Sampling Vs Real Time Sampling
- Data Collection, Comparison and Methodology
- Sampling Site Description
- Effect of flow on parameter concentration
- Statistical analysis for Conductivity and Parameter Concentration
- Conductivity – Ionic Concentration Model (OLS)
- Real Time Ionic Concentration Estimation
- Conclusion and Path Forward

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Purpose

- Determine whether differences exists in water quality parameter concentration between urban and non urban water bodies.
- Role of flow in parameter concentration.
- Identify the relationship between Conductivity and Ionic Concentration among four rivers on the island of Newfoundland.
- Apply the model to predict Ionic Concentration in real time and optimize sampling time.

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Types of Sampling

- Continuous/Real Time Sampling:
  - Provides a clearer picture of water quality over time.
  - Sample results are obtained at regular intervals
- Grab Sampling:
  - Provides a snapshot of water quality at the time the sample was taken.
  - Takes some time for the sample results to be returned from lab.

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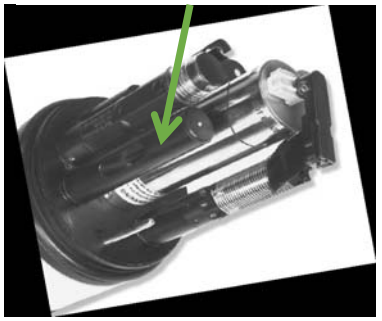
Sample Data Measurement

Field Data Measurement

Conductivity Sensor



Data Displayed in Surveyor

Collection of Grab Sample within close period of time

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Data Comparison

- The instrument measurements were compared for accuracy using the comparison chart.

Parameter		Rank				
		Excellent	Good	Fair	Marginal	Poor
Temperature °C		± 0.2	± 0.2-0.5	± 0.5-0.8	± 0.8-1.0	± 1.0
pH (units)		± 0.2	± 0.2-0.5	± 0.5-0.8	± 0.8-1.0	± 1.0
Specific Conductivity	>35 µS/cm	± 3	± 3-10	± 10-15	± 15-20	± 20
	<35 µS/cm	± 3%	± 3%-10%	± 10%-15%	± 15%-20%	± 20%
Dissolved Oxygen (mg/L)		± 0.3	± 0.3-0.5	± 0.5-0.8	± 0.8-1.0	± 1.0
Turbidity	<40 NTU	± 2	± 2-5	± 5-8	± 8-10	± 10
	>40 NTU	± 5%	± 5-10%	± 10-15%	± 15-20%	± 20%

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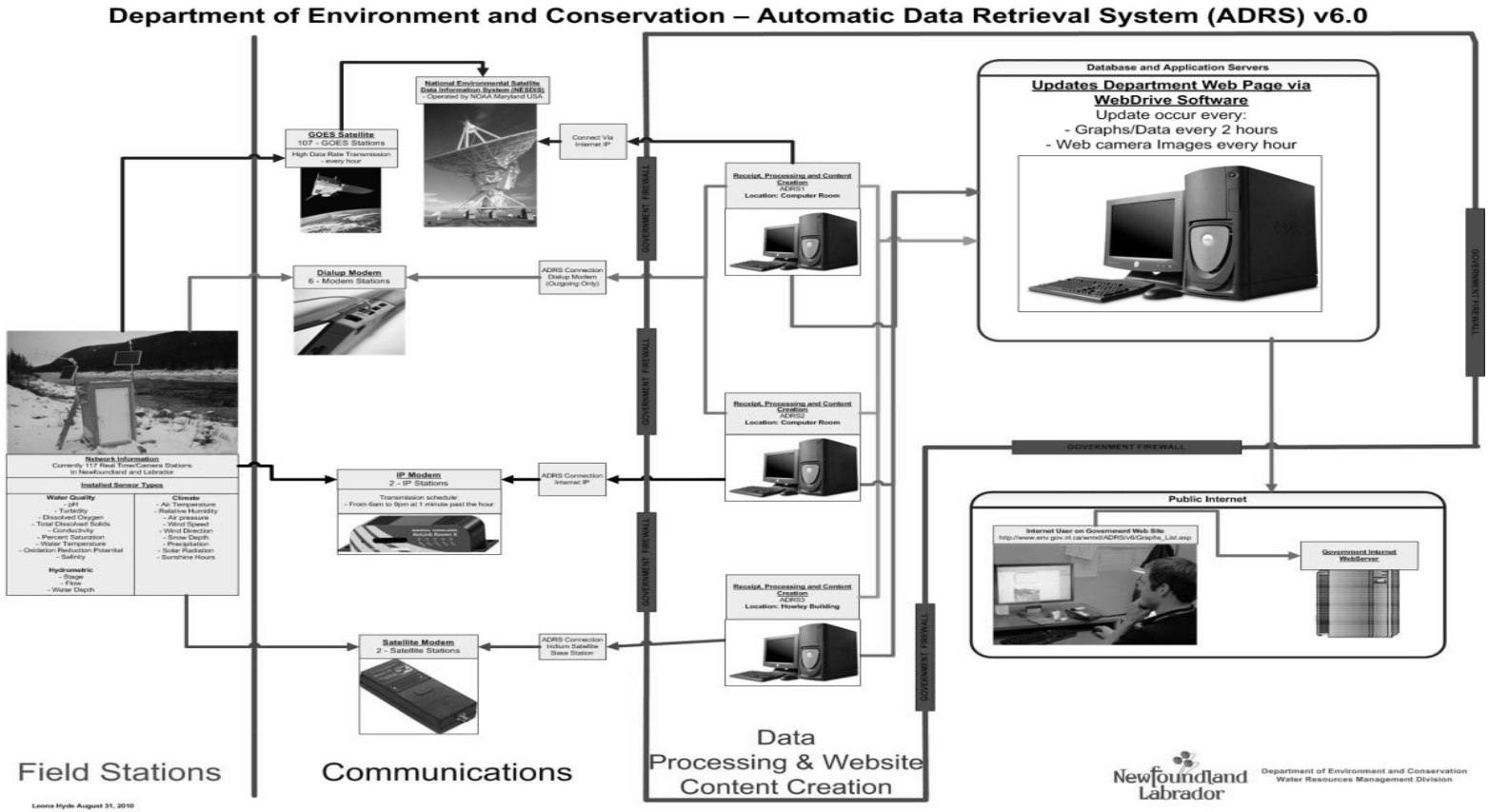
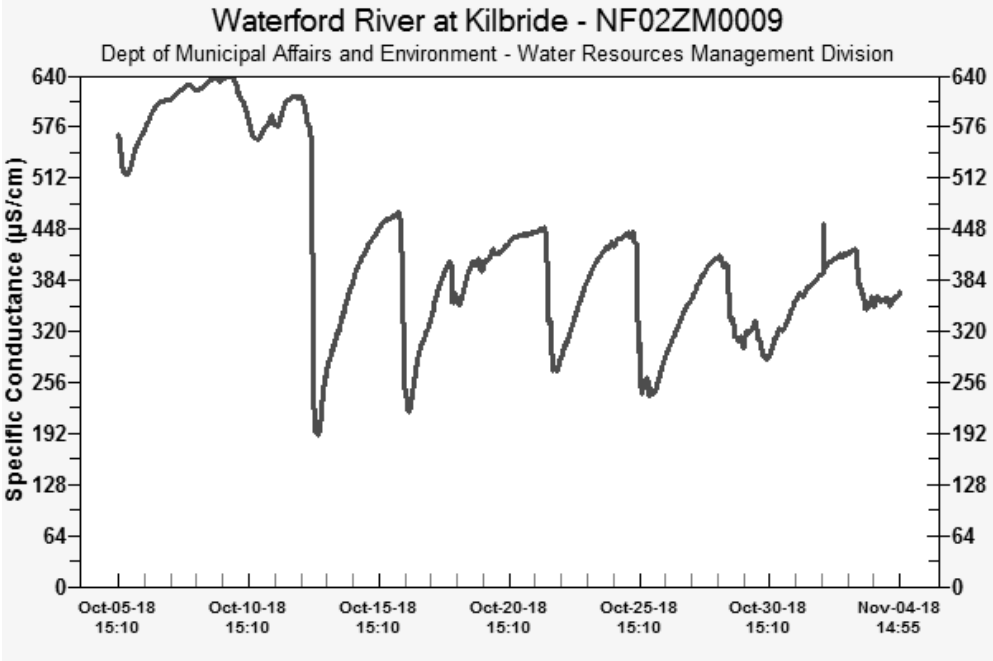
Data Collection

- Monthly Grab Sample:2010 – 2016
- Water Survey Canada – HYDAT
- Field data - Real Time Water Quality Network (Field Sheets)



Data Collection

- Individual parameters graphed independently to identify trends over specific time period.
- Available for public view.
- Updated every two hours.



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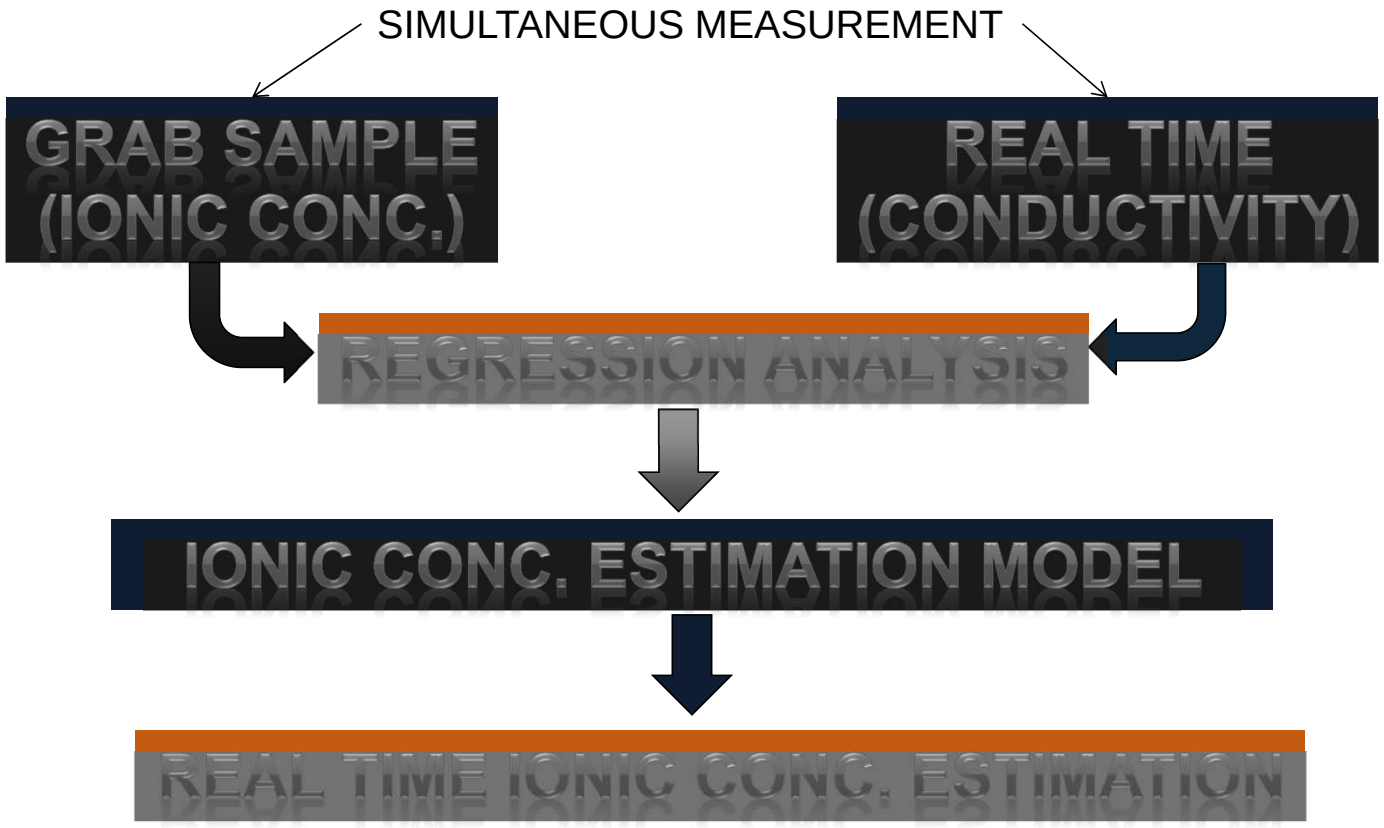
Methodology



