

SITE-SPECIFIC WATER QUALITY ANALYSIS OF SEDIMENTS AND
SURFACE WATERS IN FREDERICTON

By

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ABSTRACT

Water is the source of life, covering 71% of the earth's surface. Water is an important part of the external environment, involving life, production and other aspects. Because of water pollution, available water resources become contaminated. This report provides information on year and seasonal changes in water-affecting variables at 11 locations within the Fredericton area, New Brunswick, from river water to small streams, and upslope basin areas and water-affecting inputs, the variables refer to pH, dissolved oxygen (DO), electrical conductivity (EC) in stream and river water and sediments. Through box plotting and regression analysis, it was found that the sediment and water quality parameters varied by location, year, and season. In general, sediment $DO < \text{water } DO$, sediment $pH < \text{water } pH$, and sediment $EC \approx \text{water } EC$. Locations downstream from a road salt storage and road application had much higher sediment EC values than elsewhere. Dissolved DO was particularly low in sediments during spring, summer and fall, and highly variable in water, likely due to continuing changes in water flow rates, and the presence of photosynthesizing and respiring plants in water. Water and sediment pH values were on average lowest in winter. Possible reasons for these variations are discussed by location, season and year in terms of general expectations.

Key words: water, sediment, dissolved oxygen, pH, electrical conductivity

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1.0 INTRODUCTION

Water is necessary for all living things. It plays a key role in the natural process, and many physical and chemical reactions cannot proceed without water (Fang, et al .2005). Seventy percent of the Earth's surface is water, of which 2.5% is freshwater, yet only 0.3% is usable. Due to the development of science and technology and population growth, the world's demand for fresh water is increasing. Canada is generally a freshwater-rich country. The water in Canada's rivers amounts to about 7% of the world's renewable water supply (Canada, 2015). Water quality determines the living environment of aquatic organisms, as well as the surrounding ecosystem.

On land, water flows through watersheds as determined by topography and as affected by water shed composition in terms of natural and build-up surfaces. In detail, water flows through watersheds is further affected by extent and type of vegetation, soils, bedrock formations, wetland, open-water bodies, evapotranspiration and sources of primary and secondary pollutants (Parkes, 2017).

Water characteristics [dissolved oxygen (DO), pH, electrical conductivity (EC), etc.] are affected by the regional and local climate conditions (precipitation, air temperature, and season), topography, geology, soil conditions, vegetation and other factors. For example, surface runoff from fields contains more sediments and nutrients, while surface runoff from urban areas contain higher levels of heavy metals and hydrocarbons (Abbaspour et al., 2007).

This report summarizes water and sediment DO, pH and EC variations at 11 locations within the Fredericton area in New Brunswick. The objective is to determine how these data vary by year (2014-2017), season (winter, spring, summer fall), and sampling locations.

Dissolved oxygen (DO) refers to the amount of gaseous oxygen dissolved in water. Oxygen enters water by direct absorption from the atmosphere or as a by-product of aquatic plant photosynthesis. The range of dissolved oxygen in a stream varies is 0 mg/l to 18 mg/l (Oram, 2017). Dissolved oxygen levels below 5.0 mg / L can cause stress on obligatory aerobic organisms that live in water. Levels below 1-2 mg / L cause fish to die (Ibanez and Hernández, 2010; "What is Dissolved Oxygen?" 2017). Adding wastes with biologically active organic matter tends to water drastically lowers water and sediment DO.

pH is defined as the acidity level of water. It refers to the $[H^+]$ concentration in water, i.e., $pH = -\log_{10} [H^+]$ The higher the concentration of hydrogen ions, the lower the pH, and the water is acidity ($pH < 7$), the water is alkaline when $pH > 7$. Most aquatic animals enjoy a range of 6.5 to 9.0. High or low levels lead to the death of aquatic life. In addition, pH affects the toxicity and solubility of chemicals and heavy metals in water. Therefore, pH is used as one of the common indicators to monitor water quality.

In natural processes photosynthesis, respiration and decomposition affect water and sediment pH due to their effect on CO_2 . The pH value of uncontaminated rainwater is about 5.6. Human activities can have major influence on water and sediment pH, through local point source pollution (e.g., coal mining produces acidic run-off and groundwater seepage, Osmond et al.,

1995), and by increasing the intensity of acid rain. Due to industrial development, many nitrogen oxides, sulfur oxides and other substances enter the air and react with water to produce acid-forming substances in rain and snow. These substances are usually derived from fossil fuel combustion, mining and metal smelting. When acidified rain and snow falls on a poorly buffered area, soil and water pH decrease (Lenntech, 2013). Vegetation adds to water and sediment acidity through the build-up of organic matter consisting of fluid and humid acids (Rousk et al., 2009). Carbonate material and limestone also increase water, sediment and soil pH value through acid buffering.

EC is an indicator of water's ability to pass current. Conductive ions in water come from dissolved salts and inorganic materials. The conductivity of water increases with increasing ions present ("The Effect of Solution Concentration on Conductivity", 2018). The unit of conductivity is usually $\mu\text{Siemens} / \text{cm}$. In addition to be the basis for most salinities and total dissolved solids calculations, conductivity is an early indicator of changes in water systems. Temperature can affect electrical conductivity. For every 1°C increases in water temperature, electrical conductivity will increase by 2-4% (Hayashi, 2003). Geology is also one of the factors that influence the conductivity. The geological features determine the chemical properties of the soil in the basin, and indirectly affect the chemical properties of the surrounding waters. For example, when carbonate minerals (such as limestone) are present in basins, stream and ground water is mineral rich and therefore highly electrically conductive (Gupta and Paul 2010). In contrast, snowmelt running over and seeping through granite formations has low levels of conductivity. Water in

arid regions can have high conductivity because of elevated levels of evaporation.

1.1 Sampling locations

The map in **Fig.1** shows the sampling locations at select locations within the Fredericton area. By upslope basin area, these locations can be sequenced as follows:

Saint John River (1) >> Nashwaak River (2) >> Silver Maple (3) >> Odell Park (4) > Brookside Drive (5) > Killarney Lake (6) > Forest Hill (7) > Hyla Park (8) < UNB Woodlot (Corbett Brook, 9) > Salt Depot (10) > Outflow (11).

Portrayed in Fig. 2 are 2014-2017 daily variations in air and soil temperature, precipitation (rain, snow), soil moisture levels, stream discharge rates, on-the-ground snow accumulations, and depth of soil frost, for the Fredericton area, based on Fredericton airport weather data, and using the Forest Hydrology model (ForHyM) to simulate daily soil temperature, moisture, and stream discharge as well as snow and frost depth.

