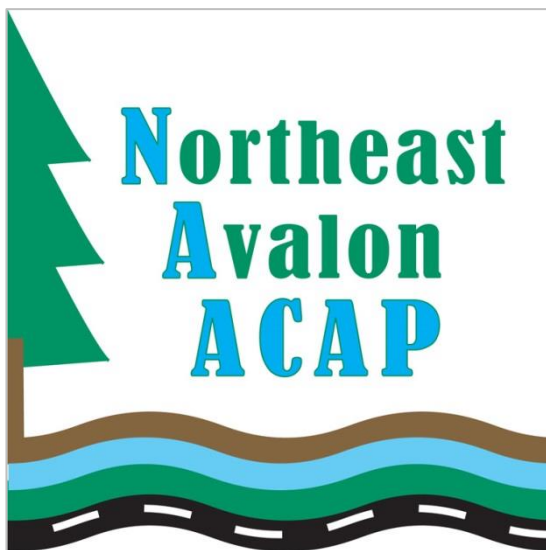




At the headwaters of the South Brook Watershed



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A Preliminary Vulnerability Assessment of a Watershed within the Proposed 2500 Acre Galway Development

Executive Summary

The South Brook Watershed is a large, iconic area of land within the boundaries of the cities of St. John's and Mount Pearl. With a proposed approximately 2500 acre development called Galway planned for the western highlands section of the watershed, there could be substantial environmental impacts associated with its completion. The goal of this report is to highlight the vulnerability of the South Brook Watershed using satellite imagery of the Northeast Avalon Peninsula, on the ground surveys, and a variety of land use / land cover (LULC) analyses within a Geographical Information System (GIS). A collection of water quality information taken at the proposed Galway development site also provides suitable data for assessing current water quality before the planned changes occur. NAACAP's wetlands survey of a green corridor section within the South Brook Watershed and proposed Galway development common area (the study area) indicates functional and sizable wetlands and associated forest are linked with the headwaters of South Brook and the Waterford River. These wetlands and forested areas are situated directly within the planned Galway development, and without protection from development functionality of these wetlands could be severely reduced. We calculate that a total of 94.2% of currently natural areas (river headlands, wetlands and forest) would be transformed under the current development proposal. Our completed analyses, including GIS mapping outcomes, allow planning and development recommendations to be made for the Galway proposal. The recommendations are based on a cautionary approach and take into consideration the wetlands and supporting forested areas currently situated in the South Brook Watershed.

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1.0 Introduction

Much scientific evidence supports the preservation of wetlands to provide key ecosystem services such as flood abatement, fish habitat and safe drinking water. Wetlands and river systems are affected by surrounding land cover, where much of the water for the wetland or river is sourced (Houlahan and Findlay, 2004). Natural land cover such as forests and bogs filter precipitation (rain, snow) cleaning and removing particulates and pollution, and releasing water slowly. Forests adjacent to wetlands and rivers also provide the necessary shade and organic matter helping to maintain water quality and provide organics to food webs (DeMaynadier and Houlahan, 2008). Land cover such as urban development brings impervious surface areas (roads, sidewalks, parking areas, rooftops), and such areas decrease infiltration into the ground and increase the rate and volume of surface runoff, which can carry pollutants and sediment (Fitzpatrick *et al*, 2005). Information on land cover of an area also helps in better understanding of the land cover/river system relationship (Kotoky *et al*, 2012). Finally, rapid industrialization and urbanization can impact water quality through increased pollutants via surface runoff such as hydrocarbons and road salt. Increased run off can also decrease bank stability and lead to increased sedimentation. These concerns prompted this study; assessing the vulnerability of the South Brook Watershed within the proposed Galway development. Since the headwaters of the South Brook Watershed lie in the proposed development area, it is expected that changes made in this area may negatively impact natural hydrological processes throughout the watershed with implications further downstream along the Waterford River system.

The South Brook Watershed is located predominately in St. John's, directly south of the municipal boundary of Mount Pearl (Figure 1). The watershed spans an area of approximately 30 km². South Brook is the largest tributary to the Waterford River, at a length of approximately 10.8 km. Its headwaters are found in natural wetlands. South Brook flows through natural, residential and agricultural areas, as well as Bowring Park before it eventually meets the main channel of the Waterford at the eastern end of Bowring Park.

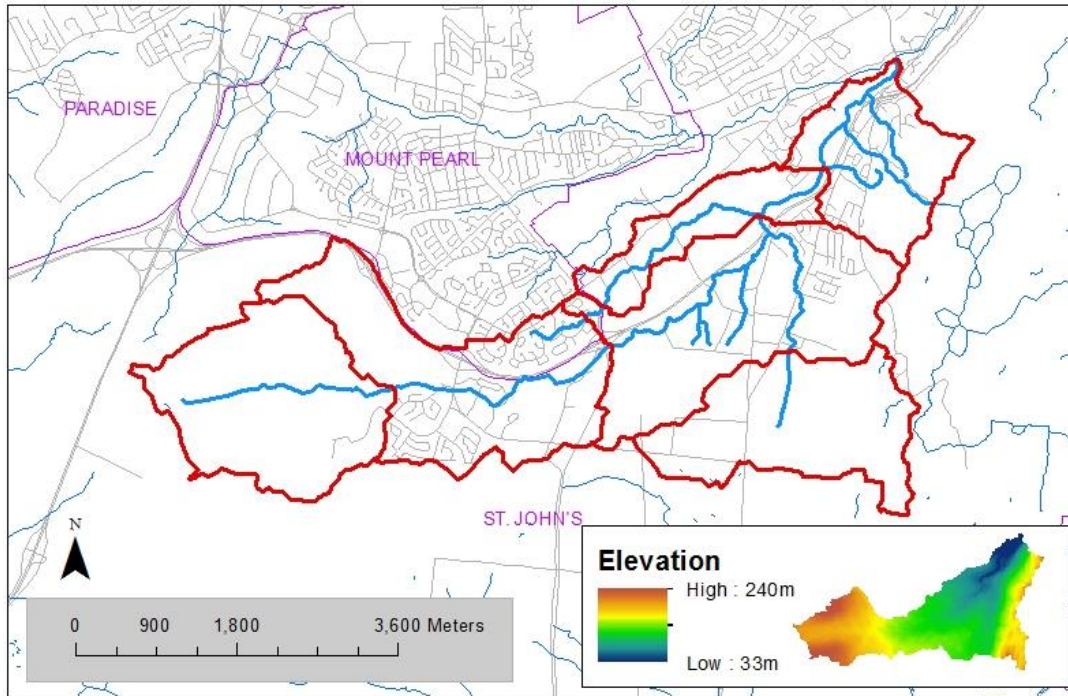


Figure 1 - The South Brook Watershed delineated in red with Digital Elevation Model (DEM) inset.

Over the years, land use has changed along the banks of South Brook. The lower reach of the river is located within Bowring Park, and has been used for recreation; there is a walking trail that follows the river in Bowring Park. There was also an outdoor swimming pool located on South Brook in Bowring Park, which was closed by the City of St. John's in the 1960's because of water quality concerns (Shalev, 2009). Tributaries and river sections upstream of Bowring Park flow through Kilbride, which was traditionally composed of farmland and low density housing. The upper reaches of South Brook were historically in their natural condition and were surrounded by wetlands and forest. However, the upper reaches have experienced increasing development pressures over time. Pitts Memorial Highway, which was constructed in the late 1970s, runs adjacent to a stretch of South Brook. The western end of the South Brook Watershed has been the most recently developed, with the Southlands subdivision area. The wetlands that compose the headwaters of South Brook are located in a relatively undeveloped area, but are now slated to be surrounded by a large proposed development, initially known as Glencrest, now formally branded Galway. With much of South Brook and the Waterford River downstream of these headwaters already flowing through urbanized areas, development of the South Brook headwaters will have negative repercussions downstream.

While there has been flooding along South Brook, the current relatively natural state of its watershed meant that there was minimal damage to the human landscape. During Hurricane Gabrielle in 2001, there was erosion caused by flooding in Bowring Park, flooding along Heavy Tree Road, and also near the Pearltown Road crossing where the water levels rose but did not overtop the bridge (Catto, personal communication, September 5, 2013). In 1996 Hurricane Hortense dropped 98 mm of rain on Mount Pearl in five hours, compared to 32 mm at St. John's airport during the same time (Butler, 2008), causing flooding along parts on South Brook that had been urbanised losing the natural flood abatement of natural wetland systems (Catto, personal communication, September 5, 2013). With increases in urbanization, flooding events

are likely to increase in frequency, compounded with heavier rain events to produce a regular occurrence of flash floods, with large increases to volume of water over a short time frame.

A development of approximately 2500 acres has recently been announced; it will be situated partly within the South Brook watershed. The parcel of development within the watershed encompasses the entire wetland complex that forms the South Brook headwaters. This development is the largest of its kind in the province and has gained much media attention.

A preliminary concept plan for the Galway development was released in May, 2013 (Figure 2). This concept plan contains four different zones: Commercial (pink), Industrial (blue), Residential (yellow) and 'Undeveloped' (green). The land use zonings used in this preliminary concept plan were used to determine the land cover change that will occur under the proposed development. Completion of the entire development, however, is slated to take many years, and detailed concept plans for the development were not released to the City during this project.

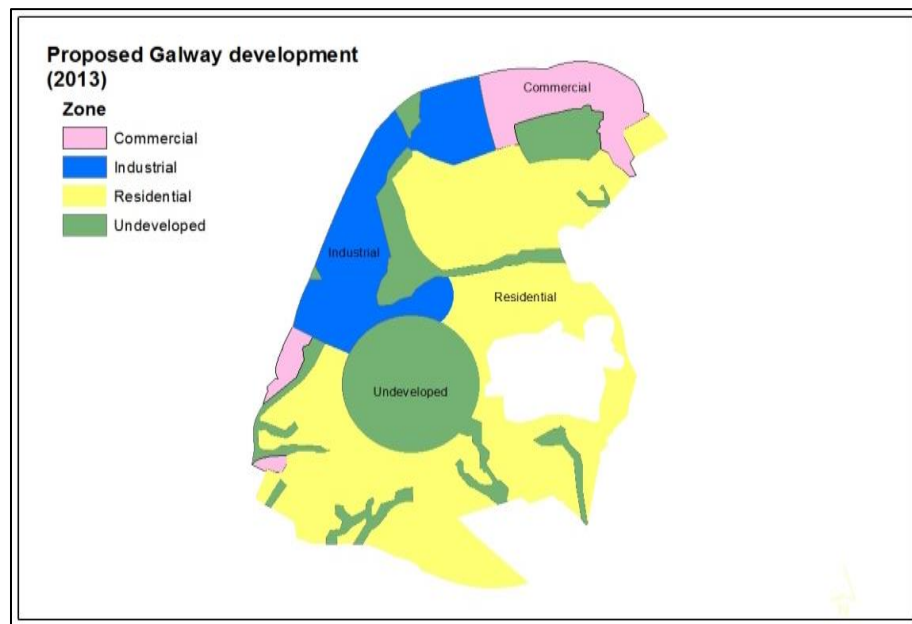


Figure 2 - The proposed Galway development concept plan, released as part of St. John's City Council meeting minutes, May 6th, 2013. There is a golf course in the mid-right area of the development proposal (white), since this golf course already exists and will not change, it has been left out of the analysis for clarity regarding what is proposed.

