STATE OF THE NASHWAAK RIVER WATERSHED

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Executive Summary

The Nashwaak River drains approximately 1,707 km^2 of central New Brunswick. It is a fifth order tributary to the Saint John River. It flows 100 km from its headwaters in Upper Nashwaak Lake on the York/Carlton County line southward to its confluence with the Saint John River in Fredericton. The river is fed by meltwater, groundwater springs, and small tributaries. The watershed is sparsely populated (~15,000 people) except for the lower 5 km and remains relatively undeveloped, with 92% of the land covered by forest. Ecologically, the Nashwaak watershed contributes significantly to the biodiversity of the province, containing rare and unique species and habitat, including at least 31 species of rare or endangered animals and 13 species of rare or endangered plants. A remnant Atlantic salmon population occurs in the Nashwaak watershed, which provides 5.69 million m^2 of salmon production area. Cold water tributaries in the headwaters provide important thermal refuges for salmonids but the main stem of the Nashwaak is warm compared to other rivers in the province. Water quality, on average, is excellent in the headwaters, becoming somewhat more degraded towards the mouth of the river.

The Nashwaak Watershed Association Inc. was founded in 1995 and is dedicated to maintaining and improving the environment of the Nashwaak River and its catchment. Clean water is one of New Brunswick's most important resources. However, today there are threats to New Brunswick's watersheds from development and climate change. Challenges include removal of riparian vegetation, erosion, pollution, habitat degradation, increased risk of flooding, and increased water temperatures. Atlantic salmon populations have suffered, dropping by over 64% in the last three generations. Sustainable watershed management is critical to all New Brunswickers.

This report covers a broad range of topics focused in seven key areas:

- History and socio-economics
- Land use
- Geology and geomorphology
- Climate and climate change
- Water quality and quantity
- Fish, wildlife and plants
- Restoration and management activities

The purpose of the *State of the Nashwaak Watershed Report* is to summarize current knowledge, comment on the environmental health of the watershed, and to provide context and the basis for the *Nashwaak Watershed 3 Year Action Plan*. The report summarizes the historical use of the watershed, the geology and land use, climate and water quality and quantity data, and other indicators of watershed health and identifies data gaps that could be filled by future research and management. This report is key to the NWAI's long term goals and is intended to provide a sound scientific base for future decision making. This *State of the Watershed Report* should not be considered a definitive statement on the condition of the Nashwaak watershed but, rather, a starting point for further management, restoration, and monitoring activities.

The Nashwaak Watershed Association Inc.

Founded in 1995 as a non-profit organization dedicated to maintaining and improving the environment of the Nashwaak River and its catchment. Major projects have included:

- Assisting DFO with salmon fry/parr densities (electrofishing), smolt escapement (smolt wheel) and adult returns (counting fence) (annually 1995 – 2014)
- Electronic tagging/mortality study of salmon smolts (1998)
- Operation of streamside rearing and gene-banking infrastructure (1998 – 2008)
- Completion of the Provincial Water Classification Process and provisional classification report (1999 – 2004)
- Salmon redd count studies (2003 – 2004)
- Assisting Canadian Rivers Institute with egg survival study on the Tay River (2003 – 2005)
- Eroding bank surveys (2005 and 2012)
- Riparian zone protection and reforestation (2005 – present)
    - including nursery operation and tree planting with community volunteers and schools
- Awarded "Intervener Status" by the Canadian Environmental Assessment Agency to review the Environmental Impact Assessment for the Sisson Mine project, with specific review and comments on impacts to the Nashwaak river and salmon habitat (2013 – 2014)
- Educational programming in local schools (2006 – present)
- Geomorphic survey (2016)

Mission

The Nashwaak River watershed should be managed as a healthy ecosystem that balances a variety of economic, recreational, social and landowner interests. All stakeholders on the Nashwaak are committed to sustaining the scenic and serene nature of the watershed in a manner consistent with the pursuits of all user groups. The Nashwaak River watershed should serve the community while maintaining a healthy resource for generations to come.

Acknowledgements

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List of Acronyms

ASF	Atlantic Salmon Federation	asl	Above sea level
BMI	Benthic Macroinvertebrate	BMP	Best Management
BOD	Biological Oxygen Demand	CCME	Canadian Council of Ministers of Environment
CITES	Convention on International Trade in Endangered Species of Wild Flora and Fauna	COSEWIC	Committee on the Status of Endangered Wildlife in Canada
DELG	Department of Environment and Local Government (NB)	DFO	Department of Fisheries and Oceans
DNRE	Department of Natural Resources and Energy (NB)	DNR	Department of Natural Resources (NB)
DO	Dissolved Oxygen	ECC	Environment and Climate Change Canada
EPA	Environmental Projection Agency (USA)	ESA	Environmentally Significant Area
HBI	Hilsenhoff Biotic Index	IUCN	International Union on the Conservation of Nature
Mya	Million years ago	NB	New Brunswick
NHS	National Household Survey	NWAI	Nashwaak Watershed Association Inc.
PID	Parcel Identifier	PNA	Protected Natural Area
PSW	Provincially Significant Wetland	RST	Rotary Screw Trap
SARA	Species at Risk Act	SJR	Saint John River
TDS	Total Dissolved Solids	TOC	Total Organic Carbon
TP-L	Total Phosphorus	UNB	University of New Brunswick
WCR	Water Classification Regulation	WMA	Wildlife Managed Area
WPA	Wildlife Protected Area	WQI	Water Quality Index
WSC	Water Service of Canada		

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1 INTRODUCTION

1.1 WATERSHEDS, SUB-BASINS, AND REACHES

A watershed encompasses all the land that is drained by a river and its tributaries into a single body of water (Figure 1). It includes ground water and aquifers that draw from, or discharge to, the streams, wetlands, ponds, and lakes. Watersheds can be small or large, and are sometimes referred to as river basins or drainage areas. A small watershed may only drain a few square kilometres of land into a small creek, which will empty into a larger river. The watershed of the creek is referred to as the sub-watershed or sub-basin of the larger watershed or river basin.

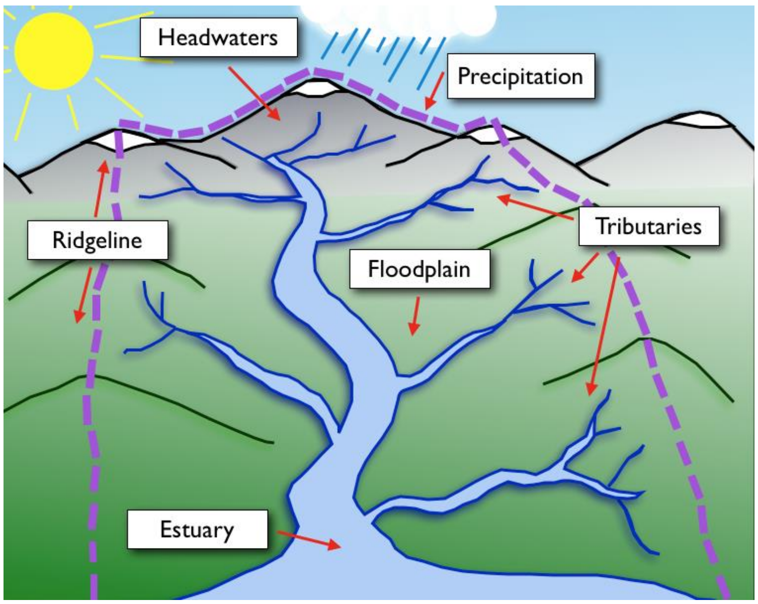


Figure 1 Simplified diagram of a watershed. Source: CSERC.

A reach is a continuous piece of a river with similar hydrologic characteristics.

The character and nature of a river are a function of the underlying geology and the climate of an area. The geology dictates the topography, which modifies the local climate, which in turn dictates the plant community that will grow in the riparian zone. These processes determine the shape of a river channel, its slope, substrate, and its flora and fauna, as well as its fertility and productivity.

Since all the water in a river is drained from the surrounding catchment, or watershed, the river and its inhabitants are dependant on the stability and health of the lands draining into the watershed. Human land use activities can significantly alter these processes, resulting in a degraded river or stream.

Watersheds have several components that each play a role in the hydrologic system.

1.1.1 The Riparian Zone

Riparian zones are the areas of land directly adjacent to a river or stream (Figure 2). Riparian zones help dissipate energy and slow the flow of flood waters. The riparian zone acts as an erosion buffer to absorb the impacts of climate change and increased urban runoff. These areas also provide corridors for wildlife movement, shelter and cover for aquatic organisms, and shade for the watercourse. Healthy riparian zones are vegetated with a diverse range of grasses, shrubs, and trees. This vegetation is the primary source of woody debris for the watercourse, which provides food and habitat for aquatic life. The root systems stabilize the streambanks and act as biofilters by absorbing nutrients that would otherwise enter the stream and degrade the water quality.

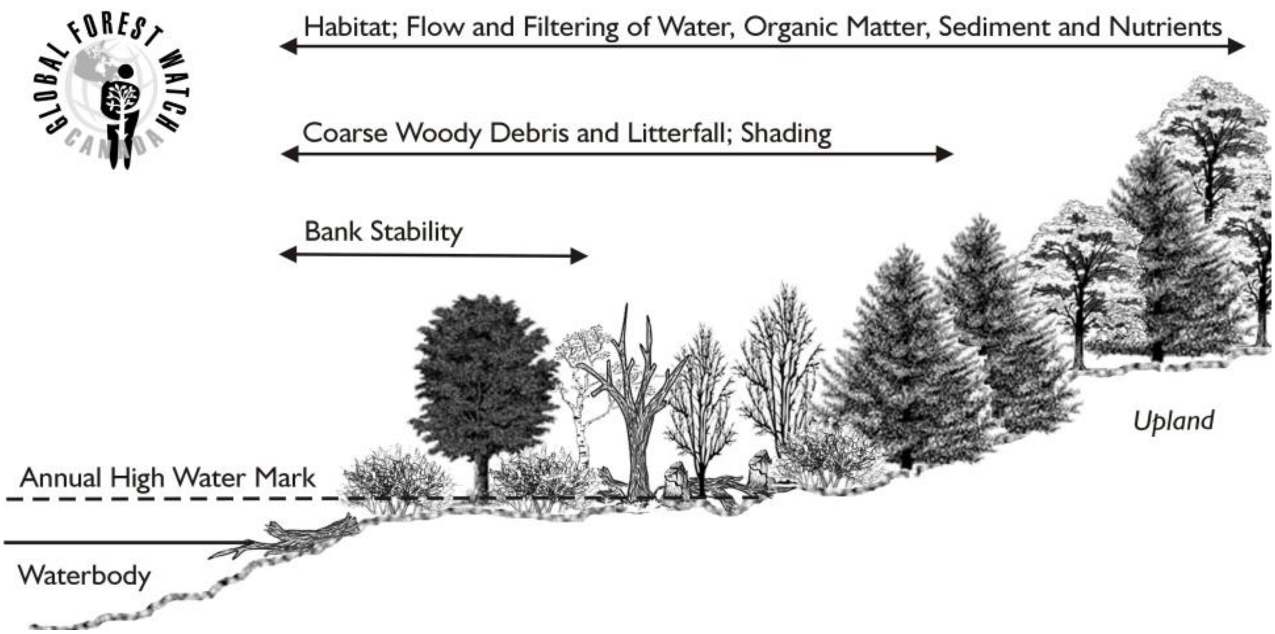


Figure 2 The riparian zone. Source: Global Forest Watch Canada.

1.1.2 Rivers and Streams

Rivers are dynamic systems, frequently changing in size and velocity. Different habitat features such as pools, riffles, run, rapids, oxbows, and cascades all provide important areas for aquatic organisms (Figure 3). Pools are deeper, slower moving water that provide a resting place for fish and remain cooler in the summer. Riffles are shallow, fast-moving water that provide nesting habitat for salmonids in the gravel bottom. Oxbows are portions of the river that have been cut off. They provide habitat for waterfowl, amphibians, and fish.

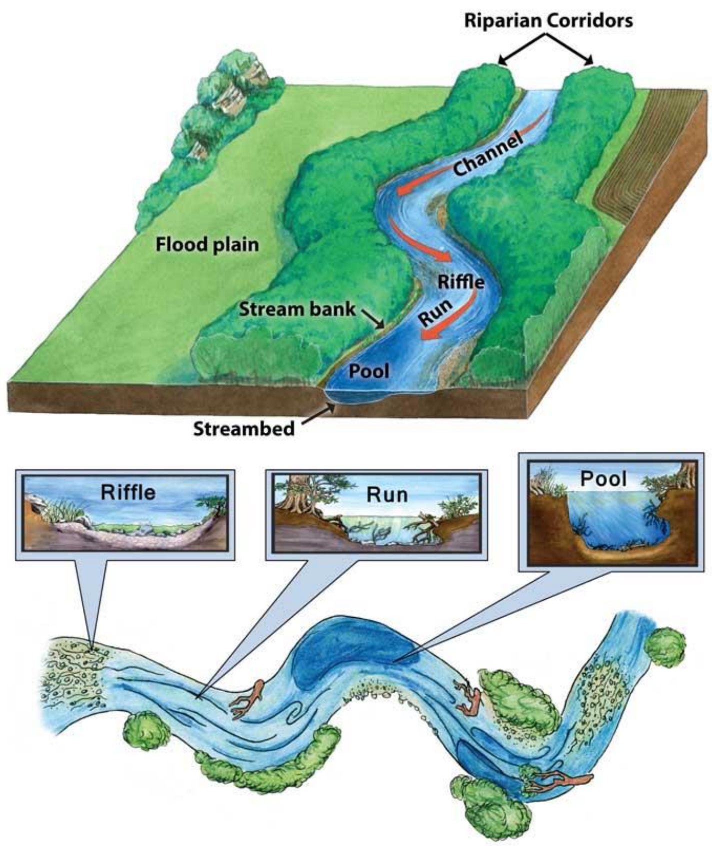


Figure 3 Features of a river. Source: Texas Aquatic Science.

1.1.3 Wetlands

Wetlands are areas of land that are saturated with water, either permanently or seasonally. Wetlands act as natural filtration systems, helping to remove pollutants from the water. They provide a storage space for water, which minimizes flooding, and slowly release water during dry periods. The four main types of wetlands are bogs, swamps, marshes, and fens.

1.1.4 Floodplains

A floodplain is an area of low-lying ground adjacent to a river, formed mainly by river sediments and subject to flooding (Figure 3). It stretches from the banks of the channel to the base of the enclosing valley walls and helps to disperse large amounts of water. As the water spills across the floodplain, it provides a continuous source of sediments that can replenish soils

1.1.5 Groundwater

Aquifers are underground bodies of water that are replenished through precipitation that infiltrates the ground. Sandy and gravelly soils allow water to infiltrate most quickly while impermeable surfaces, such as pavements, do not allow any water to infiltrate. Groundwater helps to replenish streams and wetlands with a source of cool water.

1.2 Ecosystems and Watershed Planning

An ecosystem is defined as the interaction and interdependence of living organisms with their physical, chemical, and biological environment. The watershed is the basic ecosystem unit used for planning and managing the resources of the Nashwaak River. A watershed plan discusses the biological, physical, and chemical impacts to the natural environment at a watershed scale. Sub-watershed plans look at issues on a more local scale and with more detail.

1.3 Ecosystem Services and Benefits

Healthy watersheds provide many ecosystem services for human health, ecological health, and economic health including: nutrient cycling, carbon sequestration, erosion and flood control, biodiversity support, soil development, wildlife corridors, water storage and filtration, food, timber, and recreation, as well as reduced susceptibility to invasive species and the effects of climate change. These services are vital to our social, environmental, and economic welfare but are usually under-valued when it comes to land use decisions. There is much evidence to support the thought that keeping watersheds healthy and intact avoids costly replacement and restoration and provides long-term economic opportunities (EPA, 2016).

Protecting watersheds can also lead to economic benefits as they can reduce the capital costs for water treatment plants and reduce damages to property and infrastructure due to flooding. Rivers can be used to produce energy. They also generate revenue through tourism, recreation, fisheries, forestry, etc. A healthy watershed provides safe drinking water and food resources and it provides natural green areas for people to keep active.

1.4 The Nashwaak River Watershed

The Nashwaak River watershed is a complex system composed of various land forms (geology, soil, topography), land covers (forest, wetland, etc.), land uses (agricultural, urban, etc.), and communities of animals (terrestrial and aquatic). The Nashwaak River drains approximately 1,707 km^2 of central New Brunswick, Canada (Figure 4). It is a fifth order tributary to the Saint John River with a length of approximately 110 km (Figure 5). It flows from its headwaters in Upper Nashwaak Lake on the York/Carlton County line southward and eastward through the village of Stanley and then southward to its confluence with the Saint John River in Fredericton, which empties into the Bay of Fundy.

Figure 4 Location of the Nashwaak watershed (green) within the province of New Brunswick.

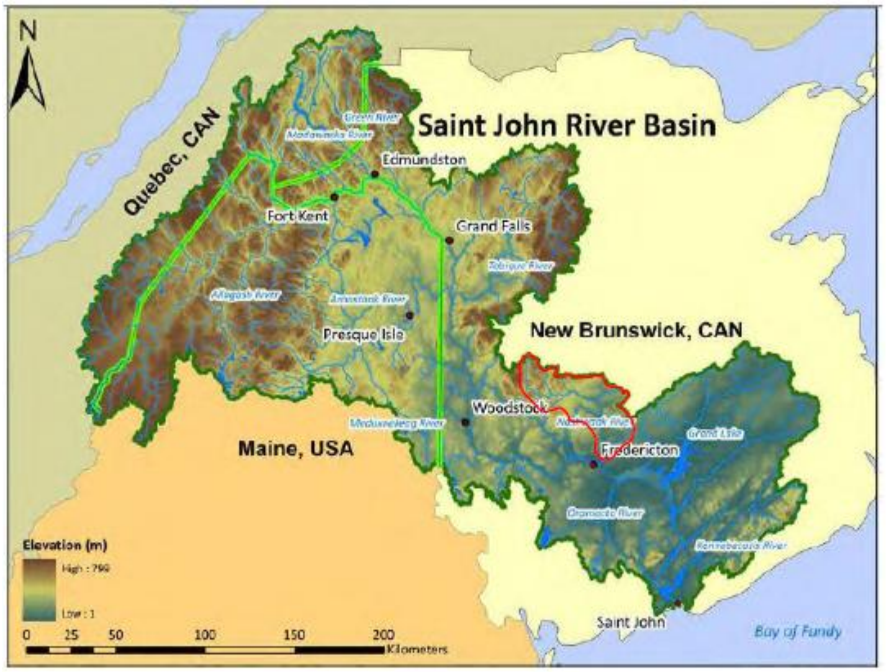


Figure 5 Location of the Nashwaak watershed (red outline) in the Saint John River watershed, which spans both Maine and New Brunswick. Source: CRI (2011).

Twenty lakes exist within the watershed, most are small and shallow, between 2-5 ha and less than 2 m deep. Larger lakes include Upper Nashwaak Lake (93 ha), Chainy Lakes (three lakes totalling 22 ha), Lower Nashwaak Lake (20 ha), Napadogan Lake (20 ha), and Grand John Lake (12 ha). Wetlands occupy around 2% of the landmass draining into the Nashwaak River (NWAI, 2004). Due to the small number of lakes and wetlands within the watershed there is limited water storage capacity and the Nashwaak River responds quickly to rainfall and melt water. The predominate substrate in the tributaries of the Nashwaak is gravel-rock bottom with small areas of fine sediment (NWAI, 1998).

According to the Canadian Ecological Land Classification System, the Nashwaak watershed lies within the Atlantic Maritime Ecozone with waters flowing through Ecoregion 122 (the Maritime Lowlands) and Ecoregion 118 (the Northern New Brunswick Highlands).

New Brunswick has developed its own system of ecological land classification for analyzing ecosystems in the province. Under this classification, the headwaters begin in the Central Uplands, an Ecoregion characterized by a moderately high elevation (<500 m) and rolling topography with small mountains west of Gorby Gulch. Forests are characterised by coniferous communities of balsam fir and spruce; while tolerant hardwoods can be found on steep slopes or on top of ridges. The river shifts into the Valley Lowlands Ecoregion around the mouth of the Napadogan Stream. This Ecoregion is warmer and drier compared to the Uplands. The predominant forest cover is red spruce, balsam fir, and red maple with scattered hemlock and white pine; however, forestry has significantly altered the original forests since the 1700s and mixed stands of white pine, tolerant hardwoods, spruce, and hemlock were probably more common in the past (DNR, 2007). The river continues to flow east and then south. As the river reaches Nashwaak Village, it shifts into the Grand Lake Ecoregion and Ecodistrict, which continues to its confluence with the Saint John River near Barkers Point. The elevations of this Ecoregion are around 150 m above sea level (asl). Grand Lake acts as a heat sink and has a moderating effect on the climate of this Ecoregion, making it the warmest in New Brunswick. The moist, rich soils are home to a unique assemblage of southern vegetation species that depend on sediment-laden flood waters. Jack pine and black spruce are common, as are floodplain species, such as silver maple and butternut, that are scarce elsewhere (DNR, 2007). The patterns of vegetation along the Nashwaak River are greatly affected by climates in the different Ecoregions and Ecodistricts.

The overall gradient of the main stem of the river is ~0.27% (NWAI, 2004). The section upstream of Nashwaak Bridge is steeper with a gradient of 0.37%, while the downstream sections slope more gently (0.10%). There are approximately 397 km of tributaries in sub-watershed with the largest including the Grand John Brook Composite, the Tay River, and Cross Creek. Table 1 lists the areas of each sub-watershed and a map can be found in Figure 6.

Table 1 Area of each sub-watershed within the Nashwaak Watershed.

Sub-watershed	Area (km^2)
Nashwaak River Headwaters	285.01
Grand John Brook Composite	258.63
Tay River	228.21
Cross Creek	201.32
Youngs Brook	154.19
Napadogan Brook	122.14
Dunbar Stream	107.19
Penniac Stream	100.47
Manzer Brook Composite	100.39
Campbell Creek Composite	64.47
McBean Brook Composite	43.84
Porters Brook Composite	24.03
North of Porters Brook Composite	17.94

Data source: Canadian Rivers Institute

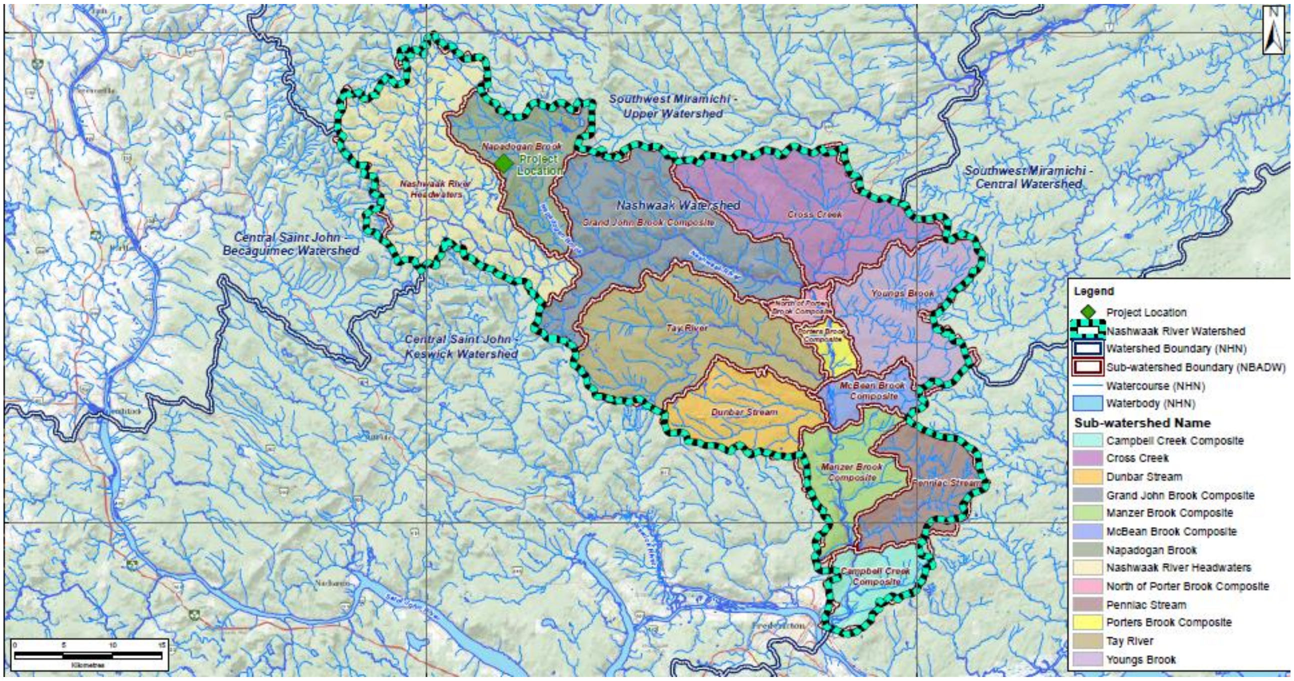


Figure 6 Delineation of sub-watersheds of the Nashwaak watershed, along with other nearby major sub-watersheds of the Saint John and Southwest Miramichi Rivers. Source: Sisson Project.

2 HISTORY

It is thought that the name Nashwaak was derived from the Maliseet word *Nahwijwauk* probably meaning "slow current", "winds among hills", or "interlaces with others", or from the word *newicewakk* meaning "strong undercurrent" (Stantec, 2013). Settlement and development activities since the 17th century in the Nashwaak watershed have brought about great changes to the forests, soils, and watercourses. Landscape changes have led to aquatic and terrestrial habitat alterations on both small and large scales causing significant degradation, modification, or elimination of good aquatic and terrestrial habitat.

2.1 PRE-1600

Archaeological records confirm that there were Aboriginal campsites in New Brunswick that date back ~11,000 years (Stantec, 2013). The Wolastoqiyik (Maliseet) and Mi'kmaq peoples have long occupied parts of New Brunswick as their traditional land for centuries and continue to use the land and its resources. It is thought that both the Maliseet and Mi'kmaq peoples are descendants of the Woodland Period peoples, who lived in the province between 2,500 and 500 years before present. The settlements and travel routes of the Wolastoqiyik people were focused around major river systems as they provided food, potable water, and transportation corridors. They used rivers and streams to access food and other resources, and portage routes connecting major watersheds were vital links for trade and communication. A major travel route was up the Nashwaak River to Cross Creek and across a portage to the Taxis River, which leads to the Southwest Miramichi River (DNR, 2007). Alteration of the rivers and land was relatively minor during this period. It is not known for sure what the Nashwaak River looked like then; however, forest and wetland cover would have served to maintain water quality sustain water levels and stream flows throughout the year, and minimize flooding; tree cover would have lessened erosion and stabilized banks; and river channels likely had a very low sediment load and little siltation.

2.2 EARLY 1600S TO 1920S

Colonization of central New Brunswick by Europeans occurred in the early 17th century with the arrival of Samuel de Champlain and French grant holders. In 1691-1692, the French, under Joseph de Villebon, set up a fort at the mouth of the Nashwaak River called Fort Nashwaak (also called Fort Saint Joseph), which was the first European settlement in the Fredericton area and became the capital of what was then called Acadia (a colony of New France that included parts of Quebec, the Maritimes, and Maine) (Figure 7). The fort was sieged by the British in 1696 and abandoned in 1700 after a devastating flood and Villebon's death.

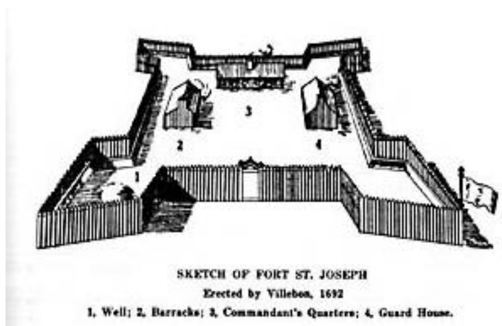


Figure 7 Fort St. Joseph (Fort Nashwaak). Source: Wikipedia.

In November 1784, Lieutenant Governor Thomas Carleton proclaimed the birth of New Brunswick. At that time, the European population was only around 5,000 (Dalton & Weatherley, 2005). European settlement continued through the 18th and 19th centuries while the Mi'kmaq and Wolastoqiyik population declined by approximately 90% during the first 100 years of European contact due to conflict and disease (Wynn, 1981).

Small villages and settlements began to develop along the lower Nashwaak River. In the 17th and 18th centuries, life was dominated by small-scale commercial fishing, logging, agriculture, hunting, trapping, and other subsistence activities that supported the development of communities but greatly affected environment of the Nashwaak River and fish habitat. New Brunswick was still almost completely forested until the mid- to late-18th century (Wynn, 1981). The vast impenetrable woodlands were only accessible by rivers at that time. Forests were dominated by thick stands of white pine, hemlock, and hardwoods. As with most of New Brunswick's watersheds, forestry played an important role in the history of the Nashwaak watershed. The timber industry began in the late 18th century. Pine forests close to rivers and streams were targeted as they provided an easy route for log conveyance from forest to sawmill. By 1835, most of the tributaries of the Saint John River were being used for the log drive as they provided access to the interior of the province (Wynn, 1981).

Figure 8 The junction of the Tay and Nashwaak in 1882. Source: Familyheritage.ca.

New Brunswick became Great Britain's woodlot beginning in the early 19th century (Dalton & Weatherley, 2005). First, ship masts were produced from New Brunswick's mighty pine forests. From 1805 to 1850, squared timber was the main lumber export. By 1820, concerns were already being voiced over the decline of large pine forests (Dalton & Weatherley, 2005). Despite this, more and more lumber mills and sawmills were built along many rivers emptying into the Saint John River, including the Nashwaak, and logging camps were built along streams. Dams were built to provide power for the industry. Sawmills supplied the British and American markets with hardwood boards, cedar shingles, and other building products from 1850 to the early 20th century. By 1897, good logs were becoming scarce in the Nashwaak watershed as the Marysville mill alone had taken over 600 million feet from the watershed (Marysville Heritage Committee, 2000). The lumber industry collapsed around 1920 due to depleted stocks, degraded watercourses, competition with the American market, and an economic recession (Dalton & Weatherley, 2005).

Figure 9 A typical New Brunswick lumber camp circa 1910. Source: NB Provincial Archives.

Agriculture, in both the form of subsistence and commercial farming, was another dominant industry in the province during the 19th century. By the mid-19th century, over 250,000 hectares had been cleared for farms, much of it near rivers or streams. Many farmers combined the seasonal employments of lumbering and farming (Wynn, 1981).

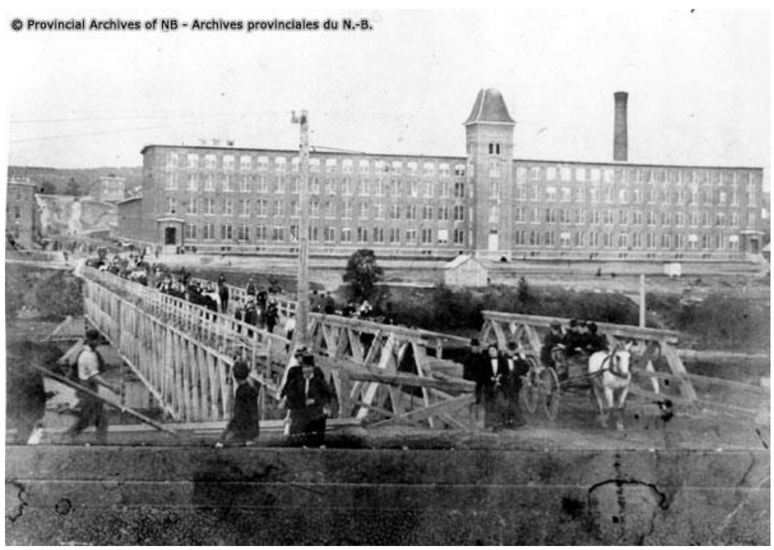


Figure 10 The Marysville cotton mill circa 1885. Source: NB Provincial Archives.

The 1870s saw increased urbanization in the cities of central New Brunswick but also a significant out-migration of skilled and semi-skilled workers, particularly from rural areas, to New England (Dalton & Weatherley, 2005). The threat of fire was common for 19th century communities and a fire in 1893 virtually destroyed the settlement of Saint Mary's Ferry (now Devon). The completion of the National Transcontinental Railway from Moncton to Quebec in 1912 and the construction of Royal Road (running from Nashwaak to Stanley) in 1832 opened central New Brunswick to new settlement and business opportunities. Until this time, boats were the main mode of transportation along rivers and coastal waters.

Figure 11 "On the Royal Road". Lithograph by William P. Kay (1836).

Construction of the Royal Road encouraged settlement by English, Irish, and Scottish immigrants who established the communities of Durham, Taymouth, and Penniac. Most of the villages and settlements were located directly along side of the river and streams. The New Brunswick and Nova Scotia Land Company was chartered in 1831 to buy up large tracts of land with the promise of infrastructure development. They established the communities of Stanley, settled in 1833, as well as Maple Creek, Cross Creek, and Williamsberg. The population of New Brunswick rose from 25,000 at the end of the 18th century to 331,121 at the end of the 19th century (Hannay, 1902).

Figure 12 The village of Stanley in 1901. Source: NB Provincial Archives.

2.3 1930s to Present Day

The demise of the lumber industry in 1920 made way for the pulp and paper industry. Pulp production increased in the province around 1930 and thrived until the late 20th century. Tracks of Crown Land were available to the industry and hydroelectric dams were built to power pulp mills. Stands of single-species softwood were, and still are, planted on cut land and replaced diverse mixed forests. This mono-specific planting practice reduced biodiversity in the native Acadian forests and has led to a significant landscape shift (Dalton & Weatherley, 2005).

Figure 13 Aerial view of Marysville circa 1965. Source: NB Provincial Archives.

Continued deforestation, increasingly intensive agricultural practices, and discharge of untreated or partially treated industrial and municipal waste resulted in major water quality and habitat impacts, particularly in the lower third of the watershed. The pace and extent of destruction increased after the Second World War.

Relative to other watersheds in the province, the Nashwaak remains relatively undeveloped. Today many communities in the watershed continue be focused on forestry or other natural resource extraction. Forestry is the main employment sector for Juniper, Napadogan, Stanley, and smaller communities in between. Many people living near the southern edge of the watershed commute to Fredericton for work in various sectors, including government, retail, education, manufacturing, and tourism. The closure of several mills has negatively affected the economy of this region.