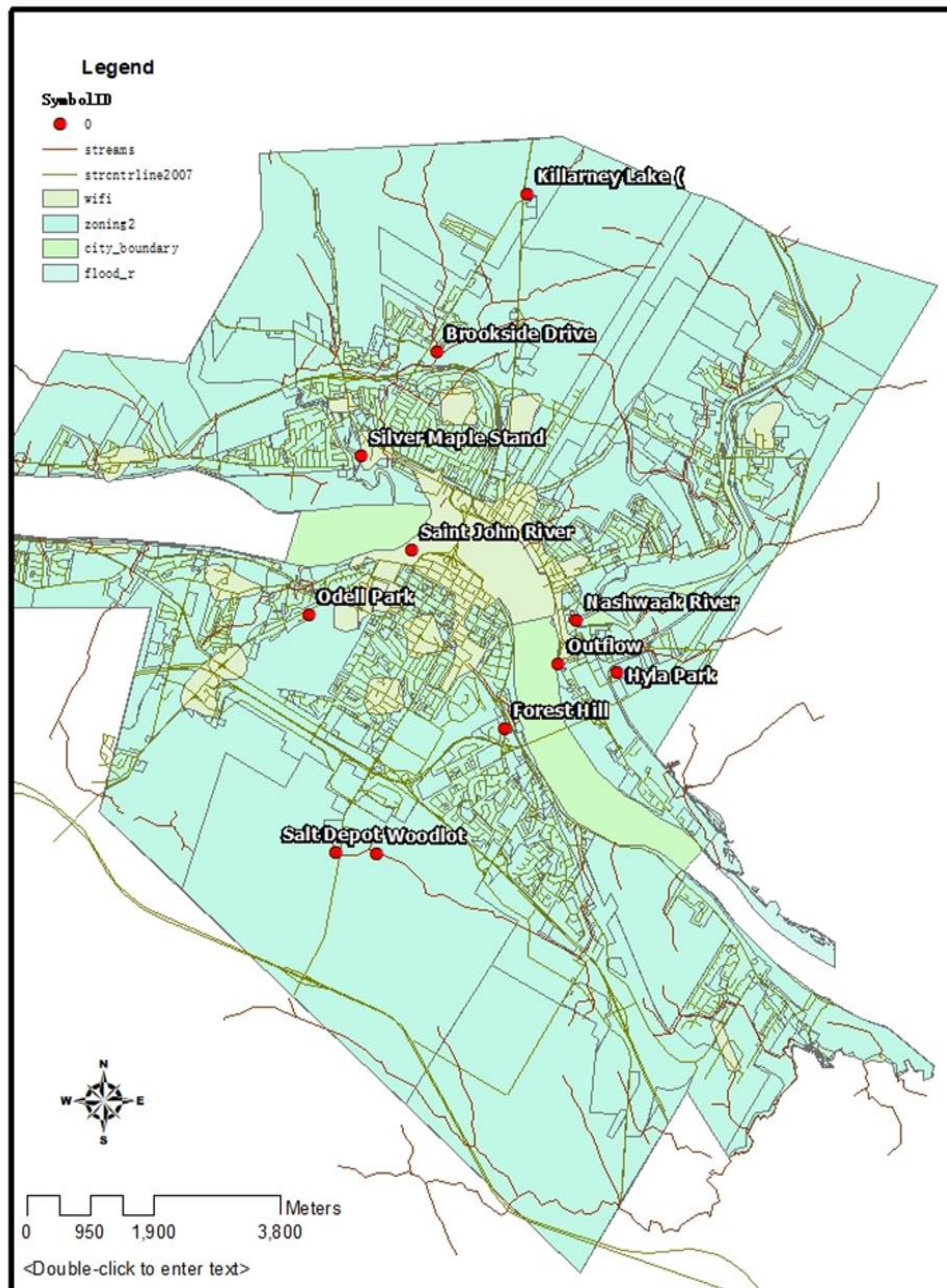


Figure 1. Location of sample sites(from north to south): 1. Killarney Lake 2. Brookside Drive 3. Silver Maple Stand 4. Saint John River 5. Odell Park 6. Nashwaak river 7. Outflow 8. Hyla park 9. Forest Hill 10. Salt Depot 11. UNB Woodlot.

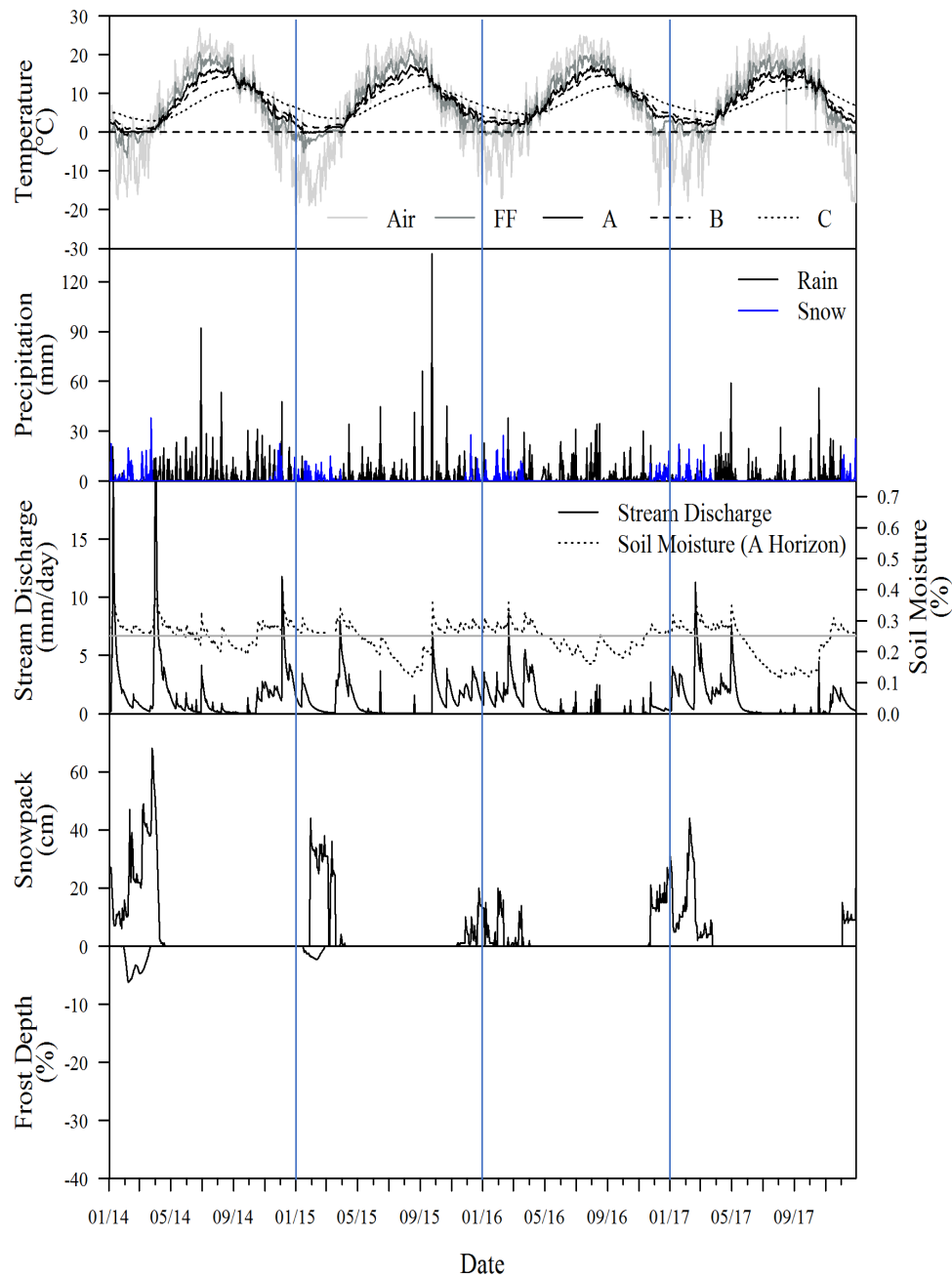


Figure 2. Hydrological conditions for the Fredericton area, 2014-2017.

Saint John River (66°39'6.445"W 45°57'59.171"N). The sampling location of Saint John River is a riverbank within Fredericton, southside. The Saint John River basin is mostly forested, interrupted by floodplains, towns, settlements, and headwater ponds all the way towards Edmunston in

northwestern New Brunswick. The headwaters are in Maine, and in part in southern Quebec as well. Riverbanks vary in texture from fine sandy to silty.

Nashwaak River (66°37'12.048"W 45°57'24.928"N). This site flows 110 km from the Upper Nashwaak Lake to the Saint John River in Fredericton. The Nashwaak River Watershed is predominantly forested (92.5%), with the remainder referring to residential areas and agriculture. Peak water levels and flow occur in April-May. Mean daily discharge has increased steadily from the 1960s to the 2010s, and the river has experienced more extreme flows over the last decade compared to historically.

Silver Maple Stand (66°39'42.304"W 45°58'44.962"N). Silver Maple Stand is located on the northside of Fredericton, NB. The site is representative of an alluvial floodplain along the lower St. John River at the confluence with the Nashwaaksis stream. The sampling location is one of the floodplain permeating flow channels. The vegetation at the site is dominated by silver maples. The immediate upslope area is covered by residential and commercial developments, while the broad floodplain along the Nashwaaksis streams varies from shrubby wetlands to taller forest vegetation.

Brookside Drive (66°38'49.552"W 45°59'35.358"N). This site is located on the northside of the city. The sampling location refers to a culvert that passes under Brookside Drive. The streambed consists mostly of silt and sediment. The upslope area is subject to expanding residential developments into otherwise mostly forest areas.

Killarney Lake (66°37'46.824"W 46°0'51.668"N). Killarney Lake Park is situated on the Northside of the city 8 km from downtown Fredericton. The Killarney Lake basin supports mixed Acadian forest growth, with birch, maple, and poplar species being dominant. The sampling location is in a low flow section at the outlet of Killarney Lake.

