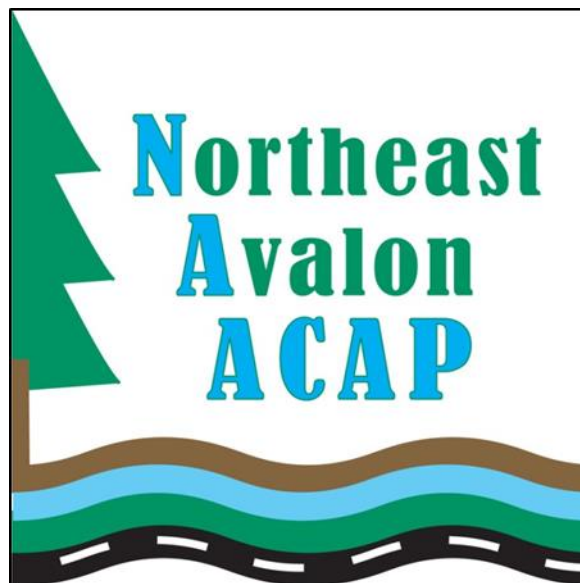


**Water Quality Analysis of Waterways Adjacent to Sod Farm
Operations on the Northeast Avalon Peninsula**

April 2014



Executive Summary

This project collected water quality information from water bodies adjacent to sod farm operations on the Northeast Avalon to determine if this type of agricultural operation has negative impacts on water quality. This information is important to inform sod farm operators as to the environmental impacts around their operations. This increased awareness is an important component of working together to protect the province's freshwater resources.

Water samples were collected from four waterways adjacent to sod farms: Rocky Brook in Bauline; Stanleys River in Bay Bulls; Holystone River and a small tributary to Cochrane Pond in St. John's. Water quality parameters tested included: temperature, pH, dissolved oxygen, specific conductance, salinity, total dissolved solids (TDS), turbidity, nitrates and phosphates. Results were compared to the Canadian Council of Ministers of the Environment (CCME) Water Quality Guidelines for the Protection of Aquatic Life and other accepted freshwater ranges.

Overall, the results indicated that the sampled waterways were within range appropriate for aquatic life in freshwater. However, there were differences in water quality downstream of the farms compared with upstream locations indicating that the sod farms have some impact on water quality.

Impacts of agricultural sod production on the surrounding environment can be minimized or avoided through the use of best management practices (BMPs), some of which are suggested in this report. There is also a need for more comprehensive water quality monitoring to track changes over time to enable sustainable sod production.

Acknowledgements

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1.0 Project Scope:

The purpose of this project was to determine if sod farms are influencing the water quality of adjacent waterways. This report contributes to sustainable land-use planning within the watershed context, in the rapidly developing urban areas of the Northeast Avalon Peninsula. It is a source of knowledge for sod farm operators through increasing awareness of general water quality and water quality issues, water quality results near their farms, and preventative measures to protect water quality of the watershed within which their operation lies.

2.0 Introduction:

The Northeast Avalon region of Newfoundland and Labrador is experiencing an increase in the speed and amount of development within municipalities. With this increase in population and development comes an increase in the demand for landscaping and turf production, resulting in the expansion of sod farming in the region. According to Statistics Canada, sod production in Newfoundland and Labrador covered 760 acres in 2010 (Statistics Canada, 2011). It appears on 2010 aerial photography that approximately 280 acres (112 hectares) of land on the Northeast Avalon was used for sod farms (Appendix A).

Sod farms in Newfoundland and Labrador are commonly developed on peatlands as these wetlands are generally flat, and contain relatively few large rocks, qualities that are appealing to agricultural land use. However, they are often nutrient deficient and too wet to grow sods, resulting in the draining of peatlands and the use of fertilizers and pesticides to successfully utilize them for sod production.

In Newfoundland and Labrador, sod farms are classified as agriculture. The Forestry and Agrifoods Agency of the Department of Natural Resources is the provincial body governing agriculture. There are no provincial regulations specific to sod farms. However, the Environmental Protection Act and the Water Resources Act apply to sod farm operations, meaning that operators have a role in ensuring that the Province's environment is protected. Specifically, the Environmental Protection Act regulates the use of pesticides, and the Water Resources Act ensures that there are no harmful effects to all water bodies in the province. As is the case with all types of development, the municipality within which the farm is located makes the decision on whether the farm is an acceptable land use within the zoning regulations for the area, as governed by the Provincial Urban and Rural Planning Act.

2.1 Water Quality and How Agriculture Can Impact It

It is important to recognize the connections between land use, water quality and the impacts agriculture can have on the surrounding aquatic environment. Water quality parameters do not function independently, and a change to one variable will often cause changes to others. Agricultural activities can negatively affect water quality primarily via surface runoff and subsurface flow, and as such are considered non-point sources of pollution. Pesticides and fertilizers applied to the fields can be carried in runoff to adjacent waterways. These materials and their components can also be leached from soil into water bodies. When areas are disturbed

or dug up for planting it may cause sedimentation, whereby soil particles are carried to nearby waterways, causing an increase in turbidity.

Chemical fertilizers and manure used to encourage growth contain the nutrients phosphorus and nitrogen that negatively affect water quality if present in large quantities. Nutrients can enter a waterway from adjacent farms in multiple ways, including surface runoff and subsurface drainage when the amount of nutrients present in soil is more than what is needed for crop growth and/or if there is heavy rain directly after application. Phosphorus is one of the main elements needed for plant growth and is found naturally in some rock types and in organic matter, but excess can have negative impacts on water quality. Phosphorus usually occurs in water as phosphate, and it is cycled between different phosphate forms (Appendix B). Total phosphate consists of organic phosphate and inorganic phosphate. Inorganic phosphate is a combination of meta(poly)phosphate and orthophosphate, the form used by plants. Organic soils, such as peat, are believed to allow transport of phosphorus from soil more so than mineral soils (Duxbury and Peverly, 1978 as cited in Zaimes and Schultz, 2002), such that agricultural areas developed on peatlands are more likely to release phosphorus to the surrounding environment than those developed on other soil types. This poses a risk to water quality by providing excess phosphorus to the surrounding water bodies. Like phosphorus, nitrogen is also found naturally but can have negative effects if present in overabundance. Nitrogen is cycled through different forms, one of which is nitrate (Appendix B). The reaction of organisms to increased nitrates varies, but include mortality of larval salmon (Kincheloe et al, 1979 as cited in Rice and Horgan, 2011), early or delayed metamorphosis in toads and frogs (Guillette and Edwards, 2005, Xu and Oldham, 1997 and Macro and Blaustein, 1999 as cited in Rice and Horgan, 2011), and endocrine disruption (Guillette and Andrews, 2005 as cited in Rice and Horgan, 2011).

An increase in nutrient concentration in water is known as eutrophication, which has been identified by the United Nations Educational Scientific and Cultural Organization (UNESCO) as a global water quality issue (UNESCO, 2009 as cited in Council of Canadian Academies, 2013). A surplus of nutrients in water can cause rampant algae and plant growth in a waterbody. As these plants and algae die and decompose oxygen is consumed by decomposers. This can lead to severely decreased levels of dissolved oxygen, needed for aquatic life. While this lack of oxygen can cause direct mortality, death can also occur across trophic levels. For example, when invertebrates die off because of lack of oxygen, fish species that feed on the invertebrates will die of starvation even if lack of oxygen does not kill them directly. Ultimately, the water can become anoxic, completely devoid of oxygen, and become a dead zone unsuitable for aquatic life. An increased growth rate of some species can also be damaging because of increases in toxins released. For example, some forms of cyanobacteria, known as blue green algae, release toxins which are relatively harmless in low quantities, but are harmful to animals and humans at high concentrations.

Increased sediment in a waterway can also cause problems for the health of aquatic life. Suspended silt and sediment can block fish gills and smother fish eggs. Sediment particles also increase water turbidity, which refers to how cloudy the water is. Increased turbidity can result in the water temperature increasing as more solar radiation is absorbed by suspended materials. Warm water has less capacity to hold dissolved oxygen, and can therefore cause stress to aquatic life due to decreased oxygen levels. Turbid water also blocks sunlight from passing through the

water, limiting the amount of light available for aquatic plants to use during photosynthesis, during which plants produce oxygen, resulting in a lack of oxygen. Suspended particles can also transport pathogens (such as *Escherichia coli* 0157:H7) which may have originated in manure used for fertilization.