3 DEMOGRAPHICS

The Nashwaak watershed is sparsely populated and with most of the human population located along the lower few kilometres of the river. Historically, settlement patterns in the Nashwaak watershed have reflected the importance that the river played in the development of the local economy. The most populous areas were, and still are, located at the mouth of the river. Population size and distribution can influence the industries, patterns of economic growth, and extent of pressure on natural resources in the watershed. Generally, a higher population means greater demands will be put on these resources and on the environment.

In 2002, the Nashwaak watershed was home to 12,000 to 14,000 residents at 4,125 households (NWAI, 2004). In 2016, the number of households in the watershed was around 5,500 with an estimated population of ~15,000 - 18,000. Within the watershed there is one city (Fredericton), one village (Stanley), 12-15 settlements, and one First Nations community (Saint Mary's). Currently, the population is fairly evenly divided between urban and rural areas (Statistics Canada, 2012). The population is decreasing in most rural areas (except for Saint Mary's Parish) but increasing faster in urban areas and on the First Nations reserve.

4 COMMUNITY PROFILES

4.1 Stanley Parish

The 2011 National Household Survey (NHS) (Statistics Canada, 2012) recorded 903 people in Stanley Parish, which encompasses several small communities but not the village of Stanley itself. The population decreased by 7% from 2006 to 2011. Population density in 2011 was 0.7 people per square kilometre and the median age was 47.6 years. Education levels were below average; 17% of the population over the age of 25 in 2006 had not completed high school. The main employment industries included manufacturing (12%), construction (12%), health care and social assistance (16%), and education (14%). 24.8% of adults were unemployed in 2011.

4.2 Stanley Village

The village of Stanley is located 57 km north of Fredericton. The 2011 NHS (Statistics Canada, 2012) recorded 419 people, down 3.2% from 2006. Population density was 24.2 people per km^2. Median age of the population was above the provincial average at 50.2 years. Education levels were very high with 100% of the residents of the age of 25 having finished high school and 23% holding a degree higher than a Bachelor's. Unemployment rate was 0% per the 2011 NHS. Major industries in 2011 were health care and social assistance (23.5%), education (18%), and retail (18%).

4.3 Douglas Parish (Napadogan, Currieburg)

The 2011 NHS (Statistics Canada, 2012) reported 6,081 people in Douglas Parish, though most of it (Burtt's Corner, in particular) lies outside the Nashwaak Watershed. Napadogan and Currieburg lie within Douglas Parish and the watershed. The population saw an increase of 5.3% from the 2006 census. Population density was 4.2 people per square kilometre. The population's median age was 41.0 years. Education levels were slightly above the provincial average with 64% of adults over 25 holding a post-secondary diploma but 12% not holding a high school certificate. Significant industries included construction (16%), retail (13%), public administration (10%), and accommodation and food serves (8%). Unemployment rate sat at 5.8% in 2011.

4.4 Saint Mary's Parish

The 2011 NHS (Statistics Canada, 2012) reported 4,725 people in Saint Mary's Parish, which encompasses with settlements of Cross Creek Station, Durham Bridge, Penniac, Nashwaak Bridge, and Taymouth. This was an increase of 12.1% from the 2006 population. Population density was 6.3 people/km^2. Median age of the population was 38.9 years. Education levels were above average with 57% of residents over the age of 25 holding a post-secondary certificate and 23% holding a Bachelor's degree or higher. Significant industries include public administration (17%), retail (9%), health care and social assistance (9%), and construction (8%). Unemployment rate sat at 9.4% in 2011.

4.5 The City of Fredericton

Only part of the north side of the city (South Devon, Barker's Point, Sandyville, and Marysville) lies within the watershed. The total population of Fredericton in 2011 was 56,224, up 11.3% from 2006. Population density was much higher than in rural areas, at 427 people per square kilometre in 2011. The populations' median age was 38.7 years, under the provincial average. Education levels in the city were higher than the provincial average with 70% of adults over 25 holding at least a post-secondary degree or diploma and 15% holding a degree higher than a Bachelor's. Major employment sectors include public administration (16%), retail (13%), education (12%), health care and social assistance (10%), and accommodation and food services (7.5%) (Statistics Canada, 2012). Unemployment rate was 10.8% in 2016 (CBC, 2016).

4.6 Saint Mary's First Nation Reserve

This area is known as Devon 30 Indian Reserve in the Census data. In 2011 the population was 864, up 12.6% from 2006. A report by Aboriginal Affairs and Northern Development Canada in 2014 noted 875 people living on-reserve and 947 living off-reserve. Population density is 316.3 people per square kilometre. The median age was 29.4 years in 2011, well below provincial average. Levels of education were also below the provincial average with 22% of the population over the age of 25 having not completed high school in 2011. Major industries include public administration (24%); arts, entertainment, and recreation (16%); retail (15%); health care and social assistance (12%); and construction (10%) (Statistics Canada, 2012). Unemployment rate was 17.1% in 2011 (AAND Canada, 2014).

5 HISTORIC PLACES

A search of the register of Canada's Historic Places and New Brunswick's Historic Places in October 2016 revealed several built heritage places and four National Historic Sites within the watershed:

- Fort Nashwaak (Naxoat) National Historic Site of Canada, Fredericton, built in 1691
- Marysville Historic District National Historic Site of Canada, Marysville, built from 1840 to 1920
- Marysville Cotton Mill National Historic Site, Marysville, built from 1883 to 1885
- Wolastoq National Historic Site of Canada (encompassing the entire Saint John River watershed)
- A number of historic houses on Canada, Downing, and Bridge streets, Marysville, built in the mid- to late-19th century
- The former Marysville Hotel Local Historic Place, Marysville, built in 1887
- 42nd Highland Memorial Cemetery Provincial Historic Site, Pleasant Valley, built in 1784
- Royals Field Local Historic Place, Marysville
- Marysville Cenotaph Local Historic Place, Marysville, monuments erected in 1925 and 1967
- Former Gibson Roundhouse Local Historic Place, Devon, built in 1885
- Former Internment Camp (880 Union) Local Historic Place, Devon, built in 1940

6 LAND USE

As noted above, the Nashwaak River and its watershed are sparsely inhabited but the population is concentrated in the lower third of the watershed and it is increasing. Development is concentrated in the lower Nashwaak below Durham Bridge, at the mouth of the Tay River, and along the Penniac Stream. Human land use activities can impair the watershed resources that both people and animals require. Human land use activities and uses of water have the potential to result in potential conflicts with habitat requirements of many animals or plants. They can also alter water quality and quantity. Poorly planned development may fragment natural areas, impact rare species, and increase surface water contamination.

The predominant land cover of the Nashwaak watershed is forest at 92.5%. Other land cover types are agriculture (2.6%), wetlands (2%), linear features such as roads, trails, and transmission lines (1.2%), residential (1%), and water (0.5%) (NWAI, 2004). Agriculture and urbanization have led to the removal of the riparian vegetation along both banks and eroding riverbanks can be clearly seen along a significant portion of the riparian zones along the lower Nashwaak River and Tay River. Aggregate extraction (soil and gravel mining) is concentrated mainly from Taymouth to Penniac. Specific land use is presented in Table 2 and Figure 14.

Table 2 Area and percentage of specific land use in the Nashwaak watershed.

Specific Land Use	Area (km^2)	Percentage (%)
Softwood forest	541.32	31.58
Mixed wood forest	527.13	30.75
Hardwood forest	472.49	27.56
Pasture or crops	44.98	2.62
Other forest	41.83	2.43

Wetland	34.09	1.99
Occupied	17.32	1.01
Road	13.16	0.77
River	7.08	0.41
Transmission lines	5.20	0.30
Cultivated trees	3.09	0.18
Lakes	2.31	0.13
Gravel pit	1.92	0.11
Trail	1.24	0.07
Pond	0.37	0.02
Airstrip	0.35	0.02
Railway	0.20	0.01
Other water	0.09	0.00
Rock outcrop	0.03	0.00
Total	**1,714.19**	**100.00**

Data: (NWAI, 2004).

Because forests are the predominant land cover, their role in watershed health is important. Forests filter pollution, absorb rainfall, regulate stream flows, moderate water temperatures, stabilize stream banks, and provide homes for wildlife. Many species require large, connected tracts of forest to carry out their life cycles. However, there is a long history of commercial logging in the watershed (at least three centuries) with forest blocks in various stages of regrowth.

The major land owners in the Nashwaak watershed are the York-Sunbury-Charlotte Forest Products Marketing Board at 30-40% and the province of New Brunswick (Crown Land) at 30-50% (Clarke et al., 2014).

To reach the forests, the logging companies built many roads throughout the upper watershed. The Nashwaak River watershed, along with the Tobique and Aroostook River watersheds, has one of the highest densities of unpaved roads crossings in the Outer Bay of Fundy region at 1.65 km/km^2 (compared to an average of 1.08 km/km^2 below the Mactaquac Dam) (Clarke et al., 2014). The typical threshold value for a wilderness area is 0.6 km/km^2. Total crossing density (paved and unpaved) was 4.61 crossings per 10 km of stream, close to the average of 4.37 for watersheds below the dam (Clarke et al., 2014). Increased road densities contribute to higher peak discharge following rainfall and lower base flows during dry periods. For road crossings see Figure 14.

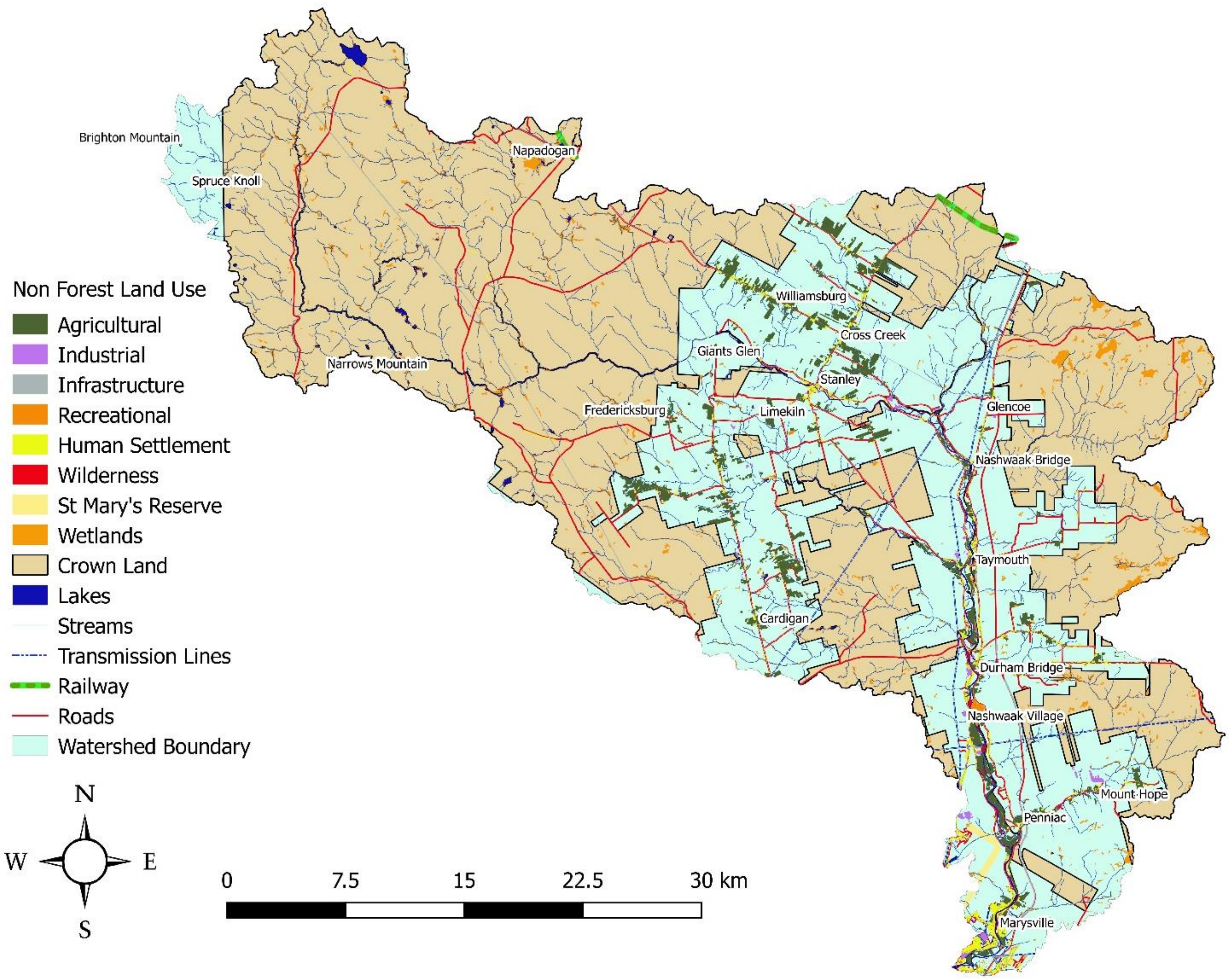


Figure 14 Non-forest land cover. Data source: GeoNB.

The Nashwaak River and its tributaries offer many opportunities for recreational usage, including canoeing, kayaking, swimming, camping, hiking, cross-country skiing, snowmobiling, fishing, and hunting. There is one golf course along the river in Penniac and a city park with many kilometres of multi-use trails on the south-western edge of the watershed (Killarney Lake). Several entrepreneurs in along the lower Nashwaak River run tubing businesses out of their home. This industry has grown significantly in the last decade and concerns have been voiced about the large amounts of garbage it generates, as well as the potential impacts to sensitive habitat and species. In response, several of the tubing companies have installed trash bins at rest areas along the route or hold clean up events.

The railway between Fredericton and McGivney has been turned into a multi-use trail. The NWAI sponsored a section of the Sentier NB Trail and has graded 20 km of trails between Penniac and Taymouth. Sport fishing is very popular on the Nashwaak River and its tributaries and is covered in detail in section 13.2.

Changes in the use of land over time can have major impacts on a watershed, changing productive creeks into less productive, flashy streams. In a forested watershed, up to 60% of the rain or snowfall is pumped back into the atmosphere by vegetation. Streams in forested areas are typically small and stable with deep, narrow channels. After clearing land for agriculture or modifying it for urban development, overland run-off increases significantly. Paved land is impervious to infiltration and as the amount of paved land increases in a watershed, precipitation has less and less chance to infiltrate or evaporate and it is quickly forced into storm sewers and then into the river. Surface run off can increase by almost 75% post-urbanization of a watershed (Grand River Conservation Authority & Ontario Ministry of Natural Resources, 2005). This alters the water budget of the watershed, which results in streams that:

- Flood rapidly and often;
- Are wide and shallow;
- Have higher erosion rates;
- Have increased sedimentation;
- Have lower flow between storms; and
- Are contaminated due to chemicals or fertilizers in the run off.

The formerly healthy streams become flashy, highly eroding, and noxious, and are often buried in pipes and sent directly to a larger lake or river. As land use changes, the watershed flow characteristics and sediment supply change and the streams begin to change form and character. If the change is slow, then streams can adjust naturally. However, if the changes are rapid, such as massive urban development without proper sediment or storm water control, the stream will adjust so quickly that the form will become unstable. Erosion, flooding, and channel degradation will occur, aquatic and riparian habitat will be lost, animal communities will change, and water quality will deteriorate. Ultimately, this will lead to a poorer quality of life for urban residents.

7 ENVIRONMENTALLY SIGNIFICANT AREAS AND PROTECTED AREAS

Protecting land helps to ensure the long-term conservation of historical, cultural, scenic, wildlife, and recreational resources in the area. Land protection can improve water quality and help prevent flooding and erosion. An increase in protected lands is one measure of success in wildlife conservation and water quality improvement. Only 4.5% of New Brunswick’s land is protected either as a Park or a Protected Natural Area.

Between 1993 and 1995, the Nature Trust of New Brunswick identified over 900 environmentally significant areas (ESAs) across the province based on presence of rare species, rich species diversity, representativeness, and their geological and ecological vulnerability. ESAs are not offered legal protection but they are used by organizations and government for planning purposes. There are six ESAs, one conservation area, and five Class II Protected Natural Areas (PNA) within the Nashwaak watershed, as well as three Wildlife Protected/Management Areas (WPA/WMA) partially within the watershed. Class II PNAs are areas permanently set aside for the conservation of biological diversity where only certain recreational activities having minimal impact will be allowed. They are controlled by the Department of Natural Resources. There are eight Provincially Significant Wetlands with a total area of 20 ha located in the lower watershed. Therefore, at least 5,401 ha (or 3.2% of the watershed) is protected by the government or by a conservation easement. PNAs, ESA, and WPAs in the watershed are shown in Figure 15 while wetlands are shown in Figure 16.

- *Buttermilk Falls ESA* – significant for aesthetic value
- *Cross Creek Station ESA* – due to the presence of unique Pennsylvanian age fossils.
- *Durham Bridge Esker ESA* – significant for geology (sub-aqueous esker fan)
- *Sutherland Siding Woods ESA* – due to the presence of several rare plants including the only known population of White Adder's Mouth Orchid *(Malaxis brachypoda)* in the province.
- *Fredericton Wildlife Refuge ESA and WPA* – due to the rich and varied natural habitat close to the city centre, significant riparian ecosystem and floodplain habitat.
- *Burpee WMA / Class II PNA*
- *Bantalor WMA / Class II PNA*
- *Barker's Point ESA and Hyla Park Conservation Area [8 ha]* – Just outside the watershed border, the park is owned by the City of Fredericton but stewarded by the Nature Trust of NB. It was the first Amphibian Park in Canada and is home to three species of salamanders and seven species of frog and toad, including the first and northeastern-most known population of grey tree frog (*Hyla versicolor*). It also shelters clammy hedge-hyssop (*Gratiola neglecta*) and purple milkwort (*Polygala sanguinea*).
- *Tay River Class II PNA [245 ha]*
- *Welch Brook Class II PNA [551 ha]*
- *Nashwaak River Class II PNA [3,983 ha]*
- *McBean Brook Class II PNA [269 ha]*
- *Sills Brook Class II PNA [325 ha]*

Additionally, New Brunswick has also developed a shoreline zoning regulation, which protects a no-development buffer around wetlands and watercourses. Publicly-owned forest lands held by the government require a 20-metre uncut, treed buffer along watercourses and >50% conifer crown closure in Deer Wintering Areas interconnected by winter travel corridors (McAfee & Malouin, 2003).

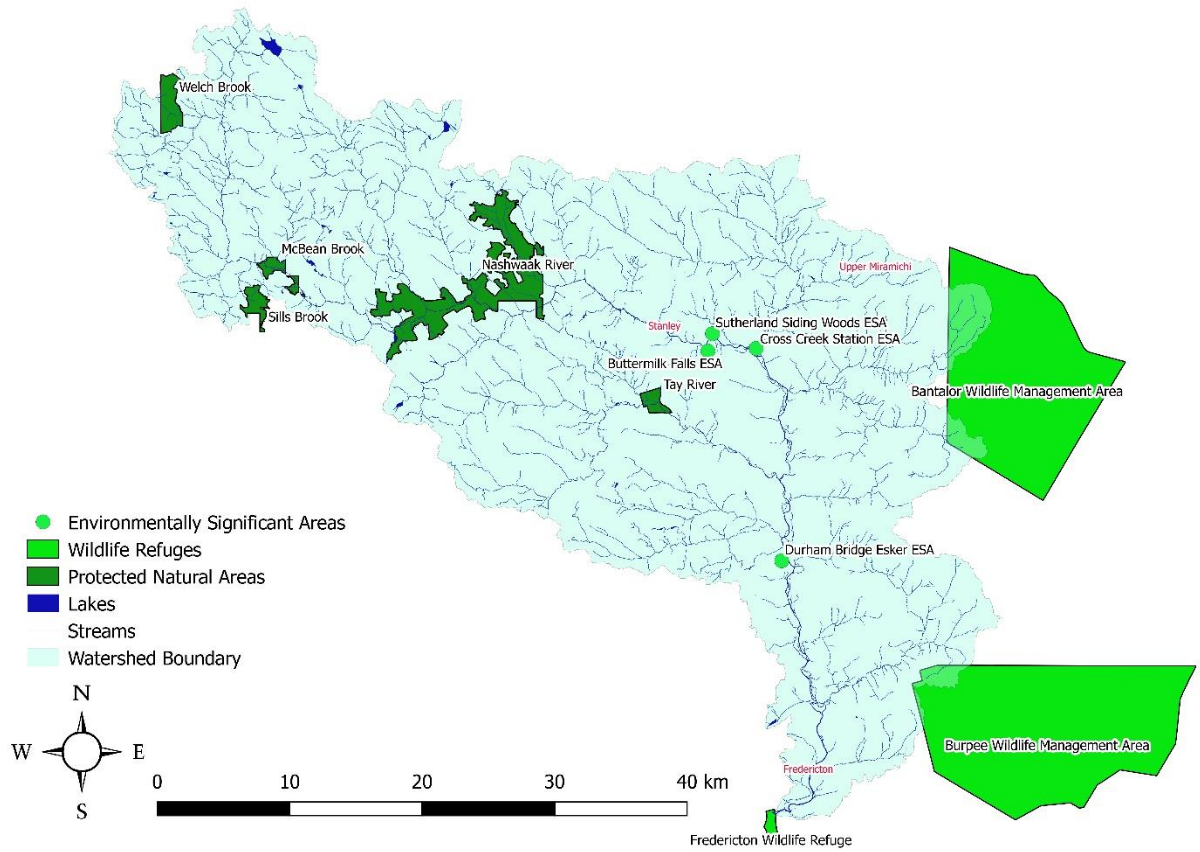


Figure 15 Protected Natural Areas, Wildlife Refuges, and Environmentally Significant Areas (ESAs) in the Nashwaak watershed. Data source: GeoNB, ACCDC (2016).

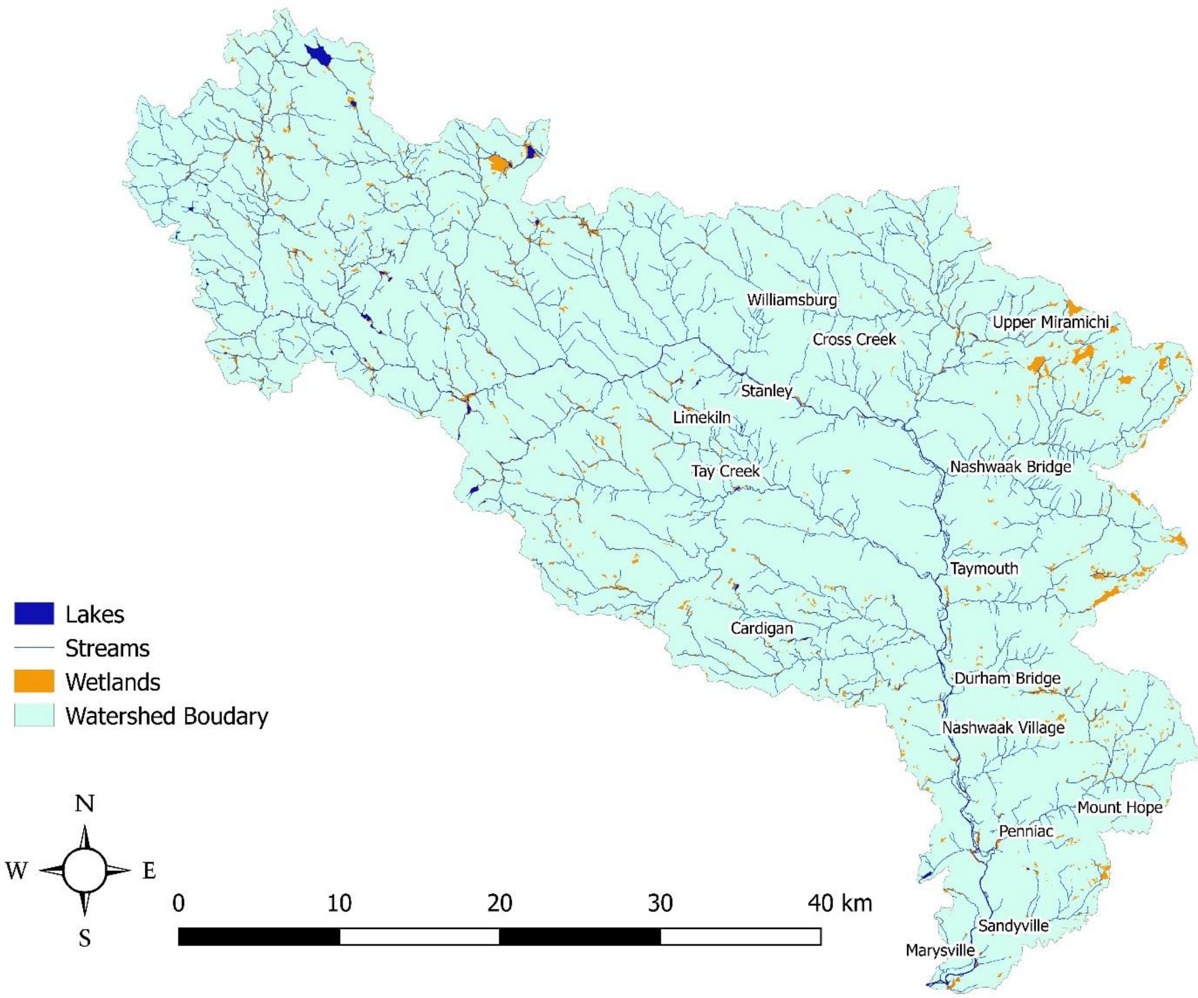


Figure 16 Location of wetlands (orange) in the Nashwaak watershed. Data source: GeoNB.

8 GEOLOGY

Geology and climate determine the surface and groundwater flow patterns and channel forms found within a watershed, which ultimately dictate the make-up of terrestrial and aquatic communities. The geology of New Brunswick was shaped by the building of the Appalachian Mountain Range between 480 and 280 million years ago (Bookes, 2012). The last 280 million years have been dominated by glacial events, weathering, and erosion that has altered the surface by moving, sorting, and depositing rocks and sediments.

The geology of a watershed can be broken up into the underlying bedrock and the overlying soils (surficial geology or overburden) that were either deposited during the last glacial period, deposited by waterbodies, or formed by weathering of the bedrock.

The bedrock of the Nashwaak watershed consists of all three major rock types: metamorphic rocks formed by heat and pressure, igneous rocks formed by volcanic processes, and a large proportion of sedimentary rocks (those formed from compacted sediments [silts, sand, clay, etc.]). The bedrock provides storage for ground water and influences the water chemistry.

8.1 Bedrock

The upper watershed, near Upper Nashwaak Lake, is underlain by metamorphic rocks, such as gneiss, schist, and minor amphibolite, grading to Devonian (419 to 359 million years ago [Mya]) plutonic (intrusive) igneous rocks, such as granite, syenite, and gabbro, that are relatively younger than the lower sections of the watershed. The central part of the watershed is underlain by a complex of older Ordovician (485 to 444 Mya) and Silurian (444 to 419 Mya) deep water marine clastics and sedimentary rocks, consisting of greywacke, slate, and minor calcareous slate as well as Devonian igneous rocks. In the Napadogan area, the bedrock is older Cambrian to middle Ordovician (541 to 465 Mya) meta-sedimentary rocks, such as greywacke (sandstone), slate, and siltstone with minor calcareous siltstone and conglomerate. This area also contains igneous rocks such as rhyolite and tuff as well as metamorphic slate, and sedimentary rocks, such as chert and limestone. Below Napadogan, the bedrock consists of igneous rocks (granite, granodiorite, tonalite, and gabbro with minor pegmatite) (NWAI, 2004).

The lower half of the watershed (below Stanley) is comprised almost entirely of younger Pennsylvanian (323 to 299 Mya) terrestrial sedimentary rocks with some outcrops of other ages. The area around Cross Creek Station is known for its Pennsylvanian plant fossils and pyrite nodules, while a road northwest of Nashwaak Bridge is home to rock outcrops with large fossils of Pennsylvanian-age trees (DNR, 2007). Near Stanley, a band of sandstone, conglomerate, and breccia with minor siltstone, mudstone, and shale cuts across the drainage area. The lower end of the basin is made up of mostly sandstone and quartz-pebble conglomerate with minor amounts of mudstone, siltstone, and shale (DNR, 2007). Basalt underlies a small area near Manzer (DNR, 2007). Bedrock geology is shown by lithology (rock type) in Figure 17 and by rock group in Figure 18.

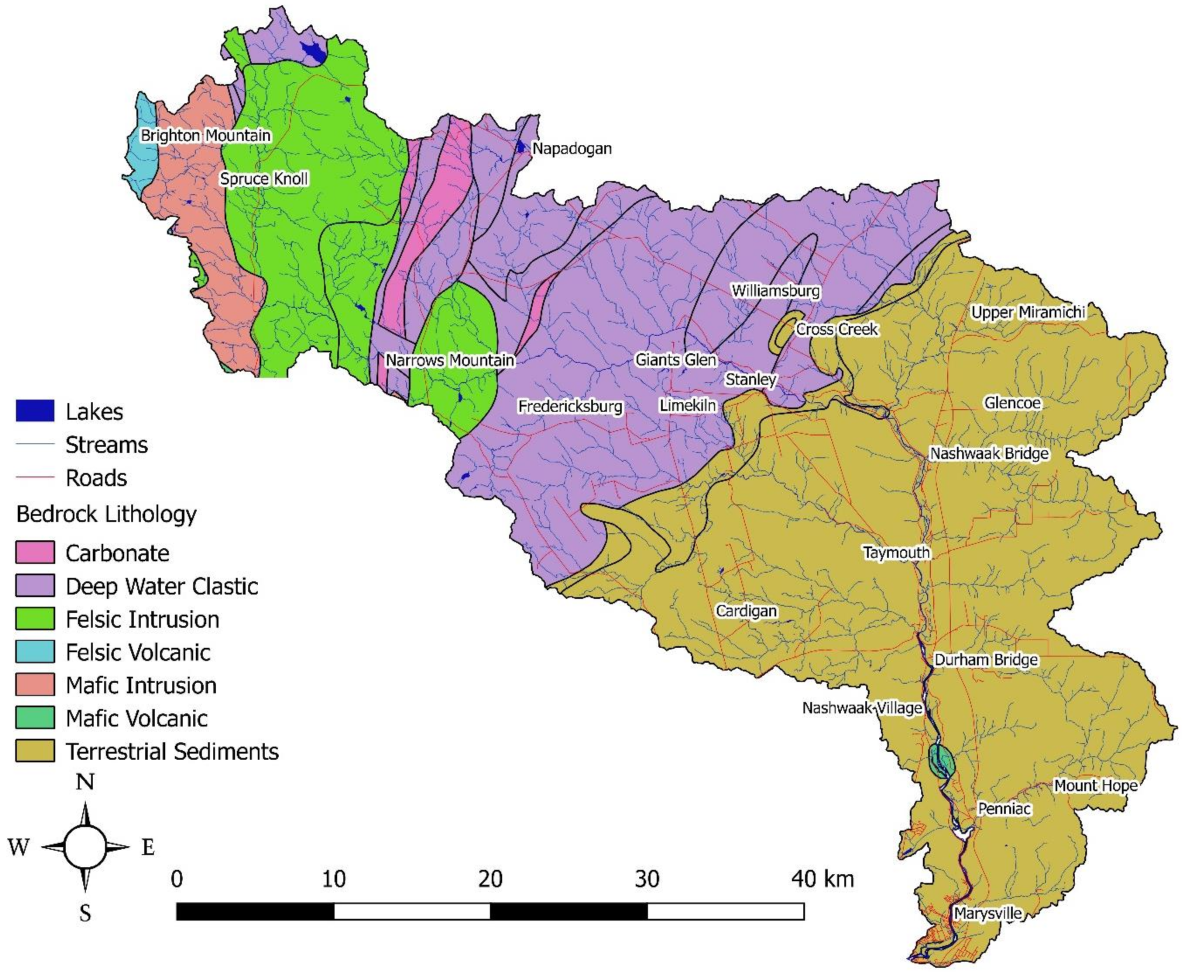


Figure 17 Bedrock lithology of the Nashwaak watershed. Data source: GeoNB.

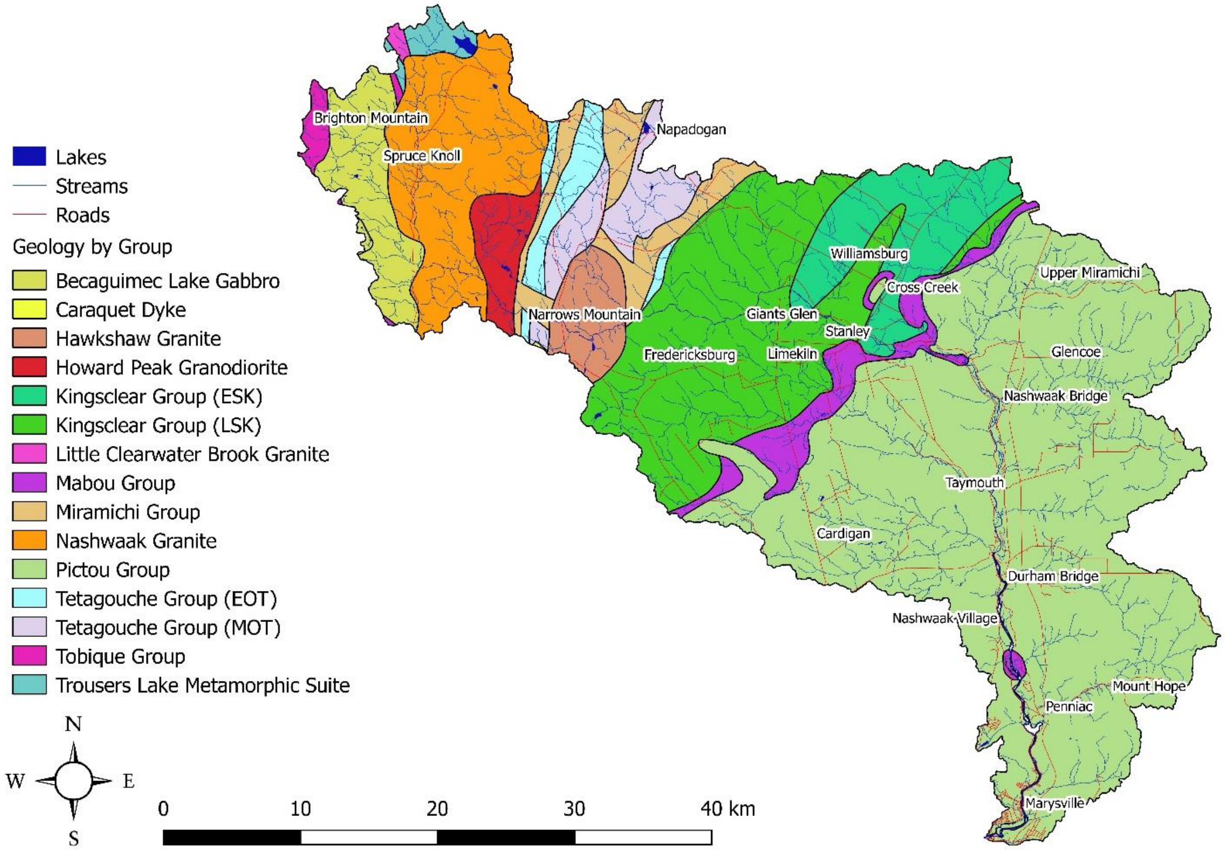


Figure 18 Bedrock geology by group of the Nashwaak watershed. Data source: GeoNB

8.2 Surficial Geology

Around 90% of New Brunswick is covered by compact or non-compact unconsolidated material that was deposited by glaciers and derived from the parent bedrock. Most landforms and unconsolidated sediments in the Nashwaak watershed were deposited or formed during the Late Wisconsian glaciation, which occurred between 85,000 and 11,000 years ago.