Odell Park (66°40'17.797"W 45°57'27.181"N). The stream and sediment location are located within the foot slope area. The upslope basin rising in elevation of more than 100 m is mostly forested and extends beyond the park across two major high-way roads, thus receiving ditch drainage from these roads and from a lagoon above the road adjacent to the densely forested park.

Forest Hill (66°38'1.764"W 45°56'32.383"N). This site is located downslope from a steep hill east of the UNB campus. The upslope area includes residences, a forest portion, and drains ditch water from the former Trans-Canada Highway.

Hyla Park (66°36'43.421"W 45°56'59.546"N). Hyla Park is located just off Greenwood Drive on Fredericton's Southside. The area of Hyla Park's was used as a quarry, with a metal scrap yard located next to it. Currently, this area is reclaimed, features wetlands and open water pools and an alluvial forest habitat, and provides recreational and cultural opportunities for Fredericton residents

Woodlot (66°39'30.316"W 45°55'31.653"N). The UNB Woodlot is located on the south side in the City of Fredericton on the east and west side of Regent Street towards New Maryland. The Woodlot consists of a 3800-acre forest wetland (NB Media Co-op, 2017). The Woodlot is part of the Corbett Brook

Watershed, permeated by forested, commercial, industrial and residential areas. The Corbett Brook Watershed is 65% forested with a mixture of hardwood and softwood trees species. Also present are bogs, swamps, and beaver meadows. There are about 108 hectares of impervious surfaces with buildings and pavements due to increasing developments.

Salt Depot (66°39'58.877"W 45°55'32.11"N). Salt depot is located near the UNB Woodlot at the junction of an urban and forested area. Arp (2001) reported that the chloride concentration in the seepage water from the salt depot reached 10,000mg/L.

Outflow (66°37'24.145"W 45°57'3.49"N). This location refers to a culvert location draining a small residential area on the north side of and adjacent to the Saint John River in Fredericton. The sampling location is above the culvert that drains this area.

2.0 METHODS

2.1 Data collection.

Samples were taken four times each year, January, April, August and November. At each site, three water and sediment samples were taken using cleaned water bottles.

Dissolved oxygen. The DO meter consists of a cathode (gold and platinum), and an anode. These electrodes are immersed in a KOH solution contained by an oxygen permeable membrane. When the electrode-containing end of the probe is immersed in water, oxygen diffuses through the membrane. Oxygen

molecules that touch the cathode are reduced to become $[\text{OH}^-]$, thereby creating an electromotive potential difference between the cathode and the anode. The resulting current – which is proportional the DO concentration in water – is determined in conjunction with water temperature and atmospheric pressure. The resulting numbers are calibrated with respect to O_2 - saturated water at 1 atm.



Figure 3. Structure and image of the DO probe.

pH. The pH meter includes a composite electrode and a voltmeter. The composite electrode includes a glass electrode and a reference electrode. The tip of the glass electrode is permeable to hydrogen ions in the solution and is therefore sensitive to the hydrogen ion activity in aqueous solutions. The reference electrode provides a constant electromotive force (emf) potential. This electrode is immersed in a saturated potassium chloride solution contained by a permeable plug to close the current circuit between the glass electrode and the reference electrode when both are dipped into the same solution (Choudhary, A. 2017). The voltmeter is used to measure the resulting emf differences between the electrodes, i.e.,

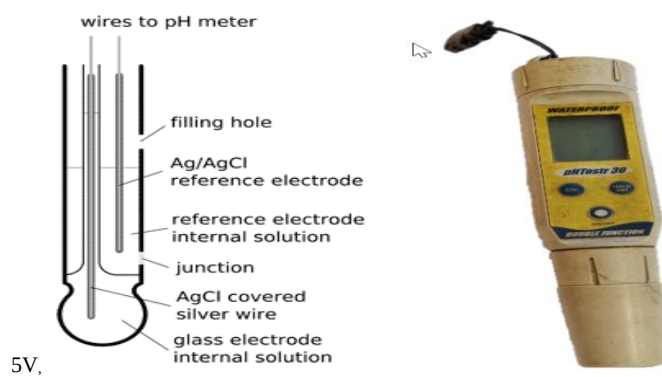


Figure 4. Structure and image of the pH probe.

EC. Water and sediment electrical conductivity increase with increasing salt, acid and base content. The probe consists of two small metal plates spaced equally apart. Dipping these plates into the solution or suspension or slurry of interest allows for measuring the electrical resistance between these plates. The resulting instrument readings were normalized to room temperature (25 °C).



Figure 5. Measuring electrical conductivity.

2.2 Data processing and statistical analyses

The resulting DO, pH and EC water and sediment data were compiled in a spreadsheet, by year, season and location. These data were box-plotted per year, per season, and location were box plotted showing the 10th, 25th, 50th, 75th and 90th percentiles as well as outliers below 10 and above 90 %. The data were also subjected to multivariate regression analyses, to determine the extent to which DO, pH, and EC would be influenced by location, year, and season, and one another by way of a least-squares fitting procedure (Marquardt). Location, year and season were coding as binary variables: 1 when applicable, and 0 otherwise. The results are presented and discussed below in the order DO, pH, and EC, box plots first, followed by the regression analyses.

3.0 RESULT AND DISCUSSION

3.1 Dissolved oxygen

A total of 170 and 66 dissolved oxygen samples were, respectively, measured for water and sediments at the 11 locations within Fredericton, by season and year. The box plots in Figures 6 and 7 show how the sediment and water DO values varied by site, season and year, with sediment DO $\approx 0.5 \times$ water DO, and with sediment DO being particularly low in spring, summer and fall, likely because of temperature induced biological oxygen demands. Water DO was also lowest during summer. From year to year, water DO levels were lowest in 2014, likely due to lower water levels and higher water temperatures during that year. Among the sites, sediment DO was lowest at Odell Park, likely due to receiving low DO seepage water. In contrast, sediment DO levels were most variable for the larger water bodies at, i.e., the Saint John River, Killarney Lake, Silver Maple and UNB woodlot sampling locations. Regarding water DO, Killarney Lake had the lowest values, likely due to its slow-flow sampling location.

The regression analysis results (Fig. 8) show that the overall water and sediment DO variations were related to one another and to season at $R^2 = 0.721$ and 0.545 , respectively, with the winter summer seasons being useful predictors for elevated DO, and more so for water DO than for sediment DO (p-values < 0.0001 and 0.0005 , respectively). In detail, increased water DO decreases sediment DO, and vice versa. This implies that, e.g., lower biological oxygen draw-down in water leads to greater biological oxygen

draw-down in sediments. This suggests, that higher water DO stimulate biological activities in sediments. The opposite might also be true: greater DO availability in sediments (due to incoming oxygen-enriched seepage water) may increase the biological activities in the water above the sediments. ("Biology of water", 1993)

Without adding water and sediment DO into the regression analysis, there was a significant drop in the R^2 value from 0.721 to 0.314 for water DO, with 2014, 2015, and Hyla Park becoming the most significant predictor variables. For sediment DO, R^2 increased from 0.545 to 0.767 with winter and Y2016 as independent variables. However, the actual versus best-fitted scatter plot was, as to be expected, blocky due to its location-specific best-fitted distribution pattern (Fig. 8).

The resulting scatterplots of actual versus best-fitted DO show that significant portions of the DO variations were not captured by using sediment or water DO site, year and season as independent regression variables. In reference to Fig. 2, the summer seasons for 2015 and 2017 appear to have been drier than the 2014 and 2016 summers. These may have led to a decrease in water DO across the entire year. The summer of 2014 was somewhat warmer than the summers of 2015, 2016 and 2017. This may have lowered water and sediment DO in 2014. In all of this, summer water and sediment DO levels would be much affected by the presence of aquatic plants including algae. These would increase DO during the day (when the DO readings were taken) because of oxygen release via photosynthesis, but lower DO during night because of uptake of oxygen via respiration (Alan Bassham & Hans Lambers, 2018).

