Hammond River Angling Association
New Brunswick Environmental Trust Fund

Hammond River Water Quality Monitoring Project
Project No: #150094
Final Report

Prepared by:
Hannah Bradford, Lee Robinson, and (ed.) Sean Doyle
Hammond River Angling Association
10 Porter Road, Nauwigewauk, NB
E5N 6X1

March 1, 2016

FOREWARD

The Hammond River Angling Association's (HRAA) mandate is to protect and preserve the Hammond River watershed through education, conservation and community interaction. This membership based group is an affiliate of the Atlantic Salmon Federation and the NB Salmon Council, provincial watershed and environmental groups, community organizations and schools throughout New Brunswick. The HRAA has engaged in many Atlantic salmon habitat and population enhancement programs since its inception. These programs include stocking fish, electrofishing for juvenile salmon, salmon spawning assessments, large scale restoration projects and bank stabilization by tree planting. The HRAA also runs an environmental summer camp, a school education program and community education through volunteer activities that promote watershed stewardship.

CONTENTS

ACKNOWLEDGEMENTS

This project was made possible through funding from the

Province of New Brunswick Environmental Trust Fund.

Other sponsor acknowledgements include:

New Brunswick Wildlife Trust Fund,

Government of Canada Science Horizons Youth Internship Program,

Youth Employment Fund,

One-Job Pledge,

National Wetland Conservation Fund

and the many other donors that have contributed to

The Hammond River Angling Association over the years.

Special thanks to: Lévis Thériault, Anne McLusky, Krista Mackenzie and Claire Caron.

Many thanks to:

New Brunswick Department of Environment and Local Government

John O'Keefe, Christie Ward, Yvette Foulkes, Dianne Howe, Shawn Prosser, Cassandra Colwell, and Kimberley Flewelling.

The numerous volunteers that have devoted time, energy and resources to the HRAA over the years.

Hammond River Angling Association

Members, Staff, Board and Executive

(Past and Present)

Special thanks to Sean Doyle (Executive Director)

and Taylor Wilson who assisted with field work, research, and data analysis.

EXECUTIVE SUMMARY

The Hammond River watershed is 512 km^2 and is located in Kings County, New Brunswick with headwaters beginning in Markhamville and eventually flowing into the Kennebecasis and Saint John Rivers. The Hammond River Watershed Management Plan synthesizes water and stream quality data with a land-use analysis to capture the current state of the watershed. This plan breaks the watershed into 11 sub-catchments, which are analyzed separately in terms of stressors from adjacent land-use and environmental condition. This report comparatively assesses sub-catchments to determine which areas are under stress and where environmental health has been measurably affected. The rank determined by evaluating stress levels and environment condition will be used to prioritize sub-catchments and focus future conservation and restoration initiatives.

The goal of this project is to update the 2008 Hammond River Watershed Management Plan, so it may continue to inform and guide successful conservation and restoration initiatives. In the summer of 2015, data on water quality, the benthic macroinvertebrate (BMI) community, environmental quality and adjacent land use was collected and used to understand the current state of each sub-catchment. Environmental conditions within the watershed suggest significant impacts from road fragmentation, mines, gravel pits and road density. Both riparian areas and the BMI community were measurably stressed in the upland and lowland areas. This report suggests that while “reactive” conservation efforts in the lowland watershed have been improving environmental quality, however, future management efforts should focus on the headwaters to pro-actively prevent further issues downstream.

In various areas throughout the watershed, there are persistent problems of pollution (e.g. E. coli), sedimentation, warm water, and flooding which affect the quality of aquatic life. There are several steps the HRAA can take to reduce these problems over the next 5-10 years and by doing so, improve quality of life for the local community, biodiversity and fish. This report has identified that the Markhamville, French Village, Nauwigewauk, Hanford Brook, and Palmer Brook eco-reaches are of high priority. While most recommendations addressed in this report focus on enhancing the natural ecosystem services provided by riparian areas and wetlands there are some areas where other interventions are needed (monitoring, sediment capture infrastructure, culvert replacement, etc.).

INTRODUCTION

Watershed assessments measure water quality to understand the relationship between land use and water within the watershed. The aim of watershed management is to maintain or enhance existing ecosystem services, such as water filtration and supply, water attenuation, the provision of food, the prevention of erosion, stream temperature regulation and habitat for wildlife (Miller *et al.*, 1989). The degradation of aquatic ecosystems, riparian areas and wetlands diminishes the natural ecosystem services of a watershed.

Watersheds typically include lotic bodies of water (river, tributaries, streams, brooks or ephermal streams), lentic bodies of water (lakes or ponds), riparian zones (the water-land interface), wetlands (marshes, bogs, fens, etc), and surrounding forested/ grassland areas. Watersheds are topographically defined as the area from which all water (surface or ground) will flow through a common area. In watershed management, the sub-catchments are delineated to help enable the isolation of poor water quality sources. Sub-catchments are defined by their drainage into a common point.

OBJECTIVES

This document replaces the 2008 Hammond River Watershed Management Plan. This updated plan will serve to guide HRAA conservation and restoration initiatives within the watershed. This plan aims to:

- → Assess the impact of land use on water quality and riparian health.
- → Assess the current state of water quality at each site, in comparison with the historical data.
- → Determine whether restoration efforts have had a successful influence on water quality.
- → Determine whether water quality is having an impact on biodiversity.
- → Provide a detailed assessment of the sites visited for future comparison.
- → Prioritize areas of concern and provide a list of recommendations to guide watershed management in the future.

To achieve these goals, data collected from 2008-2015 will be integrated into the report to provide - insight of the current state of the watershed. This data will be compared with historical data (collected in 1997 and 2007) to determine whether past management efforts were successful. This document will serve as both a management plan and compilation of work by the Hammond River Angling Association (2008-2015) to provide reference material for future stewards of the Hammond River. The document will also provide baseline data for the sites frequented by New Brunswick Department of Environment and Local Government (NBDELG) to inform future management plans.

HRAA METHODS

THE HAMMOND RIVER WATERSHED

The Hammond River watershed is located in southeastern New Brunswick, adjacent to the Saint John River valley. The watershed has a total area of 513 km^2 with 561 segments of streams, surmounting a total of 461 km in length (Avg. 0.82±0.91 km) (DNR, 2009) (Figure 1). Forest comprises 336 km^2 of the watershed while 64.9 km^2 is recognized for non-forest land use (DNR, 2009). Streams were classified according stream order which included stream orders 1-3 (headwaters) mostly in the upper (NE) reaches of the watershed and stream orders 4-5 (mid-waters) in the lower (SW) reaches including the main stem of the Hammond River.

The Hammond River watershed was broken into 11 sub-catchments with 13 sampling sites strategically placed in outpour locations of each sub-catchment (Figure 1). HRAA staff visited one sampling site per sub-catchment, with the exception of Markhamville, which was sampled at 3 different sites. These 3 sites were sampled to retain continuity with previous sampling protocols. These sites also have biological significance. The Hillsdale site is the true headwaters of the watershed, Hammondvale is an historical reference site, and the Markhamville site is at the confluence of most upland, two tributaries to form the Hammond River. Sampling sites were chosen from historical and provincially recognized sampling locations. Placing sites at the outpour point enabled the inference of water quality within the sub-catchment because all upstream water must flow through that point. Sampling locations for the Hammond River 2015 assessment begin at the most northern point, in Markhamville, and flow to the Quispamsis area with all tributaries leading to the main stem of the Hammond River. Water quality and visual assessments took place 4 times at each site during the summer of 2015.

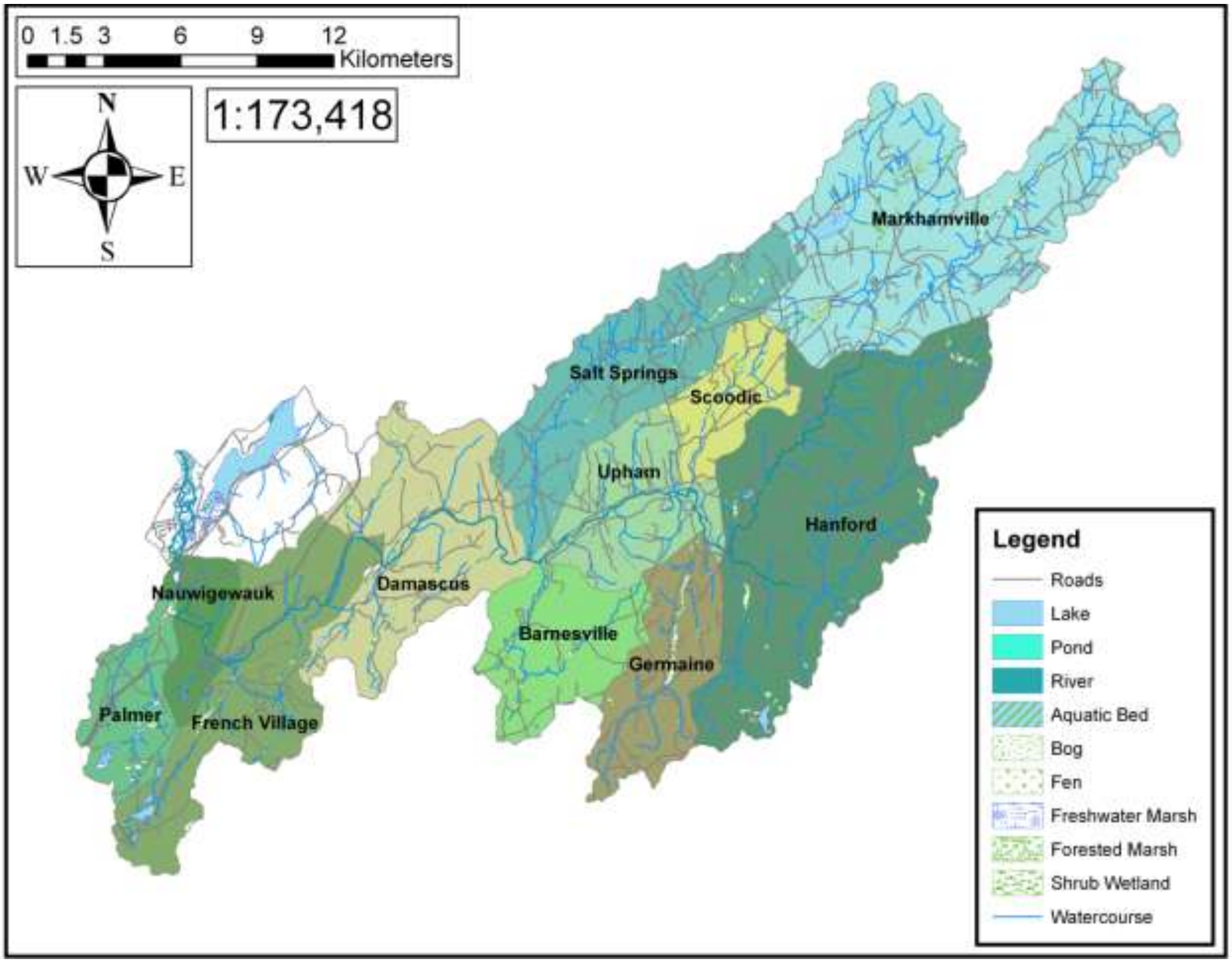


Figure 1: The Hammond River watershed is located in southeastern New Brunswick, adjacent to the Saint John River valley. Sampling locations for the Hammond River 2015 assessment begin at the most northern point, in Markhamville, and flow to the Quispamsis area with all tributaries leading to the main stem of the Hammond River. This map depicts the location of sub-catchments (2015), lakes, ponds, rivers, wetlands, and roads. *Map created using DNR GIS data, Map by H. Bradford.*

ASSESSING THE STATE OF THE WATERSHED

The Hammond River watershed was broken into 11 sub-catchments to determine areas of high conservation priority for future management. Stressors were measured using GIS data layers and environmental condition was measured using on site measurements, visual assessments, benthic macro-invertebrate collection, water quality analysis, and through the compilation of recent (2008-2015) studies performed by the HRAA. The data was analyzed to rank stream health at each site. The assessment methodology was mainly adapted from Saskatchewan's 'The State of the Watershed' report (2010) stress-condition-response model which uses several triggers as performance indicators in each category (Davies and Hanley, 2010). By adapting the stress-condition-response model the HRAA was able to determine if an area was under high, moderate or low amounts of stress and if the condition of the site was impacted, stressed or healthy.

Within this document **stressors** will refer to anthropogenic land-uses that might produce stress within a watershed. Stressor indicators include road density, land development, open pit density (gravel or mine), the prevalence of sewage fields, aquatic fragmentation and agricultural land use (Table 1) (Davies and Hanley, 2010). Stressors were quantified through the use of GIS data layers provided by DNR (2009) and were used to determine whether an area was under low, moderate or high stress from various types of anthropogenic development (Davies and Hanley, 2010). A ranking of high stress indicates that there is more anthropogenic activity in the sub-catchment, but does not necessary mean that environmental condition will be impacted or stressed. The average ranking of stress at a site was used as one (of five) categories to prioritize land management areas in the discussion.

The **condition** indicators are a collection of biological, physical and chemical parameters used to measure site condition. Indicators for site condition include surface water quality (measured in the field and *post factum* by NBDELG), benthic macroinvertebrate (BMI) communities, the state of the riparian zone (Davies and Hanley, 2010), and the quality and complexity of habitat found within the stream (collected by the HRAA) (Table 2). Condition indicators were analyzed, as defined in the methods below, to determine whether sites were healthy, impacted or stressed (Davies and Hanley, 2010). Condition rankings (Table 2) were derived by calculating an overall value from a variety of more specific measurements. The breakdown of condition indicators are include *water quality* (Appendix 2), *riparian health* (Table 3), *in-stream habitat* (Table 4) and BMI community health (**Table 5**). Each condition indicator category rank (water quality, BMI community health, riparian health and in-stream habitat) was factored into the prioritization of land management areas in the discussion.

Table 1: Stressors were quantified for each sub-catchment using road density, aquatic fragmentation, mine density, proportion of disturbed land and the density of sewage fields as indicators. Indicators were categorized for the level of stress (high, moderate or low) that they caused within that area (Davies and Hanley, 2010).

Stressor Indicator	Indicator Description	High	Moderate	Low
Road Density (km/km^2)	Density of roadways in sub-catchment	> 4.66	1.50 to 4.66	< 1.5
Aquatic Fragmentation	Proportion of stream segments that are not fragmented by culverts	< 34%	34-67%	68%
Mine Density	Number of active/inactive mines, gravel pits, etc.	>10/1000 km^2	3-10/1000 km^2	<3/1000 km^2
% of Disturbed Land¥	The % of natural landscape converted for anthropogenic use	>45%	15-45.1%	<15%
Sewage Field Density¥	Density of sewage fields in area	>45%	15-45.1%	<15%
Agricultural Land Use Density¥	Density of agricultural land use (crop land, fallow land, orchids, blueberry fields and cow pasture)	>45%	15-45.1%	<15%

¥ indicates categories created or adapted specifically to enhance relevance within the Hammond River watershed and are not specifically designated by the State of Watershed report card.

Table 2: The condition of an area was determined by evaluating: water quality from June-September 2015 (n = 4), the BMI community, riparian health, and stream habitat. Indicators were assigned a value and categorized as representing an area that was impacted, stressed or healthy (Davies and Hanley, 2010).

Condition Indicators	Indicator Description	Impacted	Stressed	Healthy
Water Quality	The grade of water quality parameters derived from their acceptable level as defined by CCME.	<45%	45-79%	80%
BMI Community	The tolerance value of each community as assigned by the Hislenhoff Biotic Index (Ecospark, 2013).	Impaired	Potentially Impaired	Unimpaired
Riparian Health	Assessment of riparian health using indicators of erosion, undercutting, overhanging vegetation and forest maturity (early to late succession).	<45%	45-79%	80%
Riparian Buffer	% of forest cover within 15 m (unless land is naturally barren, a wetland or field).	<45%	45-79%	80%
In-stream habitat¥	Assessment of substrate and flow complexity, water color, and embeddedness.	<45%	45-79%	80%

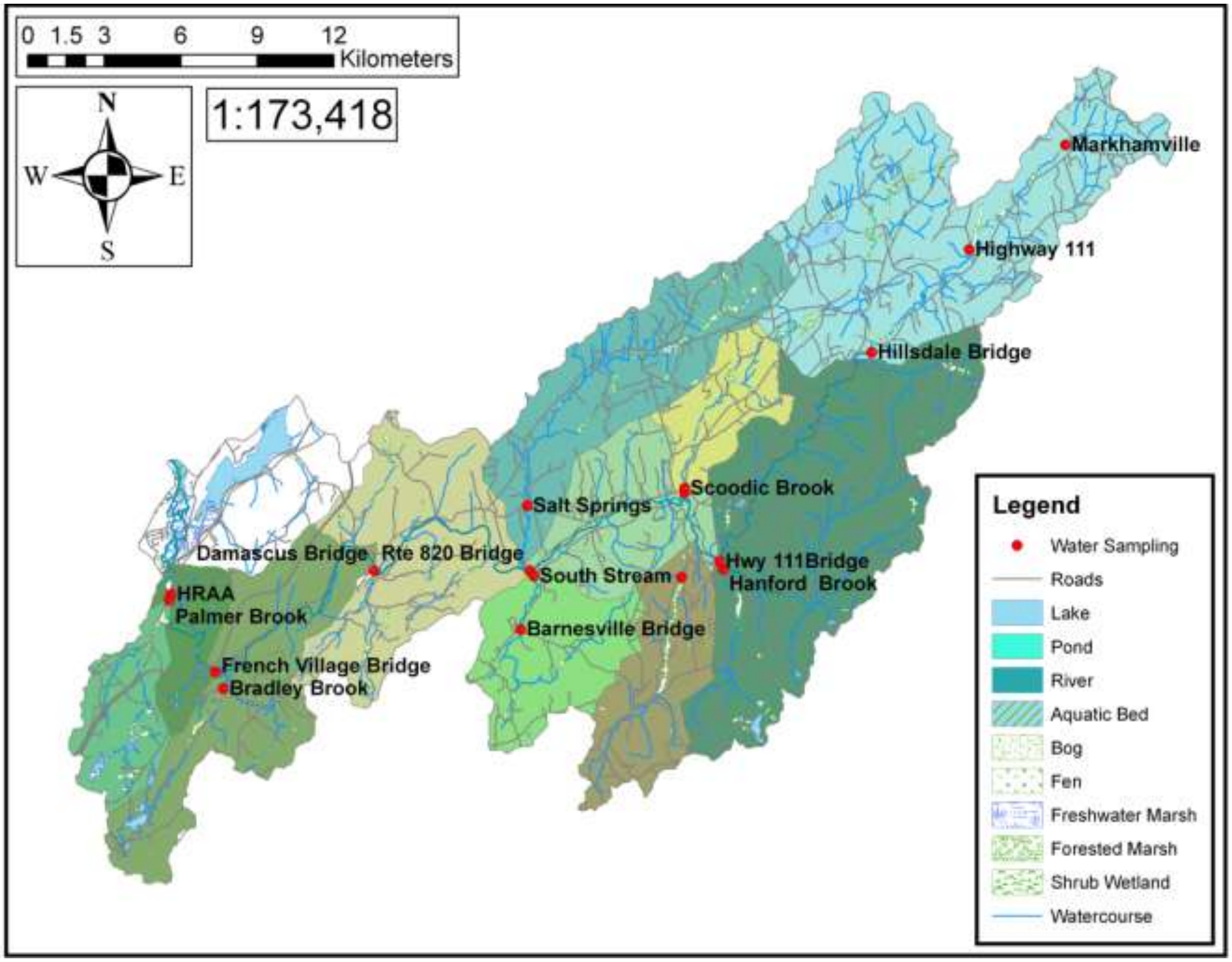


Figure 2: The location of all sites visited for water quality sampling during 2015. *Original map created by S. Campbell and S. Prosser, derived by H. Bradford using DNR GIS data layers (2009).*

All applicable water quality parameters were analyzed using the Canadian Council of Ministers for the Environment (CCME) for the Protection of Aquatic Life guidelines (Appendix 1). This process was used to assign a score to each sampling site based on how many parameters were within acceptable limits. For each site, this analysis was carried out separately for each of the 4 samples taken, and final scores were based on cumulative results of each replication. Water quality was also examined in a non-quantitative manner by identifying outliers within the 2015 data and in comparison to the historical record (1998 and 2007). If outliers were found in the historical water quality records (1998-2015), the data was further examined for trends.

Water quality is a changing notion that has many indicators and influencing factors. In an attempt to get the most thorough depiction of water quality to evaluate the health of the watershed, the HRAA has worked in collaboration with the NBDELG to analyze the water samples. This data was used to create a water quality profile for each of the sub catchments. In total, 2 microbiological, 29 chemical and 6 calculated parameters were analyzed per sample (Appendix 2). The water quality parameters analyzed were specific to the macro- and micro-nutrients that are essential elements for fish health (Appendix 3), are beneficial to fish health, and others are known pollutants detrimental to aquatic life or the environment (Appendix 2).

The condition of riparian health and in-stream habitat were evaluated during each water quality assessment. Riparian health was evaluated by ranking banks in terms of their stability, the extent to which they were undercut, the amount of overhanging vegetation, forest maturity directly adjacent to the bank, and stream cutting (Table 3). The quality of habitat was assessed by its complexity in flow types and substrate, the presence of clear water and the absence of silt (as a measure of embeddedness) (Table 4). Stream and riparian habitat data from 4 site visits were qualitatively assessed, and the average of these values were considered the result for each site (Tables 3 & 4). Qualitative data, such as embeddedness, flow type, erosion, undercutting, stream cover, and algae, were assessed by using the sampling site as a centre point and pacing 50 m each direction. Percentages were allocated at 10 m intervals and totaled after the 100 m section was complete.

RIPARIAN HEALTH

Table 3: Riparian health is evaluated by assigning percentages to bank stability, undercutting, overhanging vegetation, forest maturity and stream cover where an average less than 45% indicates an impacted site and above 80% indicates a healthy site.

Riparian Health	Ranking
Stability	Score between 0 (none) - 50 (fully stable) % for left and right bank
Undercutting	Score between 0 (fully undercut) -50 (no undercutting) % for left and right bank
Overhanging vegetation	Score between 0 (none) - 50 (overhanging vegetation present everywhere) % for left and right bank
Forest maturity	None (grassland, shrub) = 0; early successional (saplings, young trees present, immature forest species)= 25%; late (mature forest) = 50% for left and right bank
Stream Cover	Score between 0 (none) -100 (fully shaded) % stream

EROSION

Erosion is indicated by: an unstable bank where a section has detached or begun to detach, bare bank, severe sloping or indication of outfall from the bank into the adjacent stream bed. At each site the stability of both the left and right banks were recorded. A percentage value between 0% and 100% was assigned for stability for both the left and right banks.

UNDERCUT BANK

An undercut bank is a bank that rises vertically and overhangs the stream (EPA, 2013). Undercut banks can provide shade for benthic macroinvertebrates (BMI) and fish; however, serious undercutting can be an indication of bank instability (EPA, 2013). A percentage value (0 – 100%) was assigned for both the left and right banks to estimate the percentage that is undercut.

OVERHANGING VEGETATION

Overhanging vegetation is used in part as a measure of streamside cover (EPA, 2013). Streamside cover can indicate important cool water habitat for BMI and fish and in this case constitutes the overhang of grasses, shrubs and other ground vegetation (EPA, 2013). A percentage value (0 – 100%) was given for both the left and right sides of the stream to estimate the proportion of bank with overhanging vegetation.

STREAM COVER

Stream cover is caused by trees and large shrubs that shade parts of the stream and provide cool water habitats for fish. A percentage value (0 – 100%) was given based on the amount of water surface that was shaded or beneath trees. The amount of shade is, in most cases, a direct result of the amount of large overhanging vegetation and is also dependent on the time of day, time of year and weather at the time of assessment.

FOREST MATURITY

The type of vegetation was described at each site for the left and right banks. Describing the vegetation allows the HRAA to better identify why some problems may be occurring (e.g. erosion, bank undercutting, embedded substrate). By describing vegetation, we can identify primary or secondary forest succession and whether the forest is early or mature. Primary succession describes an area that wasn't previously colonized (e.g. point bar, sand dune, slip-off slope) and secondary succession is an area that has been disturbed however, there are remnants of the previous colonizers (e.g. humus, root structure). Early (pioneer) forest succession is indicated by annuals, perennials and shrubs. Eventually, this community transitions into asoftwood dominated stand with a uniform canopy and then into a mature forest consisting of hardwood stands with multiple canopy layers. Mature deciduous forests are known to increase dissolved organic carbon adsorption in the soil and increase available nitrogen (Yan *et al.*, 2015). Along with the maturity of the stand and the presence of grasses, tree species were identified at each site for both the left and right bank. Forest maturity was observed while sweeping the bank and a general category was assigned to each bank (e.g. immature, mature, wetland, grassland, secondary succession)

IN-STREAM HABITAT

Table 4: The quality of habitat is assessed by its complexity in flow types and substrate, the presence of clear water and the absence of silt (as a measure of embeddedness). An average less than 45% indicates an impacted site and above 80% indicates a healthy site.

Habitat Assessment	Ranking
Flow Types	All types present = 100%; 3 types = 75%; 2 types = 50%; 1 type = 25%
Substrate (excluding fines)	4+ types present = 100%; 3 types present = 75; 2 types present = 50; 1 type present = 25%
Water color	Gradient ranking, Clear = 100%, tannin = 80%, murky = 50%, etc.
Substrate health	Fully embedded = 0%; no embedding present = 100%

¥ A qualitative value was assigned.

FLOW TYPE

Habitat within a stream is often indicated by flow type, which is defined by current and water depth (EPA, 2013). A percentage value was assigned to estimate the type of water flow in the stream. These percentages were based on the following categories:

- Riffle: a shallow stretch of stream, where the current is above the average stream velocity and turbulence forms small rippled waves as a result. Riffles indicate good aeration within the water and a complex substrate.
- Run: indicates deeper water depth and average to fast flow velocity with no turbulence.
- Pool: a section of the stream in which the water depth is above average and the stream velocity is low. Pools provide important habitat for fish and fish spawning. Stagnant waters were otherwise indicated.

**riffle, run and pool are assigned individual percentages that together add up to 100%. An example of stream flow type would be 20% riffle, 65% run and 15% pool.*

SUBSTRATE

Substrate can indicate available habitat for benthic communities, such as BMIs. Usually, a more complex substrate indicates ample pore space and aeration for the viability of these species (EPA, 2013). Streambed composition was surveyed to identify and classify the types of substrate that composed the 13 sampling sites. There are 7 categories that were used to classify substrate types based on the size of the matter composing the streams. A percentage value was given to allocate substrate composition appropriately between categories. Substrate composition estimates were made at 3 1×1 m plots across the width of the stream. The categories were as follows:

1. Bedrock (ledge)
2. Boulder (>4.6 cm)
3. Rock (1.8-4.6 cm)
4. Rubble (.5- 1.79 cm)
5. Gravel (2.6- 50 mm)
6. Sand (0.06- 2.5 mm)
7. Fines (<0.05mm)

For example a streambed may have a composition of; 0% bedrock, 30% boulder, 40% rock, 10% rubble, 10% gravel, 5% sand and 5% fines. The total should add to 100%.

EMBEDDEDNESS

Embeddedness indicates the extent to which rocks (gravel, rubble and boulders) are sunken within silt (EPA, 2013). Embeddedness can predict benthic health because increasing embeddedness indicates less pore space for BMI habitat and fish spawning (EPA, 2013). Embeddedness is often a result of natural or anthropogenic erosion upstream and can indicate areas of instability within the watershed.

A percentage was assigned to estimate the amount of substratum (silt, sand or mud) that surround, cover or deep set rocks within the stream bottom.

ALGAE

Algae play a vital role in all aquatic ecosystems, creating a food and energy base for all organisms within a river food web. Algae create energy through primary production, using sunlight to make carbohydrates. The amount of algal growth that occurs is dependent on the conditions within the stream and is effected by variables such as adequate nutrient supply (primarily phosphorous, which is a limiting nutrient for growth), season, temperature, amount of sunlight penetrating the water column, amount inorganic nutrients available and competition. Algal succession describes the yearly cycle of algal species that occur with seasonal changes. For instance, some populations are most abundant during the spring and early summer when available light and nutrients are high and few organisms are present to feed on the algae. Alternatively, nutrient mixing in the late summer and early fall allows for algal species to thrive. By investigating the presence of algae, trophic statuses can be assigned to a site as another indicator of stream health. Algae abundance was measured at each site and classified as either , **oligotrophic** (waters are clear to great depths and have few algae), **mesotrophic** (a moderate abundance of algae), or **eutrophic** (highly saturated with algae and often associated with turbidity).

IN SITU STREAM MEASUREMENTS

At each site, characteristics of the water quality were measured and recorded, using a YSI 85 probe and pH meter. Measurements were made for water temperature (°C) conductivity (µS/cm), dissolved oxygen (D.O.) (mg/L) and pH. Conductivity, D.O. and pH were calibrated once prior to the sampling season according to manufacturer recommendations.

Water temperature (°C) was taken upon arrival at each site using a YSI 85 probe, while the air temperatures were retrieved from an online archive data base.

Water conductivity is the ability of water to conduct electrical current (EPA, 2013). Electricity will travel through dissolved inorganic particles (ions) in the water such as chloride, nitrates, sulfates, magnesium, and calcium or iron (EPA, 2013). Organic particles are known to have a low conductivity (EPA, 2013). Conductivity varies with the type of water, meaning pure water will have a lower conductivity than freshwater, which will be lower than brackish water or seawater. Therefore, water that contains a high concentration of total dissolved solids, such as highly polluted water would have a higher conductivity. Water conductivity is measured in micro Siemens per centimeter (µS/cm) and/or MHO (1/ohm or 1/Ω). Water conductivity is correlated with temperature and will be higher in warmer water.

Dissolved Oxygen Content is the amount of oxygen (O_2) that is dissolved in water. It is measured in milligrams per liter (mg/L) or as a percentage value. D.O. is vital to aquatic life and a D.O. of 9.5 mg/L is the approximate and accepted level to support a healthy aquatic community with all life stages. D.O. is affected by water temperature making cool habitats a crucial component to any healthy stream system in the summer. When D.O. is low, the community will become stressed and further reductions in D.O. can occur as well as emigration.

pH is a measure of how acidic or basic a solution is. The pH scale ranges from 1 to 12. A pH level of 7 is considered neutral, any solution with a pH level below 7 is considered acidic while a pH above 7 is considered basic. Although pH levels vary naturally, a healthy stream would have a pH level between 6 and 8. pH is represented on a logarithmic scale so a difference in a pH of one actually represent a difference of 1^{10}.

BENTHIC MACROINVERTEBRATE ANALYSIS

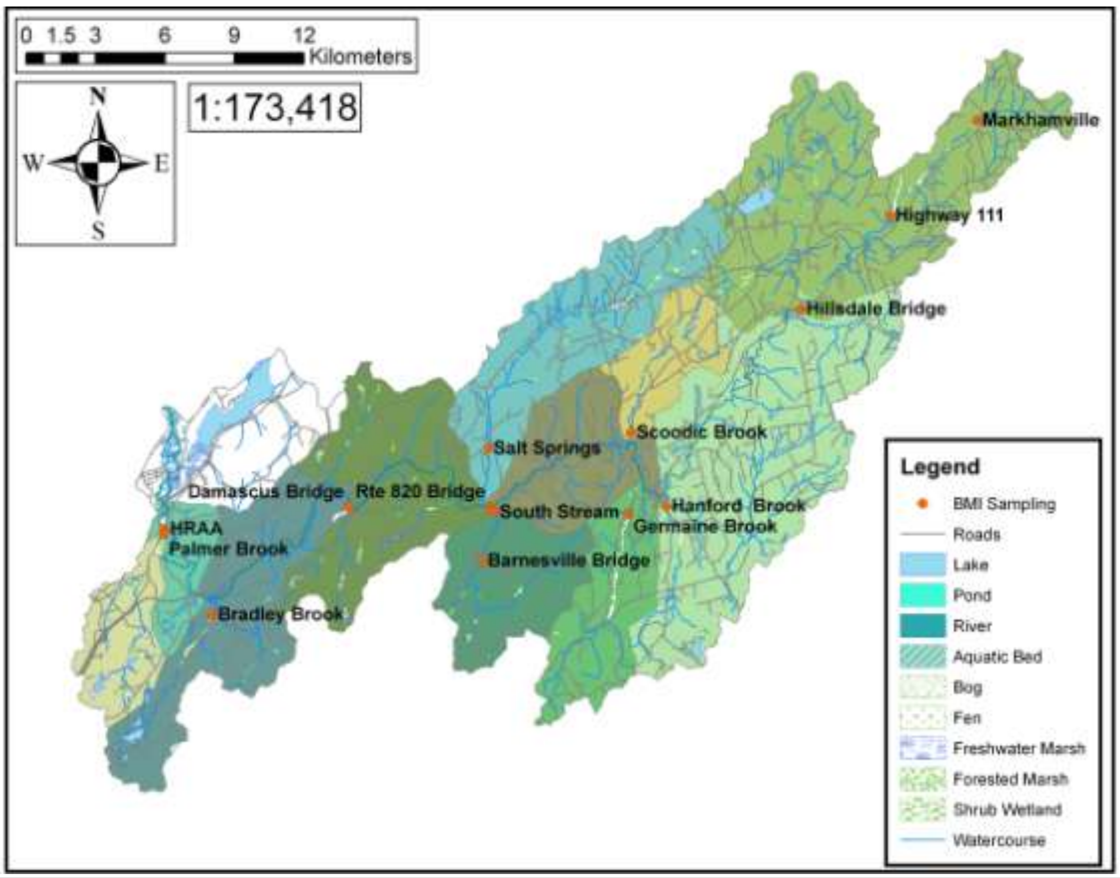


Figure 3: The location of all sites visited for benthic macroinvertebrate collection during 2015. *Original map created by S. Campbell and S. Prosser, derived by H. Bradford using DNR GIS data layers (2009).*

A macroinvertebrate is an organism that lacks a backbone and is apparent to the naked eye. While traditional sampling has focused on chemical and physical parameters, this method often only provides a snapshot of stream health. Recently, the use of benthic macroinvertebrate (BMI) collection and identification has been used to provide a long-term outlook of community health (CABIN, 2009). The addition of a biotic sampling parameter can provide the "effect" of the abiotic sampling (CABIN, 2009). Once identified, BMI can be assigned a tolerance value which provides a quantitative measure of stream health through ecological based classification (EcoSpark, 2013). BMIs are a good measure of stream health due to their ubiquity across streams, relatively sedentary range, life span (1-3 years), diversity, and importance to the local food web (CABIN, 2009). In, addition BMI species are known to have different tolerance levels to specific stressors and their presence or absence may indicate the effects of these stressors.

The Canadian Aquatic Biomonitoring Network (CABIN) provides guidelines for sampling unit effort to standardize methodology in order to make the data comparative across watersheds. CABIN protocol requires 3 minute sampling effort for the kick net sampling at 400 µm mesh size (CABIN, 2009) - 500 µm mesh size (EcoSpark, 2013). BMI sampling should occur in late summer to fall, when most of the community will be present (CABIN, 2009). Collected BMI should be drained of water as much as possible and preserved in 95% ethanol (CABIN, 2009) or isopropyl alcohol (EcoSpark, 2013).

Samples were collected with a WildCo © benthic D-net with a 500 µm mesh size and tapered open end for the easy insertion and removal of collection bottles. The benthic D-net was oriented with the large end upstream. Heel to toe movements were used to disturb the sediment and direct it toward the net across the width of the stream for 1 minute. Samples were intended to be collected from a riffle (2) and run location, if possible. Each sample was drained and preserved in anhydrous ethanol. Samples were sorted using a 100 cell Marshant by distributing the sample evenly throughout cells and sorting cells until 200 BMI were identified. The content of each cell was sorted using a 6 × 6 gridded petri dish at 20 X magnification. After the sample was sorted, the benthic aggregate assessment was performed and the condition of the community was identified.