Other water quality parameters that relate to sedimentation and soil erosion are conductivity, the water's ability to conduct electricity; salinity, a measure of the level of salts present; and total dissolved solids (TDS). Turbid water often has a higher salinity, conductivity and TDS value as it contains both suspended and dissolved particles in the water.

Another water quality parameter is pH, which is a scale used to indicate if water is acidic or basic. Small changes in pH mean a large change in the acidity level of the water, as a change of one pH unit is equal to a ten times change in acidity. For example, water with a pH of 2 is ten times more acidic than water with a pH of 3. The effect of pH changes on aquatic life varies among different species, and most organisms are resistant to a small change in pH. However, small changes in pH can impact aquatic life by influencing the solubility of compounds. This can result in a negative impact on organisms by limiting essential elements needed for biological processes, or increasing amounts of other soluble elements which can be problematic in large quantities, such as phosphorus. In Newfoundland and Labrador, soils are acidic, with a low pH not suited to the growth of many crops, making it necessary to add limestone to fields to increase soil pH.

3.0 Methods:

Sod farm operators throughout the Northeast Avalon were contacted to inform them of the project and assist with locating sod farms as the total number of farms in the region was not known. Farms and water quality sample sites were selected by using satellite and aerial imagery. Water sampling was conducted in four waterways which were adjacent to sod farms, with each waterway tested twice during the summer of 2013.

3.1 Sod farm and sample site locations:

Sod farm locations across the Northeast Avalon Region were first identified using Google Maps and 2010 aerial imagery (Appendix A). Drainage ditches on sod farms give them a stratified look in satellite imagery which made it possible to distinguish a sod farm from a hay field or vegetable garden. Once the potential sod farm locations were identified, 11 farms were traced onto 2010 aerial imagery in ArcGIS (Appendix A), and it was determined which rivers large enough to appear on a topographic map were adjacent to sod farms. Rocky Brook, Holystone River, and Stanleys River were those identified from topographic maps for sampling. In addition, field reconnaissance found a small tributary to Cochrane Pond. These waterways were carefully observed using Bing Maps high resolution "Birds Eye View" and Google Maps and tentative sample locations were determined both downstream of sod farms and upstream, in areas where there would be minimal human impacts to water quality other than the sod farms. Ponds adjacent to sod farms were not considered for sample locations due to the larger water area able to receive potential runoff inputs other than from the farm.

Due to a lack of baseline water quality data before sod farm establishment, it was decided that reference sites would be used to represent an undisturbed site for water quality comparison. Initially, a single reference site was thought to be best for comparison, but it was later decided that this was difficult to accomplish because of the lack of sites with the lack of human inputs that could truly represent reference conditions, which reflects the large human footprint on the Northeast Avalon. Therefore, reference sites were established upstream of sod farms on the targeted waterways to ensure that soil and bedrock type were comparable. Some of the tentative sample site locations were changed slightly because of accessibility issues. Maps showing sample locations can be found in Figures 1-4.

3.2 Water Quality:

Sample sites were visited twice during the summer of 2013. Sites were visited in a downstream to upstream direction so that sampling disturbances would not cause false representations of water quality downstream. Water temperature, dissolved oxygen (DO), pH, total dissolved solids (TDS), salinity and specific conductance (conductivity at 25°C) measures were taken in situ using a Quanta G multisonde that was calibrated to manufacturer specifications. Water samples were also collected at each site and placed on ice for testing for phosphates and nitrates using a Hach Stream Survey Kit. This testing was completed indoors for controlled safety related to the Hach kit reagents and because the sample needed to be boiled for phosphate testing. A turbidity tube was also used in situ to obtain turbidity values. The turbidity tube was filled to the top, and water then released until the secchi disk at the bottom of the tube was visible, and the water level was then read from the metric scale on the side of the tube. If the water was clear, the secchi disk was visible with the tube full, and no water was released, giving a maximum reading of 60 cm. Three readings were taken using the turbidity tube and the average of the three readings was recorded. The turbidity tube readings are a relative indication of turbidity as readings were not provided in turbidity units.

4.0 Results and Discussion:

The results from all water quality sampling and maps showing sample locations are presented individually for each waterway. Components of total phosphate values are presented separately from the other water quality parameters for clarity.

The water quality results were compared to guideline values ideal for aquatic life and values typical of freshwater. The Canadian Council of Ministers of the Environment (CCME) Water Quality Guidelines for the Protection of Aquatic Life state guidelines for pH, dissolved oxygen, nitrate nitrogen and nitrate. These guidelines suggest a range of 6.5 - 9 for pH (CCME, 2006), but peat soils on the island of Newfoundland typically have a pH of 3.54 - 6.52 (Wells and Pollett, 1983), meaning that the pH of waterways flowing through peatlands may be lower than the CCME guidelines. The CCME Water Quality Guidelines for the Protection of Aquatic Life also suggest a maximum concentration of 13 mg/L for nitrate (NO_3^-) and 3.0 mg/L for nitrate nitrogen ($\text{NO}_3^- \text{N}$) (CCME, 2012), and that dissolved oxygen levels be no lower than 6.0 mg/L for early life stages or 5.5 mg/L for other life stages (CCME, 1999). There are no guideline values for phosphates given in the CCME Canadian Water Quality Guidelines for the Protection of Aquatic Life. They do present a framework for phosphorus levels, where values are either compared to baseline values such that up to a 50% increase in concentrations above baseline levels is acceptable, or compared to trigger ranges whereby the upper limit of the desired range for phosphorus concentration is not exceeded (CCME, 2004). Recommended ranges for freshwater not listed in the CCME Water Quality Guidelines for the Protection of Aquatic Life are 0.050-1.5 mS/cm for specific conductance (Province of British Columbia, 1998), 0-1 g/L for total dissolved solids (TDS) (Province of British Columbia, 1998), and 0-1 PSS for salinity (Bergman, 2001). Turbidity tube readings cannot be compared to guideline values because they were read as a relative indicator of turbidity rather than as turbidity units. However, a reading of 60 cm is the highest that the turbidity tube can read, meaning that the water was clear and did not show any indication of sedimentation.

4.1 Rocky Brook:

Rocky Brook was sampled on July 29 and August 13, 2013. Table 1 and Table 2 contain the results for this sampling and sample site locations are shown in Figure 1.