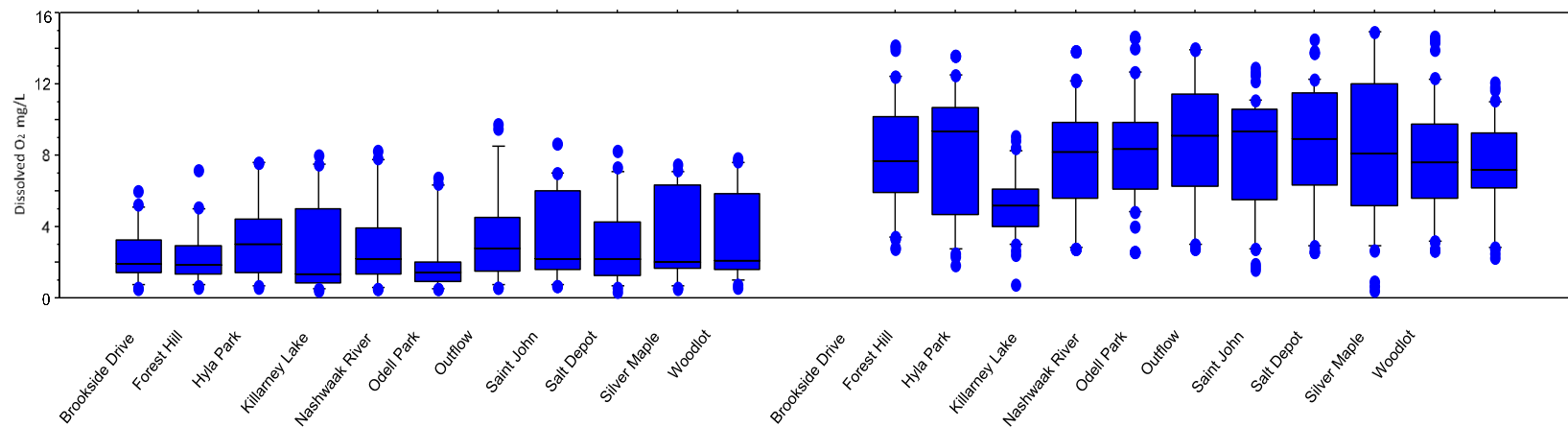


Figure 6. Boxplots showing the 10th, 25th, 50th, 75th and 90th percentiles of the DO data by site, with outliers, sediment (left), water (right.)

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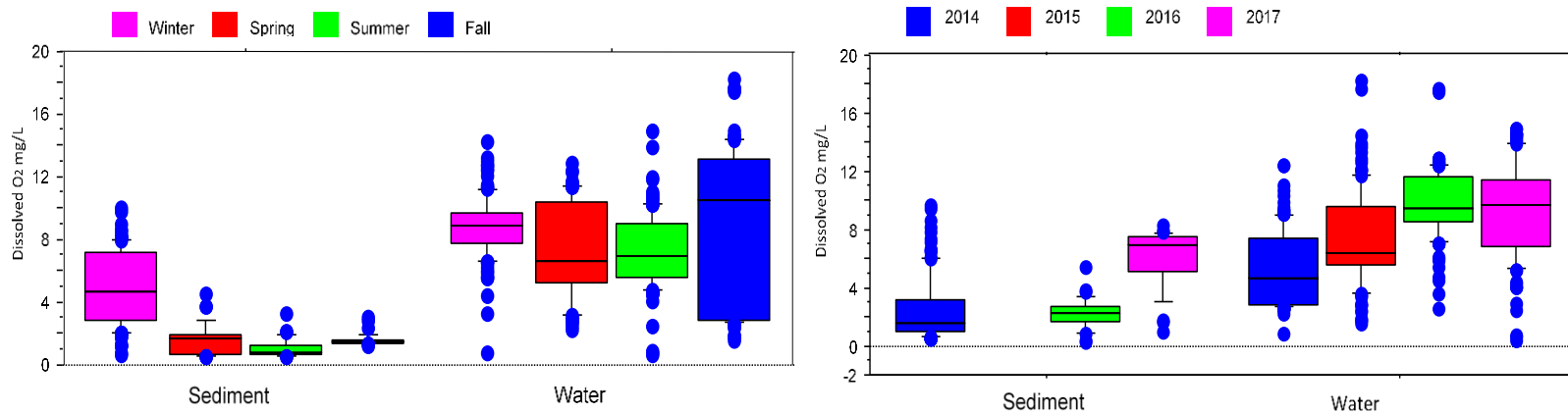
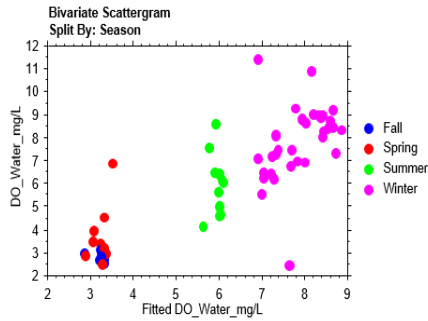


Figure 7. Boxplots showing the 10th, 25th, 50th, 75th and 90th percentiles of the DO data, split by season (left) and year (right).

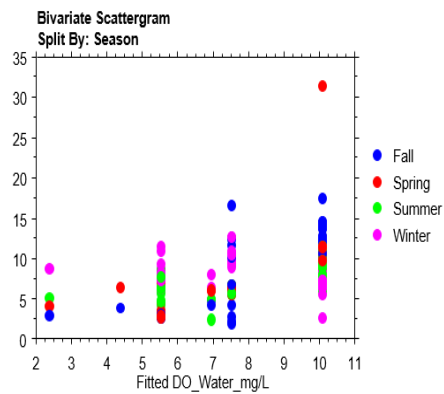
Regression Summary	
DO_Water_mg/L vs. 3 Independents	
Count	66
Num. Missing	107
R	.857
R Squared	.734
Adjusted R Squared	.721
RMS Residual	1.312

Regression Coefficients					
DO_Water_mg/L vs. 3 Independents					
	Coefficient	Std. Error	Std. Coeff.	t-Value	P-Value
Intercept	3.674	.325	3.674	11.302	<.0001
winter	5.457	.475	1.107	11.481	<.0001
Summer	2.553	.489	.386	5.225	<.0001
DO_Sed_mg/L	-.280	.103	-.255	-2.716	.0086



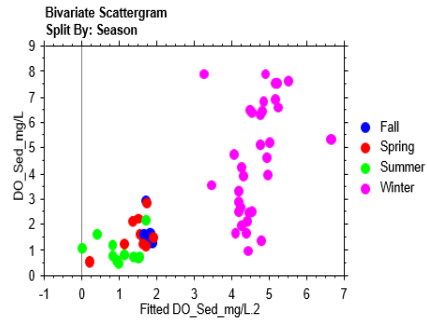
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DO_Water_mg/L vs. 3 Independents	
Count	170
Num. Missing	3
R	.561
R Squared	.314
Adjusted R Squared	.302
RMS Residual	3.168

Regression Coefficients					
DO_Water_mg/L vs. 3 Independents					
	Coefficient	Std. Error	Std. Coeff.	t-Value	P-Value
Intercept	10.100	.349	10.100	28.920	<.0001
Y2014	-4.582	.586	-.531	-7.819	<.0001
Y2015	-2.557	.612	-.284	-4.182	<.0001
Hyla Park	-3.158	.886	-.230	-3.566	.0005



Regression Summary	
DO_Sed_mg/L vs. 3 Independents	
Count	66
Num. Missing	107
R	.752
R Squared	.566
Adjusted R Squared	.545
RMS Residual	1.530

Regression Coefficients					
DO_Sed_mg/L vs. 3 Independents					
	Coefficient	Std. Error	Std. Coeff.	t-Value	P-Value
Intercept	2.833	.557	2.833	5.087	<.0001
winter	4.756	.771	1.057	6.165	<.0001
Summer	.432	.681	.072	.635	.5279
DO_Water_mg/L	-.380	.140	-.416	-2.716	.0086



Regression Summary	
DO_Sed_mg/L vs. 2 Independents	
Count	66
Num. Missing	107
R	.880
R Squared	.774
Adjusted R Squared	.767
RMS Residual	1.094

Regression Coefficients					
DO_Sed_mg/L vs. 2 Independents					
	Coefficient	Std. Error	Std. Coeff.	t-Value	P-Value
Intercept	1.407	.191	1.407	7.384	<.0001
winter	4.367	.301	.970	14.496	<.0001
Y2016	-3.495	.404	-.579	-8.648	<.0001

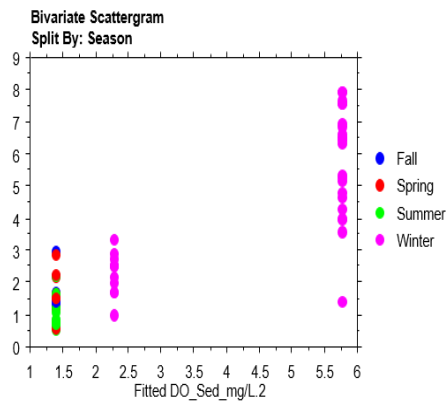


Figure 8. Best-fitted DO regression results for the water water(left) and sediment(right) samples. **Top:** relating DO in water to DO in sediments and vice versa. **Bottom:** Relating DO to sampling time and location. Only the most significant predictor variables were retained.