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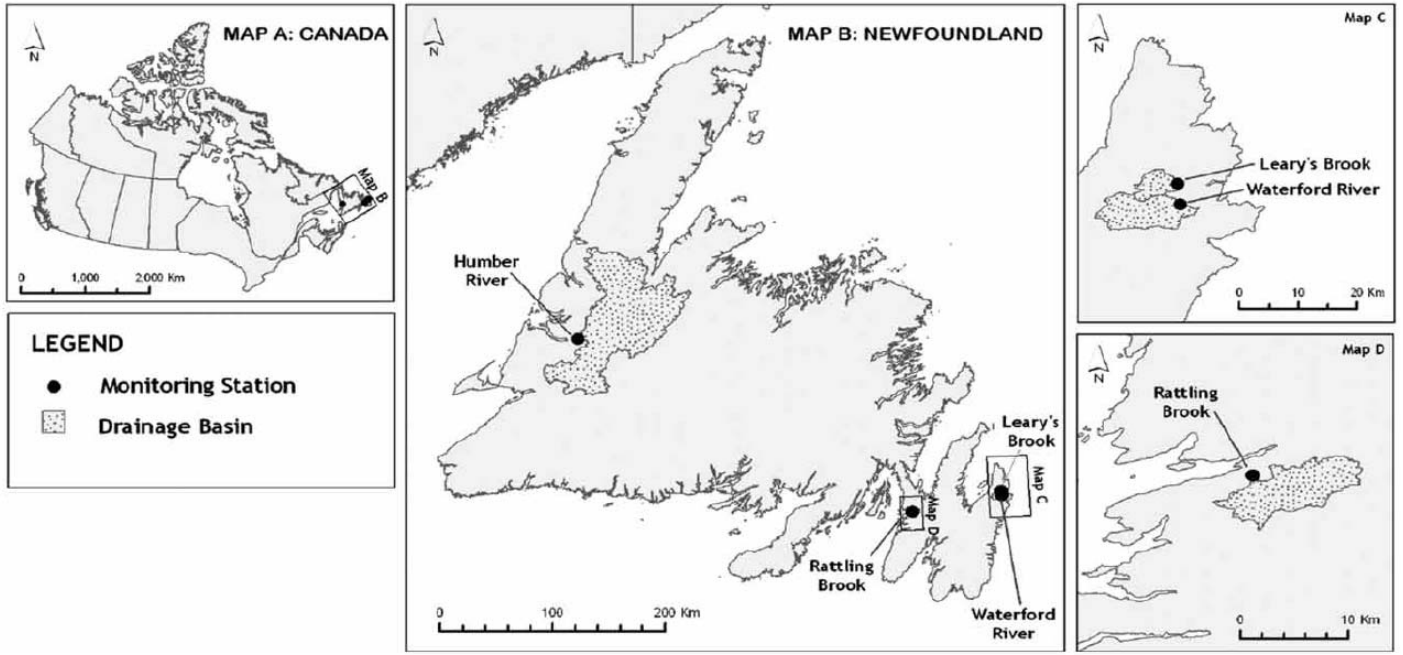
Map of the study area



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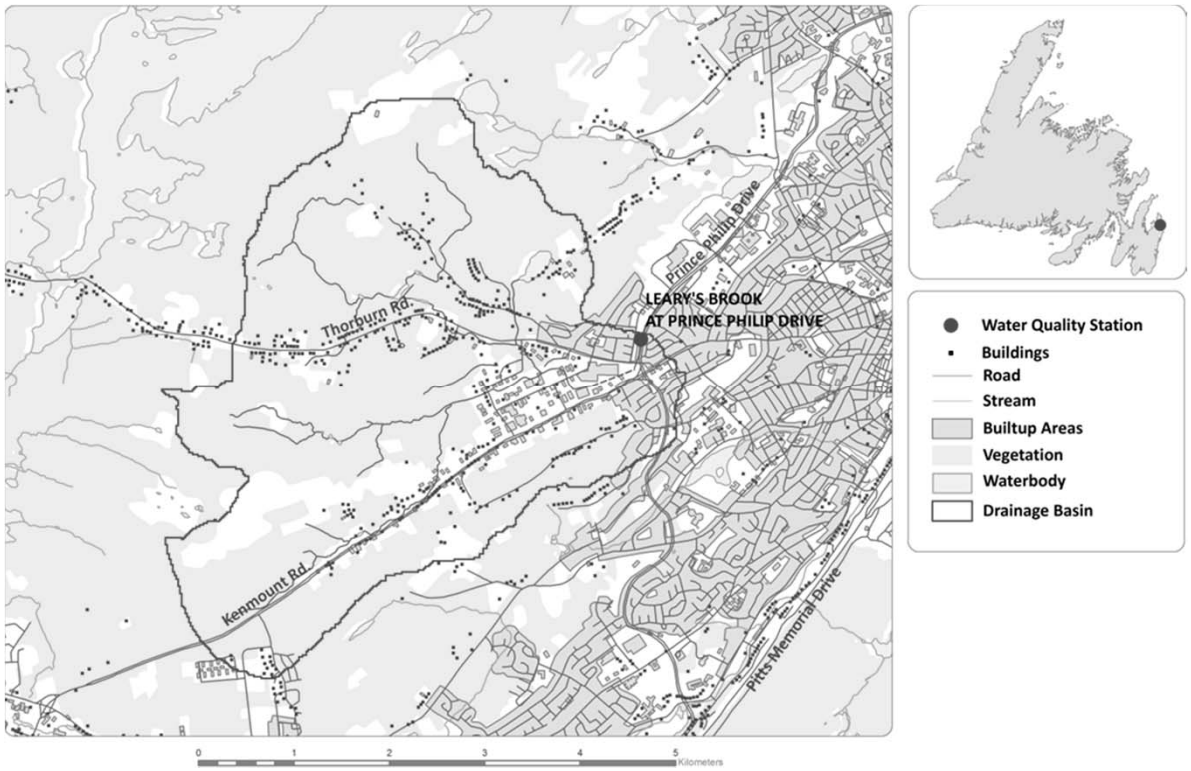
Sampling Site – Leary's Brook



- Located in the vicinity of Avalon Mall and Memorial University.
- Densely surrounded by houses, buildings, business facilities and major roads.

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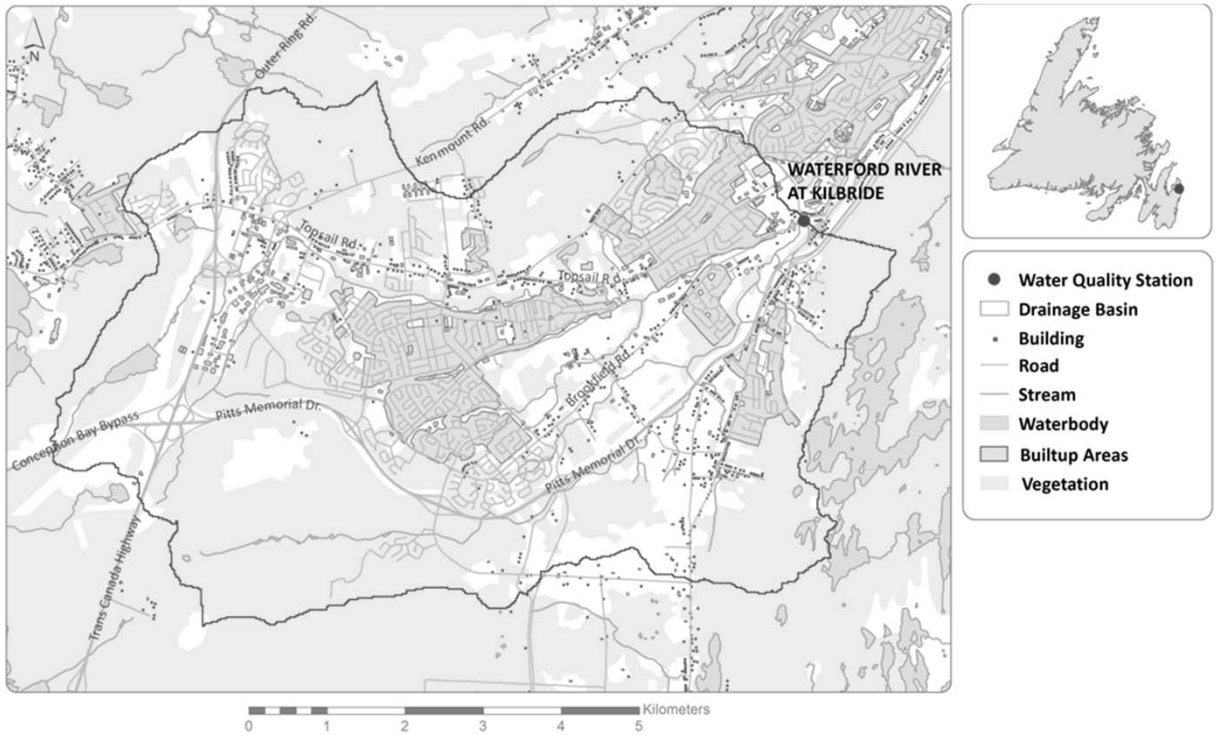
Sampling Site – Waterford River



- Situated near the downtown area of the City of St. John's.
- Major industrial areas are located within the watershed.