Sediments are predominately glacial moraine blankets and thin veneer deposits made up of compact basal till, minor ablation till, silt, sand, and gravel. (Moraines are hills of various sizes created by the action and movement of glaciers and can vary in composition based on what the glacier was carrying.) Morainal veneers in the Nashwaak watershed are generally <0.5 m with patches >1.5 m thick, while morainal blankets are generally 0.5 – 1.5 m thick. Most soils are well-drained to moderately well-drained but are highly erodible (Parish Aquatic Services, 2016).

A coarse-textured, gravelly glacio-fluvial deposit overlies the are surrounding the Penniac Stream (DNR, 2007). (Glacio-fluvial materials were deposited by riverine processes, such as meltwater streams, and are usually composed of well-sorted cobbles, gravels, and sands with high permeability.) Two large ablation deposits, with a cobbly texture and low water retention, can be found north of Killarney Lake and around Dunbar Stream (DNR, 2007). These deposits formed as glaciers were retreating.

Fine-grained glacio-lacustrine deposits have been mapped near Juniper and Napadogan, meaning that these areas were once covered by large glacial lakes. Organic deposits are common throughout the watershed. Peat soils are scattered along the headwaters of the Penniac Stream (DNR, 2007).

Alluvial (river-associated) deposits along the riverbanks consist of gravel and sandy gravel. Recent alluvial deposits cover the Tay and Nashwaak River valleys (DNR, 2007). These deposits tend to be capped with a 0.5 to 1 m thick band of more fertile fine-grained silts and sands.

Ultimately, the characteristics of the bedrock and soils play major roles in the movement of water over and through the watershed. Where and how the water moves provide opportunities for some plants and animals and constraints for others.

9 GEOMORPHOLOGY

Fluvial geomorphology is the study of the form and function of streams and the interaction between water and the landscape around it. “Fluvial” refers to the processes associated with running water, “geo” refers to the earth, and “morphology” refers the shape of a river channel. Rivers are dynamic systems that are constantly changing in space and time. In unaltered watersheds, they create forms that enable them to dissipate energy during high flow events while still retaining a relatively stable structure. Healthy rivers dissipate energy in two dimensions: vertically and horizontally. Vertical dissipation creates riffle-pool or step-pool structures and horizontal dissipation creates meanders (the curved pattern of a river). The pattern and stability of riffle-pool sequences create habitat conditions that give rise to shelter, food, and reproduction for many organisms.

A stream is in “steady-state equilibrium” when it maintains a form that remains relatively constant over time. Even though the locations and structures of pools or riffles change and adjust, the overall shape and planform (i.e., the meander pattern, sinuosity, wavelength, etc. of the river) will remain the same. In steady-state equilibrium, a stream will move within its valley at a very slow and controlled rate, adjusting for minor variations in flow and sediment load over long periods of time. This is the natural tendency of a healthy river and it maintains the appropriate form that is the most efficient to move and store water and sediment at all flows (Grand River Conservation Authority & Ontario Ministry of Natural Resources, 2005).

Stressors modify this equilibrium by affecting the balance between flow and sediment supply. Stressors can include climate change, artificial hydrologic controls (i.e., dams), and land use or land cover change(s). Any one of these can destabilize streams and force them outside of their natural equilibrium, resulting in adjustments in stream morphology. Channel form and the composition of the river’s substrate are very important factors in the productivity of a watershed and its water quality. When channel form becomes unstable, the river bed becomes packed with silt or other fine materials. In channels with fine substrate, nutrient storage and productivity suffers unless the water has access to riparian wetlands. When these features have been lost, the aquatic system is highly degraded in a physical, biological, and chemical sense (Grand River Conservation Authority & Ontario Ministry of Natural Resources, 2005).

9.1 Soil Erosion and Siltation

Sedimentation (infilling of the river bed with fine silt and sands) may result from several activities associated with forestry, agriculture, road crossings, development, etc. Increased sediment load has a negative effect on a river's ecology and erosion can lead to the loss of valuable residential, commercial, and agricultural land along the river. Silt and sediments can negatively affect fish populations by causing abrasion to eyes, skin, and gills (O'Connor & Andrew, 1998). Sediments can also cover gravel spawning substrates, smother buried eggs, and reduce suitable spawning area (Soulsby et al., 2001). Flanagan (2003) demonstrated lower survival of Atlantic salmon eggs with increasing loads of fine sediments associated with forestry activities on the Miramichi River. However, Cunjak et al. (2002) found variable effects from agriculturally derived sediments on salmon survival in streams on Prince Edward Island. The US Environmental Protection Agency has listed sediments as the number one important source of pollution in North American rivers. Considering the extensive history of forestry, agriculture, and dams on the Nashwaak River and its tributaries, sediments and their effects are important threats to consider.

9.2 2005 Soil Erosion Survey

A 2005 study by NWAI (NWAI, 2005) involved an examination of both banks of the Nashwaak from Currieburg to Barker's Point as well as the lower portions of the Tay River, Penniac Stream, and the Cross Creek Stream (for a total of 72 km). The survey noted 72 erosion sites ranging from a few metres to 2,000 metres long with the most extensive and severe being located between Taymouth and Penniac as well as on the lower portion of the Penniac Stream. The amount and distribution of the erosion sites supported the conclusion of NWAI's 2004 water quality report (discussed in section Water Quality11.1) that soil erosion was a contributing factor to poor water quality in the watershed (causing increased turbidity, iron, and manganese levels). The survey calculated that approximately 11,794 m of the surveyed riverbank was eroding and that riverbanks with established, mature vegetation were primarily stable while banks without mature vegetation were primarily eroding.

9.3 2016 Geomorphic Survey

Understanding stream morphology can aid in management decisions. Morphology influences flooding patterns, erosion rates, and sediment deposition. As streams respond to stressors and progress towards a new state of equilibrium, the stream undergoes physical change through the processes of degradation, widening, aggradation, and planimetric form adjustment (see Table 3 for explanation of these terms).

In 2016, NWAI conducted a geomorphic survey with the help of Parish Aquatic Services. (For full results, see Parish Aquatic Service (2016).) The survey covered the mainstem of the Nashwaak River from 8 km above Stanley to the confluence with the Saint John River (~65 km), as well as the lower 2 km of the Tay River and the Penniac Stream (for a total of ~69 km).

The objectives of the 2016 geomorphic survey were to: 1) understand erosion and deposition processes, 2) describe degradation and threats to salmon habitat, and 3) develop management objectives and prioritize restoration projects along the river. The survey, along with this report, along provided the basis for the NWAI's *2017-2020 Action Plan*.

Table 3 Stream morphology processes and environmental triggers

Process	Description	Trigger
Degradation	Lowering of the streambed through erosion and scour of bed material	• Increased flow • Decreased sediment supply • Increased slope due to reduced channel sinuosity
Widening	Increase in channel width through erosion	• Often follow degradation • Increased flows within a degraded channel leads to erosion of both banks
Aggradation	Building-up of the stream bed through sediment deposition	• Decreased flow • Increased sediment supply • Decreased slope due to irregular meander migrations
Planimetric form adjustment	Change in channel shape as seen from the air	• Straightened course through channel migration • Usually in response to aggradation and widening

(Source: (Credit Valley Conservation, 2012)

Based on a Rapid Geomorphic Assessment of a stream (a visual examination of geomorphic processes), stream reaches were classified based on Table 4.

Table 4 Rapid Geomorphic Assessment classifications

Stability Class	Description
Stable/ In regime	Morphology is within the expected range of variance for stable channels of a similar type. Channels are in good condition.
In transition	Morphology is within the expected range of variance but with evidence of stress. Significant adjustments have occurred.
In adjustment	Morphology is outside expected the range of variance for similar channel types and significant adjustments have occurred and are expected to continue.

A total of 69 reaches were identified along the mainstem of the river with 13 additional reaches identified on the tributaries. Overall, the geomorphic condition of the mainstem of the Nashwaak River and the assessed tributaries is unstable and has seen negative impacts due to land use changes. 51% of surveyed reaches were in a transitional state and 42% were widening, particularly in sections downstream from Taymouth where mature riparian vegetation had been removed and the stream banks were actively eroding (Figure 19 and Figure 20). The second most common geomorphic process was aggradation. Only 16% of the surveyed reaches could be classified as stable.

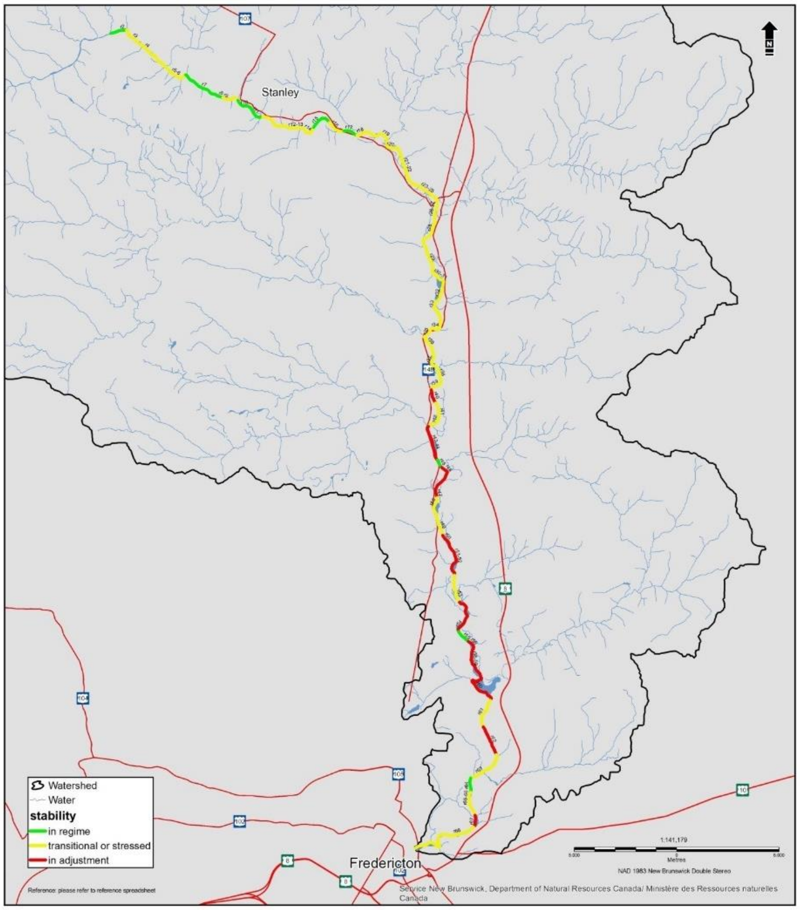


Figure 19 Stability classes for the assessed reaches along the mainstem of the Nashwaak River. Source: Parish Aquatic Services (2016).

In general, the upper watershed is experiencing degradation while the central and lower portions of the mainstem are aggrading and widening. Channel aggradation is likely occurring due to an increased sediment supply provided by erosion from bank widening in reaches where riparian vegetation has been cleared. Another source of sediment may be poorly installed culverts or bridges.

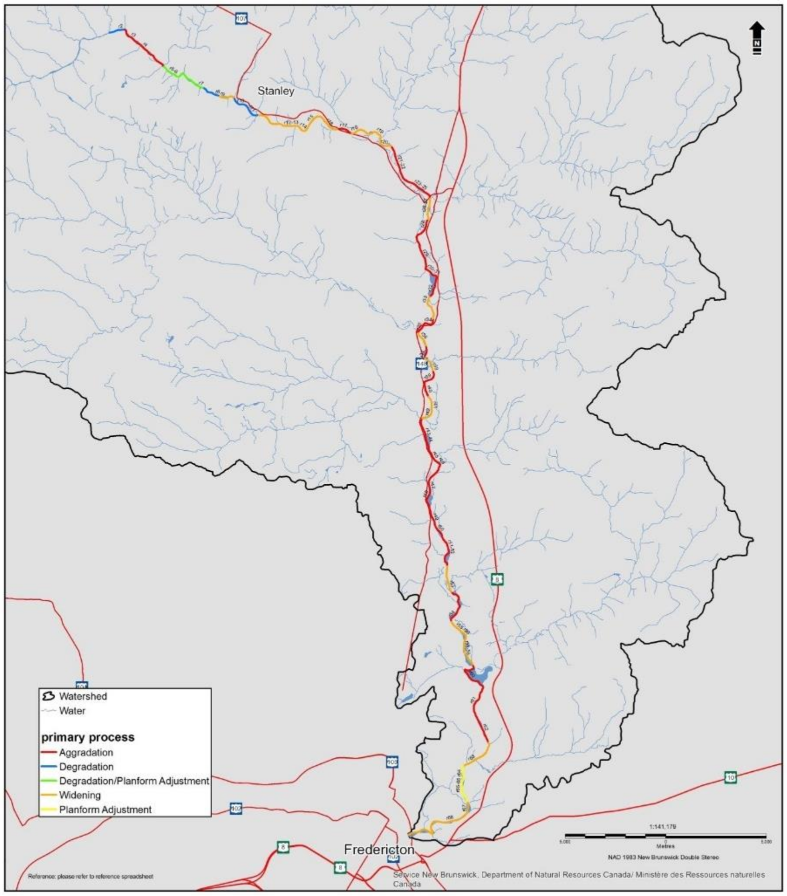


Figure 20 Primary geomorphic processes occurring on the mainstem of the Nashwaak River. Source: Parish Aquatic Services (2016).

Most of the reaches along the two surveyed tributaries were also aggrading, except for Reach M on the Penniac Stream where the highway 8 bridge crosses the stream, which was degrading. Degradation is often association with bridge crossings as hardened structures constrict water flow. The mouth of the Tay River is widening and undergoing planimetric form adjustment. Riparian vegetation along the lower Tay is almost entirely cleared up to the river bank and there is a soil mining operation at the mouth.

The upper portions of the watershed were generally in good geomorphic condition and contained suitable habitat for salmonids. Areas of suitable spawning and rearing habitat, as well as holding pools and cold water sources, were noted during field assessments (Parish Aquatic Services, 2016).

The main source of instability in the system is the abundance of eroding banks along the river and its tributaries. Many locations were identified as potential sites for bank restoration projects and the NWAI will carefully analyze and prioritize these sites in coming years. The process of prioritization will consider: the severity of impacts to the river ecosystem, landowner cooperation, funding, resources available, site access, and opportunity for volunteer involvement. Restoration will be focused on protecting riparian corridors to maintain the resiliency of the watershed.

10 CLIMATE

The climate, or the long term average weather condition, of a watershed, along with its geology, dictates how and where water moves. Trends in weather affect the amount and the timing of precipitation, sunlight, wind, etc., which, in turn, affect the hydrologic cycle, vegetation communities, and other aspects of the watershed.

The climate of central New Brunswick can be described as continental. The climate of the Nashwaak watershed is largely influenced by elevation. The Central Uplands Ecoregion makes up 22.8% of the watershed landmass. There is almost no human habitation in this region. Elevations are greater than 150 m above sea level (asl) with the highest elevation approaching 600 m. The climate is cooler and damper than the Valley Lowlands with an average of 1,400 – 1,600 growing degree days and 1159.7 mm of annual precipitation, with 499.4 mm falling during the growing season. Average temperatures range from -12.4°C in January to 17.8°C in July with an annual mean of 3.7 ± 2.9°C (ECC Canada, 2016b) (Table 5).

Only 3.3% of the landmass lies within the Grand Lake Ecoregion at the southern edge of the watershed, but it is home to most of the human population of the watershed. This Ecoregion is characterized by lower elevations (3-150 m asl) and the presence of Grand Lake, which has a moderating effect on the climate, making it warmer and drier. It has an average of 1,800 growing degree days and an annual precipitation amount of 1077.7 mm, with 438.3 mm of rain falling in the growing season. Average temperatures range from -9.4°C in January to 19.3°C in July with an annual mean of 5.6 ± 2.9°C (ECC Canada, 2016a) (Table 5).

The Valley Lowlands Eco-Region occupies most the watershed landmass (73.9%). Elevations are typically >100 m asl and the climate is cool and damp. The Valley Lowlands receive an average of 1,500 – 1,700 growing degree days (NWAI, 2004). There is no meteorological station in this Ecoregion but average precipitation amounts and temperatures are assumed to be in between those of the other two Ecoregions.

Table 5 Average daily temperatures and monthly total precipitation amounts for Fredericton and Juniper based on 1981 - 2010 data (ECC, 2016; 2016b).

Fredericton 1981-2010	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year Total
Avg. Temp (°C)	-9.4	-7.9	-2.4	4.5	11.1	16.2	19.3	18.4	13.6	7.5	1.5	-5.7	5.6
Rain (mm)	38.0	31.4	46.7	68.3	94.5	82.4	88.3	85.6	87.5	88.2	92.9	55.3	859.1
Snow (cm)	69.9	47.5	49.4	18.6	1.4	0.0	0.0	0.0	0.0	0.8	14.3	50.5	252.3
Total (mm)	95.3	73.1	93.2	85.9	96.2	82.4	88.3	85.6	87.5	89.1	106.3	94.9	1077.7
Juniper 1981-2010													
Avg. Temp (°C)	-12.4	-10.7	-4.6	2.6	10.0	15.1	17.8	16.9	12.2	5.8	-0.5	-8.0	3.7
Rain (mm)	30.1	16.4	34.2	66.6	94.0	90.2	107.4	105.3	102.5	91.7	79.4	44.8	862.6
Snow (cm)	78.9	54.7	53.4	18.7	1.2	0.0	0.0	0.0	0.1	3.1	29.0	58.1	297.2
Total (mm)	109.0	71.0	87.7	85.3	95.2	90.2	107.4	105.3	102.6	94.8	108.4	102.9	1159.7

The watershed as whole receives approximately 1116.6 mm of precipitation annually, based on 1981-2010 climate averages for Juniper and Fredericton (ECC, 2016; 2016b). This calculation assumed that the Juniper station represents the Central Uplands (22.8% of the watershed) and the Fredericton station represents the Grand Lake Ecoregion (3.3%). The Valley Lowlands (73.9%) was assumed to be the average of the Juniper and Fredericton stations as it lies between the two stations.

*Total Watershed Precipitation = (0.228*Juniper) + (0.033*Fredericton) + (0.739*((Fredericton+Juniper)/2))*

10.1 Climate Change

Climate change refers to any change in weather patterns over time, whether due to natural variability or because of human activities. Changes in the abundance of greenhouse gases, solar radiation, land surface properties can alter the local climate. The effects of global warming due to increased greenhouse gas emissions over the last century is expected to result in the warming of the earth's average temperature, leading to a change in precipitation patterns, warming of waters, and increased stress on the ecosystems. In Atlantic Canada and the American North-East, temperatures have increased 0.8°C since 1900, which is more than the global average increase of 0.6°C (Wake, 2006). Climate change will likely lead to the modification of the Nashwaak watershed through the following mechanisms:

- Surface runoff will decrease and will change in its seasonal patterns;
- Rates of groundwater recharge will decrease significantly and groundwater discharge to streams will drop;
- Streamflow will decrease while flooding will increase. There will be a greater variability of water levels and flows, which could affect public infrastructure;
- Summer water temperatures may be warmer, causing a decrease in salmonid populations and an increase in warm-water species such as bass;
- Reduced water flow may concentrate pollutants, disrupt nutrient cycling, and increase competition among aquatic organisms; and
- The watershed may become more vulnerable to invasive species.

Therefore, climate change and variability must be considered when making resource decisions in the Nashwaak watershed. How quickly effects will be observed is unknown but they will probably be felt over the next few decades.

11 WATER QUALITY AND QUANTITY

Where water comes from and where and how it moves dictates the plant and animal communities found on the land and in the rivers. Streams flowing through a watershed are also closely linked with the local water tables and regional aquifers. The hydrologic cycle is greatly influenced by climate, topography, geology, land use, and vegetation. Clean water is one of New Brunswick's most important resources. We rely on it for drinking, growing food, manufacturing goods, producing electricity, and for recreational activities. The flora and fauna of the Nashwaak watershed also rely on clean water.

Water quality and quantity in the Nashwaak watershed is currently being affected by several direct and indirect influences. Forestry, for example, affects water quantity by altering the timing and amount of run-off within sub-watersheds. Improper silviculture practices and nutrient inputs from slash or road construction also affect water quality. Other nutrient inputs include erosion due to topsoil mining, municipal runoff, direct input from cattle grazing, and fertilizer/pesticide runoff from agricultural or residential areas (which make up ~3.8% of the total watershed land area, primarily in the lower half but also near the headwaters of Cross Creek, Tay River, and Penniac Stream).

11.1 Water Quality

Maintaining the quality of the surface water is extremely important for ensuring a healthy watershed. Poor water quality is not a new issue. From the late 19th century, waste from lumbermills and sawmills was recognized as a major cause for decline in fish populations in the Saint John River (SJR) tributaries (Canadian Rivers Institue, 2011). Sawdust dumped into rivers sank to the bottom, disturbing river ecology, and floated downstream where it was deposited on banks and islands. Large quantities of solid and liquid waste from industries and urban centres very quickly led to degraded water quality in the Nashwaak River. Though most municipalities and industries have installed wastewater treatment systems over the last century and there have been gradual improvements in farming practices resulting in a drastic improvement in water quality in rivers and streams, point and non-point sources continue to discharge chemicals and nutrients in to the Nashwaak River, some under permits issued by the government. In 1972, the International Saint John River Water Quality Committee was formed to address water pollution problems in the Saint John River watershed. By 1984 pollutants had been reduced by 82% for suspended solids and 88% for biochemical oxygen demand (Carr, 2001; Culp et al., 2008). Although a this is a marked improvement from the past decades, the Nashwaak River is still affected by several types of pollution including: chemical, toxic, and deoxygenating wastes from industry, forest spraying, agricultural and urban runoff, etc.

11.1.1 Point Source Inputs

Point source pollution can be traced back to a specific source, such as a discharge pipe. Point source inputs in the Nashwaak watershed are:

- Storm water outfalls in Marysville, Barkers Point, and Stanley
  - Carry materials such as petroleum hydrocarbons, metals, road salt, pathogens, and silt,
  - May alter discharge regimes.
- Municipal waste water treatment plants in Barkers Point and Stanley
  - Can introduce suspended solids, bacteria, chlorine, ammonia, biochemical oxygen demand (BOD), phosphorus, and nitrate,
  - Waste water can alter the temperature and oxygen levels of the receiving waters,
  - All waste water outfalls in the watershed are required to be licensed by the NB DELG and when facilities are operating in accordance to the permit limits, the discharge should not result in a violation of the water quality criteria.
- A salmon hatchery at Tay Falls (now closed)
  - Increase nutrient levels and BOD, may reduce base stream flow levels and introduce exotic genetic strains of salmonids.

- Lumber mill in Devon, sawmill at McGlaggon Bridge (closed?), and veneer mill in Napadogan (closed in 2008)
    - Potential contamination by hydrocarbons, suspended solids, metals, and BOD.
- Former army encampment at McGivney
    - Used as an ammunitions depot between the late 1930s and mid-1950s, and
    - Potential contamination from ammonium, nitrate, hydrocarbons, and explosives.

11.1.2 Non-Point Source Inputs

Non-point source pollution comes from many diffuse sources and cannot be pinpointed to a specific location. Non-point source pollution poses a significant threat to New Brunswick's rivers. Carried by snowmelt, rain water, and ground water, non-point source pollution contributes sediments, nutrients, toxins, and pathogens to watercourses (Maine Rivers, 2005). Non-point source pollution in the Nashwaak watershed includes:

- Urbanization in Marysville and Fredericton and residential development below Stanley
    - Leads to the altering of streams and rivers by culverts and ditching,
    - Construction leads to sediment runoff,
    - Hard surfacing of land leads to run off and altered discharge patterns that cause erosion downstream,
    - Increased flashiness of streams, and
    - Increased human populations lead to increased releases of contaminants to the environment (metals, fuels, oils, pesticides, etc.).
- Active and closed domestic and industrial dump sites at Ryan Brook, Cross Creek Station, Durham Bridge, and Tay River
    - A wide array of potential contaminants not easily quantified due to the lack of knowledge about what's buried there. Possibilities include chloride, hydrocarbons, metals, and BOD.
- Cattle access to the river below Durham Bridge and on the Tay River due to inadequate fencing
    - Introduction of bacteria and nutrients, erosion of banks leading to suspended solids loading.
- Agriculture
    - Removal of riparian vegetation and introduction of bacteria, nitrate, phosphorus, and suspended solids through surface run-off and erosion, and
    - Spreading of manure can introduce pathogens and decrease oxygen content of water.
- Topsoil mining below Durham Bridge and aggregate (gravel) mining operations
    - Increases suspended solids in run-off as well as nutrient and bacteriological loading when manure is spread of re-seeding, and
    - Leads to eroded banks and widening of the river.
- Industrial/commercial activities in Marysville and Barkers Point
    - A wide array of potential contaminant issues including hydrocarbon, metals, etc.
- Public and logging road construction and maintenance
    - Exposes soils leading to suspended solids loading and altered discharge pattern changes,

    - Culverts can impact fish passage if not properly installed, and
    - Increases salt, chemical, and nutrient runoff.
- Forestry
    - Exposes soils over a large land mass, leading to suspended solids loading, metal leaching, reduction of shading, herbicide spraying that can contaminate waters, and road construction that can impact fish passage and change drainage patterns, and
    - Clear cutting can alter the timing of snow melt and reduce biodiversity.
- Camp development in the headwaters and septic leaks
    - Introduction of nutrients and bacteria.
- Bank erosion, especially near Taymouth
    - Introduction of metals, suspended solids loading, etc.
- Mine development at Sisson Brook
    - Potential for contamination by metals and hydrocarbons, increased road construction will alter drainage patterns, diversion of water for the mine.

11.1.3 Monitoring Stations

Water quality monitoring was carried out by NWAI in 1996 and between 1999 and 2002 in preparation for the NB Water Classification scheme. NWAI has not sampled any sites since 2002 but a graduate student from UNB sampled most established sites in the watershed in 2005. DELG sampled some sites in 1980 and 1988 and has operated a continuous monitoring site in Marysville (NASH-B). NASH-B is the only currently active monitoring site and the only site that has been monitored since 2005. All samples were grab samples taken while wading, expect at NASH-A, which was occasionally sampled from a canoe. Figure 21 shows the location of all the historic water quality sampling sites.

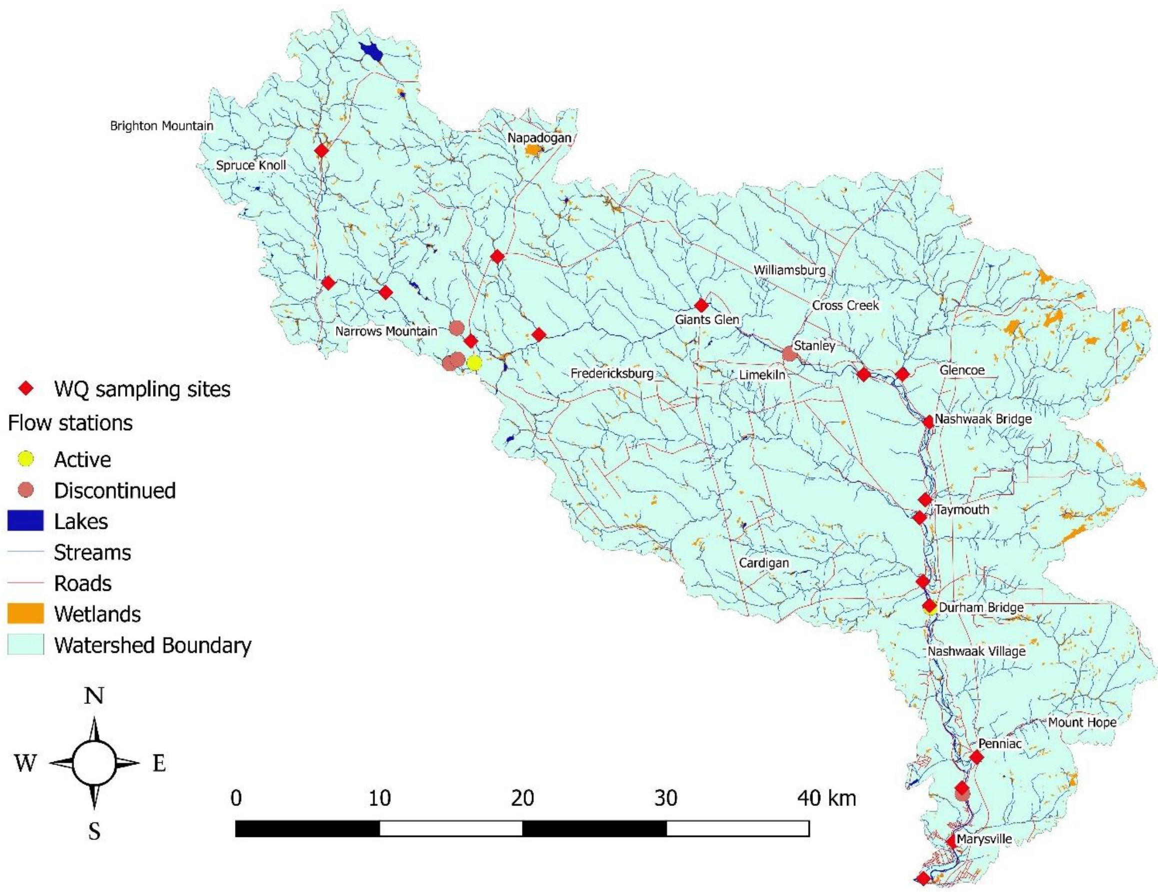


Figure 21 Map of the water quality sampling sites (red diamonds) and flow stations (circles) in the watershed. Data source: GeoNB.

NASH-A: Barker's Point (DELG Station 10535)
This station is on the mainstem of the Nashwaak near the mouth of the river, with approximately 1,627 km^2 of drainage area above. Additive drainage from Fisher and Kaines Brooks (14 km^2) is comprised of 46% forested land, 10% agricultural land, 40% urban development, and 4% roadways. Pollution sources of note at this station include a major lumber mill in Devon, urban storm water inputs, industrial and commercial activities, and dense human occupation. This area is used extensively for hiking, fishing, canoeing, and cycling.

Data for this station were taken from 1999 to 2002 and July through October.

NASH-B: Marysville (DELG Station 10536)
This station is located just above the bridge in Marysville. Campbell Creek and McConaghy and Second Gore Brooks. Additive drainage is comprised of 87.4% forested land, 6% urban development, and minor wetland, agricultural land, road ways, and gravel pits. There is significant development along both sides of the river near this station. Pollution sources of note include urban development, storm water inputs, and dense human occupation. This area is used extensively for fishing and recreation.

Data range from 1996 and 1998 to 2016 and cover all months except January and April. This is the only station that has been sampled since 2005.

NASH-C: Penniac Brook (DELG Station 10537)
This station is located on the mainstem of the Nashwaak River just below the Penniac Bridge. Manzer, Gunter, and McLean Brooks, and the lower portion of the Penniac Stream drain to this site. Additive drainage is comprised of 85% forested land, 11% agriculture, and minor wetland, human occupation, gravel pits, and road ways. Pollution sources of note are residential development, top soil mining, former dump sites, and cattle grazing on the flood plain. This area is used extensively for fishing and recreation.

Samples were taken from 1999 to 2002 and from July to October.

NASH-D: Penniac Stream (DELG Station 10539)
This station is located on the Penniac Stream just above the new bridge on rte. 628. Several tributaries drain to this station: the North Branch of the Penniac Stream, as well as Gilmore, Whitlock, Allen, Jakes, Moore, Baxter, Moosehole, and Estey Brooks. Additive drainage is comprised of 92.6% forested land, 4% agriculture, 2% wetland and minor human occupation, gravel pits, and roadways. Pollution sources of note include forestry practices, top soil mining, and significant cattle grazing. This area is used for hunting, fishing, and recreation.

This station has data from 1988, 1999 to 2002 and 2005. Data cover May to October.

NASH-E Durham Bridge (DELG Station 10540)
This site is located on the mainstem of the river approximately 100 m upstream from Durham Bridge. McBean Brook drains to this station. Additive drainage (70 km^2) is comprised of 88.3% forested land, 4% wetland, 4% agriculture, and 2% human occupation. Pollution sources of note include agriculture and cattle grazing, topsoil mining, forestry, and a former dump site on rte. 628. The Dunbar Pool has traditionally been the top salmon producing pool along the Nashwaak River.

This station has data from 1980, 1988, 1995-2002, and 2005. Data cover March to August, October, and December.

NASH-F Dunbar Stream (Station ID 10541)
This station is on Dunbar Stream about 30 m upstream from the confluence with the Nashwaak and downstream from Dunbar Falls. The station also receives water from Thomas Lake (2 Ha), Stickles Lake (1.5 Ha), North and South Dunbar Brooks, Tinkettle Brook, and Seymour Brook. Pollution sources of note include forestry and agriculture. A major waterfall (Dunbar Falls) prevents fish from ascending the stream but provides recreational opportunities for residents.

This station has data from 1988, 1999 to 2002 and 2005, which cover May to October.

NASH-G Tay River (Station ID 10542)
This station is on the Tay River approximately 50 m upstream from its confluence with the Nashwaak River. This station also receives water from the North Tay River, the South Tay River, Robinson, Pidgeon, Limekiln, Big, Barker, and Little Tay Brooks. Additive drainage is 93% forested and 5% agricultural land. Pollution sources of note include camp lot development, forestry, and major bank erosion in the lower 3 – 5 km of this river. The Tay River is popular for swimming and angling.

Data cover 1988, 1999 to 2002 and 2005 and May to October.