2.0 Methods

In order to assess the vulnerability of the South Brook Watershed to the development proposed in its headwater, information was needed that represented scenarios both before and after development. Water quality data and data obtained through surveying headwater wetlands provided insight into the environmental condition before proposed development. Geographic Information System (GIS) software was used to assess the land cover of the watershed and the

natural intactness of the watershed under pre-Galway conditions, and predict landscape changes after the proposed development is in place.

2.1 Water Quality

Water quality data were collected from South Brook during the summer of 2013. Two of the sites visited are sampled quarterly by the Provincial Department of Environment and Conservation, Water Resources Management Division as part of their Water Quality Management Agreement with Environment Canada. One of these sites, known as NF02ZM0185 by the Province, is located at Treetop Drive, while the other, known as NF02ZM0176 by the Province, is located at the mouth of South Brook in Bowring Park. These two sites were named SB201303 and SB201301 respectively, and two additional sites were added for a total of four sample sites to capture the full distribution of South Brook for this project (Figure 3). One site (SB201304) was further upstream in the headwaters of South Brook where the proposed development is scheduled, and the other site (SB201302) was upstream of Pearltown Road, which is located between the two sites sampled regularly by the Province. Large scale maps of all four sample locations are contained in Appendix A.

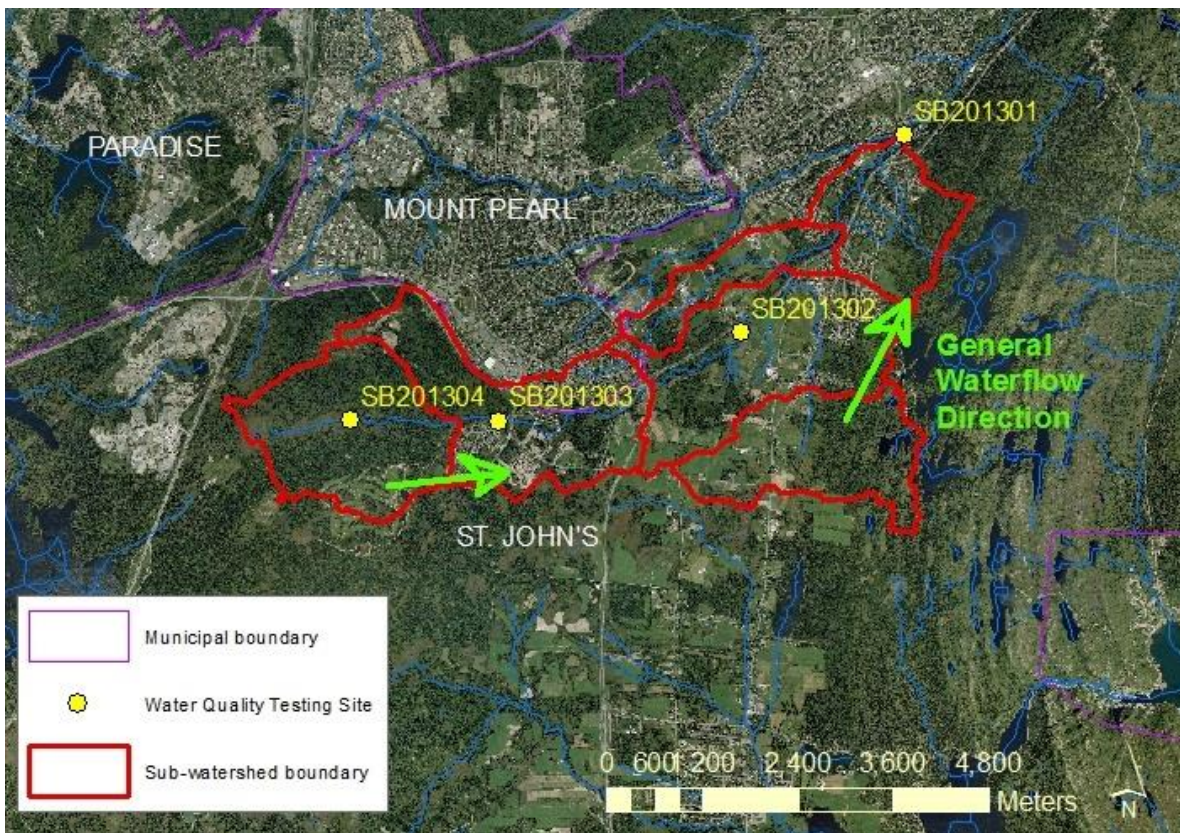


Figure 3 - Locations of NAACAP water quality testing and sub-watershed boundaries in South Brook watershed, Northeast Avalon Peninsula (NL).

The four sample sites were visited by NAACAP staff on July 11, August 1, and August 22. Water quality parameters collected in situ using a Quanta G multisonde were temperature, pH, dissolved oxygen (DO), specific conductivity, total dissolved solids (TDS), and salinity. Water samples were also collected from each site and tested for phosphates and nitrates using a

Hach Stream Survey kit, and water turbidity using a Fieldmaster turbidity tube. The turbidity tube was filled to the top with water which was then released slowly until the Secchi disk at the bottom of the tube was visible. The water level was then read off the side of the tube. The average of three readings was recorded. The maximum reading on the turbidity tube was 60 cm which indicated little/ no turbidity (clear water).

Data collected by the Water Resources Management Division from sites NF02ZM0185 and NF02ZM0176 were obtained for the period from 2006 to 2012. Their data were used for comparison to the readings obtained during this project at these sites (SB201303 and SB201301 respectively) as an indication of the normal water quality readings.

2.2 Wetlands Survey

In 2013, wetlands across the Northeast Avalon were surveyed by a Conservation Corps Newfoundland and Labrador Green Team as a continuation of the wetland survey work that NAACAP started in 2011. Two wetland areas within the South Brook watershed that fall within the geographical area proposed for the Galway development were surveyed. Surveying included plant sampling, macro-invertebrate sampling, and assessment of wetland function. Detailed methods for these surveys can be found in *Northeast Avalon ACAP's Wetland Survey Project Final Report for 2013-2014*.

2.3 GIS Vulnerability Assessment

GIS provides a means to do spatial data analysis and interpretation, particularly when combined with other data and analyses. It also provides a powerful method for monitoring environmental changes, and analysis of other environmental variables (Kotoky *et al.*, 2012). Furthermore, GIS is a powerful tool for informing decision-makers regarding conservation (Baldwin and DeMayadier, 2009, Batzer and Baldwin, 2014).

2.3.1 Determination of Watershed Boundary and Definition of Study Area

Watersheds are nested at many scales, from large areas that drain into the ocean to catchments for individual stream segments. Along with 2010 provincial satellite imagery, provincial vector data from Geobase (Canadian Council on Geomatics) were used to create a Digital Elevation Model (DEM). The vector data have spot heights indicating elevation with 50 meter spacing, as well as breaklines and waterlines suitable to the task of DEM creation. The DEM was thus created using the provincial vector data via a triangulated irregular network (TIN) modelling technique within ArcGIS. The resolution of the DEM raster grid created is 10 meters in the X and Y dimensions and 2.5 meters in the Z dimension, where the pixel value is the Z value (elevation).

Using the DEM as the primary input, a base set of catchments (sub-basins) and their associated streams was created. The appropriate catchments were aggregated based on watercourse discharge points known as pour points. Geo-processing for catchment delineation was performed using the ArcGIS Hydrology tools, a component of Spatial Analyst. The following steps were followed:

- The DEM described above was used as the primary input.
- A Flow Direction raster was generated from the DEM
- Sinks were eliminated to ensure water does not, according to the model, gather in non-drained basins.
- A Flow Accumulation raster was generated.
- The Watershed tool was successively tried with various cutoffs to generate catchments at the desired scale.
- The Catchment output was manually checked and adjusted where necessary, based on available hydrology data from federal and provincial sources, as well as local knowledge.
- Catchments were chosen pertaining to the South Brook Watershed and were manually aggregated based on pour points.

The resulting watershed boundary was reviewed and final adjustments of catchment boundaries were made based on comparison with the DEM and knowledge of the area. This was specifically necessary for the western most boundary of the South Brook Watershed, where the divide between drainage into South Brook and the Waterford River was not clear after GIS determination. As such, this boundary had to be determined manually through examination of the elevation in the area.

It was also necessary to delineate the area of the proposed Galway development, including commercial areas, residential areas and industrial areas. NAACAP attempted to obtain these data from external sources, but was not successful. Thus the media release for the Galway development was acquired and digitized in ArcGIS ArcEditor using a geo-referencing technique.

ArcGIS was used to determine the area of land common to both the proposed development and the South Brook Watershed. The common land area is the northeast section of the Galway development, sitting over the higher elevation western section of the South Brook Watershed, and will be referred to as the study area (Figure 4).

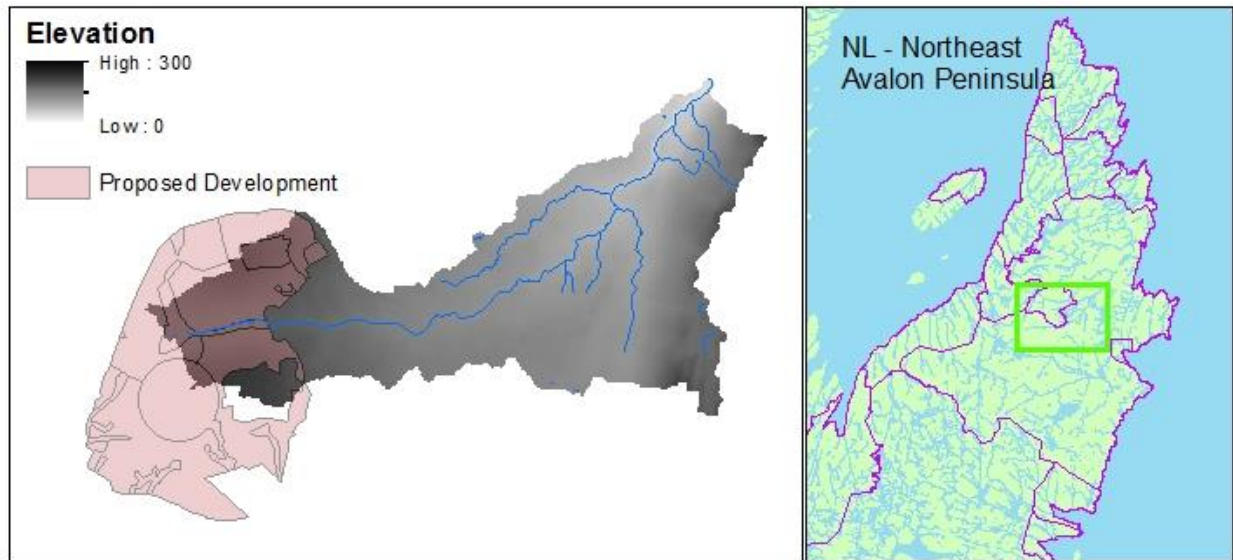


Figure 4 - The South Brook Watershed (grey), the proposed development known as Galway (rose), and the area of overlap between the two – the study area. South Brook and tributaries are marked in blue.