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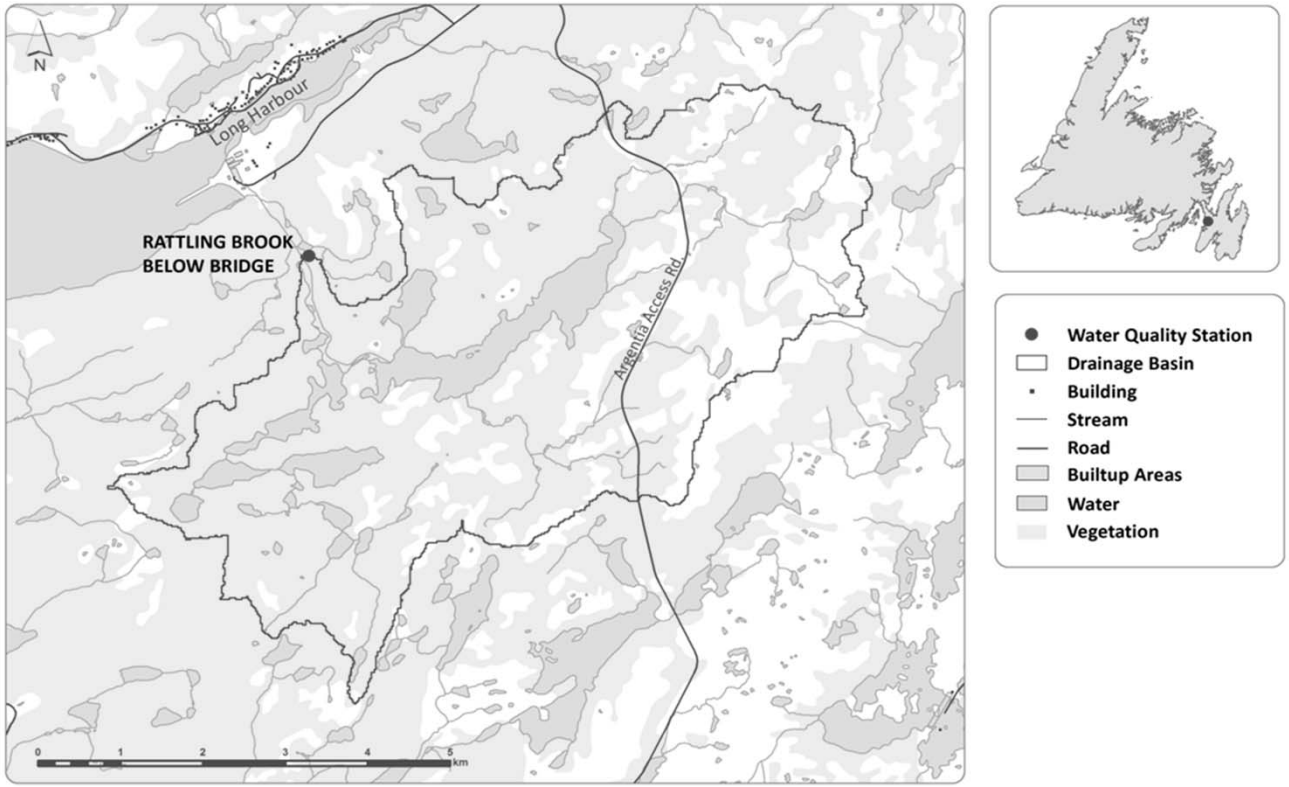
Sampling Site – Rattling Brook



- Located within the construction zone of a commercial processing facility.
- Major work resulting from the construction of the processing facility has occurred at the time of sampling.

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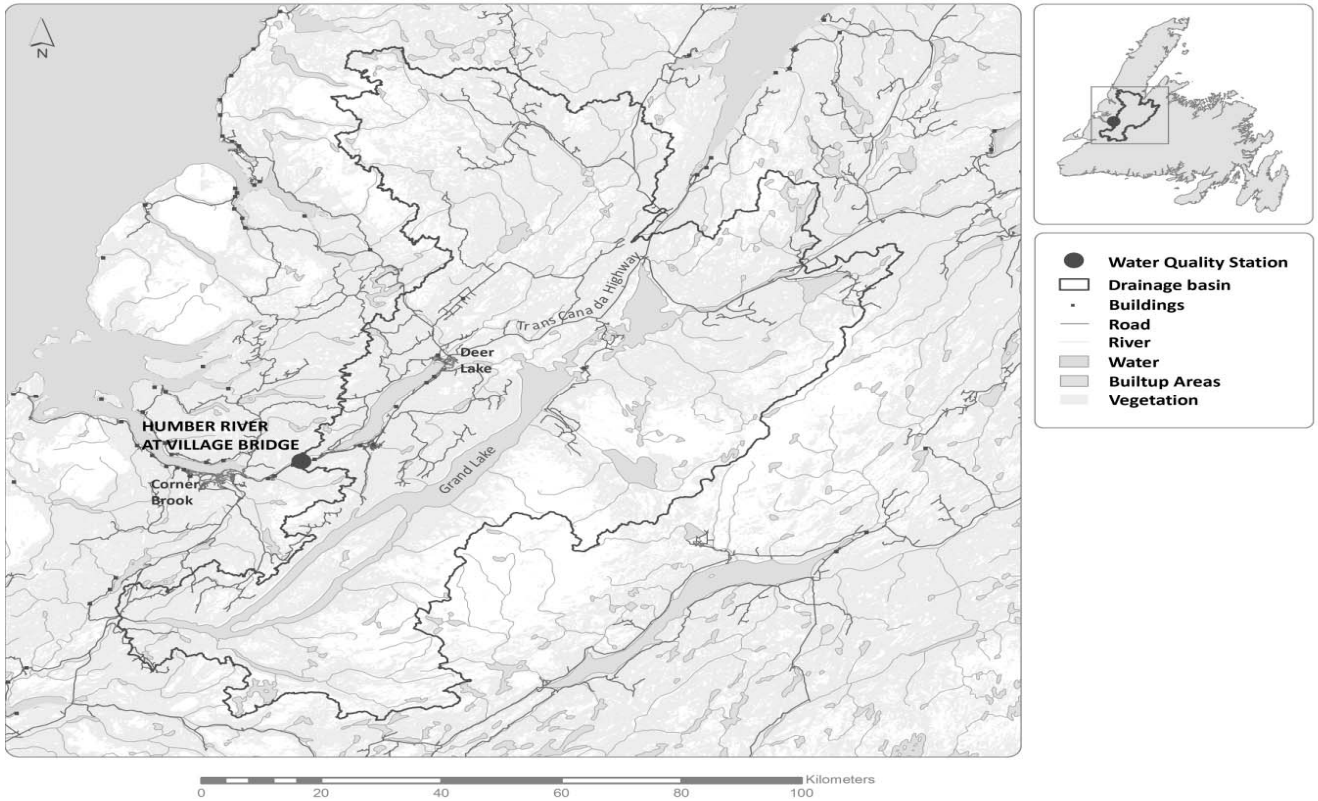
Sampling Site – Humber River



- Classified as non urban site.
- Small communities located within the watershed but the overall population density is sparse.

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Statistical Analysis

- Min, Max, Mean, Median, 25th and 75th Percentile
- Scatter plot (linearity test)
- Box Plot (Outlier test)
- Model Ionic Concentration Vs Conductivity using Ordinary Least Square.

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Statistical Analysis

Stations	Parameters	Size	Min	Max	Mean	Median	Q1	Q3
Leary's Brook @ Clinch Crescent	Conductivity	47	199.9	6262	799.8	483.1	348.9	696.1
	Sodium	47	29	1280	143.2	80	62.5	113
	Chloride	47	48	1770	220.1	131	99.5	194
	Calcium	47	4	47	11.4	9	7	12.5
	Sulphate	47	7	84	13.6	10	9	12.5
Waterford River @ Kilbride	Conductivity	46	256.7	2726	659	543	423.2	673.8
	Sodium	46	39	532	109	86.5	70.5	105.5
	Chloride	46	60	797	176	135.5	109	172.5
	Calcium	46	7	32.9	13.4	13	10	15.75
	Sulphate	46	9	31	13.4	12	11	14

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Statistical Analysis

Stations	Parameters	Size	Min	Max	Mean	Median	Q1	Q3
Rattling Brook Below Bridge	Conductivity	56	35.5	64.3	49.9	52.8	41.3	57.3
	Sodium	56	3	7.3	5.5	6	4.7	6
	Chloride	56	6	14	10.3	11	8.8	12
	Calcium	56	1	5	2.8	3	2	3
	Sulphate	56	1	5	3.3	3	3	4
Humber River @ Humber Village Bridge	Conductivity	27	30.1	43	38.5	38.6	37	40
	Sodium	27	2	3.4	2.4	2	2	3
	Chloride	27	3	5.6	4.1	4	4	4.3
	Calcium	27	3	5	4.2	4	4	4.5
	Sulphate	27	1	4	2	2	1	3