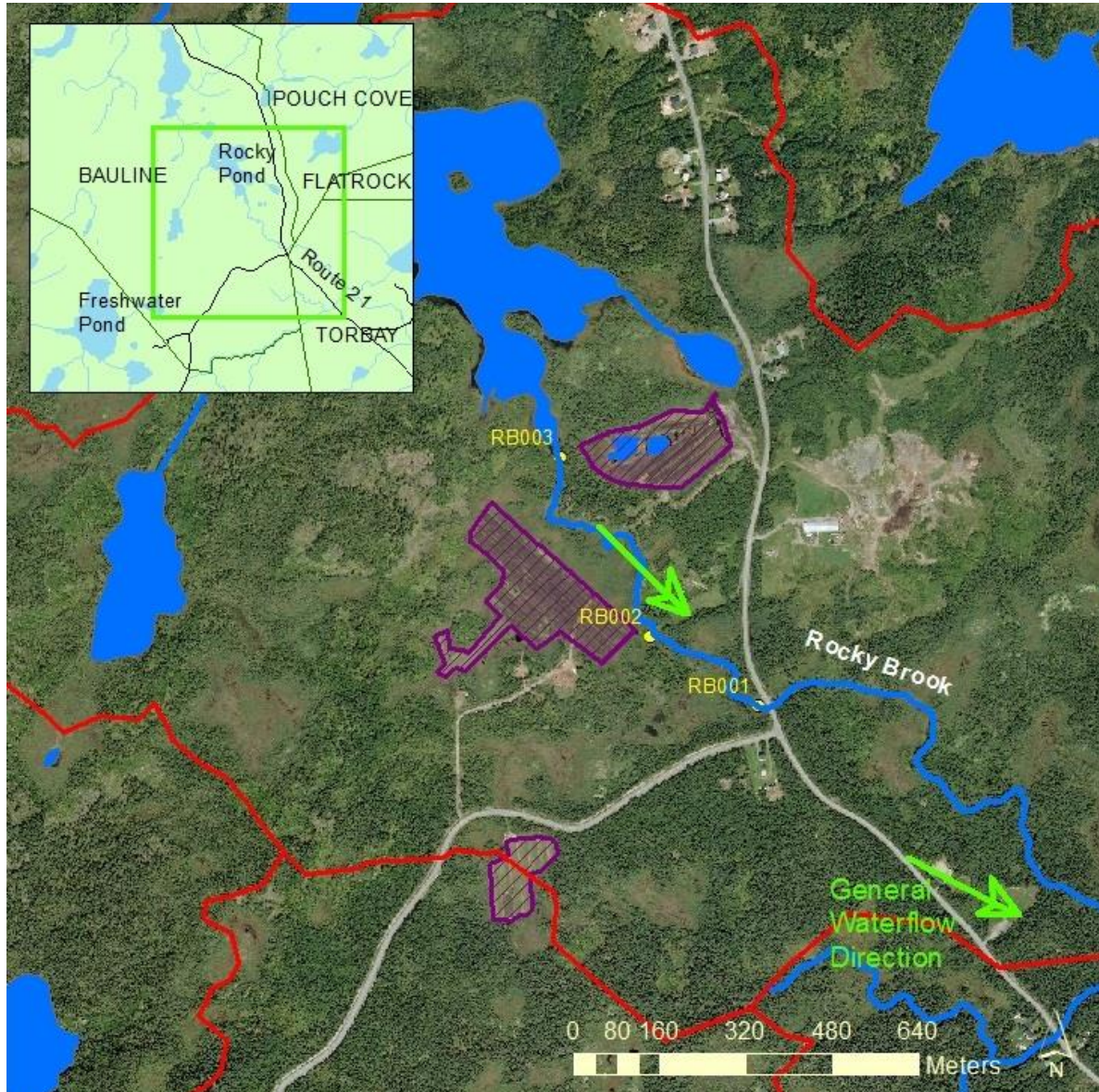


Figure 1. Map of water quality sample sites along Rocky Brook in Bauline. The purple polygons are sod farm areas traced out on aerial imagery from 2010. The reference site (RB003) was located upstream of the sod farms. Two other sample sites were located downstream of the sod farms, with one immediately downstream (RB002) and the other further downstream (RB001). The red lines indicate watershed boundaries.

All of the pH values recorded (Table 1) were lower than the range suggested in the CCME Canadian Water Quality Guidelines for the Protection of Aquatic Life (see above), but reflect the low pH associated with peatland soils. All of the Rocky Brook sites had dissolved oxygen levels that were considered acceptable for both early and other life stages, with concentrations decreasing from the upstream reference site to waters downstream from the sod farm. All of the values recorded for specific conductance, salinity and total dissolved solids (TDS) were within the recommended ranges for freshwater. The specific conductance values ranged from 0.080 mS/cm (at the reference site on July 29) to 0.088 mS/cm (at the furthest downstream site on both July 29 and August 13), while salinity and TDS values were uniform across sample sites and dates. Turbidity tube readings did not show any indication of sedimentation. There were no detectable levels of nitrate nitrogen or nitrates (less than 0.02 mg/L for nitrate nitrogen and 0.088mg/L for nitrate) at any of the sample locations on either of the sampling dates.

Table 1. Water quality readings (water temperature, pH, dissolved oxygen (DO) concentrations and percent saturation, specific conductance, total dissolved solids (TDS), salinity, turbidity tube reading, nitrate nitrogen and nitrate) obtained from sample sites along Rocky Brook. Values in red are outside of guideline ranges. Nitrate nitrogen and nitrate values recorded as LTD (lower than detectable) did not give a result when using the Hach kits, meaning that any concentrations present were lower than detectable with the kits.

Site Name	Location Relative to sod farm(s)	Date	Site Location (Decimal Degrees Longitude)	Site Location (Decimal Degrees Latitude)	Temp (°C)	pH	DO (mg/L)	DO (%) Saturation)	Specific Conductance (mS/cm)	TDS (g/L)	Salinity (PSS)	Turbidity Tube (cm)	Nitrate Nitrogen (mg/L)	Nitrate (mg/L)
RB003	Reference Site (upstream)	29/07/2013	-52.8013	47.68700	22.48	6.41	8.13	93.9	0.080	0.1	0.04	60	LTD	LTD
		13/08/2013	-52.8013	47.68700	21.05	6.4	7.05	78.5	0.085	0.1	0.04	60	LTD	LTD
RB002	Immediately Downstream	29/07/2013	-52.7991	47.68412	16.7	6.2	6.98	71.5	0.082	0.1	0.04	60	LTD	LTD
		13/08/2013	-52.7991	47.68412	17.82	6.37	6.13	64	0.085	0.1	0.04	60	LTD	LTD
RB001	Further Downstream	29/07/2013	-52.7963	47.68291	16.51	6.21	6.76	69.1	0.088	0.1	0.04	60	LTD	LTD
		13/08/2013	-52.7963	47.68291	17.78	6.25	6.6	69.1	0.088	0.1	0.04	60	LTD	LTD

There were no detectable phosphate values at any of the sample sites during the July 29 visit, but there were some phosphates detected downstream during the August 13 visit (Table 2). The reasons for this are not clear, but could be related to fertilizer or harvesting scheduling at the adjacent sod farm. There had been heavy rain the days previous to the July 29 visit, meaning that one would expect elevated phosphate levels related to an increase in surface runoff, which was not the case. On August 13, the sample site located furthest downstream (RB001) had a total phosphate reading of 0.06 mg/L, while the sample site located immediately downstream of the farms (RB002) had a reading of 0.04 mg/L, and the upstream reference site (RB003) had no detectable phosphates. At both of the downstream sites, total phosphate consisted of both organic phosphate and inorganic phosphate in the form of orthophosphate. There was no meta(poly) phosphate detected at either location. Historical data was not available, but with the reference site as a baseline value for comparison within the framework for phosphorus suggested by the CCME, an increase from no detectable levels to 0.04 mg/L and 0.06 mg/L is such that there is potential risk to water quality. The reference site would be classified as either ultra-oligotrophic

(<0.004 mg/L), or oligotrophic (0.004-0.01 mg/L) (CCME, 2004), and the upper limit of these ranges are exceeded with the downstream values. If these concentrations were to persist, there could be risk of eutrophication of the waterway.

Table 2. Phosphate readings using Hach Stream Survey kits obtained for samples taken from Rocky Brook. Values recorded as LTD (lower than detectable) did not give a result when using the Hach kits, meaning that any concentrations present were lower than detectable with the kits.

Site Name	Location Relative to sod farm(s)	Date	Site Location (Decimal Degrees Longitude)	Site Location (Decimal Degrees Latitude)	Ortho-phosphate (mg/L)	Meta(poly)-Phosphate (mg/L)	Total Inorganic Phosphate (mg/L)	Organic Phosphate (mg/L)	Total Phosphate (mg/L)
RB003	Reference Site (upstream)	29/07/2013	-52.8013	47.68700	LTD	LTD	LTD	LTD	LTD
		13/08/2013	-52.8013	47.68700	LTD	LTD	LTD	LTD	LTD
RB002	Immediately Downstream	29/07/2013	-52.7991	47.68412	LTD	LTD	LTD	LTD	LTD
		13/08/2013	-52.7991	47.68412	0.02	LTD	0.02	0.02	0.04
RB001	Further Downstream	29/07/2013	-52.7963	47.68291	LTD	LTD	LTD	LTD	LTD
		13/08/2013	-52.7963	47.68291	0.04	LTD	0.04	0.02	0.06

Overall, the results obtained indicate that the water quality in the sampled section of Rocky Brook is suitable for aquatic life in freshwater. However, it appears that water quality is more impaired downstream (Sites RB001 and RB002) of the adjacent sod farm than upstream (Site RB003) of the farm. This is evidenced by the readings for pH, dissolved oxygen, and total phosphates (Table 3).

Table 3. Comparisons of water quality at downstream sample sites along Rocky Brook to the upstream reference site

Site Name	Date	Comparison of test site to reference site for each water quality parameter								
		Temperature	pH	Dissolved Oxygen	Specific Conductance	TDS	Salinity	Turbidity*	Nitrate	Total Phosphate
RB002 (immediately downstream)	29/07/2013	Lower	Lower	Lower	Higher	Same	Same	Same	Same	Same
	13/08/2013	Lower	Lower	Lower	Same	Same	Same	Same	Same	Higher
RB001 (further downstream)	29/07/2013	Lower	Lower	Lower	Higher	Same	Same	Same	Same	Same
	13/08/2013	Lower	Lower	Lower	Higher	Same	Same	Same	Same	Higher

*Higher or lower turbidity is the inverse of the change in turbidity tube readings

4.2 Holystone River:

The results from water quality sampling at sites along Holystone River on July 18 and August 6, 2013 are given in Table 4 and Table 5 and sample site locations are illustrated in Figure 2.