2.3.2 Land Cover Classification

A crucial piece of work for the vulnerability assessment was the determination of land cover. Different types of land cover have characteristic responses to rainfall and runoff, and varying interactions with other physical and biological factors; thus identifying the land cover will allow us to better predict the changes that could occur in the watershed in light of future development. Land cover determination was achieved by utilizing satellite imagery, and applying GIS analysis to classify the land cover. This allows simplification of complex aerial imagery into a limited number of classified land cover types. The primary input for creating our land cover dataset was Spot5 scene 4731 (August 13, 2007), downloaded from GeoBase. A number of other potential options, including Provincial aerial imagery and Landsat satellite imagery, were investigated. Spot5 was chosen because it has a sufficient number of bands (four) to allow GIS classification with a 10 meter resolution output.

After investigation and advice from academia, the following final set of land cover classes were chosen:

- Barrens/Bare Rock – areas with limited, if any, naturally-occurring vegetation.
- Developed – areas with built structures, substantial pavement/asphalt and limited, if any, vegetation.
- Farms/Greenspace – areas of low, generally grassy vegetation, such as farms, sports fields, municipal parks and open green space.
- Forest – areas of medium- to high-density tree cover.
- Other Vegetation / Heath – areas predominantly covered with short stature shrubs, bushes and other low- to medium-sized vegetation.
- Water – areas under water for most of the year.
- Wetlands – land areas that are predominantly saturated with water.

Challenges faced included:

- Ground truthing (comparing results to known land cover) was limited to existing local knowledge of the project team.
- Datasets used to derive and compare the results are outdated, and from different seasons and timeframes. For instance, the provincial aerial imagery is from 2008 and the Spot satellite imagery is from 2007.
- The number of images provided by Spot is limited.

A stepwise procedure was used to derive the final land cover classes, in order to incorporate information from other datasets and to improve overall classification accuracy. For instance, a supervised classification is often more effective when detecting simple differences (e.g. wetland or not). The following steps were used:

- Pan Sharpen Spot 20 m imagery band using simple mean algorithm to create 4-band 10 m raster.
- Create mask (i.e. polygon representation of the area of interest) from land area of Watersheds GIS layer (derived primarily from Provincial 50 cm imagery).
- Identify water from:
 - Provincial water bodies and streams (derived primarily from Provincial 50 cm imagery).
 - Canvec (Natural Resources Canada) data including water bodies, waterways, named rivers, streams.
- Developed first cut from:
 - Major Roads with 50 m buffer.
 - Other Roads with 25 m buffer.
 - Canvec Transmission Lines with 25 m buffer.
 - Canvec Building Points with 10 m buffer.
 - Canvec Building Polygons with 10 m buffer.
- Create mask of area of interest without water.
- Perform maximum likelihood supervised classification of Spot imagery using mask without Water and the following classes:
 - Forest
 - Farms and Greenspace
 - Other Vegetation/Heath OR Wetlands
 - Exposed (Developed OR Barrens/Bare Rock)
- Create mask with other vegetation/heath OR wetlands only.
- Perform maximum likelihood supervised classification of Spot imagery using mask with other vegetation / heath OR wetlands only and the following classes:
 - Other Vegetation / Heath

- Wetlands
- Use Provincial 50 cm imagery to visually differentiate exposed areas outside of the first cut into the following classes:
 - Barrens / Bare Rock
 - Developed

During subsequent analysis, the results of the South Brook Watershed delineation were used in combination with the land cover results. ArcGIS ArcToolbox clip function using the watershed boundary imposed over the land cover results produced the South Brook Watershed with land cover classifications necessary for further analysis (Figure 5).

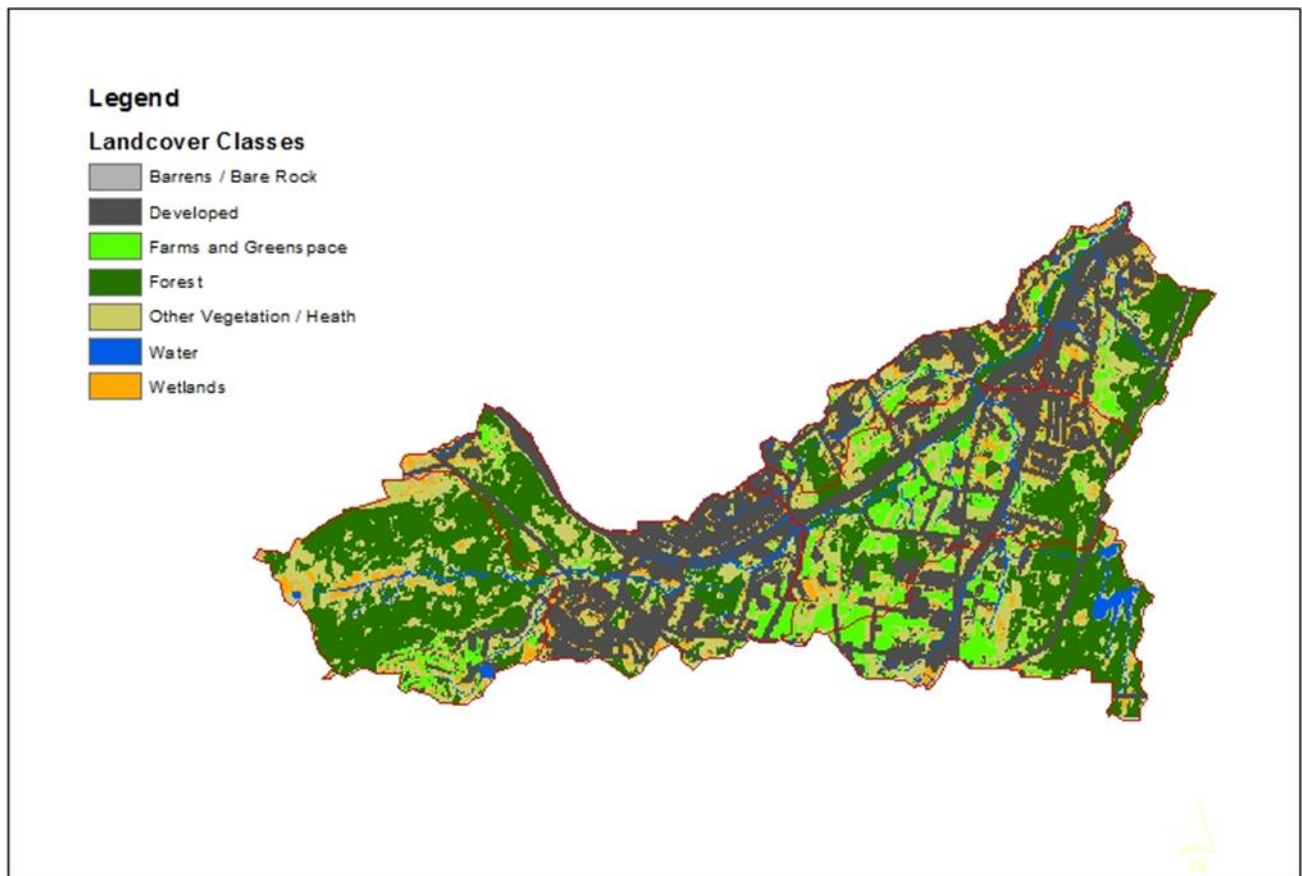


Figure 5 - Land cover classifications for the land area within the delineated South Brook watershed, Northeast Avalon Peninsula, NL.

2.3.3 Alternate Land Cover Processing

NAACAP staff completed an additional land cover classification by manual analysis to verify all land cover classifications indicated above. Visual inspection of 2010 Crown Lands aerial imagery and site visits were used to determine land cover at all locations for the study area. Appropriate polygon layers for each class were digitized over the aerial imagery for each

identified land cover type. Of the seven land use classes identified using GIS (Figure 6a), only five classes were verified through manual inspection (Figure 6b).

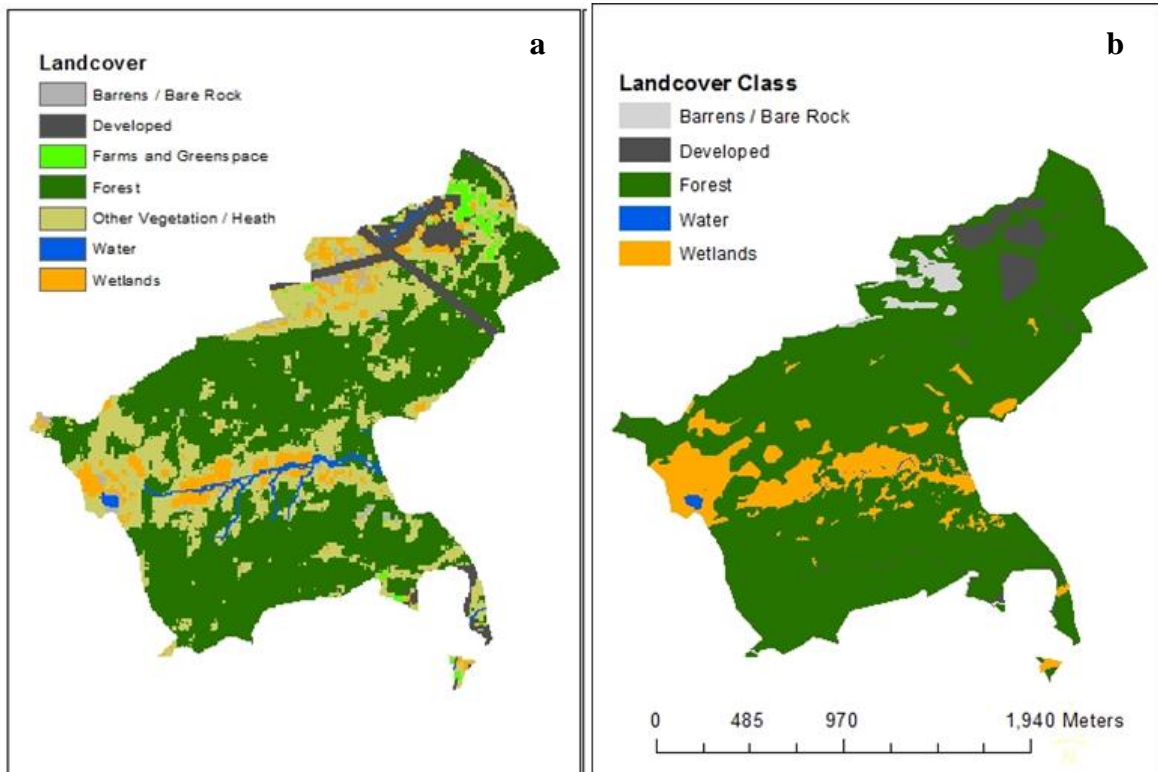


Figure 6 - ArcGIS land cover classifications (a) and manual land cover classifications (b) for the study area

2.3.4 Intactness

The seven land cover classes identified through the initial GIS maximum likelihood supervised classification were rated for intactness, that is, how continuous the natural areas are, using a 3-tier low/medium/high rating system. Using land cover as the input, Developed and Farms/Greenspace were assigned a low rating. Hundred meter buffer zones around the Developed areas and Farms/Greenspace were assigned a Medium rating. The remaining land cover classifications all received a High rating.