Benthic macroinvertebrate (BMI) communities were collected in triplicates from the 13 sampling sites on September 21st, 2015 (Figure 3). The Eco Spark Benthic Aggregate Assessment was used to evaluate BMI communities by examining species abundance, diversity and their pollution tolerance values assigned through the Hilsenhoff Biotic Index (Table 5). After all condition indicators were ranked, the ranks were assigned a numerical value and the average was used to assign an overall rank to the sub-catchment.

Table 5: Benthic macroinvertebrate indices summary (derived from the EcoSpark benthic aggregate assessment). If five or more indices are calculated outside the limits of unimpaired criteria, then the site is potentially impaired (EcoSpark, 2013).

Index	Impaired	Potentially Impaired	Unimpaired
Worm (%)	>30	10 to 30	<10
Midge (%)	>40	10 to 40	<10
Sowbug (%)	>5	1 to 5	<1
Taxonomic Groups (#)	≤11		>11
Snail (%)		0 to >10	1 to 10
Dominant Group (%)	>45	40 to 45	<40
Mayfly, Stonefly & Caddisfly (%)	<5	5 to 10	>10
True fly (%)	<15 or >50	15 to 20, or 45 to 50	20 to 45
Insects (%)	<40 or >90	40 to 50, or 80 to 90	50 to 80
Hilsenhoff Biotic Index	>7	6 to 7	<6



Figure 4: H. Bradford using a kick net sampler to collect BMI. *Photo by S. Doyle Sept 23 2015.* Figure 5: BMI being strained in the field of silt. *Photo by H. Bradford Sept 23 2015.* Figure 6: BMI at 20 X on a gridded petri plate. *Photo by H. Bradford Dec 16 2015.*

RESULTS

During the summer of 2015 water quality samples were collected four times on June 17th, July 20th, August 17th and September 23rd within the Hammond River watershed. Water quality measurements were collected at 13 sites monthly and a total of 17 sites were visited, as four sites were moved throughout the summer (Figure 2). Benthic macroinvertebrate (BMI) communities were collected in triplicates from 13 sites on September 21st, 2015 (Figure 4). Water quality samples and BMI communities were collected at 13 sites. Some water quality sampling locations were moved to nearby streams such as Bradley Brook - Hammond River (French Village Bridge), South Stream - Hammond River (Route 820), and Hanford Brook - Hammond River (St. Martins Road). There are various reasons for why the site locations were moved; however, the sites are in close proximity to one another and allowed for a broader range of data to be collected for the Hammond River watershed.

The July 20th sampling date was the only collection which occurred post/during rainfall. The Environment Canada Canadian Climate Data measured this rainfall at 15-20 mm for Saint John during July 19th and 20th. The rainfall caused unique conditions in the water quality results including high concentrations of E. coli, phosphorus and turbidity. These results provide a unique glimpse of the short-term conditions experienced during rainfall events within the watershed.   Over the course of 2015, similar trends were observed across all sites in the watershed. Trends included the increasing prevalence of algae (except Germaine Brook) and overhanging vegetation, or decreasing dissolved oxygen and water levels. The data collected for the riparian and stream habitat assessment are presented as the average to accommodate for these changes.

Table 6: The stressor ranking of each sub-catchment. Stressor data was derived from the DNR GIS data layers. *Table by H.Bradford.*

Sub-catchment	Road Density (km/km^2)	Aquatic Fragmentation	Mine Density	% of disturbed land[¥]	Sewage Field Density[¥]	Agriculture	Stressor Rank
Palmer Brook	Moderate	Moderate	High	Moderate	Low	Low	**Moderate**
Nauwigewauk	Moderate	High	Moderate	Moderate	Low	Moderate	**Moderate**
French Village	Low	High	High	Moderate	Low	Low	**Low-Moderate**
Damascus-Titus	Low	High	Moderate	Low	Low	Low	**Low**
Salt Springs	Moderate	Moderate	Moderate	Low	Low	Low	**Low-Moderate**
Barnesville	Low	High	Low	Low	Low	Low	**Low**
Upham	Moderate	High	Low	Low	Low	Low	**Low**
Germaine Brook	Moderate	High	Low	Low	Low	Low	**Low**
Scoodic	Moderate	Moderate	Low	Low	Low	Low	**Low**
Hanford	Moderate	High	Low	Low	Low	Low	**Low**
Markhamville	Moderate	High	High	Low	Low	Low	**Low-Moderate**

Table 7: The condition of each sub-catchment . Based on water quality, the aquatic BMI community, riparian health and in-stream habitat data. *Table by H. Bradford.*

Site	Water Quality	Aquatic BMI	Riparian Health	Riparian Buffer	Condition Rank
Palmer Brook	Healthy	Healthy	Impacted	Healthy	Healthy
Hammond River (Conservation Centre)	Healthy	Healthy	Stressed-Impacted	Healthy	Healthy
Hammond River (French Village)	Healthy	N/A	Stressed-Impacted	Stressed	Stressed
Bradley Brook	Healthy	Healthy	Impacted-Stressed	Stressed	Stressed
Damascus-Titus	Healthy	Healthy	Stressed-Healthy	Stressed	Potentially Stressed
Salt Springs Brook	Healthy	Healthy	Stressed	Healthy	Healthy
Hammond River (Route 820)	Healthy	Healthy	Stressed	Healthy	Healthy
Barnesville Bridge	Healthy	Healthy	Stressed-Healthy	Healthy	Healthy
South Stream	Healthy	N/A	Healthy	Healthy	Healthy
Scoodic Brook	Healthy	Healthy	Stressed	Healthy	Healthy
Hammond River (St. Martins Road)	Healthy	N/A	Stressed	Stressed	Stressed
Hanford Brook	Healthy	Stressed	Stressed	Stressed	Stressed
Germaine Brook	Healthy	Healthy	Healthy-Stressed	Healthy	Healthy
Hillsdale	Healthy	Stressed	Stressed	Impacted	Stressed
Hammondvale	Healthy	Stressed	Stressed-Healthy	Impacted	Stressed
Markhamville	Healthy	Healthy	Healthy-Stressed	Impacted	Potentially Stressed

PALMER BROOK SUB-CATCHMENT

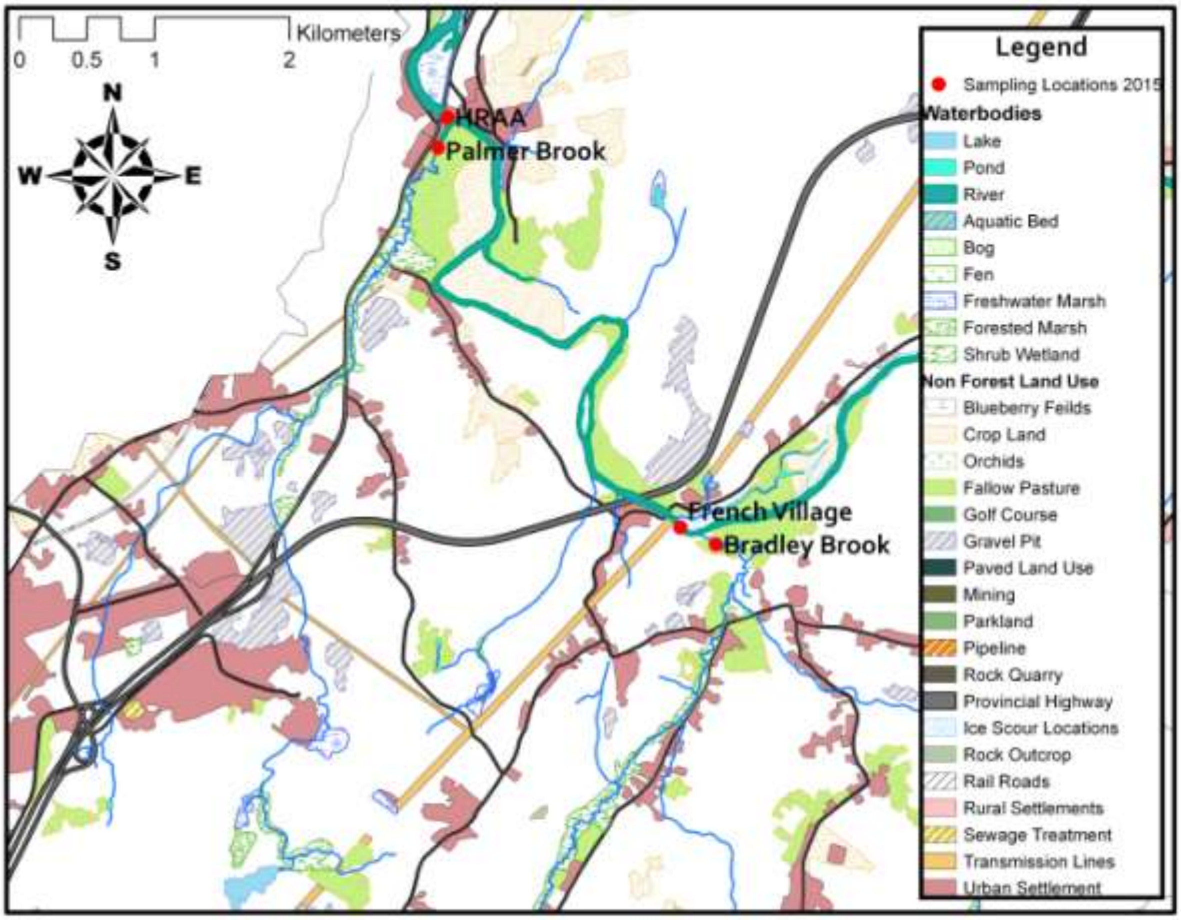


Figure 7: Map depicting Palmer Brook (bottom left) and Nauwigewauk sub-catchments (top right) and depicts land use within those areas. *Map created by H. Bradford using DNR data layers (2009) with GIS.*

The Palmer Brook sub-catchment is located in the lower reaches of the Hammond River watershed and is 19.5 km^2 in size. This sub-catchment is the most highly developed in the watershed; land use in this area consists of the Hampton highway (Route 1), the Trans Canada Highway (1), commercial and residential development, open gravel pits, a sewage field for the municipality of Quispamsis, some crop land and fallow pasture (Figure 27). Features in this area include Palmer and Colton Brook, Provincially Significant Wetlands (PSW) and fields prone to seasonal flooding. Historically, this area has been highly prioritized by the HRAA due to prominent land management issues and the resulting effects on water quality (Campbell and Prosser, 2008). Land management issues in this area have typically consisted of eroding banks and heavy sedimentation (Campbell and Prosser, 2008). These issues are still occurring to date, and are mostly attributed to the density of development in the area, as the riparian zone appears largely intact (99.9% undeveloped). Aerial photography also indicates farmland and gravel pits encroach the riparian buffer. Stress from development includes the highest density of roads (2.26 km/km^2) in the watershed, land development (35% is developed), open gravel pits (0.48 km/km^2) and residential sewage fields (exclusive to this area). In contrast, aquatic fragmentation (13 out of 23 stream segments are disrupted) and riparian disturbance are comparatively low. Overall, this sub-catchment warrants the highest stress ranking within the watershed indicating **moderate levels of stress** from development. Even though agricultural density is considerably low in this area (3.03%), Palmer Brook has been known to produce unacceptable levels of E. coli (Campbell and Prosser, 2008); E. coli is most likely diffusely sourced from sewage fields.

In 2010, a large culvert was replaced at Colton Brook road - Colton Brook intersection, a tributary of Palmer Brook. Downstream (in Palmer Brook) closer to the confluence point for the Hammond River, the riverbanks have been rehabilitated with willow clippings from the low water level to the high flood level and various hardwood species were planted at the crest of the banks (2015) (Figure 12). Currently, fallow pasture which is prone to seasonal flooding and is adjacent the lowest 250 m of Palmer Brook is undergoing wetland restoration (Figure 12). This area is area is known to contain a spring fed cool water source and holding pools and provides significant habitat for striped bass, American eel, Brook trout and nesting salmon. Currently, Palmer Brook has the highest annual fish counts however, salmon and redd beds have not been found here in recent years (Appendix 7). Tidal influx is known to cause stagnant water in lower Palmer Brook (resulting in a grease-like film on the water surface) and this segment of brook is currently closed to angling. Our current wetland restoration projects aim to improve water retention in the area and restore the natural vegetation that feed fish during spring floods.

PALMER BROOK SITE

Palmer Brook was sampled 4 times in 2015, 100 m upstream of the conflux. Palmer Brook is a tidal stream and is classified as a stream order 4. The substrate at this site was 100% **embedded** with silt with 90% **fines** and 10% rock. The predominant water flow was 90% **run** and 10% **pool.** Flow at Palmer Brook is typically stagnated in comparison to other sites because tidal influence causes backwater. The site had 0% **stream cover** and the water appeared **tannin/ murky brown** in color. Assessing all parameters, Palmer Brook was documented to have an **impacted** riparian health and **stressed** in stream habitat.

Late summer measurements indicated warm water temperatures (> 21ºC) and low dissolved oxygen levels (> 6 mg/L) (Figure 11). By mid-summer, the environment had transitioned from oligotrophic to mesotrophic. Nutrient enrichment was reflected in the BMI community, which contained a high abundance of sow bugs. The BMI community collected at this site had the second highest tolerance to pollution, although the community was ranked as **unimpaired.** E. coli was measured above the acceptable limit for the protection aquatic life (PAL) during this study (Appendix 4) and in 2007 (Campbell and Prosser, 2008). Hardness and alkalinity levels were continuously at higher than normal concentrations for the watershed. Both parameters are beneficial to water quality as hardness eases osmoregulation in fish and a high alkalinity indicates the brook had a high buffering capacity for changes to pH and carbonate ions. Despite this, Palmer Brook was found to have high concentrations of aluminum, calcium, carbonate, chromium, copper, magnesium, manganese, phosphorus, nitrogen and nitrates in comparison to other sites in the watershed. The water here was also turbid and high in total color units (Appendix 4).

Figure 8 (top left): Palmer Brook substrate. *Photo credit: H. Bradford Aug 17, 2015.* Figure 9 (bottom left): Palmer Brook at low water from left bank. *Photo credit: H. Bradford July 27, 2015.* Figure 10: Palmer Brook at high water level. *Photo credit: H. Bradford June 17, 2015.*

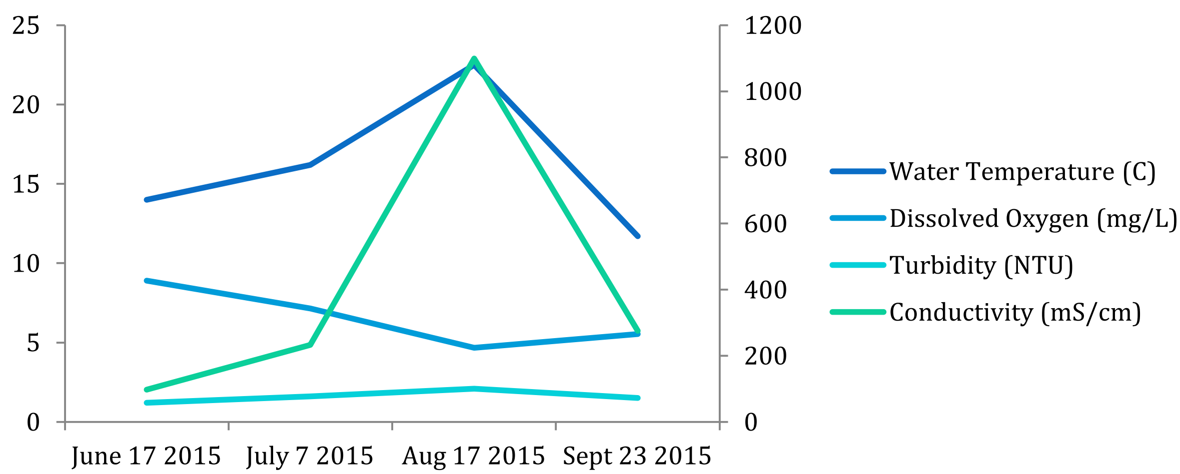


Figure 11: Water temperature, dissolved oxygen, turbidity and conductivity measurements. *Figure created by H. Bradford.*

Table 8: Bank Characteristics of the Palmer Brook site. *Table by H. Bradford, 2015.*

Characteristic	Left Bank	Right Bank
Forest type/ Vegetation	Pioneer/ Grassland	Early/ Wetland
Slope	Flat	Moderate
Drainage	Imperfect	Imperfect
Overhanging Vegetation	50	70
Undercutting	50	30
Stability (%)	45	65

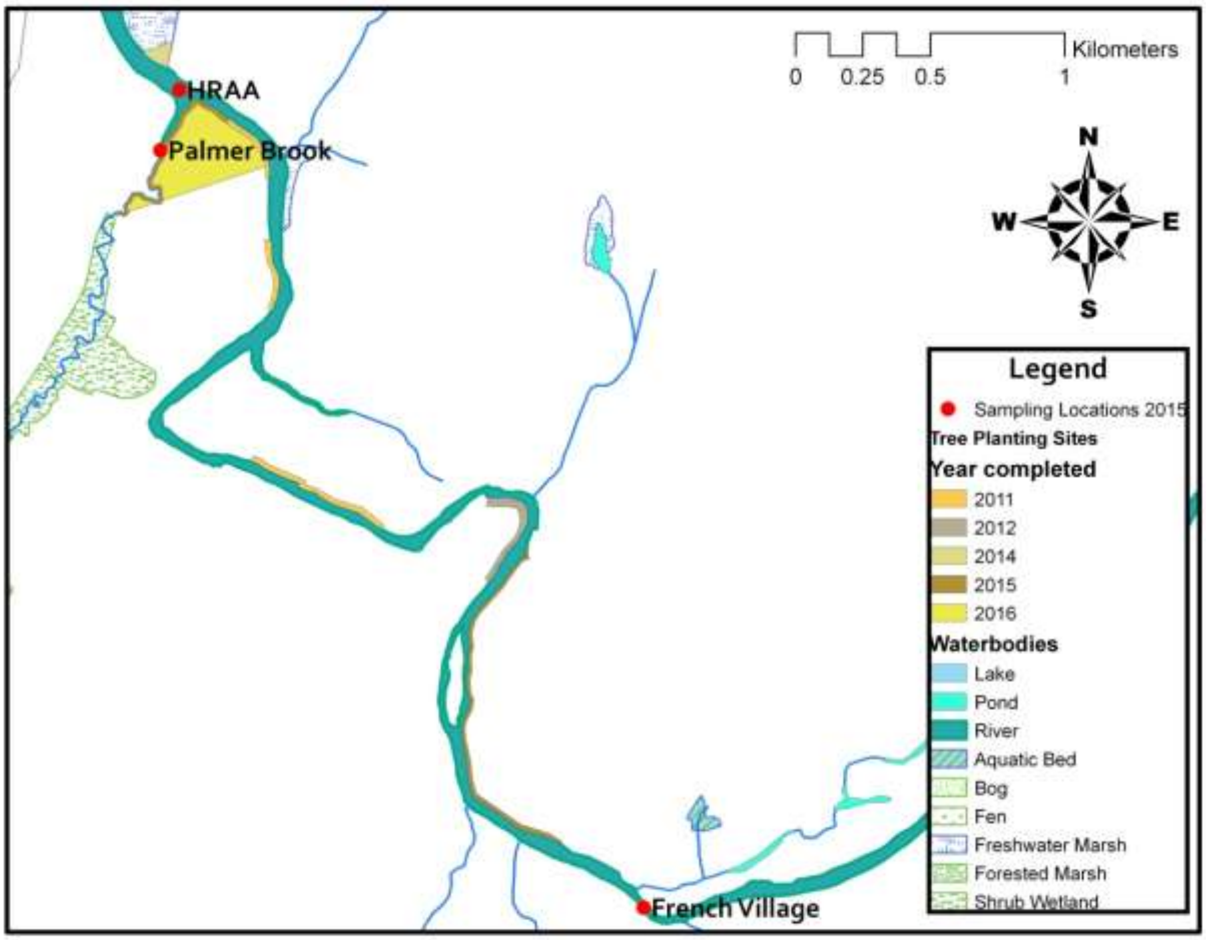


Figure 12: The HRAA has completed several riparian restoration projects along the lower Hammond River and more recently has began to restore fallow pasture to wetland. *Map created by H. Bradford.*

NAUWIGEWAUK SUB-CATCHMENT

The Nauwigewauk sub-catchment represents the point to which all water from the watershed cumulatively flows. In this sub-catchment, the Hammond River is bordered by fallow and hay pasture, residential land and a large, open gravel pit (Figure 7). Annual flooding, steep riparian banks and alluvial, unconsolidated soil characterize this area. The 12.5 km^2 sub-catchment begins at the French Village bridge and ends downstream of the HRAA conservation centre. The sub-catchment has several significant pools, Bater Brook and other tributaries. Road density (2.1 km/km^2 of road) and developed land (25.8 %) were the second highest in this sub-catchment, causing moderate levels of stress. Stress from aquatic fragmentation (9 out of 11 stream segments), agriculture (16.26%) and open gravel pits (0.4 %) were ranked as high. Overall, there were **moderate levels of stressors** found within this sub-catchment.

The condition of the riparian buffer zone was healthy (88.1% is undeveloped), due in part to restoration efforts by the HRAA. These efforts include a major riverbank rehabilitation project completed in 2011, with 2 sites upstream of the HRAA and 3 downstream (Figure 12). In total 7,308 trees were planted, restoring 1.982 km of riverbank. Currently, the HRAA has successfully established willow along several segments of the Hammond River to further riparian rehabilitation in the area (Figure 12). Other restoration work includes the reclamation of two fallow pastures (8.3 ha and 1.4 ha) upstream (restored in 2015-2016) and downstream (restored in 2014) of the HRAA building (Figure 12).

HAMMOND RIVER CONSERVATION CENTRE (HRCC) SITE

The HRCC site was sampled 4 times in 2015. Located on the main stem of the Hammond River, this site is classified as a stream order 5. **Embeddedness** at the HRCC site had increased 40% (to 80%) since observations were last made by the HRAA in 2008 (Campbell and Prosser, 2008). The stream color was consistently characterized as **tannin**. The dominant flow was **run** and there was **0% forest cover.** Assessing all parameters, the HRCC site was documented to have an **impacted** riparian health and the stream habitat was **stressed**. One major contributor to this area's impacted riparian health was the density of agriculture land, which was the highest in the watershed. Late summer measurements (Aug. 17th) indicated this area does not provide cool water habitat (> 21ºC) and dissolved oxygen levels were too low (< 7.5 mg/L) to support a healthy aquatic community (Figure 13).

The measurements taken during the rainfall event indicated this site may be periodically exposed to levels of E. coli higher than acceptable for aquatic fish health (Appendix 4). In comparison with the rest of the watershed, E. coli and ammonia were found in high concentration at this site, at 4.3 and 3.6× higher, respectively. The benthic community collected here had a large proportion of worms and midges, which are general indicators of organic pollution and water quality that does not support a healthy biotic community (Ecospark, 2013). Impaired stream quality was also indicated by the low abundance of insects. Overall, the BMI community was ranked as **unimpaired,** although it had a high tolerance to pollution (5.6) (Appendix 5) .

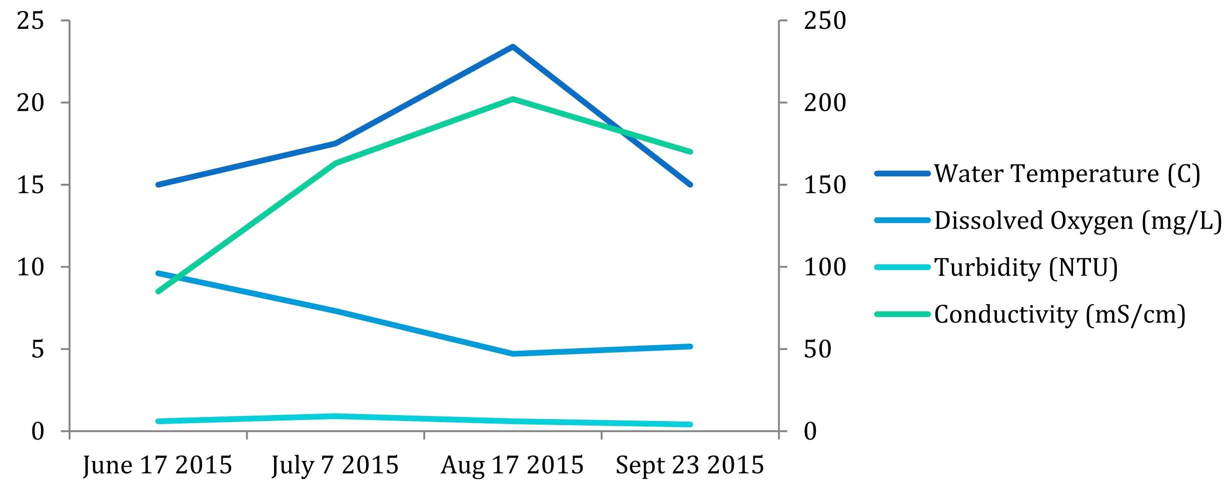


Figure 13: Water temperature, dissolved oxygen, turbidity and conductivity measurements during summer 2015. *Figure created by H. Bradford.*

Table 9: Bank Characteristics of the HRCC site. *Table by H. Bradford, 2015.*

Characteristic	Left Bank	Right Bank
Forest Maturity	Early/ Floodplain	Early/ Wetland
Slope	Gradual	Moderate
Drainage	Imperfect	Imperfect
Overhanging Vegetation	3	50
Undercutting	30	5
Stability (%)	45	90

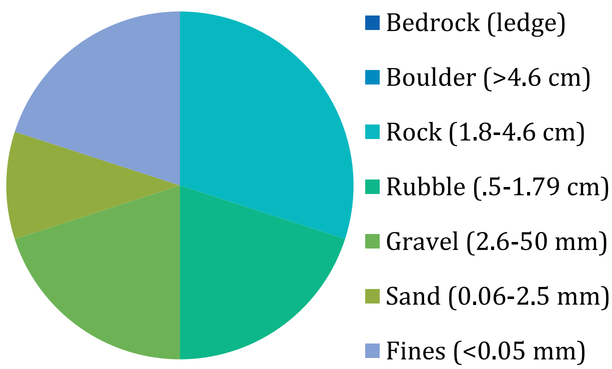


Figure 14 (top left): The substrate composition by percentile at the HRCC site. *Chart by H.Bradford.* Figure 15: Substrate at the HRCC site. *Photo by H.Bradford July 20 2015.* Figure 16: The left and right banks, facing upstream, at the HRCC site. *Photo by H. Bradford June 17 2015.*

FRENCH VILLAGE SUB-CATCHMENT

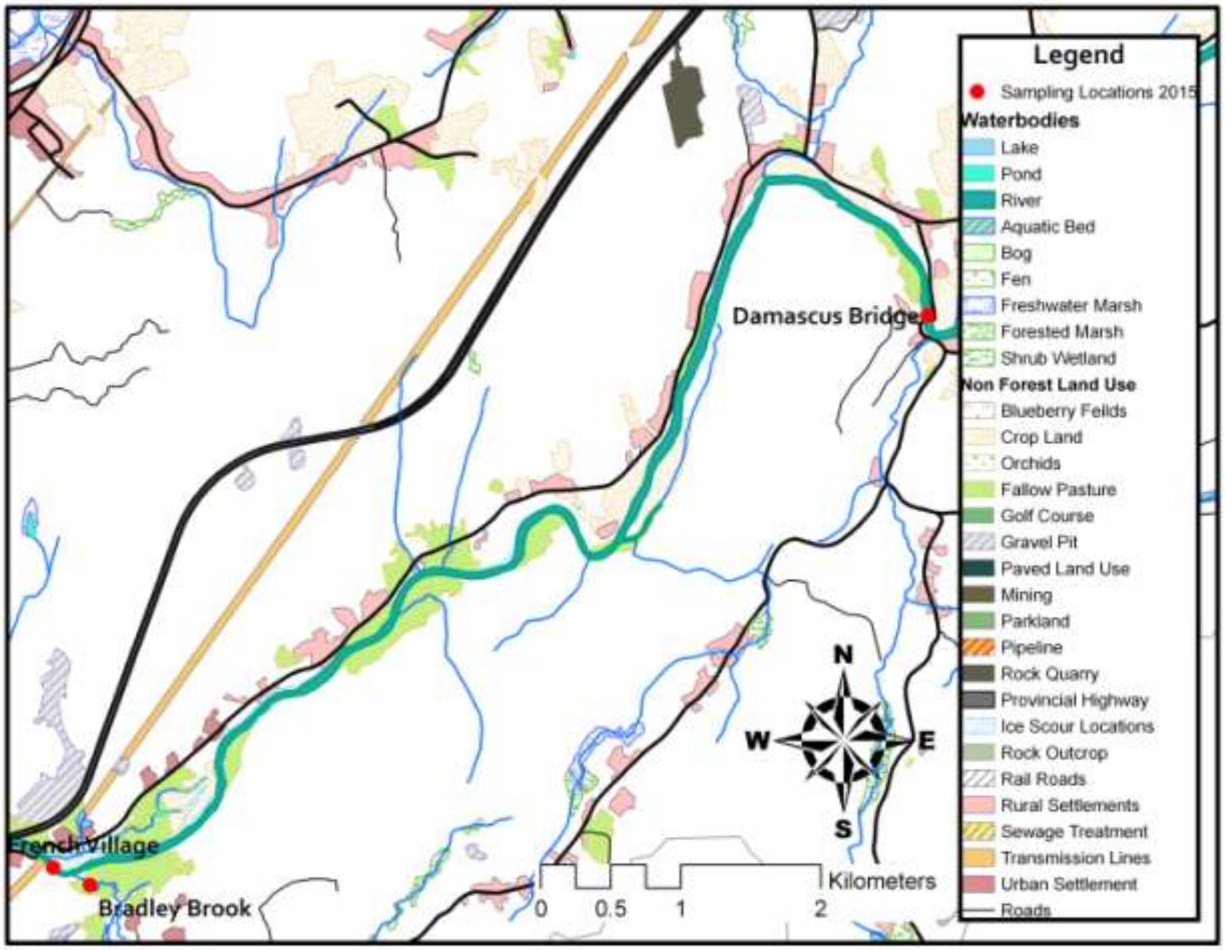


Figure 17: The French Village sub-catchment spans from the Damascus Bridge, which is just upstream of the Hammond River on this map, to the French Village Bridge. *Map by H. Bradford.*

The French Village sub-catchment covers an area 47.85 km^2, and it includes the French Village and Bradley Brook sub-catchments. Fallow pasture comprises a large proportion of the Hammond River's buffer zone in this area while other major influences are derived mainly from housing settlements and gravel pits. Tributaries to the section of the Hammond River include Jenny Langstroth Brook and Bradley Brook, which have historically been prioritized by the HRAA for poor water quality. This section of the river is prone to seasonal flooding, is frequently used for recreation and is bordered largely by fallow pasture. This sub-catchment received one of the worst riparian buffer ranks in the watershed (54.24% is undeveloped) (Figure 17). Road density (1.2 km/ km^2) in this area was low; however, stress from aquatic fragmentation (38 out of 54 stream segments) was high. This sub-catchment had a high density of land development (15.4 %) and open gravel pits (1.7 %), which were ranked the third and second highest for the watershed and cause moderate stress on water quality. Agricultural land density was moderate (4.76%) and the majority is in close proximity to the river. Overall, there are **low-moderate levels of stressors** found within this sub-catchment.

The riparian area in the lower French Village sub-catchment has been a focus of the HRAA and the Department of Transportation and Infrastructure (DTI). In 2011, riparian restoration was completed from the French Village Bridge to the deep hole and again in the spring of 2015, with willow (Figure 12). Stress from aquatic fragmentation is heightened by two culverts identified by the HRAA as needing replacement in this sub-catchment. The culverts are located at Bradley Brook – Bradley Lake Road and Route 860 – Hammond River, the latter of which is ranked as high priority for replacement (Table 6). This segment of the river annually hosts the rotary screw trap, or smolt wheel, and is an important part of the annual salmon run.

FRENCH VILLAGE BRIDGE SITE

The French Village Bridge site was sampled once on June 17th, 2015, 50 m upstream of the bridge and displayed no abnormalities in water quality. This site is located on the (stream order 5) Hammond River, adjacent to Route 860 within Quispamsis. The substrate was 10% **embedded** with silt. The stream was characterized by **clear** coloration with great visibility and was defined by two different flow types (50% run and 50% riffle). **Stream cover** (3%) was minimal for this site. Assessing all parameters in the field, riparian health was discovered to be impacted while the in stream habitat was healthy.