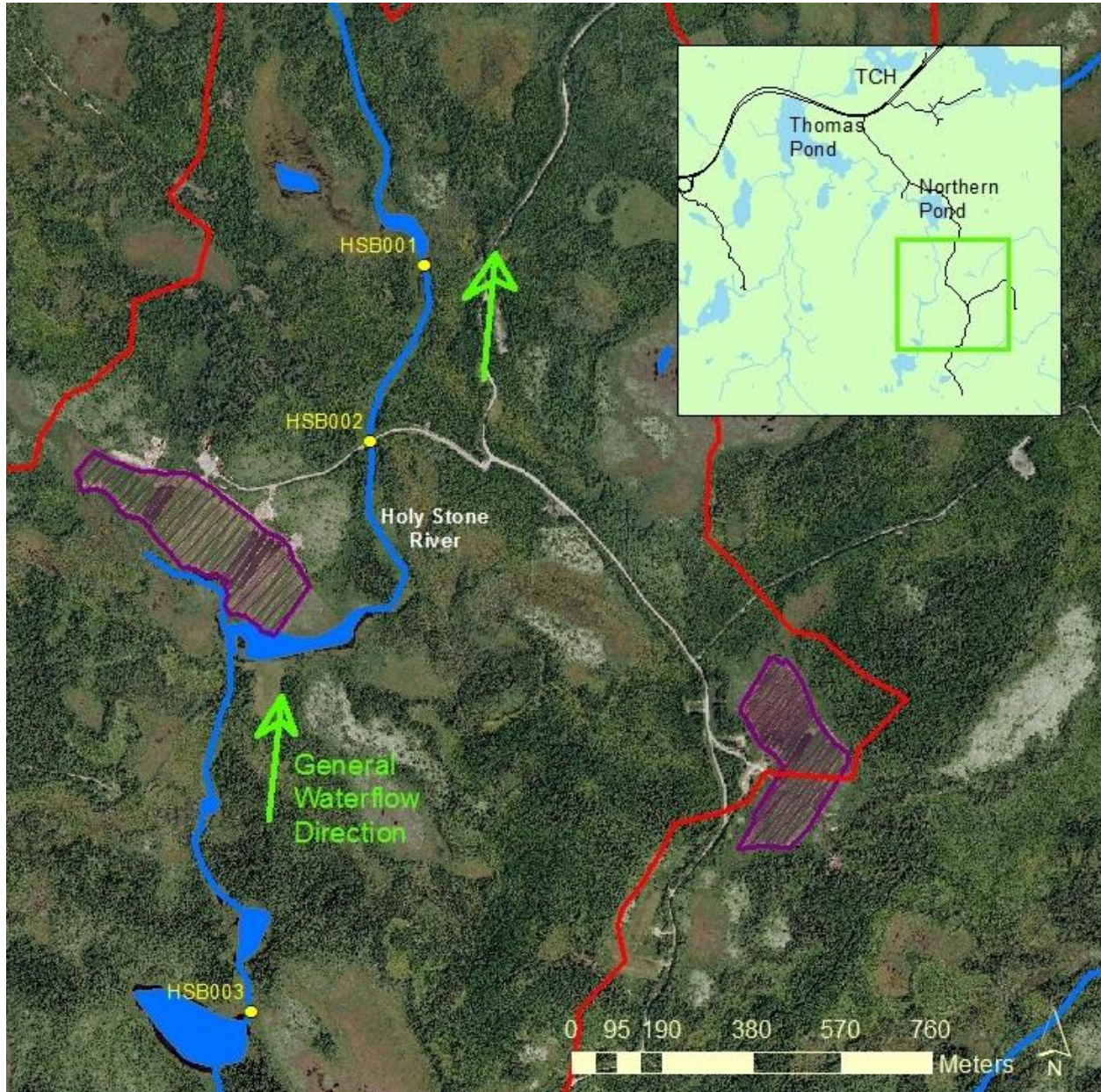


Figure 2. Map of water quality sample sites along the Holystone River in St. John's. The purple polygons are sod farm areas traced out on aerial imagery from 2010. The reference site (HSB003) was located upstream of any inputs from sod farms. Two additional sample sites were located downstream of the sod farm, with one site (HSB002) immediately downstream, and the other site (HSB001) further downstream. The red lines indicate watershed boundaries. .

Water temperature values ranged from 13.98°C (Site HSB002 on July 18) to 19.71°C (Site HSB003 on August 6) (Table 4). All of the pH values recorded were below the

recommended range for the protection of aquatic life, but this is due to the low pH associated with peatland soils. All of the dissolved oxygen concentrations recorded were above the lowest acceptable levels suggested in the CCME Water Quality Guidelines for the Protection of Aquatic Life (CCME, 1999). The reference site (HSB003) had the highest dissolved oxygen level during both visits. All of the recorded values for specific conductance were lower than the suggested range for freshwater, which is less of a concern than if they were higher. Recorded conductance values were almost the same during both sample visits at all three sample sites, with the reference site (HSB003) showing the lowest values. The total dissolved solids (TDS) and salinity values were uniform across sample sites and both dates, with both of these parameters within ranges typical for freshwater. For the most part, the turbidity tube readings were at the maximum of 60 cm, except for at the farthest downstream site (HSB001) on July 18, when the water had increased turbidity as illustrated by a lower turbidity tube reading. This could be related to the heavy rain experienced during the day, but the other two sites did not show a similar increase in turbidity. Nitrate nitrogen and nitrate readings were not obtained for the samples collected on July 18, and there were no detectable levels of these two parameters (less than 0.02 mg/L for nitrate nitrogen and 0.088mg/L for nitrate) detected from the August 6 samples.

Table 4. Water quality readings (water temperature, pH, dissolved oxygen (DO) concentrations and percent saturation, specific conductance, total dissolved solids (TDS), salinity, turbidity tube reading, nitrate nitrogen and nitrate) obtained from sample sites along Holystone River. Values in red are outside of guideline ranges. Nitrate nitrogen and nitrate values recorded as LTD did not give a result when using the Hach kits, meaning that any concentrations present were lower than detectable with the kits. The nitrate nitrogen and nitrate values for July 18 were not included because of complications with the Hach kits on that day.

Site Name	Location Relative to sod farm(s)	Date	Site Location (Decimal Degrees Longitude)	Site Location (Decimal Degrees Latitude)	Temp (°C)	pH	DO (mg/L)	DO (%) Saturation)	Specific Conductance (mS/cm)	TDS (g/L)	Salinity (PSS)	Turbidity Tube (cm)	Nitrate Nitrogen (mg/L)	Nitrate (mg/L)
HSB003	Reference Site (upstream)	18/07/2013	-52.88459	47.41704	15.24	5.21	8.81	87.9	0.025	0	0.02	60	NA	NA
		06/08/2013	-52.88459	47.41704	19.71	5.13	9	98.1	0.025	0	0.02	60	LTD	LTD
HSB002	Immediately Downstream	18/07/2013	-52.88124	47.42783	13.98	5.94	7.03	68.2	0.037	0	0.02	60	NA	NA
		06/08/2013	-52.88124	47.42783	16.43	5.15	7.47	78.2	0.037	0	0.02	60	LTD	LTD
HSB001	Further Downstream	18/07/2013	-52.87974	47.43125	14.36	5.82	6.61	64.1	0.036	0	0.02	31.8	NA	NA
		06/08/2013	-52.87974	47.43125	15.69	5.46	7.79	78.1	0.037	0	0.02	60	LTD	LTD

Table 5 contains phosphate values for the sample sites on Holystone River. There was no phosphate testing performed for the samples collected on July 18. On August 6, there were no phosphates detected at the reference site (HSB003), but there were detectable levels at the two downstream sites (HSB001 and HSB002). The furthest downstream sample site (HSB001) contained only inorganic phosphate in the form of orthophosphate, while the immediately downstream sample site (HSB002) contained both organic and inorganic phosphate, with a larger concentration of inorganic in the form of orthophosphate. Comparing the total phosphate values with the CCME phosphorus trigger ranges using the reference site as baseline data indicates that an increase from no detectable levels to 0.07 mg/L (HSB002) and 0.08 mg/L (HSB001) is such that there is a potential threat to water quality. The reference site would be classified as either ultra-oligotrophic (<0.004 mg/L), or oligotrophic (0.004-0.01 mg/L) (CCME, 2004), and the

upper limit of these ranges were exceeded with the downstream values. Unfortunately, only having phosphate values for this river for one sample date means that conclusions cannot be made about whether these reading are typical for these sites, but if these concentrations were to persist, there could be an increased possibility of eutrophication of the waterway.