3.2 pH

A total of 127 pH samples were measured at the 11 locations within Fredericton by year and season. Fig. 9 shows the box plot variations for sediment and water pH by site, and Fig. 10 shows these variations by season and year. Ranking the water pH values from highest to lowest produced the following sequence:

Odell Park (1) > Saint John River (2) > Nashwaak River (3) > Forest Hill (4) > Salt Depot (5) > Killarney Lake (6) > Brookside Drive (7) > Silver Maple (8) > UNB Woodlot (Corbett Brook, 9) > Outflow (10) > Hyla Park (11).

After deleting the Forest Hill and Salt Depot locations, water pH was somewhat related to upstream basin area such that

$$\text{pH rank (water)} = 0.58 + 3.9 \ln (\text{basin area rank}), R^2 = 0.808.$$

In general, pH is expected to increase with increasing upslope area due to the increasing near pH-neutral groundwater contributions to stream and river water. In detail,

$$\text{pH (run off)} < \text{pH groundwater seepage}$$

due to low dissolved organic matter (dissolved organic acid) content and increased stripping of H^+ ions as the groundwater moves through consolidated and unconsolidated bedrock materials (Seibert, Stendahl & Sørensen, 2007).

The low water and sediment pH values for Hyla Park are likely due to high levels of organic matter accumulations within wetlands and shallow water pools of this park. The higher than expected pH values for the Forest Hill stream and the stream below the Salt Depot are likely due to surface run-off from road salt storage and applications. In this regard, the Forest Hill stream

carries run off from ditch water generated along the divided portion of the former Trans-Canada Highway.

By season, sediment and water pH increased from winter to summer and decreased again (slightly) in the fall. This was likely due to changing levels of dissolved organic acids in sediment and water, being subject to increasing decomposition in the summer than in winter. By year, water pH was low in 2014 and 2015 compared to 2016 and 2017. This may have been due to the cooler and snowier winters in 2014 and 2015, leaving stream and water temperature somewhat cooler not only in the winter but also in spring. Sediment pH, however, followed the opposite trend, being lowest in 2017. This may have been related to lower summer and fall temperatures in 2016 and 2017, thus increasing sediment organic acid content due to reduced decomposition rates.

By way of regression analysis (Fig. 11), water pH was affected by year (positive, increasing from 2014 to 2015), season (winter, negative), and sediment pH (positive): $R^2 = 0.329$. Hence increasing sediment acidity renders water pH to be acidic as well. The relation was more systematic for sediment pH by year (negative), site (Hyla Park, Killarney Lake, Nashwaak River, Silver Maple Brookside Drive, all negative) and water pH (positive) inclusion ($R^2 = 0.514$). Hence, across the sites: the more acidic the water, the more acidic the sediments.

Redoing the regression analysis with water and sediment pH improved the predictions for water pH somewhat by inclusion of the winter (negative), year (positive) and site (Odell Park, Saint John River and Forest Hill) variables:

$R^2 = 0.458$ (Fig. 11). For sediment pH, the best-fitted results decreased somewhat, with year (negative) and site variables (Odell Park, Outflow, Saint John River and salt depot (positive) as predictor variables: $R^2 = 0.362$.

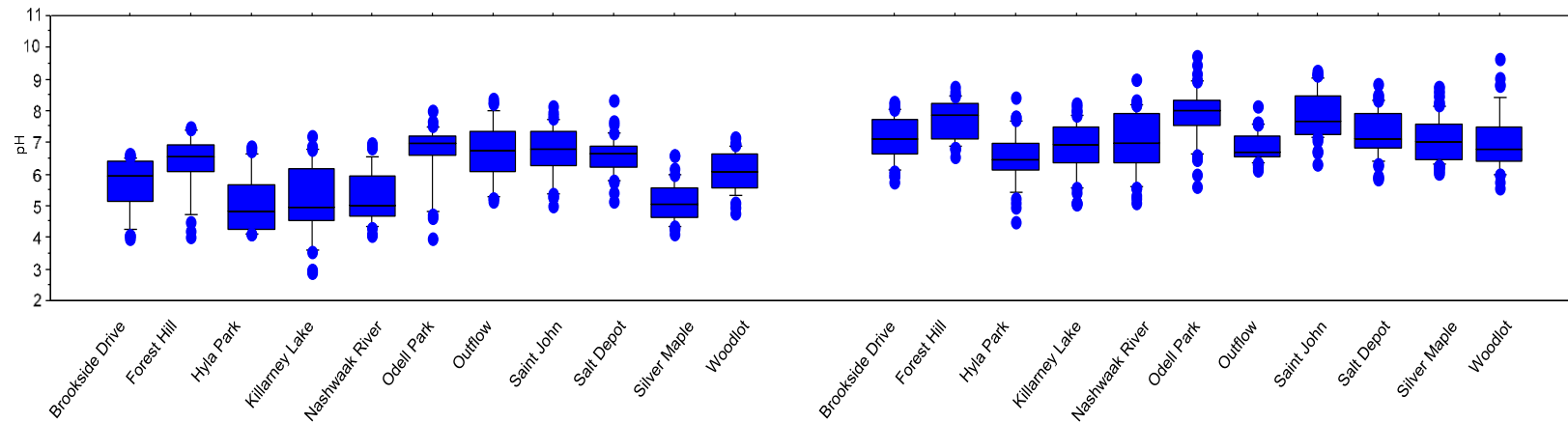


Figure 9. Boxplots showing the 10th, 25th, 50th, 75th and 90th percentiles of the pH data by site, with outliers, sediment (left), water (right).

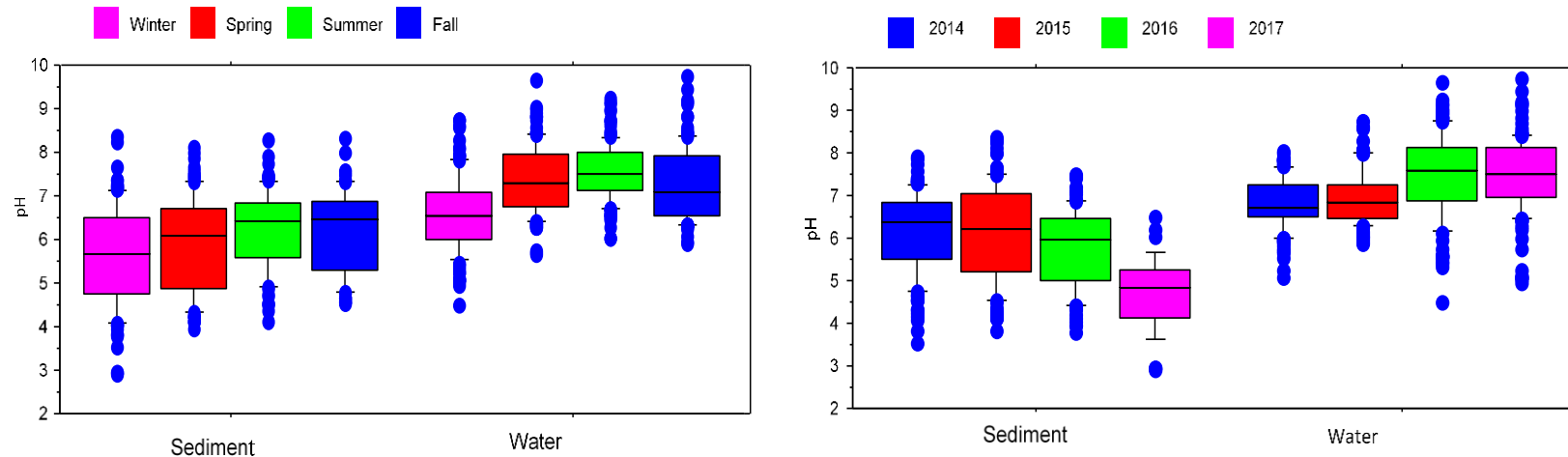
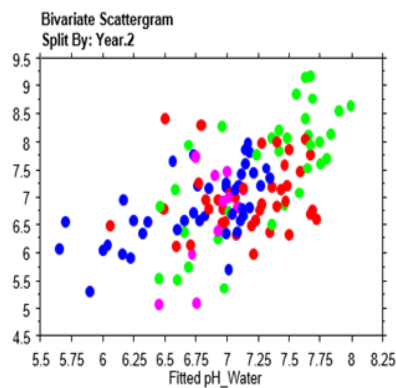


Figure 10. Boxplots showing the 10th, 25th, 50th, 75th and 90th percentiles of the pH data, split by season (left) and year (right).