Table 10: Bank Characteristics of the French Village site. *Table by H. Bradford, 2015.*

Characteristic	Left Bank	Right Bank
Forest Maturity	Early/ Grassland	Mature
Slope	Moderate - Flat	Steep
Drainage	Imperfect	Imperfect
Overhanging Vegetation	100	100
Undercutting	75	75
Stability (%)	50	90

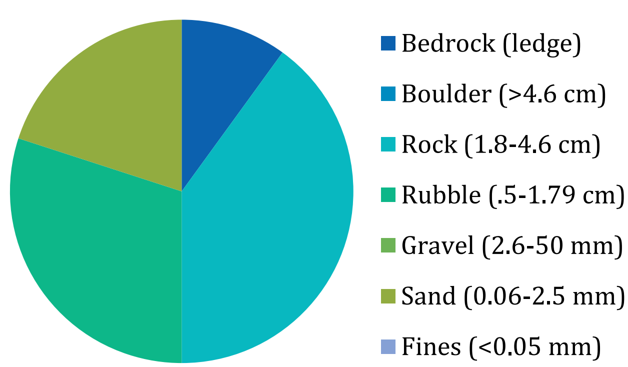


Figure 18 (bottom left): Substrate composition by percentile. *Chart by H. Bradford.* Figure 19 (top left): The French Village bridge site in early summer. *Photo by H. Bradford June 17, 2015.*

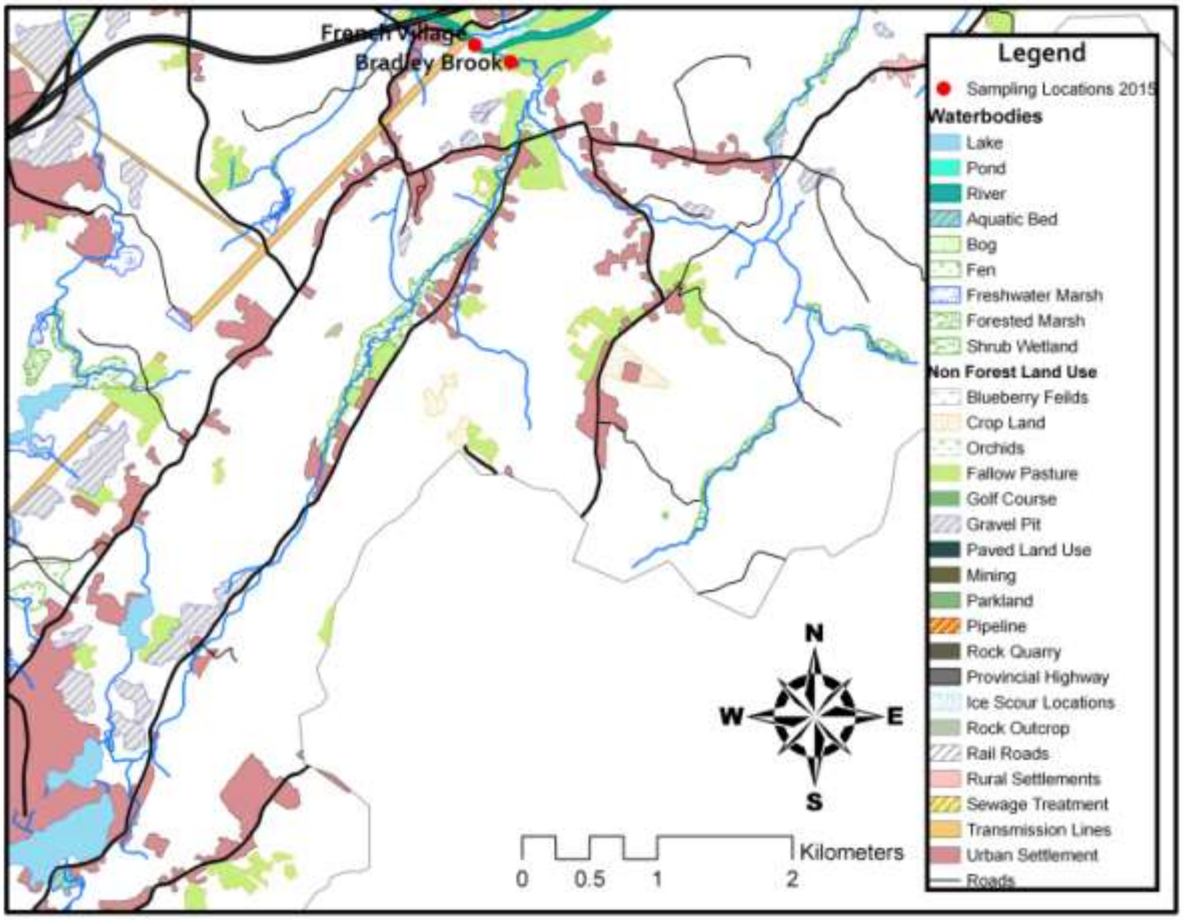


Figure 20: The Bradley Brook sub-catchment spans from Bradley Lake to its confluence with the Hammond River. This tributary is mainly surrounded by residential area, open gravel pits and fallow pasture. *Map by H. Bradford.*

BRADLEY BROOK SITE

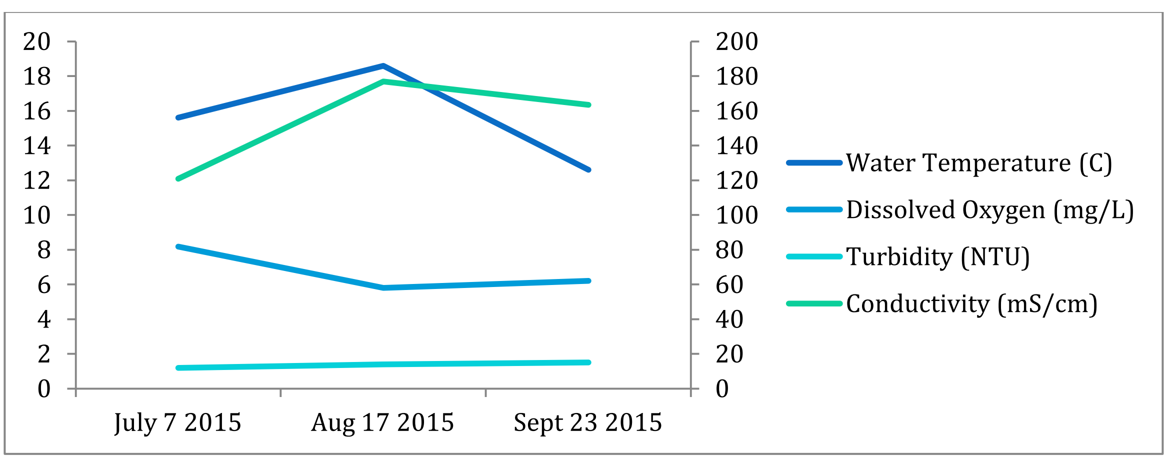
Bradley Brook (stream order 4) is a tributary of the Hammond River and was sampled 3 times during 2015 (July 20th, August 17th and September 23rd, 2015). Sedimentation is a regular occurrence with rainfall events at this site, and substrate was (80%) **embedded** (Figure 5**)**. The stream was characterized by **tannin** coloration with murky visibility and defined by two different flow types 90% run and 10% rapid. The stream cover from grasses was minimal (20%) although this site is identified as a **cool water habitat** (<21ºC). E. coli (Appendix 4) and dissolved oxygen (Figure 25) were measured above the acceptable limits for healthy aquatic life in August (480 MPN/ 100 ml). Water quality measurements indicated turbid water with above average concentrations of iron, copper and potassium (Appendix 4). The proportion of midges and fly larvae found within the BMI community collected indicate that water quality is poor and may not support a healthy community.

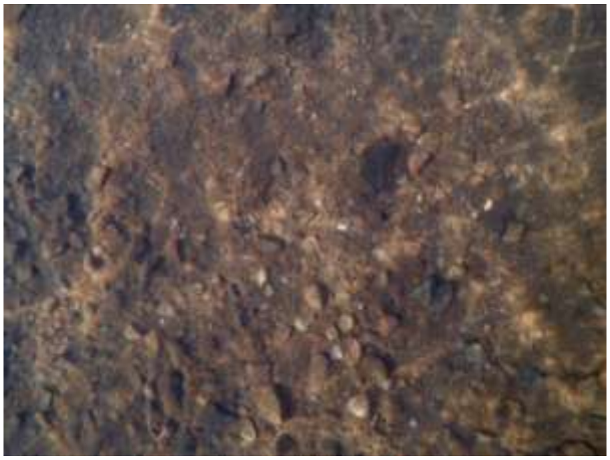
Table 11: Bank Characteristics of the Bradley Brook site. *Table by H. Bradford, 2015.*

Characteristic	Left Bank	Right Bank
Forest Maturity	Early/ Grassland/ Wetland	Early/ Grassland
Land Use	Fallow pasture	Fallow pasture
Slope	Flat	Flat
Drainage	Imperfect	Imperfect
Overhanging Vegetation	100	100
Undercutting	60	60
Stability (%)	85	85

Figure 21 (left): Sedimentation flowing from Bradley Brook into the Hammond River. Figure 22 (right): Sediment laden water running from Bradley Brook. All *photos by S. Doyle Aug 27 2015.*

Figure 23: Water temperature, dissolved oxygen, turbidity and conductivity measurements. *Figure created by H. Bradford.*





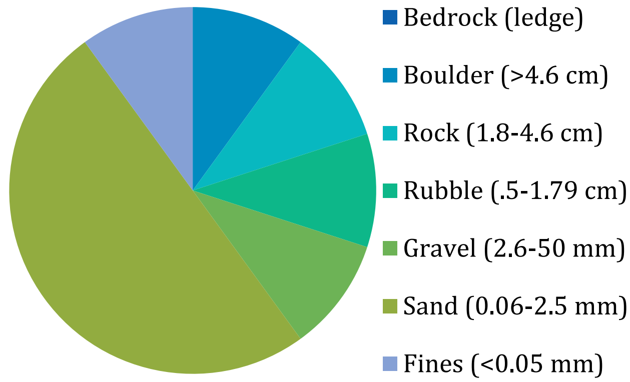


Figure 24 (top right): Substrate at Bradley Brook. *Photo by H. Bradford Aug 17 2015.* Figure 25 (top left): Substrate by percentile at Bradley Brook. *Chart by H. Bradford.* Figure 26: Right and left bank of Bradley Brook facing downstream (toward the conflux). *Photo by H. Bradford Aug 17 2015.*

DAMASCUS SUB-CATCHMENT

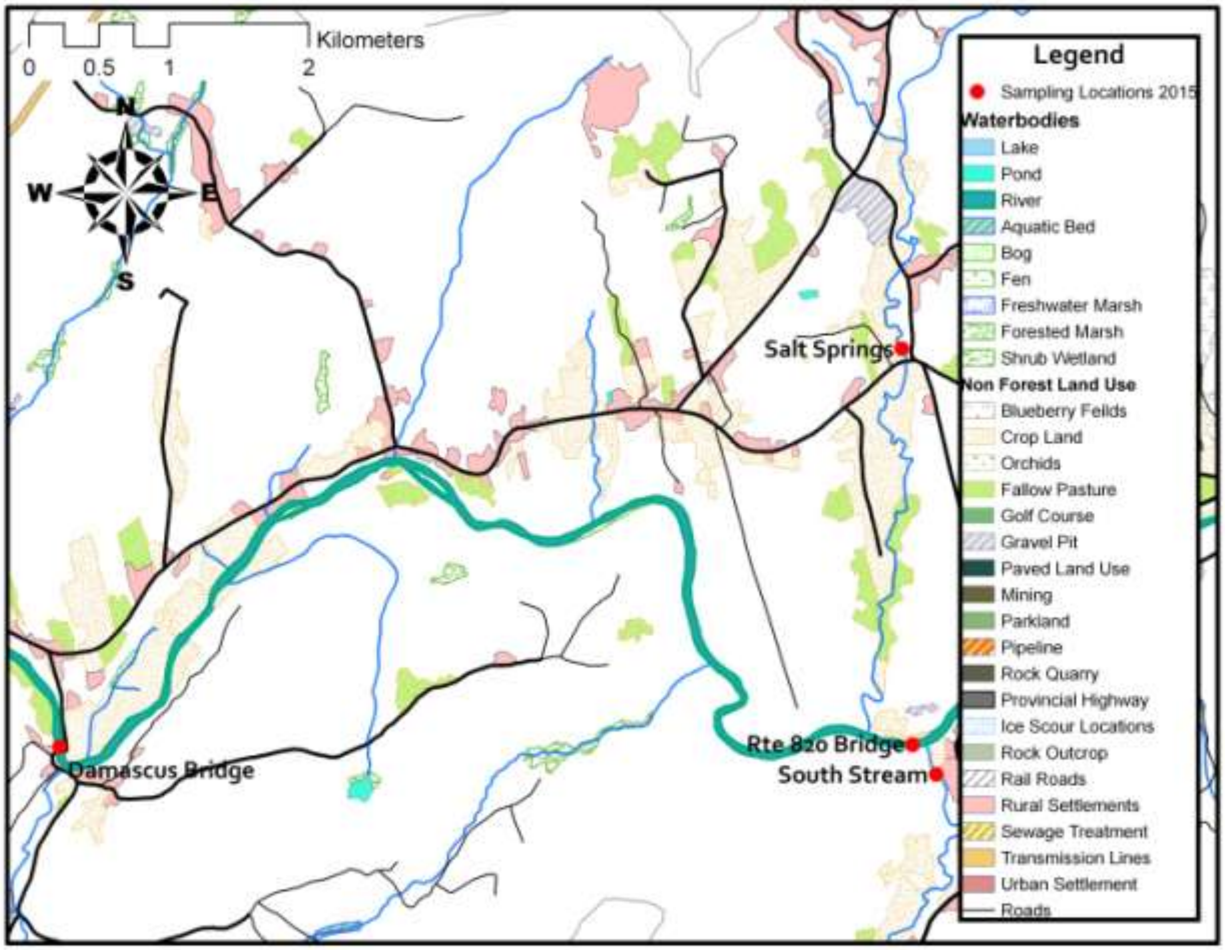
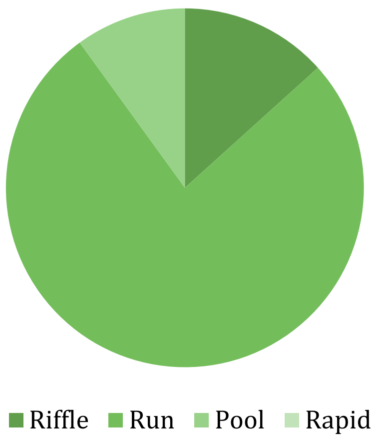


Figure 27: The Damascus sub-catchment spans from the Damascus Bridge, up the Hammond River to confluence of Salt Springs and South Stream. *Map created using DNR GIS data layers (2009) by H. Bradford.*

The Damascus sub-catchment spans an area of 50.77 km^2 from Damascus to Titusville, covering most of the Smithtown area. Cropland and residential settlements comprise a large proportion of the buffer zone in this area. Brawley Brook and Titus Brook are tributaries to this section of the Hammond River and are largely surrounded by farmland and rural settlements. An evaluation of stressor sources within Damascus indicates low stress from road density (1.23 km/km^2), land development (9.1%), open gravel pits (0.5 %) and agriculture (4.82%). However, the proximity of agricultural land to the Hammond River and its ranking as the 4^{th} highest in the watershed warrant special attention. This sub-catchment had the highest proportion of aquatic fragmentation (22 out of 26 stream segments are disrupted) in the watershed as well as the most impacted riparian buffer, which was ranked as stressed (51.51% is developed). Overall, there were **low levels of stressors** found within this sub-catchment.



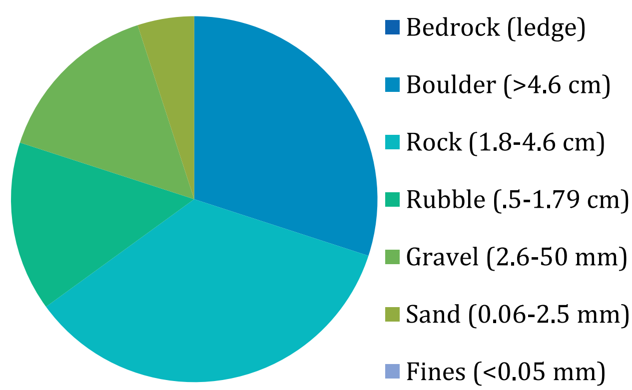


Figure 28 (top left): Flow type by percentile for the Damascus bridge site. *Chart by H. Bradford.* Figure 29 (top right): Right banks, facing downstream of the Damascus bridge. *Photo by H .Bradford June 17 2015.*Figure 30 (bottom left): Substrate at Damascus bridge site. *Photo by H. Bradford Aug 17 2015.* Figure 31: Substrate by percentile at Damascus bridge site. *Chart by H. Bradford.*

Table 12: Bank characteristics at the Damascus bridge site. *Table by H. Bradford*

Characteristic	Left Bank	Right Bank
Forest Maturity	Mature	Mature
Slope	Steep	Steep
Drainage	Well drained	Well drained
Overhanging Vegetation	100	30
Undercutting	60	65
Stability (%)	90	95

Damascus Bridge crosses the Hammond River (stream order 5) and the sampling station is downstream of a known local fishing and swimming hole. The substrate was 5% **embedded**. The stream had a **clear** coloration with great visibility and was defined by several different flow types (Figure 28). The river had 0% **crown cover** at this location. Assessing all parameters, Damascus was documented to have a **stressed** riparian health, while the in-stream habitat was found to be **healthy**. Pools at this site are known to provide salmon habitat as well as habitat for other fish. However, late summer measurements of dissolved oxygen and temperature identify unacceptable limits for a healthy community. E. coli levels at this site increased (190 MPN/ 100 mL) during the rainfall event in July (Appendix 4). The BMI community had a large proportion of fly larvae and insects indicating this site cannot support a variety of organisms and has potentially impaired water quality (Appendix 5). Overall the benthic community was **unimpaired**.

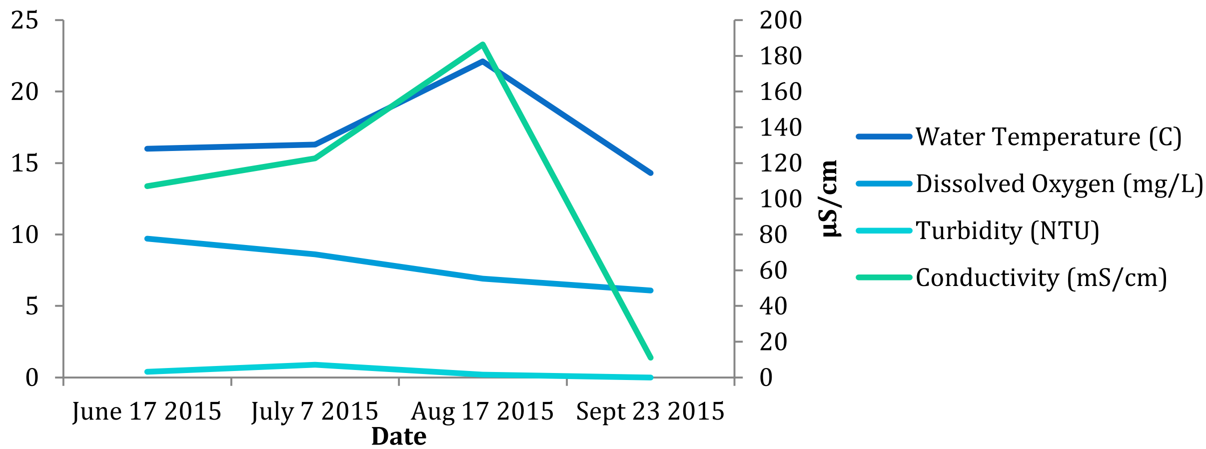


Figure 32: Water temperature, dissolved oxygen, turbidity and conductivity measurements during summer 2015. *Figure created by H. Bradford.*

Figure 33 (left): The occurrence of white foam on the water's surface during late summer. *Photo by K.Flewellin, Aug. 17, 2015.* Figure 34 (right): Algae was prominent at the benthos in late summer. *Photo by H. Bradford Aug. 17 2015.*

SALT SPRINGS SUB-CATCHMENT

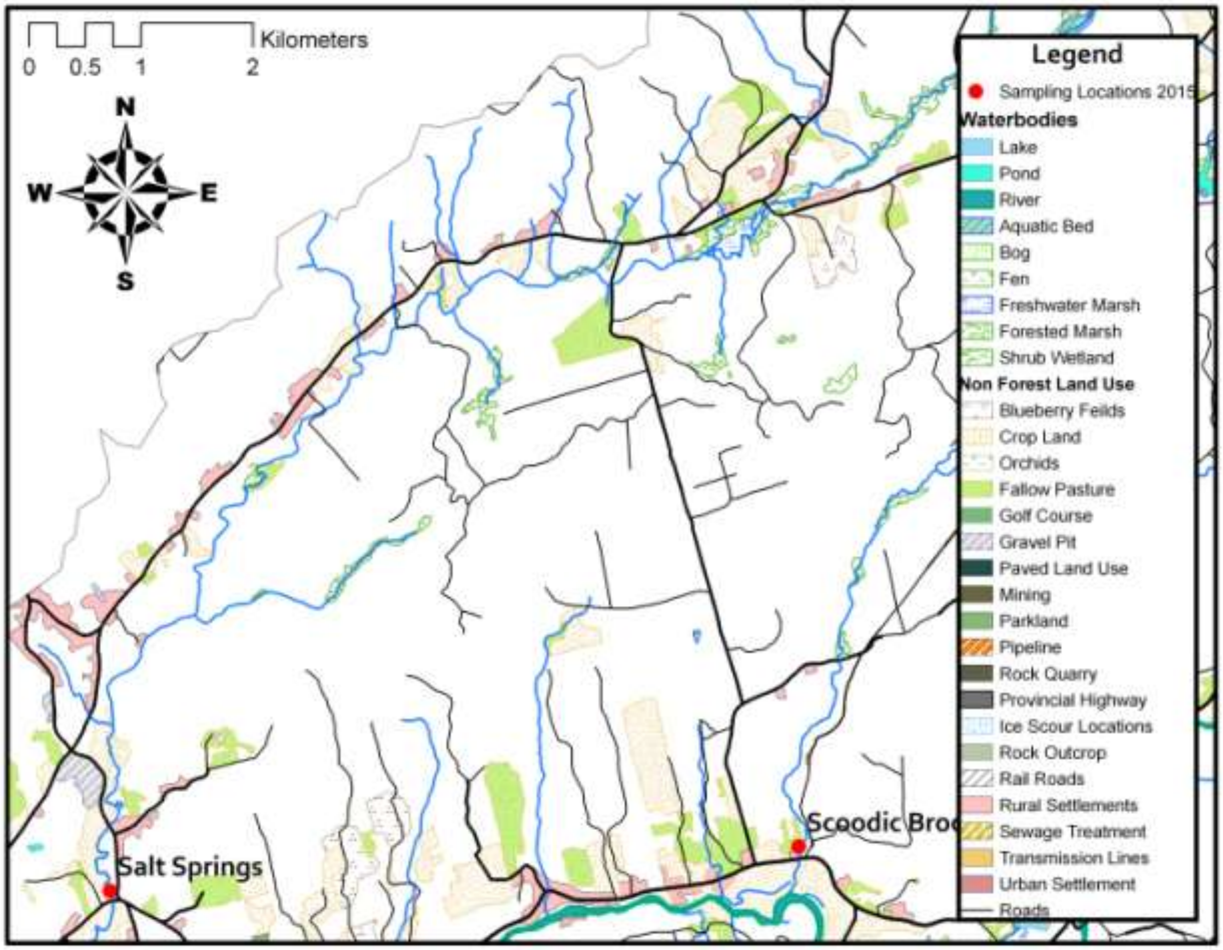


Figure 35: The Salt Springs sub-catchment comprises the entire Titusville area. *Map by H. Bradford.*

This sub-catchment is 49.51 km^2 in are spanning the length of the Salt Springs Brook tributary. Cropland, fallow pasture and settlements comprise a large proportion of the buffer zone in this area. Salt Springs Brook (stream order 2) is bordered by forest, forested wetland, housing developments and pasture in the lower reaches. Moderate stress is caused by the second highest occurrence of aquatic fragmentation (30 out of 51 stream segments are disrupted) in the watershed, high road density (1.6 km/ km^2) and the local Potash mine. Agricultural land density is the third highest in the watershed (8.24%). Although this land use is estimated to cause low amounts of stress, it has been historically noted that cattle fording and access to the brook cause poor water quality within the stream (Campbell and Prosser, 2008). Low levels of development (12.1 %) have left the riparian buffer largely intact (81.6% is undeveloped) and classified as healthy. Developed riparian areas are largely the result of housing and agricultural land use. Overall, there are **low-moderate levels of stressors** found within this sub-catchment.

SALT SPRINGS BROOK SITE

Salt Springs Brook was sampled four times during 2015 located at the Titusville Road – Lake Road intersection (Figure 35). The sampling location is a known local fishing site and has the second highest annual fish and salmon abundance values in the watershed (Appendix 7). The substrate at this location was 45% **embedded.** The stream was characterized by **clear - tannin** coloration and run and pool flow types. The stream cover in this area was 37.5%. Assessing all parameters, Salt Springs Brook was documented to have an **impacted** riparian health, while the in stream habitat was **stressed**. Interestingly, the rainfall event recorded on July 20th resulted in decreased conductivity measurements, when they are normally exceptionally high (Figure 39). During the rainfall event it was also noted that the stream progressed from oligotrophic to mesotrophic conditions. Water temperature measurements indicated Salt Springs to be a **cool water habitat** however, dissolved oxygen levels were below acceptable limits for a healthy community by late summer (Figure 39).

Water quality analysis revealed a site unique to the watershed and most of these abnormalities could be attributed to the natural salt and potassium deposits upstream. This site had higher than average levels of chlorine, calcium, copper, sodium, potassium, and sulfate in comparison to the other sites. The water was slightly turbid (especially after rainfall) and hard. Poor water quality was indicated by the high occurrence of fly larvae within the BMI community (Appendix 5). E. coli levels at this site reached 310 and 160 MPN/ 100 mL during 2015 (Appendix 4). This site consistently had the highest levels of conductivity in the watershed, which was 1030 µS/ cm during the August and September samples (Appendix 4). While conductivity is likely from natural geological deposits upstream, E. coli is probably a result of farming practices.

This site has the second highest annual fish abundance count and the highest annual count of juvenile Atlantic salmon (Appendix 7). Salt Springs had also been recognized for salmon spawning habitat however, this Brook was not examined for redds in 2015. The BMI community collected here was **unimpaired,** although it had the highest tolerance to pollution at 5.88(Appendix 5). The presence of sow bugs is a potential indicator of nutrient enrichment and a low proportion of Diptera indicates impaired water quality.

Table 14: Bank characteristics at the Salt Springs site. *Table by H. Bradford.*

Characteristic	Left Bank	Right Bank
Forest Maturity	Immature/ Wetland	Immature/ Wetland
Slope	Steep	Steep
Drainage	Well drained	Well Drained
Overhanging Vegetation	10	10
Undercutting	10	5
Stability (%)	87.5	90

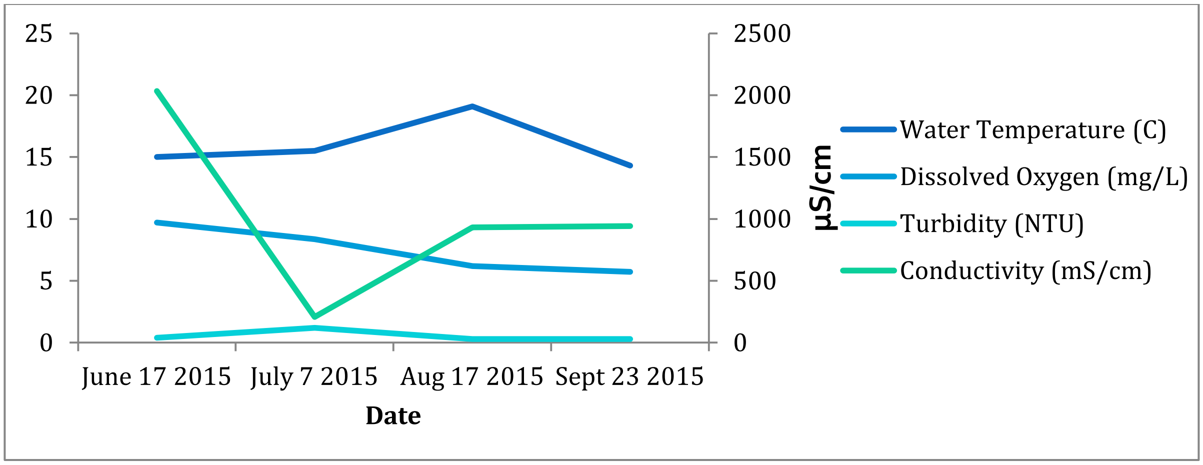


Figure 39: Water temperature, dissolved oxygen, turbidity and conductivity measurements during summer 2015. *Figure created by H. Bradford*

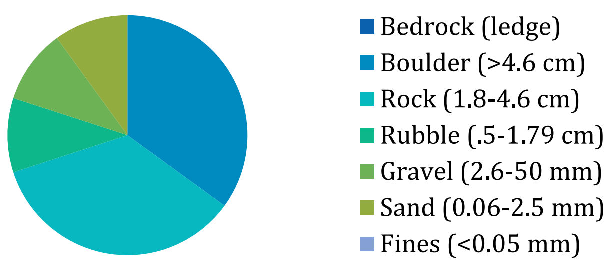


Figure 36 (top left): Substrate at the Salt Springs site by percentile. *Chart by H.Bradford.* Figure 37 (top right): Substrate at Salt Springs. *Photo by H. Bradford July 20 2015.* Figure 38: The left banks, facing upstream, at the Salt Springs site. *Photo by H. Bradford Aug 17 2015.*

BARNESVILLE SUB-CATCHMENT

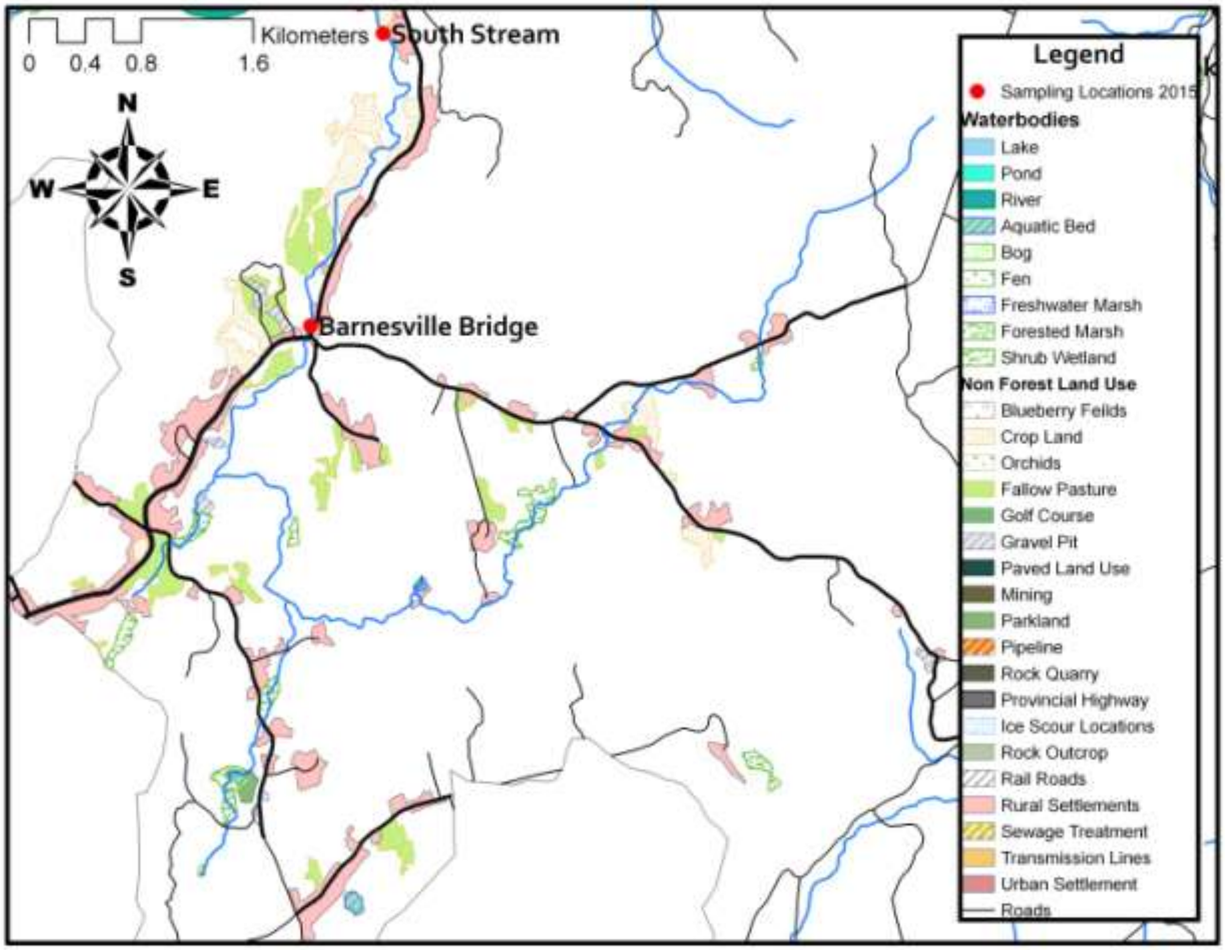


Figure 40: The Barnesville Bridge sub-catchment comprises the entire South Stream area. *Map by H. Bradford.*

The Barnesville sub-catchment is 30.71 km^2 in size. Housing settlements, crop land, and fallow pasture comprise a large proportion of the buffer zone in this area. The main tributary in this area, South Stream, is classified as a stream order 3. This area contains some residential land, fallow pasture and crop land. The analysis indicated high levels of stress from aquatic fragmentation (6 out of 7 stream segments) albeit, stress from land development (9.1%), gravel pits (0.3 km/ km^2) and road density (1.3 km/ km^2) was low. The riparian buffer was classified as **healthy** (84.5% is undeveloped) and agricultural land use was low (1.06%). Overall, the Barnesville sub-catchment contains **low levels of stress**.

BARNESVILLE BRIDGE SITE

The Barnesville site is located downstream of the Route 820 - South Stream crossing (Figure 40) and was sampled 4 times during the summer of 2015. The substrate was 5% **embedded** and the streambed was comprised largely of bedrock, large boulder and cobble. The stream was characterized by **clear** coloration with great visibility, and **stream cover** was high at 50%. Dissolved oxygen decreased to unacceptably low concentrations during this sampling campaign while water temperature was lowest here during late summer, indicating a **cool water habitat (**Figure 41**)**. Turbidity and conductivity were comparatively low at this site.

A low number of taxonomic groups within the BMI community indicate that this environment cannot support a variety of organisms, although this is most likely due to the streams rocky substrate. Low abundance of fly larvae indicates water quality may be poor however, caddisflies, mayflies and stoneflies were very abundant and they have a low tolerance to pollution (Ecospark, 2013). Overall, the BMI community was ranked as **unimpaired** with a low tolerance for pollution at 4.4 (Appendix 5). There were no indications of poor water quality in the analysis.