Land cover classes were thus assessed based on the simple 3-tier rating in order to visualise the intactness of the South Brook watershed. The map is created by substituting a single visual representation (a colour for each of low, medium or high intactness level) for each land cover class within ArcGIS. The resulting South Brook watershed intactness map based on 2010 aerial imagery is shown (Figure 7). From this GIS representation it is evident that the development area encompasses the largest continuous area with the highest level of intactness within the South Brook Watershed.

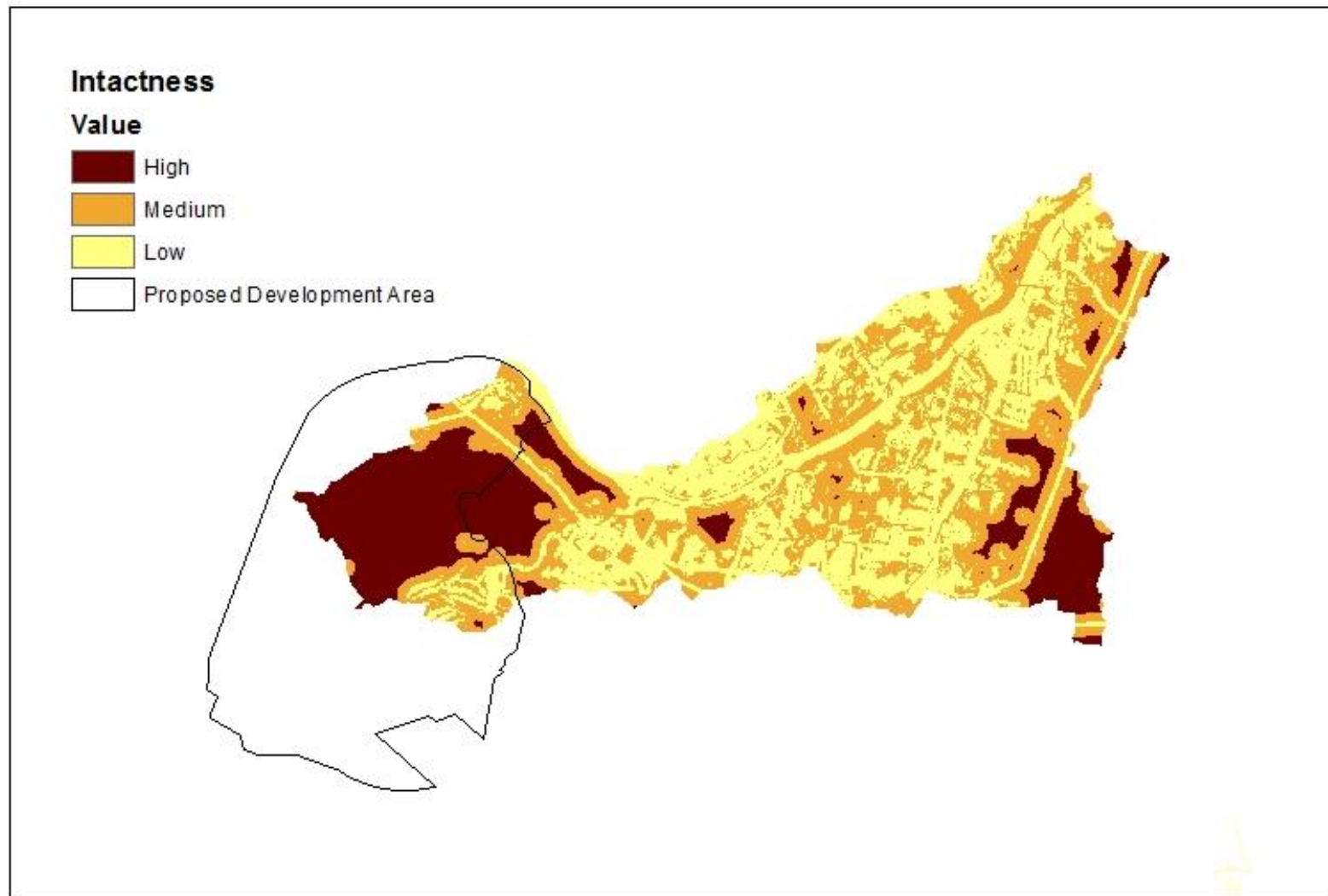


Figure 7 – Visual representation of intactness classification for the South Brook Watershed. A large area of high intactness is clearly visible at the western extent, within the boundary for the Galway concept plan outlined in black.

3.0 Results and Discussion

3.1 Water Quality

The water quality data collected from South Brook during summer 2013 are given below in Tables 1 and 2. Recorded water temperature values ranged from 13.9°C (Bowring Park on July 11) to 22.7°C (at the headwaters on August 1), while pH values ranged from 5.8 (headwaters on August 1) to 8.29 (Bowring Park on August 22). Some of these pH values were lower than the range of 6.5-9 suggested by the CCME Canadian Water Quality Guidelines for the Protection of Aquatic Life (CCME, 2006). These low values are expected for this type of ecosystem and are a result of the acidity associated with peatland soils. The lower readings were recorded at the two furthest upstream sample sites, located in the headwaters where there are a number of wetland complexes. Peat soils on the island of Newfoundland typically have a pH of 3.54-6.52 (Wells and Pollett, 1983), which in turn means that the pH of waterways that flow through these soils will likely be lower than that suggested by the CCME for freshwater environments.

All of the dissolved oxygen concentrations were above the lowest acceptable level in warm water of 6.0 mg/L for early life stages and 5.5 mg/L for other life stages suggested in the CCME Water Quality Guidelines for the Protection of Aquatic Life (CCME, 1999).

The specific conductance readings ranged from 0.04 mS/cm (headwaters on August 1) to 0.388 mS/cm (Bowring Park). The 0.04 mS/cm reading is slightly lower than the recommended range of 0.050-1.5 mS/cm for freshwater (Province of British Columbia, 1998), but is less of a concern than if the freshwater range was exceeded.

Total dissolved solids (TDS) values varied between 0.3 g/L and 0.2 g/L at the site in Bowring Park, were consistently 0.2 g/L at Pearltown Road, and were 0 g/L at Treetop Drive and the headwaters site during all visits, with all values falling within the recommended freshwater range of 0-1g/L (Province of British Columbia, 1998).

Salinity values ranged from 0.02 PSS at the headwaters site during all visits to 0.18 PSS at the Bowring Park site on July 11, which is typical of freshwater where salinity values are usually less than 1PSS (Bergman, 2001).

All of the turbidity tube readings were 60 cm, indicating that the water was not turbid.

Table 1 - Water quality data collected from South Brook (St. John's, Newfoundland and Labrador) during summer of 2013 in situ using a Quanta G multisonde and a turbidity tube.

Site Name	Site Location	Date	Site Location (decimal degrees longitude)	Site Location (decimal degrees latitude)	Temperature (° C)	pH	DO (mg/L)	DO (%)	Specific Conductance (mS/cm)	TDS (g/L)	Salinity (PSS)	Turbidity Tube (cm)
SB201301	Upstream of railway bridge, Bowring Park	11/07/2013	-52.7451	47.52787	13.85	7.43	11.15	107.4	0.388	0.3	0.18	60
SB201302	Upstream Pearltown Road	11/07/2013	-52.7725	47.50561	16.95	7.16	10.14	102.4	0.366	0.2	0.17	60
SB201303	Upstream of Treetop Drive	11/07/2013	-52.8129	47.49566	19.13	6.43	8.43	91.1	0.069	0	0.04	60
SB201304	Headwaters	11/07/2013	-52.8376	47.49583	20.74	5.43	8.71	97.3	0.038	0	0.02	60
SB201301	Upstream of railway bridge, Bowring Park	01/08/2013	-52.7451	47.52787	17.20	7.34	9.00	93.9	0.325	0.2	0.15	60
SB201302	Upstream Pearltown Road	01/08/2013	-52.7725	47.50561	17.67	7.16	8.88	92.5	0.286	0.2	0.14	60
SB201303	Upstream of Treetop Drive	01/08/2013	-52.8129	47.49566	21.61	6.37	7.44	84.7	0.060	0	0.03	60
SB201304	Headwaters	01/08/2013	-52.8376	47.49581	22.66	5.38	6.50	74.8	0.040	0	0.02	60
SB201301	Upstream of railway bridge, Bowring Park	22/08/2013	-52.745	47.5278	16.13	8.29	10.66	107.9	0.329	0.2	0.16	60
SB201302	Upstream Pearltown Road	22/08/2013	-52.7725	47.50561	18.71	7.20	8.90	95.2	0.314	0.2	0.15	60
SB201303	Upstream of Treetop Drive	22/08/2013	-52.8129	47.49566	20.16	6.35	7.54	83.3	0.064	0	0.03	60
SB201304	Headwaters	22/08/2013	-52.8376	47.49581	19.32	5.53	7.09	76.3	0.037	0	0.02	60

Table 2 contains phosphate and nitrate values for water samples analysed using Hach Stream Survey kits. There were no phosphate values given for the July 11, 2013 sample data, as the Hach kits malfunctioned. During the August 1 and August 22 visits, there were only detectable phosphate values downstream at the Bowring Park (SB201301) and Pearltown Road (SB201302) sites. The total phosphate make up was different at both of these sites on the two sample dates. On August 1, total phosphate consisted only of organic phosphate, while on August 22 total phosphate consisted only of inorganic phosphate in the form of orthophosphate. Total phosphate concentrations were higher on August 22 than August 1 at both sites. This is likely because of heavy rainfall on August 21 which could have resulted in increased surface runoff carrying phosphates to the river from land sources including farms and residential lawns, highlighting the lack of filtering abilities of urban and agricultural systems. Also, total phosphate levels were higher at the Bowring Park site (SB201301) than at Pearltown Road (SB201302) on both dates. This is likely because being farthest downstream the Bowring Park site (SB201301) has a larger area to contribute phosphates to the water, with phosphates being transported from upstream areas and from the many upstream tributaries.

There are no guidelines for phosphates or phosphorus in the CCME Water Quality Guidelines for the Protection of Aquatic Life, but there is a framework for phosphorus levels, where values are either compared to baseline values such that up to a 50% increase in concentrations above baseline levels is acceptable, or compared to trigger ranges whereby the upper limit of the desired range for phosphorus concentration is not exceeded (CCME, 2004). Provincial government data collected quarterly from two sites on South Brook contained total phosphorus readings. The total phosphorus concentrations from site NF02ZM0176 (SB201301) in Bowring Park from 2006 to 2012 fell mainly with the phosphorus trigger range categories of mesotrophic (0.01-0.02 mg/L) and meso-eutrophic (0.02-0.035 mg/L) (CCME, 2004). The phosphorus concentrations from site NF02ZM0185 (SB201303) at Treetop Drive fell mainly in the phosphorus trigger range category of oligotrophic (0.004-0.01 mg/L) (CCME, 2004). Phosphorus exists in water in the form of phosphates, so it is possible to compare total phosphate values collected in 2013 (Table 2) to these trigger ranges. It appears that total phosphate concentrations at the Bowring Park site exceed the upper limits of the trigger range typical of the area, indicating a potential water quality risk, while it is believed that the trigger range for the Treetop Drive location was not exceeded.