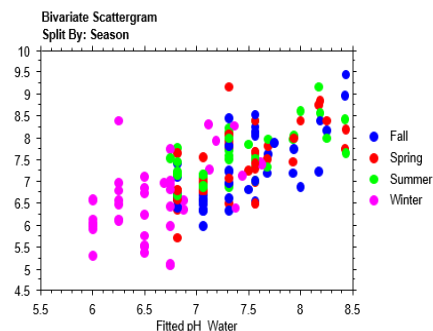
Regression Summary	
pH_Water vs. 3 Independents	
Count	127
Num. Missing	46
R	.573
R Squared	.329
Adjusted R Squared	.312
RMS Residual	.690

Regression Coefficients					
pH_Water vs. 3 Independents					
	Coefficient	Std. Error	Std. Coeff.	t-Value	P-Value
Intercept	-699.130	139.585		-5.009	<.0001
Year	.350	.069	.411	5.054	<.0001
winter	-.790	.139	-.449	-5.665	<.0001
pH_Sed	.243	.066	.295	3.689	.0003



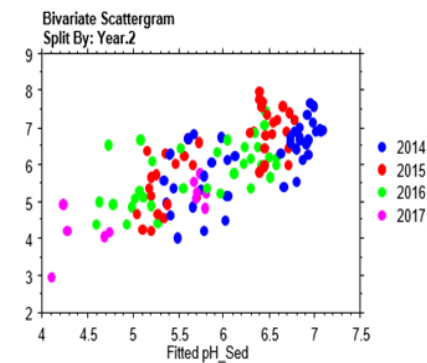
Regression Summary	
pH_Water vs. 5 Independents	
Count	170
Num. Missing	3
R	.689
R Squared	.474
Adjusted R Squared	.458
RMS Residual	.620

Regression Coefficients					
pH_Water vs. 5 Independents					
	Coefficient	Std. Error	Std. Coeff.	t-Value	P-Value
Intercept	-493.768	85.024		-5.807	<.0001
winter	-.811	.109	-.419	-7.404	<.0001
Odell Park	.874	.165	.304	5.309	<.0001
Saint John	.869	.165	.302	5.275	<.0001
Year	.249	.042	.334	5.892	<.0001
Forest Hill	.690	.181	.218	3.816	.0002



Regression Summary	
pH_Sed vs. 7 Independents	
Count	127
Num. Missing	46
R	.717
R Squared	.514
Adjusted R Squared	.485
RMS Residual	.724

Regression Coefficients					
pH_Sed vs. 7 Independents					
	Coefficient	Std. Error	Std. Coeff.	t-Value	P-Value
Intercept	790.223	135.199		5.845	<.0001
Year	-.390	.067	-.377	-5.804	<.0001
Hyla Park	-.996	.250	-.267	-3.985	.0001
Killarney Lake	-1.167	.234	-.339	-4.983	<.0001
Nashwaak River	-1.127	.230	-.328	-4.904	<.0001
Silver Maple	-1.335	.228	-.388	-5.862	<.0001
Brookside Drive	-.785	.228	-.228	-3.436	.0008
pH_Water	.224	.083	.184	2.694	.0081



Regression Summary	
pH_Sed vs. 5 Independents	
Count	129
Num. Missing	44
R	.622
R Squared	.387
Adjusted R Squared	.362
RMS Residual	.802

Regression Coefficients					
pH_Sed vs. 5 Independents					
	Coefficient	Std. Error	Std. Coeff.	t-Value	P-Value
Intercept	726.349	147.578		4.922	<.0001
Year	-.358	.073	-.345	-4.884	<.0001
Odell Park	.992	.248	.288	3.995	.0001
Outflow	1.124	.248	.326	4.529	<.0001
Saint John	1.147	.248	.333	4.623	<.0001
Salt Depot	1.007	.248	.292	4.059	<.0001

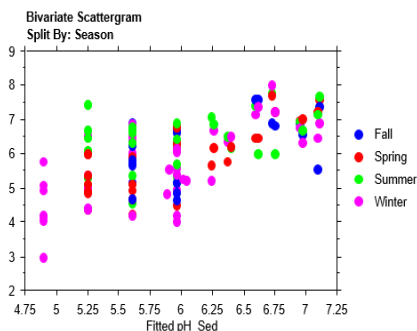


Figure 11. Best-fitted pH regression results for the water water(left) and sediment(right) samples. **Top:** relating pH in water to pH in sediments and vice versa. **Bottom:** Relating pH to sampling time and location. Only the most significant predictor variables were retained.

3.3 Electrical conductivity

A total of 170 EC samples were measured at the 11 locations within Fredericton. Figure 12 shows how that water EC varied much more than sediment EC. In detail, water ED was much affected by upslope road salt loadings, being highest immediately below the Salt Depot (Fig. 14), as follows:

Salt Depot > Forest Hill, > Odell Park > UNB Woodlot < Outflow > Hyla Park > Saint John River > Brookside Drive > Killarney Lake > Silver Maple > Nashwaak River.

The sequence for sediment EC followed another pattern, presumably due to a combination of (i) upstream basin size, which would have naturally added to the salt content in sediments due to cumulative of mineral-enriched upslope ground water seepage, and (ii) immediate upslope road salt loading. The EC sequence for sediments was as follows:

Salt Depot > UNB Woodlot > Saint John River > Outflow > Odell Park > Nashwaak River > Killarney Lake > Hyla Park > Forest Hill, Silver Maple > Brookside Drive.

The highly ranked UNB Woodlot position in this sequence is likely caused by pre-2014 commercial developments immediately above the water pond leading to the Woodlot sampling location. By season, sediment and water EC values are least in spring and fall, likely due to increased dilution on account of increased water flow rates due to spring melt (spring) and reduction of evapotranspiration (fall; Fig. 13). By year, sediment EC did not vary much, while water EC was lower in 2016 and highest in 2017. According to Fig.2,

2017 had the driest summer, and the winters of 2016 and 2017 had the least amount of snow accumulation. This being so, road salt applications may have increased as road surfaces would have experienced much freezing often leading to black ice formation. For 2014 and 2015, snow accumulations were higher than in 2016 and 2017, thus leading to more stable winter conditions with perhaps less need for road salt applications.

At the Salt Depot (Fig. 14, 15), sediment and water EC followed more or less similar trends by season and year, being lower in spring and fall than winter and summer, and lower in 2014 and 2015 than in 2016 and 2017.

The EC regression analyses confirmed that water EC was related to location (positive for Salt Depot, Forest Hill, and Odell Park; negative for Nashwaak River) and positively influenced by sediment EC, with $R^2 = 0.631$ (Fig. 16). In contrast, sediment EC was most affected by the Salt Depot location (positive), water EC (positive) and year (2015, negative). Hence, increased water EC increases sediment EC and vice versa, as to be expected. By location, year and season alone, sediment EC was positively related to the Salt Depot location, and negatively related to 2015, with $R^2 = 0.476$. In contrast, water EC was strongly related to location, being negative for Brookside Drive, Killarney Lake, Nashwaak River, Saint John River, and Silver Maple locations, and positive for the Salt Depot location, with $R^2 = 0.655$.