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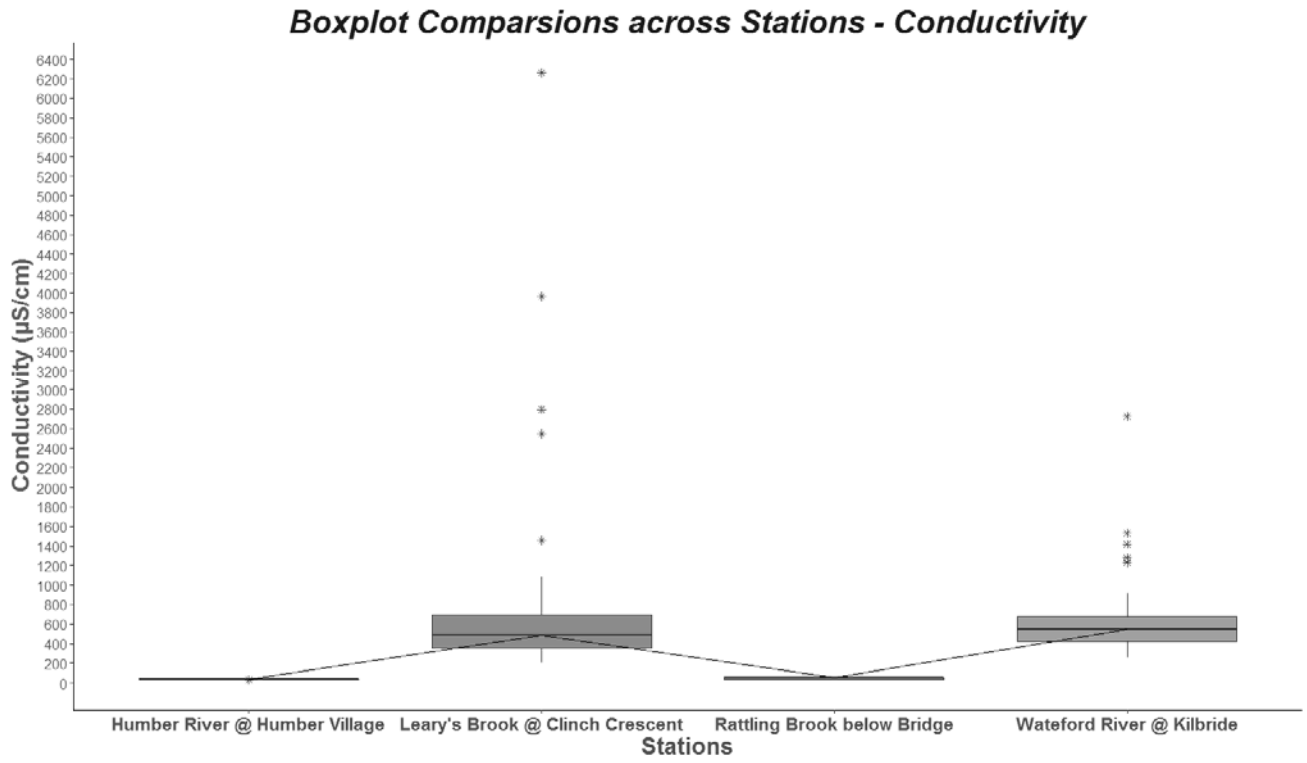
Parameter Comparisons Across Locations



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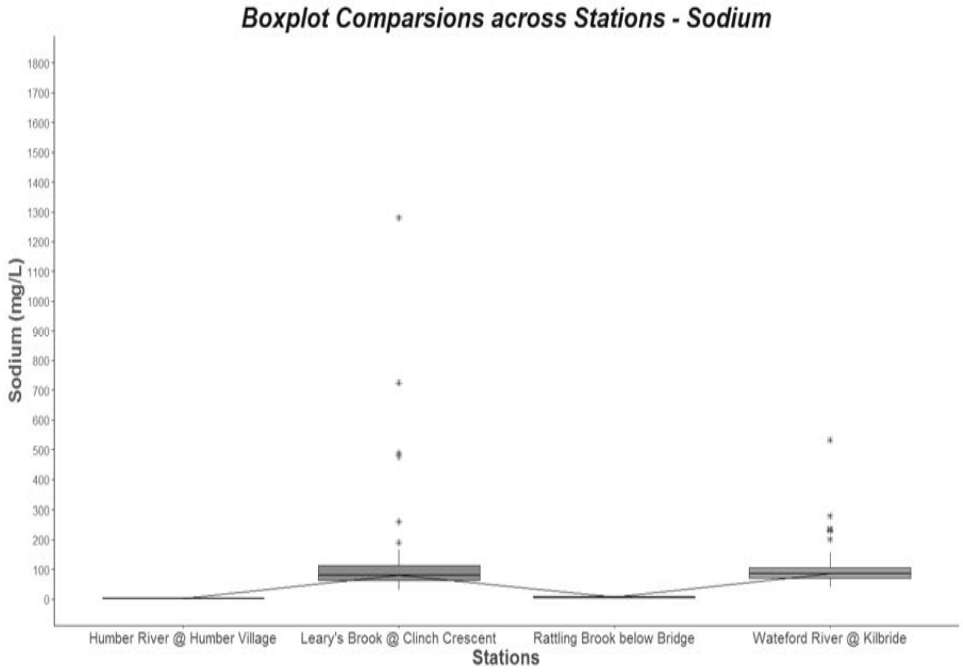

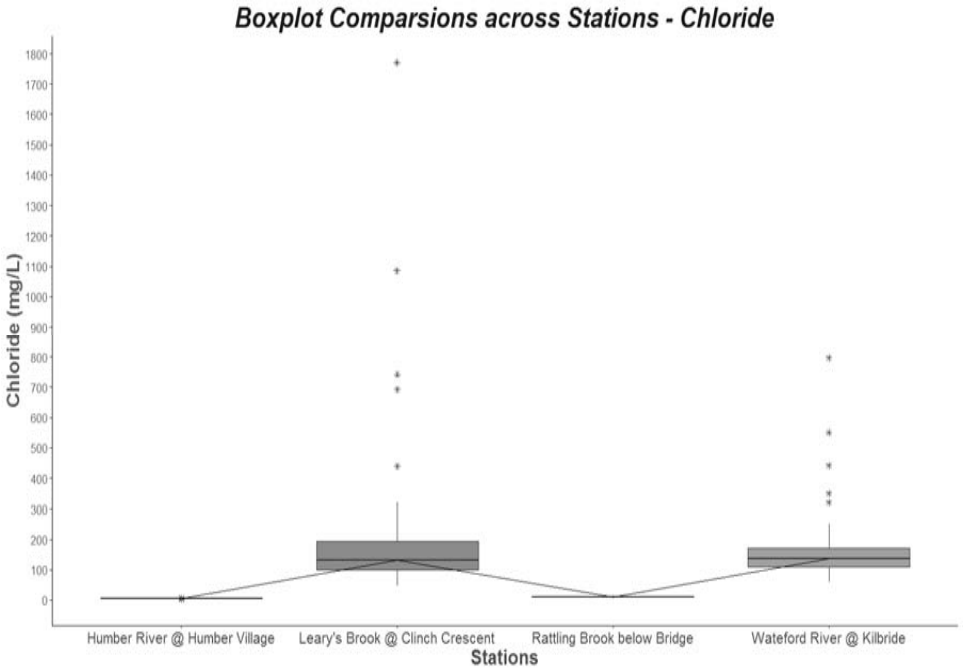

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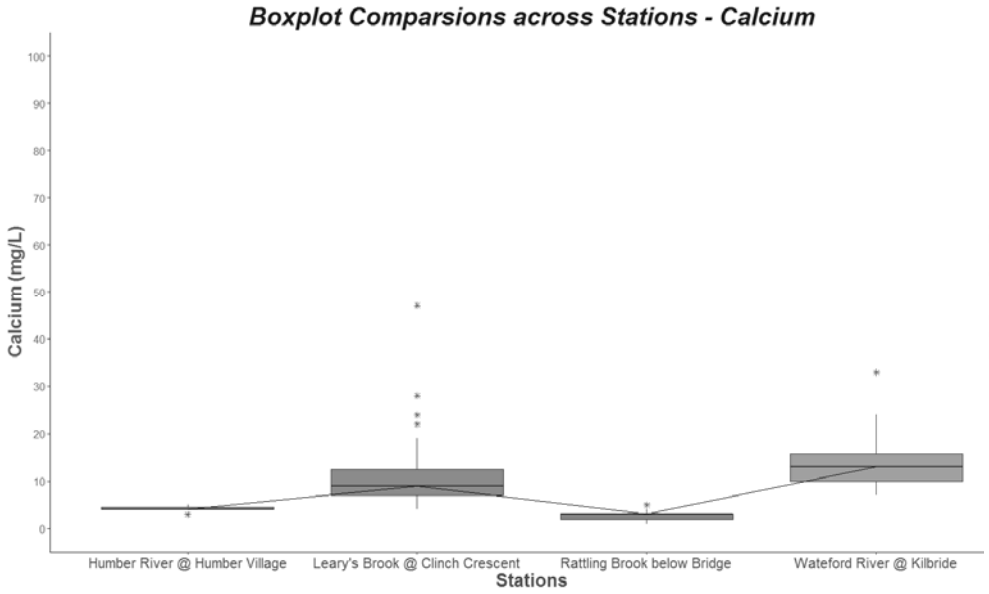