NASH-H Taymouth (Station ID 10543)
This station is located on the mainstem of the Nashwaak near the community of Taymouth (approximately 75 m upstream from the bridge). This station also receives water from Porters, Young's, McKenzie, and McCallum Brooks. Additive drainage is approximately 93.5% forested land, 4% wetland, and minor human occupation. Pollution sources of note include residential development in Taymouth, forestry, and agriculture.

This station has data from 1988 and 1999 – 2002 and from May to October.

NASH-I Young's Brook/ Nashwaak Bridge (DELG Station 10544)
This station is located on the mainstem of the Nashwaak above the confluence with Young's Brook near the community of Nashwaak Bridge. The station also receives water from Schoolhouse, Cathle, and Falls Brooks. Additive drainage is small (25 km^2) and 98% forested land with minor agriculture and human occupation. Important pollution sources include a former sawmill at Cathle Brook, camp development, and minor agriculture near Ward Settlement. This area is popular for swimming and angling.

This station has data from 1980, 1988, 1999 to 2002, and 2005 and from May to October.

NASH-J and J2 Cross Creek Stream (DELG Station 16938)
Station NASH-J is located on Cross Creek stream approximately 400 m upstream from the walking bridge near the mouth of the stream. Station NASH-J2 is located approximately 50 m above the walking bridge. As they are so close the data were analyzed together and called NASH-J. This station also receives water from Arnold, McGivney, Six Mile, Five Mile, Four Mile, and Two Mile Brooks as well as from the North and West Branches of Cross Creek Stream and from Arnold Brook Lake (<0.5 Ha). Additive drainage is 81.3% forested land, 7% agriculture, and minor human occupation and wetlands. Pollution sources of note include agriculture near Williamsburg, Centreville, and Greenhill, a small sawmill, a former army encampment at Five Mile Brook, and a closed landfill.

Cross Creek has traditionally been the second most productive salmon producing tributary to the Nashwaak River. There is a heavily used walking trail along the stream and it is a popular place to swim. Just upstream from the mouth there is a double waterfall.

Samples were taken in 1999, 2001, 2002, and 2005 and cover July to October.

NASH-K and K2: McGlaggan Bridge (DELG Station 10546)
Station NASH-K is located on the Nashwaak River near McGlaggan Bridge while NASH-K2 is located downstream of the bridge. The data from these two stations were analyzed together as NASH-K. This station also receives water from MacPherson, Sands, and Bests Brooks, and from Stones Lake. Additive drainage is comprised of 78% forested land, 19% agriculture, and 2.5% human habitation. Important pollution sources include residential development, waste water treatment from Stanley, a sawmill, and municipal storm water inputs. There is a waterfall and environmentally significant area (Buttermilk Falls) below Stanley.

Data are from 1988, 1998 to 2002, and 2005 and from May to October

NASH-L: Currieburg (DELG Station 10547)
This station is located on the Nashwaak River downstream of Currieburg. It receives water from Grand John Lake (12 Ha), Rocky Brook Lake (4 Ha), Fleetwood Lakes (2 Ha), and Mountain, Rocky, Grand John,

Wadham, McLean, Middle, Meadow, and Ryan Brooks. The 232 km^2 drainage to this site is comprised of 93% forested land and 6% wetland. There is little human occupation in this area aside from hunting camps. Pollution sources of note include a closed landfill on Ryan Brook, gravel pits at the headwaters of McLean and Rocky Brooks, a cluster of camps near Grand John Brook, and forestry. There are a series of waterfalls at Rocky Brook known as the Rocky Brook Stairs.

This station has data from 1999 to 2002 and from July to October.

NASH-M: Napadogan Brook
This station is located on Napadogan Brook approximately 50 m upstream from the confluence with the Nashwaak River. It receives water from Lower Nashwaak Lake (20 Ha) and Lake and Manzer Brooks. There is very little human occupation in this area; it is almost 100% forested land. The major sources of pollution are forestry and minor camp development. The Sisson Brook Mine could cause future pollution.

Data range from only 1999 to 2001 and from September to November.

NASH-T: Napadogan Stream (DELG 15449)
This station is located on the Napadogan Stream about 8 km above the confluence with the Nashwaak River at the intersection with the Saint Anne Nackawic Haul Road. This station also receives water from Mud Lake (7 Ha), Napadogan Lake (20 Ha), Martha Lake (1.5 Ha), East, Bird, and Sisson Brooks. The 71 km^2 drainage to this location is comprised of 98% forested land and 2% wetland. The major source of pollution minor camp development, forestry, and road construction. The Sisson Brook Mine could cause future pollution issues.

Samples were only taken in 2001, 2002, and 2005 and between July and October.

NASH-N: Narrows Mountain (DELG Station 10549)
This station is located on the Nashwaak River at Valley Road Bridge near Narrows Mountain. Elevations in this region are around 185 m. The station receives water from Hayden Brook and several unnamed tributaries. The 218 km^2 drainage area is 100% forested land with minor logging road development. Sources of pollution are minor camp development and forestry practices.

Data cover 1980 and 1999 to 2002 and May to October.

NASH-O: McBean Brook (DELG station 10550)
This station is located at the mouth of McBean Brook just above Narrows Mountain. It receives water from Barker Lake (5 Ha), Trouser Lake (6 Ha), Christmas Lake (5 Ha), Chainy Lakes (3 lakes totalling 22 Ha), and Barker Brook. The 44 km^2 drainage area is 100% forested land. There is minor road and camp development in the area. Sources of pollution include forestry and camp development.

Data cover only 2000 to 2002 and July to October.

NASH-P: South Sisters Brook (DELG Station 10551)
This station is located on the Nashwaak River at the bridge below South Sisters Brook. It receives water from Doughboy Lake (3 Ha), Little Doughboy Lakes, Silver Lake (3 Ha), Cedar Lake (3 Ha), East, Doughboy, Little Doughboy, North Sisters, and South Sisters Brooks, as well as several unnamed

tributaries. Land use draining to this site (147 km^2) is ~100% forested. Sources of pollution include minor camp development, forestry, and road construction.

Data range from 1999 to 2002 and July to October.

NASH-Q: Gorby Gulch (DELG Station 10552)
This station is located on the mainstem of the Nashwaak approximately 20 m upstream from the Gorby Gulch Road Bridge. This is the uppermost monitored location on the mainstem and is at an elevation of 275 m. This station receives water from Upper Nashwaak Lake (93 Ha), Governor's, Otter, and Welch Brooks, and the East and West Branches of the Nashwaak River. The 87 km^2 of land drainage above the station is 100% forested. Pollution source include minor camp development, forestry, and road construction.

Data range from 1999 to 2002 and from July to November.

11.1.4 Water Quality Data

Complete water quality data tables are available in Appendix A. Selected parameters are presented in the tables and figures below. Data were grouped per decade (1980s, 1990s, etc.) and analysed graphically per site to look at changes over time or between sites. Not all sites had data for a specific parameter or date, which made comparisons, in some cases, very difficult. Limits for certain contaminants have been developed by the Canadian Council of Environment Minsters (CCME, 1999).

Overall water quality improves moving upstream in the watershed. Patterns of water quality parameters were as expected based on land use patters. Areas of concern are from the Penniac Stream downstream to the mouth of the river.

11.1.4.1 Total Dissolved Solids

Total dissolved solids (TDS) is a measure of the combined organic and inorganic substances suspended in water. TDS comprise inorganic salts (mainly calcium, magnesium, potassium, sodium, bicarbonates, chlorides, and sulfates) and a small amount of organic matter dissolved in water.

TDS contents were only available for selected sites from the 1980s and the 2000s. At all sites with data for both decade groupings (except for the mouth of the Tay River, which was just within error) TDS contents decreased significantly (Figure 22). Potential sources of TDS include agricultural and residential run-off, storm-water run-off, and road salts. TDS may also arise from weathering of rocks and erosion of soils, which could explain the elevated levels at the mouth of the Tay.

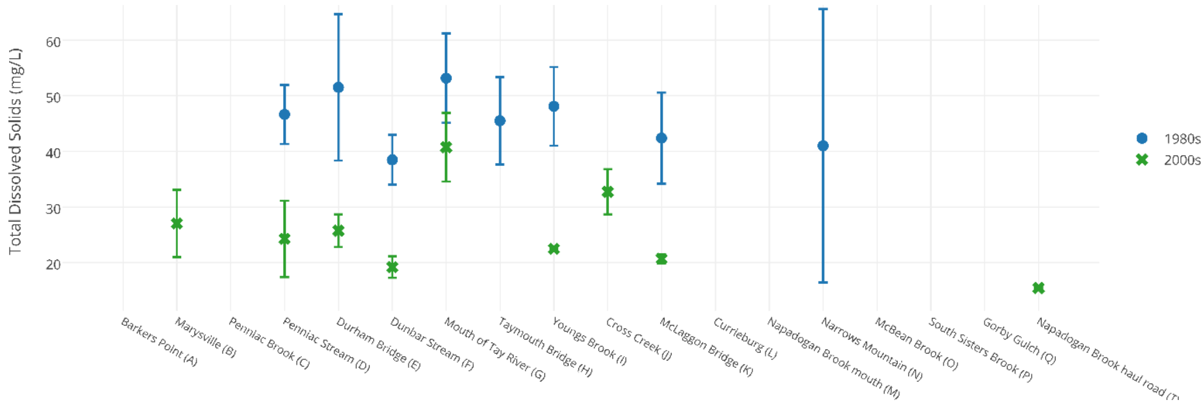


Figure 22 Mean total dissolved solid contents (mg/L) per site per decade for the Nashwaak watershed. Error bars represent standard deviation.

11.1.4.2 Suspended Sediments and Turbidity

Turbidity is a measure of the extent to which light penetration in water is reduced due to the amount of sediment suspended in the water column. Suspended sediments are fine particles, primarily clays, silts, and fine sands that require low water velocities to remain in suspension. It naturally varies depending on soil type, shoreline erosion, and surrounding land use. Generally, values below 10 NTU are acceptable. Values greater than 10 NTU mean that light will be blocked from reaching aquatic plants and feeding of zooplankton will be disrupted. Turbidity normally spikes during and immediately after periods of high rainfall or snowmelt. Turbidity values were, in general, very low for all sites (median values of 0.1 to 1.6). Values were highest in 1980 and 2005, possibly due to high rainfall amounts. Slight increases were observed near Gorby Gulch, Barker's Point, Marysville, and Penniac Stream (Figure 23). However, sampling avoided periods of high rainfall and high water. Visual observations following significant summer precipitation noted an increase in turbidity on the Penniac Stream and below Durham Bridge. Topsoil mining and road construction were determined to be major sources (NWAI, 2004).

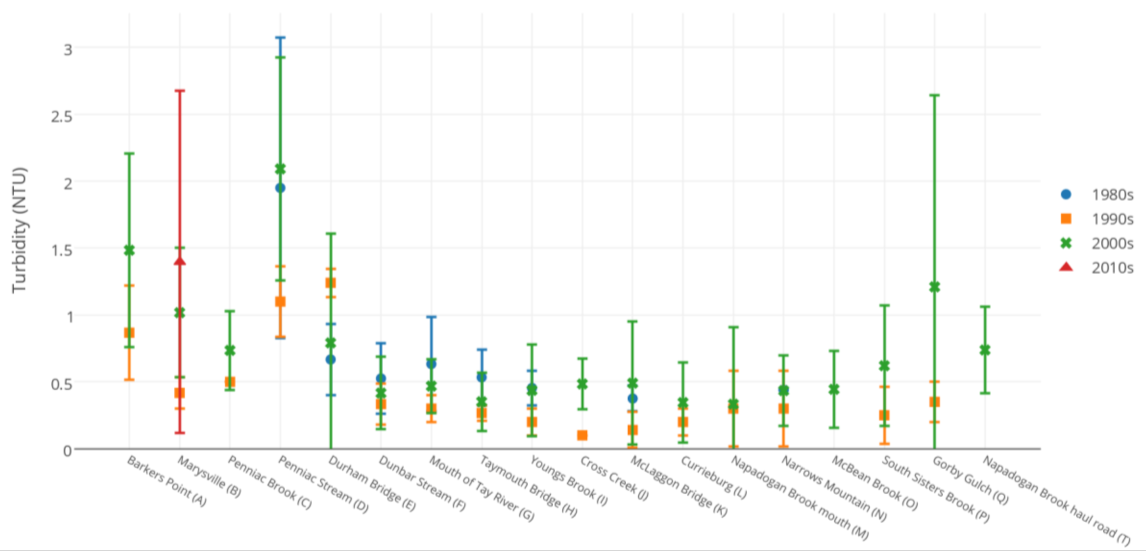


Figure 23 Turbidity (NTU) per site per decade in the watershed. Error bars represent standard deviation.

Suspended sediment loads have, in general, increased at most sites from the 1980s to the 2000s. Increased sediment loads can aggrade channels, which in turn leads to bank erosion and the destruction of habitat. It appears, however, that detection limits have increased from the 1980s to the 2000s, making comparisons difficult.

11.1.4.3 Dissolved Oxygen

Dissolved oxygen (DO) is a widely used and important indicator of aquatic health. Organisms require oxygen dissolved in the water to survive. Levels below 6.5 mg/L can cause stress, especially for cold water fish, and levels below 9.5 mg/L can cause stress to early life forms. Dissolved oxygen decreases as water temperature increases (i.e., warm water can hold less oxygen than the same volume of cold water). Sewage or algal blooms resulting from elevated nutrients can lower the DO content by consuming oxygen.

Rivers, in general, can accept and assimilate a certain amount of oxygen-demanding wastes. However, if too much organic material is discharged, oxygen can become severely depleted leaving insufficient oxygen for aquatic organisms. Fish under stress from low oxygen levels become more susceptible to the effects of other substances discharged into the river.

In general, DO content has increased from the 1980s, when several sites in the middle of the watershed (Durham Bridge, mouth of the Tay, Young's Brook, and McLaggon Bridge) were below the CCME limit for early life stages (Figure 24). About half of the results at Barker's Point in the 2000s and a third of the results from Marysville in both the 2000s and the 2010s were below the limit as well. One or two samples from the headwaters sites in the 2000s were also below the limit. All the exceedances happened in the summer, when temperatures were the highest. Average DO contents (across all data) ranged from a low of 9.65 at NASH-A to a high of 11.67 at NASH-H with averages at most sites in the range of 10.5 to 11.0.

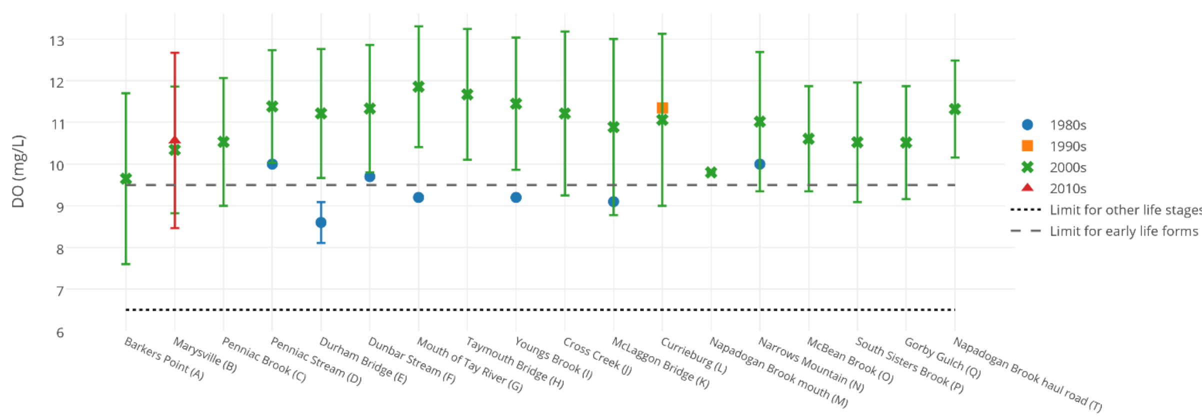


Figure 24 Mean dissolved oxygen content (mg/L) per site per decade. Error bars represent standard deviation. Dashed lines indicate CCME limits for early life forms (9.5 mg/L) and all other life stages (6.5 mg/L).

11.1.4.4 pH

pH is a measure of the acid/basic nature of the water. It is measured on a scale from 0-14 with 0 being acidic, 14 being basic, and 7 being neutral. pH levels should remain within the range of 6.5 to 9.0 to ensure freshwater health. pH varies naturally but can be affected by human interference and by acid rain.

pH levels for the watershed were within the CCME limits (Figure 25). Only one sample from Penniac stream in the 1980s was below the lower limit. In general pH is lower (more acidic) in the upper reaches of the watershed and higher near the mouth of the river. Data also show that pH has increased (become less acidic) at every site from the 1980s/1990s to the 2000s/2010s. Values are considered protective of aquatic life.

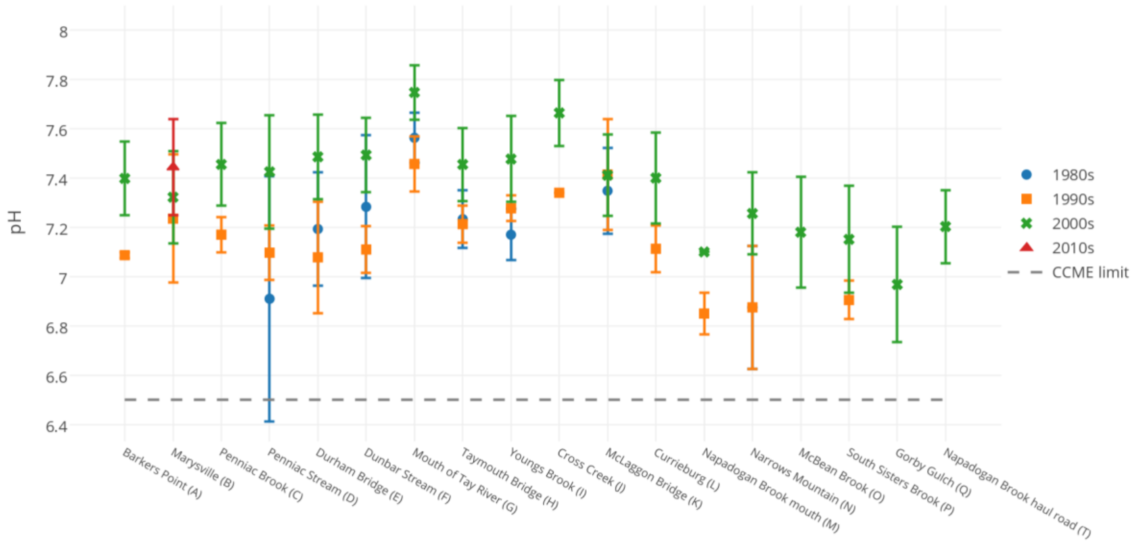


Figure 25 pH level per site per decade. Error bars represent standard deviation. The dashed line represents the CMME lower limit. The upper limit of 9.0 is off the graph.

11.1.4.5 Metals

CCME has set a limit of 0.1 mg/L aluminum at pH of >6.5 for fresh water aquatic life. The limit for drinking water and for aesthetics and recreation is 0.2 mg/L. Aluminum is a naturally occurring element in many rocks and soils. Therefore, concentrations are expected to rise with increased erosion.

Aluminum levels were the highest in the 1980s, especially in Penniac and around Durham Bridge (Figure 26). Levels were slightly above the limit in the upper reaches of the watershed (Napadogan to Gorby Gulch) in the 1990s and 2000s as well. Aluminum levels at most sites did not change significantly between the 1980s and 2000s. Most Atlantic Canadian rivers have elevated levels of aluminum due to the underlying bedrock geology rather than human activity (Canadian Rivers Institue, 2011). Increased amounts of bank erosion lead to increased concentrations of metals in streams. The aluminum is often complexed with organic compounds meaning that it is not harmful to aquatic life (ISCRWB, 2010).

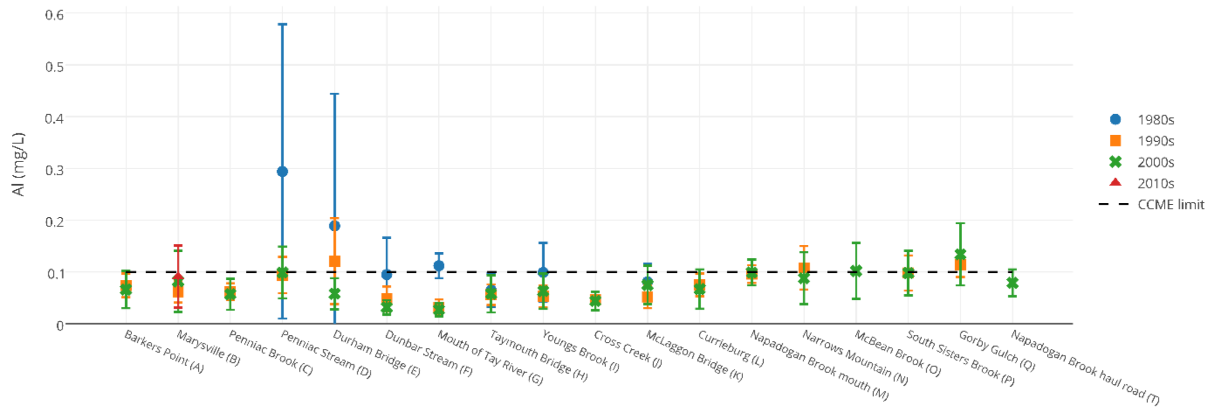


Figure 26 Aluminum content (mg/L) per site per decade. Error bars represent standard deviation. The dashed line represents the CCME limit of 0.1 mg/L.

Iron is another metal that occurs naturally in rocks and sediments. However, it may be derived from industrial waste or corroding metal pipes. Bank erosion leads to increased levels of metals in streams due to sediment run-off.

Iron contents for the Nashwaak watershed were well below the CCME limit of 0.3 mg/L at all sites except for three, Barker's Point, which exceeded the limit in the 1990s, Penniac Stream, which exceeded the limit in the 1980s, 1990s, and 2000s, and Gorby Gulch, which exceeded the limit in the 2000s (Figure 27). Iron contents have not changed significantly at any site since the 1980s.

Soil erosion is likely the cause of elevated iron contents. Penniac Stream displayed high levels of both Al and Fe, particularly in the 1980s, indicating that soil erosion was likely an issue at this time but erosion levels have possibly diminished since, as concentrations of both metals have decreased.

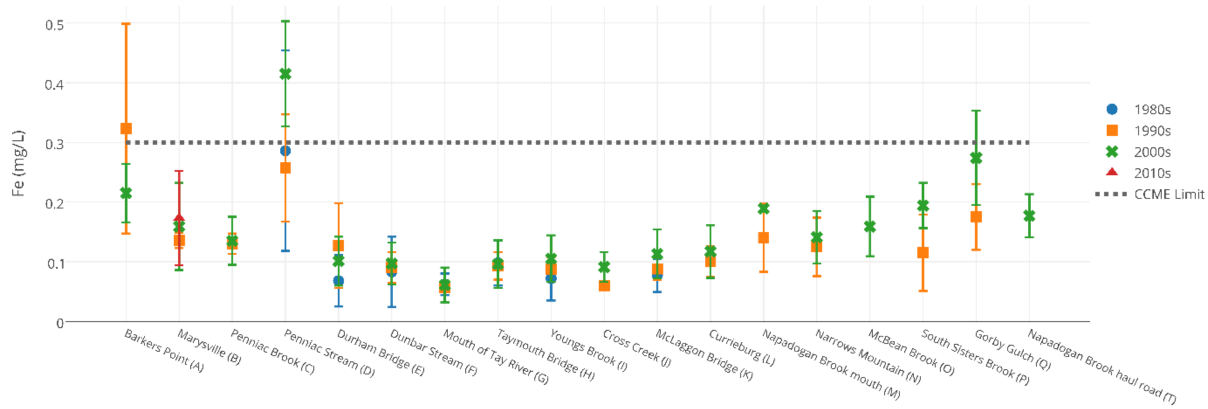


Figure 27 Mean iron content (mg/L) per site per decade in the watershed. Error bars represent standard deviation. The dotted line represents the CCME limit of 0.3 mg/L.

Other metals (i.e., copper, cadmium, lead) can be associated with industrial inputs. Concentrations of these elements were mostly below detection levels and were relatively consistent throughout the watershed.

11.1.4.6 E. coli

E. coli are bacteria that live in the digestive tract of warm blooded animals and are used to indicate the potential presence of harmful organisms. Potential sources of contamination include poorly maintained septic systems or sewage treatment plants, domestic animals, aquatic wildlife, and livestock.

E. coli contents were generally higher in the downstream sampling sites, particularly downstream from Penniac, where there is increased human habitation, and especially in the 1990s (Figure 28). *E. coli* may be contaminating the water from faulty septic systems or sewage treatment plants or it may be coming from animal waste. Several samples from the 2000s at Gorby Gulch and from the 1990s at Marysville were also well above the CCME limit of 400 MPN/100 mL for a single grab sample from recreational waters and may be indicative of faulty septic systems at camp lots.

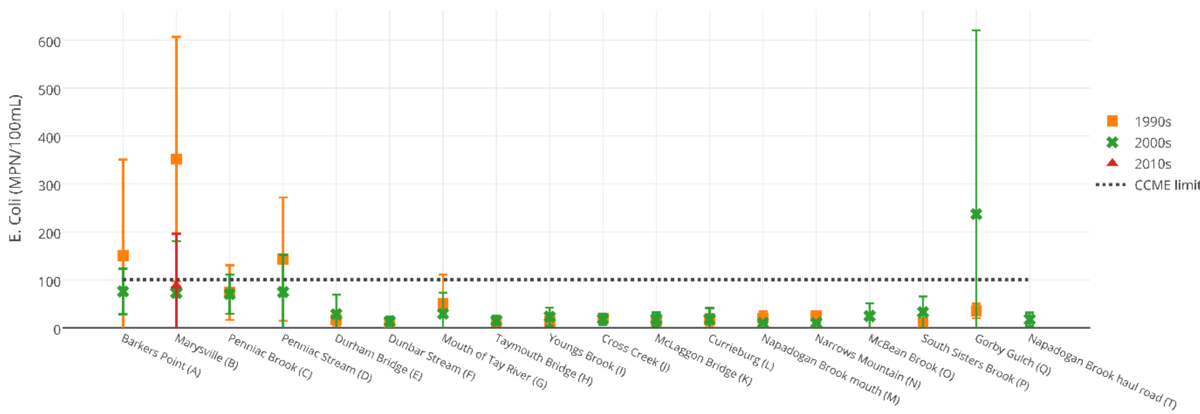


Figure 28 Mean E. Coli contents (MPN/100 mL) per site per decade in the watershed. Error bars represent standard deviation. The dashed line represents the CCME limit of 100 MPN/ 100 mL for a geometric mean of samples from recreational waters.

11.1.4.7 Nitrogen and Phosphorus

Nitrogen and phosphorus are nutrients essential for all life forms and they occur naturally in rocks and soils. However, when present in elevated concentrations, they can degrade water quality by causing algal blooms, which lower DO contents. Nitrogen levels below 0.9 mg/L and total phosphorus levels below 0.03 mg/L are considered acceptable. Major sources of nutrients include wastewater discharges, agricultural run-off (chemical fertilizers), faulty septic systems, wastewater treatment plants, manure storage, and erosion.

Nutrient levels in the watershed were generally low with phosphorus levels typically around 0.01 mg/L. Average values across all data were all below the CCME limit (Figure 29). Highest levels were recorded at Penniac Stream. Agricultural inputs or soil erosion may be the source.

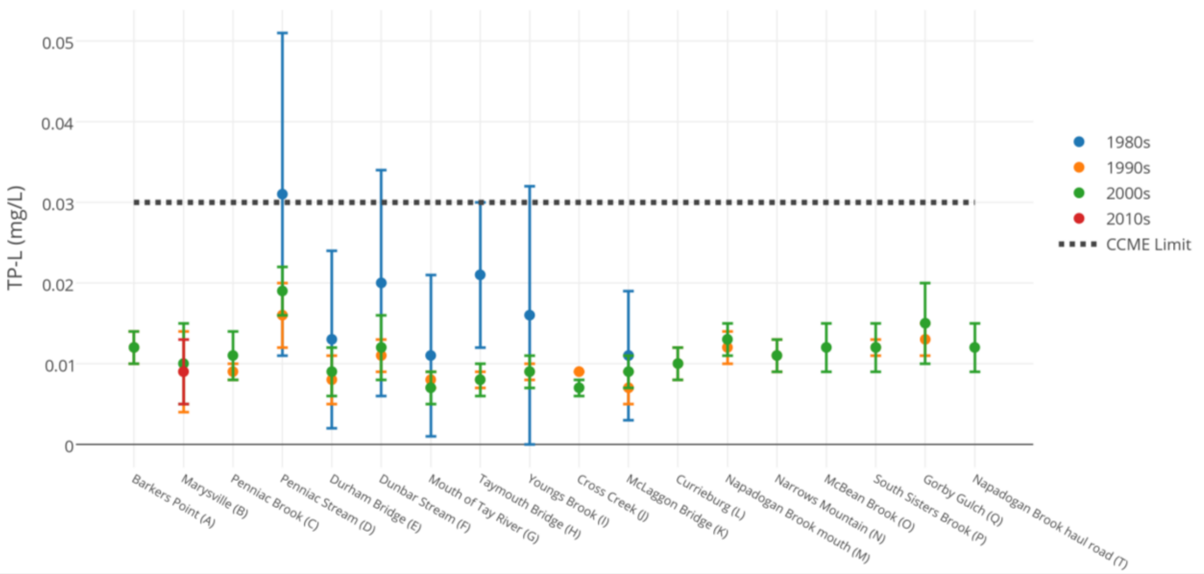


Figure 29 Total phosphorus (TP-L) per site per decade in the watershed. Error bars represent standard error. The dashed line represents the CCME limit of 0.03 mg/L.

11.1.4.8 Total Organic Carbon

Total Organic Carbon (TOC) is a combination of humic substances, as well as partly degraded animal and plant material. TOC may enter a watercourse via run-off from agriculture or from urban or industrial areas. It may also enter via wetlands. There is no CCME limit for TOC; however, low levels are important to prevent the consumption of oxygen during decomposition.

TOC levels were highest in the upper watershed at McBean Brook, South Sisters, and Gorby Gulch, where average values exceeded 10 mg/L. This may be due to the wetlands in this area. Penniac Stream also displayed high TOC, possibly due to the wetlands located in its headwaters. Levels were particularly high throughout the watershed in 2001.

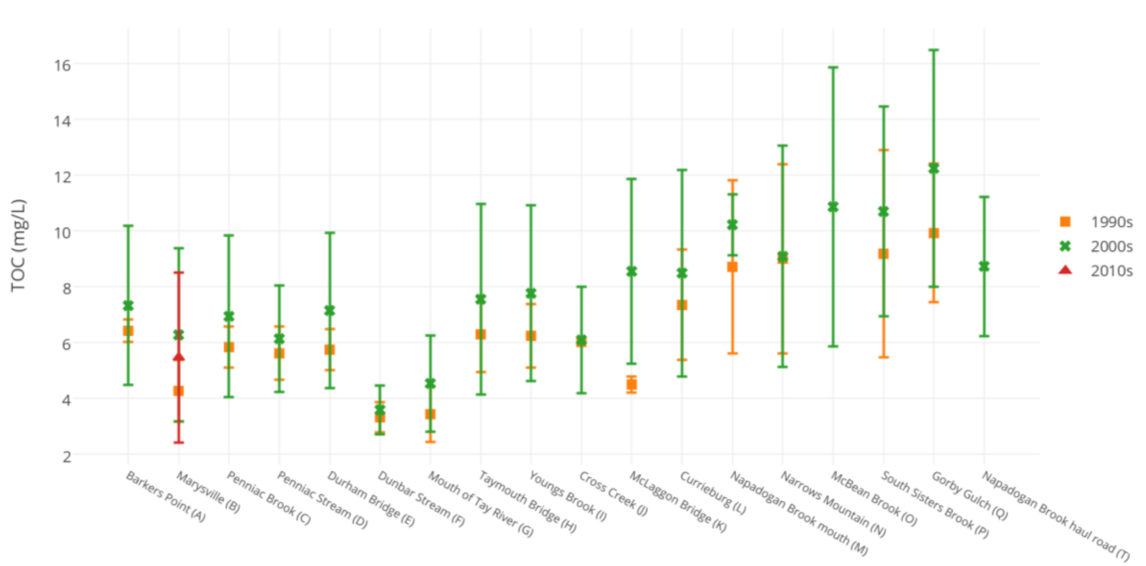


Figure 30 Total Organic Carbon (TOC) per site per decade across the watershed. Error bars represent standard error.

11.1.5 Water Quality Index (WQI)

The Water Quality Index, or WQI, is a means to provide a consistent way to report water quality information. The Canadian WQI was developed by the Canadian Council of Ministers of the Environment (CCME) and it provides a single number that expresses the overall water quality at a certain time and location based on selected parameters. Ratings are follows:

Table 6 Water Quality Index rating based on CCME guidelines.

Rating	WQI
Excellent	95-100
Good	80-94
Fair	60-79
Marginal	45-59
Poor	0-44

WQIs for each site and year were calculated using the CCME's Water Quality Index 1.1 Calculator and are shown in Appendix A. WQIs were site are shown in Figure 31. Overall, over quality issues do exist within the watershed, though not severe or abundant, that do impact the health of the river and streams. In general, WQI's were mostly in the Good to Excellent range. The poorest results were, overall, from the 1980s. Major contamination issues were heavy metals, dissolved oxygen, and phosphorus. NASH-E (Durham Bridge) and NASH-D (Penniac Bridge) displayed the poorest WQIs, due to heavy metal and nutrient contamination, possibly caused by sedimentation from the soil mining or agricultural operations in the area. NASH-C (below Penniac Brook) and NASH-J (Cross Creek) consistently displayed the highest WQIs.

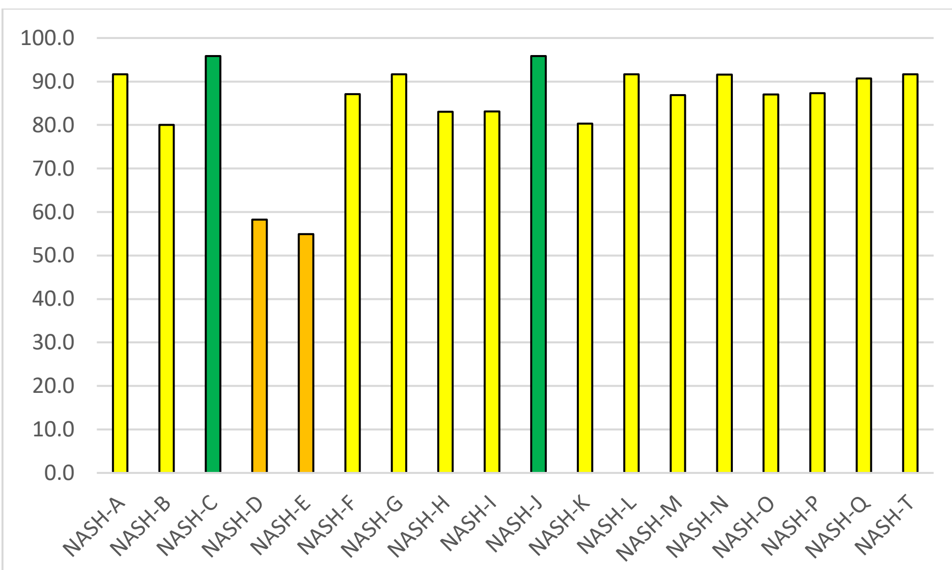


Figure 31 WQIs calculated per site using NWAI's historical data.