Table 15: Bank characteristics at the Barnesville Bridge site. *Table by H. Bradford.*

Characteristic	Left Bank	Right Bank
Forest Maturity	Variegated (Mature/ Wetland)	Mature
Slope	Steep	Gradual - Moderate
Drainage	Rapid, moderately well	Well
Overhanging Vegetation	80	50
Undercutting	100	10
Stability (%)	75	90

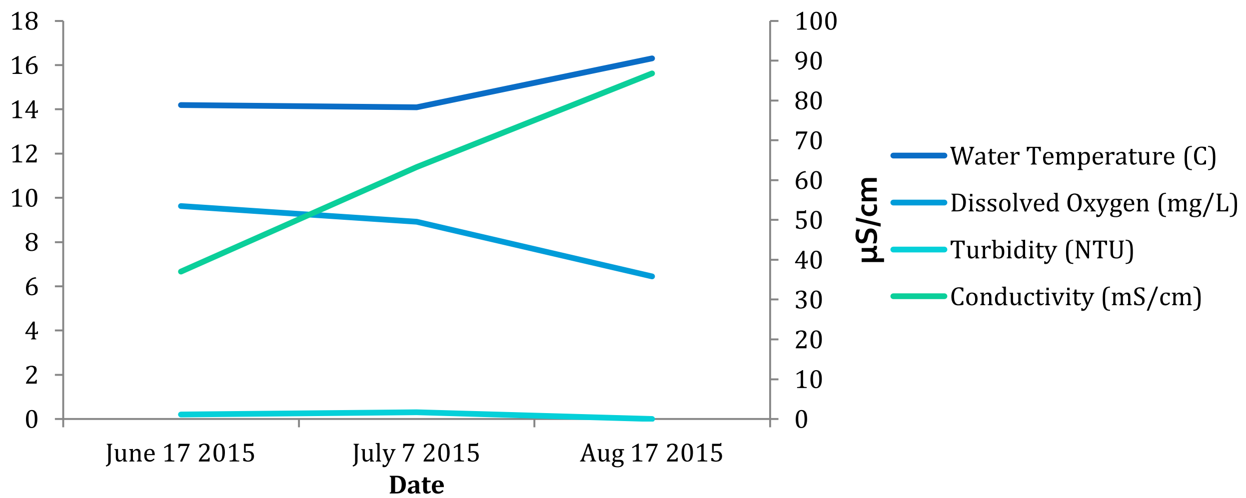
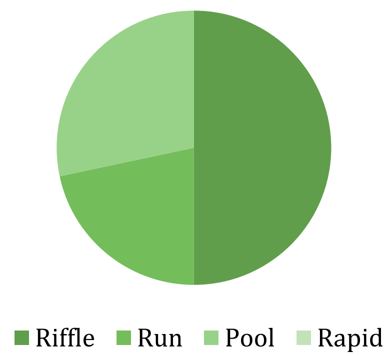


Figure 41: Water temperature, dissolved oxygen, turbidity and conductivity measurements taken during 2015 at the Barnesville Bridge site. *Figure created by H. Bradford*



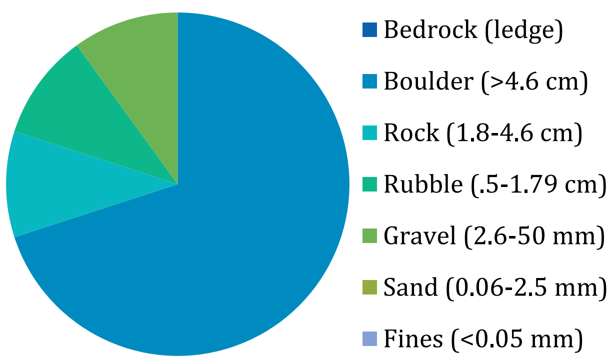


Figure 42 (top left): Riffle flow downstream of the Barnesville Bridge. *Photo by H. Bradford Aug 17 2015.* Figure 43 (top right): Flow by percentile. *Chart by H. Bradford.* Figure 44(middle left): Substrate by percentile. *Chart by H. Bradford.* Figure 45 (middle right): South Stream substrate at the Barnesville Bridge. *Photo by H. Bradford July 20 2015.* Figure 46: Cross section of south stream, facing upstream at the Barnesville Bridge. *Photo by H. Bradford Aug 20 2015.*

SOUTH STREAM SITE

South Stream is a tributary of the Hammond River that is located in SW Upham. This site was sampled once on July 20th, 2015 at the mouth of South Stream above the convergence with the Hammond River. The substrate was 2.5% **embedded**, the stream was characterized by a **clear** coloration with great visibility and defined as 100% **riffle**. The **stream cover** was 65%. **There are no potential sources of pollution on site.**

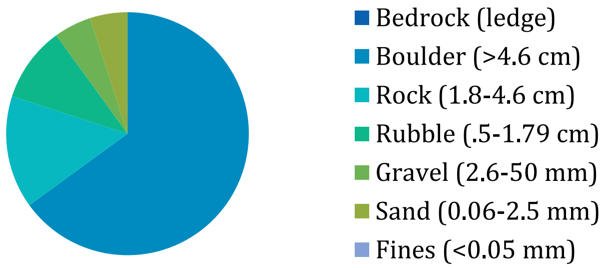


Figure 47 (top left): Substrate by percentile. *Cha*

rt

by H. Bradford. Figure 48 (top right): Substrate at the South Stream confluence point. *Photo by H. Bradford June 20 2015.*Figure 49: Cross-section of South Stream facing upstream, depicting a dominant riffle flow. *Photo by H. Bradford June 20 2015.*

Table 16: Bank characteristics at the South Stream site. *Table by H. Bradford.*

Characteristic	Left Bank	Right Bank
Forest Maturity	Mature	Variegated – Wetland/ Mature
Slope	Severe	Severe
Drainage	Moderately well	Imperfect
Overhanging Vegetation	100	100
Undercutting	25	50
Stability (%)	95	80

UPHAM SUB-CATCHMENT

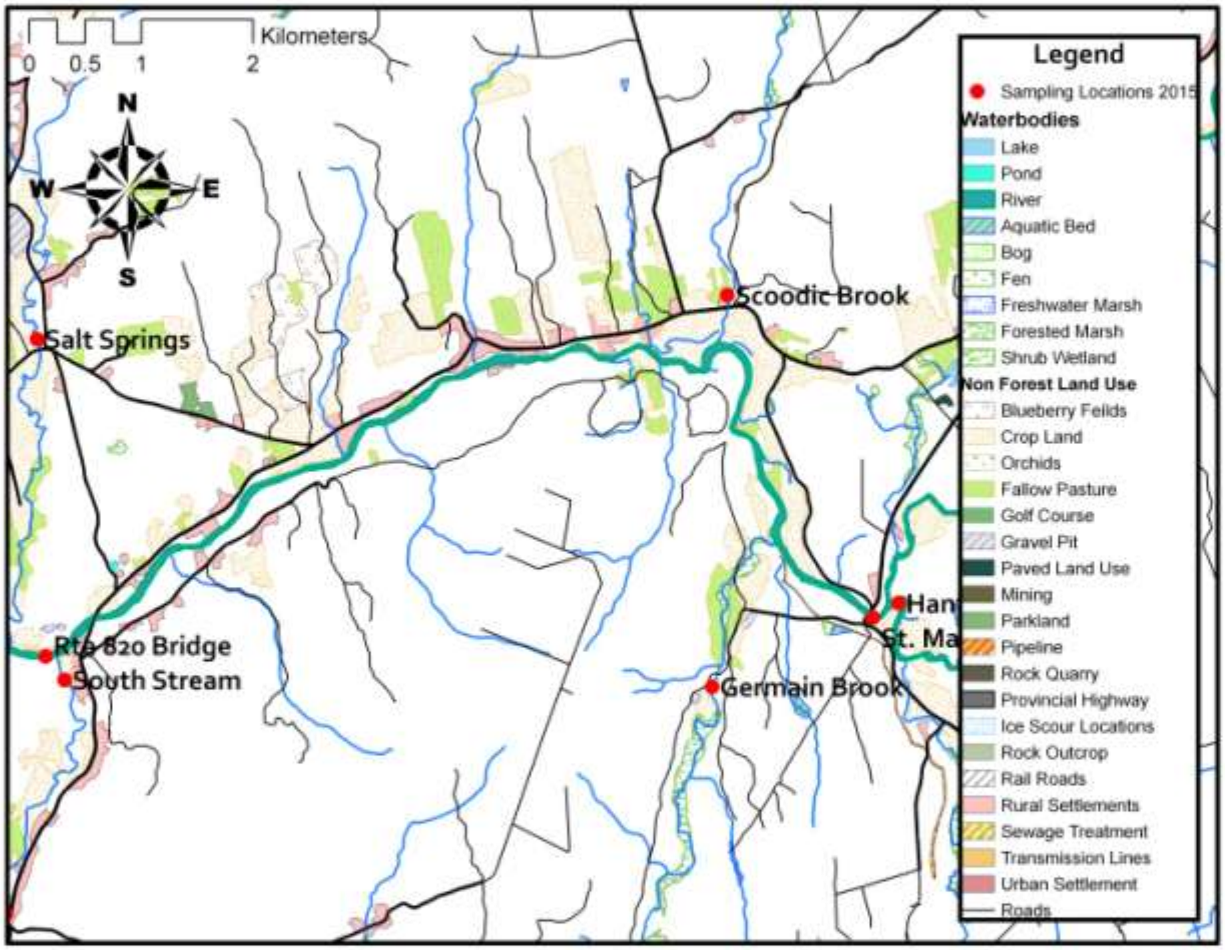


Figure 50: The Upham sub-catchment comprises the Tabor area, which is made up of several small tributaries and the Hammond River. *Map by H. Bradford.*

The Upham sub-catchment is 30.44 km^2 in area and contains a segment of Hammond River with several small tributaries. Cropland, settlements and blueberry fields comprise a large proportion of this area. This area is predominately used for farming to the north (left bank) and is forested to the south, with the lowest amount of land development in the watershed (1.1%). The riparian buffer within this sub-catchment is **healthy**, with 87.76% of the banks undeveloped. Stress from agricultural land use (3.73%) is low, although a large proportion of this land is located on the northern bank of the Hammond River. This sub-catchment contains high levels aquatic fragmentation (19 out of 24 stream segments) which coincides with moderate stress from road density (2.0 km/km^2), the third highest in the watershed. Overall, the Upham sub-catchment contains **low amounts of stress**.

HAMMOND RIVER (ROUTE 820) SITE

The Route 820 site is located approximately 150 m downstream of the Route 820 bridge crossing downstream of the South Stream tributary. The site was sampled June 17th, August 17th and September 23rd in 2015. The substrate was 5% **embedded** and the stream was characterized by a **clear** coloration. The **stream cover** was approximately 25%, however, this was more dependent on the position of the sun than other sites due to the large width of the river.

The lack of stream cover and the width of the river contribute to water temperatures being higher than the acceptable limit during late summer. Dissolved oxygen was the second lowest at this site during late summer (5.4 mg/L), well below the acceptable limit for aquatic life (Figure 51). This area was noted to have high levels of nitrates (Appendix 4). The BMI community analysis resulted in 4 counts of an impaired classification, although the overall site ranking is **unimpaired**. A low variety of taxonomic groups indicated habitat and water quality at the site cannot support a variety of species. There was a low abundance of fly larvae, indicating poor water quality. Although there were a high proportion of insects within the population, these were mainly cadisflies, mayflies and stoneflies, which have a low tolerance for pollution (Appendix 5).

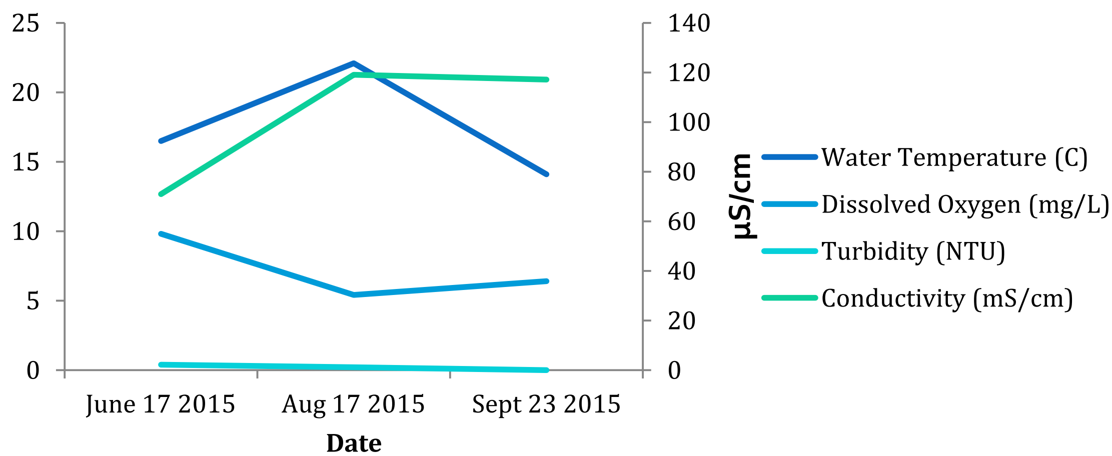


Figure 51: Water temperature, dissolved oxygen, turbidity and conductivity measurements taken during summer 2015 at the Route 820 Bridge site. *Figure created by H. Bradford*

Table 17: Bank characteristics of the Hammond River at the Route 820 site. *Table by H. Bradford.*

Characteristic	Left Bank	Right Bank
Forest Maturity	Mature	Mature
Slope	Severe	Severe
Drainage	Moderately well	Imperfect
Overhanging Vegetation	15	50
Undercutting	80	25
Stability (%)	80	90

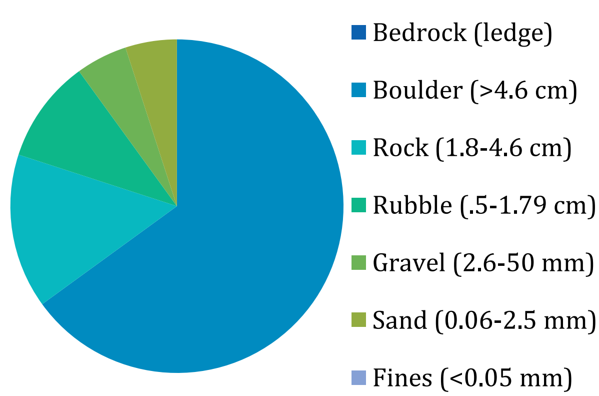


Figure 52: A cross section of the Hammond river at the Route 820 site facing downstream (of the convex with South Stream) at the normal water level. *Photo by H. Bradford June 17 2015*. Figure 53 (bottom left): A cross section of the Hammond River at the Route 820 site facing upstream (of the confluence with South Stream) at low water levels in late summer. *Photo by H. Bradford Aug 17, 2015*. Figure 54 (bottom right): Substrate by percentile. *Chart by H. Bradford.*

SCOODIC BROOK SUB-CATCHMENT

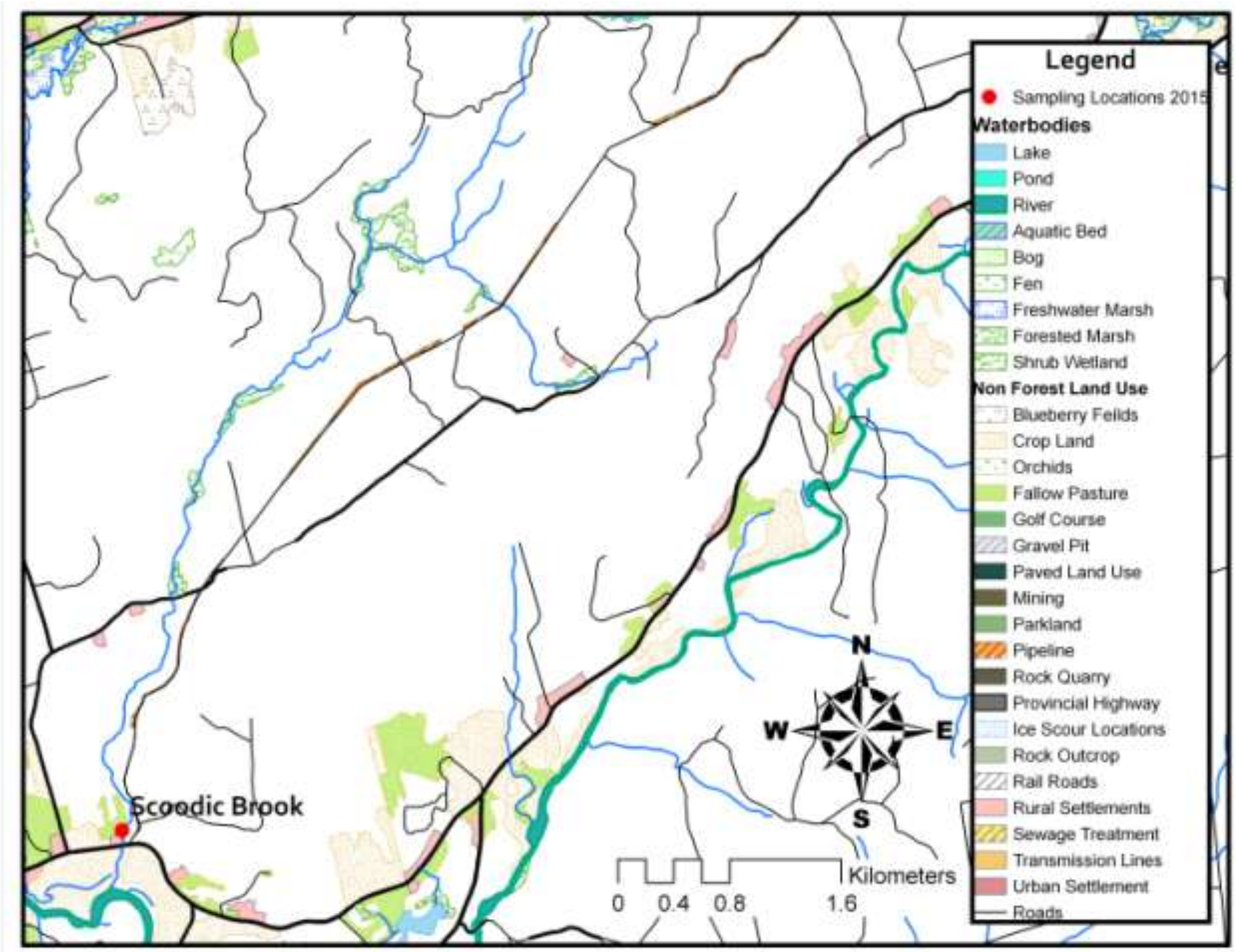


Figure 55: The Scoodic Brook sub-catchment comprises the Scoodic area, which includes the Scoodic tributary. This area is mostly forested however, a DIT building and cropland are adjacent the site sampled. *Map by H. Bradford.*

Scoodic Brook is a tributary of the Hammond River and is classified as stream order 3. The Scoodic area sub-catchment is 17.88 km^2 in size, surrounding Scoodic Brook. Land development (2.3 %) was measured to place low amounts of stress on this sub-catchment and the density of agricultural land use was the lowest in the watershed (0.194%). Moderate stress levels were result from road density (1.8 km/km^2) and aquatic fragmentation (6 out of 12 stream segments disrupted). The riparian buffer zone is ranked to be extremely **healthy** (98.23% is undeveloped). Overall, this sub-catchment contains **low stress levels.** Several restoration projects have been completed in this area to combat flooding and erosion. Downstream of the DTI building bank re-establishment was initiated by tree planting (Figure 60), the installation of sediment fences and the addition of boulder rock walls. Historically, bank re-establishment initiatives and the creation of large pool fish habitat occurred downstream of the Scoodic Brook - Hammond River confluence. Due to low survival among trees planted beneath the confluence point, the (left) riverbank was planted again in 2015 (Figure 56).

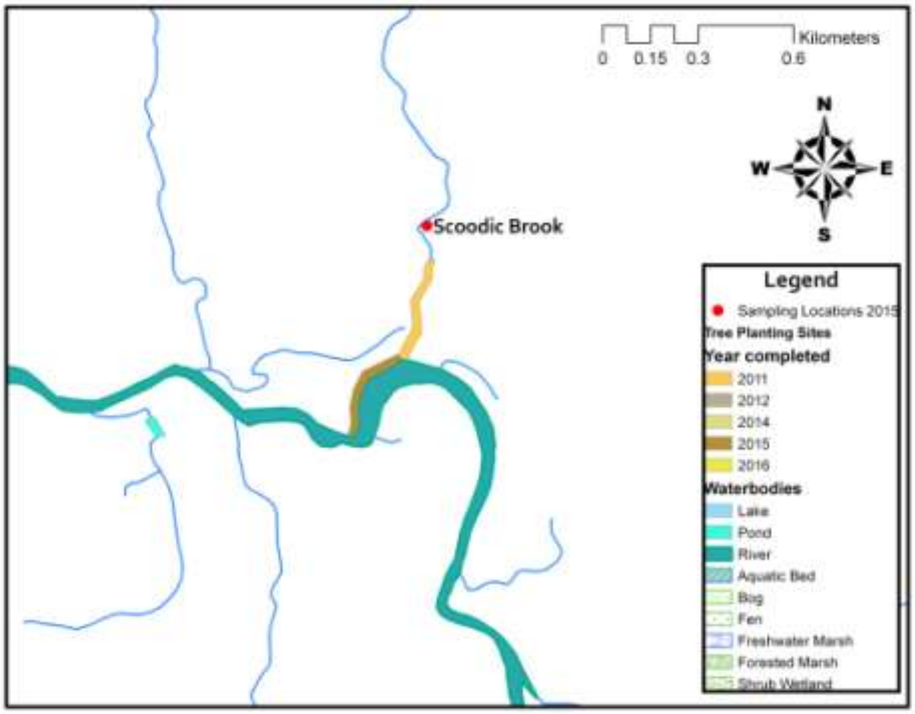


Figure 56: Recent planting sites at Scoodic Brook by year completed. *Map created by H. Bradford using DNR data layers (2009).*

SCOODIC BROOK SITE

The Scoodic Brook site is located adjacent to a DTI building in Upham, NB. On June 17th, water quality was sampled upstream of the building and moved downstream of the building for subsequent samples. The **s**ubstrate was 20% **embedded**. The stream was characterized by **clear** coloration, progressing to a tannin color by late summer. The **stream cover** was 50% and the stream habitat was **healthy,** although Scoodic Brook was documented to have a **stressed** riparian health. The **flow type** changed drastically throughout the sampling period in 2015 from riffle (50%) and run (50%) to include many stagnant pools caused by low water levels and exposed substrate. This site is designated as a **cool water habitat** (≤18.6 ºC) and had the highest dissolved oxygen measurement (6.97 mg/L) in August 2015. Despite this, the site is shown to have comparatively low (to moderate) fish and juvenile Atlantic salmon abundances annually. Large amounts of fish were even abundantly visible in the stagnant pools during late summer. Historically, this area has been a salmon nesting habitat although the brook was not examined in 2015 (Appendix 7).

During the 2015 sampling period, aluminum levels in Scoodic Brook were continuously higher than the acceptable limit for aquatic life. The site transitioned from oligotrophic to mesotrophic during the July and September measurements and this periodic transition most likely caused the prevalent algae film on the substrate. This site also had higher than average levels of nitrogen and turbidity (Appendix 4). The benthic community had a prominent midge and insect population and a low number of taxonomic groups, which indicated that the brook was not able to support a healthy biotic community and most likely experienced poor water quality (Appendix 5). However, the BMI communities collected here were ranked as **unimpaired**.

Table 18: Bank characteristics at the Scoodic Brook site. *Table by H. Bradford.*

Characteristic	Left Bank	Right Bank
Forest Maturity	Primary	Mature
Slope	Moderate	Moderate
Drainage	Imperfect	Imperfect
Overhanging Vegetation	10	10
Undercutting	70	70
Stability (%)	75	90

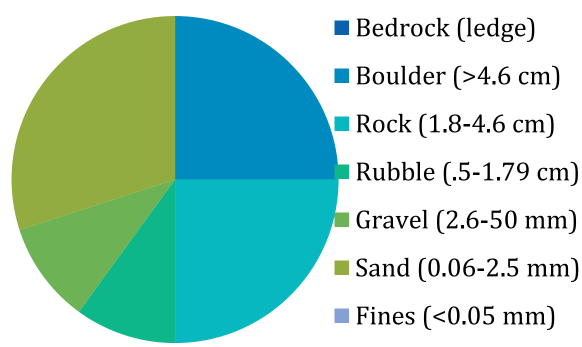


Figure 57 (left): Scoodic Brook upstream of the DOT building in early summer. *Photo by H. Bradford June 17 2015.* Figure 58 (right): Substrate by percentile. *Chart by H. Bradford.*

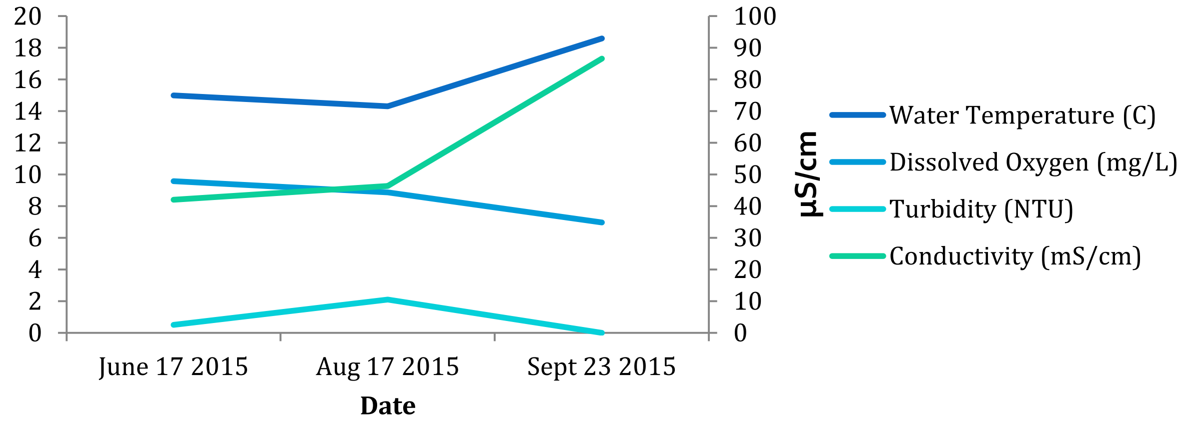


Figure 59: Water temperature, dissolved oxygen, turbidity and conductivity measurements taken during summer 2015 at the Scoodic Brook site. *Figure created by H. Bradford.*




Figure 60 (top left): Willow trees previously planted by the HRAA. Figure 61 (top right): Scoodic Brook bank rehabilitation included supplementing banks with boulders and planting trees in 2011. Figure 62 (bottom left): Low water levels during the summer cause Scoodic Brook to become fragmented, trapping many fish in hot, stagnant water. Figure 63 (bottom right): Algae appears to be a prominent issue in Scoodic Brook during late summer. *All photos by H. Bradford Aug 20 2015.*

HANFORD BROOK SUB-CATCHMENT

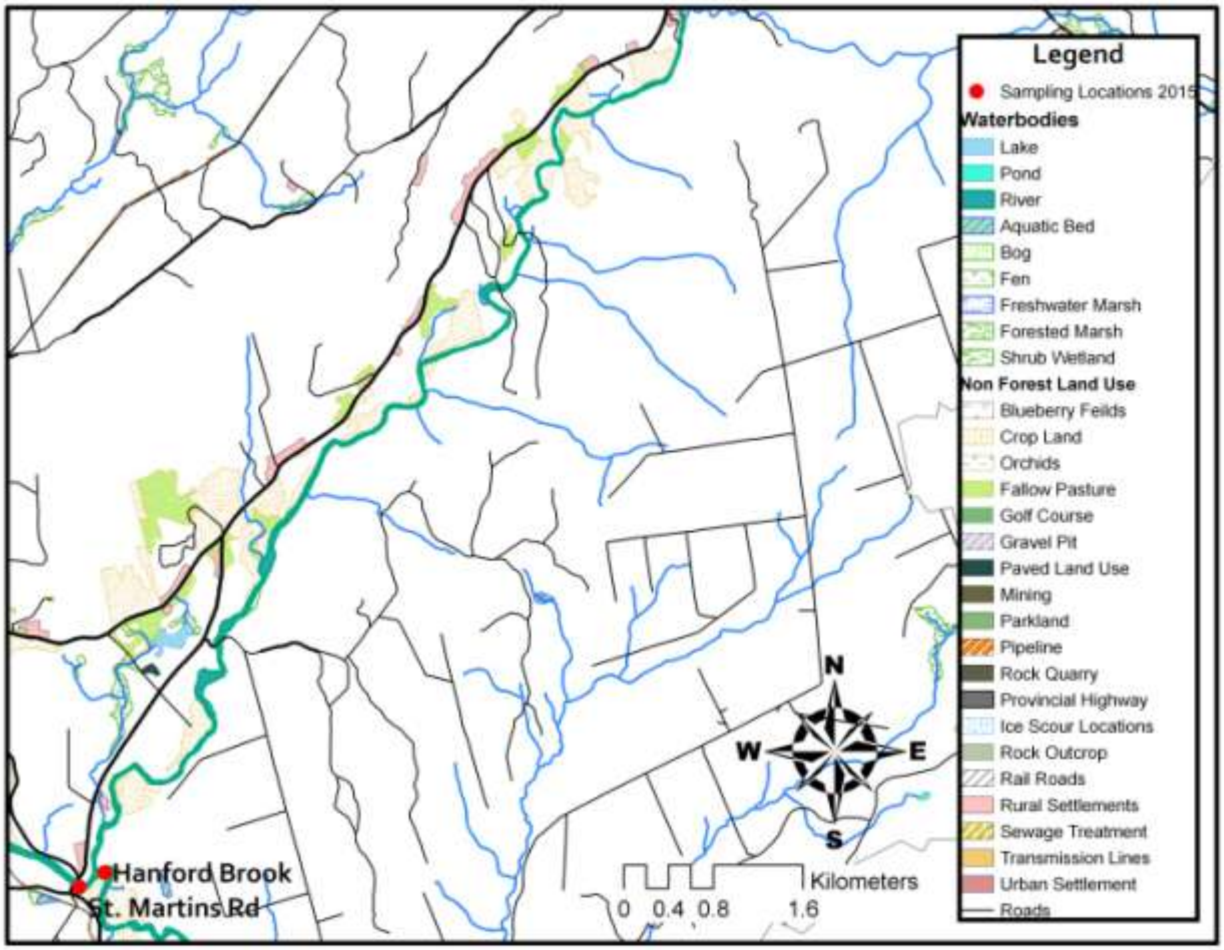


Figure 64: The Hanford brook sub-catchment comprises a large area in the southeastern reaches of the Hammond River watershed. This is area is characterized by low levels of development and high levels of agriculture. *Map by H. Bradford.*

Hanford Brook is located SW of Upperton, NB and is a tributary to the Hammond River. This sub-catchment is 96.67 km^2 in size and experiences moderate stress from road density (1.6 km/km^2 of road) and high aquatic fragmentation (38 out of 117 stream segments). Overall, the sub-catchment contains low levels of land development (4%), agriculture use (2.73%) and comparatively low gravel pit density (0.2 %). Due to agricultural land development, the condition of the riparian buffer in this area is **stressed** (57%). Overall, this sub-catchment has **low levels of stress**.

HAMMOND RIVER (ST. MARTINS RD) SITE

The Hammond River (St. Martins Road) site was sampled on June 17th, 2015. The substrate was 5% **embedded** with silt. The stream was **clear** in coloration with great visibility and defined by run (75%), riffle (20%) and pool (5%) flow types. The **stream cover** was low at 2.5%. The substrate at this site is identical to the Hanford Brook.


Figure 65 (left): Cross-section of the Hammond River (St. Martins Road) facing upstream. *Photo by H. Bradford June 17, 2015*. Figure 66 (right): Unique geological formation on exposed bedrock downstream of the St. Martins Road bridge. *Photo by H. Bradford July 17 2015.*

Table 19: Bank characteristics for the Hammond River by the St. Martins Road. *Table by H. Bradford.*

Characteristic	Left Bank	Right Bank
Forest Maturity	Variegated (Wetland, Mature)	Variegated (Mature, Wetland)
Slope	Moderate	Steep
Drainage	Moderately, well	Imperfect
Overhanging Vegetation	80	10
Undercutting	90	20
Stability (%)	85	70

HANFORD BROOK SITE

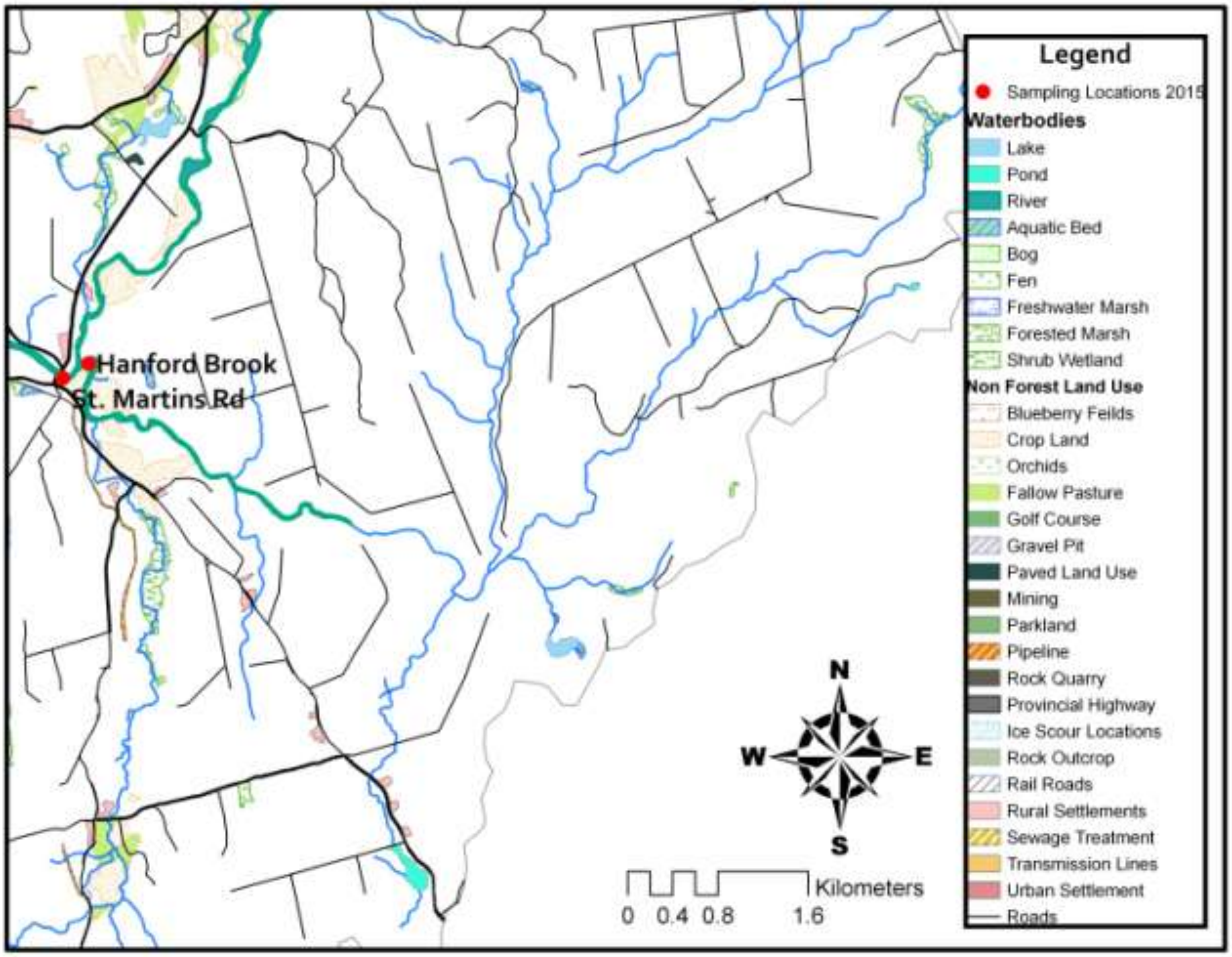


Figure 67: The Hanford Brook sub-catchment comprises a large area in the southeastern reaches of the Hammond River watershed. *Map by H. Bradford.*

Hanford Brook is a tributary of the Hammond River and is classified as a stream order 4. The site is located 30 m upstream of the Hanford Brook – Hammond River confluence, with wetlands and agricultural land use upstream. The substrate was 5% **embedded**. The stream was characterized as **clear** in early summer and turned **tannin** by late summer. **Stream cover** was 15%. The flow type was 70% **run**, 20% **riffle**, and 10% **pool.** Moderate fish and juvenile Atlantic Salmon abundance is typical in this brook (Appendix 7). Historically this area has provided important salmon spawning habitat, reflected in annual redd counts, however, redds were not observed here in 2015 (Appendix 7).

Water quality analysis found pH to be significantly (1.1×) more acidic than the average observed across the watershed. Nitrogen was found to be higher at this site in comparison with levels across the watershed. E. coli levels were found to increase drastically during the rainfall captured in July. Water temperatures (≥21°C) and dissolved oxygen (<6 mg/L) in August indicated this area could not support a healthy aquatic community. Similarly, a high proportion of worm species in the BMI community indicate this site is probably characteristic of high amounts of organic matter and low dissolved oxygen. There were several other triggers of poor water quality among the BMI community including abnormally low proportion of larval flies and low diversity among taxonomic groups signifying this site cannot support a variety of organisms. Despite this community having the overall lowest tolerance to pollution (4), the BMI community is ranked as **potentially impaired**.