Table 5. Phosphate readings using Hach Stream Survey kits obtained for samples taken from Holystone River. Values recorded as LTD did not give a result when using the Hach kits, meaning that any concentrations present were lower than detectable with the kits. The values for July 18 were not included because of complications with the Hach kits on that day.

Site Name	Location Relative to sod farm(s)	Date	Site Location (Decimal Degrees Longitude)	Site Location (Decimal Degrees Latitude)	Ortho-phosphate (mg/L)	Meta(poly)-Phosphate (mg/L)	Total Inorganic Phosphate (mg/L)	Organic Phosphate (mg/L)	Total Phosphate (mg/L)
HSB003	Reference Site (upstream)	18/07/2013	-52.88459	47.41704	NA	NA	NA	NA	NA
		06/08/2013	-52.88459	47.41704	LTD	LTD	LTD	LTD	LTD
HSB002	Immediately Downstream	18/07/2013	-52.88124	47.42783	NA	NA	NA	NA	NA
		06/08/2013	-52.88124	47.42783	0.06	LTD	0.06	0.01	0.07
HSB001	Further Downstream	18/07/2013	-52.87974	47.43125	NA	NA	NA	NA	NA
		06/08/2013	-52.87974	47.43125	0.08	LTD	0.08	0	0.08

Overall, the results obtained indicate that the water quality in the sampled section of Holystone River is suitable for aquatic life in freshwater. The sites downstream of the sod farms (HSB001 and HSB002) show a decrease in dissolved oxygen, an increase in conductivity, and an increase in phosphates compared to the upstream reference site (HSB003) (Table 6), which indicates that sod farms are having a negative impact on water quality.

Table 6. Comparisons of water quality at downstream sample sites along Holystone River to the upstream reference site

Site Name	Date	Comparison of test site to reference site for each water quality parameter								
		Temperature	pH	Dissolved Oxygen	Specific Conductance	TDS	Salinity	Turbidity*	Nitrate	Total Phosphate
HSB002 (immediately downstream)	18/07/2013	Lower	Higher	Lower	Higher	Same	Same	Same	-	-
	06/08/2013	Lower	Higher	Lower	Higher	Same	Same	Same	Same	Higher
HSB001 (further downstream)	18/07/2013	Lower	Higher	Lower	Higher	Same	Same	Higher	-	-
	06/08/2013	Lower	Higher	Lower	Higher	Same	Same	Same	Same	Higher

*Higher or lower turbidity is the inverse of the change in turbidity tube readings

4.3 Stanleys River:

Sites along Stanleys River in Bay Bulls were sampled on July 30 and August 27, 2013. The water quality results from these visits are given below in Table 7 and Table 8 and sample site locations are shown in Figure 3.

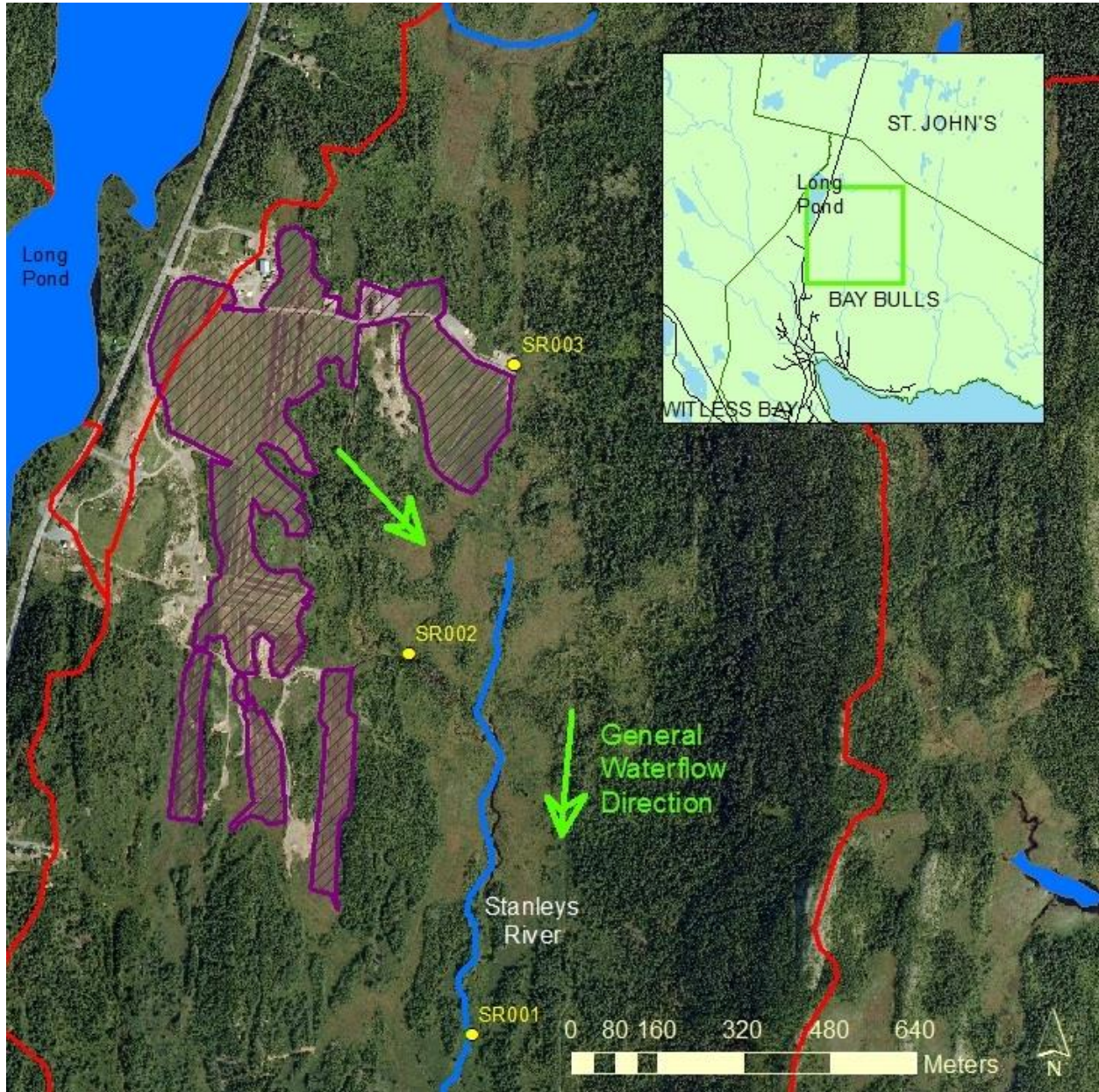


Figure 3. Map of water quality sample sites along Stanleys River in Bay Bulls. The purple polygons are the sod farm traced out on aerial imagery from 2010. The reference site (SR003) was located upstream of the sod farm. The other sample sites were located downstream of the farm, with one located on a tributary to Stanleys River (SR002), and the other further downstream on Stanleys River (SR001). The red lines indicate watershed boundaries.

All of the pH values recorded (Table 7) except at the furthest downstream site (SR001) on July 30 were below the recommended range for aquatic life, but reflect the low pH associated

with peatland soils. All of the dissolved oxygen concentrations were considered appropriate for aquatic life by the CCME guidelines. The specific conductance values recorded for the reference site (SR003) on both sample dates were lower than the suggested range for freshwater, which is less of a concern than if they were higher. The conductance readings were higher at the downstream sites than at the reference site, with the site located along the tributary to Stanleys River (SR002) having the highest readings. The TDS readings were all within the suggested range for freshwater, with the highest reading occurring in the tributary (SR002) on July 30. The salinity readings were also all within the range expected for freshwater. For the most part, the water at the sample sites was not turbid, with the maximum average reading of 60 cm obtained. However, an average reading of only 8.7cm was obtained at the reference site (SR003) on July 30. This was because of a large amount of organics in the small stream, and not because of sediment which commonly causes turbidity. The shallow water at that site also made it difficult to obtain a water sample without disturbing the bottom. There were no detectable levels of nitrate nitrogen or nitrate (less than 0.02 mg/L for nitrate nitrogen and 0.088mg/L for nitrate) at any of the sample sites on either sample date.