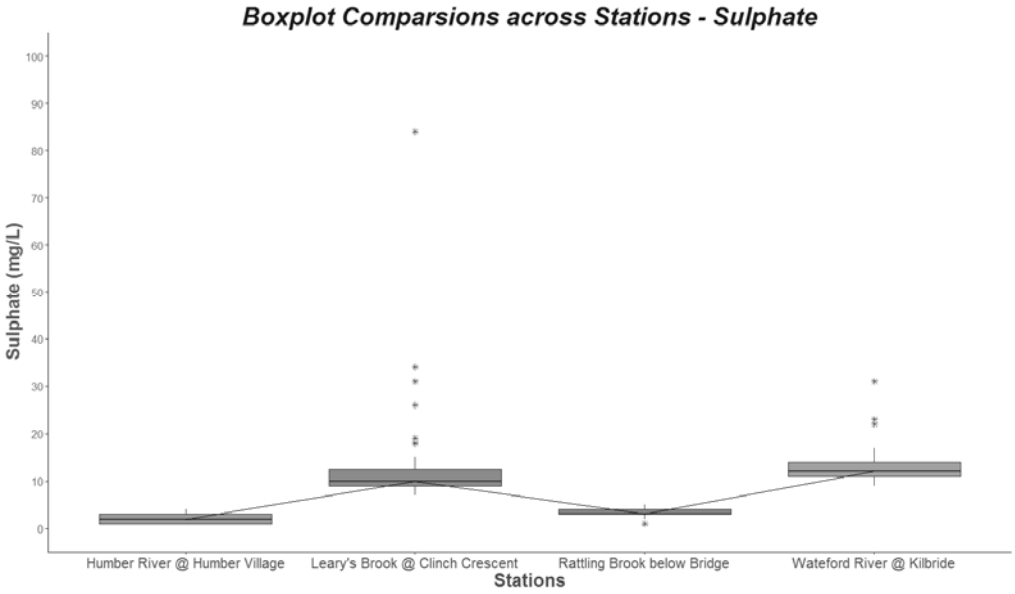

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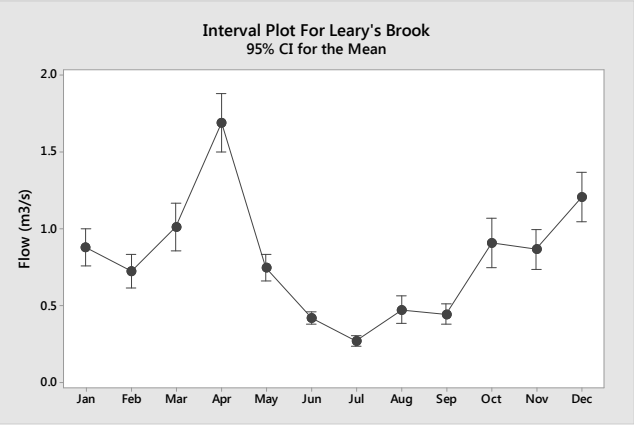
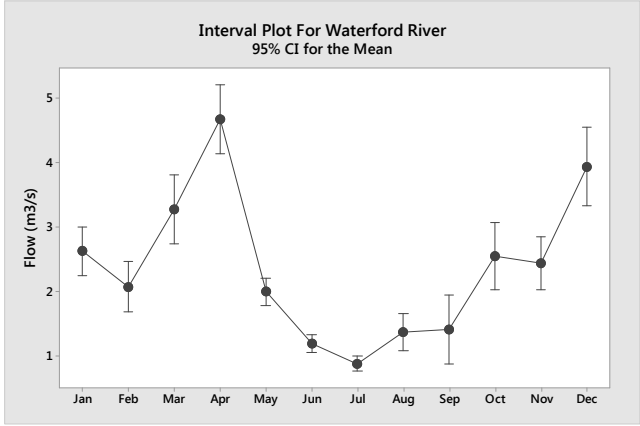
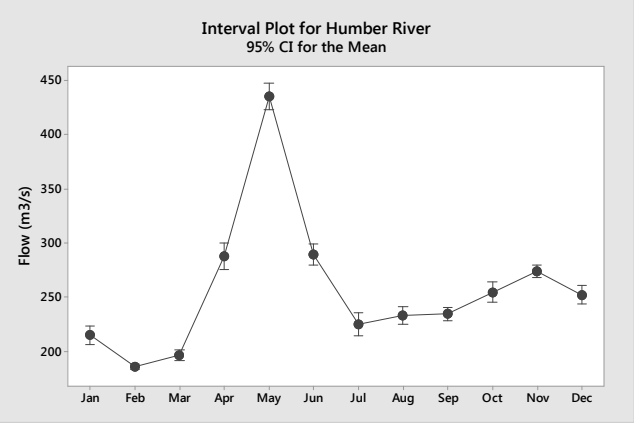
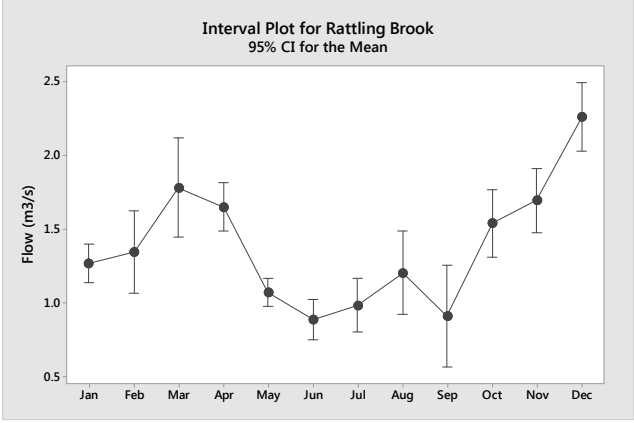
Sampling Location Flow Profiles









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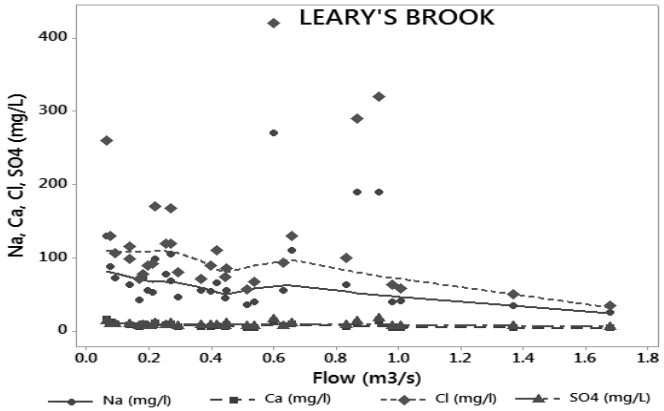
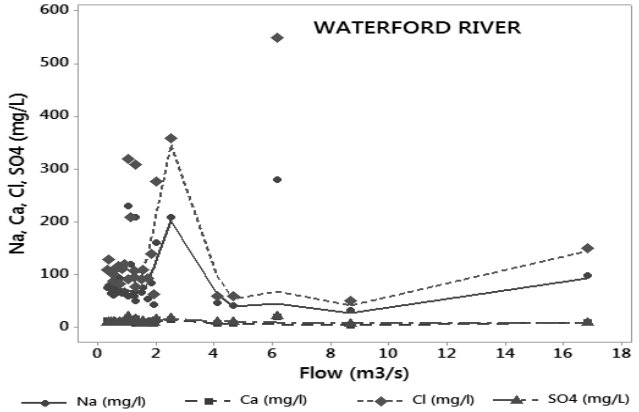
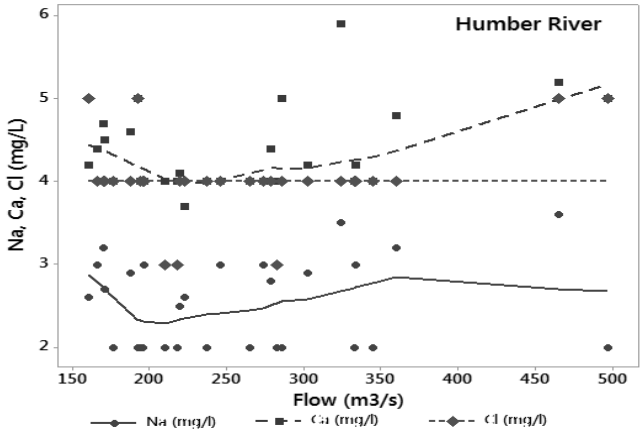
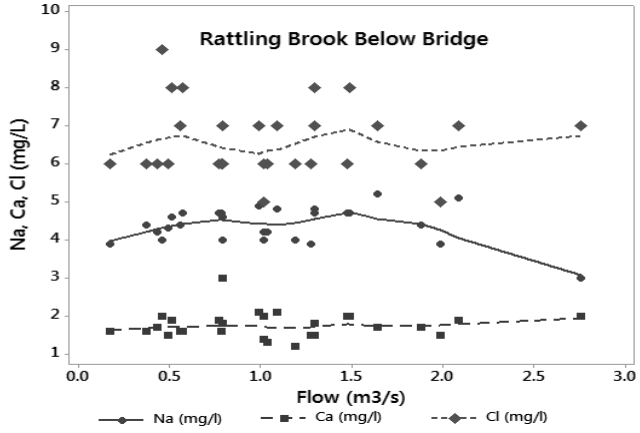
Effect of Flow on Parameter Concentration









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Effect of Flow on Parameter Concentration

Variable	Regression Model	R-square	P-Value	Regression Model	R-square	P-Value
LEARY'S BROOK				**WATERFORD RIVER**		
Sodium	Na = 79.12 – 2.72 × Flow	0%	0.915	Na = 88.82 + 1.643 × Flow	0%	0.644
Calcium	Ca = 9.78 - 3.11 × Flow	13.3%	0.025	Ca = 11.49 - 0.1744 × Flow	0%	0.367
Chloride	Cl = 128.8 – 12.05 × Flow	0%	0.201	Cl = 137.5 + 4.056 × Flow	0%	0.523
Sulphate	SO4 = 10.07 - 0.54 × Flow	0%	0.672	SO4 = 12.11 - 0.047 × Flow	0%	0.816
HUMBER RIVER				**RATTLING BROOK**		
Sodium	Na = 2.29 + 0.0009 × Flow	0%	0.443	Na = 4.492 – 0.0913 × Flow	0%	0.548
Calcium	Ca = 3.734 + 0.0023 × Flow	0%	0.413	Ca = 1.737 + .0283 × Flow	0%	0.802
Chloride	Cl = 3.598 + 0.0016 × Flow	5%	0.128	Cl = 6.722 – 0.106 × Flow	0%	0.735

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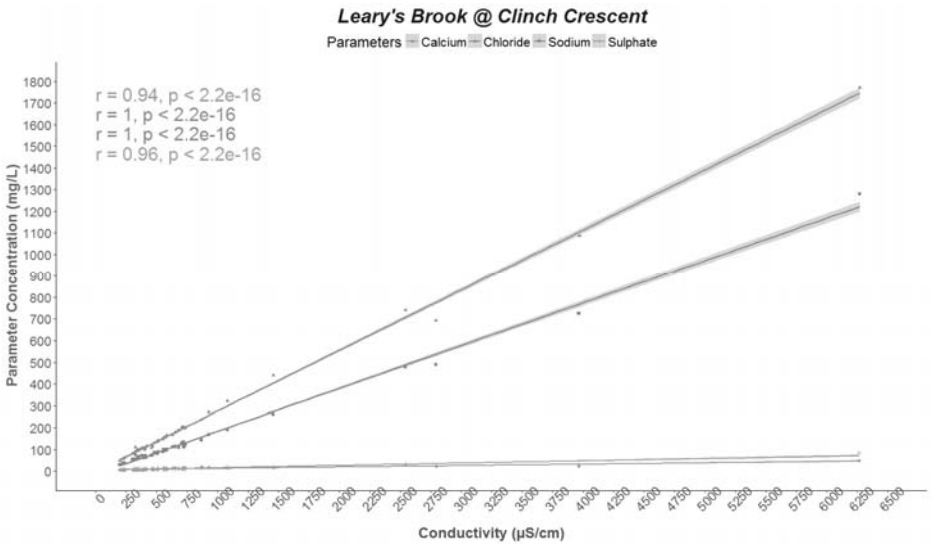
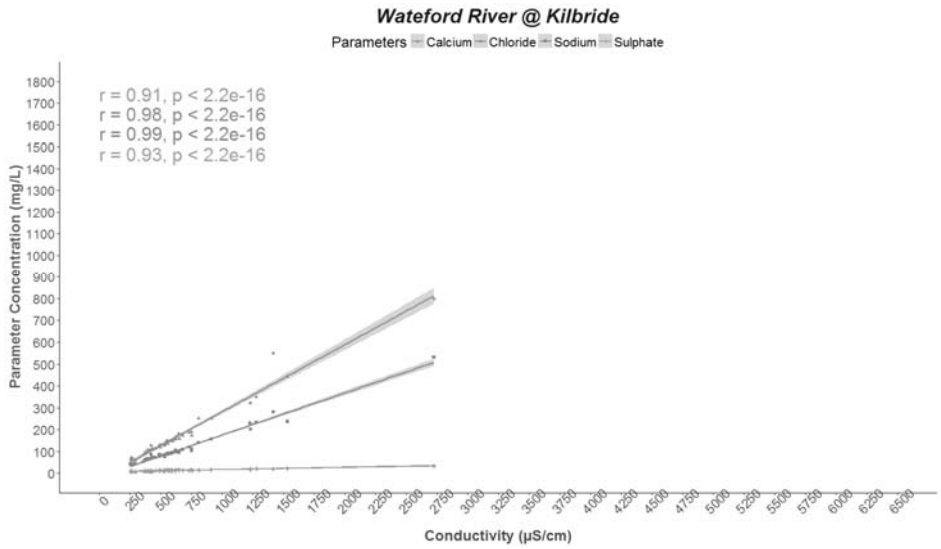
Effect of Conductivity on Parameter Concentration