Table 20: Bank characteristics at the Hanford Brook site. *Figure by H. Bradford.*

Characteristic	Left Bank	Right Bank
Forest Maturity	Mature	Variegated (Mature/ Wetland)
Slope	Moderate	Moderate
Drainage	Moderately, well	Imperfect
Overhanging Vegetation	40	0
Undercutting	30	0
Stability (%)	70	90

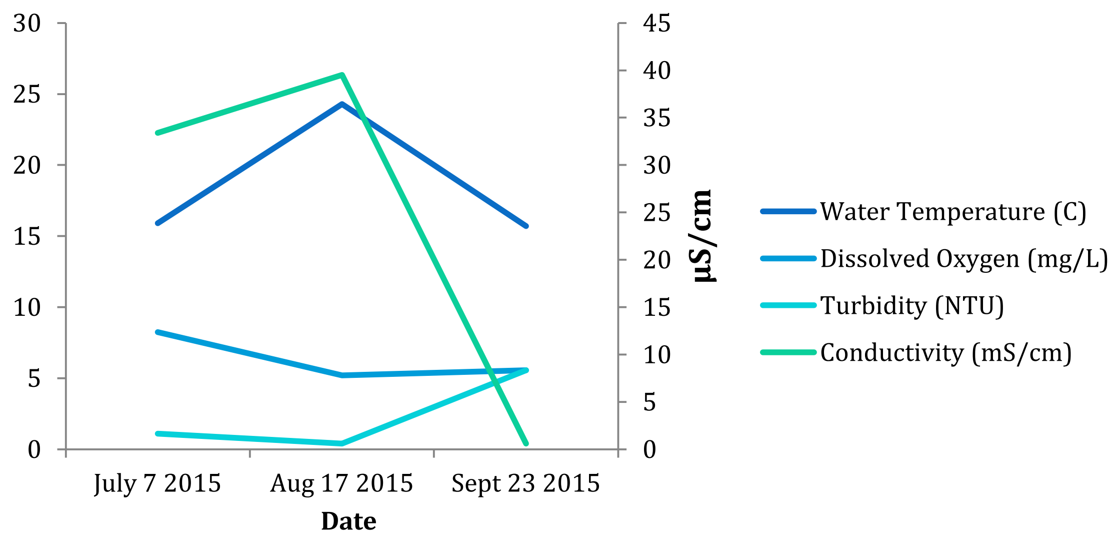


Figure 68: Water temperature, dissolved oxygen, turbidity and conductivity measurements taken during summer 2015 at Hanford Brook site. *Figure created by H. Bradford*

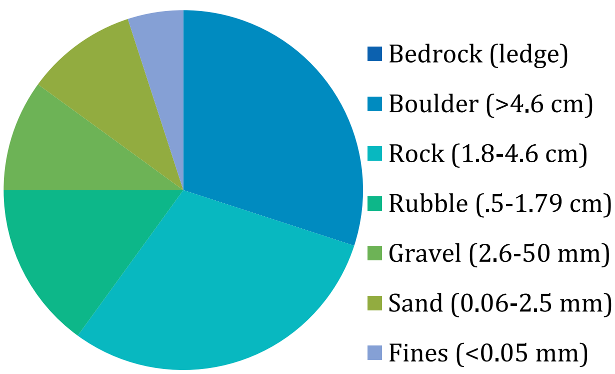
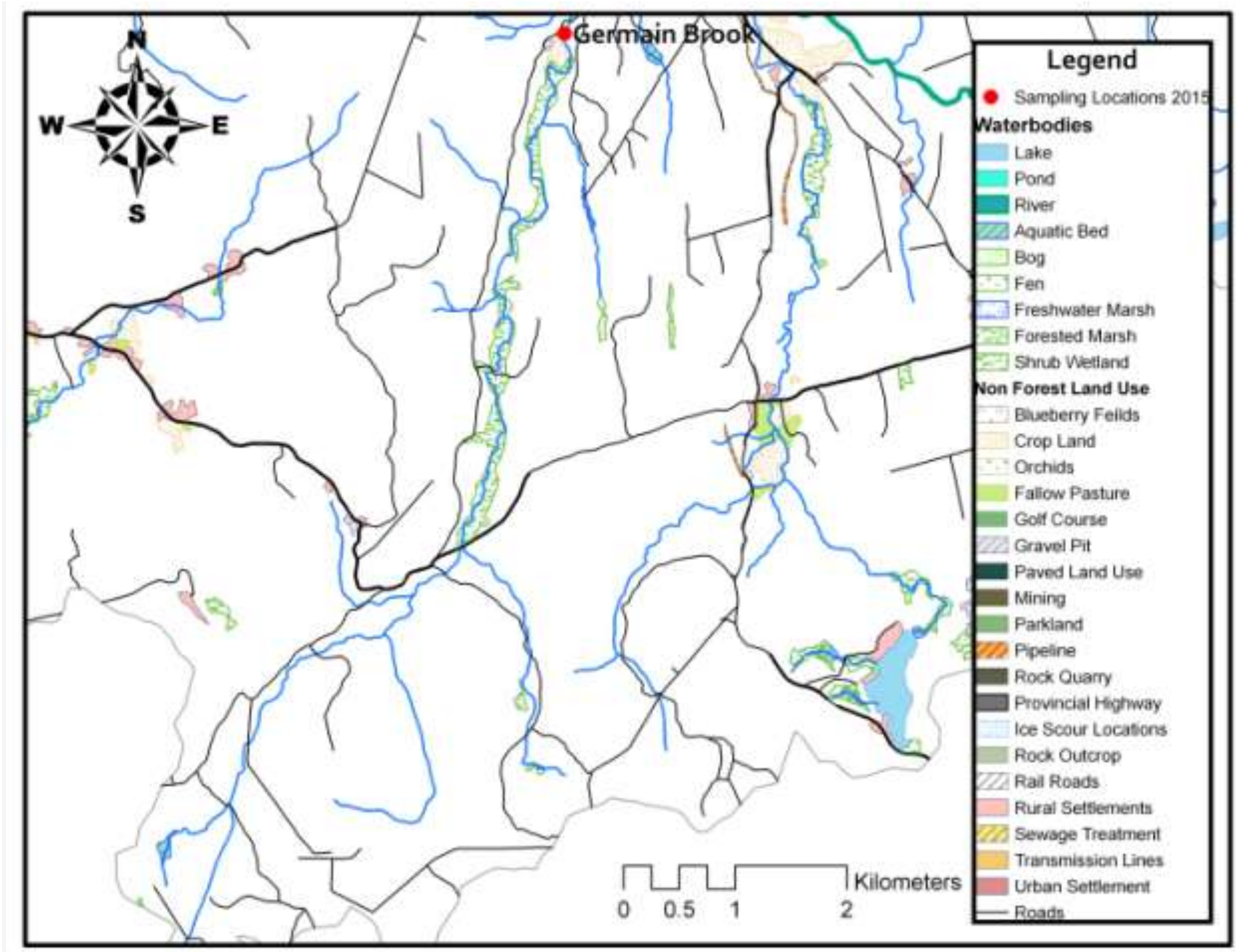


Figure 69 (top left): Cross section of the Hanford Brook site facing upstream, slanting trees indicate left banks instability and the right bank is sustained by its predominately boulder substrate. Figure 70 (top right): Severe undercutting is visible on the left bank, along with slanting trees. Figure 71 (bottom left): Substrate by percentile. *Chart by H. Bradford.* Figure 72 (bottom right): Comparison of exposed substrate and summered substrate in late summer. *All photos by H. Bradford Aug 20 2015.*

GERMAINE BROOK SUB-CATCHMENT



The Germaine Brook tributary is bordered by shrub marshland and steep slopes along the west bank. *Bradford.*

Germaine Brook is west of Upperton and runs north toward the Hammond River and the sub-catchment is 29.82 km^2. There was **moderate stress** present caused by road development (1.6 km/km^2) with high levels of aquatic fragmentation (19 out of 27 stream segments). Stress from land development (1.5%) and agriculture (0.325%) was low in this area. The riparian buffer was classified as **healthy** (98.4%) and the stress level was **low.**

The lower portion of Germaine Brook was planted in 2007, however, this rehabilitation work was regarded as unsuccessful. In 2010, a second attempt at riparian restoration efforts was successful at removing blockages created by bottlenecked debris and creating a 10 meter buffer zone along the bank of the brook. Subsequently, this work has eroded away and the lower Germaine Brook is experiencing major changes to the channel pathway causing significant bank erosion, damage to adjacent farmland and the loss of important salmon spawning habitat (Figure 75). The HRAA hopes to restore this area in the near future.

GERMAINE BROOK SITE

Germaine Brook is a tributary of the Hammond and is classified as a stream order 3. The brook had the appearance of the most pristine site visited in the watershed and was sampled four times in 2015. The site was found to have no signs of **embedded** substrate. The stream was characterized by **clear** coloration with great visibility and defined by two different flow types (70% **run** and 30% **riffle**). The **stream cover** was 35%. This site was identified as a **cool water habitat** and water temperatures were measured below 21°C (Figure 74). Dissolved oxygen levels were lower than the acceptable limit for aquatic life in the September 2015 sample and conductivity was very low (Figure 74).

The water quality analysis displayed all parameters within acceptable limits, and the BMI community collected here was ranked as **unimpaired.** Even so, the BMI community collected at this site had low diversity among taxonomic groups, a high proportion of midges, and a low proportion of fly larvae. These community characteristics indicate the site may not be able support a variety of organisms, that there is most likely a lot of organic matter with a low concentration of dissolved oxygen present and that water quality is likely to be poor (Appendix 4). During annual surveys, this site has moderate abundances of fish and juvenile Atlantic salmon (Appendix 7).

Table 21: Bank characteristics at the Germaine Brook site. *Figure by H. Bradford.*

Characteristic	Left Bank	Right Bank
Forest Maturity	Mature/ Grassland	Mature
Slope	Moderate	Moderate
Drainage	Well	Moderately well
Overhanging Vegetation	70	50
Undercutting	7	35
Stability (%)	95	90

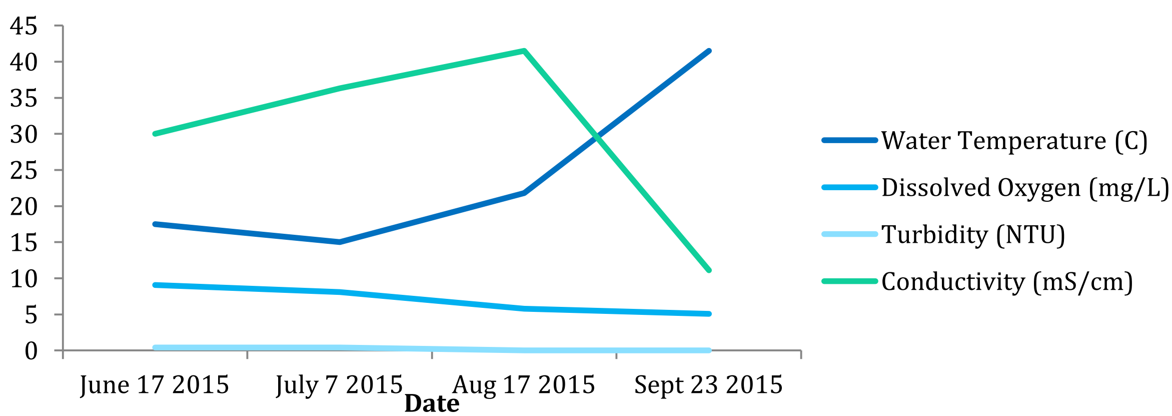


Figure 74: Water temperature, dissolved oxygen, turbidity and conductivity measurements taken during summer 2015 at Germaine Brook site. *Figure created by H. Bradford*

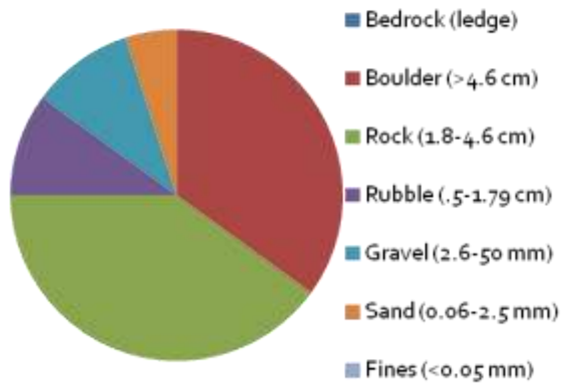


Figure 77 (left): A cross-section of Germaine Brook facing upstream. *Photo by H. Bradford June 17 2015.* Figure 78 (top right): Substrate by percentile at Germaine Brook. *Chart by H. Bradford.* Figure 79: During the late summer, Caddisfly shells appeared to be coating every rock in the Brook. *Photo by H. Bradford Aug 20 2015.*

Figure 75: (left) Recent bank erosion along lower Germaine Brook. Figure 76: (right) Bank erosion has led to trees being uprooted. *All photos by H. Bradford Dec 14, 2015.*

MARKHAMVILLE SUB-CATCHMENT

The Markhamville sub-catchment contains the majority of the Hammond River headwaters, located in the northwest watershed within the townships of Hillsdale, Hammondvale and Markhamville. This sub-catchment is 93.75 km^2 in size. Road density (1.7 km/km^2) was measured to cause moderate stress in this area, which has led to high stress from aquatic fragmentation (99 out of 144 stream segments are disrupted). On top of the severely fragmented waterways, several culverts in this area are in need of replacement or repair (Appendix). The area has low stress from land development (13.6%) although it is comparatively high for the watershed. Land use mainly includes housing settlements, crop and agriculture land (8.94%), gravel pits and/or mining (14.23%) which are the second and third highest density here, respectively. Unfortunately, this sub-catchment is the largest and has the lowest quality of **riparian buffer** (18.88 % is undeveloped) warranting a rating of **impacted**. During annual fish surveys, the Markhamville area is characterized by moderate fish abundance and relatively high counts of juvenile Atlantic salmon. It appears that this area is being increasingly used for salmon spawning habitat, with 47 redds found in this area in 2015 (Appendix 7).

HILLSDALE BRIDGE SITE

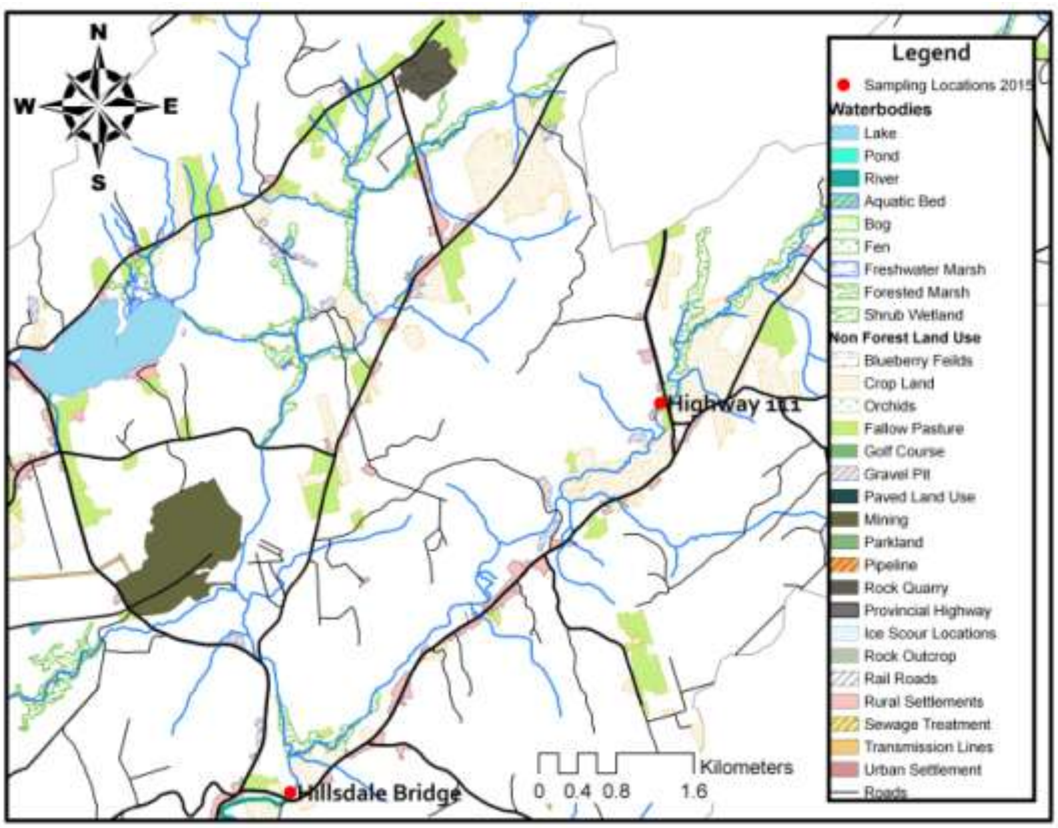


Figure 80: The Hillsdale Bridge site is the outpour point for the North Branch Brook, Fowler Brook and Cassidy lake tributaries and marks the beginning of the Hammond River. *Map by H. Bradford.*

The Hillsdale site marks the beginning of the Hammond River and is classified as stream order 4. This area contains cropland, fallow pasture, some residential development and a potash mine. This site is located 30m upstream of the Highway 111 (St. Martins) stream crossing in Devine Corner. This site was sampled four times during the summer of 2015. There were no signs of **embeddedness** in the substrate. The stream was characterized as 40% **riffle** and 60% **pool** with **clear** coloration and great visibility. Water levels here did not appear to drastically decrease during the late summer as with other sites. There was 8% **stream cover**. The Hillsdale site was documented to have a **stressed** riparian health, while the in stream habitat was found to be **healthy**.

Conductivity was comparably high at this site, which may be attributed to mining practices upstream. By mid-summer the site had transitioned from oligotrophic to mesotrophic. During the rainfall event in July, potassium concentrations increased drastically to 17 mg/ L, which was a **1600% increase** from the average concentrations on that date. During the summer of 2015, this site was recognized as an important **cool water habitat.** A high proportion of midge and insects in the BMI community indicated poor water quality and poor stream conditions. Low diversity among taxonomic groups also means the site is not able to support a variety of organisms. The BMI community at this site was **potentially impaired** and indicated a moderate tolerance for pollution at 5.3 (Appendix 5).

Table 22: Bank characteristics at the Hillsdale Bridge site. *Figure by H. Bradford.*

Characteristic	Left Bank	Right Bank
Forest Maturity	Variegated – Wetland/Mature	Mature
Slope	Moderate	Flat
Drainage	Very poor	Poor
Overhanging Vegetation	70	50
Undercutting	0	0
Stability (%)	85	75

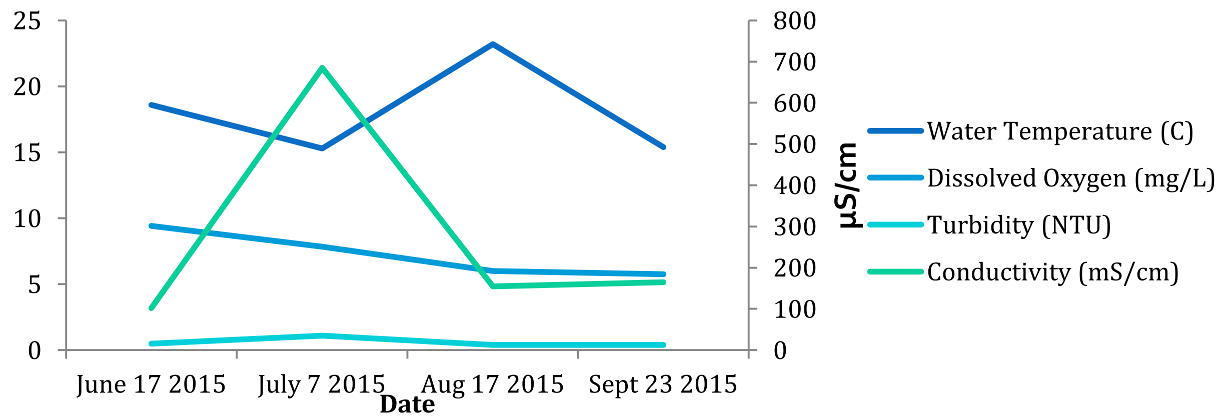


Figure 81: Water temperature, dissolved oxygen, turbidity and conductivity measurements taken during summer 2015 at the Hillsdale bridge site. *Figure created by H. Bradford*

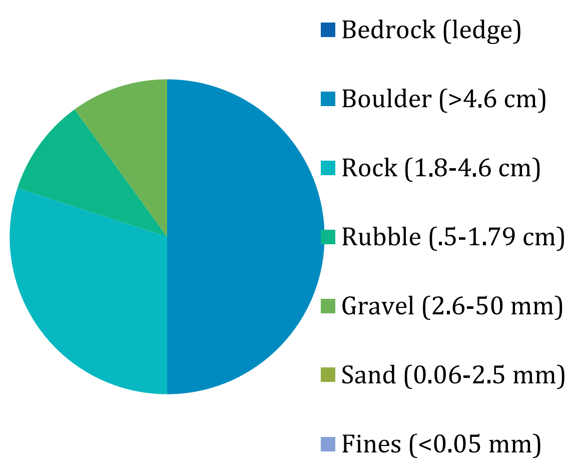


Figure 82 (top): A cross-section of the river at the Hillsdale site, facing upstream. *Photo by H. Bradford June 17 2015*. Figure 83 (bottom left): The left bank is significantly impacted from long term tree removal, and appears to be previously stabilized with rock. *Photo by H. Bradford June 17 2015*. Figure 84 (bottom right): Substrate by percentile. *Chart by H. Bradford.*

HIGHWAY 111 BRIDGE SITE

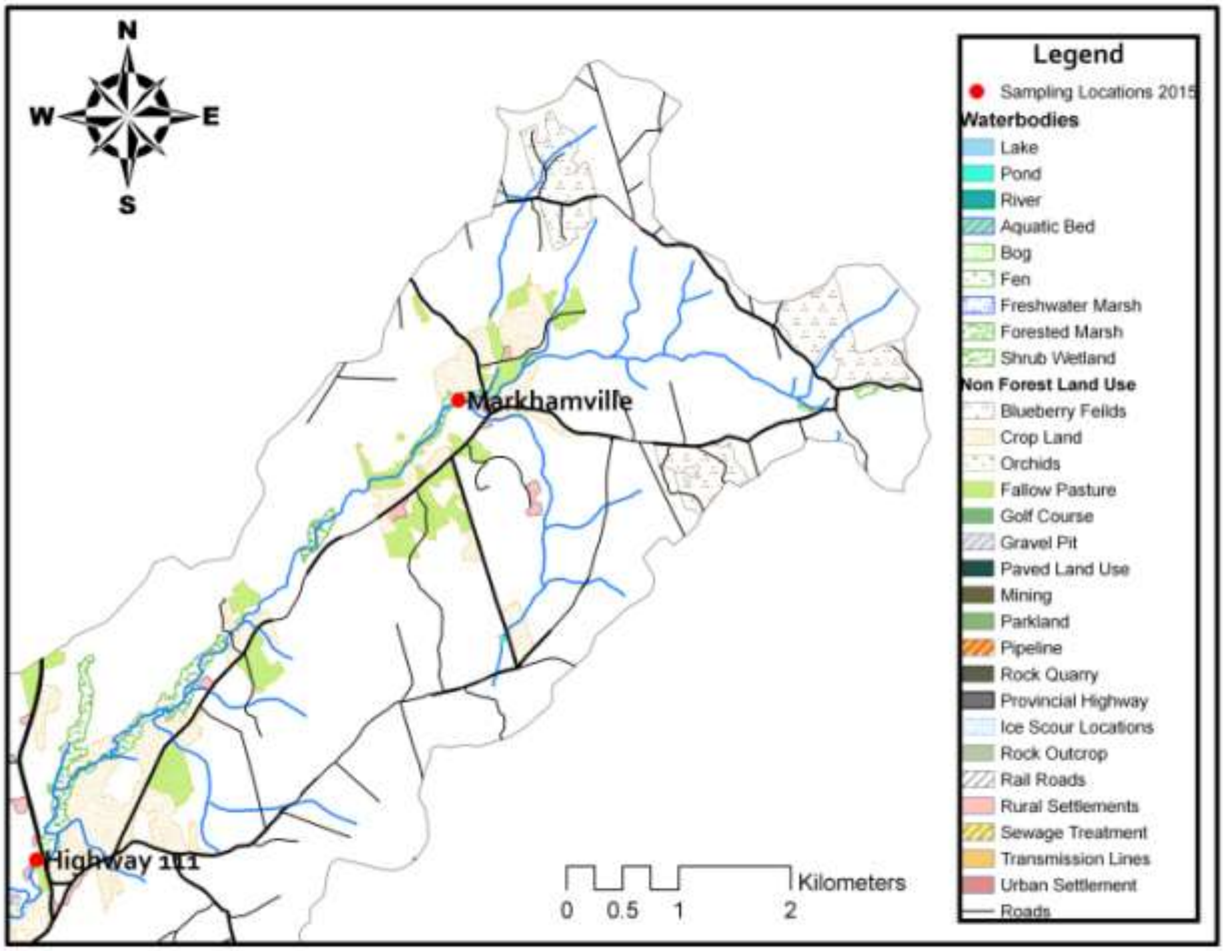


Figure 85: The highway 111 site is considered to be a reference location for the Hammond River, due to its relatively undeveloped land. This land largely contains cropland and fallow pasture with most water flowing through shrub wetland. *Map by H. Bradford.*

The Highway 111 (St. Martins Road) site is located in Hammondvale and is classified as stream order 4. This site was visited 4 times during 2015. With regards to the substrate, there was no visible **embedding**. The stream is characterized by **clear** coloration and high visibility. The **stream cover** was 35%. Assessing all parameters, Highway 111 Bridge site was documented to have a **stressed** riparian health, which is consistent with previous findings (Campbell and Prosser, 2008). The in-stream habitat was found to be **healthy**. Dissolved oxygen dipped below the acceptable limit (<6 mg/L) for a healthy aquatic community by mid-summer and water temperatures reached a high of 20.5 ºC (Figure 87). Despite being considered a reference location, the BMI community indicated the site was **potentially impaired**. A high proportion of midges and insects indicate that the site has potentially poor water quality and may not support a healthy community.

Figure 86: Cross section (facing downstream) at the Hammondvale site. *Photo by H. Bradford Aug 17 2015.*

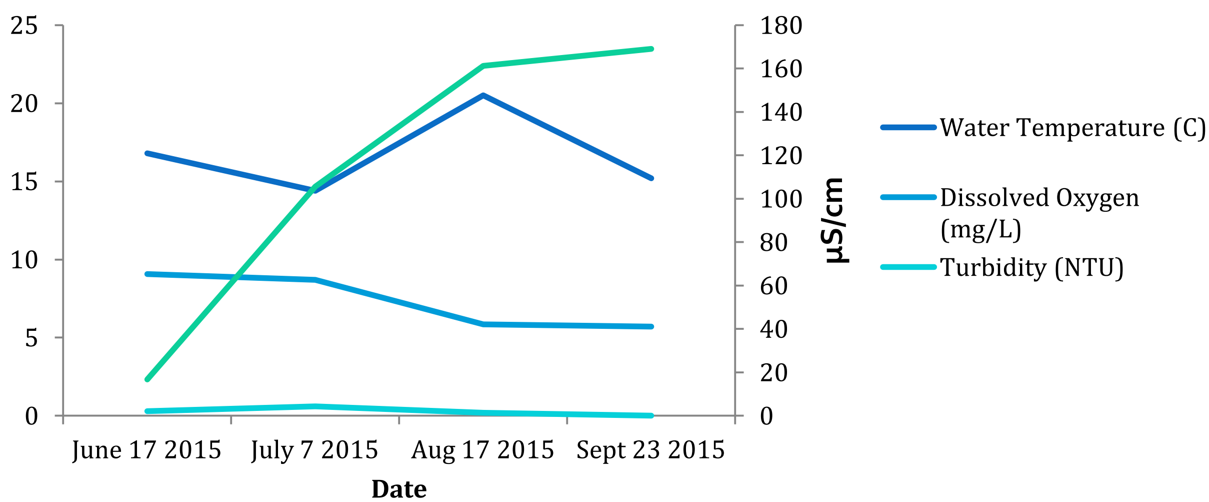
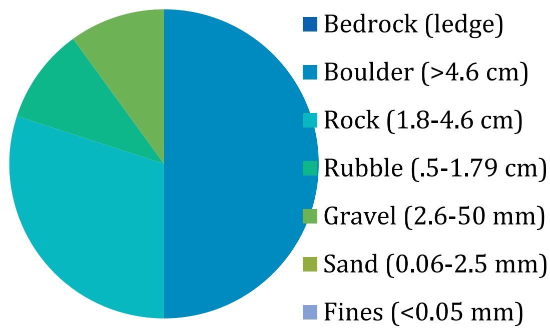


Figure 87: Water temperature, dissolved oxygen, turbidity and conductivity measurements taken during 2015 at the Highway 111 site. *Figure created by H. Bradford*

Table 23: Bank characteristics at the Hillsdale Bridge site. *Figure by H. Bradford.*

Characteristic	Left Bank	Right Bank
Forest Maturity	Grass	Variegated – Wetland/Mature
Slope	Moderate	Flat – Moderate
Drainage	Poor	Poor
Overhanging Vegetation	100	50
Undercutting	13	2
Stability (%)	90	85



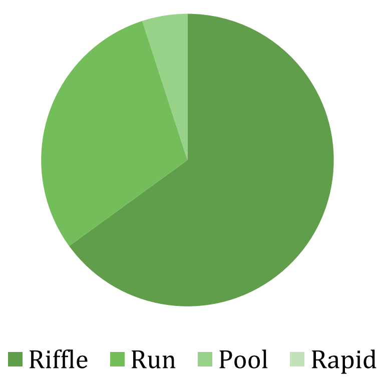


Figure 88 (top left): Aquatic plants flourish in Hammondvale (compared to the other sites). *Photo by H. Bradford Aug 17 2015.* Figure 89 (top right): Substrate by percentile. *Chart by H. Bradford.* Figure 90 (bottom left): Flow type by percentile. *Chart by H. Bradford.* Figure 91 (bottom right): Substrate at Hammondvale. *Photo by H. Bradford July 20 2015.*

MARKHAMVILLE SITE

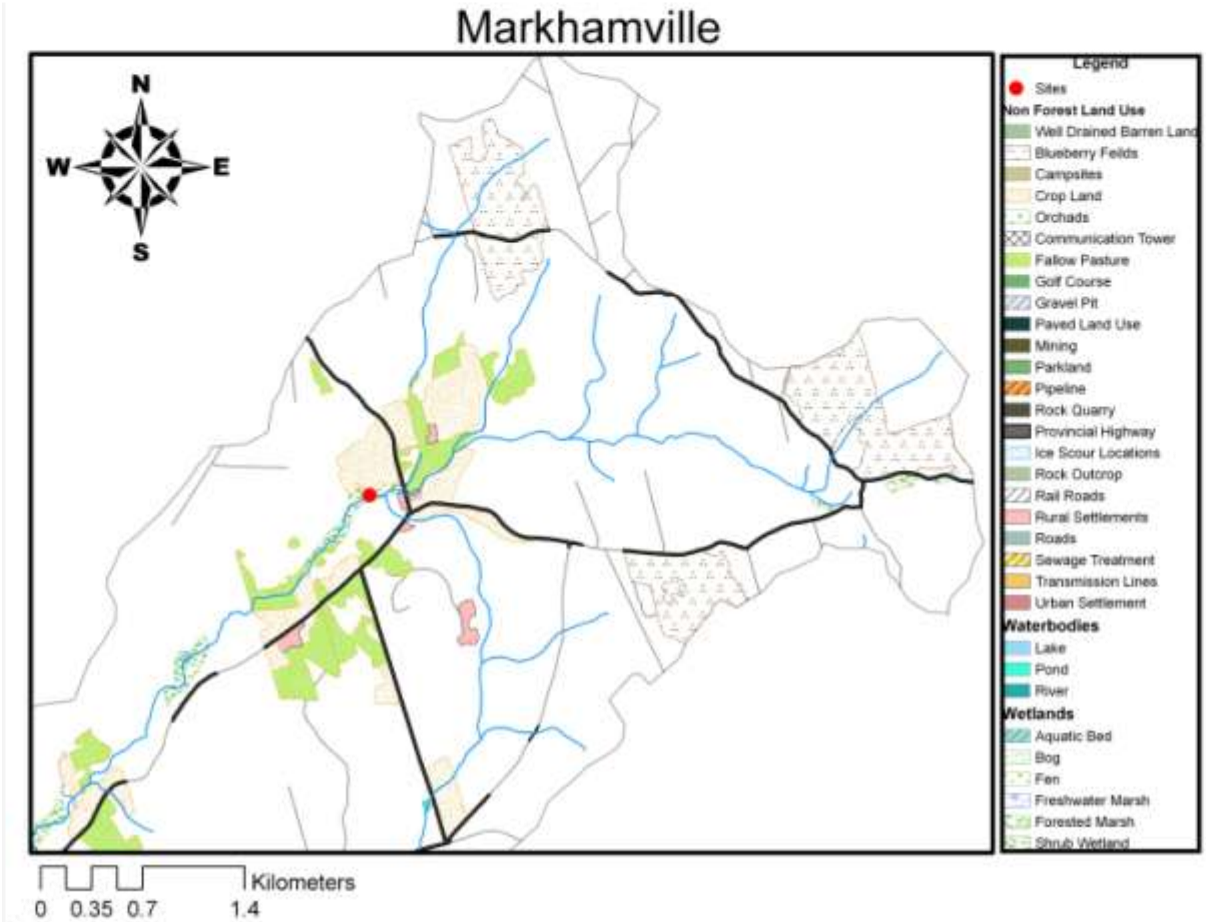


Figure 92: Markhamville is in the most upper reaches sampled within the Hammond River watershed. *Map by H. Bradford.*

Located in Markhamville, this tributary is classified as stream order 4 and is downstream of the Markhamville Road stream crossing. This area contains cropland, fallow pasture and blueberry fields as well as shrub wetland. The site was visited four times during 2015. The substrate was not visibly **embedded** at this site. The stream was characterized by **clear** coloration during early summer; however, it began to develop an algal film and the appearance of turbid waters later in the season. **Stream cover** was 90%. Assessing all parameters, Markhamville was documented to have a **stressed** riparian health, while the in stream habitat was found to be **healthy**. Water temperature was equal or less than 18°C throughout the summer and this site was identified as **cool water habitat** for fish refuge (Figure 93). The site retained relatively acceptable levels of dissolved oxygen until the September samples, when D.O. dropped below the threshold to 5.11 mg/L.

The BMI community was **unimpaired**, with an average tolerance value of 4.8. A high occurrence of insects and midges at this site indicated stream conditions might not support a healthy community and may have poor water quality (Appendix 4).   The water quality analysis indicated that concentrations of chromium, manganese and phosphorus were considerably higher than what was found across the watershed. This site was consistently identified as mesotrophic during all sampling periods. In contrast, most other sites were permanently oligotrophic, oligotrophic by summer's end or were found to be oligotrophic only after the rainfall.