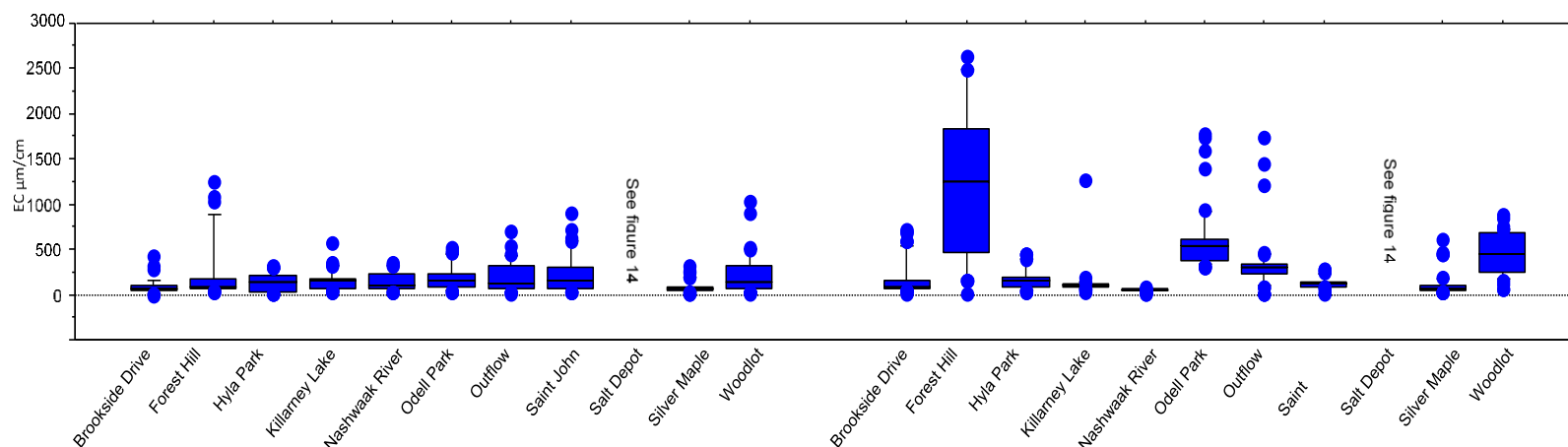


Figure 12. Boxplots showing the 10th, 25th, 50th, 75th and 90th percentiles of the EC data by site (except salt depot), with outliers, sediment (left), water (right).

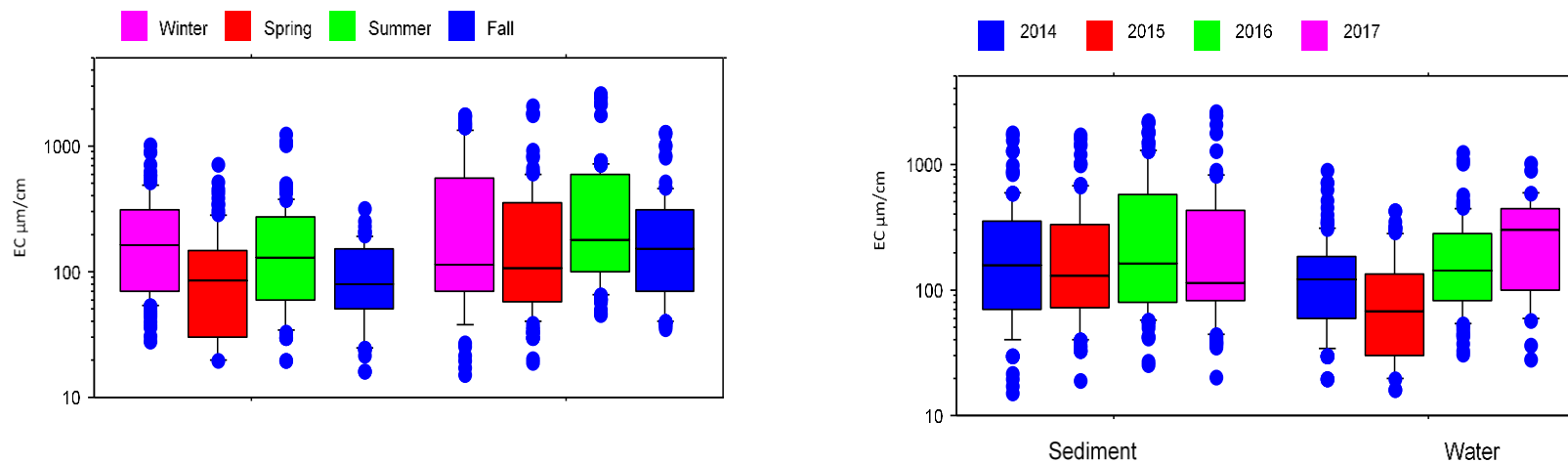


Figure 13. Boxplots showing the 10th, 25th, 50th, 75th and 90th percentiles of the EC data (except salt depot), split by season (left) and year (right).

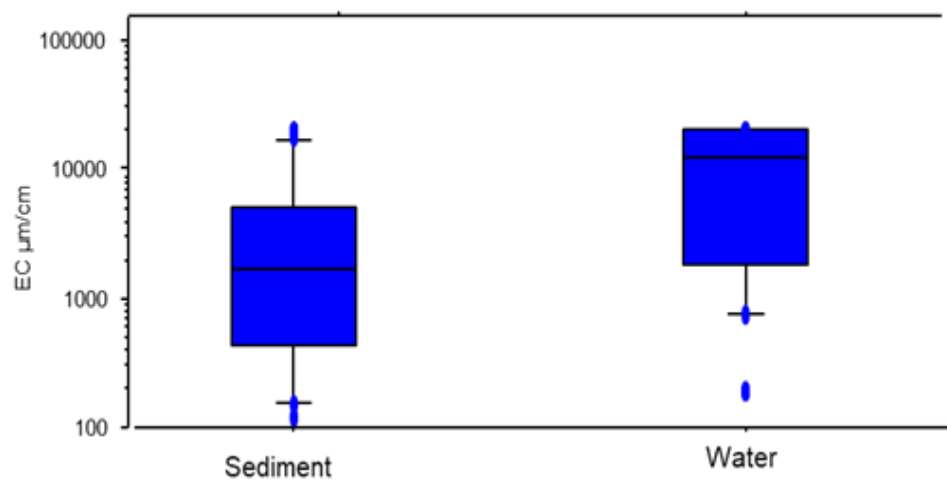


Figure 14. Boxplots showing the 10th, 25th, 50th, 75th and 90th percentiles of the EC data for the salt depot; sediment (left), water (right).