Table 2 also contains nitrate levels detected in samples from each site. Detectable levels ranged from 0.0227 mg/L at Pearltown Road (SB201302) on August 22 to 0.968 mg/L at Pearltown Road (SB201302) on July 11. Hence, all detected nitrate levels were below the guideline value of 13 mg/L for long term exposure given in the CCME Water Quality Guidelines for the Protection of Aquatic Life (CCME, 2012). On July 11, there were detectable levels of nitrate only at Pearltown Road (SB201302) and the headwaters site (SB201304). On both August 1 and August 22, there were detectable levels of nitrate only at the Bowring Park site (SB201301) and the Pearltown Road site (SB201302). This is similar to the results for phosphate, with the two sites located further downstream having the highest concentrations, but the nitrate values were lower on the August 22 visit than the August 1 visit, whereas phosphate values were higher.

Table 2 - Water Quality data collected from South Brook (St. John's, Newfoundland and Labrador) using the Hach Stream Survey kit, summer 2013. Total phosphate values are broken down into its components, such that orthophosphate and meta(poly)phosphate add together to give total inorganic phosphate, and total inorganic phosphate and organic phosphate add to give total phosphate. NA indicates readings that were not obtained for phosphate components on July 11, 2013 because of problems with the Hach kits. LTD stands for "lower than detectable" and indicates concentrations lower than the range measureable by the Hach kits.

Site	Site Location	Date	Site Location (decimal degrees longitude)	Site Location (decimal degrees latitude)	Ortho- phosphate (mg/L)	Meta (poly)- phosphate (mg/L)	Total Inorganic Phosphate (mg/L)	Organic Phosphate (mg/L)	Total Phosphate (mg/L)	Nitrate (mg/L)
SB201301	Upstream of railway bridge, Bowring Park	11/07/2013	-52.7451	47.52787	NA	NA	NA	NA	NA	LTD
SB201302	Upstream Pearltown Road	11/07/2013	-52.7725	47.50561	NA	NA	NA	NA	NA	0.968
SB201303	Upstream of Treetop Drive	11/07/2013	-52.8129	47.49566	NA	NA	NA	NA	NA	LTD
SB201304	Headwaters	11/07/2013	-52.8376	47.49583	NA	NA	NA	NA	NA	0.088
SB201301	Upstream of railway bridge, Bowring Park	01/08/2013	-52.7451	47.52787	LTD	LTD	LTD	0.04	0.04	0.704
SB201302	Upstream Pearltown Road	01/08/2013	-52.7725	47.50561	LTD	LTD	LTD	0.02	0.02	0.528
SB201303	Upstream of Treetop Drive	01/08/2013	-52.8129	47.49566	LTD	LTD	LTD	LTD	LTD	LTD
SB201304	Headwaters	01/08/2013	-52.8376	47.49581	LTD	LTD	LTD	LTD	LTD	LTD
SB201301	Upstream of railway bridge, Bowring Park	22/08/2013	-52.745	47.5278	0.08	LTD	0.08	LTD	0.08	0.616
SB201302	Upstream Pearltown Road	22/08/2013	-52.7725	47.50561	0.04	LTD	0.04	LTD	0.04	0.0227
SB201303	Upstream of Treetop Drive	22/08/2013	-52.8129	47.49566	LTD	LTD	LTD	LTD	LTD	LTD
SB201304	Headwaters	22/08/2013	-52.8376	47.49581	LTD	LTD	LTD	LTD	LTD	LTD

Based on the information recorded in Table 1 and Table 2 the Pearltown Road (SB201302) and Bowring Park (SB201301) sites indicated the poorest water quality, with higher conductivity, salinity, TDS, and total phosphate values than the two sites located further upstream. The upstream sites (SB201304 and SB201303) had the highest water quality because the sites were more ecologically intact and had less human development, and were located towards the headwaters of the river, compared to the downstream sites (SB201302 and SB201301).

Data obtained from Provincial Water Resources Management Division for quarterly sampling at their NF02ZM0185 (SB201303, Treetop Drive) and NF02ZM0176 (SB201301, Bowring Park) sites from 2006 to 2012 were compared to data collected by NAACAP in 2013. Table 3 contains these comparisons to NAACAP readings. Data from site SB201301 in Bowring Park were within 2 standard deviations of the average values collected by the province for all parameters with the exception of one reading for pH taken on July 11 which was higher. The variance associated with the 2013 readings was much higher compared to the Province's data for site SB201303 at Treetop Drive than there were for the Bowring Park site. Dissolved oxygen concentrations recorded by NAACAP on August 1 and 22 were lower than 2 standard deviations from the Province's average and all specific conductivity readings greater than two standard deviations from the average of the Province's data. This increase in conductivity could be related to ongoing construction in the area of Cypress Street, upstream of the sample site, during summer 2013. It is possible that this construction disturbed soil materials that contain minerals and salts which could increase conductivity, allowing them to be transported to the river through overland runoff and via a culvert located at the corner of Cypress Street and Southlands Boulevard. While the Provincial data did not contain values for TDS or salinity for comparison, it is likely that 2013 readings would be higher than those from 2006-2013 for the same reason.

Table 3 - Comparison of dissolved oxygen, pH, specific conductance and temperature data collected by the Province for sites NF02ZM0176 and NF02ZM0185 to data collected by NAACAP at same locations, named SB201301 and SB201303 respectively, based on calculations of average and standard deviation (SD) of Provincial data obtained in July and August from 2006 to 2012

Water Quality Parameter (units)	NF02ZM0176 July and August Average \pm 1SD	SB201301 (Bowring Park) Data Comparison	NF02ZM0185 July and August Average \pm 1SD	SB201303 (Treetop Drive) Data Comparisons
Dissolved Oxygen (mg/L)	10.24 \pm 0.75	All within 2SD	8.97 \pm 0.60	July 11 within 1SD, August 1 and 22 lower than 2SD
pH	7.39 \pm 0.19	July 11 and August 11 within 2SD, August 22 higher than 2SD	6.39 \pm 0.10	All within 1SD
Specific Conductance (μ S/cm)	336.86 \pm 89.99	All within 1SD	37.78 \pm 11.05	All higher than 2SD
Temperature ($^{\circ}$ C)	16.36 \pm 3.02	All within 1SD	15.60 \pm 3.01	All within 2SD

While the data collected suggest water quality in South Brook was not severely impaired with regards to suitability for aquatic life in freshwater, there is evidence of influence from human surroundings, including residential and agricultural areas. This influence will likely increase as the watershed is developed further, including the proposed Galway development and

new housing being built in the Kilbride and Southlands areas. One visual sign of this increasing influence on water quality is recent siltation of South Brook. These events were noted at various times throughout this project year, including on June 6, 2013 at the corner of Cypress Street and Southlands Boulevard (Figure 8), and November 21, 2013 when a tributary which enters South Brook in the vicinity of Old Bay Bulls Road became sediment laden (Figure 9), and caused both South Brook and the downstream portions of the Waterford River to become turbid.



Figure 8 - Siltation of South Brook (St. John's, Newfoundland and Labrador), June 6, 2013 located in the area of Cyprus Street and Southlands Boulevard. A small tributary that enters South Brook via a culvert appeared to be the source of the siltation. (Photo courtesy of Nick White).



Figure 9- Sediment laden water enters a tributary to South Brook (St. John's, Newfoundland and Labrador), downstream of Bay Bulls Road November 22, 2013. (Photo courtesy of Diana Baird).

Past water quality studies determined that the water quality differs at the headwaters compared to the lower reaches of South Brook (Pomeroy and Collins, 1993). While this was partly due to differences in geology, it was also believed that there was water quality deterioration downstream caused by human surroundings, including sewer inputs, specifically from two main tributaries, and road salt inputs (Pomeroy and Collins, 1993). While fecal

coliform levels were not tested as indicators of sewer inputs in 2013, there were no visual indicators of sewage outfalls observed, and there have been advancements with the septic sewer system in St. John's since the early 1990s aimed at diverting sewage to a treatment facility at St. John's Harbour rather than into local rivers. Also, as testing was performed during summer, it is difficult to comment on current road salt influences on water quality. However, the study from 1993 does bring attention to water quality issues commonly associated with increased development.

3.2 Wetlands Survey

Two wetlands inside the study area were sampled to obtain basic biological data from the wetland ecosystem (Figure 10). These wetlands were named Southlands Site 1 and Southlands Site 2 by the Conservation Corps NAACAP Green Team.

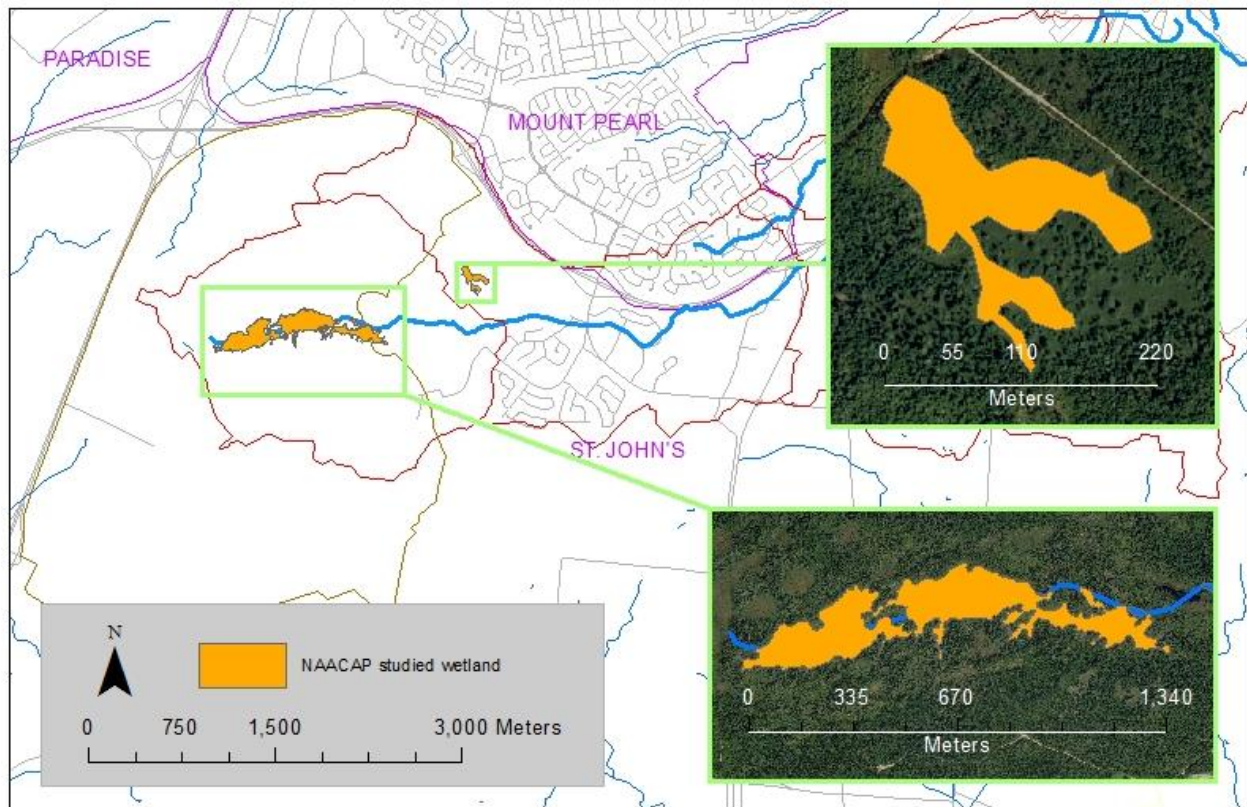


Figure 10 - Wetland sites visited by NAACAP's Green Team in summer 2013. Inset area Southlands Site 1 (upper right) and Southlands Site 2 (lower right).