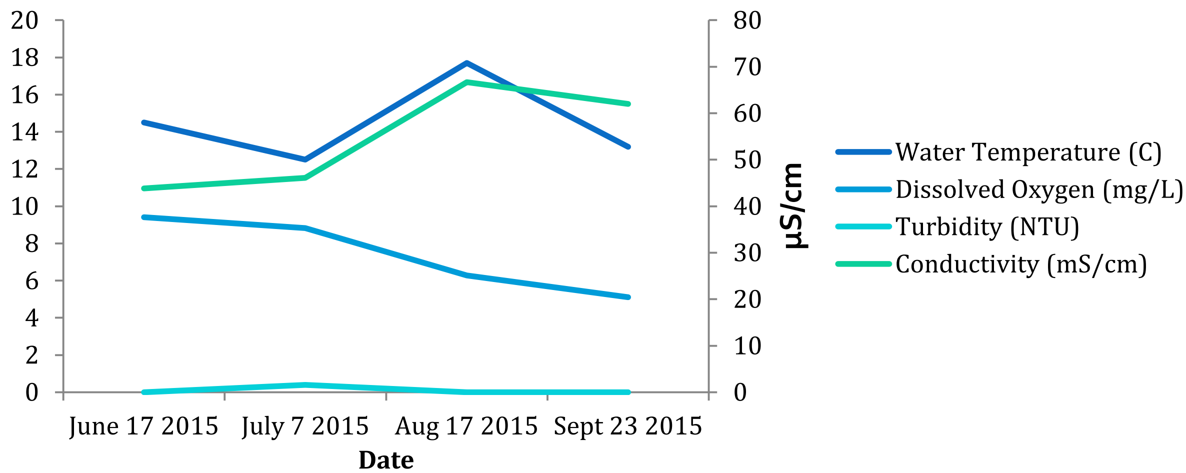
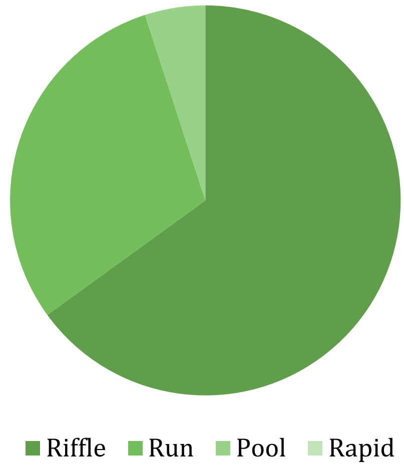


Figure 93: Water temperature, dissolved oxygen, turbidity and conductivity measurements taken during 2015 at the Markhamville site. *Figure created by H. Bradford.*

Table 24: Bank characteristics at the Hillsdale Bridge site. *Figure by H. Bradford.*

Characteristic	Left Bank	Right Bank
Forest Maturity	Grass	Mature
Slope	Flat - Moderate	Flat
Drainage	Poor	Poor
Overhanging Vegetation	90	50
Undercutting	5	15
Stability (%)	80	95



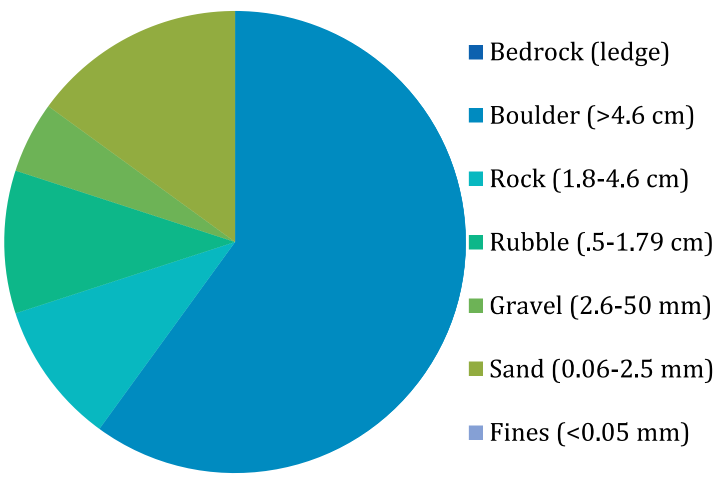


Figure 94: (top left) A cross-section of the Markhamville site facing upstream. *Photo by H. Bradford July 20, 2015*. Figure 95: (top right) Flow type by percentile. *Chart by H. Bradford.* Figure 96: (bottom left) Substrate by percentile. *Chart by H. Bradford.* Figure 97: (bottom right) Substrate at Markhamville. *Photo by H. Bradford Aug. 20, 2015.*

DISCUSSION

PRIORITY AREAS

Using the Water Classification Program in HRAA's last strategic watershed management plan, Bradley Brook, Scoodic Brook and Palmer Brook were prioritized for their class "C" rating (Campbell and Prosser, 2008). While some remediation has occurred at the Scoodic Brook site in particular, there are still overarching problems with sedimentation and E. coli in Palmer and Bradley brook. This section will use the stress-condition-response model to re-assess sub-catchments within the watershed and serve to guide watershed management by the HRAA over the next 5-10 years. The evaluation of stressors indicated low to moderate stress from development across the watershed, with the Palmer Brook and Nauwigewauk eco-reach having the largest amount of stress (Figure 98). Environmental conditions within the watershed ranged from healthy to stressed, with stressed conditions in the Markhamville, French Village, Hanford and Scoodic sub-catchments. Using all environment condition ranks (averaged for sub-catchment) and by summarizing the stressor ranks, a priority rank was developed:

Priority	Eco-Reach
1	Palmer Brook
2	French Village
3	Markhamville
4	Nauwigewauk
5	Hanford
6	Damascus-Titus
6	Salt Springs
7	South Stream
7	Scoodic
8	Germaine Brook
9	Barnesville

This priority rank is based on the worst ranking sub-catchments and the top 5 sub-catchments will be considered the focus of the HRAA over the next 5-10 years. Sub-catchments that received equal priority ranks, received an equivalent score for environmental condition and the level of stressor indicators.

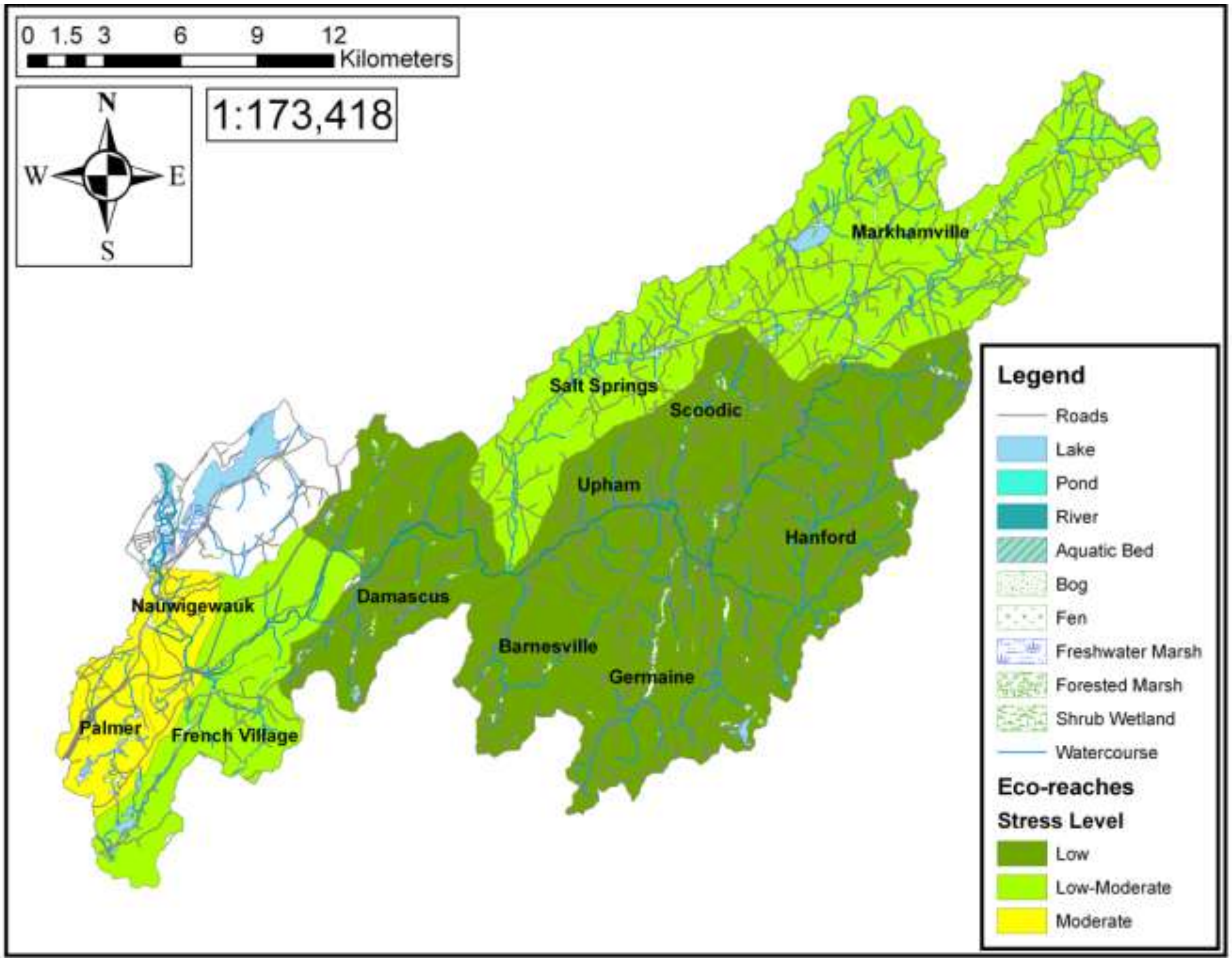


Figure 98: Stress level indicated by measuring road density, aquatic fragmentation, land development, mine and/or gravel pit density, agricultural land use and sewage field density within each sub-catchment. *Map by H. Bradford.*

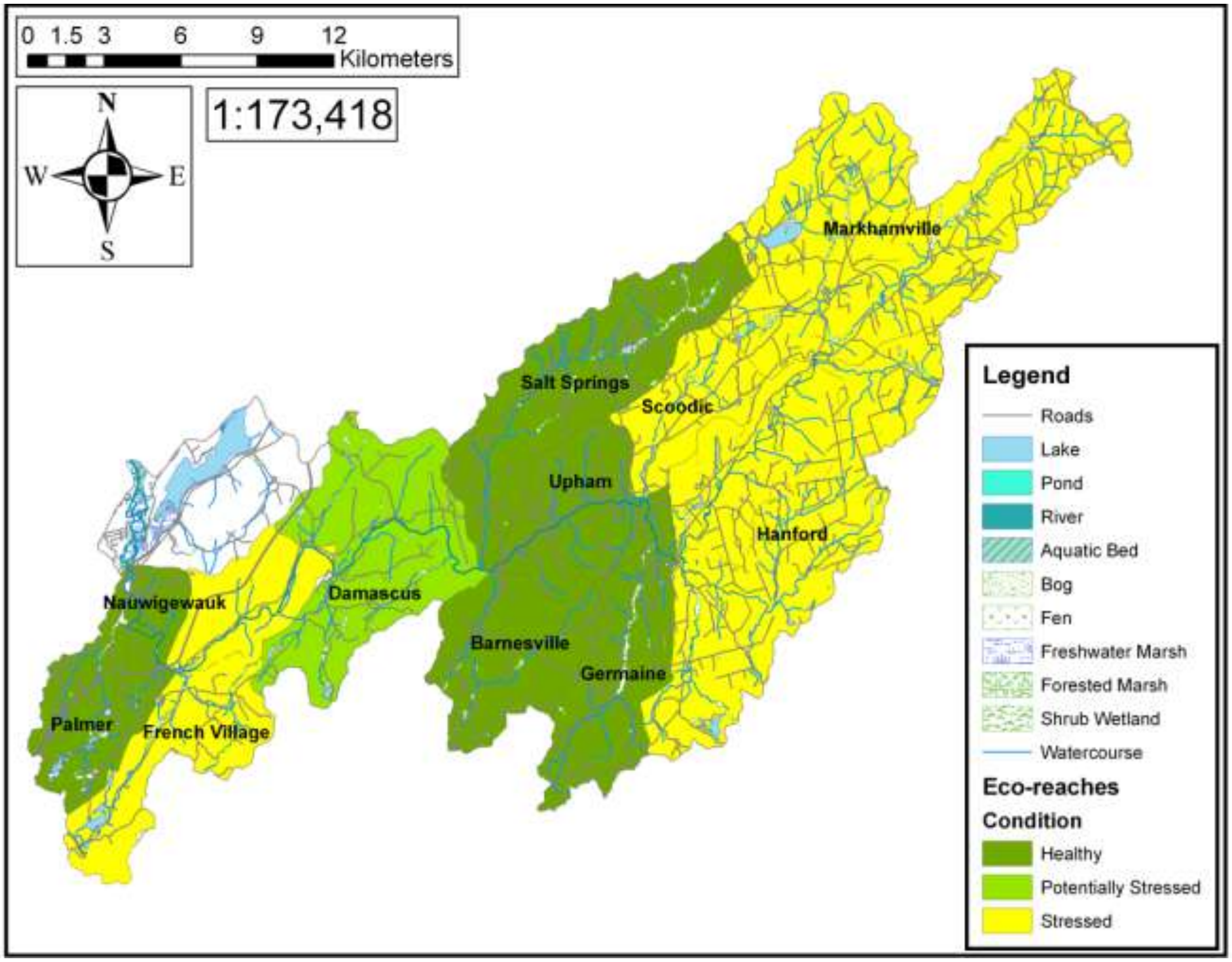


Figure 99: The condition of environmental quality indicators as determined by water quality analysis, the BMI community, development within the riparian areas and qualitative assessments of riparian health and in-stream habitat at sites within the sub-catchments. *Map by H. Bradford.*

Stressors were tested in order to better understand their effect on environmental condition. Pearson Product Moment Correlation tests were used to compare all water quality parameters with the density of each stressor within the sub-catchment. Riparian health was not included in this analysis as it is impossible to estimate riparian health for the entire sub-catchment without physically walking the length of every stream. While many weak correlations were identified between stressors and water quality indicators, only 5 stressors (road density, gravel and mine pit density, land disturbance, agricultural density, and aquatic fragmentation) showed statistically significant ($p < 0.1$) correlations with environmental conditions. Such correlations strongly suggest that these stressors are affecting certain environmental conditions.

Road density was significantly correlated with magnesium, ammonia, nitrogen, phosphorus, and alkalinity indicating roadways may be a major source of the pollutants found in these waterways. Road density was also correlated with the BMI index, suggesting that road density is contributing to a change in the invertebrate community as the most sensitive species are not surviving in these areas. Embeddedness was also correlated with road density. As embeddedness is a measure of previous sedimentation events, this relationship suggests that roads are contributing sediment into the water and/or contributing to bank erosion. To manage the negative effects of roads, major seepage points displaying the effects of runoff, need sedimentation infrastructure to reduce these pollutants from directly flowing into nearby streams and brooks during rainfall events.

Mine and gravel pit density was strongly correlated to several water quality parameters, indicating a very strong likelihood that mines and gravel pits are contributing many pollutants (ammonia, manganese, iron, phosphorus, magnesium) to the water column. The correlation between mine/gravel pit density and water colour, hardness and alkalinity similarly suggests a link between poor water quality and the density of mines in adjacent lands. Embeddedness was also correlated with mine/gravel pit density, suggesting that mines are contributing sediment into the water. Gravel pits and mines often expose rock and soil aggregates, which are susceptible to entering the waterways via run off. Finally the relationship between mines/gravel pits and e-coli suggests that mines and gravel pits are contributing to unacceptable levels of these bacteria into the water.

The density of agricultural land showed significant relationships with conductivity, hardness and sulfate suggesting that agriculture plays a significant role in deteriorating water quality. Correlations with embeddedness suggest that agriculture is contributing sedimentation into the water, either through runoff or erosion exasperated by poorly vegetated stream banks within agricultural land. The correlation between agricultural land density and BMI community tolerance suggests that agriculture is having a negative effect on the macroinvertebrates, and water quality in general.

Table 25: Person's product-moment correlation coefficient ($p < 0.10$) was used to assess if a relationship existed between stressor type (road density, aquatic fragmentation, mine density, land disturbance and density of agriculture) and the environmental condition variables assessed in 2015. The environmental condition variables investigated were quantitative (to be more representative of the sub-catchment condition versus individual sites) and included all water quality parameters, the tolerance of the benthic macro-invertebrate community toward pollution, and embeddedness.

	Road Density	**Agriculture**	**Land Development**	**Mine and Gravel Pits**	**Aquatic Fragmentation**
Alkalinity	0.384		0.757	0.823	0.286
Aluminum					0.292
Ammonia	0.262		0.352	0.355	
BMI community tolerance	0.548	0.572	0.659		
Chloride					-0.428
Color			0.275	0.344	
Conductivity		0.231	0.303		-0.328
E. Coli			0.335	0.448	
Embeddedness	0.429	0.261	0.78	0.582	
Hardness		0.264	0.576	0.513	
Iron			0.426	0.56	0.303
Manganese			0.325	0.419	0.237
Magnesium	0.236		0.687	0.687	
Nitrogen	0.283				0.297
Phosphorus	0.368		0.515	0.666	0.311
Sodium					-0.411
Sulfate		0.33			-0.535

The density of land development within an eco-reach includes all development, including roads, mines, gravel pits, agricultural, residential, commercial and industrial development. Each of the water quality variables that were correlated with land development were also correlated with either road density, mine/gravel pit density or agriculture, suggesting that pollutants or increased nutrient concentrations are likely caused by more than one type of development. What these relationships do tell us is the development in general is strongly related to degrading water quality. Land development typically consists of stripping the natural landscape of vegetation which reduces the infiltration and evapo-transpiration of water. Land development has likely contributed to many common problems in the watershed including an increased frequency of flooding events, prominent sedimentation, degrading riparian health and increased concentrations of water quality variables.

Finally, aquatic fragmentation had significant correlations with several water quality parameters. These relationships suggest that aquatic fragmentation is having a minimal effect on water quality. However, aquatic fragmentation is still a problem for fish, as it may limit access to important fish habitat.

Awareness of the impact individual stressors have on specific environmental conditions will help to prioritize management actions in the future. For instance, while the actual density of roads cannot be changed the HRAA can work to control runoff from roadways into nearby waterways. Within the Hammond River watershed developed land density is relatively low, but appears to be having a significant impact on environmental condition. It is suspected that the impact of land development stems mainly from development patterns (near rivers and streams, sprawl, more space equals larger lawns, etc.). A cross jurisdictional approach could include raising land tax on new properties developing near waterways. Within highly developed areas such as near Bradley Lake and Quispamsis, incentive programs should be developed for home sewage field (a major cause of E. Coli to the local area). On home by home basis, educational tools should be made available for eco-terracing and developing more sustainable lawnscapes including information on species native to the area, their function within the environment and conceptual designs for an eco-friendly lawn. In the short term, one of the most feasible opportunities the HRAA has is to delineate and wetlands across the watershed. Current wetland maps within New Brunswick do not represent a significant proportion of wetlands, leading to the mismanagement and development of wetland areas. Wetland Ecosystem Mapping Protocol for Atlantic Canada (WESP-AC) should be combined with wetland delineation to improve wetland maps, as WESP-AC places function and value on specific wetlands allowing the public a more transparent reason to support wetland conservation specific to their area.

RECCOMENDATIONS FOR PRIORITY AREAS

1, 2 & 3. THE LOWER HAMMOND RIVER WATERSHED

The evaluation of the level of stressors within each sub-catchment and the environmental conditions found at the sites indicate French Village, Nauwigewauk and Palmer Brook sub-catchments to be high priority management areas . Several commonalities characterize the lower reaches of the Hammond River (Palmer Brook, French Village and Nauwigewauk sub-catchments). Due to their proximity, their recommendations will be discussed together. Reasons these areas were prioritized include:

- → High levels of developed land, road density, open gravel pits and agricultural land use.
- → Moderate-severe sloping along the river, floodplains of alluvial, unconsolidated soils and fallow pasture make the area susceptible to increased rates of sedimentation.
- → Low levels of forest cover over the water and immature/grassland dominating riparian areas.
- → Important fish habitat during "runs" (exit/entry point to the watershed) and high fish abundance (particularly in Palmer Brook which has pools with large striped bass, American eel, historic Atlantic salmon nesting grounds, and a spring fed cool water supply).
- → Midges were prevalent at all sites in this area. Midges are indicators of poor stream quality because they have multiple reproductive periods a year, giving them a competitive advantage over other BMI species.
- → Fly larvae was over-abundant within Palmer Brook and found in low abundance at the HRAA and Bradley Brook sites, too low or high larval abundance indicates poor water quality.
- → Ranked <u>for impacted riparian health</u> and <u>stressed in-stream habitat.</u>

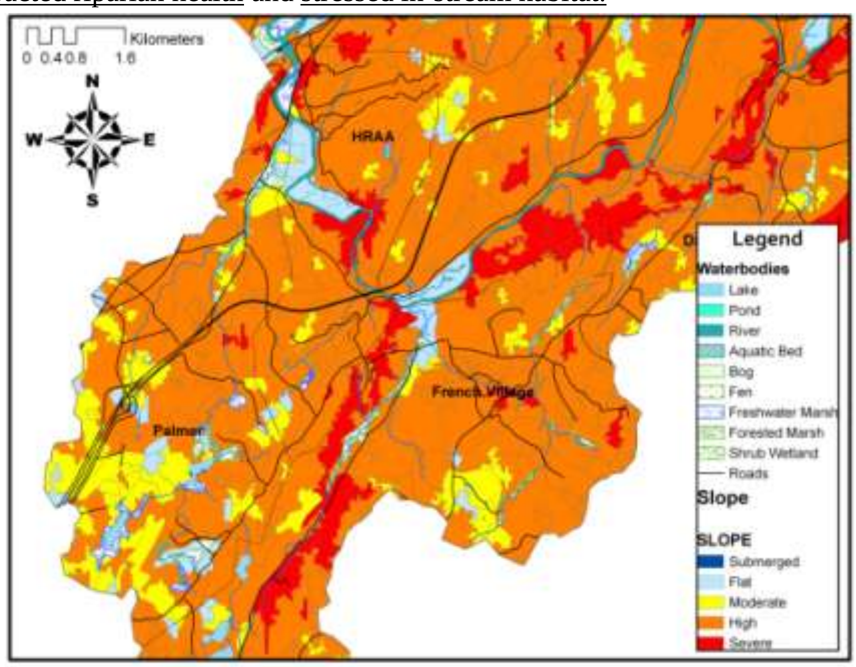


Figure 100: Slope grades in the lower reaches of the Hammond River watershed. *Map created using DNR GIS data layers (2009) by: H. Bradford*

SPECIAL CONCERN: PALMER BROOK & BRADLEY BROOK

Palmer and Bradley Brook have historically been ranked as class C tributaries (Campbell and Prosser, 2008) and were identified throughout this study to have the highest level of stressors within the watershed. Causes of stress in Palmer Brook include the Trans Canada highway (crossing Palmer and Colton Brook), municipal sewage, high rates of expansion for residential development and a high density of gravel pits. Bradley Brook faces similar stressors from high levels of aquatic fragmentation, numerous gravel pits and land development (which mostly consist of cottages and homes around Bradley Lake). While several recommendations from the last strategic management plan have been fulfilled, sedimentation, E. coli and Bradley Brook faces similar stressors from high levels of aquatic fragmentation, numerous gravel pits and land development (which mostly consist of cottages and homes around Bradley Lake). While several recommendations from the last strategic management plan have been fulfilled, sedimentation, E. coli and unrestricted development are still on-going issues.

Even though the GIS data (2009) indicated the Palmer Brook riparian buffer to be largely intact, this data appears to be somewhat outdated. Especially in lower Palmer Brook, riparian health appears poor due to a lack of mature vegetation in riparian areas, bank instability and undercutting. These bank characteristics provide little forest cover and greatly reduce the capacity for runoff water filtration. For instance, the poorly vegetated riparian area is most likely contributing to unacceptably high levels of E. coli of 500 MPN/ 100 ml during high water temperature (August 2015), low dissolved oxygen and other water quality results undesirable for water quality. Alkalinity is the ability of a water body to buffer against sudden changes in pH. In Palmer Brook, alkalinity is greater than (avg. 3.09X) the normal range (+ 2 SD) for the watershed, which may attribute to its comparatively high pH (avg. 8.04). Hardness, which represents the amount of soluble, divalent, metallic cations, is second highest in the watershed. Hardness is a result of major cations like magnesium and calcium sopping up excess H^+ ions. In general, high levels of alkalinity and hardness represent favorable conditions for fish health, by easing osmoregulation in fish and resilience in the system (WHO, 2011). Despite the capacity of this system for buffering and providing favorable conditions for aquatic life, levels of aluminum, chromium, copper and manganese are found in above average concentrations (+ 2 SD) for the watershed. At this pH level, chromium and copper adsorption to organic materials and the precipitation of manganese should be increased. These elements (chromium, copper and manganese) and aluminum are often correlated to the prevalence of industrial spills or industrial byproduct, sewage plants, traffic density, and treatment plants, respectively (CCME, 2014). While municipal sewage and roadways are the probable diffuse source of E. coli and other undesirable chemicals in this brook, it is imperative that the HRAA find solutions to remediate on-going problems within the brook. One solution would be protecting and enhancing natural vegetative buffers such as wetlands and riparian areas because the sources of pollutants are diffuse in nature. Working with local landowners and industry to help control pollution at the source would also be very helpful in restoring water quality to Palmer Brook.

Lower Bradley Brook is characterized by a poor riparian area with immature forest, little stream cover, unstable and undercut banks. This stream is often found to have high levels of sedimentation, which visibly flows from the tributary during rainfall events. The substrate provides evidence of bank instability and sedimentation as it was fully embedded with silt. Another unresolved issue in this brook is poor water quality, including higher than average concentrations of iron (3.3×), copper (5.5×), potassium (4.9×), and turbidity (3.2×) found during the 2015 samples. These problems, especially turbidity, are most likely caused by the high density of gravel pits upstream, aquatic fragmentation, and high levels of development concentrated around Bradley Brook and Bradley Lake. Copper and iron are usually found in high concentration in sewage effluents, but they may also originate from other sources (copper pipes, naturally occurring, etc.). It is possible that residential sewage fields along Bradley Brook are contributing to these abnormally high levels. Similar to Palmer Brook, one solution would be protecting and enhancing natural vegetative buffers such as wetlands and riparian areas. While this may not solve all problems within the brook, it will likely improve the environmental condition. In the future, the HRAA should seek funding to identify pollutant sources in both Bradley and Palmer Brook. This data could then be used to have informative and meaningful discussions with the town of Quispamsis and local residents about best practices for water quality, conservation and the benefits of preserving their local environment.

RECOMMENDATIONS FOR THE LOWER HAMMOND RIVER WATERSHED:

For the remediation of the Palmer Brook, Nauwigewauk and French Village sub-catchments include:

→ Enhance stream cover in areas with immature forest type to increase cool water habitat
- Restore the riparian area in the lower reaches of Palmer and Bradley Brook.
- Increase riparian buffer width in areas with steep slopes from 15 to 30 m (Nauwigewauk sub-catchment).
- Encourage local landowners to remediate property with natural vegetation indirectly by providing information and consultation or directly by providing seedlings/saplings.

→ Gain public support for more wetland reclamation projects by detailing the work that has been completed by the HRAA so far. Seek volunteer land donations and money for land acquisition in flat, fallow pasture.
- Specific land parcels of interest include: GeoNB IDs 00196626, 30247118, 30115471, 30115455, 30249361, 30205843, 30205827, and 30200901.

→ Develop a better understanding of gravel pits in the area.
- Identify whether gravel pits are active/inactive, beneath the water table and/or adjacent to a water body.
- Monitor turbidity near outflow. While open gravel pits are generally a "clean process", mechanical aggregate extraction can lead to increased fine particles which are collected in ground water reservoirs and runoff during rainfall events.
- Identify gravel pits that may contribute to sedimentation and ensure adequate sedimentation fencing is installed and properly placed.
- Create and initiate action plans for the rehabilitation of fallow gravels pits.

→ Conduct studies that identify and monitor pollutant sources within Palmer and Bradley Brooks with the objective of creating an action plan for environmental remediation.

4. MARKHAMVILLE SUB-CATCHMENT

The Markhamville sub-catchment, containing the Markhamville, Hammondvale and Hillsdale sites, has received the highest priority rating (. In 2008 the Hammond River in Markhamville and North Brook (Hillsdale) sites were identified as class "A" sites according to the Water Classification Program (Campbell & Prosser, 2008). The 2015 assessment indicated that this sub-catchment may have deteriorating environmental conditions including a stressed riparian buffer and benthic macroinvertebrate community. These conditions are correlated with mine density (value?), aquatic fragmentation (value?), and road density (value?) in the area.

Headwaters (stream orders 1-3), like the waterways in the Markhamville sub-catchment, are usually characterized by strong riparian areas that shade the stream, cool water temperature, and limited autotrophic production with the majority of energy input from organic matter detritus (Vannote *et al.*, 1980). Using data layers provided by the Department of Natural Resources (DNR) for GIS (2009), 81% of riparian areas in the Markhamville sub-catchment were developed with the majority of this development from agriculture. Poor riparian health is also evident throughout the area, with a high occurrence of undercutting and little stream cover, as pasture or grassland dominates the banks. The weak vegetative riparian buffer and poor water drainage may contribute significantly to reductions in water attenuation, filtration and normal headwater functions. For instance, chromium and manganese are heavy metals that redistributed in the environment through practices like mining, agrochemical use, sewage and livestock manure and they were found at high concentrations at the Markhamville site. The Markhamville site was also the only area continuously classified as mesotrophic, indicating higher than average concentrations of phosphorus. Filtration in this area is suspected to be already hindered by largely developed riparian areas, albeit, this has yet to lead to prominent sedimentation, pollution or flooding downstream. The effect of reduced stream forest cover is also noticeable via high water temperatures, low dissolved oxygen, and increased primary production, evident through the algal and aquatic plant community dominating the substrate at the Markhamville and Hammondvale sites. Remediation of these riparian areas will be a proactive step in the conservation and protection of our watershed. By focusing on the enhancement and preservation of riparian habitat in the headwaters, we can help the watershed buffer against the effects of climate change (such as more severe flooding events and warmer temperatures), filter pollutants and ultimately protect natural community structure. While the benefits of this work will not be immediate, riparian remediation in the Markhamville eco-reach is expected to have many cost saving benefits in the future.

RECOMMENDATION:

Prioritize riparian zone protection and remediation in the northern branch of the watershed. Devise projects that encourage development away from waterways and wetlands through incentives, community outreach and education. GeoNB land parcels of interest include: 00153445, 00153247, 30112171, 30112262, 0020593, 00153668, 00153486, 00153460, 00154104, 30181838, 30297154, 30181879, and 00153593.

Mining may also be causing prominent problems to the Markhamville area. The potential effects of local mines were more obvious during the water quality sampling campaign that occurred post-rainfall in which potassium levels at the Hillsdale site (located downstream of the potash mine) were 9.2× greater than the average potassium levels at other sites for that date. Overall, potassium was 3.9× greater at this site in comparison to the average concentrations during 2015. Conductivity is another water quality parameter increased downstream of mines (Daniel *et al.*, 2014) and conductivity measurements were among the highest in the watershed at the Hillsdale site. Research has shown the effects of mines located in the headwaters are more widespread than previously anticipated downstream and include impacts to species diversity, evenness, specific life histories, habitat preferences and trophic ecologies (Daniel *et al.,* 2014). While the fish community was not adversely affected (with spawning salmon showing preference to this area), the BMI community was potentially impaired at the Hillsdale site. The BMI is an important part of fish diet and it is expected that an impaired community will eventually affect the fish community as well.

RECOMMENDATION:

Develop an understanding of environmental monitoring at local mines. Implement a long term monitoring study or work in cooperation with mining facilities to enhance best practices and ensure environmental protection.

The poor environmental quality of the Hammond River headwaters identified through this document will help provide invaluable foresight into preserving the health of the river. The headwaters are the most fragile component of a watershed (Daniel *et al.*, 2014) and jeopardizing their integrity and resilience can have longstanding implications for environmental quality downstream. It is even more crucial to protect this area because it provides important spawning habitat for salmon. Moving forward, the HRAA should consider a shift in focus from the downstream effects of poor land use to taking preventative steps in the upstream habitat.

5. HANFORD BROOK SUB-CATCHMENT

Another surprising result of the stress-response evaluation was the poor rating received by Hanford Brook. Previously, Hanford Brook was rated as a class "A" site by the Water Classification Program (Campbell and Prosser, 2008). The stressed environmental condition being classified was the reason for prioritization of Hanford Brook. The BMI community was rated as potentially impaired, with a high abundance of worms, which is uncharacteristic for a mid-land stream as organics often accumulate in the lower reaches of a watershed. A high abundance of worms in the BMI community is an indicator of organic enrichment and low dissolved oxygen. Dissolved oxygen averaged 6.4 mg/L in 2015 in comparison to >9.5 mg/L and water temperature was 24.5ºC by mid-afternoon in August 2015 in comparison to <20.9ºC in 2007 (Campbell and Prosser, 2008). Hanford Brook was comparatively more acidic than other sites, with high levels of nitrogen and algae by August. Other factors that contribute to the prioritization of this site are high road density and visible bank instability with prominent undercutting, low stream cover (7.5%) and a vegetative buffer (57% developed) interspersed with cropland and immature forest types. Previously, Hanford Brook was characterized by slow moving water with eroding banks (70%), silt laden substrate and modest stream cover (40-75%). While development upstream (forestry, pipeline, agriculture and roads) are most likely contributing to poor water quality this is probably exasperated by decreasing forest cover and slow moving water. In the future, the HRAA should focus on remediating riparian buffers in the area while identifying and conserving wetlands.

RECOMMENDATION:

The naturally large width of the stream makes it difficult to improve water quality with riparian restoration alone. A complete evaluation of Hanford Brook (via walkthrough) to identify any potential problems may generate a more comprehensive understanding of how to protect water quality in the region. Another solution could be working with the local forestry industry in this area to better protect waterways.

FOLLOW UP: SCOODIC BROOK

Scoodic Brook was previously recognized as a class "C" stream according to the Water Classification Program (Campbell and Prosser, 2008). In 2015 the condition of this brook was identified as stressed, however, there were no prominent land management issues identified. Since 2008, a lot of work has been completed at the site to remediate the riparian area and to reduce fording by cattle and overall microbial levels. In 1998 and 2008 E. coli averaged (± 1 SD) 390 (± 310) MPN/ 100 ml and in 2015 this average had decreased to 87.5 (± 30) MPN/ 100 ml. Despite the improvements to microbial parameters, Scoodic Brook still had unacceptably high levels of aluminum, E. coli and turbidity and low levels of D.O. Nitrogen and phosphorus were also found to be exceptionally high throughout the summer of 2015. Other indications of poor environmental condition were found in the riparian area which was undercut (26.5%), with immature forest bordering the lower left bank and affecting forest cover (64%). A pronounced midge population and low taxonomic diversity within the BMI community also indicated poor stream conditions. In August, sediment deposits in the lower portion of Scoodic Brook had grossly disconnected the stream, leaving stagnant pools throughout the river bed filled with algae and fish. One potential problem could be the large open gravel pit located upstream of the Scoodic Brook site with no barriers in place to prevent sediment laden runoff. It is clear that while improvements have been made in Scoodic Brook, water filtration in the area is still low. Although the Scoodic Brook sub-catchment did not receive a priority rank, the HRAA will still need to monitor the area to ensure riparian areas are remediating (from tree planting). It is expected that the benefit of this riparian remediation will become more pronounced over time.

RECOMMENDATION:

Mitigate sedimentation runoff from the gravel pit. Continue to monitor tree survival at lower Scoodic Brook and attempt to negotiate a larger buffer zone area.

GENERALIZED RECOMMENDATIONS: MOVING FORWARD

Several times throughout this report the remediation of buffer areas was recommended. Moving forward, the HRAA should use any opportunities in the field to take note of riparian areas in need of protection and enhancement. In the past, willow stakes have often been used due to their short reproduction time and efficiency at taking root. Willow is a more suitable species for the lower reaches of the Hammond River watershed and other species will need to be acquired for priority areas located in the upland and mid reaches . In the future, the HRAA should continue to seek funding to restore riparian areas and use other resources (Canada Summer Jobs, Volunteers, etc.) to complete these community services.

RECOMMENDATION:

Focus on remediating and extending riparian areas within the priority sub-catchments in the interim (5-10 years). In general the HRAA should work to enhance the natural ecosystem services in our watershed.

In 2013 and 2014 the HRAA worked closely with UNB and the Forest Watershed Research Centre to delineate wetlands in the Hammond River watershed using Light Detection and Ranging (LiDAR) derived wet area maps (WAM). This research was completed in the Palmer Brook sub-catchment and identified many unmapped wetland areas. From this research we have identified that provincially recognized wetland maps under represent wetlands in the area and that land development may be removing these critical habitats from our system. Wetlands provide many ecosystem services to our watershed including flood water attenuation, water filtration (of pollutants and sediment), habitat for wildlife and fish and mitigating the effects of climate change. In 2015, the HRAA applied for funding to continue wetland delineation in the Bradley Brook area which has among the highest rates of land development in the watershed. While this funding will provide a more accurate representation of wet areas in the lowest reaches of the Hammond River watershed, it does not account for other priority areas where development was identified as an issue. It is crucial that the HRAA continue to seek funding for wetland mapping while lobbying for their use in land management decision making and zoning.

RECOMMENDATION:

After wetland maps are updated within the lower Hammond River watershed, focus on wetland identification and functional assessment in other priority areas (Markhamville and Hanford sub-catchment).