Table 7. Water quality readings (water temperature, pH, dissolved oxygen (DO) concentrations and percent saturation, specific conductance, total dissolved solids (TDS), salinity, turbidity tube reading, nitrate nitrogen and nitrate) obtained from sample sites along Stanleys River. Values in red are outside of guideline ranges. Nitrate nitrogen and nitrate values recorded as LTD did not give a result when using the Hach kits, meaning that any concentrations present were lower than detectable with the kits.

Site Name	Location Relative to sod farm(s)	Date	Site Location (Decimal Degrees Longitude)	Site Location (Decimal Degrees Latitude)	Temp (°C)	pH	DO (mg/L)	DO (%) Saturation)	Specific Conductance (mS/cm)	TDS (g/L)	Salinity (PSS)	Turbidity Tube (cm)	Nitrate Nitrogen (mg/L)	Nitrate (mg/L)
SR003	Reference Site (upstream)	30/07/2013	-52.8033	47.34288	16.77	6.1	8.09	83.1	0.047	0	0.03	8.7	LTD	LTD
		27/08/2013	-52.8033	47.34288	15.61	5.92	8.03	81	0.044	0	0.02	60	LTD	LTD
SR002	Downstream on tributary to Stanleys River	30/07/2013	-52.8059	47.33802	16.41	6.39	7.43	76	0.071	0.1	0.04	60	LTD	LTD
		27/08/2013	-52.8059	47.33802	13.72	6.32	7.89	76.3	0.076	0	0.04	60	LTD	LTD
SR001	Further Downstream	30/07/2013	-52.8044	47.33163	16.17	6.94	10.44	106.1	0.057	0	0.03	60	LTD	LTD
		27/08/2013	-52.8044	47.33163	13.06	6.49	10.46	98.9	0.051	0	0.03	60	LTD	LTD

Table 8 contains phosphate values obtained from the sample sites for Stanleys River. On July 30 all downstream samples collected had detectable total phosphate levels compared with the reference site (SR003) which had below detectable levels. At the two downstream sites phosphates detected consisted of only orthophosphate types. On August 27 all of the sites had orthophosphates, while meta(poly) phosphates were found only at the downstream sites (SR001 and SR002). Organic phosphates were found at the furthest downstream site (SR001) and the reference site (SR003). Phosphate concentrations were higher on August 27 than July 30, which could be attributed to heavy rain on August 26. On both sample dates, the reference site (SR003) had the lowest total phosphate concentrations and the sample site located on the tributary (SR002) had the highest concentrations. Using the reference site as baseline data to apply the framework for phosphorus given in the CCME Water Quality Guidelines for the Protection of Aquatic Life indicates that there is potential for risk to water quality downstream. The concentrations at the two downstream sample sites exceed the upper limit of the trigger ranges

that the reference site is classified as on both sample dates. Also, the concentrations at the downstream sites are above the accepted maximum 50% increase from the reference concentration. If these conditions persisted over time there is potential for eutrophication of the waterway.

Table 8. Phosphate readings using Hach Stream Survey kits obtained for samples taken from Stanleys River. Values recorded as LTD did not give a result when using the Hach kits, meaning that any concentrations present were lower than detectable with the kits.

Site Name	Location Relative to sod farm(s)	Date	Site Location (Decimal Degrees Longitude)	Site Location (Decimal Degrees Latitude)	Ortho-phosphate (mg/L)	Meta(poly)-Phosphate (mg/L)	Total Inorganic Phosphate (mg/L)	Organic Phosphate (mg/L)	Total Phosphate (mg/L)
SR003	Reference Site (upstream)	30/07/2013	-52.8033	47.34288	LTD	LTD	LTD	LTD	LTD
		27/08/2013	-52.8033	47.34288	0.04	LTD	0.04	0.04	0.08
SR002	Downstream on tributary to Stanleys River	30/07/2013	-52.8059	47.33802	0.18	LTD	0.18	LTD	0.18
		27/08/2013	-52.8059	47.33802	0.24	0.06	0.3	LTD	0.3
SR001	Further Downstream	30/07/2013	-52.8044	47.33163	0.08	LTD	0.08	LTD	0.08
		27/08/2013	-52.8044	47.33163	0.12	0.02	0.14	0.02	0.16

Overall, there are differences in water quality upstream and downstream of the farm (Table 9), which suggests that the downstream sites are negatively affected by the presence of the sod farm compared with the upstream reference site. The sample site located on the tributary (SR002) appeared to have the most impacted water quality, with lower dissolved oxygen levels, higher conductivity, TDS (during only the July 29 visit), salinity, and phosphate values than the other downstream site.

Table 9. Comparisons of water quality at downstream sample sites along Stanleys River to the upstream reference site

Site Name	Date	Comparison of test site to reference site for each water quality parameter								
		Temperature	pH	Dissolved Oxygen	Specific Conductance	TDS	Salinity	Turbidity*	Nitrate	Total Phosphate
SR002 (downstream on tributary to Stanleys River)	30/07/2013	Lower	Higher	Lower	Higher	Higher	Higher	Lower	Same	Higher
	27/08/2013	Lower	Higher	Lower	Higher	Same	Higher	Same	Same	Higher
SR001 (further Downstream)	30/07/2013	Lower	Higher	Higher	Higher	Same	Same	Lower	Same	Higher
	27/08/2013	Lower	Higher	Higher	Higher	Same	Higher	Same	Same	Higher

*Higher or lower turbidity is the inverse of the change in turbidity tube readings

4.4 Cochrane Pond Tributary:

A small tributary to Cochrane Pond was sampled on August 6 and August 19, 2013. The water quality results of this sampling are given in Table 10 and Table 11 and sample site locations are shown in Figure 4. There was no upstream reference sample site for this waterway.