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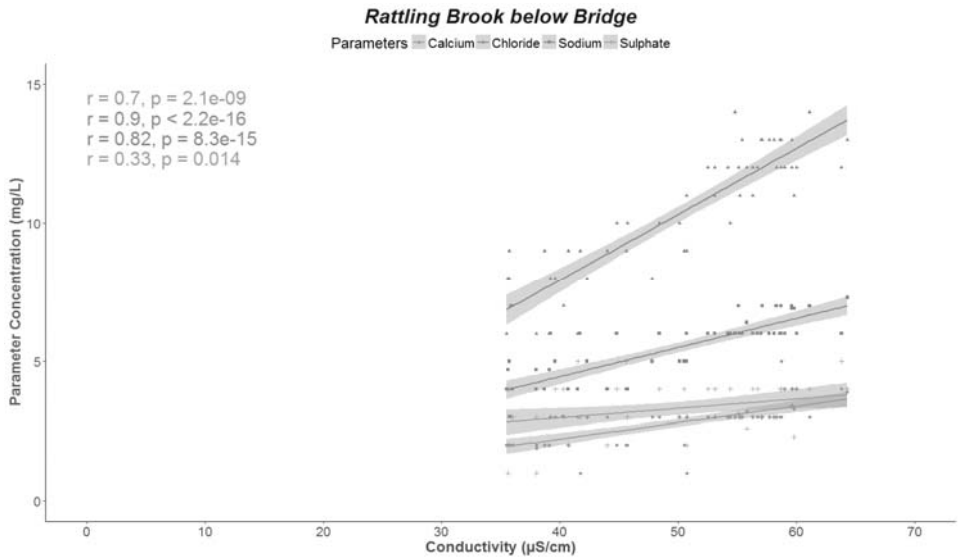
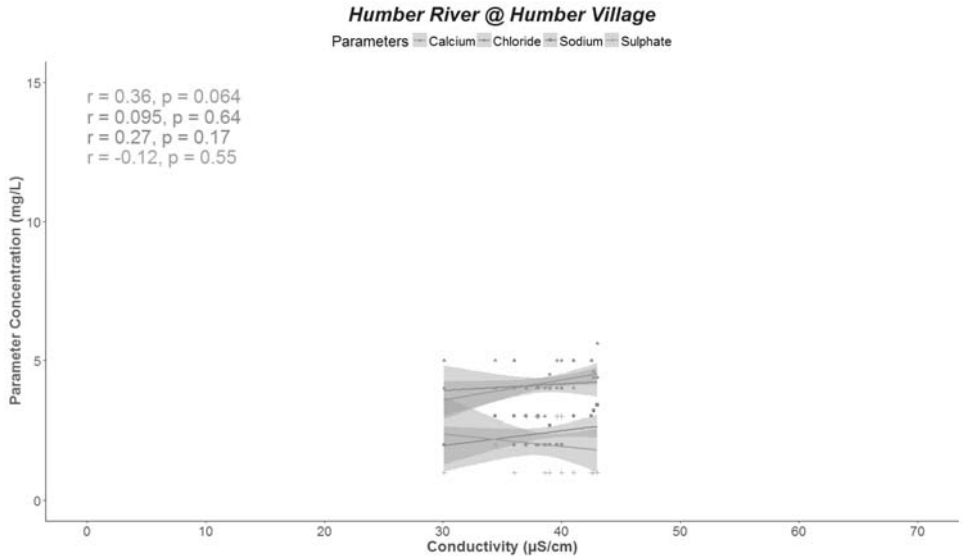
Effect of Conductivity on Parameter Concentration





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Effect of Conductivity on Parameter Concentration

Stations	Parameters	Regression Model	R- square [a]	P-Value [b]	Bias Corr. [c]
Leary's Brook @ Clinch Crescent	Sodium	log(Na) = - 0.8909 + 1.045 × log(Cond)	0.99	<0.01	1.0027
	Chloride	log(Cl) = - 0.6339 + 1.0244 × log(Cond)	0.99	<0.01	1.0017
	Calcium	log(Ca) = - 0.7562 + 0.639 × log(Cond)	0.89	<0.01	1.0115
	Sulphate	log(SO4) = - 0.5362 + 0.5857 × log(Cond)	0.91	<0.01	1.0094
Waterford River @ Kilbride	Sodium	log(Na) = - 0.9876 + 1.07 × log(Cond)	0.978	<0.01	1.0029
	Chloride	log(Cl) = - 0.8706 + 1.102 × log(Cond)	0.976	<0.01	1.0017
	Calcium	log(Ca) = - 0.6766 + 0.644 × log(Cond)	0.807	<0.01	1.0109
	Sulphate	log(SO4) = - 0.2268 + 0.4848 × log(Cond)	0.77	<0.01	1.0077

[a]R-square (adjusted): the proportion of variation in the response data that is explained by the predictor;
[b]P-value: statistical significance between the association between the response and predictor;
[c]Bias Correction: Bias Correction performed according to (Duan, 1983).

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Effect of Conductivity on Parameter Concentration

Stations	Parameters	Regression Model	R- square [a]	P-Value [b]	Bias Corr. [c]
Rattling Brook Below Bridge	Sodium	log(Na) = - 0.93748 + 1.1833 × log(Cond)	0.639	<0.01	1.0089
	Chloride	log(Cl) = - 1.0007 + 1.11 × log(Cond)	0.778	<0.01	1.0065
	Calcium	log(Ca) = - 1.3081 + 1.0276 × log(Cond)	0.394	<0.01	1.0231
	Sulphate	log(SO4) = - 0.6554 + 0.6829 × log(Cond)	0.13	<0.01	1.0437
Humber River @ Humber Village	Sodium	log(Na) = - 0.7416 + 0.704 × log(Cond)	0.02	0.218	1.0205
	Chloride	log(Cl) = 0.3876 + 0.1398 × log(Cond)	-0.036	0.759	1.0129
	Calcium	log(Ca) = - 0.3131 + 0.5883 × log(Cond)	0.07	0.098	1.0073
	Sulphate	log(SO4) = 1.5825 + -0.8448 × log(Cond)	-0.026	0.56	1.139

[a]R-square: the proportion of variation in the response data that is explained by the predictor;
[b]P-value: statistical significance between the association between the response and predictor;
[c]Bias Correction: Bias Correction performed according to (Duan, 1983).

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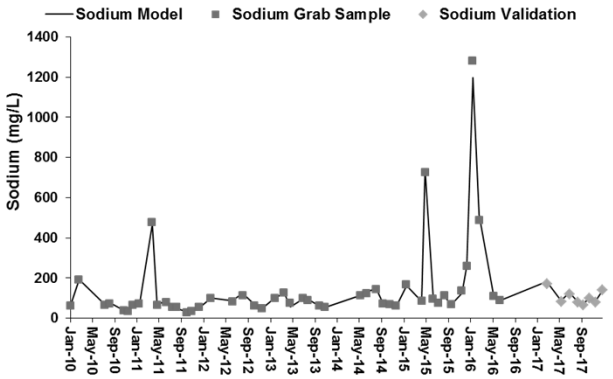
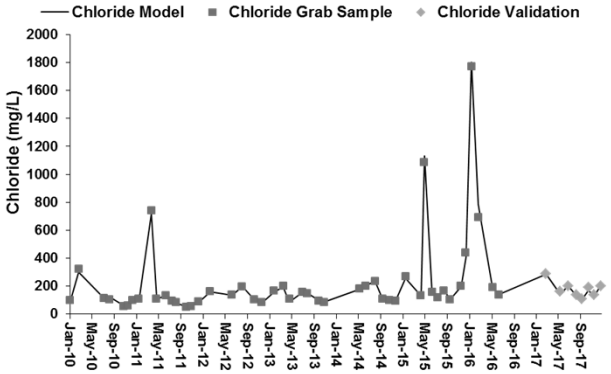
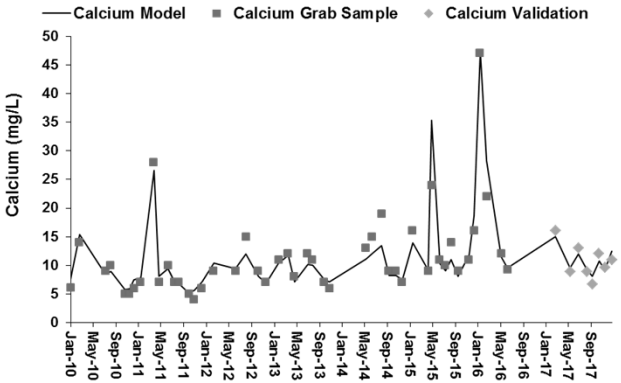
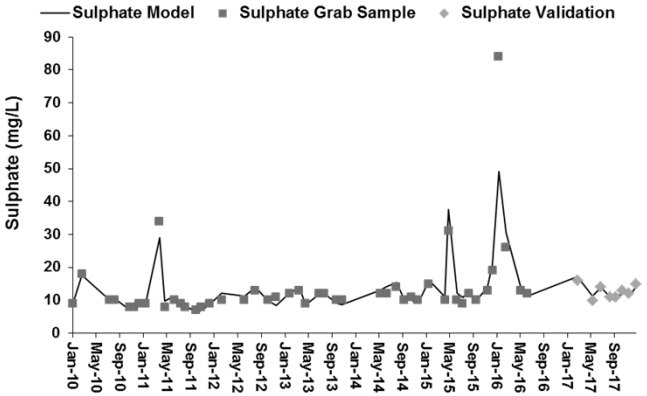
Model Validation – Leary's Brook