Several species found within the Hammond River watershed are listed as noteworthy by the Committee on the status of Endangered Wildlife in Canada (COSEWIC) including the American eel and Atlantic salmon. The Atlantic salmon is listed as endangered by COSEWIC and the Hammond River is one of the few remaining watersheds that provide habitat to the outer Bay of Fundy (oBoF) population. Another species listed as threatened by COSEWIC is the American eel. In part these statuses are due to a long life history and barriers to migration upstream. The preservation of Atlantic salmon is a major reason the HRAA was founded and conserving this species is one of our main priorities. While mortality at sea is listed as the biggest threat to Atlantic salmon, juvenile habitat improvement is recognized as the most important undertaking possible for conservation of this species within our watershed (Min. Adv. Comm. Atl. Sal., 2015). Impediments to juvenile Atlantic salmon habitat include agriculture, forestry, mining, transportation, development and climate change (Min. Adv. Comm. Atl. Sal., 2015). In order to protect the watershed against the negative effects of these industries while maintaining a balance with the needs of the local economy, the HRAA will need to develop relationships that maintain an open dialogue with these industries and allow us to make effective recommendations to protect environmental quality. One solution may be to gain access to materials that we can volunteer for specific on-going projects (e.g. providing sediment fences to a small forestry operation to place in low lying areas). Another would be enforcing the replacement of improperly placed or damaged culverts; however, there are many barriers to this kind of work. Currently, the HRAA hopes to pilot a restoration project for Atlantic salmon habitat in Germaine Brook (Figure 75). This project will seek funding for a fluvial geomorphic assessment of the area to identify the most responsible way to restore this habitat. In the future, we hope the community will take it upon themselves to inform us of similar areas that are rapidly changing and known important habitat for fish.

RECOMMENDATION(S):

- → Work to identify and protect fish and Atlantic salmon habitat throughout the watershed.
  - Use existing knowledge of pools and ground fed springs to identify critical habitat.
  - Maintain an updated Fisheries Management Plan
- → Continue to prioritize annual fish and salmon population assessments (redd counts, electrofishing surveys and smolt wheel).
- → Identify programs that work to replace improperly placed and damaged culverts (formerly HADD) and prioritize replacing the most dysfunctional culverts first (Appendix 6) as all sub-catchment experience moderate to high levels of aquatic fragmentation.
- → Continue to seek funding for wetland mapping while lobbying for their use in land management decision making and zoning.

CONCLUSION

Results from this report have given the HRAA a fresh perspective for managing the Hammond River watershed over the short and long term. While this report has identified that one previous area of concern (Scoodic Brook) is improving, there are still persistent issues that will only be resolved as pivotal features of the watershed (such as riparian areas and wetlands) are protected and conserved. This report has identified that refocusing management to include the headwater and upland regions, which can have long-standing impacts on environmental quality downstream, will benefit the watershed over the long term, especially if these recommendations are acted upon proactively. Fortunately, there are many projects that the HRAA can undertake in the interim to identify sources of pollutants, reduce sedimentation and enhance natural ecosystem services. The success of such efforts should be analyzed during our next watershed strategic management plan assessment to determine whether further, more complex and most likely expensive solutions are required. Despite the many opportunities for management within the watershed, the HRAA still faces the major challenge of improving declining populations of fish and Atlantic salmon. The HRAA will need to tread carefully in this area, finding innovative and feasible solutions to tackle problems such as restoring fish access and maintaining fish habitat in the area, while keeping a watchful eye on populations across the watershed.

LITERATURE CITED

Addy, K. 1996. Natural Resource Facts. College of Resource Development Department of Natural Resources Science , University of Rhode Island.

Bacteria and Water Quality (n.d). Retrieved from http://www.usawaterquality.org/volunteer/ecoli/june2008manual/chpt2_ecoli.pdf

CABIN. 2009. Field Manual. Ministry of Environment, Science & Information Branch, Watershed and Aquifer Science Section for the Resources Information Standards Committee. *1.*

CCME. 2014. Canadian Environmental Guidelines for Aquatic Fish Health. Canadian Council of Ministers for the Environment.

Daniel, W. M., Infante, D. M., Hughes, R. M., Tsang, Y-P., Esselman, P. C., Wieferich, D., Herreman, K., Cooper. A.R., Wang, L., Taylor W. W. 2014. Characterizing coal and mineral mines as a regional source of stress to stream fish assemblages. Ecological Indicators 50: 50-61

Davies, H. and Hanley, P.T. 2010. State of the Watershed Report. Saskatchewan Watershed Authority.

EcoSpark. 2013. Water Quality Monitoring with Benthic Macroinvertebrates: Field Manual.

EPA. 2013. Our Waters: Rivers & Streams. *4.1.* Retrieved from http://water.epa.gov/type/rsl/monitoring/vms41.cfm

GNB. 2015. Facts on Drinking Water. Government of New Brunswick.

Health Canada. 2012. Guidelines for Canadian Recreational Water Quality. 3: 1-161.

Ministers Advisory Committee on Atlantic Salmon. 2015. A Special Report on Wild Atlantic Salmon in Eastern Canada.

Tacon, A.G.J. 1987. Chapter 1: A training manual. In The Nutrition and Feeding of Farmed Fish and Shrimp. Food and Agriculture Organization of the United Nations. Retrieved from http://www.fao.org/3/contents/d66b3e1f-c059-50fa-9ba2-717e9940b7f1/AB

Vannote, R. L., Minshall, G.W., Cummins, K.W., Sedell, J.R., Cushing, C.E. 1980. The River Continuum Concept. Can. J. Fish. Aquat. Sci. 37: 130-137.

World Health Organization. 2011. Guidelines for drinking water quality. 1 (4): 1-564

Yan, J. Kun, L., Wang, and Wantong. 2015. Changes in dissolved organic carbon and total dissolved nitrogen fluxes across subtropical forest ecosystems at different successional stages. Water Resources Research. 51 (5): 3681-3694.

APPENDICES

APPENDIX 1

Information on feeding requirements for fish from *The Nutrition and Feeding of Farmed Fish and Shrimp: a training manual* (Tacon, 1987). This information was acquired to provide context to the reader as for why some chemical parameters are important during sampling. With the exception of organically bound compounds (like hydrogen, carbon, nitrogen and oxygen) there are about 20 inorganic minerals elements that are essential to animal life. These nutrients are acquired in minute amounts as micronutrients or constitute the bulk of energy intake as macronutrients (Table 26).

Table 26: The microelements' and microelements associated with fish health. The abundance of each mineral element in the body tissues is correlated with its functional role.

Macroelements		**Trace or microelements**	
Principal cations	*Principal anions*	Iron (Fe)	Fluorine (F)
Calcium (Ca)	Phosphorus (P)	Zinc (Zn)	Vanadium (V)
Magnesium (Mg)	Chlorine (Cl)	Manganese (Mn)	Chromium (Cr)
Sodium (Na)	Sulphur (S)	Copper (Cu)	Molybdenum (Mo)
Potassium (K)		Iodine (I)	Selenium (Se)
		Cobalt (Co)	Tin (Sn)
		Nickel (Ni)	Silicon (Si)

Function of trace elements:

- Skeletal structure like bones and teeth
- Maintenance of osmotic pressure (regulate solute- water exchange)
- Structural component of soft tissues
- Muscle contractions and nerve impulses
- Acid-base equilibrium regulating internal pH

Function of macro elements:

- **Calcium:**

- Essential component of bone and cartilage
- Regulates the uptake of nutrients
- Promotes muscle tone and regular heartbeat
- Essential for normal blood clotting

- **Phosphorous:**

- Key role in energy and metabolism

- **Magnesium:**
- Key role in carbohydrate, protein and lipid metabolism

- **Sodium, Potassium and Chlorine:**
- Important role in water metabolism
- Absorption of carbohydrates
- Metabolic breakdown of glucose + protein synthesis
- Transport of oxygen and carbon dioxide in blood

- **Sulphur:**
- Detoxification of aromatic compounds within the animal body.

Function of micro elements:

- **Iron:**
- Tissue oxidation and electron export

- **Zinc:**
- Wound healing

- **Manganese:**
- Bone formation
- Regeneration of red blood cells
- Carbohydrate metabolism
- Reproductive cycle

- **Copper:**
- Involved with iron metabolism
- Red blood cell production and maintenance
- Skin pigmentation
- Connective tissue
- Maintenance of nerve fibers

- **Chromium:**
- Carbohydrate, cholesterol and amino acid metabolism

- **Fluorine:**
- Component of bone apatite

APPENDIX 2

MICROBIOLOGICAL PARAMETERS

Table 27: The microbiological parameters measured by NBELG for HRAA in 2015 include E. Coli and turbidity. Descriptions are sourced from the government of New Brunswick facts on drinking water (2015) and acceptable levels for aquatic fish health are described from the CCME water quality guidelines for aquatic fish health (2012).

E.Coli	Used as an indicator of microbial concentrations in water, sources of contamination include human and animal fecal matter. Human sources incorporate failing septic tanks, leaking sewer lines, wastewater treatment plants, combined sewer. Fecal indicator bacteria can be significantly correlated with human density. Animal sources include manure spread on land, livestock in runoff or in streams, improperly disposed farm animal wastes, pet wastes, wildlife and birds. E.coli can be transported to waterways through runoff. The velocity of transport i is dependent on the land type (e.g. Run off on non developed land is sopped up by vegetation leading to increase infiltration into the ground and an overall reduction of runoff entering that waterway). Seasonal fluctuations are expected; often an increase in bacteria is associated with heavy rainfall. *Acceptable levels of E. Coli for the protection of aquatic fish health are ≤ 400 MPN/ 100 mL (Health Canada, 2012).*

CHEMICAL AND PHYSICAL PARAMETERS

Table 28: Twenty-nine chemical and physical parameters were analyzed by NBDELG for water quality samples collected by HRAA in 2015. Descriptions are sourced from the government of New Brunswick facts on drinking water (2015) and acceptable levels for aquatic fish health are described from the CCME water quality guidelines for aquatic fish health (2012).

Alkalinity	A measure of the streams buffering capacity. Indicates the waters capacity to resist changes to pH or neutralize an acid. Alkalinity is derived from the presence of carbonate ions and is closely related to hardness
Aluminum	Sources include treatment plants using aluminum-based coagulants as well as naturally occurring aluminum that is found in groundwater. *Acceptable levels of Aluminum for the protection of aquatic fish health is 0.005 if pH is <6.5 and 0.1 is pH is >6.5.*
Antimony	A naturally occurring chemical parameter caused by erosion and soil run off. Antimony has also been found to leak from plumbing and industrial outflow. Health considerations with regards to antimony are microscopic changes that occur in tissues and organs such

	as kidneys and liver.
Arsenic	Often a by-product of mining; however, arsenic also occurs naturally with erosion and weathering of soils and minerals. Health concerns associated with arsenic are skin, neurological and vascular effects. Arsenic is also classified as a carcinogen. *The acceptable level of arsenic for the long term protection of aquatic fish health is ≤ 5 µg/ L.*
Cadmium	Can be caused by leaching from galvanized pipes as well as industrial and municipal waste. Cadmium has been linked with softening of bones and kidney damage. *The acceptable level of cadmium for the long term protection of aquatic fish health is ≤ 0.09 µg/ L and in the short term is 1 µg/ L.*
Calcium	Is naturally occurring from erosion and weathering of soils and minerals.
Chloride	Sources include industrial effluents, highway salt, sewage, irrigation and naturally occurring salt deposits as well as the potential intrusion of sea water. High concentrations leadoff chloride can cause corrosion. *The acceptable level of chloride for the long term protection of aquatic fish health is ≤ 120 mg/ L and in the short term is 650 mg/ L.*
Chromium	A byproduct of industrial spills as well as naturally occurring events such as erosion and weathering of minerals. Potentially adverse effects include enlarged liver, skin, respiratory and gastrointestinal irritation. *The acceptable level of chromium for the long term protection of aquatic fish health is 1-8.9 µg/ L.*
Color	Associated with naturally occurring organic substances. Low levels of color are more desirable. The color was rated based on the Hazen Scale which is a way of interpreting "white water" and measuring waste water using gradient values of yellowness. It evaluates the purity of water and detects any trace of organic substances and other impurities. True colour depends on the dissolved fraction of water, which can include natural minerals such as ferric hydroxide and dissolved organic substances such as humic or fulvic acids , dyes (e.g., acid blue toilet flush), wood preservatives, antisapstains, and various other dissolved organic substances from anthropogenic sources. In freshwater, there is a strong positive correlation between primary production and water colour. Changes in the spectral quality of light in water may have a profound impact on primary productivity, phytoplankton species composition, algal species, fish foraging behaviour and habitat selection of invertebrates and fish.
Conductivity	Measures the ability of water to carry an electrical current. It increases as the amount of dissolved minerals (ions) increases and can signal the presence of other contaminants in the water column.
Copper	Is naturally occurring but can also be sourced from leaching copper pipes. Too much copper can cause gill fraying in fish, which limits their ability to regulate the transport of salts and ultimately, effects their cardiovascular and nervous systems. *Acceptable limits of copper for the protection of aquatic fish health are dependent on hardness and ranges from 2-4 ug/L.*
Fluoride	A naturally occurring element from soil and rock erosion. High levels of fluoride can result in fish and aquatic invertebrate toxicity. *Acceptable levels of fluoride for the protection of aquatic fish health with long term exposure is 120 µg/L.*
Iron	Naturally occurring through mineral and rock erosion. Industrialized and sewage

	effluents are a common source. High levels of iron will build up in tissues and can cause toxicity in fish. *Acceptable levels of fluoride for the protection of aquatic fish health is 0.3 mg/L.*
Lead	Leaching from plumbing. Accumulates in fish liver, kidneys and gills and may cause structural lesions and physical disturbances. *Acceptable levels of lead is based on hardness and can range from 1-7 ug/L.*
Magnesium	Naturally occurring from erosion and weather processes.
Manganese	Naturally occurring from erosion and weather processes.
Nickel	A by-product of manufacturing that is released into the environment. Has a high affinity for organic matter. Nickel poisoning in aquatic organisms can result in surfacing, rapid mouth and operculum movements, convulsions and loss of equilibrium. *Acceptable levels of Nickel ranges from 25-180 ug/L.*
Nitrate	Naturally occurring; leaching or runoff from agricultural fertilizer use, manure and domestic sewage. Nitrates can lead to anoxic or hypoxic water conditions and can result in fish toxicity. *Acceptable levels of Nitrate (as N-calc) for the protection of aquatic fish health is 2.8 mg/L.*
Nitrite	Naturally occurring; leaching or runoff from agricultural fertilizer use, manure and domestic sewage. Can effect ion regulation, respiratory function, cardiovascular, endocrine and execratory processes in fish. *Acceptable levels of Nitrite (as N) for the protection of aquatic fish health is 0.06 mg/L.*
pH	Saturation pH is a theoretical pH at which water is stable and will neither form a scale nor corrode. Can influence the formation of disinfection by-products. Toxic to fish outside of the acceptable range. *Acceptable levels of Nitrate (as N-calc) include for long term protection of aquatic fish health is <6.5 and >9.0.*
Potassium	Is naturally occurring but the most common source is water softeners.
Phosphorous	Phosphorus is a limiting nutrient for photosynthesis in fresh water and too much phosphorus can cause eutrophication in water bodies. Phosphorus is a common constituent of agricultural fertilizer, manure, organic wastes in sewage and industrial effluents. Adverse effects only occur at extreme levels. *Acceptable levels of phosphorus for the protection of aquatic fish health according to the Ontario provincial guideline is 0.03 mg/L.*
Sodium	All groundwater naturally contains some sodium. It is an essential element required in small amounts by all living organisms. No adverse effects. Primary cation found in inter cellular fluid that assists in the acid-base balance and osmoregulation.
Sulphate	Is found naturally in groundwater through the weathering of rocks. Is known to cause acute and chronic toxicity in some fish species.
Total Ammonia	Sources include sewage, fertilizer or naturally occurring through weathering processes. It can also be associated with increased bacteria level. *The acceptable limit levels of ammonia for the protection of fish health are dependent upon temperature and pH.*

Total Hardness	Arguably one of the most important parameters to investigate with regards to fish health. Hardness has an effect on pH and pH stability, the toxicity of some compounds and causes changes to osmoregulation (regulation of water and salt concentrations) in fish. Hardness is formed from the presence of calcium and magnesium carbonates, which have a major effect on pH. In general, more hardness means the fish work less to osmoregulate.
Total Nitrogen	Nitrogen is limiting in freshwater environments, meaning excess nitrogen can cause nutrient enrichment. Nitrogen is needed for plant growth, however, too much nitrogen can result in algal blooms, anoxic conditions and reduced biodiversity. Nitrogen is often a by-product of farming practices.
Total Organic Carbon	Total Organic Carbon (TOC) is used to measure dissolved compounds found in water derived from plant and animal (organic) materials.
Turbidity	Sources of turbidity include clay, silt, and inorganic matter from natural sources. Turbidity is a measure of water clarity. Increased turbidity may associated with an increased occurrence of bacteria or pathogens within the water. *Acceptable levels of turbidity based on the Surface Water Monitoring Data as provided by the New Brunswick Department of Environment and Local Government is 10 NTU.*
Zinc	Is naturally occurring, but the most common source of zinc in drinking water is the corrosion of galvanized plumbing and well materials. High quantities of zinc are toxic to fish. *Acceptable levels of zinc for the long term protection of aquatic fish health is ≤ 30 mg/L.*

CALCULATED PARAMETERS

Sum of Cations	The cation sum is the sum of positive ions (cations) present in water. It is used to calculate the ion balance. Major contributors to the cation sum are usually calcium, magnesium, and sodium. It is a check of the analytical accuracy of the data.
Sum of Anions	The anion sum is the sum of the negative ions (anions) present in water. It is used to calculate the ion balance. Major contributions to the anion sum are usually alkalinity, chloride, and sulphate. It is a check of the analytical accuracy of the data.
Bicarbonate and carbonate	Bicarbonate and carbonate, as $CaCO_3$, are derived from carbonate rocks, carbon dioxide (CO_2) in the atmosphere, and the weathering of feldspars and other minerals. Both are major contributors to alkalinity.

APPENDIX 3

Table 29: Water quality results were evaluated according to the CCME PAL guidelines for acceptable limits (in most cases), as summarized in this table, and graded as the proportion of parameters within the acceptable limits in comparison to the total number of parameters designated with acceptable limits.

Parameter	Unit	Acceptable Limit
E. Coli	MPN/100 mL	**400**
Aluminum	mg/L	0.005 if pH is <6.5 and 0.1 is pH is >6.5
Arsenic	µg/L	**0.09**
Cadmium	µg/L	Short Term: **1**; Long Term: **0.09**
Chloride	mg/L	Short Term: **640**; Long Term: **120**
Copper	µg/L	If hardness ≤ 82 mg/L = **2**; If hardness is 82-180 = $\mathbf{0.2Xe^{\{0.8545[ln(hardness)]-1.465\}}}$; If hardness ≥ 180 = **4**
Fluoride	mg/L	**0.12**
Iron	mg/L	**0.3**
Lead	µg/L	If hardness ≤ 60 mg/L = **1**; If hardness is 60-180 mg/L = $\mathbf{e^{\{1.273[ln(hardness)]-4.705\}}}$; If hardness ≥ 180 mg/L: **7**
Nickel	µg/L	If hardness ≤ 0-60 mg/L = **25**; If hardness is 60-180 mg/L = $\mathbf{e^{\{0.76[ln(hardness)]+1.06\}}}$; If hardness ≥ 180 mg/L: **150**
Nitrate as N	mg/L	**2.9**
Nitrite as N	mg/L	**0.06**
pH		**6.5-9**
Sulfate	mg/L	**1000**
Phosphorous Low	mg/L	ultra-oligotrophic < **4**; oligotrophic: **4-10**; mesotrophic: **10-20**; meso-eutrophicL **20-35**; eutrophic: **35-100**; hyper-eutrophic: >**100**
Total Ammonia	mg/L	Temperature and pH dependent
Turbidity	NTU	**10**
Zinc	µg/L	**30**
D.O.[¥]	mg/L	**6.5**

[¥] Measured in field using HRAA's YSI 80 meter.

APPENDIX 4

Table 30: Chemical parameters analyzed by NBDELG for the thirteen sites water samples were collected from on June 17th, 2015 in the Hammond River watershed. Parameters are in alphabetical order (A-Con) and outlier values (± 2 SD) are displayed by a bolded cell.

Site Name	Alkalinity (mg/L)	Aluminum (mg/L)	Antimony (µg/L)	Arsenic (µg/L)	Cadmium (µg/L)	Calcium (mg/L)	Chloride (mg/L)	Chromium (mg/L)	Colour (HU)	Conductivity (µS/cm)
Palmer Brook	69.8	0.068	1	1	0.1	27.1	35.7	0.0027	48	263
HRAA	25.9	0.054	1	1	0.1	11.7	13.7	0.0008	29	115
French Village	22.1	0.051	1	1	0.1	10.8	13.9	0.0008	26	110
Damascus-Titus	20.7	0.048	1	1	0.1	11	14.7	0.0007	26	113
Salt Springs	23.1	0.06	1	1	0.1	15.4	48.5	0.0008	39	247
Barnesville	15.9	0.051	1	1	0.1	5.47	4.7	0.0005	21	53.6
Route 820 Bridge	17.9	0.057	1	1	0.1	9.58	5.77	0.0005	26	79.9
Germaine Brook	11.7	0.068	1	1	0.1	3.65	1.61	0.0005	26	32.8
Scoodic	20.6	0.1	1	1	0.1	6.79	1.09	0.0007	47	45.5
Hillsdale Bridge	24.5	0.054	1	1	0.1	12.5	11.6	0.0008	28	109
Highway 111 Bridge	26.6	0.034	1	1	0.1	15.5	1.82	0.0009	12	97.1
Markhamville	20.3	0.023	1	1	0.1	6.9	1.35	0.0006	7.7	47.9
St. Martins Road	22.6	0.05	1	1	0.1	13.8	7.43	0.0006	27	106

Table 31: Chemical parameters analyzed by NBDELG for the thirteen sites water samples were collected from on June 17th, 2015 in the Hammond River watershed. Parameters are in alphabetical order (Cop-Po) and outlier values (± 2 SD) are displayed by a bolded cell.

Site Name	Copper (mg/L)	Fluoride (mg/L)	Iron (mg/L)	Lead (µg/L)	Magnesium (mg/L)	Manganese (mg/L)	Nickel (mg/L)	Nitrate as N-Ca (mg/L)	Nitrate-nitrite as N (mg/L)	Nitrite as N (mg/L)	pH	Potassium (mg/L)
Palmer Brook	0.0009	0.1	0.185	1	3.49	0.11	0.005	0.15	0.15	0.05	7.90	1.1
HRAA	0.0006	0.1	0.078	1	1.12	0.022	0.005	0.07	0.07	0.05	7.54	2
French Village	0.0005	0.1	0.066	1	0.88	0.011	0.005	0.06	0.06	0.05	7.60	2.2
Damascus-Titus	0.0005	0.1	0.063	1	0.87	0.01	0.005	0.07	0.07	0.05	7.60	2.4
Salt Springs	0.0006	0.1	0.088	1	1.09	0.015	0.005	0.05	0.05	0.05	7.49	1.3
Barnesville	0.0005	0.1	0.054	1	0.76	0.007	0.005	0.08	0.08	0.05	7.43	0.29
Route 820 Bridge	0.0005	0.1	0.07	1	0.7	0.012	0.005	0.07	0.07	0.05	7.58	1.6
Germaine Brook	0.0005	0.1	0.084	1	0.61	0.01	0.005	0.06	0.06	0.05	7.30	0.24
Scoodic	0.0005	0.1	0.094	1	0.49	0.011	0.005	0.05	0.05	0.05	7.53	0.27
Hillsdale Bridge	0.0005	0.1	0.09	1	0.91	0.02	0.005	0.08	0.08	0.05	7.64	2.2
Highway 111 Bridge	0.0005	0.1	0.028	1	0.75	0.02	0.005	0.13	0.13	0.05	7.60	0.34
Markhamville	0.0005	0.1	0.024	1	0.43	0.045	0.005	0.11	0.11	0.05	7.55	0.27
St. Martins Road	0.0005	0.1	0.072	1	0.78	0.015	0.005	0.06	0.06	0.05	7.67	1.8

Table 32: Chemical parameter (and units) results from June 17th, 2015 for all thirteen sites evaluated within the Hammond River watershed. Parameters are in alphabetical order (Sod-Zinc) and outlier values (± 2 SD) are displayed by a bolded cell.

Site Name	Sodium (mg/L)	Sulfate (mg/L)	Phosphorous Low Level (mg/L)	Total Ammonia (mg/L)	Total Hardness (mg/L)	Total Nitrogen (mg/L)	Total Organic Carbon (mg/L)	Zinc (mg/L)
Palmer Brook	22.1	6.28	0.008	0.02	82	0.3	5	0.005
HRAA	8.35	9.15	0.008	0.173	33.8	0.3	3.7	0.005
French Village	8.36	10.1	0.005	0.045	30.6	0.3	3.4	0.005
Damascus-Titus	8.88	11	0.005	< 0.010	31	0.3	3.6	0.005
Salt Springs	32.2	19	0.007	< 0.010	42.9	0.3	5.3	0.005
Barnesville	4.22	2.58	0.005	< 0.010	16.8	0.3	3.2	0.005
Route 820 Bridge	4.27	10.1	0.005	0.194	26.8	0.3	3.7	0.005
Germaine Brook	2.27	2.15	0.005	< 0.010	11.6	0.3	3	0.005
Scoodic	2.25	1.44	0.007	< 0.010	19	0.3	6.1	0.005
Hillsdale Bridge	6.69	11	0.007	0.108	35	0.4	3.8	0.005
Highway 111 Bridge	2.5	17.8	0.007	0.152	41.8	0.3	1.9	0.005
Markhamville	2.19	2.23	0.011	0.066	19	0.3	1.4	0.005
St. Martins Road	5	16.5	0.005	0.158	37.7	0.5	3.4	0.005

Table 33: Microbiological and chemical parameter results from June 17th, 2015 for all thirteen sites evaluated within the Hammond River watershed. Outlier values (± 2 SD) are displayed by a bolded cell.

Site Name	E.Coli (MPN/ 100 ml)	Turbidity (NTU)	Sum of Cations	Sum of Anions	Saturation Index @ 25ºC	CO_3 (as $CaCO_3$)	HCO_3 (as $CaCO_3$)
Palmer Brook	80	1.2	2.65	2.55	-0.11	0.52	25.8
HRAA	20	0.6	1.11	1.10	-1.22	0.08	69.24
French Village	20	0.4	1.04	1.05	-1.26	0.08	22
Damascus-Titus	50	0.4	1.08	1.07	-1.29	0.08	20.6
Salt Springs	20	0.4	2.3	2.23	-1.24	0.07	23.02
Barnesville	10	0.2	0.54	0.52	-1.85	0.04	17.82
Route 820 Bridge	10	0.4	0.78	0.74	-1.42	0.06	15.85
Germaine Brook	10	0.4	0.35	0.33	-2.27	0.02	20.52
Scoodic	50	0.5	0.5	0.48	-1.54	0.07	22.48
Hillsdale Bridge	20	0.5	1.06	1.06	-1.12	0.1	11.67
Highway 111 Bridge	40	0.3	0.97	0.97	-1.03	0.1	24.38
Markhamville	10	0.2	0.49	0.50	-1.52	0.07	26.48
St. Martins Road	10	0.4	1.03	1.01	-1.08	0.1	20.21

Table 34: Chemical parameters analyzed by NBDELG for the thirteen sites water samples were collected from on July 20th, 2015 in the Hammond River watershed. Parameters are in alphabetical order (A-Con) and outlier values (± 2 SD) are displayed by a bolded cell.

Site Name	Alkalinity (mg/L)	Aluminum (mg/L)	Antimony (µg/L)	Arsenic (µg/L)	Cadmium (µg/L)	Calcium (mg/L)	Chloride (mg/L)	Chromium (mg/L)	Colour (HU)	Conductivity (µS/cm)
Palmer Brook	71	0.086	< 1.0	< 1.0	< 0.1	26	30.1	0.0027	52	259
HRAA	32.1	0.048	< 1.0	< 1.0	< 0.1	16	21.8	0.001	27	172
French Village	42.6	0.076	< 1.0	< 1.0	< 0.1	14.2	12.5	0.0016	46	136
Damascus-Titus	25.7	0.053	< 1.0	< 1.0	< 0.1	13.7	13.3	0.0008	33	135
Salt Springs	27.3	0.082	< 1.0	< 1.0	< 0.1	14.4	41.1	0.0008	64	234
Barnesville	22.4	0.046	< 1.0	< 1.0	< 0.1	7.48	5.9	< 0.0005	30	73.4
South Stream	23.1	0.039	< 1.0	< 1.0	< 0.1	7.58	5.63	< 0.0005	24	74.4
Germaine Brook	14.2	0.053	< 1.0	< 1.0	< 0.1	4.61	1.64	< 0.0005	23	41.9
Scoodic	22.2	0.15	< 1.0	< 1.0	< 0.1	7.92	1.25	0.0006	69	53.5
Hillsdale Bridge	26.7	0.073	< 1.0	< 1.0	< 0.1	16.2	31.3	0.0007	57	208
Highway 111 Bridge	29.9	0.048	< 1.0	< 1.0	< 0.1	18.7	1.83	0.0007	25	120
Markhamville	22.2	0.032	< 1.0	< 1.0	< 0.1	7.07	1.35	< 0.0005	18	53.9
Hanford Brook	12.2	0.094	< 1.0	< 1.0	< 0.1	3.74	2.26	< 0.0005	34	39.7

Table 35: Chemical parameter (and units) results from July 20th, 2015 for all thirteen sites evaluated within the Hammond River watershed. Parameters are in alphabetical order (Cop-Po) and outlier values (± 2 SD) are displayed by a bolded cell.

Site Name	Copper (mg/L)	Fluoride (mg/L)	Iron (mg/L)	Lead (µg/L)	Magnesium (mg/L)	Manganese (mg/L)	Nickel (mg/L)	Nitrate as N-Ca (mg/L)	Nitrate-nitrite as N (mg/L)	Nitrite as N (mg/L)	pH	Potassium (mg/L)
Palmer Brook	**0.0009**	< 0.100	0.185	< 1.0	**3.35**	0.07	< 0.005	0.15	0.15	< 0.05	7.96	0.97
HRAA	< 0.0005	< 0.100	0.067	< 1.0	1.44	0.012	< 0.005	0.06	0.06	< 0.05	7.79	1.1
French Village	0.0007	< 0.100	0.187	< 1.0	2.44	0.033	< 0.005	0.1	0.1	< 0.05	7.85	0.41
Damascus-Titus	< 0.0005	< 0.100	0.092	< 1.0	1.03	0.008	< 0.005	0.08	0.08	< 0.05	7.73	1
Salt Springs	0.0006	< 0.100	0.196	< 1.0	1.04	0.021	< 0.005	0.07	0.07	< 0.05	7.6	1.2
Barnesville	< 0.0005	< 0.100	0.089	< 1.0	0.97	0.009	< 0.005	0.17	0.17	< 0.05	7.63	0.38
South Stream	< 0.0005	< 0.100	0.061	< 1.0	0.88	0.007	< 0.005	**0.2**	**0.2**	< 0.05	7.69	0.42
Germaine Brook	< 0.0005	< 0.100	0.098	< 1.0	0.75	0.009	< 0.005	0.1	0.1	< 0.05	7.5	0.27
Scoodic	< 0.0005	< 0.100	0.153	< 1.0	0.53	0.016	< 0.005	0.06	0.06	< 0.05	7.63	0.31
Hillsdale Bridge	< 0.0005	< 0.100	0.178	< 1.0	1.2	0.025	< 0.005	0.1	0.1	< 0.05	7.69	**17**
Highway 111 Bridge	< 0.0005	< 0.100	0.046	< 1.0	0.86	0.016	< 0.005	0.12	0.12	< 0.05	7.72	0.34
Markhamville	< 0.0005	< 0.100	0.058	< 1.0	0.47	**0.089**	< 0.005	0.12	0.12	< 0.05	7.65	0.25
Hanford Brook	< 0.0005	< 0.100	0.172	< 1.0	0.67	0.014	< 0.005	0.12	0.12	< 0.05	**7.32**	0.29

Table 36: Chemical parameter (and units) results from July 20th, 2015 for all thirteen sites evaluated within the Hammond River watershed. Parameters are in alphabetical order (Sod-Zinc) and outlier values (± 2 SD) are displayed by a bolded cell.

Site Name	Sodium (mg/L)	Sulfate (mg/L)	Phosphorous Low Level (mg/L)	Total Ammonia (mg/L)	Total Hardness (mg/L)	Total Nitrogen (mg/L)	Total Organic Carbon (mg/L)	Zinc (mg/L)
Palmer Brook	19.9	5.72	0.015	0.025	78.7	0.3	6.8	< 0.005
HRAA	13.2	14.3	0.004	0.095	45.9	0.5	3.8	< 0.005
French Village	8.61	3.83	0.008	< 0.010	45.5	< 0.3	6	< 0.005
Damascus-Titus	9.12	16	0.006	< 0.010	38.4	< 0.3	5	< 0.005
Salt Springs	27.4	15.6	0.01	0.029	40.2	0.4	9	< 0.005
Barnesville	5.2	2.7	0.007	< 0.010	22.7	< 0.3	4.6	< 0.005
South Stream	4.99	3.09	0.005	< 0.010	22.6	0.3	3.8	< 0.005
Germaine Brook	2.48	2.06	0.005	< 0.010	14.6	< 0.3	3.6	< 0.005
Scoodic	2.35	1.59	0.012	0.105	22	1.2	9.7	< 0.005
Hillsdale Bridge	9.56	13.2	0.013	< 0.010	45.4	< 0.3	6.5	< 0.005
Highway 111 Bridge	2.65	21.6	0.01	< 0.010	50.2	< 0.3	3.4	< 0.005
Markhamville	2.42	2.02	0.01	< 0.010	19.6	< 0.3	2.3	< 0.005
Hanford Brook	2.81	1.95	0.007	< 0.010	12.1	< 0.3	4.3	< 0.005

Table 37: Microbiological and chemical parameter (and units) results from July 20th, 2015 for all thirteen sites evaluated within the Hammond River watershed. Outlier values (± 2 SD) are displayed by a bolded cell

Site Name	E.Coli (MPN/ 100 ml)	Turbidity (NTU)	Sum of Cations	Sum of Anions	Saturation Index @ 25°C	CO_3 (as $CaCO_3$)	HCO_3 (as $CaCO_3$)
Palmer Brook	380	1.6	2.49	2.4	-0.06	0.6	70.35
HRAA	110	0.9	1.53	1.56	-0.76	0.18	31.88
French Village	250	1.2	1.31	1.3	-0.62	0.28	42.28
Damascus-Titus	190	0.9	1.2	1.23	-0.97	0.13	25.54
Salt Springs	310	1.2	2.05	2.04	-1.08	0.1	27.18
Barnesville	60	0.3	0.7	0.69	-1.37	0.09	22.29
South Stream	430	0.3	0.69	0.7	-1.29	0.11	22.97
Germaine Brook	60	0.4	0.42	0.39	-1.89	0.04	14.14
Scoodic	100	2.1	0.58	0.52	-1.34	0.09	22.09
Hillsdale Bridge	140	1.1	1.78	1.7	-0.94	0.12	26.55
Highway 111 Bridge	80	0.6	1.14	1.11	-0.79	0.15	29.73
Markhamville	10	0.4	0.51	0.54	-1.37	0.09	22.08
Hanford Brook	210	1.1	0.39	0.36	-2.23	0.02	12.17

Table 38: Chemical parameters analyzed by NBDELG for the thirteen sites water samples were collected from on Aug. 17th, 2015 in the Hammond River watershed. Parameters are in alphabetical order (A-Con) and outlier values (± 2 SD) are displayed by a bolded cell.