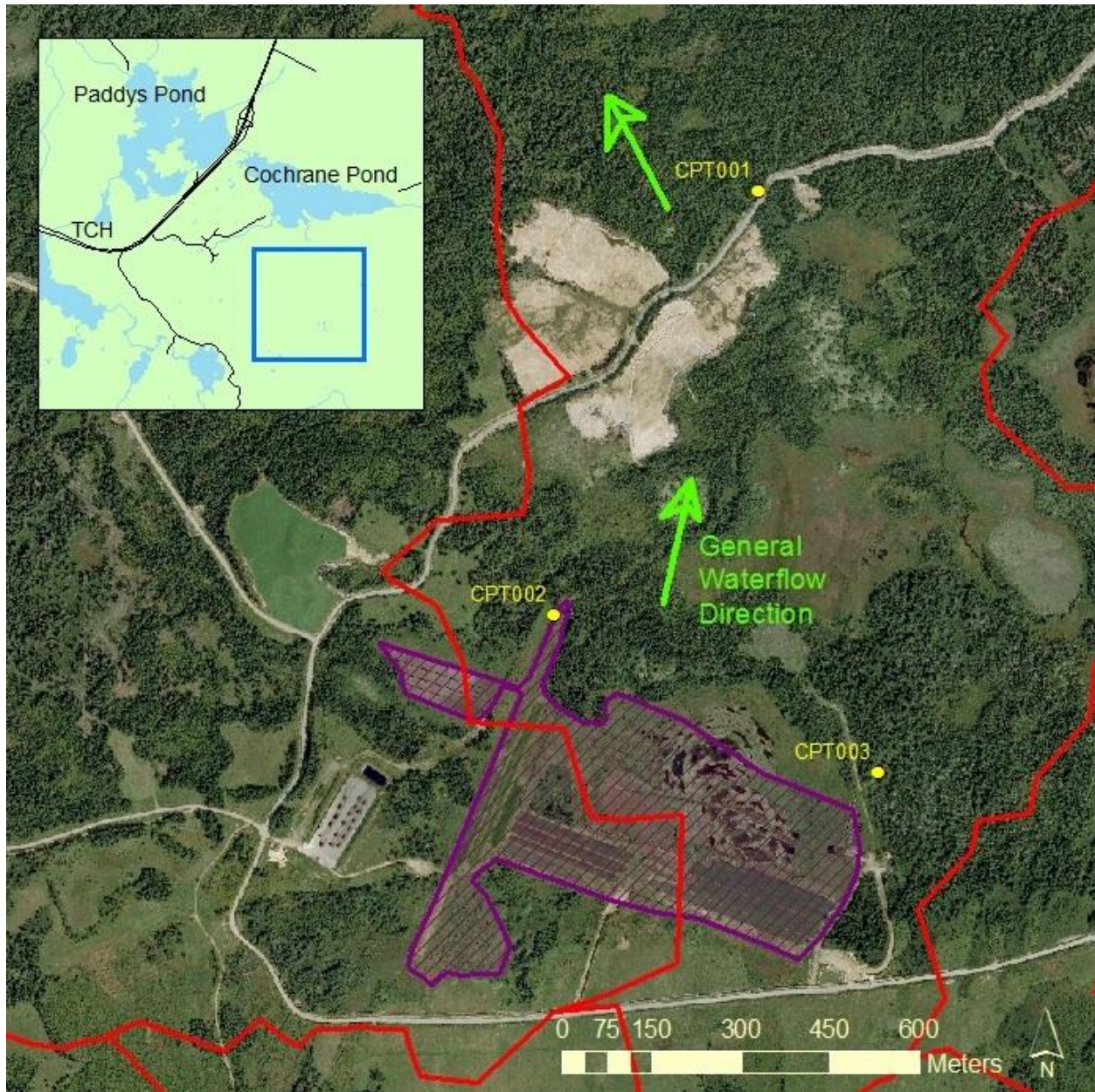


Figure 4. Map of water quality sample sites along a tributary that flows into Cochrane Pond in St. John's. The tributary was too small to have its path represented in the 1:50,000 GIS steams layer, and as such is not marked on the map. The purple polygons are sod farm areas traced out on aerial imagery from 2010. There was no flow found upstream, so there was no upstream reference site. Sample sites were located immediately downstream of the sod farm in outflows located at the northeast (CPT003) and northwest (CPT002) corners of the farm, and further downstream, where the outflows join into one flow and the tributary crosses the gravel road (CPT001). The red lines indicate watershed boundaries.

All of the recorded pH values (Table 10) were lower than the range recommended by the CCME for the protection of aquatic life, but reflect the low pH associated with peatland soils. The dissolved oxygen concentrations were below the lowest acceptable level, with the exception of the sample site located in the northwest corner of the farm (CPT002) on August 6. These low dissolved oxygen levels could be related to low water levels and low flow at the sites. The specific conductance values at the further downstream sample site (CPT001) were lower than the recommended range for freshwater on both sample dates, which is less of a concern than if they were higher. All of the recorded values for TDS were 0 g/L. The salinity values did not change between sample dates at each site and were all typical of freshwater. The turbidity tube readings did indicate slight water turbidity. The water at these sites appeared dark, but not muddy. This could be an indicator of high organic content. There were no detectable levels of nitrate nitrogen or nitrate (less than 0.02 mg/L for nitrate nitrogen and 0.088mg/L for nitrate) in any of the collected samples.

Table 10. Water quality readings (water temperature, pH, dissolved oxygen (DO) concentrations and percent saturation, specific conductance, total dissolved solids (TDS), salinity, turbidity tube reading, nitrate nitrogen and nitrate) obtained from sample sites along the Cochrane Pond tributary. Values in red are outside of guideline ranges. Nitrate nitrogen and nitrate values recorded as LTD did not give a result when using the Hach kits, meaning that any concentrations present were lower than detectable with the kits. Site CPT003 was not accessed during the August 19 sampling visit.

Site Name	Location Relative to sod farm(s)	Date	Site Location (Decimal Degrees Longitude)	Site Location (Decimal Degrees Latitude)	Temp (°C)	pH	DO (mg/L)	DO (% Saturation)	Specific Conductance (mS/cm)	TDS (g/L)	Salinity (PSS)	Turbidity Tube (cm)	Nitrate Nitrogen (mg/L)	Nitrate (mg/L)
CPT003	Outflow at northeast corner	06/08/2013	-52.85175	47.44822	19.25	5.28	4.73	51	0.054	0	0.03	24.7	LTD	LTD
		19/08/2013	-52.85175	47.44822	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
CPT002	Outflow at northwest corner	06/08/2013	-52.85886	47.45072	19.46	5.44	6.28	68.5	0.052	0	0.03	56.5	LTD	LTD
		19/08/2013	-52.85886	47.45072	15.78	5.45	4.71	47	0.049	0	0.03	55.9	LTD	LTD
CPT001	Further downstream	06/08/2013	-52.85441	47.45697	16.24	5.32	5.07	51.9	0.043	0	0.02	54.3	LTD	LTD
		19/08/2013	-52.85441	47.45697	15.24	5.41	3.8	36.9	0.044	0	0.02	60	LTD	LTD

Table 11 contains results for phosphate testing at the Cochrane Pond Tributary sample sites. All of the water samples collected from this stream were found to contain phosphates, consisting of both organic and inorganic forms. Inorganic phosphate consisted of orthophosphate, and meta(poly) phosphate, except on August 6 at the furthest downstream site (CPT001) and the site located in the northwest corner of the farm (CPT002), where there were no detectable meta(poly) phosphates. Total phosphate values appeared to be higher on the August 19 visit than on the August 6 visit, which could be related to farm fertilization and harvesting scheduling. There was no upstream reference site available for this waterway, but the reference sites for the other sampled waterways were mainly classified as ultra-oligotrophic (<0.004 mg/L P) or oligotrophic (0.004-0.01mg/L P) in the framework for phosphorus given in the CCME Water Quality Guidelines for the Protection of Aquatic Life (CCME, 2004). Comparing the total phosphate concentrations obtained from the samples in the Cochrane Pond Tributary to the reference sites suggest that there is potential risk to water quality, as the concentrations are much higher than the upper limit of the trigger ranges of the reference sites.

Table 11. *Phosphate readings using Hach Stream Survey kits obtained for samples taken from the Cochrane Pond tributary. Values recorded as LTD did not give a result when using the Hach kits, meaning that any concentrations present were lower than detectable with the kits. Site CPT003 was not accessed during the August 19 sampling visit.*

Site Name	Location Relative to sod farm(s)	Date	Site Location (Decimal Degrees Longitude)	Site Location (Decimal Degrees Latitude)	Ortho-phosphate (mg/L)	Meta(poly)-Phosphate (mg/L)	Total Inorganic Phosphate (mg/L)	Organic Phosphate (mg/L)	Total Phosphate (mg/L)
CPT003	Outflow at northeast corner	06/08/2013	-52.85175	47.44822	0.22	0.04	0.26	0.02	0.24
		19/08/2013	-52.85175	47.44822	NA	NA	NA	NA	NA
CPT002	Outflow at northwest corner	06/08/2013	-52.85886	47.45072	0.08	LTD	0.08	0.08	0.16
		19/08/2013	-52.85886	47.45072	0.12	0.04	0.16	0.16	0.32
CPT001	Further downstream	06/08/2013	-52.85441	47.45697	0.08	LTD	0.08	0.14	0.22
		19/08/2013	-52.85441	47.45697	0.14	0.18	0.32	0.04	0.36

While the water quality values found in Table 7 illustrate some exceedance of guidelines related to the protection of aquatic life and typical of freshwater (pH, DO and specific conductance), they are likely due in large part to the low flows. All of the concentrations of phosphates (Table 11) are concerning, since low flow has the potential to amplify concentrations because of low amounts of dilution. There was no upstream reference site for this waterway for comparison of upstream against downstream of sod farm, but the total phosphate readings for the sample sites along the Cochrane Pond tributary are among the highest observed on the waterways sampled for this project (Table 2, Table 5, Table 8 and Table 11). While this small stream is not likely to be fish bearing, there were frogs observed at the northwest corner of the farm (CP002) and there is potential to impact Cochrane Pond and other water bodies in the same drainage basin.

5.0 Conclusions and Recommendations:

The results obtained for this project suggest that the water quality at the sampled waterways is suitable for aquatic life. However, sampling at Rocky Brook, Holystone River, and Stanleys River indicate that water quality has been negatively affected downstream of the farms. While the Cochrane Pond Tributary did not have an upstream location for comparison, the water quality also appears to be negatively affected downstream of the farms.

There are steps that can be taken to ensure that the activities needed to produce a sustainable and viable sod crop do not have a negative effect on the aquatic environments that surround them. It is easier to prevent pollution than it is to clean it up afterwards. Preventative measures to ensure that the environment is protected from possible negative effects from farming are known as Best Management Practices (BMPs). BMPs can be generalized into three main types: reducing inputs, controlling erosion and runoff; and managing/installing barriers and buffers (Hilliard and Reedyk, 2000). Effective BMPs can vary from farm to farm and have

various levels of effectiveness at controlling the potential for water pollution from farming activities.