Both of the sampled wetland sites appeared to have a large diversity of plant species, and there were no non-native species found at either site (Table 4). Plant richness is a measure of the number of different plants or plant groups found in a sample area and is an indication of biodiversity. Macroinvertebrates found during sampling were considered to be somewhat pollution tolerant. Wetland function is the services that a wetland provides to the larger ecosystem independent of humans. The two surveyed sites are believed to have a variety of

wetland functions (Table 4). A variety of wildlife, or evidence of it, was found in these wetlands, including a variety of birds, frog tadpoles, moose, and rabbits.

Table 4 Summary of data collected during Green Team sampling of two wetland areas within the Galway development area, including plant richness values, the number of non-native plants identified, and wetland functions that each site was determined to serve

Wetland Site Name	Plant Richness	Number of Non-native Plants	Wetland Functions
Southlands Site 1	30	0	Storing surface water, groundwater discharge, habitat for wildlife
Southlands Site 2	25	0	Storing surface water, maintaining stream flow, ground water discharge, retaining sediment and particulates, shoreline stabilization and habitat for wildlife

3.3 GIS Vulnerability Assessment

As shown in Table 5, prior to the Galway development, based on the 2010 aerial imagery, 82.8% (268.6 hectares) of the study area is forested and 11.4 % is wetlands and water. Change from a natural land cover type (forest, wetlands) to an urban land cover type increases the amount of impermeable surfaces. These land cover changes, even in the absence of changes in precipitation, could increase runoff and river discharge, which is especially a concern within the Waterford River system, which the City of St. John's has been advised has no capacity for increased storm water discharge (Sharpe, 2012). The City's Stormwater Detention Policy states that pre-development runoff rates must be maintained in post-development scenarios. Residents living along the lower reaches of the Waterford River system have already experienced increased flooding due to past urbanization. Even before development is completed, the runoff pattern can be affected and the water quality and quantity adversely impacted following land clearing (i.e. cutting of trees). As mentioned above, sedimentation has already been an issue in the lower reaches of the Waterford River, and it is expected that sedimentation from South Brook would compound existing issues.

Table 5 – Amount of each manual land cover classification within the study area, before the Galway development.

Land cover classification	Area (hectares)	Percent of total study area
Barren / Bare Rock	6.0 ha	1.8%
Developed	13.0 ha	4.0%
Forest	268.6 ha	82.8%
Water	0.9 ha	0.3%
Wetlands	36.0 ha	11.1%
	324.5 ha	100%

Figure 11 shows the manual land cover classifications for the study area, determined prior to the Galway development. The large wetland complex in Figure 11 contains the headwaters of South Brook, and the upper reaches of the river flow through the centre of these wetlands. Part of this wetland complex was visited during 2013 by NAACAP field staff, as described above (Southlands Site 2 in Section 3.2).

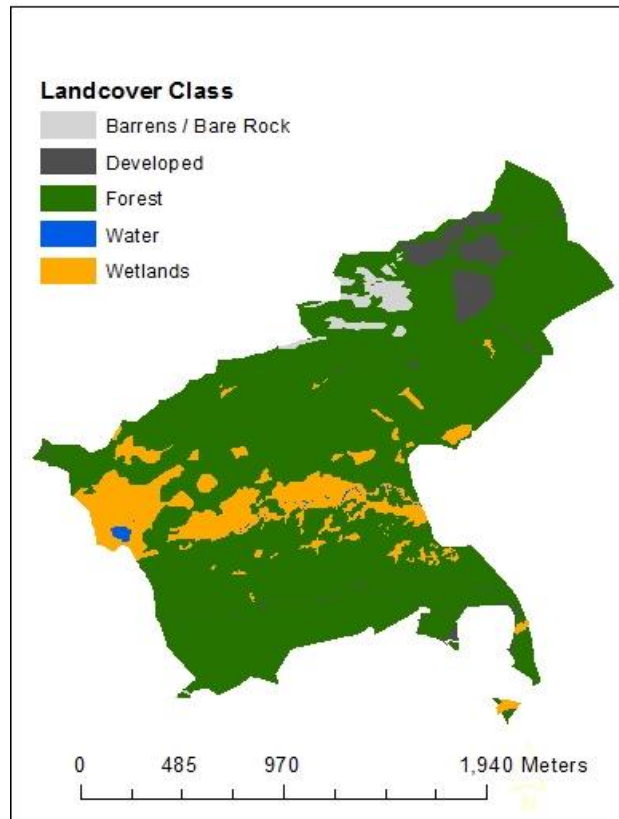


Figure 11 – Manual land cover classifications for the study area before the Galway development.

Part of this large wetland falls within a proposed corridor of undeveloped land on the preliminary Galway development plan. Figure 12 shows the manual land cover classifications with the proposed undeveloped areas. This illustrates the limited amount of wetlands that will be conserved based on the preliminary development plan, assuming that areas that are zoned residential, industrial or commercial will not contain conservation areas. It can be seen that the boundaries of the proposed undeveloped corridor located in the center of the study area (Figure 12) will run through the wetlands and along South Brook, and does not appear to follow the natural wetland boundaries. This undeveloped corridor measured in GIS software ranged from approximately 58 meters at the narrowest point to 134 meters at the widest point. To sustain the wetland, there should also be a section of forest included around the wetland area to act as a buffer. The exact extent of the undeveloped area needed to sustain the wetland depends on several parameters including surrounding vegetation, slope, soil type, rainfall etc. These parameters need to be considered when determining buffer width. Table 6 shows a breakdown of the land cover classifications within the undeveloped zone surrounding South Brook in the center

of the study area. While 61% of this undeveloped area is wetlands, moving the boundaries of the undeveloped zone may allow a greater percentage of wetlands to be conserved without increases in total undeveloped land.

Table 6 – Amount of land cover types within the undeveloped corridor in the center of the study area.

Land Cover	Area (hectares)	Percent of area
Forest	10.0 ha	36%
Water	0.8 ha	3%
<i>Wetlands</i>	<i>17.0 ha</i>	<i>61%</i>
	27.8 ha	100%

However, the undeveloped zones in the proposed Galway development do not represent areas that have not been nor will be developed; there are currently developed areas within the proposed undeveloped area at the northwest corner of the study area. As such, the undeveloped areas in the preliminary development plans are not guaranteed to be set aside for conservation purposes.

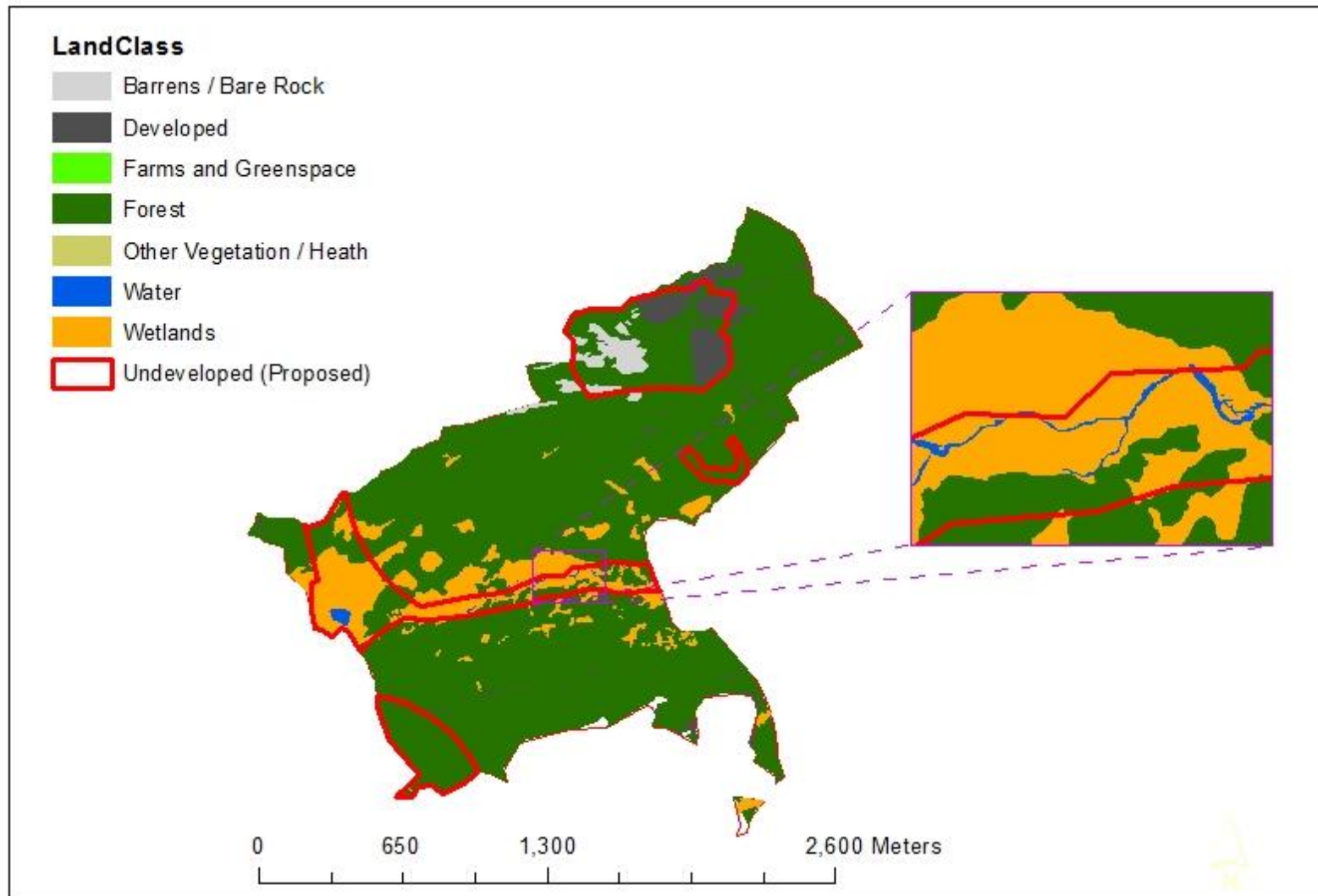


Figure 11 - The manual land cover classifications with the undeveloped sections of the proposed Galway development plan outlined in red. A corridor of proposed undeveloped area runs west to east along the center of the study area.

Prior to Galway, the study area was largely undeveloped and thus mostly highly intact (Figure 13a). This area will be developed into a large residential area with smaller industrial areas (Figure 13b).