Site Name	Alkalinity (mg/L)	Aluminum (mg/L)	Antimony (µg/L)	Arsenic (µg/L)	Cadmium (µg/L)	Calcium (mg/L)	Chloride (mg/L)	Chromium (mg/L)	Colour (HU)	Conductivity (µS/cm)
Palmer Brook	89.4	0.057	< 1.0	< 1.0	< 0.1	31.5	32.6	0.003	41	306
HRAA	41.9	0.027	< 1.0	< 1.0	< 0.1	20.4	27.2	0.0013	16	213
Bradley Brook	65	0.04	< 1.0	< 1.0	< 0.1	22	18.1	0.0023	29	198
Damascus-Titus	33	0.013	< 1.0	< 1.0	< 0.1	19.8	28.7	0.001	10	220
Salt Springs	37.8	0.019	< 1.0	< 1.0	< 0.1	52.2	241	0.0014	13	1030
Barnesville	35.2	0.011	< 1.0	< 1.0	< 0.1	10.2	8.06	0.0009	6.7	97.8
Route 820 (Hammond River)	30.1	0.015	< 1.0	< 1.0	< 0.1	18.2	8.09	0.0008	11	141
Germaine Brook	16.4	0.021	< 1.0	< 1.0	< 0.1	4.8	1.8	< 0.0005	11	46.4
Scoodic	41.9	0.018	< 1.0	< 1.0	< 0.1	13.5	2.68	0.0013	13	97.9
Hillsdale Bridge	40.5	0.023	< 1.0	< 1.0	< 0.1	22.1	12	0.0012	17	170
Highway 111 Bridge	35	0.012	< 1.0	< 1.0	< 0.1	28.7	2.98	0.001	7.7	180
Markhamville	34.3	0.025	< 1.0	< 1.0	< 0.1	11	1.24	0.001	8.2	75.2
Hanford Brook	14.1	0.046	< 1.0	< 1.0	< 0.1	4.02	2.66	< 0.0005	15	43.8

Table 39: Chemical parameter (and units) results from Aug. 17th, 2015 for all thirteen sites evaluated within the Hammond River watershed. Parameters are in alphabetical order (Cop-Po) and outlier values (± 2 SD) are displayed by a bolded cell.

Site Name	Copper (mg/L)	Fluoride (mg/L)	Iron (mg/L)	Lead (µg/L)	Magnesium (mg/L)	Manganese (mg/L)	Nickel (mg/L)	Nitrate as N-Ca (mg/L)	Nitrate-nitrite as N (mg/L)	Nitrite as N (mg/L)	pH	Potassium (mg/L)
Palmer Brook	0.0008	<0.1	0.193	< 1.0	3.83	0.098	< 0.005	**0.29**	0.29	<0.05	8.14	1.3
HRAA	< 0.0005	<0.100	0.052	< 1.0	1.92	0.022	< 0.005	0.05	0.05	<0.05	7.9	1.6
Bradley Brook	< 0.0005	<0.100	**0.217**	< 1.0	3.67	0.048	< 0.005	0.1	0.1	<0.05	8.04	0.57
Damascus-Titus	< 0.0005	<0.1	0.014	< 1.0	1.44	0.006	< 0.005	0.06	0.06	<0.05	7.87	2
Salt Springs	**0.0012**	< 0.100	0.024	< 1.0	3.31	0.027	< 0.005	< 0.05	< 0.05	< 0.05	7.65	**4.7**
Barnesville	< 0.0005	< 0.100	0.013	< 1.0	1.15	0.006	< 0.005	< 0.05	< 0.05	< 0.05	7.86	1.9
Route 820 (Hammond River)	< 0.0005	< 0.100	0.011	< 1.0	1.15	0.013	< 0.005	0.24	0.24	< 0.05	7.75	0.48
Germaine Brook	0.0007	< 0.1	0.012	< 1.0	0.83	< 0.005	< 0.005	0.07	0.07	< 0.05	7.88	0.57
Scoodic	< 0.0005	< 0.100	0.032	< 1.0	0.81	0.005	< 0.005	0.1	0.1	< 0.05	7.58	0.33
Hillsdale Bridge	< 0.0005	< 0.100	0.051	< 1.0	1.41	0.017	< 0.005	0.07	0.07	< 0.05	7.92	2.9
Highway 111 Bridge	< 0.0005	< 0.100	0.011	< 1.0	1.2	0.001	< 0.005	0.13	0.13	< 0.05	7.79	0.48
Markhamville	< 0.0005	< 0.100	0.115	< 1.0	0.63	**0.36**	< 0.005	0.16	0.16	< 0.05	7.82	0.32
Hanford Brook	0.0005	< 0.1	0.077	< 1.0	0.74	0.011	< 0.005	0.05	0.05	< 0.05	**7.4**	0.34

Table 40: Chemical parameter (and units) results from Aug. 17th, 2015 for all thirteen sites evaluated within the Hammond River watershed. Parameters are in alphabetical order (Sod-Zinc) and outlier values (± 2 SD) are displayed by a bolded cell.

Site Name	Sodium (mg/L)	Sulfate (mg/L)	Phosphorous Low Level (mg/L)	Total Ammonia (mg/L)	Total Hardness (mg/L)	Total Nitrogen (mg/L)	Total Organic Carbon (mg/L)	Zinc (mg/L)
Palmer Brook	21.6	7.11	0.021	0.66	94.4	0.7	4.3	< 0.005
HRAA	17.5	16.3	0.006	0.022	58.8	< 0.3	3.2	< 0.005
Bradley Brook	12.3	4.15	0.007	<0.01	70	< 0.3	3	< 0.005
Damascus-Titus	18.5	22.5	0.004	0.012	55.4	< 0.3	2.3	< 0.005
Salt Springs	136	59.6	0.009	< 0.010	144	< 0.3	2.9	< 0.005
Barnesville	6.82	3.25	0.004	< 0.01	30.2	< 0.3	1.7	< 0.005
Route 820 (Hammond River)	5.75	22	0.005	0.016	50.2	< 0.3	2.1	< 0.005
Germaine Brook	2.79	2.41	0.005	0.011	15.3	< 0.3	2	< 0.005
Scoodic	4.99	2.42	0.004	0.028	37.1	< 0.3	3.1	< 0.005
Hillsdale Bridge	7.12	20	0.01	0.011	61	< 0.3	2.2	< 0.005
Highway 111 Bridge	3.11	42.6	0.006	0.035	76.6	< 0.3	1.5	< 0.005
Markhamville	2.66	2.64	0.017	0.204	30.1	< 0.3	1.7	< 0.005
Hanford Brook	3.25	2.12	0.004	0.014	13.1	< 0.3	2.8	< 0.005

Table 41: Microbiological and chemical parameter (and units) results from Aug. 17th, 2015 for all thirteen sites evaluated within the Hammond River watershed. Outlier values (± 2 SD) are displayed by a bolded cell.

Site Name	**E.Coli (MPN/ 100 ml)**	**Turbidity (NTU)**	**Sum of Cations**	**Sum of Anions**	**Saturation Index @ 25ºC**	**CO_3 (as $CaCO_3$)**	**HCO_3 (as $CaCO_3$)**
Palmer Brook	500	2.1	2.92	2.88	0.29	1.14	88.19
HRAA	50	0.6	1.99	1.95	-0.44	0.31	41.55
Bradley Brook	480	1.4	1.97	1.91	-0.08	0.66	64.28
Damascus-Titus	30	0.2	1.97	1.95	-0.59	0.23	32.73
Salt Springs	160	0.3	8.92	8.8	-0.44	0.16	37.62
Barnesville	10	0.2	1.31	1.3	-0.66	0.2	29.86
South Stream	10	< 0.2	0.92	1.02	-0.93	0.18	34.99
Germaine Brook	10	< 0.2	0.44	0.44	-1.73	0.06	16.32
Scoodic	120	< 0.2	0.98	0.97	-0.61	0.3	41.57
Hillsdale Bridge	30	0.4	1.61	1.57	-0.4	0.31	40.14
Highway 111 Bridge	10	0.2	1.68	1.68	-0.49	0.2	34.77
Markhamville	20	< 0.2	0.76	0.79	-0.83	0.21	34.06
Hanford Brook	10	0.4	0.42	0.41	-2.05	0.03	14.05

Table 42: Chemical parameters analyzed by NBDELG for the thirteen sites water samples were collected from on Sept.23rd, 2015 in the Hammond River watershed. Parameters are in alphabetical order (A-Con) and outlier values (± 2 SD) are displayed by a bolded cell.

Site Name	Alkalinity (mg/L)	Aluminum (mg/L)	Antimony (µg/L)	Arsenic (µg/L)	Cadmium (µg/L)	Calcium (mg/L)	Chloride (mg/L)	Chromium (mg/L)	Colour (HU)	Conductivity (µS/cm)
Palmer Brook	90.6	0.044	<1.0	<1.0	<0.1	34.3	33.8	0.003	43	303
HRAA	39	0.021	<1.0	<1.0	<0.1	19.7	23.4	0.00012	16	191
Bradley Brook	59.5	0.022	<1.0	<1.0	<0.1	20.5	16.8	0.002	34	180
Damascus-Titus	29.1	0.012	<1.0	<1.0	<0.1	18.5	24.9	0.0007	11	189
Salt Springs	36.2	0.015	<1.0	<1.0	<0.1	51.7	251	0.0013	15	1030
Barnesville	27.2	0.015	<1.0	<1.0	<0.1	8.89	6.94	0.0007	11	83.5
Route 820 (Hammond River)	26.5	0.017	<1.0	<1.0	<0.1	17.1	8.51	0.0008	13	130
Germaine Brook	14.4	0.023	<1.0	<1.0	<0.1	4.53	1.82	<0.0005	15	42
Scoodic	40.4	0.016	<1.0	<1.0	<0.1	13.7	2.14	0.0011	17	91.6
Hillsdale Bridge	37.2	0.029	<1.0	<1.0	<0.1	22.4	18.4	0.001	17	180
Highway 111 Bridge	34.5	0.009	<1.0	<1.0	<0.1	30.8	2.21	0.001	8	184
Markhamville	31.7	0.01	<1.0	<1.0	<0.1	10.6	1.49	0.009	7.6	69.7
Hanford Brook	13.2	0.06	<1.0	<1.0	<0.1	4.05	2.63	<0.0005	23	41.4

Table 43: Chemical parameter (and units) results from Sept. 23rd, 2015 for all thirteen sites evaluated within the Hammond River watershed. Parameters are in alphabetical order (Cop-Po) and outlier values (± 2 SD) are displayed by a bolded cell.

Site Name	Copper (mg/L)	Fluoride (mg/L)	Iron (mg/L)	Lead (µg/L)	Magnesium (mg/L)	Manganese (mg/L)	Nickel (mg/L)	Nitrate as N-Ca (mg/L)	Nitrate-nitrite as N (mg/L)	Nitrite as N (mg/L)	pH	Potassium (mg/L)
Palmer Brook	0.0006	< 0.100	0.201	< 1.0	3.93	0.1	< 0.005	0.28	0.28	<0.05	8.02	1.2
HRAA	< 0.0005	< 0.100	0.046	< 1.0	1.72	0.017	< 0.005	<0.05	<0.05	<0.05	7.77	1.2
Bradley Brook	< 0.005	< 0.100	0.217	< 1.0	3.25	0.03	< 0.005	0.11	0.11	<0.05	7.93	10.9
Damascus-Titus	< 0.0005	< 0.100	0.016	< 1.0	1.24	<0.005	<0.005	<0.05	<0.05	<0.05	7.81	1.3
Salt Springs	0.0013	< 0.100	0.024	< 1.0	3.06	0.019	< 0.005	<0.05	<0.05	<0.05	7.6	4.5
Barnesville	<0.0005	< 0.100	0.027	< 1.0	1.01	0.009	< 0.005	0.16	0.16	<0.05	7.69	0.4
Route 820 (Hammond River)	<0.0005	< 0.100	0.02	< 1.0	1.02	<0.005	< 0.005	<0.05	<0.05	<0.05	7.81	1.3
Germaine Brook	<0.0005	<0.100	0.033	<1.0	0.73	0.005	<0.005	0.09	0.09	<0.05	7.53	0.29
Scoodic	<0.0005	< 0.100	0.02	< 1.0	0.78	<0.005	<0.005	<0.05	<0.05	<0.05	7.83	0.44
Hillsdale Bridge	<0.0005	<0.100	0.066	<1.0	1.37	0.03	<0.005	<0.05	<0.05	<0.05	7.94	4
Highway 111 Bridge	<0.0005	<0.100	<0.010	<1.0	1.16	0.006	<0.005	0.16	0.16	<0.05	7.75	3.06
Markhamville	<0.0005	<0.100	0.053	<1.0	0.5	0.14	<0.005	0.12	0.12	<0.05	7.81	0.29
Hanford Brook	<0.0005	<0.100	0.086	< 1.0	0.77	0.009	<0.005	<0.05	<0.05	<0.05	7.4	0.3

Table 44: Chemical parameter (and units) results from Sept 23rd, 2015 for all thirteen sites evaluated within the Hammond River watershed. Parameters are in alphabetical order (Sod-Zinc) and outlier values (± 2 SD) are displayed by a bolded cell.

Site Name	Sodium (mg/L)	Sulfate (mg/L)	Phosphorous Low Level (mg/L)	Total Ammonia (mg/L)	Total Hardness (mg/L)	Total Nitrogen (mg/L)	Total Organic Carbon (mg/L)	Zinc (mg/L)
Palmer Brook	21	6.67	0.013	<0.010	102	0.4	3.7	<0.005
HRAA	14.3	16.9	0.003	<0.010	56.3	<0.3	2.1	<0.005
Bradley Brook	4.12	4.12	0.003	<0.010	64.6	< 0.3	2.4	<0.005
Damascus-Titus	14.8	21.3	<0.002	<0.010	51.3	<0.3	1.9	<0.005
Salt Springs	134	63.4	0.006	<0.010	142	<0.3	2.4	<0.005
Barnesville	5.93	3.22	0.003	<0.010	26.4	<0.3	1.6	<0.005
Route 820 (Hammond River)	5.29	21.1	0.003	<0.010	46.9	<0.3	1.8	<0.005
Germaine Brook	2.61	2.53	0.004	<0.010	14.3	<0.3	1.5	<0.005
Scoodic	4.21	2.98	0.004	<0.010	37.4	<0.3	2.9	<0.005
Hillsdale Bridge	7.24	20.14	0.008	<0.010	61.6	<0.3	2	<0.005
Highway 111 Bridge	48.4	0.003	<0.010	<0.010	81.7	<0.3	<1.0	<0.005
Markhamville	2.5	2.81	0.01	0.012	28.5	<0.3	<1.0	<0.005
Hanford Brook	3.04	2.24	0.004	<0.010	13.3	<0.3	2.1	<0.005

Table 45: Microbiological and chemical parameter (and units) results from Sept. 23rd, 2015 for all thirteen sites evaluated within the Hammond River watershed. Outlier values (± 2 SD) are displayed by a bolded cell.

Site Name	E.Coli (MPN/ 100 ml)	Turbidity (NTU)	Sum of Cations	Sum of Anions	Saturation Index @ 25ºC	CO_3 (as $CaCO_3$)	HCO_3 (as $CaCO_3$)
Palmer Brook	210	1.5	3	2.93	0.21	0.88	89.67
HRAA	20	0.4	1.87	1.8	-0.61	0.21	38.27
Bradley Brook	100	1.5	7.93	1.76	-0.25	0.47	58.99
Damascus-Titus	10	<0.2	1.71	1.74	-0.73	0.18	28.89
Salt Springs	50	0.3	8.78	9.13	-0.51	0.13	36.05
Barnesville	20	<0.2	0.8	0.82	-1.16	0.12	27.05
Route 820 (Hammond River)	<10	<0.2	1.2	1.22	-0.79	0.16	26.31
Germaine Brook	20	<0.2	0.41	0.4	-1.86	0.05	14.34
Scoodic	80	<0.2	0.95	0.94	-0.67	0.25	40.11
Hillsdale Bridge	<10	0.4	1.66	1.7	-0.41	0.3	36.85
Highway 111 Bridge	10	<0.2	1.78	1.78	-0.51	0.18	34.29
Markhamville	20	<0.2	0.7	0.75	-0.89	0.19	31.48
Hanford Brook	10	0.6	0.42	0.39	-2.08	0.03	13.16

APPENDIX 5

Table 46: The benthic macroinvertebrate community collected at the Hammond River Angling Association site on September 21, 2015 according to percentage of the community that is worm, midge, sowbug, snail, dominant group, EPT (Mayfly, Stonefly and Cadisfly), diptera (true fly) and insect, the number of taxonomic groups present and the average tolerance value of the community. Each category is classified as unimpaired, potentially impaired or impaired using the Benthic Aggregate Assessment (EcoSpark, 2013).

HRAA	Run	Run	Run	Average	Class
% Worms	27.2	12.1	19.1	19.5	Potentially Impaired
% Midge	1.2	11.3	30.8	14.4	Potentially Impaired
% Sowbug	0.0	0.0	0.0	0.0	Unimpaired
% Snail	2.4	0.8	7.4	3.5	Unimpaired
# of taxon	10.0	10.0	16.0	12.0	Unimpaired
% Dominant	27.8	27.4	30.8	28.7	Unimpaired
% EPT	41.4	51.6	14.8	35.9	Unimpaired
% Diptera	5.9	13.7	49.2	23.0	Potentially Impaired
% Insect	53.3	69.4	65.5	62.7	Unimpaired
Tolerance Value	5.8	5.4	5.5	5.6	Unimpaired
					Unimpaired

Table 47: The benthic macroinvertebrate community collected at the Palmer Brook site on September 21, 2015 according to percentage of the community that is worm, midge, sowbug, snail, dominant group, EPT (Mayfly, Stonefly and Cadisfly), diptera (true fly) and insect, the number of taxonomic groups present and the average tolerance value of the community. Each category is classified as unimpaired, potentially impaired or impaired using the Benthic Aggregate Assessment (EcoSpark, 2013).

Palmer	Run	Run	Run	Average	Class
% Worms	3.4	5.6	0.9	3.3	Unimpaired
% Midge	37.0	37.6	28.3	34.3	Potentially Impaired
% Sowbug	0.0	0.0	0.0	0.0	Unimpaired
% Snail	0.0	0.6	0.0	0.2	Unimpaired
# of taxon	13.0	14.0	13.0	13.3	Unimpaired
% Dominant	37.0	36.5	32.6	35.4	Unimpaired
% EPT	31.3	30.3	57.5	39.7	Unimpaired
% Diptera	43.3	43.8	36.1	41.0	Potentially Impaired
% Insect	89.9	87.6	97.4	91.7	Impaired
Tolerance Value	5.3	6.0	5.8	5.7	Unimpaired
					Unimpaired

Table 48: The benthic macroinvertebrate community collected at the Damascus site on September 21, 2015 according to percentage of the community that is worm, midge, sowbug, snail, dominant group, EPT (Mayfly, Stonefly and Cadisfly), diptera (true fly) and insect, the number of taxonomic groups present and the average tolerance value of the community. Each category is classified as unimpaired, potentially impaired or impaired using the Benthic Aggregate Assessment (EcoSpark, 2013).

Damascus	Riffle	Run	Run	Average	Class
% Worms	1.5	0.3	4.7	2.2	Unimpaired
% Midge	0.3	6.9	0.7	2.6	Unimpaired
% Sowbug	0.0	0.0	0.0	0.0	Unimpaired
% Snail	0.0	0.6	0.0	0.2	Unimpaired
# of taxon	8.0	11.0	8.0	9.0	Impaired
% Dominant	63.6	60.8	62.4	62.2	Impaired
% EPT	90.4	89.0	87.1	88.8	Unimpaired
% Diptera	0.6	3.0	2.9	2.1	Impaired
% Insect	98.2	93.3	95.7	95.7	Impaired
Tolerance Value	4.6	4.8	4.5	4.6	Unimpaired
					Unimpaired

Table 49: The benthic macroinvertebrate community collected at the Salt Springs site on September 21, 2015 according to percentage of the community that is worm, midge, sowbug, snail, dominant group, EPT (Mayfly, Stonefly and Cadisfly), diptera (true fly) and insect, the number of taxonomic groups present and the average tolerance value of the community. Each category is classified as unimpaired, potentially impaired or impaired using the Benthic Aggregate Assessment (EcoSpark, 2013).

Salt Springs	Riffle	Run	Riffle	Average	Class
% Worms	4.813	9.211	13	9.00779	Unimpaired
% Midge	0	9.211	13	7.40351	Unimpaired
% Sowbug	0	0.439	1	0.47953	Potentially Impaired
% Snail	0	0.439	0.5	0.31287	Unimpaired
# of taxon	10	13	13	12	Unimpaired
% Dominant	35.29	31.14	21	29.1448	Unimpaired
% EPT	49.73	49.56	45.5	48.2647	Unimpaired
% Diptera	14.97	2.632	6.5	8.03495	Impaired
% Insect	91.44	75.44	49.5	72.1275	Unimpaired
Tolerance Value	5.5	5.929	6.231	5.88645	Unimpaired
					Unimpaired

Table 50: The benthic macroinvertebrate community collected at the Route 820 site on September 21, 2015 according to percentage of the community that is worm, midge, sowbug, snail, dominant group, EPT (Mayfly, Stonefly and Cadisfly), diptera (true fly) and insect, the number of taxonomic groups present and the average tolerance value of the community. Each category is classified as unimpaired, potentially impaired or impaired using the Benthic Aggregate Assessment (EcoSpark, 2013).

Route 820	Riffle	Run	Riffle	Average	Class
% Worms	3.9	2.3	0.6	2.3	Unimpaired
% Midge	0.0	0.0	0.0	0.0	Unimpaired
% Sowbug	0.0	0.0	0.0	0.0	Unimpaired
% Snail	0.0	0.0	0.0	0.0	Unimpaired
# of taxon	9.0	8.0	7.0	8.0	Impaired
% Dominant	53.5	63.6	42.8	53.3	Impaired
% EPT	86.4	93.6	91.0	90.4	Unimpaired
% Diptera	1.3	4.6	2.6	2.8	Impaired
% Insect	97.4	96.5	98.8	97.6	Impaired
Tolerance Value	4.7	4.5	4.2	4.5	Unimpaired
					Unimpaired

Table 51: The benthic macroinvertebrate community collected at the Barnesville site on September 21, 2015 according to percentage of the community that is worm, midge, sowbug, snail, dominant group, EPT (Mayfly, Stonefly and Cadisfly), diptera (true fly) and insect, the number of taxonomic groups present and the average tolerance value of the community. Each category is classified as unimpaired, potentially impaired or impaired using the Benthic Aggregate Assessment (EcoSpark, 2013).

Barnesville	Riffle	Run	Riffle	Average	Class
% Worms	2.5	1.2	0.0	1.2	Unimpaired
% Midge	9.6	0.6	11.9	7.4	Unimpaired
% Sowbug	0.0	0.0	0.0	0.0	Unimpaired
% Snail	0.0	0.0	0.0	0.0	Potentially Impaired
# of taxon	11.0	10.0	8.0	9.7	Impaired
% Dominant	27.4	29.5	29.5	28.8	Unimpaired
% EPT	70.1	92.2	73.6	78.6	Unimpaired
% Diptera	5.1	0.6	7.3	4.3	Impaired
% Insect	81.7	97.6	78.2	85.9	Potentially Impaired
Tolerance Value	5.5	3.0	4.8	4.4	Unimpaired
					Unimpaired

Table 52: The benthic macroinvertebrate community collected at the Scoodic Brook site on September 21, 2015 according to percentage of the community that is worm, midge, sowbug, snail, dominant group, EPT (Mayfly, Stonefly and Cadisfly), diptera (true fly) and insect, the number of taxonomic groups present and the average tolerance value of the community. Each category is classified as unimpaired, potentially impaired or impaired using the Benthic Aggregate Assessment (EcoSpark, 2013).

Scoodic Brook	Riffle	Run	Riffle	Average	Class
% Worms	4.8	8.8	8.3	7.3	Unimpaired
% Midge	28.0	2.9	47.8	26.3	Potentially Impaired
% Sowbug	0.0	0.0	0.4	0.1	Unimpaired
% Snail	0.0	0.7	0.0	0.2	Unimpaired
# of taxon	10.0	10.0	11.0	10.3	Impaired
% Dominant	30.0	42.3	45.7	39.3	Unimpaired
% EPT	47.8	73.0	30.9	50.6	Unimpaired
% Diptera	39.1	9.1	51.1	33.1	Unimpaired
% Insect	89.4	87.6	86.7	87.9	Potentially Impaired
Tolerance Value	4.3	4.3	5.4	4.7	Unimpaired
					Unimpaired

Table 53: The benthic macroinvertebrate community collected at the Hanford Brook site on September 21, 2015 according to percentage of the community that is worm, midge, sowbug, snail, dominant group, EPT (Mayfly, Stonefly and Cadisfly), diptera (true fly) and insect, the number of taxonomic groups present and the average tolerance value of the community. Each category is classified as unimpaired, potentially impaired or impaired using the Benthic Aggregate Assessment (EcoSpark, 2013).

Hanford	Riffle	Run	Riffle	Average	Class
% Worms	1.5	31.2	2.1	11.6	Potentially Impaired
% Midge	0.0	0.0	6.1	2.0	Unimpaired
% Sowbug	0.0	0.0	1.2	0.4	Unimpaired
% Snail	0.0	0.0	0.0	0.0	Potentially Impaired
# of taxon	10.0	7.0	13.0	10.0	Impaired
% Dominant	35.1	6.5	36.4	26.0	Unimpaired
% EPT	77.6	29.0	34.3	46.9	Unimpaired
% Diptera	1.5	2.2	11.6	5.1	Impaired
% Insect	97.1	95.9	76.8	89.9	Impaired
Tolerance Value	4.1	3.6	4.1	4.0	Unimpaired
					Potentially Impaired

Table 54: The benthic macroinvertebrate community collected at the Germaine Brook site on September 21, 2015 according to percentage of the community that is worm, midge, sowbug, snail, dominant group, EPT (Mayfly, Stonefly and Cadisfly), diptera (true fly) and insect, the number of taxonomic groups present and the average tolerance value of the community. Each category is classified as unimpaired, potentially impaired or impaired using the Benthic Aggregate Assessment (EcoSpark, 2013).

Germaine	Riffle	Run	Riffle	Average	Class
% Worms	7.0	1.9	0.0	3.0	Unimpaired
% Midge	29.5	0.0	23.7	17.7	Potentially Impaired
% Sowbug	1.0	0.0	0.0	0.3	Unimpaired
% Snail	0.0	0.0	0.0	0.0	Potentially Impaired
# of taxon	13.0	6.0	10.0	9.7	Impaired
% Dominant	29.0	42.3	23.2	31.5	Unimpaired
% EPT	47.5	90.4	53.5	63.8	Unimpaired
% Diptera	35.5	3.8	31.3	23.6	Impaired
% Insect	84.5	96.5	31.3	70.8	Unimpaired
Tolerance Value	5.2	4.3	4.5	4.7	Unimpaired
					Unimpaired

Table 55: The benthic macroinvertebrate community collected at the Hanford Brook site on September 21, 2015 according to percentage of the community that is worm, midge, sowbug, snail, dominant group, EPT (Mayfly, Stonefly and Cadisfly), diptera (true fly) and insect, the number of taxonomic groups present and the average tolerance value of the community. Each category is classified as unimpaired, potentially impaired or impaired using the Benthic Aggregate Assessment (EcoSpark, 2013).

Bradley	Riffle	Run	Riffle	Average	Class
% Worms	8.6	5.3	6.3	6.7	Unimpaired
% Midge	15.0	0.0	18.4	11.1	Potentially Impaired
% Sowbug	0.5	0.0	0.0	0.2	Unimpaired
% Snail	0.0	3.5	0.0	1.2	Unimpaired
# of taxon	15.0	9.0	12.0	12.0	Unimpaired
% Dominant	22.5	38.6	25.2	28.8	Unimpaired
% EPT	44.9	50.9	42.7	46.2	Unimpaired
% Diptera	21.9	3.5	22.3	15.9	Potentially Impaired
% Insect	84.0	30.6	90.8	68.5	Unimpaired
Tolerance Value	4.5	4.1	4.4	4.3	Unimpaired
					Unimpaired

Table 56: The benthic macroinvertebrate community collected at the Markhamville site on September 21, 2015 according to percentage of the community that is worm, midge, sowbug, snail, dominant group, EPT (Mayfly, Stonefly and Cadisfly), diptera (true fly) and insect, the number of taxonomic groups present and the average tolerance value of the community. Each category is classified as unimpaired, potentially impaired or impaired using the Benthic Aggregate Assessment (EcoSpark, 2013).

Markhamville	Riffle	Riffle	Riffle	Average	Class
% Worms	0.0	3.4	0.0	1.1	Unimpaired
% Midge	26.2	0.0	38.0	21.4	Potentially Impaired
% Sowbug	0.0	0.0	0.0	0.0	Unimpaired
% Snail	0.0	0.5	0.0	0.2	Unimpaired
# of taxon	9.0	11.0	9.0	9.7	Unimpaired
% Dominant	43.6	44.4	35.5	41.1	Potentially Impaired
% EPT	61.8	61.5	50.9	58.0	Unimpaired
% Diptera	30.7	26.3	43.6	33.5	Unimpaired
% Insect	95.1	93.7	94.4	94.4	Impaired
Tolerance Value	5.2	4.1	5.2	4.8	Unimpaired
					Unimpaired

Table 57: The benthic macroinvertebrate community collected at the Hammondvale site on September 21, 2015 according to percentage of the community that is worm, midge, sowbug, snail, dominant group, EPT (Mayfly, Stonefly and Cadisfly), diptera (true fly) and insect, the number of taxonomic groups present and the average tolerance value of the community. Each category is classified as unimpaired, potentially impaired or impaired using the Benthic Aggregate Assessment (EcoSpark, 2013).

Hammondvale	Run	Riffle	Run	Average	Class
% Worms	2.0	0.8	1.2	1.3	Unimpaired
% Midge	0.0	27.6	40.6	22.8	Potentially Impaired
% Sowbug	0.0	0.3	0.4	0.2	Unimpaired
% Snail	0.0	0.0	0.0	0.0	Potentially Impaired
# of taxon	7.0	13.0	10.0	10.0	Impaired
% Dominant	53.0	27.4	40.6	40.3	Potentially Impaired
% EPT	75.0	51.0	41.4	55.8	Unimpaired
% Diptera	19.0	35.2	44.2	32.8	Unimpaired
% Insect	97.5	97.7	98.4	97.9	Impaired
Tolerance Value	4.8	5.8	5.3	5.3	Unimpaired
					Potentially Impaired

Table 58: The benthic macroinvertebrate community collected at the Hillsdale site on September 21, 2015 according to percentage of the community that is worm, midge, sowbug, snail, dominant group, EPT (Mayfly, Stonefly and Cadisfly), diptera (true fly) and insect, the number of taxonomic groups present and the average tolerance value of the community. Each category is classified as unimpaired, potentially impaired or impaired using the Benthic Aggregate Assessment (EcoSpark, 2013).

Hillsdale	Riffle	Run	Riffle	Average	Class
% Worms	2.0	0.8	1.2	1.3	Unimpaired
% Midge	0.0	27.6	40.6	22.8	Potentially Impaired
% Sowbug	0.0	0.3	0.4	0.2	Unimpaired
% Snail	0.0	0.0	0.0	0.0	Potentially Impaired
# of taxon	7.0	13.0	10.0	10.0	Impaired
% Dominant	53.0	27.4	40.6	40.3	Potentially Impaired
% EPT	75.0	51.0	41.4	55.8	Unimpaired
% Diptera	19.0	35.2	44.2	32.8	Unimpaired
% Insect	97.5	97.7	98.4	97.9	Impaired
Tolerance Value	4.8	5.8	5.3	5.3	Unimpaired
					Potentially Impaired

APPENDIX 6

Table 59: In 2012, the Environmental Trust Fund supported a watershed wide culvert assessment to identify stream-road intersections that may pose hazardous to fish health by obstructing or blocking passage. The assessment identified 17 culverts that require replacement, repair or maintenance due to improper alignment, debris causing obstructions, aging infrastructure, undercutting along banks or perching the stream bed, etc. Previously (2010) a culvert intersecting Colton Brook was replaced, since then the HRAA has requested assistance for further habitat impact assessments and culvert replacements but has been unsuccessful to date. *Table extracted from table created by L. Robinson*

Sub-catchment	**Location**	**Street - Stream**	**Inflow**	**Outflow**
Palmer	N45 25.758 W65 56.161	Phinney Lane- Colton Brook	N/A	Debris, 12 cm perched, 12 cm undercut
HRAA	N45 27.290 W65 54.072	Porter Rd- Tr. To Hammond River	crushed	Crushed, 30 cm perched, 150 cm undercut
French Village	N45 23.669 W65 54.322	Bradley Lake Rd - Bradley Brook	Debris	25 cm perched, 60 cm undercut
	N45 26.995 W65 50.901	RTE 860- Tr. To Hammond River	Obstructions = Metal Bars	32 cm perched
Salt Springs	N45 32.518 W65 40.574	RTE 860- Tr. - Salt Springs	Debris, 10 cm perched/ undercut	Debris, 100 cm perched, 100 cm undercut
	N45 32.044 W65 41.885	RTE 860- Tr. - Salt Springs	Debris	Debris, 20 cm perched, 20 cm undercut
	N45 30.227 W65 43.758	RTE 860- Tr. - Salt Springs	Debris	Debris, 26 cm perched
Upham	N45 28.914 W65 41.595	RTE 820- Tr. To Hammond River	Debris	Debris, 52 cm perched
	N45 28.216 W65 42.584	Back River Rd - Donnelly Brook	Debris	Debris, 30 cm
	N45 28.651 W65 41.654	Back River Rd - Donnelly Brook	Debris	Debris, 100 cm perched
Hanford	N45 30.996 W65 31.065	Vaughan Creek North Tr. - Mill Brook	Debris	Debris, 22 cm perched
	N45 24.485 W65 37.471	Town Plot Rd - Tr. To Henry Lake	Obstructions, Debris	Debris, 13 cm perched
	N45 26.055 W65 35.862	RTE 111- Isaac Brook	Obstructions, Debris, 5% crushed	Debris, 40 cm perched
Markhamville	N45'36.737 W65'24.684	Lisson Rd - Hammond River	Debris	Debris, Perched, 20 cm Undercut
	N45'36.206 W65'26.279	Hunter Rd- Hammond River	N/A	22 cm perched
	N45'35.349 W65'29.021	Markamville Rd- Hammond River	Debris	Debris, 38 cm perched
	N45'34.550 W65'28.970	Shepody Rd - Hammond River	N/A	9 cm perched

APPENDIX 7

Table 60: A summary of the average # of fish and juvenile Atlantic Salmon caught per 100 m^2 during the HRAA's annual electrofishing survey and the total number of redds found within an sub-catchment through visual surveys from 2010 – 2015.

Average # of fish/ 100 m^2

Sub-catchment	2010	2011	2012	2013	2014	2015	Average
Palmer	161	142	273	42	25	25	111
Markhamville	33	0	70	77	7	26	36
Damascus	70	35	42	19	8	28	34
French Village	19	65	218	62	44	25	72
Germaine	18	47	41	16	15	28	27
HRAA	0	0	137	0	0	25	27
Hanford	36	134	100	40	6	19	56
Salt Springs	0	156	88	149	41	21	76
Scoodic	0	33	22	25	10	25	19
Barnesville	0	69	38	12	7	24	25

Average # of juvenile Atlantic Salmon/ 100 m^2

Sub-catchment	2010	2011	2012	2013	2014	2015	Average
Palmer	0	15	5	1	2	0	4
Markhamville	18	0	35	44	1	7	17
Damascus	0	10	0	1		0	2
French Village	6	15	37	7	1	0	11
Germaine	1	11	20	6	4	2	7
HRAA	0	0	108	0	0	0	18
Hanford	8	61	30	4	0	0	17
Salt Springs	0	54	25	43	3	1	21
Scoodic	0	10	1	0	0	1	2
Barnesville	0	12	16	5	0	7	7

Total # of redds

Sub-catchment	2010	2011	2013	2015	Average
Markhamville	0	0	4	47	8.5
French Village	2	0	0	0	0.3
Germaine	0	19	3	0	4
HRAA	5	0	0	0	1
Hanford	3	7	1	0	2
Salt Springs	0	0	3	0	0.5
Scoodic	1	3	0	0	1
Upham	1	0	0	0	0.1