Reducing inputs refers to reducing the amount of materials available to runoff or leach from farm areas into a nearby waterway. Specifically, this involves only applying as much pesticide and fertilizer as is needed and only when rain is not predicted. Pesticide use as outlined by manufacturers and government regulations reduces the potential for harm to the surrounding environment and the applicator. Regular soil and plant tissue testing is an effective way to ensure that the amount of fertilizer added to a farm is the correct amount for ideal growing conditions. This is also economical, as it not only ensures that soil conditions are optimum for growth, but also ensures that fertilizer is not wasted, as it is when soil reaches its maximum capacity to contain nutrients and the excess is lost to the surrounding environment.

Controlling erosion and runoff refers to minimizing the movement of disturbed soil from farm areas into surrounding waterways. One way that this can be achieved is by installing silt fencing along the perimeter of newly disturbed areas to contain sediment movement. Silt fencing is only effective in areas where there is not a direct water flow, must be installed slightly below the soil surface for stability, and requires regular maintenance and removal of deposited soil. Erosion can also be avoided by keeping vegetation along the sides of drainage ditches for soil stabilization. This will also slow runoff speed, which will reduce erosion and allow suspended materials to be deposited before being carried into waterways. Water flow in drainage ditches can also be slowed by reducing slope and by using u-shaped channels instead of v-shaped to increase surface area. As suspended material may also contain nutrients, deposition aids in reducing the amount of excess nutrients being carried to adjacent waterways.

Buffers refer to leaving a vegetated area between farm operations and waterways. Ideally, buffer areas should be left natural or planted with native species. These vegetated areas can decrease water flow rates and remove sediment and nutrients from runoff. Barriers also serve as interceptors between the farm and the adjacent waterway, and include installations such as berms.

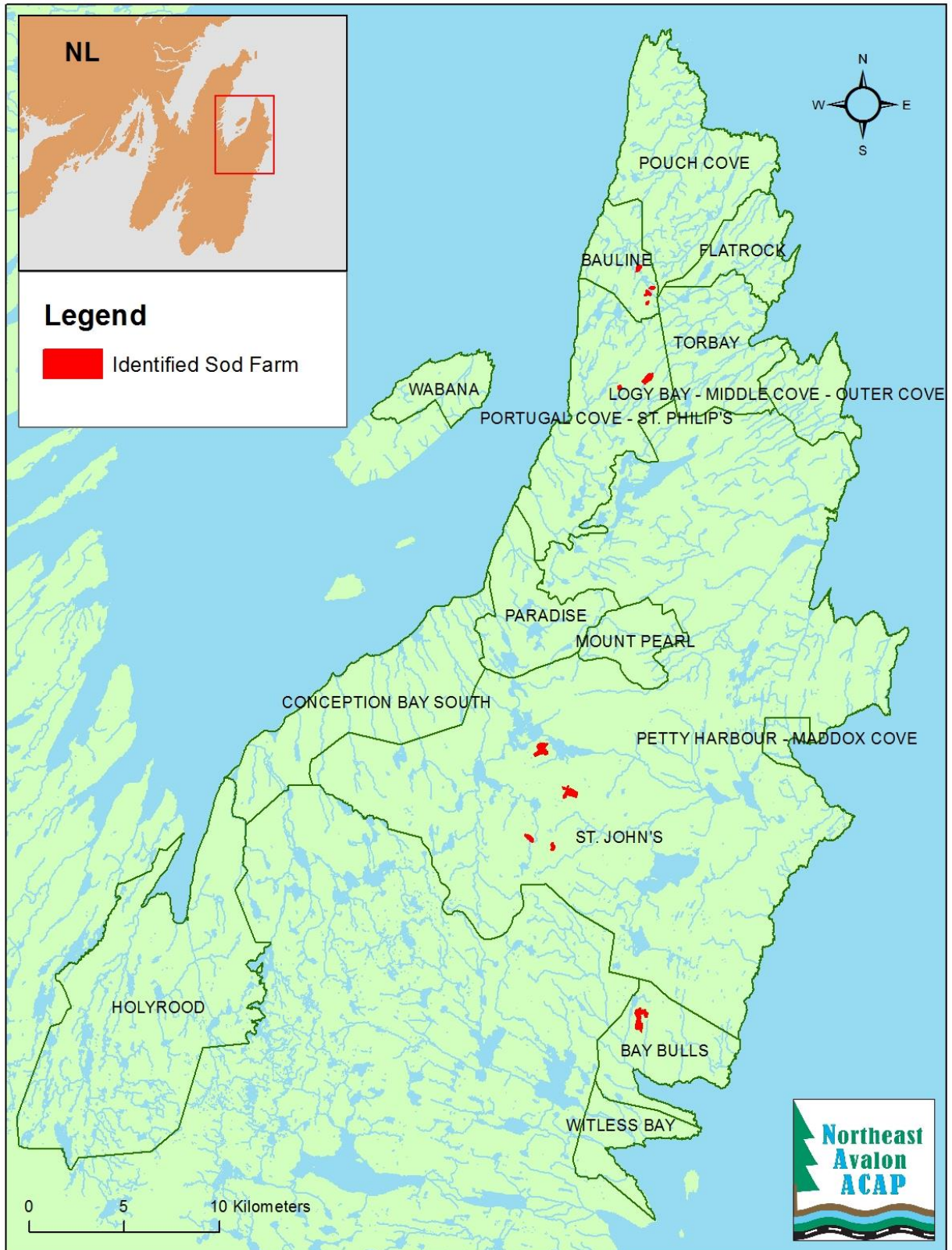
6.0 Closing Statements:

Given the rapid proliferation of sod farms on the Northeast Avalon, awareness of nearby waterways and the potential effects that a sod farm can have on them is an important component of protecting our waterways. Regular water quality monitoring of waterways is key in ensuring that protective measures on the farm are effective at maintaining the aquatic integrity of the waterway. Regular water quality monitoring would provide more detailed data from which long term trends could be determined. Laboratory testing of water samples for nutrients and pesticides would also provide further details related to the water quality of the waterways, and should be considered as components of future monitoring.

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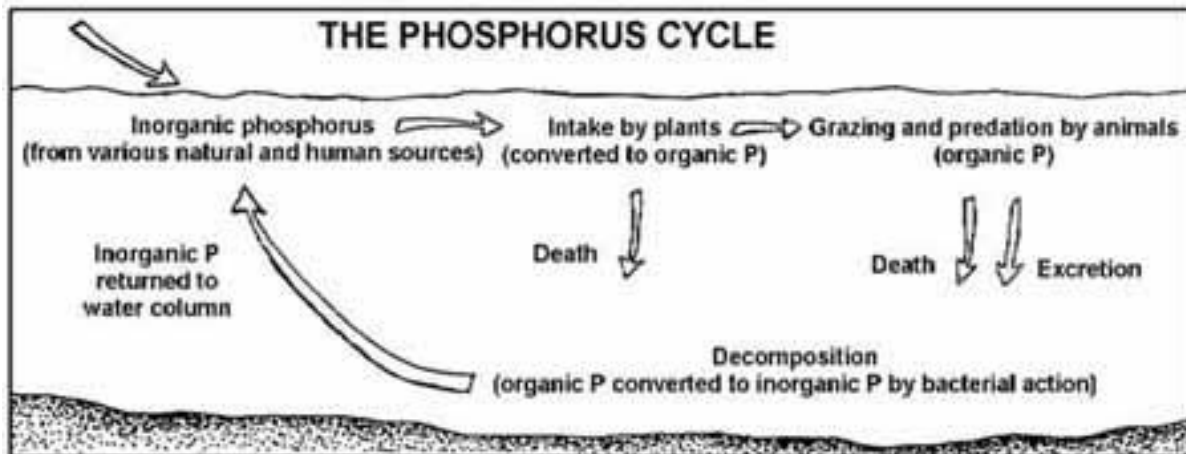
Appendix A- Map of all sod farms on the Northeast Avalon Peninsula identified on 2010 imagery



Appendix B- Diagrams of phosphate and nitrogen cycling

The Phosphorus Cycle in Water:

Image taken from the US EPA *Water: Monitoring and Assessment 5.6 Phosphorus* Retrieved February 21, 2014 from <http://water.epa.gov/type/rsl/monitoring/vms56.cfm>



The Nitrogen Cycle:

Image taken from Pidwirny, M. (2006). "The Nitrogen Cycle". *Fundamentals of Physical Geography, 2nd Edition*. Retrieved February 21, 2014 from <http://www.physicalgeography.net/fundamentals/9s.html>