11.1.6 Water Classification

The *Water Classification Regulation* (WCR) was a regulation under the New Brunswick provincial *Clean Water Act* in the late 1990s and early 2000s. The purpose was to set water quality goals to ensure the proper protection of aquatic life and promote better management of the watershed. The WCR established water classes (A, B, C, with A being the highest) and standards, along with guidelines, which were to be regulated by law. Unfortunately, the WCR was never implemented.

The NWAI participated in water classification from 2001 to 2004 supported by funding from the Environmental Trust Fund. The process involved identifying and contacting stakeholders, performing water quality and benthic macroinvertebrate sampling, mapping land and water features and uses, holding public meetings, providing information to the public, and developing an action plan to meet water quality goals. A general picture of the current conditions on the Nashwaak River emerged.

Water quality throughout the Nashwaak River was generally of "Class A" (protective of aquatic life), with areas of concern around Stanley, Penniac Stream, and, particularly, the mainstem below Penniac (Table 7).

Table 7 Suggested water classification categories per section of the Nashwaak River

River Section	Suggested Classification*	Main Issues
Above Gorby Gulch (NASH-Q)	A	Forestry and logging roads
Gorby Gulch to South Sisters (NASH-P)	A	Forestry and logging roads
All of McBean Brook (NASH-O)	A	Forestry and logging roads
South Sisters to Narrows Mountain (NASH-N)	A	Forestry and logging roads
Napadogan Stream above Napadogan (NASH-M, T)	A	Forestry and logging roads
Narrows Mtn to Currieburg (NASH-L)	A	Forestry, logging roads, gravel mining, farming
Currieburg to McLaggon Bridge (NASH-K)	A except mixing zone near Stanley (B)	Stanley sewage treatment plant, farming, forestry, roads, gravel mining
McLaggon Bridge to Cross Creek (NASH-J)	A	Forestry, logging roads, gravel mining, farming
Cross Creek to Youngs Brook (NASH-I)	A	Forestry, logging roads, farming
Youngs Brook to Taymouth (NASH-H)	A	Residential development, farming (manure), forestry and logging roads
All of Tay River (NASH-G)	A except mixing zone at hatchery (B) now closed	Fish hatchery (Tay Falls), farming, forestry and logging roads
All of Dunbar Stream (NASH-F)	A	Forestry, logging roads, farming
Taymouth to Durham Bridge (NASH-E)	A	Residential development, top soil mining, farming, forestry and logging roads
Penniac Stream (NASH-D)	B	Farming, residential development / sewers, forestry and logging roads, gravel mining
Durham Bridge to Penniac (NASH-C)	B	Residential development, top soil mining, farming
Penniac to Marysville (NASH-B)	B	Urban development and runoff, farming, commercial development, gravel mining

Marysville to Barker's Point (NASH-A)	C	Urban development and runoff, farming, commercial development

*Suggested classification taken from (NWAI, 2004) report.

An action plan was developed (NWAI, 2004) to address the water quality issues noted above; however, the action plan was never implemented as the WCR did not go ahead. The action items from the 2004 report are listed below. These action items have been evaluated and reconsidered for the NWAI's *2017-2020 Action Plan*.

11.1.6.1 The Nashwaak River above Stanley

Monitoring and diligence to maintain the existing water quality. Work with forestry companies and landowners so that:

- Logging roads are built and maintained in an environmentally friendly way;
- Riparian zones are maintained; and
- Camp lots have adequate sewage treatment.

11.1.6.2 Stanley

Maintain good water quality by:

- Working with the village's waste water treatment facility;
- Working with the rural planning district commission to develop better Best Management Practices (BMPs) for housing developments, such as proper riparian zone setbacks; and
- Continuing to monitor water quality.

11.1.6.3 Penniac Stream

Monitor with constant vigilance. Improve water quality by working with farmers to:

- Apply for funding for fencing to prevent or limit cattle access to the stream;
- Restore riparian buffer zones; and
- Improve manure storage facilities.

11.1.6.4 Tay River

The rearing facility that was causing minor issues is now closed. Water quality should continue to be monitored.

11.1.6.5 The Nashwaak River below Penniac

Monitor with constant vigilance. (The Marysville station is the only place where water quality samples have been taken since 2005.) Improve water quality by:

- Contacting storm sewer and waste water treatment operators to improve current practices;
- Working with low income families to repair or replace faulty septic systems; and
- Establishing and maintaining contact with the local planning commission to ensure proper riparian buffer zones and BMPs are followed for new construction.

11.1.6.6 Overall Improvement of the Nashwaak Watershed's Water Quality

In addition to the specific action items mentioned above, there were several action items suggested for the entire watershed:

- Addressing the practice of top soil mining by ensuring that existing legislation is adhered to and force fining or permit cancellation of operators who do not comply with regulations;
    - Lobbying government to use the power of existing legislation(s);
- Ensuring that BMPs are followed by logging companies and that any infractions are communicated to DELG or DNRE;
- Working with landowners to ensure proper road construction and maintenance;
- Working with gravel mining operators to ensure that BMPs are followed and to improve buffer zones;
- Working with farmers on fencing projects and buffer planting to limit or restrict cattle access to the river and tributaries;
    - Research has shown that a channel's structure responds relatively quickly to cattle fencing but that the full recovery of a stream will take 50-100 years if active restoration is not a part of the cattle exclusion program (Grand River Conservation Authority & Ontario Ministry of Natural Resources, 2005).
- Working with farmers to improve top soil conservation and manure management practices and BMPs;
- Partnering with waste water treatment facilities to improve current practices;
- Working with local and rural planning commission to ensure that proper riparian setbacks are adhered to and BMPs are being followed;
- Reporting any dumping or abuse of the river to DELG or DNRE; and
- Riverbank stabilization and problem area assessment.

11.2 Water Quantity

Stream flow is a combination of overland flow, interflow (flow below the ground surface but above the water table), and ground water discharge. However, it is the constant discharge of ground water that maintains the base flow of a river or stream during dry periods.

High flows are a natural occurrence and happen when large amounts of water swell the river channel due to a storm event or rapid snow melt. High flows result when the land no longer has sufficient ability to store the water and are governed by geology, topography, land cover, and land use. Streams with a high surface run-off (either naturally or due to man-made changes in land cover) respond quickly to storm events, creating dangerous floods and erosion conditions. They also have lower and more irregular flows during dry periods. In general, the faster a watercourse responds to a storm event, the more likely the watershed is to lose important fish communities, to de-stabilize banks, and to degrade water quality.

The flow patterns and pathways of a river system control the movement and access of migrating fish from the mainstream into tributaries. There are windows of opportunity during high flow events that regulate the movement of fish into small tributaries. Many species of fish and invertebrates use the floodplain areas for reproduction and feeding when flow periods are sustained for long enough periods (Grand River Conservation Authority & Ontario Ministry of Natural Resources, 2005). Many hydrological factors control the productivity of aquatic communities, including:

- Quantity of water and its source;
- How it is delivered to the stream; and

- The magnitude, duration, and frequency of extreme flow patterns.

The Water Survey of Canada (WSC) operates an extensive network of hydrometric monitoring stations. 150 stations have been operational in New Brunswick at one time or another. There were eight stations in the Nashwaak watershed (currently two are operational) (Table 8). Locations are shown in Figure 21.

Table 8 Water Survey of Canada hydrometric monitoring stations in the Nashwaak watershed.

Station Number	Name	Available Data	Drainage Area (km^2)
01AL001	Penniac	1918-1919	1,660
01AL002	Durham Bridge	1962-current	1,450
01AL003	Hayden Brook	1970-1993	6.48
01AL004	Narrows Mountain Brook	1970-current	3.89
01AL005	Narrows Mountain Brook Branch 1	1975-1980	0.80
01AL006	Narrows Mountain Brook Branch 2	1975-1980	0.91
01AL007	Narrows Mountain Brook Branch 3	1977-1980	0.41
01AL008	Stanley	1982-1995	641

Source: (WSC, 2017)

The amount of run-off in a year is directly related of the amount of precipitation. The watershed as whole receives approximately 1116 mm of precipitation annually, based on 1981-2010 climate averages for Juniper and Fredericton. However, this has varied in recent years from a low of 691 mm in 2015 to a high of 1,310 mm in 1981. The last six years have been drier than the 1981-2010 climate averages. Like most eastern Canadian rivers, the Nashwaak experiences peak water levels and discharge in April-May, after the annual thaw, followed by a low flow period in the summer. A second, smaller pulse occurs in the fall (November) related to rain events associated with tropical storms in the Atlantic Ocean.

The mean daily discharge for the Nashwaak River at Durham Bridge between 1962 and 2013 was 36.23 m^3/s. Mean daily discharge has increased steadily from the 1960s to the 2010s and the river has experienced more extreme flows over the last decade compared to historically (Figure 32). This may be due to increased or heavier rainfall but is also probably being affected by amplified runoff due to more impervious surface in the watershed, which is causing the river to become flashier (or respond more quickly to rainfall events). The highest mean daily discharge occurred in 2005 (54.6 m^3/s) and the lowest in 2001 (20.8 m^3/s). Discharge rates were highest, on average, in April (mean 108.26 m^3/s) and lowest, on average, in August (mean 14.13 m^3/s). Mean daily flow at Stanley was 15.3 m^3/s from 1982-1993.

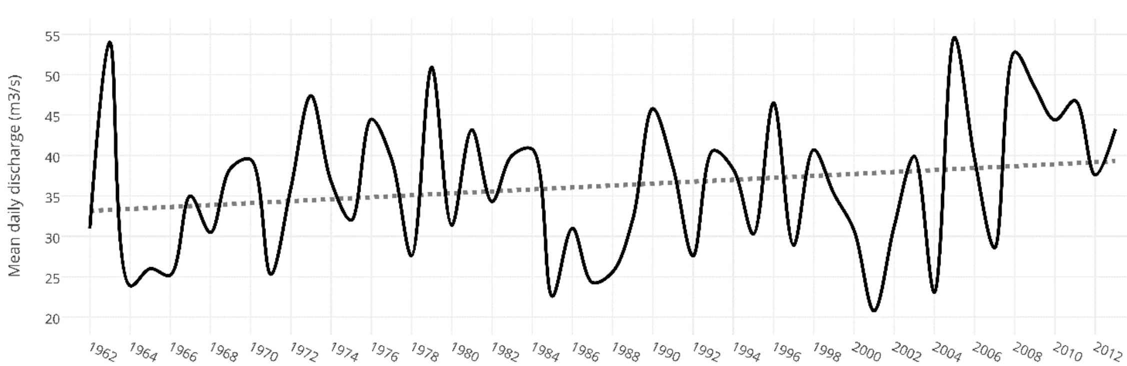


Figure 32 Mean daily discharge (m^3/s) per year at station #01AL002 (Durham Bridge).

Instantaneous peak flows (the highest flow at any one measured point during the year) for the Durham Bridge station averaged 442.91 m^3/s between 1962 and 2013 with the highest instantaneous flow occurring in 2010 (1,530 m^3/s on December 14th – well above the 1:100-year flood (Table 9)). The lowest instantaneous flows for the Durham Bridge were recorded in 2001 (2.16 m^3/s on September 20th).

Table 9 Flood flows (m^3/s) for the Nashwaak River (Durham Bridge station) at recurrence intervals in years determined by Cassie (1997) using a 3-parameter log normal distribution function.

Recurrence Interval	3	5	10	20	50	100
Flow Rate	321	478	580	676	799	890

Figure 33 Mean monthly flow (m^3/s) per month for four stations in the watershed. and Table 10 show mean daily discharge per month for four stations in the watershed. Full data tables for overall daily mean, maximum daily, and minimum daily discharge per year for the Durham station between 1962 and 2013 are available in Appendix B.

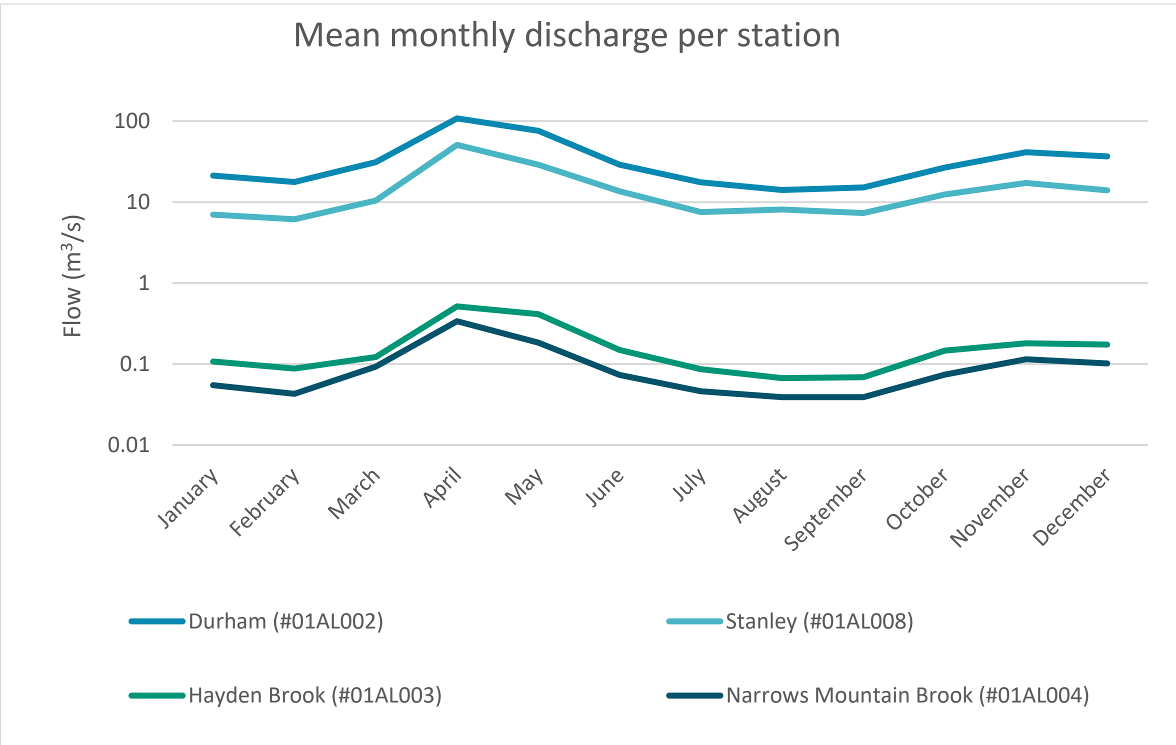


Figure 33 Mean monthly flow (m^3/s) per month for four stations in the watershed.

Table 10 Mean monthly flow (m^3/s) for four selected stations in the watershed.

	Durham (#01AL002)	Stanley (#01AL008)	Hayden Brook (#01AL003)	Narrows Mountain Brook (#01AL004)
January	21.2	7.02	0.107	0.055
February	17.7	6.13	0.088	0.043
March	31.0	10.4	0.122	0.093
April	108.0	50.8	0.515	0.338
May	75.8	29.0	0.412	0.183

June	29.0	13.6	0.149	0.073
July	17.6	7.52	0.086	0.046
August	14.1	8.08	0.067	0.039
September	15.2	7.32	0.069	0.039
October	26.7	12.4	0.147	0.074
November	41.4	17.2	0.181	0.114
December	36.7	14.0	0.174	0.102
Annual Mean	**36.2**	**15.3**	**0.177**	**0.010**
Years of data	1962-2013	1982-1993	1972-1993	1972-2013

Data: (WSC, 2017)

While carrying out the environmental impact assessment on the Sisson Brook Mine project, Geodex Minerals installed six hydrometric stations on small tributaries in the watershed. A summary of April 2008 stream flows for five stations can be found in Table 11 Mean daily stream flows for five stations installed near the Sisson Book mine in April 2008.

Table 11 Mean daily stream flows for five stations installed near the Sisson Book mine in April 2008.

Station Name	Flow (m^3/s)
Sisson Brook	0.063
Napadogan Brook	2.177
Bird Brook	0.047
McBean Brook	0.259
Chainey Lakes Outlet	0.235

Data source: (Rescan, 2008).

A 1999 report by NWAI showed that salmon returns during the summer/fall migration period correlated positively with discharge patterns (i.e., higher discharge equaled higher salmon returns). However, average discharge rates do not necessarily reflect opportunity for salmon to ascend to their spawning locations. High water in June/July combined with low water in August to October offers less opportunity for salmon ascent than does a dry summer combined with high water in October (NWAI, 1999).

If minimum low flow conditions occur more frequently compared to historical trends (i.e., changing from irregular to frequent) this can reduce spawning success, lead to a loss of juvenile fish, and deplete adult fish stocks. Smaller, cold-water tributaries are more susceptible to alterations of their baseflow. Larger cold-water streams are less susceptible to extremes but are vulnerable to longer-term low flows.

Industrial use of the Nashwaak River began more than two centuries ago with the construction of dams, initially for log driving and milling. The watershed has supported many industrial operations, including forestry, agriculture, saw mills, pulp mills, a cotton textile mill, fish hatcheries, and now gravel and soil mining. Increased development and urbanization puts more demand on the water resources of the watershed, which can affect the hydrologic regime. Additionally, increased impervious areas (pavement, etc.) limits the recharge potential of groundwater. These uses have had significant effects on the water quality and quantity of the Nashwaak watershed.

11.2.1 Water Levels

Only two stations, Durham Bridge (2011 to 2016) and Narrows Mountain Brook (2011 to 2016), measured water levels. In 2016, water levels reached 21.5 m in the spring at Durham Bridge and dropped to a low of 17.8 m in the summer and water levels averaged 18.29 m from 2011 to 2016. At

Narrows Mountain Brook in 2016, water levels reached 5.85 m in the spring and dropped to 5.09 m in the summer. Average water levels at Narrows Mountain Brook from 2011 to 2016 were 5.31 m.

11.2.2 Flooding

Though the Nashwaak River is short, its flooding potential is great. Areas susceptible to floods within the watershed are the mouth of the river, due to backup from the Saint John River, Penniac, Nashwaak Bridge, and the area around Stanley, which frequently experiences ice jams in the spring. Figure 34 shows the 1:100 and 1:20 year flood lines for the watershed as well as the flood envelope.

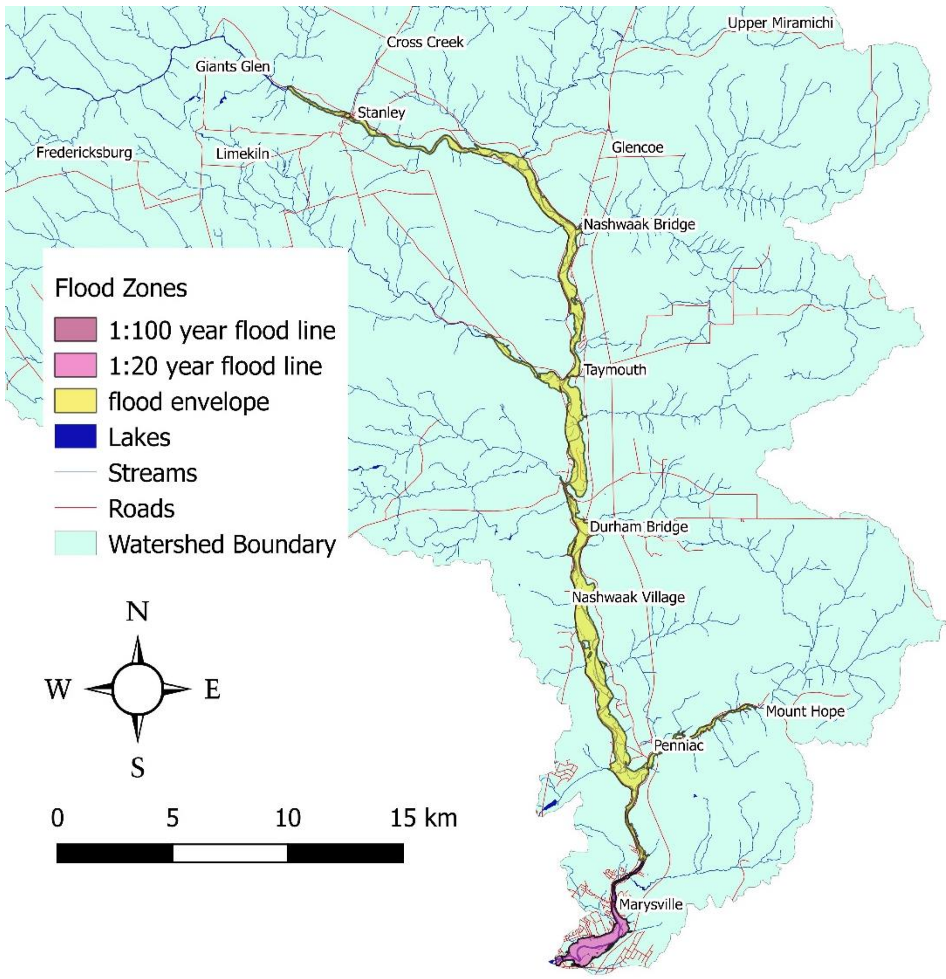


Figure 34 1:100 (dark pink) and 1:20 (light pink) year flood lines as well as the flood envelope (yellow) for the watershed. Data source: GeoNB.

Some of the worst recorded floods on the Nashwaak were in 1798, 1887, 1902, 1923, 1936, 1950, 1961, 1970, 1973, 1978, 1979, 1987, 1998, 2005, 2008, and 2012 (DELG, 2017). The flood of 1902 happened on March 19th when heavy rain and mild weather early in the spring created so much melt water that the dam above the Narrows gave way to the pressure of ice and water behind it. The raging water also carried away the Lower Lake Dam, the Foreman Dam (above Stanley), the mill dam at Stanley, the Murray Dam, several bridges, and millions of feet of sawed logs awaiting the spring log drive. Only the Covered Bridge above Penniac was spared; however, it was swept away in the 1923 flood. There was considerable damage to farms and homes and the railway was under water at several points (Young, 1984). The flood was province-wide and damages were estimated at over \$50,000.

The province-wide flood of 1923 washed out bridges, mills, logs, and rail lines, and damages were estimated at \$5-10 million at the time of the flood (equivalent to \$70-140 million in 2016). This flood cause the dam at Stanley to break causing a log jam that shifted the steel bridge at Marysville about 2 m. Flow during the flood was estimated to be 1,130 m^3/s at Marysville and the water rose 3.4 m (11 feet) in 36 hours at the mouth of the Nashwaak. The flood of 1940 caused a 3.5 km long ice jam between the mouth of Cross Creek and Covered Bridge. The flood of 1950 caused the highest water levels on the Nashwaak since 1923 and inundated the rail line. The floods of 1961, 1970, and 1973 also caused extensive damage to homes, property, roads, bridges, transmission lines, and railways. 1961 property damages totalled \$110,000 in the Nashwaak River basin alone (equivalent to \$901,000 in 2016). The 1970 flood caused over \$4,000 of damages to roads just in Marysville. The 2008 flood caused the highest water levels since 1973 (8.36 m in Fredericton and 22.25 m in Durham Bridge) and province-wide damages were estimated to be on the order of \$23 million (DELG, 2017). The 2012 flood caused the highest water levels at Durham Bridge since 1950 (22.54 m – about 4 m above average levels) (River Watch, 2017).

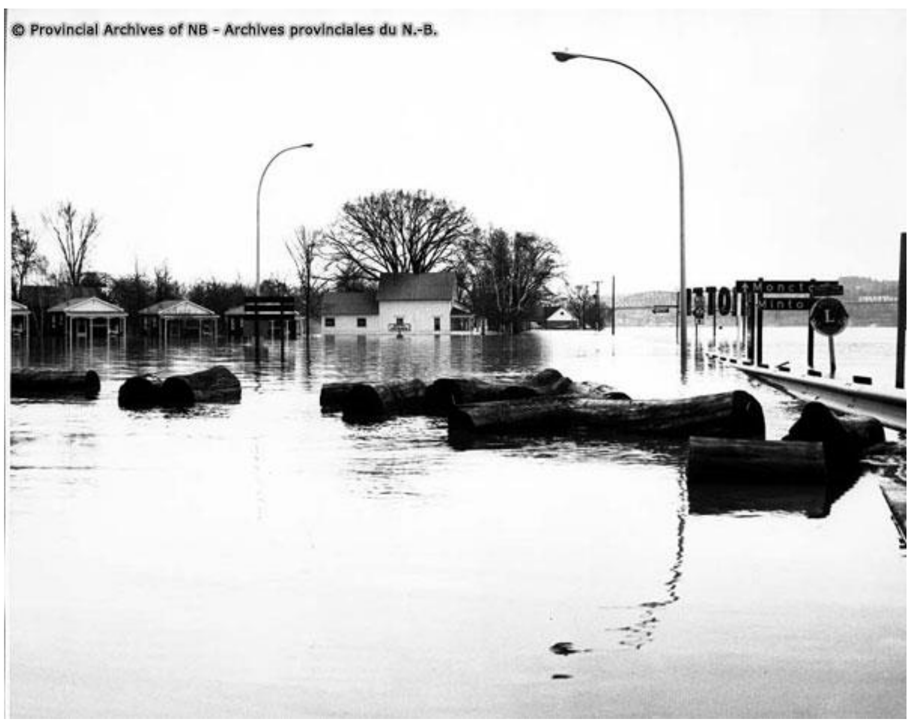


Figure 35 Barker's Point flooded in an undated photo. Source: NB Provincial Archives.

The NB Provincial Government implemented the River Watch program, with the goal of being able to better predict floods and improving flood preparedness in the Saint John River Basin. The Nashwaak Watershed Association is not currently participating in the River Watch program as the Nashwaak is not considered an Index River.

11.3 Water Temperature

The risk of extreme temperature events in a river increases with riparian zone alteration and water extraction (Caissie, 2006). Other factors that increase river temperatures include higher air temperatures, sedimentation, and input from water treatment plants. The removal of forests requires road networks, which typically lead to an increase in water temperatures and increased sediment in rivers. Both factors impact distribution of cool- and cold-water fishes (Curry & Gautreau, 2010). However, most present day operations are regulated to protect aquatic ecosystems. The persistent impacts from historical forestry operations remain unknown.

"Spring-fed creeks" occur in areas where there are deep deposits of coarse soils that infiltrate a large portion of rain or snowmelt and where water tables are large and steeply sloped. Spring-fed creeks have more uniform and stable flows and temperatures. They can be extremely productive habitat for cold-water fish and can protect fish from high summer water temperatures. Major upwelling or groundwater discharge areas are also critical locations for spawning and egg incubation. Areas of coarse gravel or sand with upwelling groundwater are the most sensitive and rare environments in a salmonid stream.

Warmer water contains less oxygen than colder water so as river temperatures rise and dissolved oxygen decreases, fish begin to experience stress, particularly salmonids (salmon, charr, and trout species). To escape warm waters in the mid-summer, many fish species will move to smaller, cooler tributaries or pools near cold seeps to survive. High temperatures can delay migration, exhaust energy reserves, which can result in reproductive failure, reduce egg survival, slow growth of fry and smolts, and decrease resistance to disease (McCollough, 1999).

Adult Atlantic salmon are less tolerant to high temperatures than juveniles. A DFO (2012) report determined that incipient lethal temperature (or the temperature that a fish can tolerate for at least seven days) was 27.8°C while for adults it was around 25°C. The report noted that juvenile and adult salmon begin aggregating near cool water sources and stopped feeding when minimum night time temperatures remained above 20°C for two consecutive nights. Therefore, 20°C is considered the threshold minimum temperature for assessing physiological stress in Atlantic salmon (DFO, 2012).

Optimum temperature for growth of juvenile salmon is in the range of 16-20°C (Elliott & Elliott, 2010). Parr growth occurs ideally at temperatures above 7°C (Allen, 1941). Smolt migration usually takes place at night during the spring when water temperatures are between 8 and 10°C. The Nashwaak RST recorded peak catches in the spring that corresponded to mean daily water temperatures of 8-10°C (Jones et al.,, 2014). The migration usually ends when temperatures reach 15°C, around the end of May (NWAI, 2003).

Limited temperature data exist for the Nashwaak watershed. Temperatures loggers were placed by the NWAI in at least seven locations in 2002 and several locations in 1999; however, the whereabouts of the raw data is unknown. Information was pulled from a NWAI's Water Classification report (NWAI, 2004). Temperature was also measured for some water quality grab samples taken between 1999 and 2015.

Measurements for water quality grab samples ranged from a low of 0.03°C in February 2011 to a high of 28.3°C in August 2015 (both extremes were measured at NASH-B, Marysville). Temperature of water quality grab samples exceeded 20°C 23 times and 24°C six times.

For the logger data from reports, measurements ranged from 0.3 to 25°C for the main stem of the river. Temperatures in the watershed peak from the last week of June to first week of August and then drop off quickly in September. NWAI's Water Classification report (NWAI, 2004) noted that overall results for the watershed were within acceptable range for salmonids and two tributaries (Messer's Brook and an unnamed tributary to the Tay River near its mouth) displayed temperatures of 8-11°C throughout the year, which are exceptional temperature regimes. Mean summer temperatures from the 2002 logger data ranged from a low of 14.38±2.48°C for Cathle Brook to a high of 17.05±3.81°C for Cross Creek Stream; however, data was not taken over exactly the same time period and its unclear if erroneous data (the loggers being in a truck, for example) were included in the calculations.

DFO has compared temperature regimes of several New Brunswick rivers. 1999 was a particularly warm year with five "heat wave" events between mid-June and late-August. The Nashwaak, Tobique, Little Southwest Miramichi, and the Tomogonops all reached 29°C that summer due to extremely high air temperatures. The Nashwaak was the most severely affected river with temperatures exceeding 23°C 67 days that summer (Table 12). Figure 36 compares various rivers across the Outer Bay of Fundy region. The Nashwaak appears to be much warmer than the Kennebecasis, the Gulquac, and the Shikatehawk but show a similar temperature profile to the Tobique-Arthurette.

Table 12 Number of days per year when maximum water temperatures exceeded 23°C.

Year	Nashwaak River	Little Southwest Miramichi River
1996	6	10
1997	24	14
1998	30	15
1999	67	62
2000	25	19
2001	46	52
Total	198	172

Source: (NWAI, 2004)

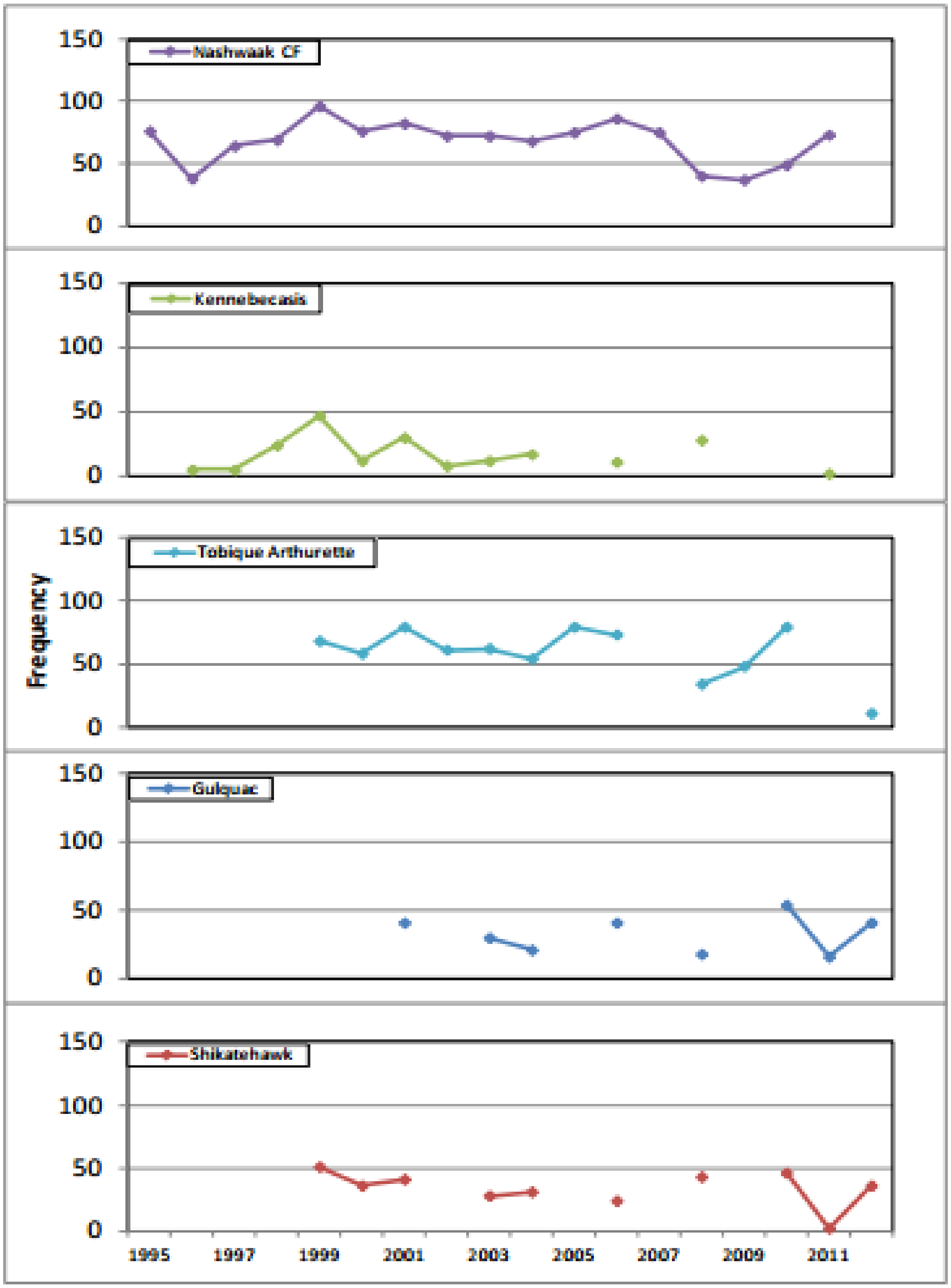


Figure 36 Frequency of days per year where minimum temperature was 20°C or greater recorded for the Nashwaak, Kennebecasis, Tobique, Gulquac (a tributary of the Tobique), and Shikatehawk rivers between 1995 and 2012. Data from Clarke et al. (2014).