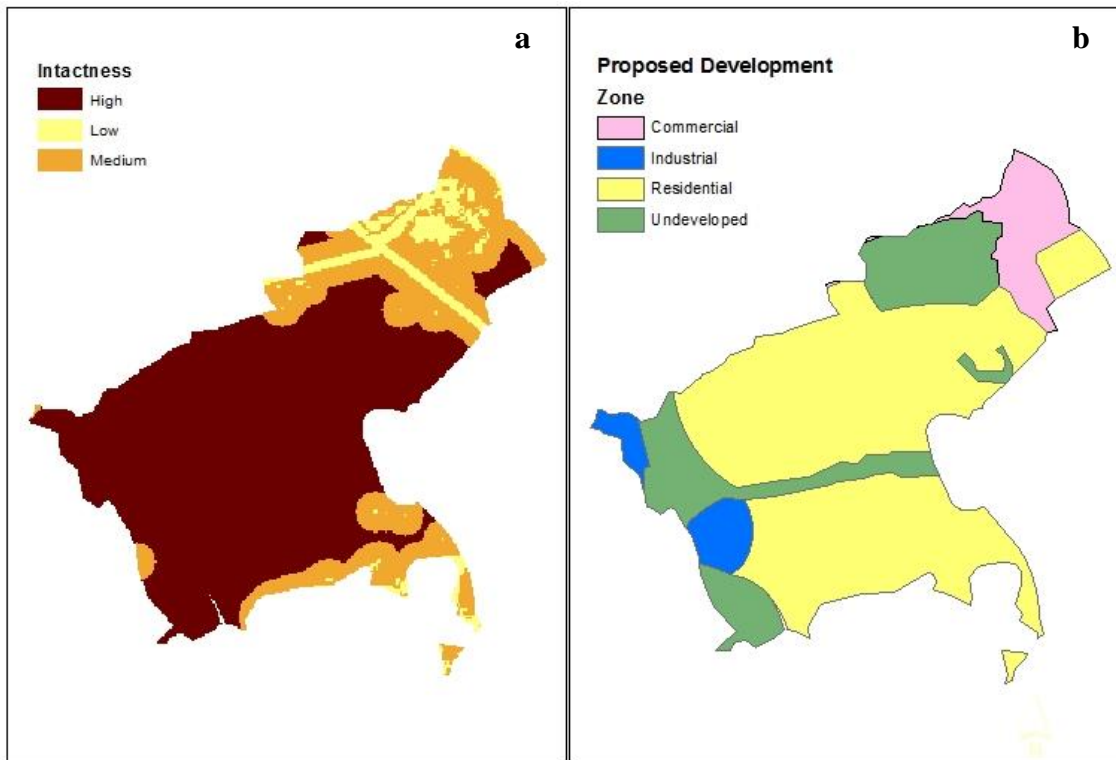


Figure 13 – Pre-development intactness (a) and proposed Galway development zones (b) for the study area.

The percentage of land area classified as low, medium or high for the study area before Galway is shown in Table 7; 70.3% of the proposed development area within the South Brook watershed was rated high for intactness. The area includes a large, clearly defined area of uninterrupted high intactness measuring 223.7 hectares, or 68.7% of the study area.

Table 7 – Amount of each intactness classification (low, medium and high) within the study area, pre-Galway development.

Level of Intactness	Area (hectares)	Percent of total
Low	21.0 ha	6.5%
Medium	75.6 ha	23.2%
High	229.1 ha	70.3%
	325.8 ha	100%

These pre-development intactness ratings were then compared to the predicted post-development intactness. Commercial, residential and industrial zones (Figure 13b) are considered to have low intactness. The undeveloped zones (Figure 13b) are considered to have high intactness.

Table 8 – A breakdown of the study area based on Galway proposed zoning and the intactness of those zones

Development Zone	Level of Intactness	Area (hectares)	Percent of total
Commercial	Low	26.7 ha	8.2%
Industrial	Low	15.4 ha	4.7%
Residential	Low	214.4 ha	65.8%
Undeveloped	High	69.3 ha	21.3%
		325.8 ha	100%

As seen in Table 8, the largest component of the study area will be residential at approximately 65.8% of the area. For the proposed Galway development, only 21.3% of the study area is to remain undeveloped, although less than this will be left in a natural state as the undeveloped areas are not necessarily conservation areas. The 69.3 ha of high intactness is a slight overestimate since it doesn't take into account the fact that some of the area that is considered undeveloped already has some disturbance, and was originally classified as low and medium intactness.

4.0 Recommendations

There is concern that land cover and land use changes associated with the Galway development will negatively impact the South Brook Watershed. The importance of maintaining the health of the Waterford River was recently recognized by all three of the municipalities through which the river flows. The three mayors met on World Rivers Day 2013 to announce cooperation between the municipalities regarding all matters pertaining to the river. Said Town of Paradise Mayor Dan Bobbett (2013) regarding the cooperation and the river itself:

"I am especially glad to see, coming newly into the position of Mayor that the three councils are cognizant of the need for us all to be working as one in looking after this river which is such a tremendous asset to our citizens".

The following are recommended to maintain the natural integrity of the headwaters and ensure that there are no negative downstream impacts to water quality and water quantity while incorporating natural areas into developed areas.

1. Ensure that wetlands along the headwater segment of South Brook are left intact, and are surrounded by sufficient forest buffer

There are many benefits and ecosystem services that come from wetland areas. They act as habitat for wildlife, improve water quality, retain flood waters, and store carbon. As much of the proposed Galway development area consists of wetlands, it should be ensured that they are maintained in their natural condition so that they can provide these natural services. To properly maintain wetlands, it is also necessary to leave a sufficient forested buffer around them.

Since the wetland surrounding the headwater segment of South Brook is large and is the foundation of the headwaters of the river system, it is necessary to make recommendations specific to this area. The proposed undeveloped corridor surrounding the headwater segment of South Brook does not follow the natural wetland boundaries. The extent of this corridor should be studied in more detail and redesigned prior to developing the area so that it does not divide the

wetland complex and impair wetland function and to ensure that the proper forest buffer is in place. The exact size of the buffer will need to be based on such factors as soil type, slope and ground cover, and will likely vary in different areas. Dividing the wetlands provides an entrance point for non-native flora, and as mentioned above there were no non-native plants found when the wetland was studied by the Green Team. Having a buffer around these wetlands could prevent introduced species from altering wetland function.

This undeveloped corridor should also be designated as a conservation zone rather than an undeveloped zone, to further ensure that it remains in a natural state. This does not mean that the space cannot fill a planning need, as it would be the ideal location for a walking trail.

2. Manage storm water retention with an environmental focus

Given that the Galway development is proposed for the headwaters of South Brook, the largest tributary to the Waterford River, the risk of increased flooding downstream is a concern. The City of St. John's now has a Stormwater Detention Policy which states that post-development runoff rates must not exceed that of pre-development rates. Thus, there will need to be further consideration given to the final design of the Galway development and how zero net runoff can be incorporated to ensure that the development does not increase flooding downstream. However, the Stormwater Detention Policy is designed to control flooding only, which is only one of the concerns with increased development. Besides increased flooding from runoff, there are also concerns with negative impacts to water quality and destruction of habitat. Storm water detention can be achieved in a variety of ways; including underground water storage tanks, creating man made wetlands, or maintaining natural wetlands. While these methods may result in storm water retention, they are not equal in terms of protecting the environment. A wetland provides habitat, carbon storage, oxygen, and natural water filtration, while an underground storage tank solely controls runoff rates. Wetlands both natural and artificial also have aesthetic value over traditional concrete retention tanks, and may also have recreational uses. It is recommended that planners and developers consider a range of storm water retention options for this development.

3. Incorporate the environment into community design

As populations grow and urbanization puts pressure on remaining natural areas such as wetlands and forests, there is a movement to incorporate green spaces into development plans, with the goal of sustaining wetlands and riverine systems. Proper storm water and runoff management, maximizing green areas within the development, and minimization of the amount of impermeable surfaces found throughout the development area would be critical to help protect the South Brook Watershed in light of the Galway development.

At the community level, continuous impermeable surface area should be minimized. One method that can be used is incorporating treed areas between developed areas. Natural vegetation absorbs precipitation and minimizes runoff. These natural areas can be designed so that they connect to storm water management systems. This allows water to slowly enter the storm water system, while the natural soil and vegetation filters contaminants contained in the storm water.

Given the significant slope of much of the development area, these treed areas could also be used to stabilize the hillside and could be incorporated into engineering plans for erosion control.

4. Creating a dialogue with planners, developers, NGOs and the public.

Galway is a very large scale development and will take place over several years. In the past, maintaining environmental integrity was not prioritized, and thus rivers were channelized, buried or rerouted; wetlands were often filled and habitat connectivity was lost. Now the value of river systems is gaining recognition, but it is also becoming evident that it is very expensive, if not impossible to rehabilitate degraded waterways. Galway is currently a blank canvas. It provides an opportunity to learn from the past and implement greener design. There is a wealth of knowledge in our community and we recommend that an ongoing dialogue is established among planners, developers, NGOs and the public. There will be several stages of this development, and interested parties should be consulted at regular intervals.

5. Continued monitoring

As mentioned above, the Galway development will take place over a number of years. Thus it is recommended that monitoring continue, on a variety of scales, throughout the course of development. Monitoring water quality and other environmental parameters at regular intervals could allow any changes to be identified. If the quality of the environment is shown to be deteriorating this information could be used to prevent further deterioration. The recommendations in this report are general in nature as they are based on the preliminary plans for the development. These recommendations should be considered when making future plans. As the development progresses, more targeted recommendations can be made based on monitoring of the specific areas that are scheduled to be developed.

5.0 Conclusion

The location of the proposed Galway development at the headwaters of South Brook makes it very likely that changes in land cover and land use in the area will impact the downstream areas along South Brook and also the lower reaches of the Waterford River.

This project is the result of a preliminary study into the possible impacts of this increase in development on the watershed. Examination of water quality along South Brook indicated that the waterway appears to be suitable for aquatic life, and showed that the developed downstream reaches had poorer water quality than the undeveloped upstream areas. Also, surveying of the wetlands within the proposed Galway development indicated that the wetlands support a diversity of wildlife.

Future planning for the development should ensure that the natural integrity of the area is maintained. While we have made some recommendations based on the preliminary development plan, it is evident that there needs to be further in depth study of the area to be considered while developing detailed plans for area.