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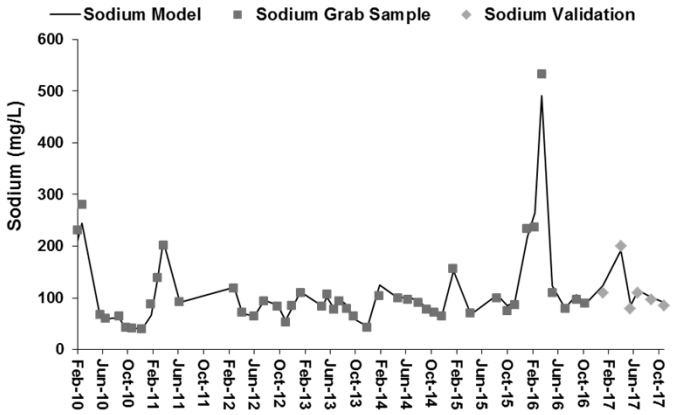
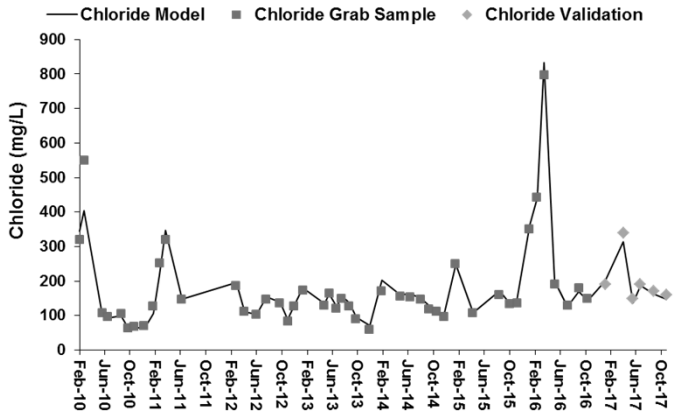
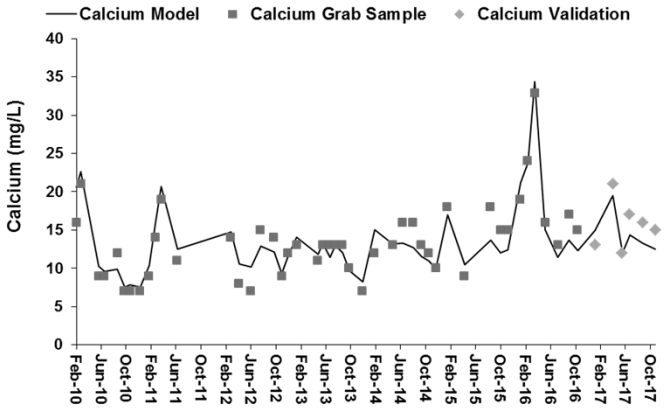
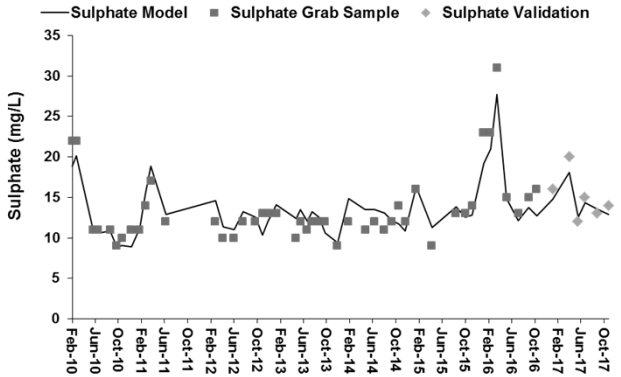
Model Validation – Waterford River









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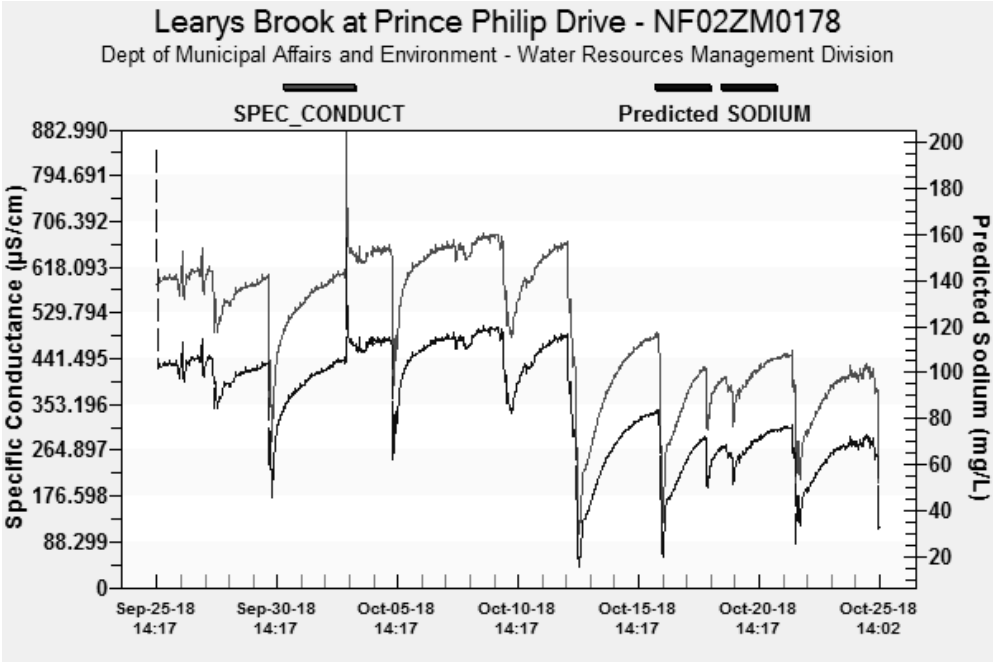
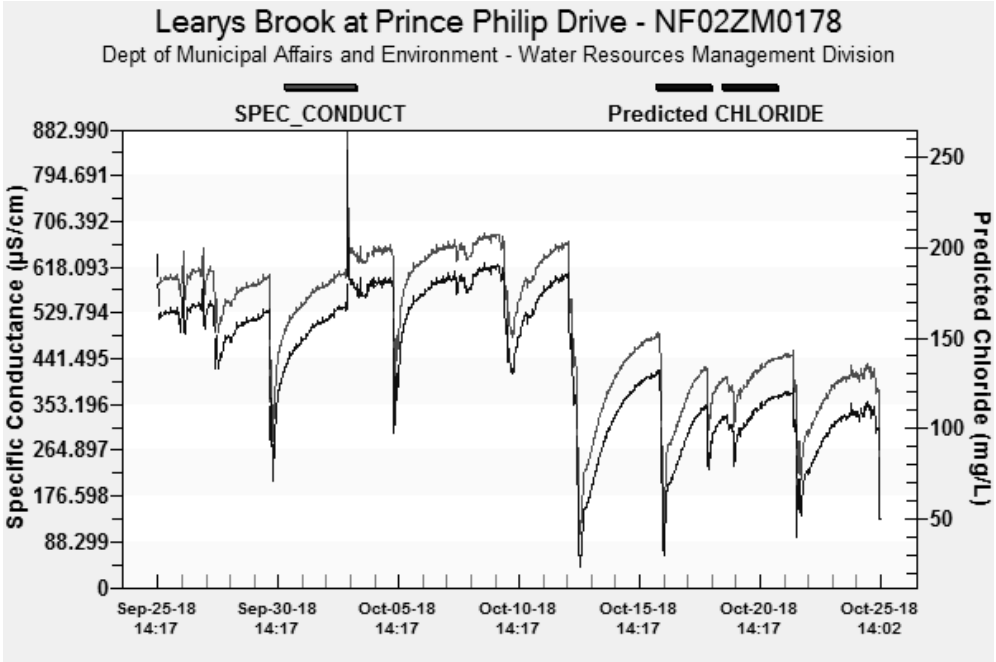
Model Application – Leary's Brook





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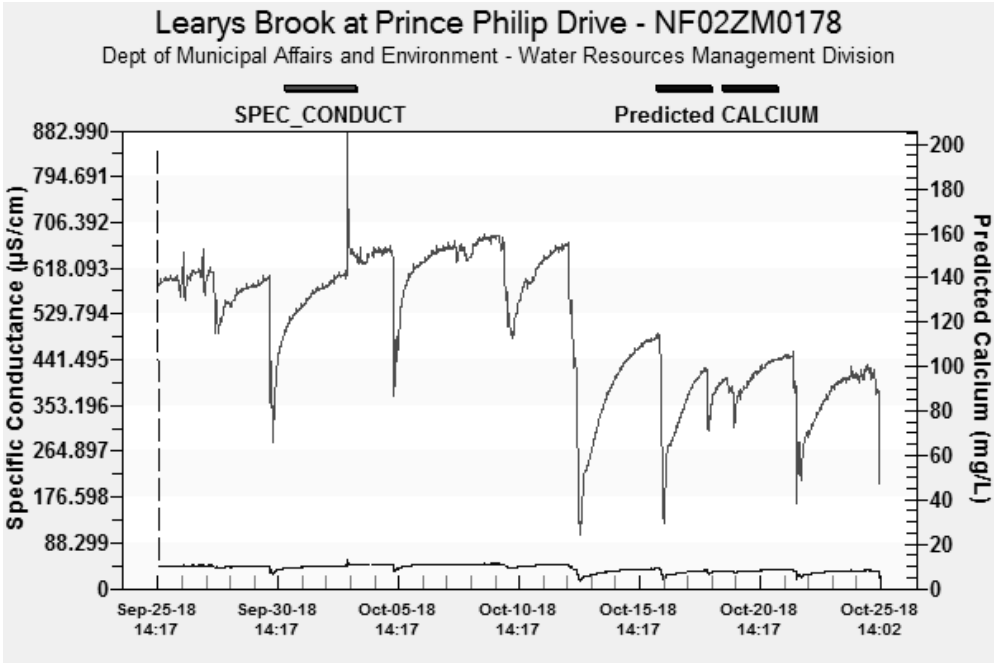
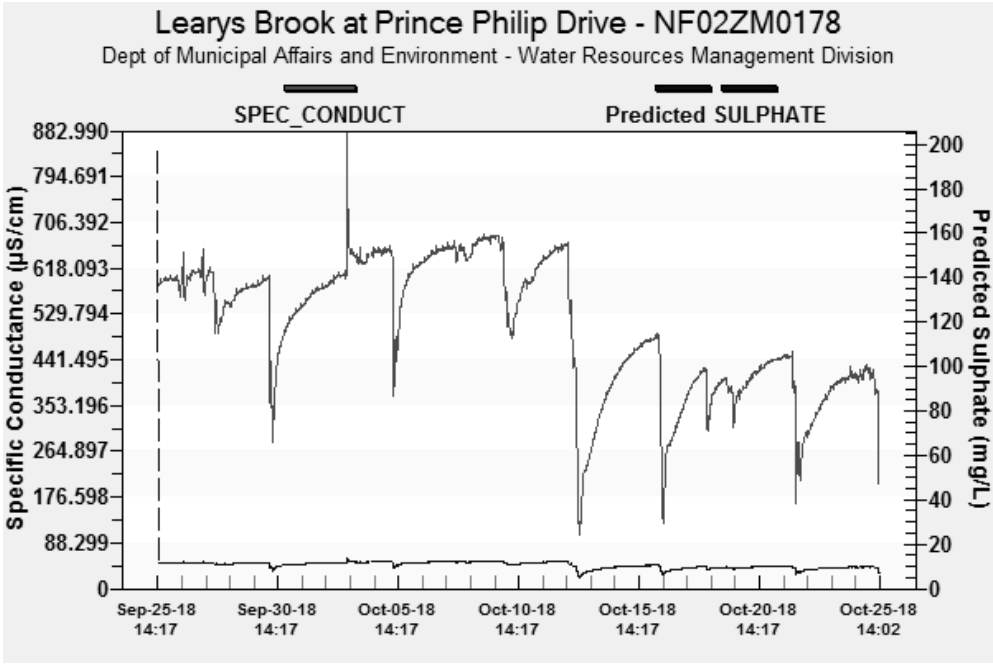
Model Application – Leary's Brook