Caissie et al. (2012) reported no apparent trend in the frequency of days in the year with minimum water temperatures above 20°C in select location in the Saint John River basin monitored since 1995. However, climate change is expected to increase both air and water temperatures. Western New

Brunswick is anticipated to experience some of the most dramatic increases in air temperature in Atlantic Canada (DFO & MNRF, 2009). Changes in the thermal regime of a river affect survival rate of species, invasive species presence and rate of spread, and overall biodiversity. Atlantic salmon and brook trout populations depend on cold water refuges and, therefore, are predicted to be highly affected by global temperature increases, which will reduce the number and extent of these thermal refugia (Monk & Curry, 2009). The location of thermal refuges in the Nashwaak watershed has yet to be studied. Creating an inventory would provide critical information for important restoration and management decisions, especially given the future compromise of cold water refuges due to global climate change.

12 AIR QUALITY

Because most of the Nashwaak watershed is uninhabited and remote, air is generally of very high quality. There is only one air quality monitoring station in the watershed, in Fredericton, which is run by the NB DELG and measures ozone, particulate matter, carbon monoxide, and nitrogen oxides. There is no acid rain monitoring station in the watershed. There were no exceedances of the NB objectives in 2012, 2013, or 2014. The 2014 average particulate matter daily metric levels were 14 $\mu g/m^3$, which is below the Canadian standard of 28 $\mu g/m^3$. Annual metric levels were 4.8 $\mu g/m^3$, the lowest in the province. Both daily and annual metrics were in the “Yellow Zone” management levels. Ground-level ozone annual metrics for 2014 were 50 ppb, below the Canadian standard of 63 ppb and in the “Green Zone” management level (DELG, 2016b).

Ground-level ozone and particulate matter are the primary components of smog. Ozone forms in the air when emissions from vehicles, machinery, power plants, and industry react with heat and sunlight. Particulate matter is airborne particles made up of several components, including acids, organic chemicals, metals, and soil particles. Particulate matter and ozone are linked to serious health problems including chronic bronchitis, asthma, and heart and lung disease. Other effects of these pollutants include reduced visibility, crop damage, and greater vulnerability to disease for some tree species. Emissions that cause air pollution can travel long distances.

Other air pollutants include sulfur dioxide, hydrogen sulfide, nitrogen oxides, carbon monoxide, and carbon dioxide. Most of these result as by-products of burning oil and coal or from industrial sources like pulp mills, waste water treatment facilities, livestock feedlots, and agriculture.

Acid deposition, also referred to as acid rain, is a generic term used to describe a process in which certain pollutants combine with moisture in the air. When this happens, it can create a very dilute acid, which in turn produces acid rain, snow, fog and dust particles. Acid rain harms sensitive ecosystems by changing the chemistry of lakes, streams, and forest soils. It can also damage trees and agriculturally important plants. Infrastructure is also impacted by acid rain, as it can degrade paints and protective coatings, which accelerates corrosion. The main sources of these acid-forming pollutants are vehicles, industrial facilities, and power-generating plants. However, more than half of the acid deposition we receive in New Brunswick is transported from sources in central Canada and the eastern United States (DELG, 2016). Levels of acid rain have declined significantly since the 1980s when measures to reduce the emissions that cause acid rain were undertaken. Emission reduction strategies have reduced sulphate and nitrate by about 77% since peak levels in 1989 (DELG, 2016b). Although levels have declined, acid rain monitoring remains important for New Brunswick because sensitive areas are still being impacted. Continued efforts are required to reduce emissions and ensure that our most sensitive lakes and rivers are provided with long-term protection from acid damage.

Mercury is typically released into the air when coal is burned to produce electricity at power plants, or from sources such as hazardous waste, among others. Once released into the air, mercury may end up in the ground or water. Biological processes transform the mercury into an organic form that bioaccumulates in fish, ultimately accumulating up the food chain and exposing humans and animals to mercury when they eat contaminated species.

In New Brunswick, our air is protected by the *Clean Air Act* legislation under the NB DELG. Air Quality Advisories are rare and usually happen in July or August due to forest fires in surrounding provinces or due to unusual wind patterns that cause elevated ground-level ozone. There were no Air Quality Advisories issued in 2014 (DELG, 2016b).

13 WILDLIFE

The Nashwaak watershed provides a significant amount of habitat for many mammals, amphibians, reptiles, fish, and birds. However, animals and plants that live within the watershed must now share their resources with humans. Through sound resource management, we should be able to balance the requirements and resource uses of people with the resources required to sustain animal and plant populations.

A typical Maritimes assemblage of wildlife is present within the watershed, including moose (*Alces alces*), white-tailed deer (*Odocoileus virginianus*), American black bear (*Ursus americanus*), eastern coyote (*Canis latrans*), American mink (*Mustela vison*), Canada beaver (*Castor canadensis*), striped skunk (*Mephitis mephitis*), porcupine (*Erethizon dorsatum*), raccoon (*Procyon lotor*), and varying hare (*Lepus americanus*). Small mammals such as red squirrel (*Tamiasciurus hudsonicus*), Eastern chipmunk (*Tamias striatus*), voles, shrews and mice are also common and widespread. Remnant populations of Canada lynx (*Lynx canadensis)*, pine marten (*Martes martes*), and fisher (*Martes pennanti*) exist as well, along with a confirmed Eastern cougar (*Puma concolor*) scat found at Nashwaak Lake in 1992 [(NWAI, 2004); (ACCDC, 2016)]. The Eastern cougar is considered *Data Deficient* under the Species at Risk Act (SARA) and has been extirpated from much of its range. (Forbes, McAlpine, & Scott, 2010) listed 38 species of mammal presently living in the SJR valley with another six possibly occurring. One species of mammal, the Maritime shrew (*Sorex maritimensis*) is endemic (occurs no where else) to the Atlantic Maritime Ecozone and occurs in Ecoregion 121, which includes the Nashwaak watershed (Forbes, McAlpine, & Scott, 2010). Several species have been extirpated from the region, including the grey wolf (*Canus lupus*), last recorded in 1921, the wolverine (*Gulo gulo*), last recorded before 1800, and the woodland caribou (*Rangifer tarandus*), which disappeared by the late 1920s (Forbes, McAlpine, & Scott, 2010). Beavers (*Castor canadensis*) were nearly extirpated in the 1840s due to exploitation but have recovered gradually since.

Fifteen amphibian and seven reptile species (25% of Canadian herpetofauna) can be found in the SJR basin (Canadian Rivers Institue, 2011). No non-native species are established. Most amphibians and reptiles remain widespread; but, one reptile, the wood turtle (*Glyptemys insculpta*) is listed as *Threatened* by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) and is protected by SARA (COSEWIC, 2007). There are several records of wood turtle within the Nashwaak watershed although a full survey has never been carried out.

There are 211 confirmed breeding species of birds in New Brunswick with 189 breeding in the SJR basin (Canadian Rivers Institue, 2011). Most of these birds are migratory so the species composition changes considerably throughout the year. Eight species have been introduced (mostly game birds, such as pheasant, grouse, and partridge). Other introduced but well-established species include the rock pigeon, the European starling, the house finch, and the house sparrow. One species, the passenger pigeon, was once one of the most abundant birds in the Maritimes and is now confirmed extinct due to heavy exploitation and habitat destruction (Sabine, 2010). The peregrine falcon disappeared as a breeding species from the Maritimes in the mid-1900s (owing to effects from contamination by pesticides such as DDT). The species is now re-occupying its historic range thanks to re-introduction programs. Protection of many species under the *Migratory Bird Act* has allowed them to rebound in numbers and recolonize historic breeding sites (Sabine, 2010).

Although as society we tend to assign more value to rare or at-risk species, it is impossible to have a healthy watershed without valuing the species and communities that both characterize and accentuate the landscape. At least 31 species of animals living in the Nashwaak watershed are listed as either *Endangered*, *Threatened, Special Concern,* or *Regionally Endangered* by SARA and/or COSEWIC (Table 13 Species at Risk confirmed to inhabit the Nashwaak watershed at some life stage).

Table 13 Species at Risk confirmed to inhabit the Nashwaak watershed at some life stage

Species	**Taxon**	**Status**	**Source**	**Importance of Nashwaak watershed to species**
Atlantic salmon ***Salmo salar*** **(Inner Bay of Fundy population)**	Fishes	Endangered	SARA	Pool & riffle habitat, cold tributaries
Striped bass ***Morone saxatilis*** **(Bay of Fundy population)**	Fishes	Endangered	COSEWIC	Feeding
American eel ***Anguilla rostrate***	Fishes	Threatened	COSEWIC, NB SARA	Juvenile and adult feeding
Shortnose sturgeon ***Acipenser brevirostrum***	Fishes	Special concern	SARA	Complete lifecycle
Redbrest sunfish ***Lepomis auritus***	Fishes	Data Deficient, Special Concern	COSEWIC, SARA	Complete lifecycle
Wood turtle ***Glyptemys insculpta***	Reptiles	Threatened	COSEWIC, SARA	Complete lifecycle, depend on beaches to lay eggs
Snapping turtle ***Chelydra serpentine***	Reptiles	Special Concern	COSEWIC, SARA	Complete lifecycle, live in shallow streams and ponds
Canada lynx ***Lynx canadensis***	Mammals	Endangered	NB SARA	Forested habitat, prey

Eastern cougar ***Puma concolor***	Mammals	Data Deficient, Regionally Endangered	COSEWIC, NB SARA	Forested habitat, prey
Little brown bat ***Myotis lucifungus***	Mammals	Endangered	COSEWIC, SARA	Prefers to roost and forage near water
Northern long-eared bat ***Myotis septentrionalis***	Mammals	Endangered	COSEWIC, SARA	Forested habitat, forage in forests
Bald eagle ***Haliaeetus leucocephalus***	Birds	Regionally endangered	NB SARA	Feeding, nesting sites. Fish are main prey.
Canada warbler ***Wilsonia canadensis***	Birds	Threatened	COSEWIC, SARA	Forested wetlands
Common nighthawk ***Chordeiles minor***	Birds	Threatened	COSEWIC, SARA	Nesting, feeding. Drawn to urban areas for insects
Olive-sided flycatcher ***Contopus cooperi***	Birds	Threatened	COSEWIC, SARA	Nesting in coniferous woods and feeding on insects near water
Chimney swift ***Chaetuar pelagica***	Birds	Threatened	COSEWIC, SARA	Roosting sites
Wood thrush ***Hylocichla mustelina***	Birds	Threatened	COSEWIC, NB SARA	Nesting and feeding, sensitive to forest fragmentation
Barn swallow ***Hirundo rustica***	Birds	Threatened	COSEWIC, NB SARA	Roosting sites and feeding
Bank swallow ***Ripara riparia***	Birds	Threatened	COSEWIC	Roosting sites and feeding
Whip-poor-will ***Caprimulgus vociferus***	Birds	Threatened	COSEWIC, SARA	Nesting in mixed woods, feeding
Bobolink ***Dolichonyx oryzivorus***	Birds	Threatened	COSEWIC, NB SARA	Benefits from abandoned hay fields
Eastern wood-pewee ***Contopus virens***	Birds	Special concern	COSEWIC, NB SARA	Nesting and feeding
Northern bobwhite ***Colinus virginianus***	Birds	Endangered	COSEWIC, SARA	Nesting and feeding in grasslands and abandoned fields
Bicknell's thrush ***Catharus bicknelli***	Birds	Threatened, Special Concern	COSEWIC, SARA	Breeds in coniferous forests
Least bittern ***Ixobrychus exilis***	Birds	Threatened	COSEWIC, SARA	Nests in marshes
Peregrine falcon ***Falco peregrinus***	Birds	Regionally Endangered	NB SARA	Nesting and feeding
Short-eared owl ***Asio flammeus***	Birds	Special Concern	COSEWIC, SARA	Feeds in open grasslands and abandoned fields
Barrow's goldeneye Eastern population ***Bucephala islandica***	Birds	Special Concern	COSEWIC, SARA	Breeds in wooded lakes and ponds, feeds on aquatic insects and crustaceans
Yellow rail ***Coturnicops noveboracensis***	Birds	Special Concern	COSEWIC, SARA	Breeds in meadows, fens, and shallow marshes
Monarch ***Danaus plexippus***	Insects	Special Concern	COSEWIC, SARA	Breeding, feeds on milkweed and nectar of wild flowers
Yellow lampmussel ***Lampsilis cariosa***	Molluscs	Endangered, Special Concern	IUCN, COSEWIC	Complete lifecycle

Data from (ACCDC, 2016) and COSEWIC website.

The Nashwaak River is home to 21-30 fish species, including both diadromous (sea-run) and freshwater species. It is noteworthy that at least five fish species that are considered *Endangered, Threatened*, or of *Special Concern* can be found in the watershed. A remnant Atlantic salmon (*Salmo salar*) population exists in the main stem and tributaries. The striped bass was recently upgraded to *Endangered* (COSEWIC, 2012).

Seven species of freshwater mussels can be found in the Nashwaak watershed (McAlpine & Smith, 2010). One species (the yellow lampmussel) is listed as *Endangered* by the International Union for Conservation of Nature (IUCN) and as *Special Concern* by SARA.

According to ACCDC (2016), there were 212 observations of 61 species of rare and/or endangered fauna within 20 km of the lower floodplain (below Stanley) (Figure 37). Additionally, there were 16,665 records of 127 vertebrate and 1,068 records of 71 invertebrate faunae; 8,826 records of 351 vascular and 149 records of 76 non-vascular florae within 100 km of the study area.

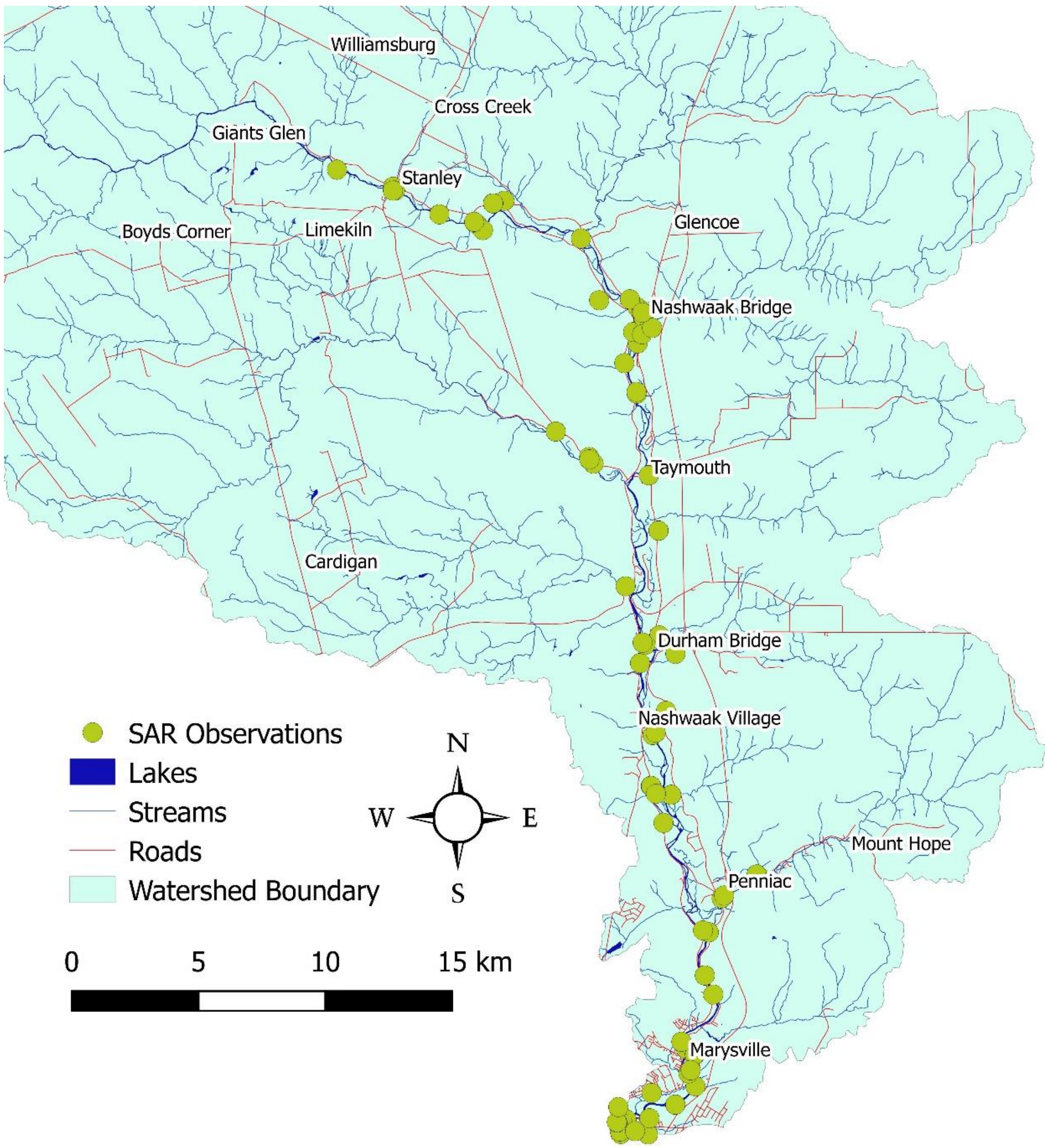


Figure 37 Observations of Species at Risk (Endangered, Threatened, or Special Concern) in the lower floodplain. Data from: ACCDC (2016).

13.1 FISH

The fish population of the Nashwaak watershed is diverse, consisting of 21-30 confirmed species (Curry & Gautreau, 2010). This represents 42-60% of all freshwater fish species found in New Brunswick. 50 freshwater species have been confirmed in New Brunswick but only 24 are thought to be native freshwater obligates, with another five introduced and now established, and an additional 13 species of native diadromous fish (those that move between fresh and salt water) (Curry & Gautreau, 2010). Some species distribution maps are available online at http://canadianriversinstitute.com/ and complete species lists are available in Curry & Gautreau (2010).

13.1.1 Fish Habitat

The NWAI has carried out habitat assessments targeted specifically at brook trout (NWAI, 1998) and Atlantic salmon (NWAI, 1999) habitat. Fifteen tributaries were surveyed between 1995 and 1998 with a total length and area surveyed of 42,594 m and 299,667 m^2, respectively. All streams assessed displayed good salmon habitat to varying degrees, with mixtures of pool, riffle, run, and rapids and a high proportion of gravel or rubble substrate. The average habitat was 41% riffle, 35% run, 14% pool, and 10% rapids. Substrate was, on average, 47% rubble, 23% gravel, 14% rock, 4% bedrock, 10% sand, and 4% fines. Temperature profiles, dissolved oxygen contents, and water quality were indicative of healthy salmonid-bearing streams, particularly in the upper Nashwaak and remote sections of tributaries. Sands and Cathle Brooks displayed particularly good spawning and rearing habitat for salmon, though the flow rate of Sands Brook was thought too possibly be too low to establish a self-sustaining salmon run.

Significant deforestation has happened in the watershed since 1945. Tributaries now appear as thin ribbons of forested buffers within almost entirely clear-cut areas. Effects from forestry, agriculture, and urbanization have all have negative impacts on fish habitat. Infilling of the substrate with fine sand and silt appears to be one of the major issues affecting spawning and rearing habitat in the Nashwaak watershed. Most of the scientific research and habitat restoration efforts have been focused on the remnant Atlantic salmon population, and, to a lesser degree, the brook trout population, probably due to their economic and cultural value.

13.1.2 Atlantic Salmon

The Outer Bay of Fundy (OBoF) population of Atlantic salmon, which includes the Nashwaak River, are anadromous fish, and, as such, reproduce in fresh water but spend most of their lives feeding and growing in the open ocean. Salmonids require clear, cool, well-oxygenated, flowing water free from pollution and siltation. They prefer natural channels with riffle and pool habitat, a gravel bottom, and temperatures below 23°C in the summer. The Saint John River is the third largest salmon producing river in New Brunswick (after the Miramichi and the Restigouche) and the Nashwaak is the largest salmon-producing tributary to the Saint John below the influence of the Mactaquac Dam. Amiro (1993) estimated that the Nashwaak watershed provides 5.69 million m^2 of salmon production area (gradient >0.12%), or 28.5% of the total salmon production area downriver of the Mactaquac Dam (Jones et al., 2010). The Tay River represents approximately 8% of the spawning and rearing habitat in the Nashwaak Watershed (NWAI, 1999). The OBoF Atlantic salmon population dropped by 64.3% over the last three generations (COSEWIC, 2010).

In the past, monitoring of Atlantic salmon in the Nashwaak watershed (by the NWAI, DFO, UNB, and other researchers) has consisted of:

1. A counting fence to estimate returns of wild and hatchery fish;
2. Surveys for juveniles at multiple sites;
3. Acoustic tracking of smolts to the Bay of Fundy;
4. A smolt wheel and a rotary screw trap (RST); and
5. Redd counts.

Locations of data collection are noted on a map in Figure 38. Below we present a brief overview of the findings of decades of research that is by no means exhaustive.

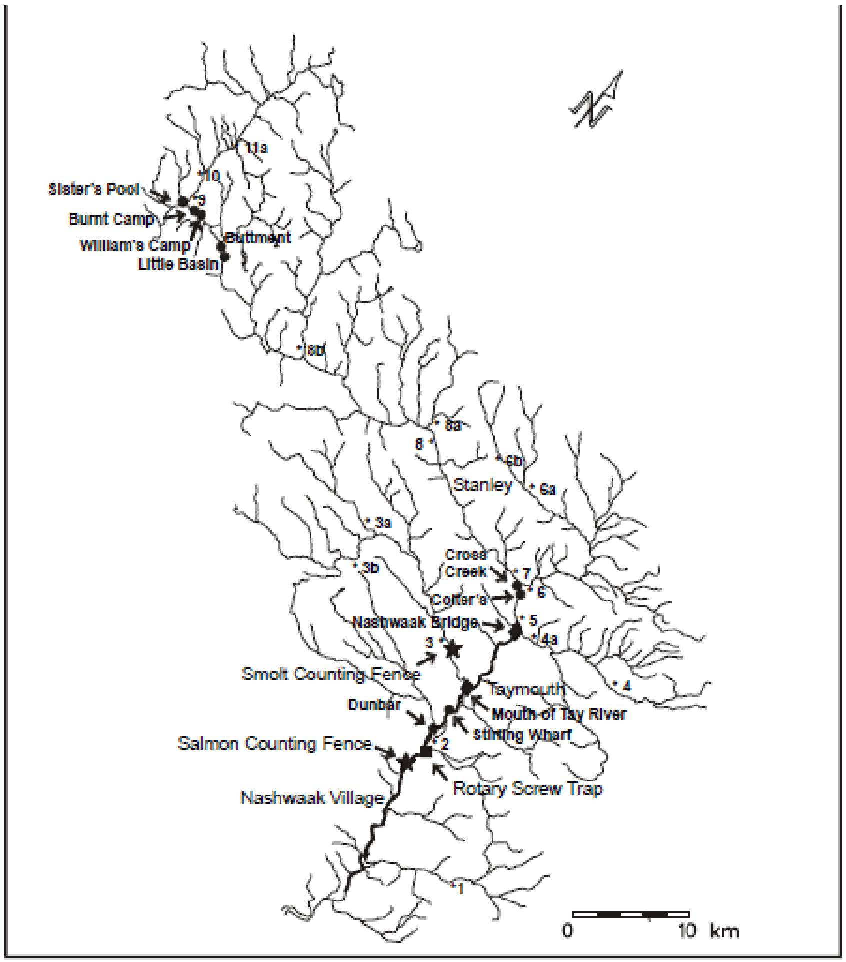


Figure 38 Map of the watershed indicating the adult counting fence site (star), rotary screw trap site (square), smolt fence (star), seined pools (circled), and electrofishing sites (*). Historical index sites for juveniles are 1,2,3,5,8,9, and 10. Source: Jones et al., 2010.

13.1.2.1 Overview of the Atlantic Salmon Life Cycle

For the Outer Bay of Fundy population, spawning typically occurs in late October or early November. Eggs are deposited in 10-30 cm deep nests, known as "redds", excavated in the gravel substrate. Milt from an adult male fertilizes the eggs. Hatching begins the following April and the larvae (known as "alevins") remain in the gravel until May or June, when they emerge as "fry" (Gibson et al., 2016). As they grow, their behaviour changes and they move to different habitats in the river. Fry reach a length of ~5-8 cm before transforming to “parr” in the autumn and developing vertical markings on their flanks that help them camouflage (ASF, 2017). Parr are young salmon actively feeding in freshwater. Wild-origin parr in OBoF rivers typically remain in fresh water for 2 to 6 years depending on water temperature and food availability (ASF, 2017). although most migrate out at age-2 or age-3 (Gibson et al., 2016). 70-80% of migrating smolts from the Nashwaak River are age-2 (NWAI, 2004b). Prior to their migration, parr undergo physical changes (smoltification) that allow them to survive in the ocean. This normally happens when the parr reach 12 to 24 cm in length (ASF, 2017). These juvenile salmon are now referred to as “smolt” and will migrate to the sea from late April to early June. Timing of the smolt run varies somewhat with environmental conditions (Gibson et al., 2016). Nashwaak watershed smolts migrate into the Saint John River at Fredericton and then to the Bay of Fundy, eventually swimming to their feeding habitat in the Labrador Sea near southwestern Greenland, where they feed on crustaceans and small fish. Adult salmon return to their natal rivers between April and November. Once in freshwater, they do not feed but live off fat reserves (ASF, 2017). See Figure 39 for a visual explanation of the life cycle of an Atlantic salmon.

For OBoF populations, salmon mature after either one winter at sea (when they are called “one sea-winter salmon” (1SW) or “grilse”), or two winters at sea (known as “two sea-winter salmon” (2SW)). Some salmon return to spawn multiple times and are referred to as “multi sea-winter salmon” (MSW).

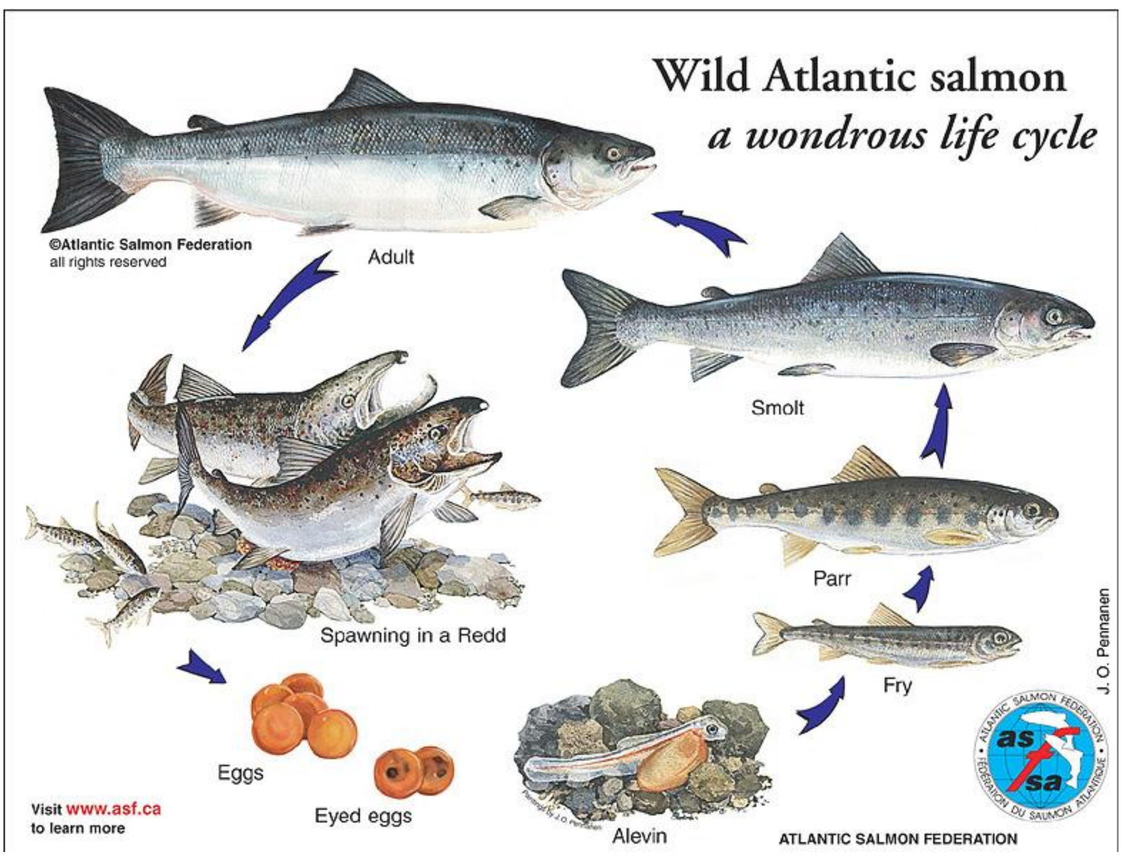


Figure 39 Life cycle of the Atlantic salmon. Source: (ASF, 2017).

13.1.2.2 Juvenile Surveys

Electrofishing surveys for juveniles (parr and fry) have been conducted annually at seven sites in the watershed since 1981 (Figure 40). An additional 19 sites were added in 2004/5 and 10 more sites were added in 2008. Electrofishing has been done by DFO in partnership with Woodstock First Nation. Juvenile densities have trended downwards over the last four decades (Fig. 24). In 2008, mean density of wild fry (age-0) at the seven historical sites and 10 additional sites was 7.4 fry/100 m^2 while mean density of age-1 and older parr was 6.4 fish/100 m^2 (Jones et al., 2010). By 2015 these numbers had dropped to 0.9 fry/100 m^2 and 2.2 parr/100 m^2. These numbers are more than an order of magnitude below Elson's norm reference value of 29 fry/100 m^2 and 38 parr/100 m^2 (Elson, 1967).

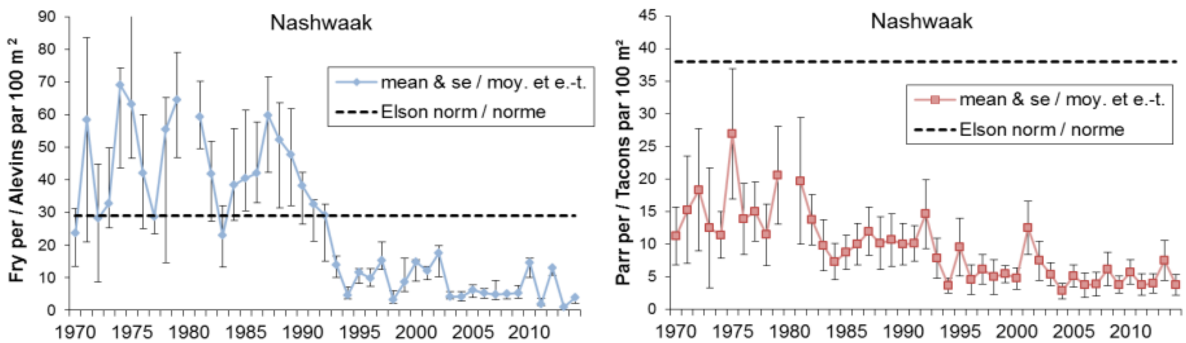


Figure 40 Fry and parr densities per 100m² from 1970 to 2014 on the Nashwaak River. From Jones et al. (2015).

Salmon parr data do not appear to be correlated to adult salmon returns. For example, parr densities in 1983-1986 were low while returns for 1984-1988 were strong. Conversely, parr densities in 1989-1992 were some of the highest recorded but preceded a crash in adult return numbers in 1993-1995 (NWAI, 1999).

13.1.2.3 Smolt Studies

A Rotary Screw Trap (RST) has been operating on the main stem of the Nashwaak River since 1998 and is a partnership between DFO and NWAI (Figure 38). The RST is operated between early May and early June when the smolt are migrating downstream and 33% and 100% of all wild and hatchery smolts are be measured and scale sampled, respectively. Scale and tissue samples are taken from all smolts suspected of being of aquaculture origin. All other species are counted. All obvious aquaculture escapees are lethally sampled. The Nashwaak River is one of the few rivers in the Maritimes with return rate data for wild salmon smolt (Table 14 Estimates of wild-origin Atlantic salmon smolt abundance upriver of Durham Bridge, production per unit area of habitat (smolts/100m²), ad the smolt-to-adult return rates for the Nashwaak River, 1998-2015 from DFO (2016).

Mark-recapture data generated an estimate of 7,900 wild smolts emigrating from the Nashwaak River in 2015 (DFO, 2016). DFO (2016) estimated 2015 smolt abundance in the Nashwaak River to be 0.15 fish/100 m^2, which is very low in comparison to the reference value of 3.8 smolts/100 m^2 (Symons, 1979). Smolt abundance has not been above 0.50 smolt/100 m^2 since 1999.

Table 14 Estimates of wild-origin Atlantic salmon smolt abundance upriver of Durham Bridge, production per unit area of habitat (smolts/100m²), ad the smolt-to-adult return rates for the Nashwaak River, 1998-2015 from DFO (2016).

Year	Mode	Smolts/100 m²	1SW return (%)	2SW return (%)
1998	22,750	0.43	2.91	0.67
1999	28,500	0.54	1.79	0.84
2000	15,800	0.30	1.53	0.28
2001	11,000	0.21	3.11	0.90
2002	15,000	0.28	1.91	1.26
2003	9,000	0.17	6.38	1.58
2004	13,600	0.26	5.13	1.28
2005	5,200	0.10	12.73	1.52
2006	25,400	0.48	1.81	0.62
2007	21,550	0.41	5.63	1.26
2008	7,300	0.14	3.86	2.05
2009	15,900	0.30	12.41	3.31
2010	12,500	0.24	7.86	0.35
2011	8,750	0.17	0.33	0.98
2012	11,050	0.21	1.63	0.29
2013	10,120	0.19	1.61	0.45
2014	11,100	0.21	2.86	NA
2015	7,900	0.15	NA	NA

A 2002 – 2004 project by NWAI, in cooperation with DFO, surgically implanted acoustic tags in salmon smolt from the Nashwaak River and tracked them to the Bay of Fundy. The final resting places of a portion of the acoustic tags from unsuccessful salmon smolt were located and the survival rate to various milestones in the seaward migration of smolt were calculated. In 2002, 58% of the smolts migrated out of the Saint John River successfully (NWAI, 2003). However, in 2003, only 37% of the smolt migrated out successfully (NWAI, 2004b). The areas of greatest concern in 2003 appeared to be the 10 kilometres between Penniac and the mouth of the Nashwaak River, where 6 smolt were lost. This may have been due to the late timing of the run and/or increased predation. Results of the 2002 and 2003 study showed that the area between Evandale and the mouth of the Saint John River is hindering smolt survival and migration with 44% loss in 2002 and 50% loss in 2003.