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Appendix A
Maps of each water quality sample location along South Brook

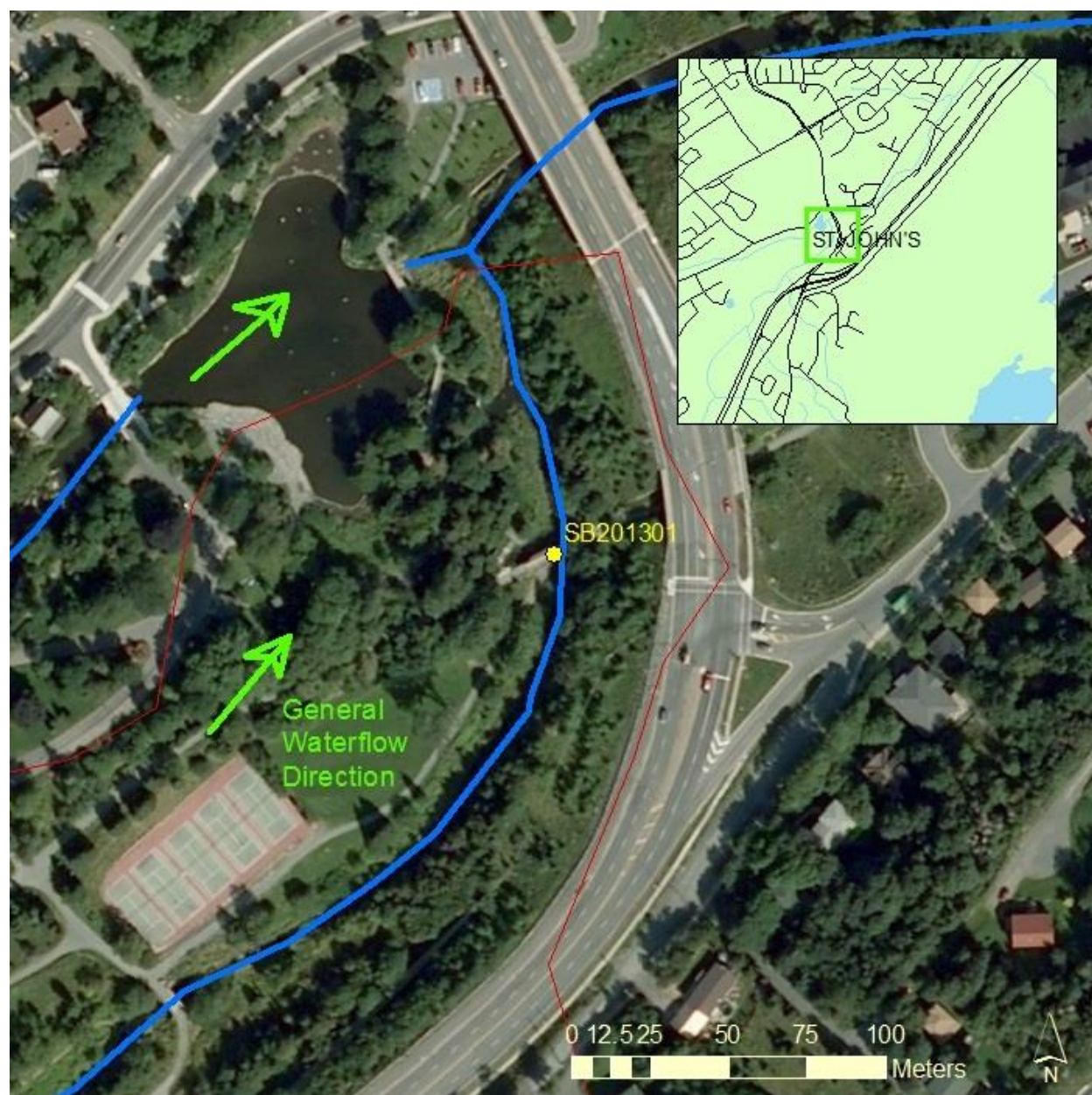


Figure A1. Location of sample site SB201301 the furthest downstream water quality sample site in St. John's, Newfoundland and Labrador. Sampling occurred upstream of the railway crossing in Bowring Park. The red line indicates the boundary of the South Brook watershed, which is bounded on the east by Columbus Drive. To the north of site SB201301, South Brook enters the Waterford River, which flows eastward out of Bowring Park.

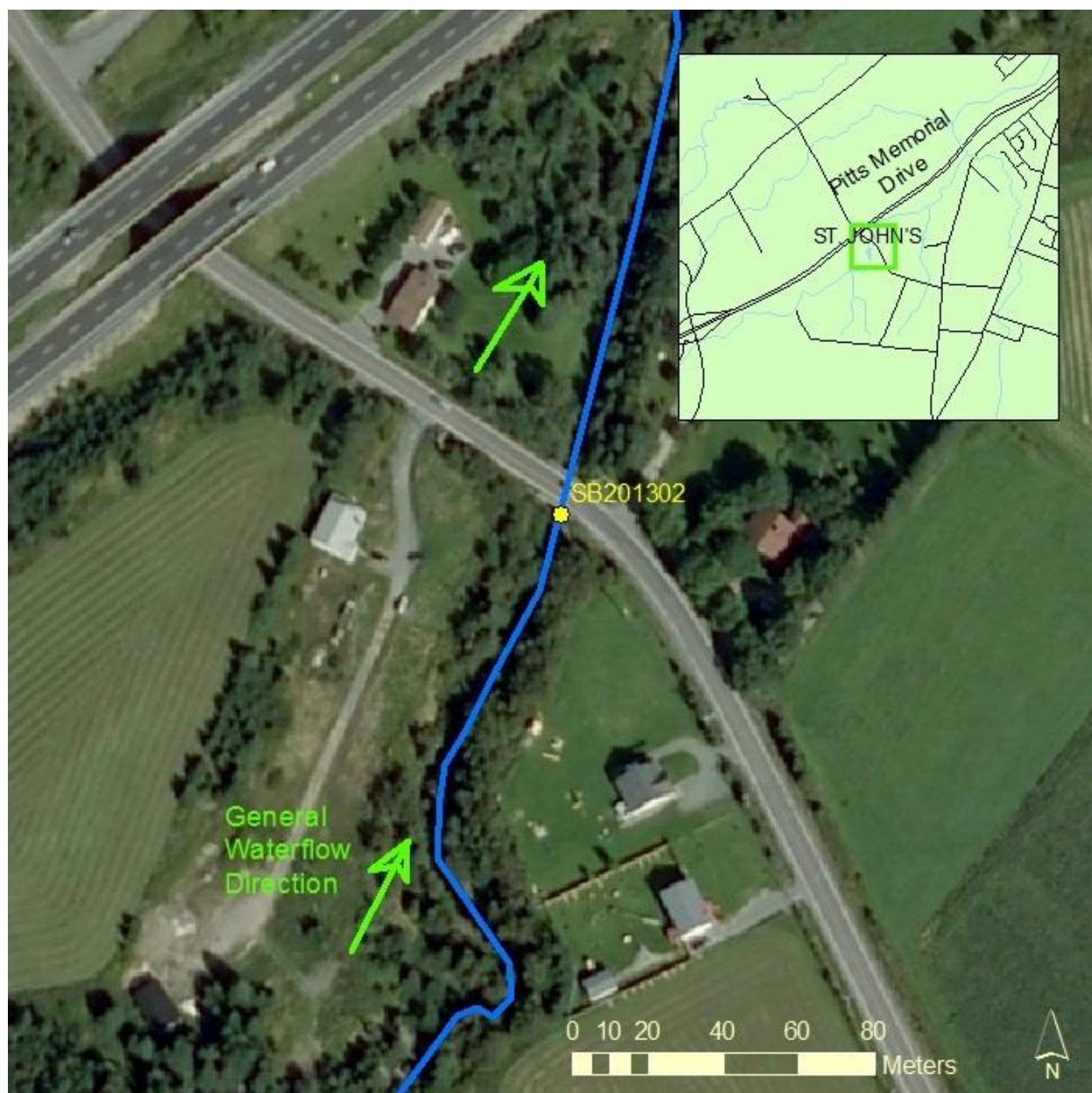


Figure A2. Location of water quality sample site SB201302, located upstream of Pearl Town Road. The dominant land use in the area is agricultural. The divided highway located in the northwest corner of this image is Pitts Memorial Drive.



Figure A3. Location of water quality sample site SB201303, located upstream of Treetop Drive in the Southlands development. The double highway to the east is Southlands Boulevard. Note: the blue line representing South Brook is a generalisation of the flow

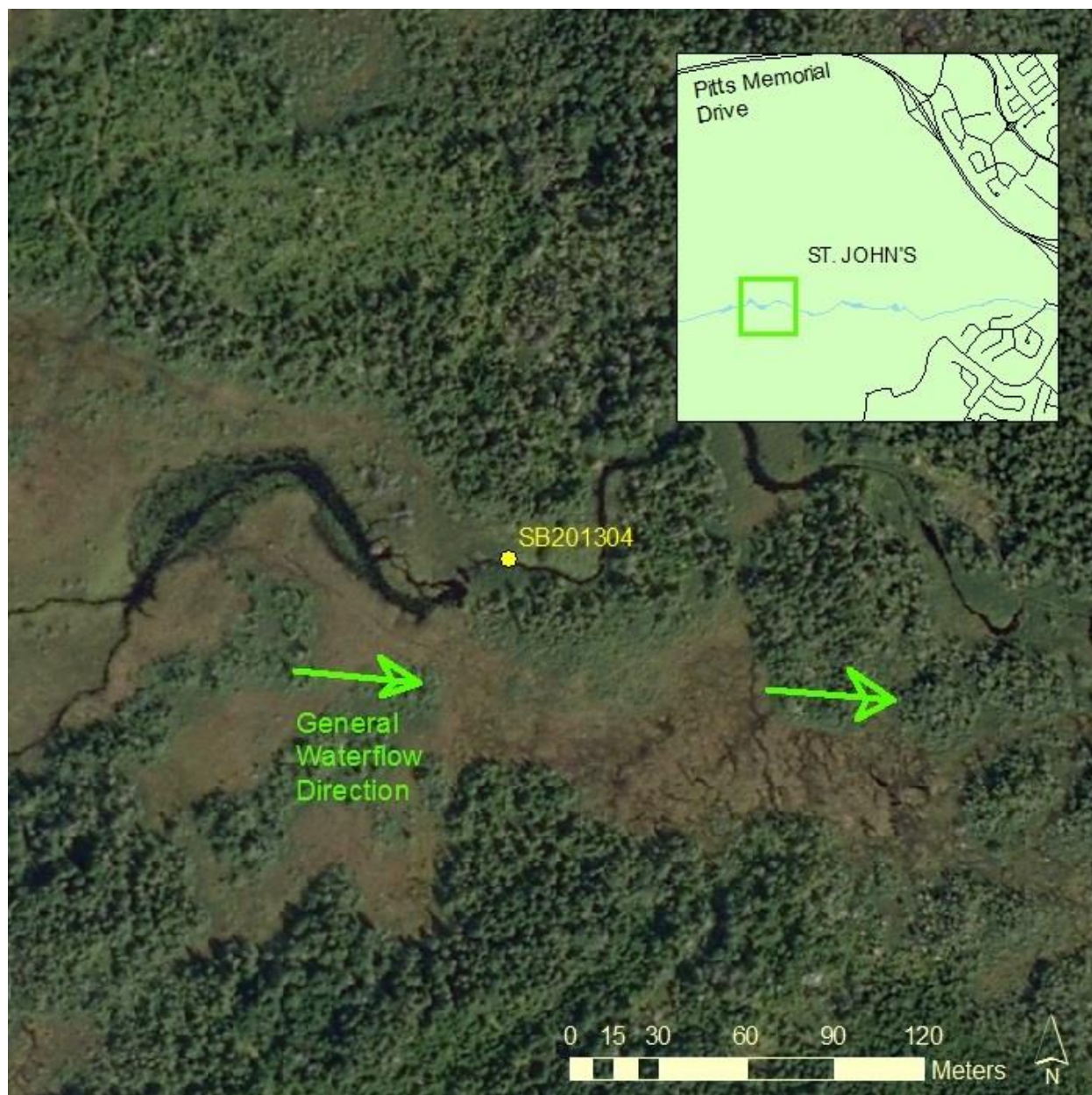


Figure A4. Location of water quality sample site SB201304, located in the headwaters of South Brook, where the river originates and flows out of a wetland area. This site is located within the boundaries of the proposed Galway development