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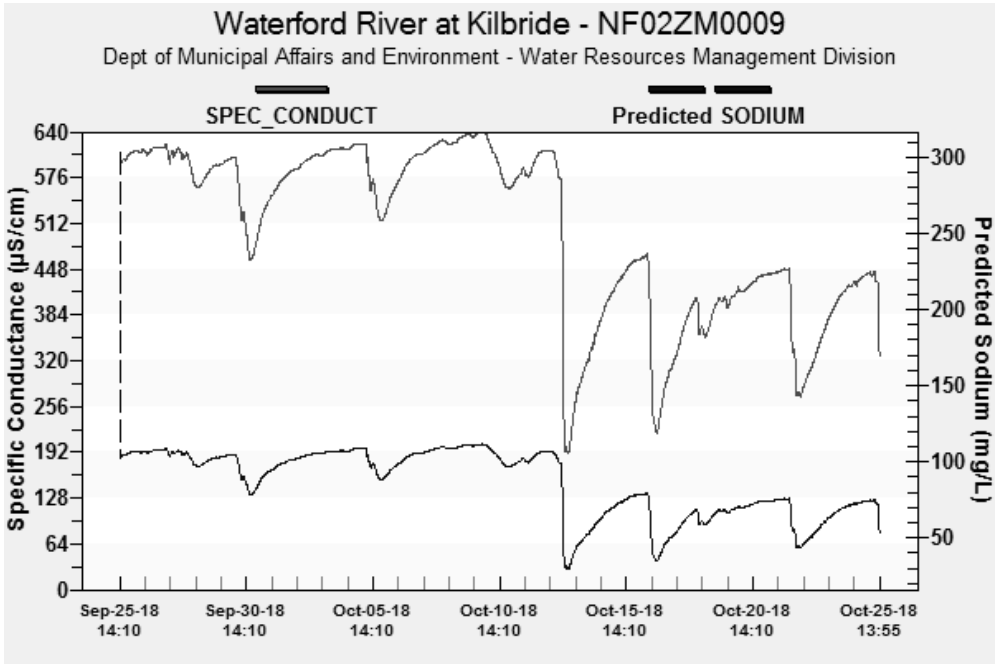
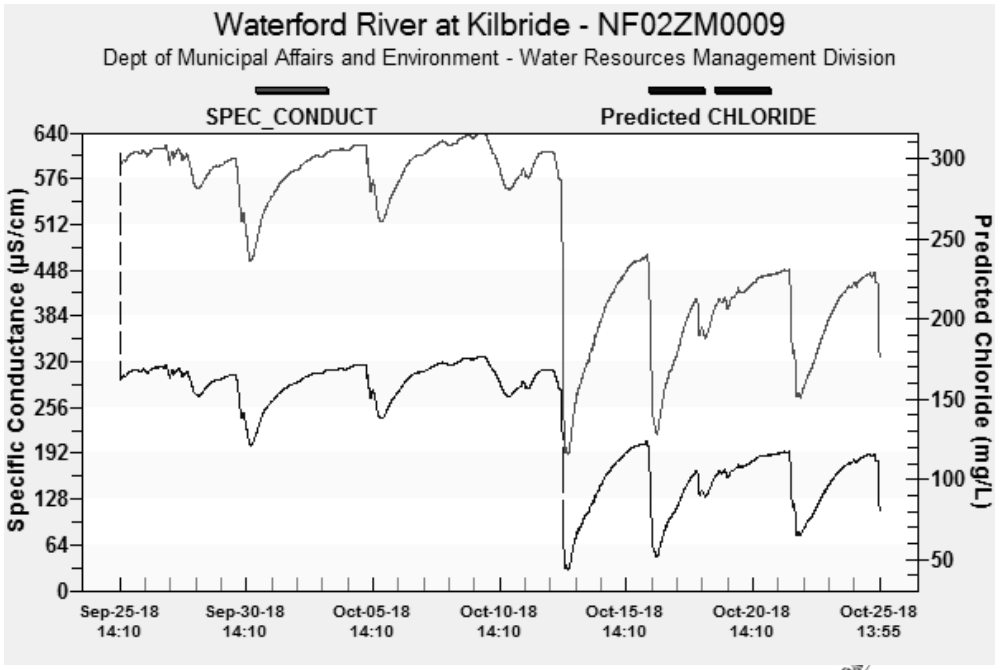
Model Application – Waterford River





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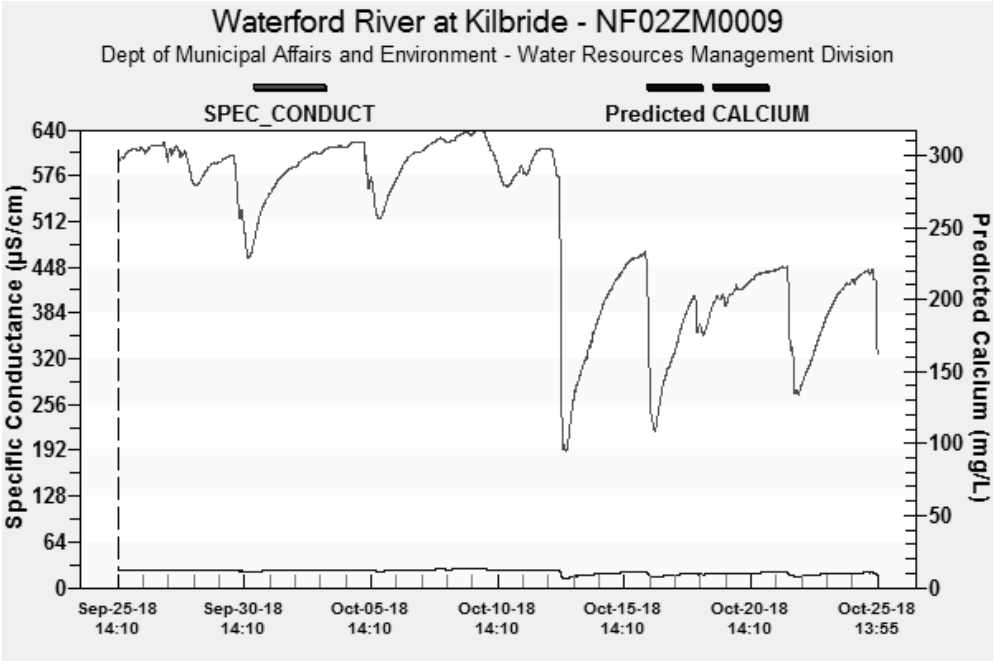
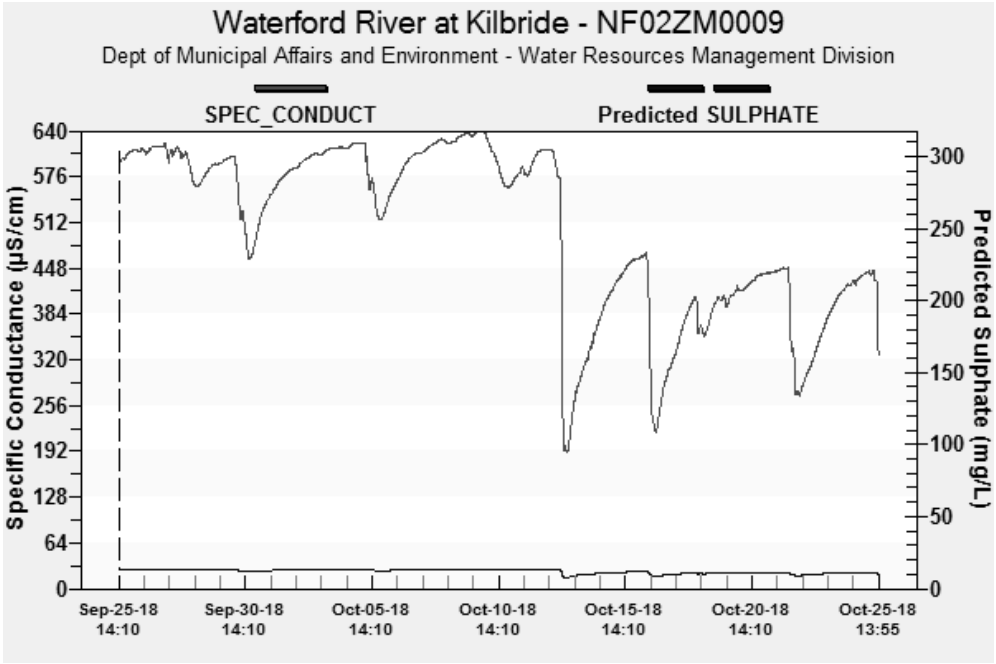
Model Application – Waterford River





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Conclusion

- Urban stations showed greater variability in parameter concentration as a result of anthropogenic influence.
- Ionic concentration of selected parameters can be predicted in real time using real time conductivity as a predictor at certain sites.
- The relationship between the predictor and the estimated parameters were stronger in urban sites in comparison to non urban sites.
- The models would greatly aid in estimation of ionic concentration parameters saving time and resources required in grab sampling.

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Path Forward

- Potential parameters of interest such as total suspended solids can be estimated in emerging real time sites using real time parameters such as turbidity as predictors by applying the methodological analysis applied in this study.
- Real time identification of impact of water quality due to the application of road salts.
- Real Time Detection of Salt water intrusion.

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