The average travel time to reach the mouth of the Saint John River from Durham Bridge was 151 hours with an average speed of 0.5 km/hr at the start of the migration and 1.0 km/hr near the end. Bottom water temperatures ranged from 8.8 to 13.6°C and surface temperatures from 9.9 to 11.7°C (NWAI, 2003; 2004b).

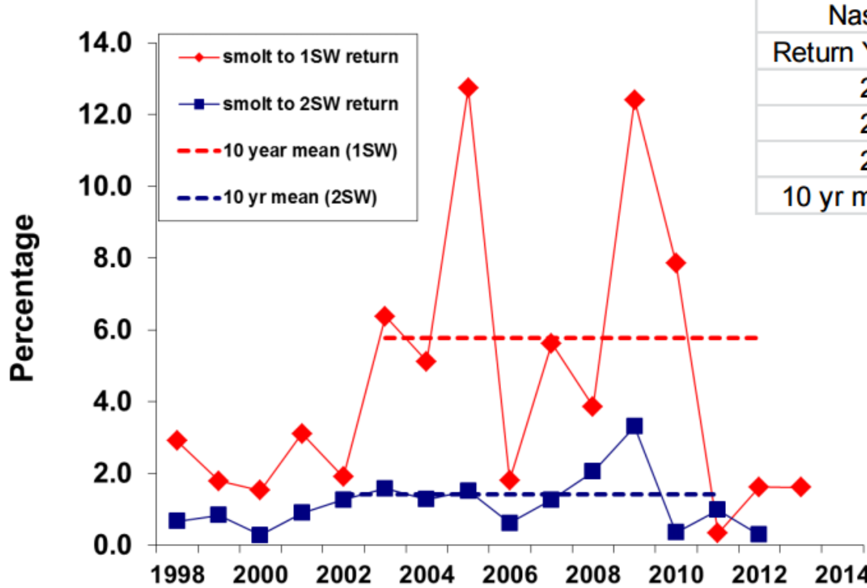
13.1.2.4 Adult Returns

A counting fence is located 23 km up the Nashwaak from the confluence with the St. John River and has operated from 1972-1973 and 1975 by DFO and, since 1993, in partnership with the Kingsclear and Oromocto First Nations (through the Aboriginal Fisheries Strategy) and the Nashwaak Watershed Association (Figure 38 and Figure 41). Counts are done between May and October. The fish that enter the river in the spring are thought to spend the entire summer in the river before spawning upriver of Stanley in October, while fish entering the river during the fall run in September spawn mostly in the lower reaches of the Nashwaak below Stanley (NWAI, 2006b). Seining adult salmon upstream of the fence is performed to obtain ratios of counted to uncounted salmon.

Figure 41 The Nashwaak counting fence in July 2016. Photo by N. Wilbur (ASF).

The fence counts are divided by the ratio of counted to uncounted fish to obtain a return estimate. DFO estimated the salmon returns for 1970-1978 and 1980-1982 inclusive based partially on salmon fry densities at eight electro-seining sites. Returns for 1986-1992 were calculated based on correlations between the numbers of salmon returning to Mactaquac and to the counting fence during years when data was available from both locations. Accurate returns for these years will probably never be available, therefore the data utilized here must be considered in light of possible inaccuracies.

The current year (e.g., 2016) 1SW and 2SW counts provide a return rate estimate for the smolt class of the previous years (e.g., 2015 smolt numbers would be used to calculate smolt-1SW fish and 2014 smolt numbers would be used to calculate smolt-2SW fish). Return rate for 1998 to 2013 is shown in Figure 42.



Nashwaak - wild smolt		
Return Year	1SW	2SW
2014	1.61	0.29
2013	1.63	0.98
2012	0.33	0.35
10 yr mean	5.78	1.42

Figure 42 Nashwaak River smolt-to-1SW and -2SW adults, as well as the 10 year means for 1SW and 2SW fish

In 2015, an estimated 318 1SW grilse returned from 11,100 smolts in 2014 for a smolt-to-1SW salmon return rate of 2.86%. The smolt-to-2SW salmon return rate was 0.45% from the estimated 10,120 smolts in 2013. Both the smolt-1SW and smolt-2SW return rates in 2015 were below the 1998-2014 long-term averages for the fourth consecutive year (Gibson et al., 2016).

Figure 43 shows counts of salmon returns for 1SW and 2SW fish at the fence between 1970 and 2015. The Nashwaak River had sufficient adult salmon returns, on average, to meet the spawning requirements to fully utilize the rearing habitat until the mid 1980s. Based on Marshall et al.'s (1997) conservation requirement calculation of 12.8 million eggs upriver from the counting fence, the number of spawners necessary would be 2,040 MSW and 2,040 1SW salmon. Returns of 2SW salmon began a steady decline around 1985. However, returns of 1SW salmon did not decline until the mid 1990s.

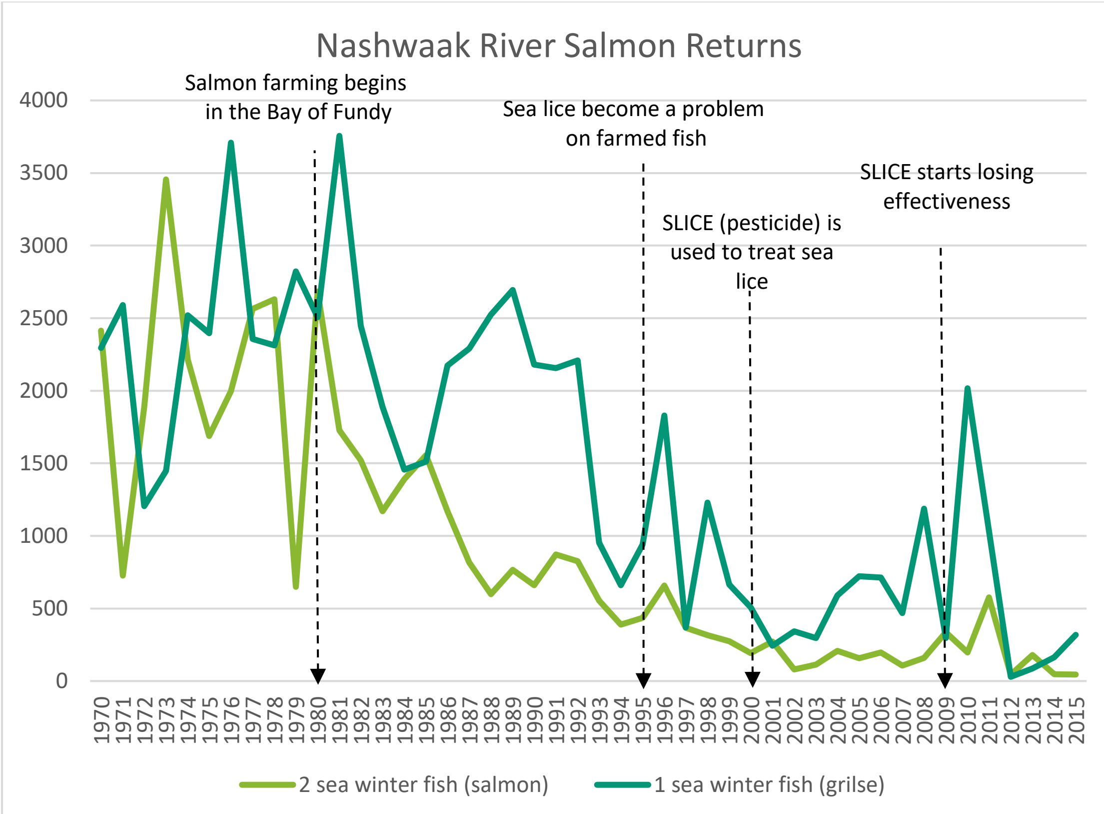


Figure 43 Salmon returns between 1970 and 2015 (Durham Bridge counting fence numbers). Data source: DFO.

From 1993 to 2002, previous spawners averaged about 25% of the returning Nashwaak River multi-sea winter (MSW) salmon, but have only comprised about 11% of the MSW returns since 2003 (Jones et al., 2010). Overall, 3.1% of 1SW salmon and 9.0% of 2SW salmon return to spawn for a second time in the Nashwaak River (Gibson et al., 2016). A population estimate is available in the following section. Table 15 summarizes the most recent available information (from Gibson et al., 2016) for Atlantic salmon on the Nashwaak River and compares it to data for the Saint John River.

Table 15 Atlantic salmon assessment information for the Nashwaak and St John rivers for 2015 (adapted from Gibson et al. (2016).

(Marshall, Jones, & Pettigre, Status of Atlantic Salmon Stocks of Southwest New Brunswick, 1996, 1997)	**Saint John River (above Mactaquac Dam)**	**Nashwaak River (above Durham Bridge)**
Angling Season	Closed	Closed
Assessment Techniques	• Fishway count • Juvenile electrofishing surveys • Pre-smolt assessment	• Counting fence (mark-recapture) • Juvenile electrofishing surveys above and below counting fence • Smolt assessment (mark-recapture)
Conservation (egg) requirement (millions of eggs)	32.30	5.35*
Fishway or Fence Counts:		
1SW Salmon	611	200
MSW Salmon	95	31
Marks/Recaptures/Captures	n/a	M=228/ R=20 / C=32

Estimated returns:		
-1SW Salmon	617	318
% hatchery	35%	n/a
-MSW Salmon	97	48
% hatchery	39%	n/a
% Conservation (egg) requirement		
-Without captive reared	2	6
-With captive reared	14	n/a
Captive-reared adult releases	1,013	n/a
Juvenile releases:		
-Age-1 Smolt	21,033 (May)	n/a
-Unfed Fry	552,000 (June)	n/a
-Age-0 Parr	237,063 (Sept/Oct)	n/a
-Age-1 Parr	n/a	n/a
Electrofishing densities (fish/100 m²)		
-Number of sites	16	10
-Age-0 Parr (fry)	2.0	0.9
-Total Age-1 and older Parr	2.1	2.2
Wild-origin pre-smolt/smolt estimate (2.5 and 97.5 percentiles)	4,690 (2,850-10,410)	7,900 (6,520-9,980)
Pre-smolt and smolt (fish/100 m²)	0.06	0.15

n/a = not applicable

*The conservation (egg) requirement reported by Marshall et al. (1997) was calculated based on the habitat area above the counting fence at Durham Bridge (i.e., 90%)

13.1.2.5 Salmon Redd Counts and Egg Survival

A salmon redd count was carried out on the upper portion of the main stem and a portion of the Tay River, Cross Creek Stream, and Limekiln Brook in 1998 (NWAI, 1999). The intent was to generate a mathematical model to compare red counts with the salmon return counts at the counting fence but data was insufficient to allow model creation. A total of 23 salmon redds were counted, with 16 of them being in Cross Creek Stream.

Egg survival studies were conducted by Rick Cunjack from UNB in 2001. The results indicated very low egg to fry survival in the Tay River and Cross Creek, possibly due to sediment loading of spawning gravels. The number of eggs/m^2 fell sharply in 2011 to almost zero but has slowly increased since then (Figure 44). Egg density is calculated using the percentage of females and the size of spawners. The Nashwaak is operating around 5% of the conservation requirement and the last five years have been below 10%.

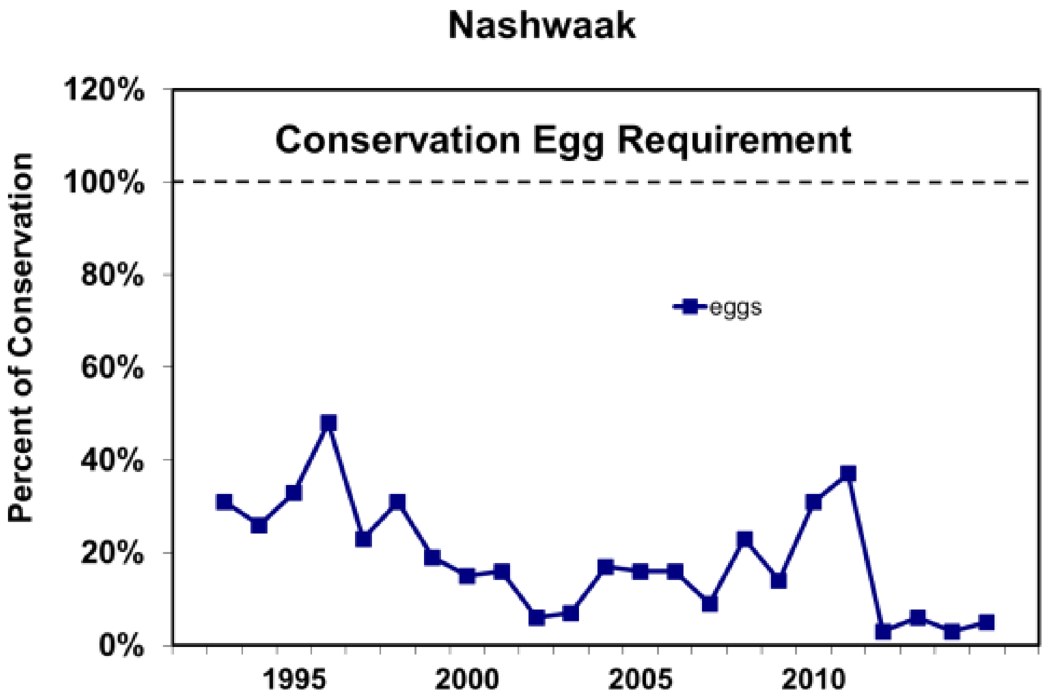


Figure 44 Estimated egg deposition in terms of the conservation requirement upriver of the counting fence 1993-2015. The dashed line represents the conservation requirement. Source: Jones et al. (2015).

13.1.2.6 Life History Parameters, Population Estimates, and Conclusions

The Nashwaak population is one of only two OBoF populations with enough data to estimate values for life history parameters (the other being the Tobique River population). For the Nashwaak, a model was set up by Gibson et al. (2016) using data from 1970 to 2011. Mortality from egg to mid-summer fry stages was estimated to be 96%. At most, 54% of the remaining fry survive to the age-1 parr stage. ~61% of the age-2 parr undergo smoltification in the spring and emigrate from the river. The estimated annual mortality of parr older than age-1 is 53%. Therefore, the survival rate from egg to smolt is only ~0.7%.

Based on their model, Gibson et al. (2016) concluded that smolt abundance in the 1970s and 1980s would have been 2 to 5 times higher than at present. The smolt production per 100 m^2 has decreased from 0.94 to 0.25 smolts over the last 10 years. These values are low relative to those seen in other Maritime rivers. The very low maximum survival rate from egg to smolt (0.7%) could be considered indicative of poor habitat quality.

In 2008 numbers of 1SW salmon were 60% of the conservation requirement and numbers of MSW were 8% of the requirement with an overall estimated adult abundance of 23% of the conservation requirement (Jones et al., 2010). This is down from an estimate of ~30% of the requirement in 1999. Number have since dropped to 5.8% in 2015. The MSW return five-year average has been below the conservation requirement since 1978 and the 1SW five-year average has been below since 1986 (NWAI, 1999). Given that the conservation requirement has only been met for 4 years since 1970, it is possible that the conservation requirement is set too high for the system (NWAI, 1999).

Historically, the Nashwaak River was the site of some of the best salmon angling in the Maritimes. It was also one of the few publicly accessible rivers that supported a significant recreational salmon fishery. Overall, the retrospective examination of the recreational fishery on the Nashwaak River population indicated that the fisheries did reduce population size, and that this reduction was great enough to have been a contributing factor to the overall population decline: a 60% reduction in egg depositions in the 1973-1982 period when retention fisheries were open for both large and small salmon (Gibson et al., 2016). All recreational and native fisheries have been closed on the Nashwaak River since 1998 and commercial fisheries affecting this population have been closed since 1984, so the lower proportion of previous spawners in the MSW returns is likely related to an increase in mortality at sea (Gibson et al. 2006). Freshwater threats, such as forestry, agriculture, and competition with invasive species, combined with low marine survival appear to be limiting the recovery of the Nashwaak River's Atlantic salmon population (Jones et al., 2010). Clarke et al. (2014) determined the top threats to the Nashwaak River salmon population include: silt and sedimentation, forestry, salmonid aquaculture, and diseases and parasites. Wild Atlantic salmon stocks of many Maritime rivers have declined at similar rates and salmon have been extirpated from some rivers. The biggest loss appears to be MSW spawners. Recovery to previous population levels with today's returns will be difficult.

According to Gibson et al. (2016), abundance trajectories for the present day Nashwaak River salmon population indicate that this population is expected to decline towards extirpation (local extinction) and has zero probability of reaching its recovery target. The probability of extirpation increases after about 40 years, with 28% of the simulated populations being extirpated within 100 years. In contrast, abundance trajectories using the past (1973-82) dynamics indicate rapid population growth. Using historical numbers, none of the simulated population trajectories extirpate within 100 years, but only about 55% of the simulated populations are above the recovery target, in any given year, 50 years in the future. The analyses indicate that in the absence of human intervention or a change in survival for some other reason, the Nashwaak River salmon will continue to decline. The Nashwaak River Atlantic salmon are extremely close to the threshold between disappearing forever and being viable (Gibson et al., 2016).

13.1.2.7 Sea Lice

Around 2000, a concern arose about the possible contribution of large numbers of aquaculture-origin sea lice causing mortality for smolt migrating through the Bay of Fundy. A pesticide, SLICE, was developed to control the sea lice but began losing effectiveness around 2009.

13.1.3 Other Fish Species of Concern

13.1.3.1 Brook trout

Like Atlantic salmon, brook trout also prefer cool, clear, clean, well-oxygenated waters. A relatively healthy population can still be found in Nashwaak and its tributaries. In the summer, brook trout look for cooler thermal-refuges (generally in the headwaters and tributaries) to escape from warm waters. Brook trout are highly valued as environmental indicators and sport fish but are not listed as a species of concern. Brook trout are stocked by NB DNR in Killarney and Upper Nashwaak Lakes (DNR, 2016). The brook trout is not a Species of Concern.

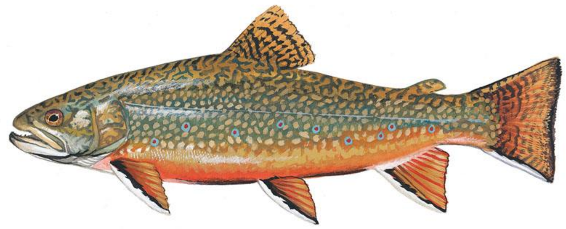


Figure 45 Brook trout drawing courtesy of the South Carolina Department of Natural Resources

13.1.3.2 American eel

The American eel (*Anguilla rostrata*) is listed as *Threatened* by COSEWIC (COSEWIC, 2012b) but has not been put on the SARA registry. The fish is catadromous, meaning that it spends much of its life in freshwater and migrates to spawn in saltwater. It is threatened by barriers to migration, mortality in hydroelectric dams, fisheries, pollutants, swim bladder parasites, and climate change (COSEWIC, 2012b).

Figure 46 American eel drawing courtesy of the American Eel Sustainability Association

13.1.3.3 Striped bass

Striped bass (*Morone saxatilis*) are considered *Endangered* by COSEWIC (COSEWIC, 2012) but have not been listed on the SARA registry. The striped bass was once commercially important in Eastern Canada and is still highly prized by anglers. It is an anadromous species that historically spawned in the Saint John River watershed. Spawning in Canada is currently limited to the Miramichi and the Shubenacadie Rivers. The disappearance of the Saint John River spawning population since 1979 is thought to be due to degraded water quality and changes in water flow (dam construction) (COSEWIC, 2012). However, striped bass have been recently caught on the Nashwaak.

Figure 47 Striped bass drawing courtesy of PixShark

13.1.3.4 Shortnose sturgeon

The shortnose sturgeon (*Acipenser brevirostrum*) is an ancient and long-lived species that can grow over 1 m in length and live over 65 years. Within Canada, it only occurs within the Saint John River watershed. In Canada, it is considered a species *of Special Concern* due to its limited distribution

(COSEWIC, 2005). It is listed as *Vulnerable* by the IUCN (Friedland & Kynard, 2004) and is on Appendix 1 of the Convention on International Trade in Endangered Species (CITES) The recreation fishery is regulated under the New Brunswick Fish and Wildlife Act. The SJR population is thought to be on the order of 5,000 to 15,000 fish (Friedland & Kynard, 2004).

Figure 48 Shortnose sturgeon drawing courtesy of the South Carolina Department of Natural Resources.

13.1.3.5 Redbreast sunfish

The redbreast sunfish (*Lepomis auritus*) is native to the southwestern New Brunswick. It prefers quiet, vegetated and rocky pools. Due to its small size, it is not often sought after as a sportfish. The Saint John River watershed represents the northern edge of its range. The redbreast sunfish is *considered Data Deficient* by COSEWIC (COSEWIC, 2008) and *Special Concern* by SARA due to its limited distribution in Canada.

Figure 49 Redbreast sunfish drawing from Maine Department of Inland Fisheries

13.1.4 Introduced or Invasive Species

Invasive species are one of the dominant causes of biodiversity loss around the globe (Hermoso et al., 2011). Competition with introduced species may lead to environmental or ecosystem shifts. Atlantic salmon and brook trout are vulnerable to competition with several species of non-native fish including: smallmouth bass (*Micropterus dolomieu*), muskellunge (*Esox masquinongy)*, chain pickerel (*Esox niger*), and rainbow trout (*Oncorhynchus mykiss*). Terrestrial invasive species include Japanese knotweed, garlic mustard, glossy buckthorn, purple loosestrife, woodland angelica, and common angelica. Introduced fungi include those that cause Dutch elm disease and butternut canker.

Smallmouth bass has slowly expanded its range in New Brunswick by both natural and unauthorized human introductions (Curry & Munkittrick, 2005). They were initially introduced into western New Brunswick (Lake Chiputneticook, St. Croix watershed) by anglers and by the government around 1869 as a sport fish and are now a dominant species in the system (Clarke, Ratelle, & Jones, 2014). These fish are of concern as they can compete with Atlantic salmon for habitat, as well as predate on juveniles (Valois et al., 2009). Smallmouth bass have been captured in the Nashwaak RST and at the counting fence (Figure 51) (Marshall et al., 1999). The species' popularity entices anglers to introduce it to new waters, unaware of the serious negative impacts that it can have on native fish communities (Curry & Gautreau, Freshwater fishes of the Atlantic Maritime Ecozone, 2010).

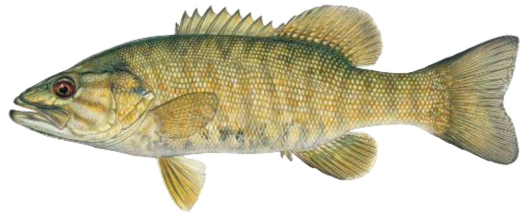


Figure 50 Smallmouth bass drawing courtesy of the Maryland Department of Natural Resources.

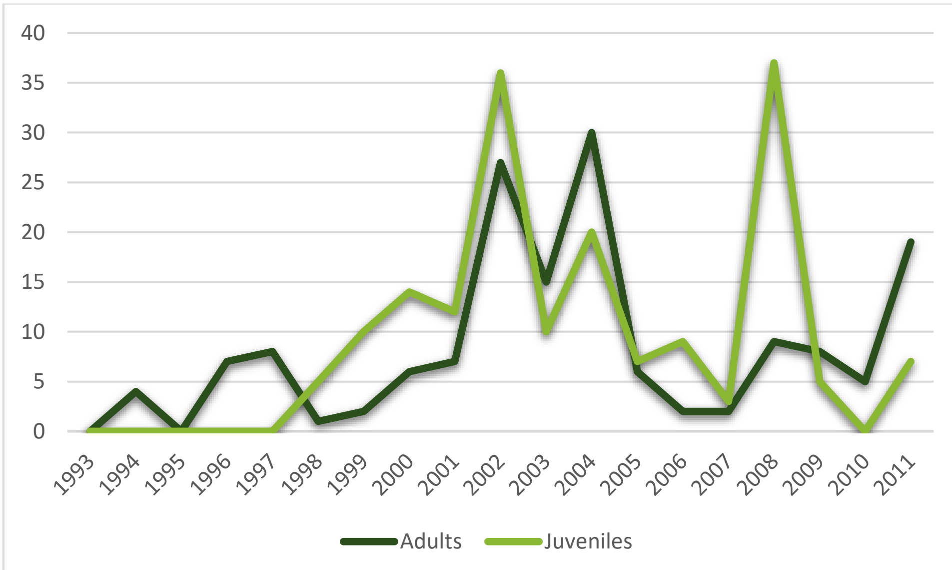


Figure 51 Counts of smallmouth bass (when identified) at the Nashwaak counting fencing (adults) and RST (juveniles). Data from Clarke et al. (2014).

Chain pickerel was introduced to NB in the 1800s by anglers and by the government and are now well-established in many rivers in southwestern NB (Curry & Munkittrick, 2005). The chain pickerel predates on juvenile salmon (Clarke et al., 2014).

Figure 52 Chain pickerel drawing courtesy of Arkansas Game and Fish.

Rainbow trout, one of the world's most widely introduced species, have been stocked in New Brunswick since the early 1900s as a sport fish and some populations are now considered naturalized (Thibault et al., 2009). In 2008, the Invasive Species Specialist Group listed rainbow trout as one of the "Top 100 Worst Invasive Alien Species" in the world. Rainbow trout compete with Atlantic salmon and brook trout for food and predate on juveniles, transfer disease, and reduce breeding success of the native species (Clarke et al., 2014). A rainbow trout was captured at the Nashwaak counting fence in 1996.

Figure 53 Rainbow Trout drawing from the Kentucky Department of Fish and Wildlife

Muskellunge (or muskie) were introduced into the headwaters of the Saint John River system in the 1970s as a part of a planned management introduction in the province of Quebec (Stocek et al., 1999). The species has now spread throughout the SJR watershed. Curry et al. (2007) determined that the impact of muskellunge to Atlantic salmon was variable, though they are known to predate on smolts. The same study reported a large tagged muskellunge (89.5 cm) that had migrated into the lower Nashwaak River. The species now supports a growing fishery from the Maine border to Fredericton (Curry & Gautreau, 2010).

Figure 54 Muskellunge drawing from Ontario Fish Species

Humans continue to directly alter the distribution of fishes across the Maritimes. Anglers hoping to enhance their fishing opportunities continue to stock these species illegally today and their distributions are predicted to expand in the future (Curry & Gautreau, 2010). Additionally, many aquaculture strains of salmon and trout are not indigenous to the region and the escapees can impact the genetic integrity of the native fish. Aquacultured fish can also pass non-endemic diseases and parasites to wild, native populations (Curry & Gautreau, 2010). Regulations exist to protect against threats from aquaculture but careful monitoring is lacking.

13.2 Fish Resource Use

Native fishers depended on healthy rivers, streams, and coastal waters to supply them with fish for thousands of years. The Mi'kmaq and Wolastoqiyik made the Atlantic salmon runs an integral part of their diet. Conflict with the European settlers over fish resources began in the late 18th century (Parenteau, 1998). Settlers places nets across rivers, blocking the salmon and other fish from traveling upstream and depriving those above the nets access to the fisheries (Dalton & Weatherley, 2005). These actions significantly impacted Mi'kmaq and Wolastoqiyik bands.

Overfishing caused dramatic reductions in the population of salmon, gaspereau, shad, bass, trout, and sturgeon throughout New Brunswick. Land clearing for agriculture caused erosion and siltation of watercourses, and forestry practices caused a reduction in water levels and increased summer water temperatures. Mill dams reduced the ability of salmon and other fish to reach their spawning grounds on many rivers and streams. Dams also destroyed spawning riffles and inundated floodplains. The log drives had a severe impact on fish populations as they reduced the fish's ability to navigate upriver. (The last log drive on the Nashwaak continued near Stanley until the early 1970s.)

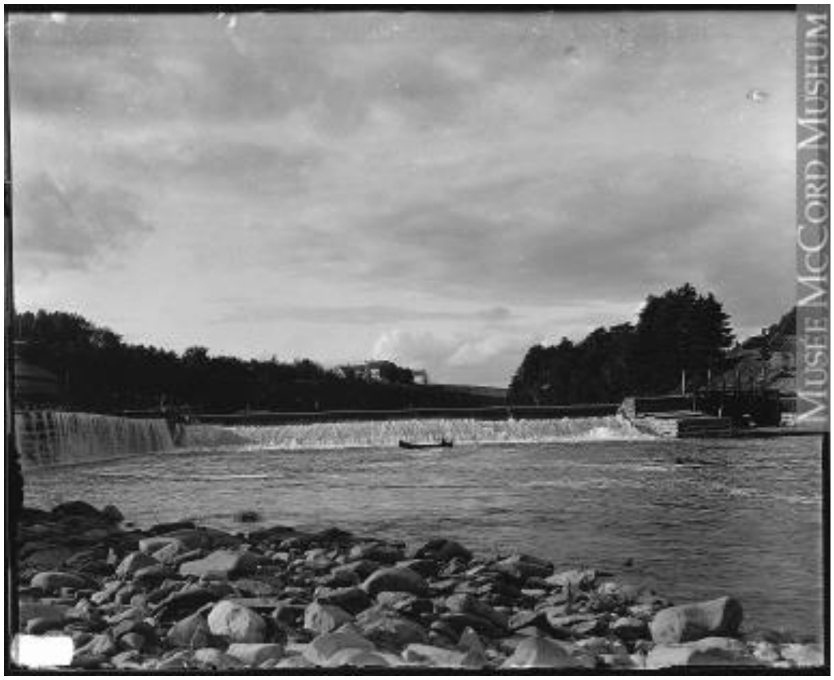


Figure 55 The Marysville dam in 1915. Source: McCord Museum archives.

Figure 56 A log jam on the Nashwaak River takes out a covered bridge circa 1915. Source: NB Provincial Archives.

The migratory behaviour of salmon and trout make them vulnerable to natural and man-made barriers. COSEWIC (2010) determined that dams, with and without fish passage, probably account for the majority of salmon habitat loss in North America. 70-80% of salmon habitat in the Maritimes was affected by dams built between 1815 to 1855. The Marysville dam (built around 1840) received much criticism for its impact on trout and salmon populations (the dam has since been removed). Commercial and industrial activities resulted in the river being used for waste disposal. Sawmills and lumber camps created huge amounts of pollution that was swept into the river (Parenteau, 1998). By the mid-19th century, the Department of Fisheries was somewhat successful in clearing waterways of mill debris but sawdust remained a persistent problem (Dalton & Weatherley, 2005).

The 1857 Fisheries Act was the first piece of conservation legislation passed and enforced in Upper Canada. Closed seasons for certain fisheries were implemented in the late 19th century. Gear restrictions and the requirement of fish-ways in mill dams were also instituted at this time. Much of the impetus to preserve fish populations came from the British colonial administration who were sport fishermen (Dalton & Weatherley, 2005). Native fishermen were banned from using their traditional harvesting methods and were eventually eliminated from the salmon fishery altogether.

Currently, there are no commercial fisheries operating in the watershed but there is an extensive recreational sport fishery on the Nashwaak River and some of its tributaries. The Nashwaak River is a popular angling river with a variety of fishing opportunities found throughout the watershed. The cold waters of the upper watershed provide high quality fly-fishing opportunities for trout. The lower watershed is easily accessible from Fredericton. The section above Penniac to the East Branch of the Nashwaak River is fly fishing only from July 1 and three other sections are closed to angling after June 15 (DNR, 2016).

Smallmouth bass has an open season from April 15 to October 15 in rivers and brooks and from May 1 to September 15 in lakes. Fishing for brook trout is permitted between April 15 and September 15 (DNR, 2016). Fishing is also permitted for non-sport fish during periods of the year when there is a sport fishery open, should these species be present: burbot (*Lota lota*), American eel (*Anguilla rostrata*), gaspereau/alewife (*Alosa pseudoharengus*), muskellunge (*Esox masquinongy*), chain pickerel (*Esox niger*), American shad (*Alosa sapidissima*), rainbow smelt (*Osmerus mordax*), striped bass (*Morone saxatilis*), white perch (*Morone americana*), whitefish (*Coregonus* spp.), yellow perch (*Perca flavescens*), and sturgeon (*Acipenser* spp.). There is no open fishing season for Atlantic salmon anywhere in the Nashwaak watershed. All recreational and native fisheries on the Nashwaak River have been closed since 1998. There are occasional reports of illegal fishing activities within the watershed but the contribution of these activities to the population decline is unknown.

13.3 Fish Rearing and Stocking

Stocking of game fish in New Brunswick began in the mid-1800s in an attempt to mitigate losses due to habitat destruction and overfishing. Stocking included both native fish, such as Atlantic salmon, as well as a number of non-native fish, such as: smallmouth bass (*Micropterus dolomieu*), muskellunge (*Esox masquinongy)*, chain pickerel (*Esox niger*), and rainbow trout (*Oncorhynchus mykiss*). Section 12.5 discusses the impact of these introduced species. Currently, brook trout are stocked in Killarney and Nashwaak Lakes (DNR, 2016). From 1947 to 1971, over 1.4 million salmon fry were stocked in the Nashwaak River (Meth, 1972).

Satellite rearing of salmon and sea-run trout has been quite popular with salmon conservation groups for the last few decades as it builds interest in the species and gives volunteers a "feel-good" experience. However, consideration was seldom given to the competition with wild fish and the localized overcrowding that releasing reared fry would create. The net gain to a salmon stream has been calculated to be ~10 salmon/year for every $4,000 and 200 person-hour investment, which does not represent an efficient salmon enhancement tool.

The NWAI started raising salmon fry in 1998. Hatchling salmon were reared over the summer to the fall fed fry stage for release into the wild. The fall fed fry program was intended to augment the declining Nashwaak salmon populations by circumventing much of the natural mortality that occurs between spawning and the end of the first summer of river life. In 1998, the NWAI constructed and operated a satellite rearing station that contributed as many as 40,000 six-week-old feeding Atlantic salmon fry in June and 30,000 fall fed fry in October (NWAI, 1999). The project continued to 2009 when 60,000 fry were being stocked annually.

The NWAI had a policy not to release reared fish into productive salmon streams, even if these streams were under-utilized. In this situation, competition with wild parr is avoided and the released salmon can generate self-sustaining salmon runs.