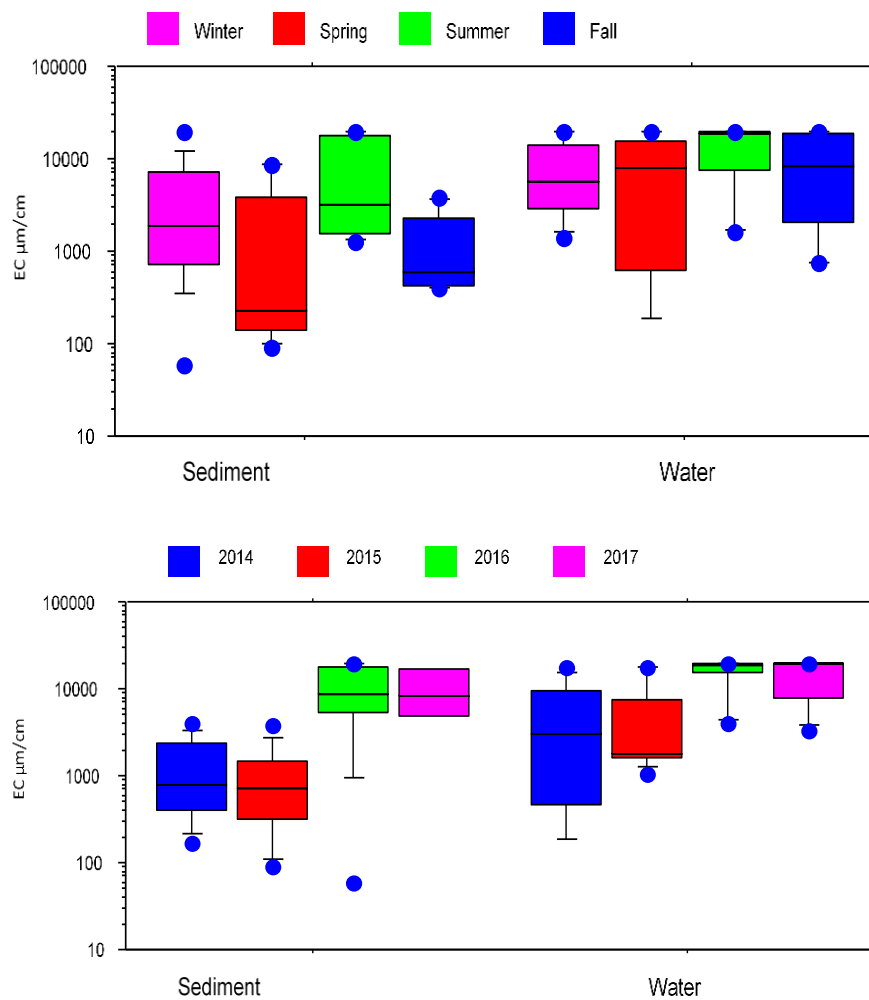


Figure 15. Boxplots showing the 10th, 25th, 50th, 75th and 90th percentiles of the EC data for the salt depot, split by season (left) and year (right).

Regression Summary

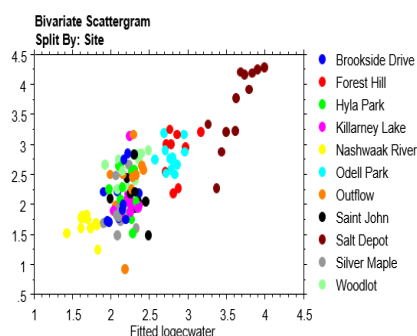
logecwaer vs. 5 Independents

Count	127
Num. Missing	46
R	.803
R Squared	.645
Adjusted R Squared	.631
RMS Residual	.394

Regression Coefficients

logecwaer vs. 5 Independents

	Coefficient	Std. Error	Std. Coeff.	t-Value	P-Value
Intercept	1.521	.176	1.521	8.624	<.0001
Salt Depot	1.041	.159	.471	6.549	<.0001
logecwaer	.333	.084	.281	3.958	.0001
Forest Hill	.630	.139	.250	4.544	<.0001
Nashwaak River	-.533	.122	-.241	-4.371	<.0001
Odell Park	.542	.122	.245	4.428	<.0001



Regression Summary

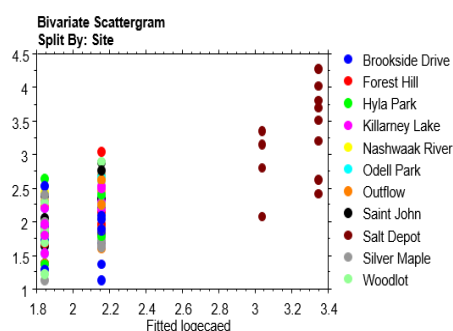
logecwaer vs. 2 Independents

Count	129
Num. Missing	44
R	.690
R Squared	.476
Adjusted R Squared	.468
RMS Residual	.397

Regression Coefficients

logecwaer vs. 2 Independents

	Coefficient	Std. Error	Std. Coeff.	t-Value	P-Value
Intercept	2.153	.044	2.153	49.213	<.0001
Salt Depot	1.196	.120	.640	9.924	<.0001
Y2015	-.310	.075	-.266	-4.120	<.0001



Regression Summary

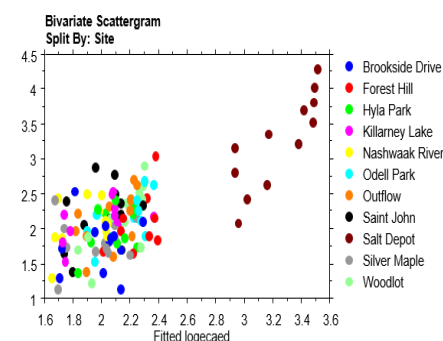
logecsed vs. 3 Independents

Count	127
Num. Missing	46
R	.734
R Squared	.539
Adjusted R Squared	.528
RMS Residual	.376

Regression Coefficients

logecsed vs. 3 Independents

	Coefficient	Std. Error	Std. Coeff.	t-Value	P-Value
Intercept	1.600	.156	1.600	10.228	<.0001
logecwaer	.243	.066	.289	3.666	.0004
Y2015	-.315	.072	-.267	-4.358	<.0001
Salt Depot	.865	.147	.464	5.896	<.0001



Regression Summary

logecsed vs. 6 Independents

Count	170
Num. Missing	3
R	.817
R Squared	.668
Adjusted R Squared	.655
RMS Residual	.389

Regression Coefficients

logecsed vs. 6 Independents

	Coefficient	Std. Error	Std. Coeff.	t-Value	P-Value
Intercept	2.569	.045	2.569	56.809	<.0001
Brookside Drive	-.504	.107	-.223	-4.696	<.0001
Killarney Lake	-.511	.107	-.226	-4.765	<.0001
Nashwaak River	-.894	.107	-.395	-8.338	<.0001
Saint John	-.487	.107	-.215	-4.538	<.0001
Salt Depot	1.191	.107	.526	11.105	<.0001
Silver Maple	-.677	.107	-.299	-6.316	<.0001

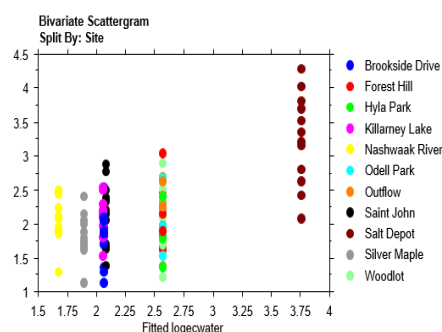


Figure 16. Best-fitted EC regression results for the water (left) and sediment (right) samples. **Top:** relating EC in water to EC in sediments and vice versa. **Bottom:** Relating EC to sampling time and location. Only the most significant predictor variables were retained.

4.0 CONCLUDING REMARKS

This study shows that the DO, pH and EC data in the Fredericton area vary by sampling location, season and year, generally in a somewhat predictable fashion. A large portion of the data variations, however, remains unexplained and therefore requires further study in relation to factors that might also influence these variables pertaining to each locality. For example, conducting a study detailing the relationship between actual upslope road salt loading and downslope stream water and sediments and year-round weather conditions would be of interest. Also, important would be the daily monitoring and analysis of water and sediment DO, pH and EC through automated means to establish direct relationship between these variables and daily weather and stream/river water variations. From a geospatial perspective, it would be important to trace the flow pattern of storm water through storm-water guiding flow channels upslope from the above sampling locations. To this end, this study may prove to be useful in directing spatial studies that not only account for hydrological throughputs at each sampling location, but also quantify the flow of water and waste from location to location.

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Curriculum Vitae

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EDUCATION

Northeast Forestry University

Sep. 2012- Jun. 2016

- Field of Study: Environmental Science
- Main Courses: Meteorology and Climatology, Hydrology, Pedology, General Ecology, Pollution Meteorology, Environmental Planning and Management, Water Treatment, Environmental Impact Assessment, Remote Sensing Technology, Environmental Monitoring and etc.
- GPA: 3.23/4.00

University of New Brunswick

- Field of study: Forestry Supervisor: Dr. Paul A. Arp
- Main Courses: GIS in forestry I, Water Hydro/Water Management, Forest Watershed and Water Quality Management, Environmental Impact Assessment
- GPA: 3.3/4.30

ACTIVITIES AND COMMUNITY INVOLVEMENT

2013 Took part in the Waste Recovery Activity to make clothes from wasted material produced by other student societies.

2013 Conducted meteorological monitoring under the guidance of professor

2014 Conducted water quality investigation and meteorological survey under the guidance of our professor.

2015 Worked as a part-time waitress in a restaurant for one month.

2015 Visited the ecological stations and learned their work content

HONORS

- Third-Class Scholarship

INTERESTS AND ADDITIONAL SKILLS

- Interests: Painting, Yoga
- Language Skills: Mandarin (Native) and English (Fluent)
- Computer Skills: Proficient in operating office software such as Word, Excel and PowerPoint