In 2004, a privately constructed Atlantic salmon gene banking facility was constructed and established in conjunction with stakeholders on the Nashwaak River (NWAI, 2006b). The facility was intended for rearing downstream migrating juveniles smolts towards spawning size in fresh water. The gene banking program was initiated to maintain at least a representation of Nashwaak salmon genetics in the case that ocean returns collapsed entirely. At the time, there was also concern that if returns diminished much more there was a possibility that a substantial portion of adult fish would be required for eggs and milt to supply hatchling salmon fry for the fall fed fry program. The gene bank would serve as a backup source of fertilized eggs if there was a total collapse of adults returning from the ocean. The project continued until the winter of 2005, when winter weather damaged the Tay Rearing Site.

In 2008, the NWAI assisted DFO with a comparative stocking study between unfed salmon fry in the spring and fall fed salmon fry released in the fall. Results of the study concluded that feeding salmon fry in tanks in the summer was counterproductive to their survival and growth to the life stage at which they migrate seaward as smolt (NWAI, 2009).

13.4 Fish Passage

The migratory behaviour of several fish species makes them vulnerable to natural and man-made barriers. These obstructions restrict adult fish from reaching spawning habitat upriver and prevent juveniles from reaching feeding grounds and thermal refuges. In general, obstructions greater than 3.4 m in height will restrict the upstream movement of adult salmon, while the ability of juveniles to pass barriers is much less (Powers & Osborn, 1985).

13.4.1 Man-made Barriers

It is believed that railway construction, along with dams, created barriers to fish passage beginning in the 1800s. Mill dams have been linked to the losses of anadromous fish in the region since at least this time (Curry & Gautreau, Freshwater fishes of the Atlantic Maritime Ecozone, 2010). Historically Sands and Cathle Brooks were inaccessible to fish but the barriers were removed by washouts in the 1980's

(NWAI, 1998). Until its removal in 2012, the Barker Dam below Nashwaak Lake was preventing fish passage for two to three months of the year (Smith, 1969). A dam on Campbell Creek in Marysville is a barrier but in 2016 it had sprung a leak and a discussion had begun about its potential removal. Historically a log driving dam (Irving Dam) operated on the Nashwaak River just below the "Narrows" but it was not considered to be a barrier to fish passage. Marshall et al. (1997) identified an additional four barriers to fish migration although the one identified at the mouth of Mackenzie (Young) Brook is no longer considered a barrier as wild juvenile salmon have been captured during electrofishing surveys above the barrier (Jones et al. 2004).

A full culvert and fish passage assessment has not been conducted in the watershed but many culverts exist along both the main stem and the tributaries. A fish passage assessment of the watershed is due to begin in 2017.

13.4.2 Natural Barriers

Dunbar Falls, an impassable waterfall on the Dunbar Stream, approximately 0.8 km upstream from its confluence with the Nashwaak River, is a natural barrier to salmon migration. There are also several smaller falls throughout the watershed that may be barriers to fish passage.

14 BENTHIC MACROINVERTEBRATES

Benthic macroinvertebrate (BMI) are aquatic animals without a backbone that live at or near the bottom substrate of the river and are large enough to see with the naked eye. This community includes insect larvae, leeches, worms, and snails. The diversity and number of invertebrates serves as an overall indicator of local water quality since macroinvertebrates have low mobility compared to other organisms. Monitoring BMIs is, therefore, a useful way to assess the spatial extent of potential environmental impairments.

There are four major groups in the BMI community: shredders, filter-collectors, grazers, and predators. Shredders feed on plant material and some dead animal material and break it down into smaller pieces (e.g., stoneflies [*Plecoptera*]). Collectors feed on fine particulate matter in the water column (e.g., caddisflies [*Dicoptera*] and blackflies [*Diptera*]). Grazers feed on algae and other plant material on rocks and other surfaces (e.g., snails and beetles [*Coleoptera*]). Predators feed on other macroinvertebrates (e.g., dragonflies [*Odonta*]). Individual species may fit into more than one of these groups (DeLange et al., 1994).

Macroinvertebrates dominate in clear, clean water though certain pristine environments may have low species diversity due to cold temperatures and/or low nutrient levels. Most macroinvertebrates are found in riffles of streams. The flow of water over these areas oxygenates the water and provides food particles. Slow flow areas tend to be dominated by decomposer communities that can tolerate lower dissolved oxygen levels and higher sedimentation. As turbidity and sedimentation increases, rock dwelling or attaching BMIs such has mayflies, stoneflies, and caddisflies will be replaced by silt-tolerant snails, leeches, and aquatic worms. BMIs can be categorized as either pollution sensitive, somewhat sensitive, or tolerant.

Pollution sensitive: *Plecoptera* (stonefly larvae), *Ephemoptera* (mayfly larvae), and *Trichoptera* (caddisfly larvae) require a high dissolved oxygen content and tend to be found in cold, flowing water with a gravel bottom (Peckarsky et al., 1990). These groups cannot tolerate any level of organic pollution.

Somewhat pollution sensitive: *Coleoptera* (aquatic beetles) adults are more tolerant of low oxygen conditions and low pH as they live at the air-water interface. Larvae are more sensitive and prefer clean waters. *Odonata* (dragonfly and damselfly nymphs) prefer slow-moving water. They can withstand lower oxygen levels and are more tolerant of organic matter enrichment (Peckarsky et al., 1990).

Pollution tolerant: *Diptera* (midge and blackfly larvae) live on silty bottoms or on solid substrates. They can tolerate fairly high levels of pollution (Peckarsky et al. 1990). Other pollution tolerant families include leeches, aquatic worms, and snails.

14.1 Benthic Community of the Nashwaak River

The BMI community of the Nashwaak River was sampled in eight locations in October 2001. Organisms were identified to the lowest taxonomic level (genus or species, but sometimes only family). The sampling procedure involved placing a bag of rocks in the river and later characterizing the types and number of organisms present.

The Hilsenhoff Biotic Index (HBI) was calculated for each replicate based on tolerance values reported in Hilsenhoff (1987) and Hilsenhoff (1988). The tolerance value is a number between 0 and 10 that is assigned based on pollution sensitivity (Table 16 Hilsenhoff Index for water quality and degree of organic pollution The HBI is a scale for measuring the quality of the environment and provides a simple measure of stream pollution. It is calculated as follows:

$$HBI = \frac{\sum(n_i * a_i)}{N} \text{ where:}$$

a = tolerance value for taxon *i*
n = number of specimens in taxon *i*
N = total number of specimens in a sample

Table 16 Hilsenhoff Index for water quality and degree of organic pollution

Family Biotic Index	Water Quality	Degree of Organic Pollution
0.00-3.75	Excellent	Unlikely
3.76-4.25	Very Good	Slightly possible
4.26-5.00	Good	Some probable
5.00-5.75	Fair	Likely fairly substantial
5.76-6.50	Fairly Poor	Likely substantial
6.51-7.25	Poor	Likely very substantial
7.26-10.00	Very Poor	Likely severe

Six families were present in 2001: *Plecoptera, Ephemoptera, Trichoptera, Coleoptera, Odonata,* and *Diptera*. The high percentage of *Plecoptera, Ephemoptera,* and *Trichoptera* in the samples (between 69 and 80% of the total specimens) indicates that the water quality was excellent at the time of sampling. Only one replicate sample (replicate A from NASH-N [Narrows Bridge]) was outside the range for Excellent water quality (at 3.88 it was classified as Very Good). Table 17, below, summarizes the data from 2001.

Table 17 Summary of benthic macroinvertebrate sampling in 2001.

Site	NASH-B Marysville Bridge	NASH-E Durham Bridge	NASH-G Tay River	NASH-H Above Tay River	NASH-J Cross Creek	NASH-K McLaggon Bridge	NASH-L Currieburg	NASH-N Narrows Mountain	NASH-T Napadogan Bridge
Total # individuals	361	1322	1033	450	563	727	781	406	659
Taxonomic richness	39	58	51	50	43	49	45	31	45
Most abundant taxon	E/P	T	E	E	E	E	T	T	T
Total # EPT taxa	41	44	40	38	33	34	36	24	33
% EPT	79%	76%	78%	76%	77%	69%	80%	77%	73%
Site HBI	2.88	3.44	2.74	2.78	3.00	2.60	2.46	3.64	2.32
Classification	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent

E – Ephemoptera
P – Plecoptera
T – Trichoptera
HBI – Hilsenhoff Biotic Index / Family Biotic Index

15 VEGETATION AND RARE PLANTS

The forests of the Nashwaak watershed have been logged since the 1700s (DNR, 2007), which has led to patchy stands of young forest along the river and its tributaries. Forestry is still one of the major industries in the watershed despite the closure of several sawmills. Older forests are mostly mature softwoods, while new growth forests are a mixture of hardwood and softwood.

There are at least thirteen rare plants (S1, S2) noted in the watershed floodplain, and listed in Table 18.

Table 18 Rare plants in the Nashwaak watershed. Data from AC CDC (2016).

Species	Status	Source for Status
Butternut ***Juglans cinerea***	Endangered	SARA, COSEWIC
White adder's mouth ***Malaxis brachypoda***	S1 Critically imperiled	NBDNR
Kalm's hawksweed ***Hieracium kalmia var. fasciculatum***	S1 Critically imperiled	NBDNR
Anticosti aster ***Symphyotrichum anticostense***	Regionally Endangered	NB SARA
Prototype quillwort ***Isoetes prototypus***	Regionally Endangered	NB SARA
Woodland pinedrops ***Pterospora andromedea***	Regionally Endangered	NB SARA
Water smartweed ***Polygonum amphibium var. emersum***	S2 Imperiled	NBDNR

Orange-fruited tinker's weed ***Triosteum aurantiacum***	S2 Imperiled	NBDNR
Round-lobed Hepatica ***Hepatica nobilis var. obtusa***	S2 Imperiled	NBDNR
Shining ladies'-tresses ***Spiranthes lucida***	S2 Imperiled	NBDNR
Lance-leaved figwort ***Scrophularia lanceolate***	S2 Imperiled	NBDNR
Calypso ***Calypso bulbuosa var. americana***	S2 Imperiled	NBDNR
Small yellow lady's slipper ***Cypripedium parviflorum var. makasin***	S2 Imperiled	NBDNR

16 RIVERBANK STABILIZATION (TREE PLANTING)

Both the 2005 soil erosion survey (NWAI, 2005) and the 2016 geomorphic survey (Parish Aquatic Services, 2016) noted that riverbanks with established, mature vegetation were more stable than those without mature vegetation. The 2005 NWAI report concluded that the composition of the flora on the riverbanks and adjacent riparian zone appeared to be the most important factor influencing the rate of erosion. The Nashwaak River watershed is fairly small (1,707 km^2) but most of its landscape has been altered either by forestry, agriculture, or by urbanization. Restoring native trees to the riparian landscape will help to address watershed health issues and could have many positive ecological benefits such as:

- **Erosion control**: Roots will hold sediment in place and the tree canopy will slow down rain water, which can help improve its retention and absorption.
- **Absorption of runoff**: A well-forested riparian zone will absorb storm water before it reaches the river and will slow it down significantly. This allows nutrients to be used and contaminants to be filtered before they enter the watercourse.
- **Shading**: The presence of trees will provide streamside cover, helping to cool the water temperature, which increases its oxygenation. This will prevent the spread of bacteria and algal blooms and increase biodiversity by improving instream habitats. Cooling the water will also reduce the stress on aquatic organisms.
- **Providing shelter**: The shelter of the tree canopy will also help shade the terrestrial landscape and moderate ground temperatures, which can minimize competition from grass and encourage the survival of micro-organisms. Eventually this will improve the soil conditions and promote the development of other Acadian tree species, increasing habitat complexity.
- **Prevent the spread of invasive species**: Planting native species leaves little room for invasives to spread.
- **Provide food**: The addition of organic debris and decaying foliage will provide food and nutrients to the river.
- **Carbon sequestration**: Trees remove carbon dioxide from the atmosphere and store it in their wood. The carbon is locked up until the tree is burned or decomposes.

The Nashwaak River is threatened by riparian damage (Figure 57). The presence of old growth Acadian upland and floodplain forests are essential to maintain and restore the ecological health of the Nashwaak watershed. The NWAI believes that planting native shrubs and trees along the eroded riverbanks, combined with cattle fencing (where necessary), is the most environmentally sustainable and cost effective technique available for reducing erosion and loss of land. Therefore, NWAI started tree planting in 2005 in an effort to stabilize riverbanks.

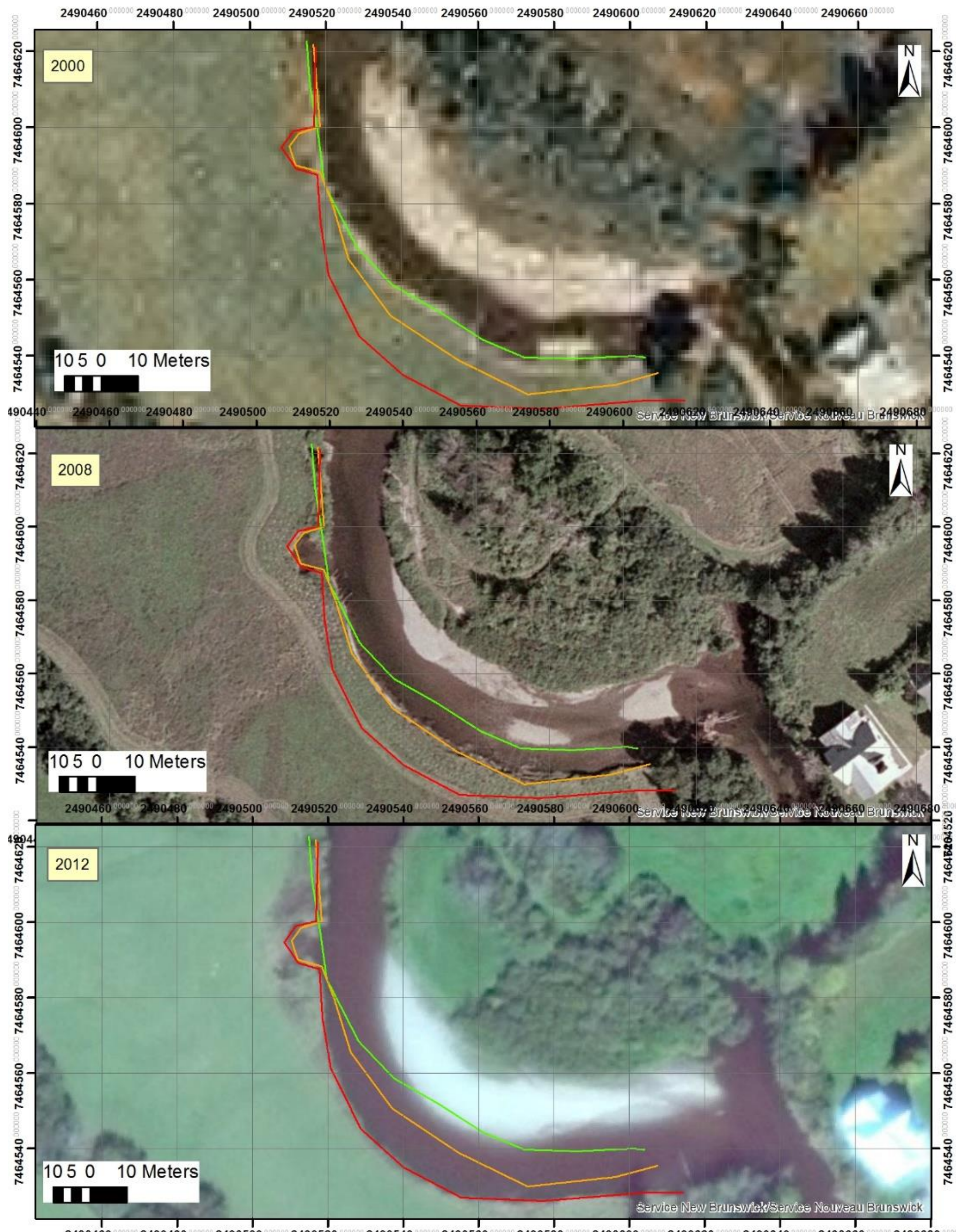


Figure 57 Change in the shoreline of the mouth of the Tay River from 2000 to 2012. Source: Nathan Wilbur, ASF (pers. comm.).

Replanting banks with native vegetation may reduce soil erosion to its natural rate and may limit sedimentation of the river. However, planted trees and seedlings require sufficient time to become deep-rooted and well-established. This can be accomplished by planting the young trees far enough from the river that they will not be lost to erosion, ice scour, or high water episodes. Since it takes several decades for trees to grow large enough to shade the stream, it may be a long time before we detect a stream temperature response to planting efforts. In the meantime, fish may find refuge in small shaded tributaries in the headwaters.

Factors that can limit the long-term success of riverbank stabilization tree planting are: ice scouring of the banks, severe and repeated flooding of the project sites, and/or soil erosion at a high enough rate that the seedlings are lost before they are mature. NWAI has also observed that by mowing the grass, especially around trees planted in abandoned hay fields, survival rate of the seedlings increases.

The tree planting project started with the goal of re-establishing vegetation on ecologically degraded land and to collaborate with landowners to improve ecological health. Another goal was to engage volunteers in the tree planting efforts, especially youth. In the 2005/6 field season, five sites with a total length of 1,450 m on private land were planted with a variety of species totally 4,722 seedlings and acorns. Landowners were identified through the 2004/2005 soil erosion study and contacted to gauge their interest in participation. Unfortunately, mortality rates were above 90% due to predation of acorns by raccoons (over 1,200 lost), damage due to farming practices and mowing, as well as high water and ice scouring events that swept away small seedlings close to the river. Acorns planted from 2006 onwards were planted with a repellant (black pepper) to deter predators (NWAI, 2007). Acorns were also planted in the spring instead of the fall, when predator rates are higher. In 2006, willows and alder seedlings were planted further up the eroding bank, which reduced mortality to about 75%. From 2007 onwards, NWAI planted cuttings or live stakes of willows directly into the eroding banks instead of planting seedlings as the cuttings are easier to plant and cheaper to obtain (NWAI, 2008).

By early 2009, approximately 1,700 of the 4,900 seedlings (35%) planted between 2005 and 2008 were well-established (had survived at least one winter). Table 19 outlines the numbers of seedlings, acorns, and cuttings planted per year and the length of riverbank planted. Between 2005 and 2016, NWAI enhanced at least 6.95 km of shoreline with a minimum of 20,708 trees, acorns, and cuttings. Table 20 shows the mix of species planted in the first year of the riverbank stabilization tree planting project.

Table 19 Number of seedlings, acorns, and cuttings planted and length of bank restored by NWAI per field season

Field season	Length of bank planted (m)	# of tree seedlings	# of acorns	# of willow, dogwood, alder cuttings
2005/2006	2,450	833	1,800	2,338
2006/2007	1,250	1,139	1,933	2,500
2007/2008	500	1,065	125	1,060
2008/2009	900	830	500	1,200
2009/2010	1,100	1,500	600	700
2010/2011	Unknown	Unknown	Unknown	Unknown
2011/2012	500	Unknown	Unknown	Unknown
2012/2013	-	375	Unknown	Unknown

2013/2014	Unknown	700	-	-
2014/2015	Unknown	550	-	60
2015/2016	Unknown	Unknown	Unknown	Unknown
2016/2017	250	900	0	0
Total	6,950	7,892	4,958	7,858

Table 20 Number and species of trees and shrubs planted on private properties along the Nashwaak River in 2005 – 2007 in the first years of NWAI's riverbank stabilization tree planting program.

Species	2005	2006	2007
Red maple	376	281	274
Silver maple	-	95	-
Hybrid larch	145	-	-
Tamarack	153	-	-
Pitch pine	94	739	739
Black ash	65	24	-
Yellow birch	-	-	52
Alder	-	252	-
Red osier dogwood	468	-	-
Riverbank willow	1,870	1,818	-
Tree willow	-	177	-
Grass-leaved willow	-	178	-
Unidentified willow	-	75	875
Burr oak (acorns)	950	452	-
Red oak (acorns)	850	1,481	125
Red oak (seedlings)	-	-	472
Total	**4,971**	**5,572**	**2,956**

16.1 Silver Maple Floodplain Forest

In 2015, management plans were developed for both the Marysville Flats and the Neil's Flats locations. Both properties had been cleared for agriculture in the past. Before clearing, the land was likely composed of a silver maple-dominated floodplain forest community. It is estimated that up to 90% of the original floodplain habitat along the Nashwaak River was destroyed due to past and present land clearing for agriculture and development (Noseworthy, 2016). Satellite imagery suggests a similar pattern for throughout the lower Saint John River watershed. Floodplain forests are critically important ecosystems that support a very high diversity of plants and animals (Naiman et al., 1993) up to twice as much biodiversity as upland forests (Gregory et al., 1991). They are among the most threatened and least protected ecosystems in northeastern North America (Dynesius & Nilsson, 1994); (MacDougall & Loo, 2002). Numerous species at risk use these forests for breeding, nesting, and feeding.

Floodplain forests also provide a variety of ecosystem services to local communities. One of the main benefits of a healthy floodplain forest is its ability to mitigate flood damage (and erosion) by absorbing large amounts of water and slowing the speed and reducing the height of floodwaters. A study conducted by the US National Wildlife Federation found that a silver maple floodplain forest was worth 72,000 USD/hectare/year based on flood mitigation alone (Noseworthy, 2016). A mature silver maple tree (*Acer saccharinum*) can draw up, and subsequently released into the atmosphere, up to 220 L of water every hour (Kozlowski & Davies, 1975) and intercept over 11,000 L of rainfall annually (Peper, et al., 2007). Additionally, these communities help moderate the temperature of the Nashwaak River by providing shade and decreasing nutrient loads. The silver maple is the most flood tolerant of all New Brunswick's native tree species.

The lower Saint John River Valley harbours a unique assemblage of floodplain tree species found nowhere else in the Maritimes (Noseworthy, 2016). In addition to the diversity of the trees, a number of at-risk or rare tree species are association with these floodplain forests, such as bur oak (*Quercus macrocarpa*), black willow (*Salix nigra*), and butternut (*Juglans cinerea*).

16.1.1 Management Plan for Restoring Silver Maple Floodplain Forests

The NWAI has committed to restoring these important silver maple floodplain forest communities along the Nashwaak River and particularly in two areas known as the Marysville Flats and Neil's Flats. These properties are owned by the City of Fredericton but the NWAI has begun the process of obtaining a lease for one or both properties that would allow us to steward the properties and restore them back to silver maple floodplain forests. Both properties have been divided into four management zones (A-D) to guide restoration activities.

The objectives are to:

- Prevent riverbank erosion and sedimentation
- Restore floodplain forest species composition and structure

Management Zone A is designated for planting willow cuttings to stabilize the riverbank. Management Zone B is the most ecologically sensitive area. It buffers backwater wetlands and watercourses and machinery should not be used for site preparation or planting. Management Zone C are old fields and cleared land that are not considered ecologically sensitive. Machinery can be used for site preparation. Management Zone D is the area that has already been planted by NWAI.

The best practice management actions will involve:

- Proper site preparation to ensure that planted trees can reach their full growth potential. This will involve:
    - Controlling competing vegetation by mowing or mulching in sensitive areas or plowing and disking in less sensitive areas.
    - Creating pit and mound topography to produce structural complexity and important habitat.
- Planting red-tipped willow (*Salix eriocephala*) and sandbar willow (*Salix exigua*) cuttings along riverbanks to slow erosion.

    - Willows will need to be replanted annually along sections due to ice scouring.
    - Planting should occur along a 4-metre swath of land along the river (Zone A).
    - Outside curves should be planted first as they are most susceptible to erosion.
- Planting a mix of 85% silver maple (*Acer saccharinum*) and 15% white elm (*Ulmus Americana*) in Zones B and C.
    - Planting stock should be >30 cm and preferably >50 cm or even 1 m.
    - Density should be 2 x 2 m spacing (2,500 trees/hectare), which will create competition and encourage upwards growth and facilitate rapid canopy closure, which will help supress field vegetation
        - If machinery is needed to mow, then spacing should be 3 x 1.5 m (2,000 trees/hectare)
    - Field vegetation should be regularly mowed for at least three years after planting to control competition and discourage rodents from nesting and girdling young trees.
    - White elms are susceptible to Dutch Elm Disease and it expected that some may die. However, resistant strains are becoming available and it is expected that in the future a resistant variety from the genetic stock of the St John River watershed will be available.
- Fill planting can be carried out in forests that are already established (either naturally or planted).
    - Replacing dead trees on newly planted sites
    - Planting canopy openings in existing floodplain forests
    - Planting patches that are cut for the purpose of planting in degraded forests.
- Pruning planted trees after their third growing season and every 2-3 years afterwards, as needed.

16.1.2 Neil's Flats

Two properties totalling 50.7 hectares (125.3 acres) located along the Nashwaak River are owned by the City of Fredericton and are almost entirely within a Provincially Significant Wetland (PSW). The City obtained the land in 2013. Approximately 70% of the properties are abandoned hayfields now covered with dense grasses and other herbaceous field vegetation (Figure 58). Evidence of a historical forest community exists as fragmented patches of silver maple floodplain forests. Trees are mostly silver maple (*Acer saccharinum*) with white elm (*Ulmus Americana*) scattered throughout. A large beach and a 1.8 km trail network exist on the property. The trail was closed to vehicles in 2015. Due to the PSW designation for parts of this property, heavy machinery is not allowed and restoration will need to be done by hand or small machinery that will not cause soil disturbance.

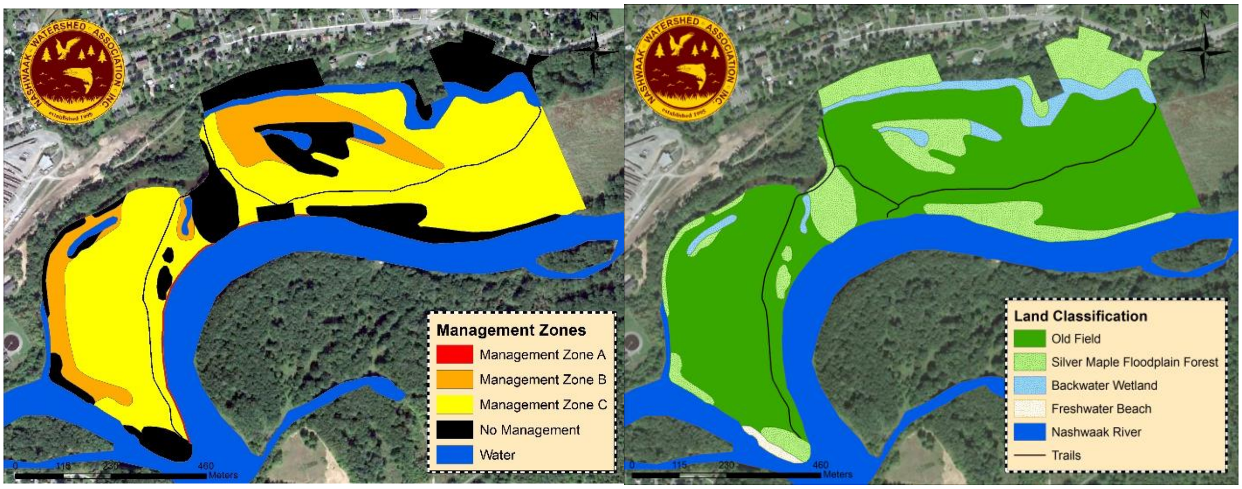


Figure 58 Management zones (left) and land classification of the Neil's Flats. Source: NWAI (2015b).

16.1.3 Marysville Flats

The Marysville Flats total 11.2 hectares (27.6 acres) (PID #75457440) and they are owned by the City of Fredericton under the jurisdiction of the Parks and Trees Division. The City has been supportive of the NWAI using the land for restoration and community outreach purposes, though a formal agreement has yet to be finalized. The property falls entirely within a PSW. 76% of the property is an abandoned field, covered mostly with dense grasses and other herbaceous field vegetation (Figure 59). A few large, scattered silver maple trees are scattered along the shoreline, most likely left as shade trees for cattle. The flats are flooded annually in the spring and a low-lying area supports a number of backwater wetlands that remain saturated year-round. A significant amount of shoreline is devoid of any vegetation other than grasses and, in those locations, severe erosion has occurred. Recent construction on a sewer line under the Gibson trail resulted in land cleared of vegetation that has since become somewhat unstable. The NWAI has already planted ~0.5 hectares of old field with a variety of tree species, which now makes up ~4.5% of the property. This property is part of what we are now calling “The Greenway” (see section 17 for details).

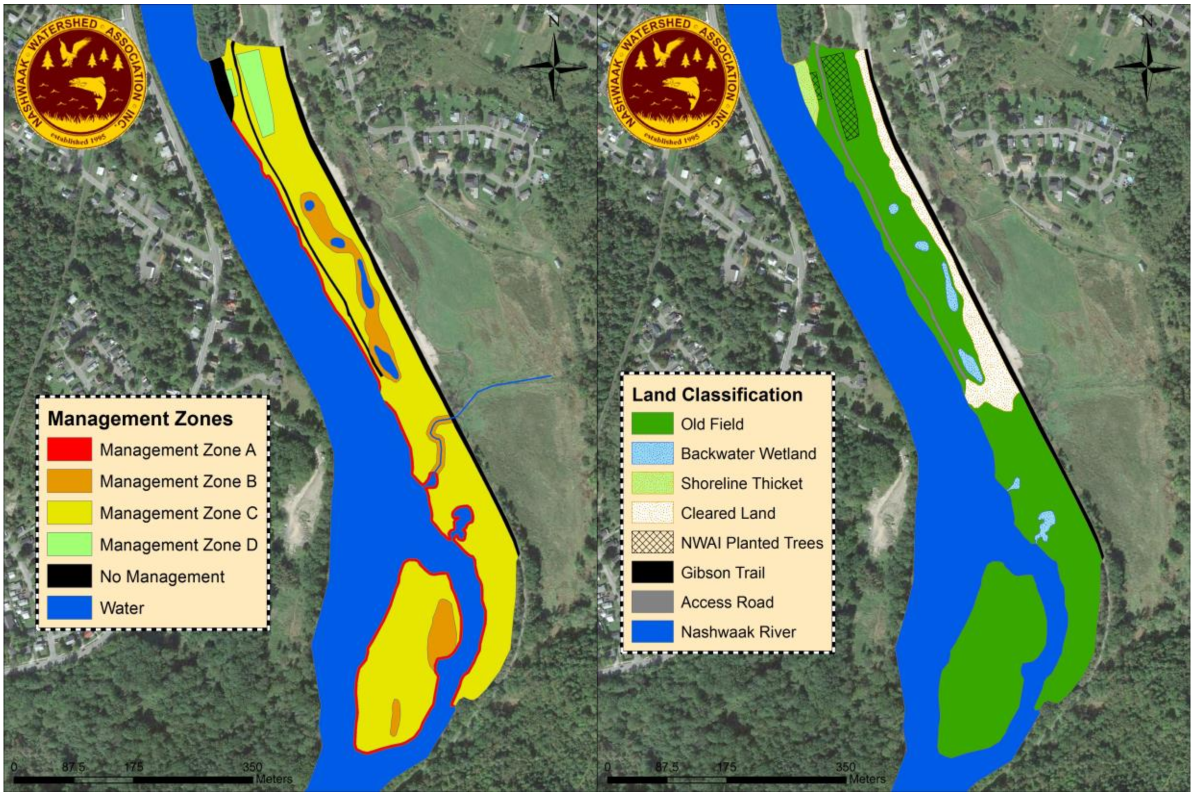


Figure 59 Management zones (left) and land classification (right) of the Marysville Flats. Source: NWAI (2015).

16.1.4 Future Management

As planted stock grows and competes, individual trees will begin to die and leave gaps in the canopy. NWAI could do enrichment plantings in these gaps using other floodplain species that will serve to enrich wildlife habitat and increase the conservation value of the land by supporting rare or at-risk species. Three potential species have been identified: butternut (*Juglans cinerea*), red ash (*Fraxinus pennsylvanica*), and bur oak (*Quercus macrocarpa*) (NWAI, 2015). Butternut is native to the Nashwaak River's floodplain but it is susceptible to butternut canker, an exotic fungal disease that has infected all known populations. It does not appear that resistant genetic stock is commercially available. The NWAI could survey the watershed for butternuts that appear to be resistant and collect seeds.

Red ash and bur oak are floodplain species with limited distribution and both are considered species of conservation concern in New Brunswick (Powell & Beardmore, 2002). The NWAI collected >2,000 bur oak acorns from the lower SJR floodplain in late 2016 but viability was only 10%. 35 bur oak seedlings were obtained from Department of Natural Resources greenhouse and planted on the Marysville Flats in the fall of 2016.

16.1.4.1 Crop Tree Release

The 2015 NWAI management plans suggest implementing crop tree release using the crown-touch method. This method removes adjacent trees that touch the crowns of selected crop trees (Nyland, 1996). It has been shown that silver maples can triple their wood volume in the 10 years following a release (Larsson, 1968), which would quicken the development of a mature floodplain forest.

16.1.4.2 Restoring Wetlands

Restoring wetlands on floodplains refers to creating vernal pools on past agricultural land. Vernal pools are seasonal wetlands that are recharged with floodwater each year. These were normally filled in when the land was converted for agriculture. They are naturally small, shallow, and disconnected from the river after flooding subsides, which means they rarely support fish. This makes them very important breeding and foraging habitat for a variety of wildlife, including turtles, amphibians, invertebrates, waterfowl and wading birds. Although labour intensive, creating vernal pools as part of floodplain restoration can provide enormous benefits to wildlife (Noseworthy, 2016).

17 THE GREENWAY PROJECT

The Nashwaak Watershed Association, along with the Fredericton Area Watersheds Association, has been working with the City of Fredericton since 2011 to develop a “Greenway” along the banks of the Nashwaak River. The boundaries of the Greenway were established using the 1:20 year flood zone (Figure 34). As the land falls within the floodplain and cannot be used for housing or grey infrastructure, much of it is retired hayfields. The hope is that the Greenway will be a publicly held forest and wetland area, with trails and river access points, maintained as a natural landscape within walking distance the city centre for all to use. The proposed area will offer the enjoyment and experience of an untouched forest, a clean and bountiful river for fishing, paddling, or swimming, and all the activities, benefits, and natural beauty most city dwellers must drive great distances to find in provincial or national parks.

The majority of land in the Greenway is agricultural land (37.3%). Only 5.2% of the Greenway is occupied by human settlement. Based on analysis by (Noseworthy, 2016b) up to 23.3% of the Greenway could be restored back to floodplain forest and another 2.0% could be restored back to Acadian forest. Figure 60 and Table 21 show specific land use in the Nashwaak Greenway.

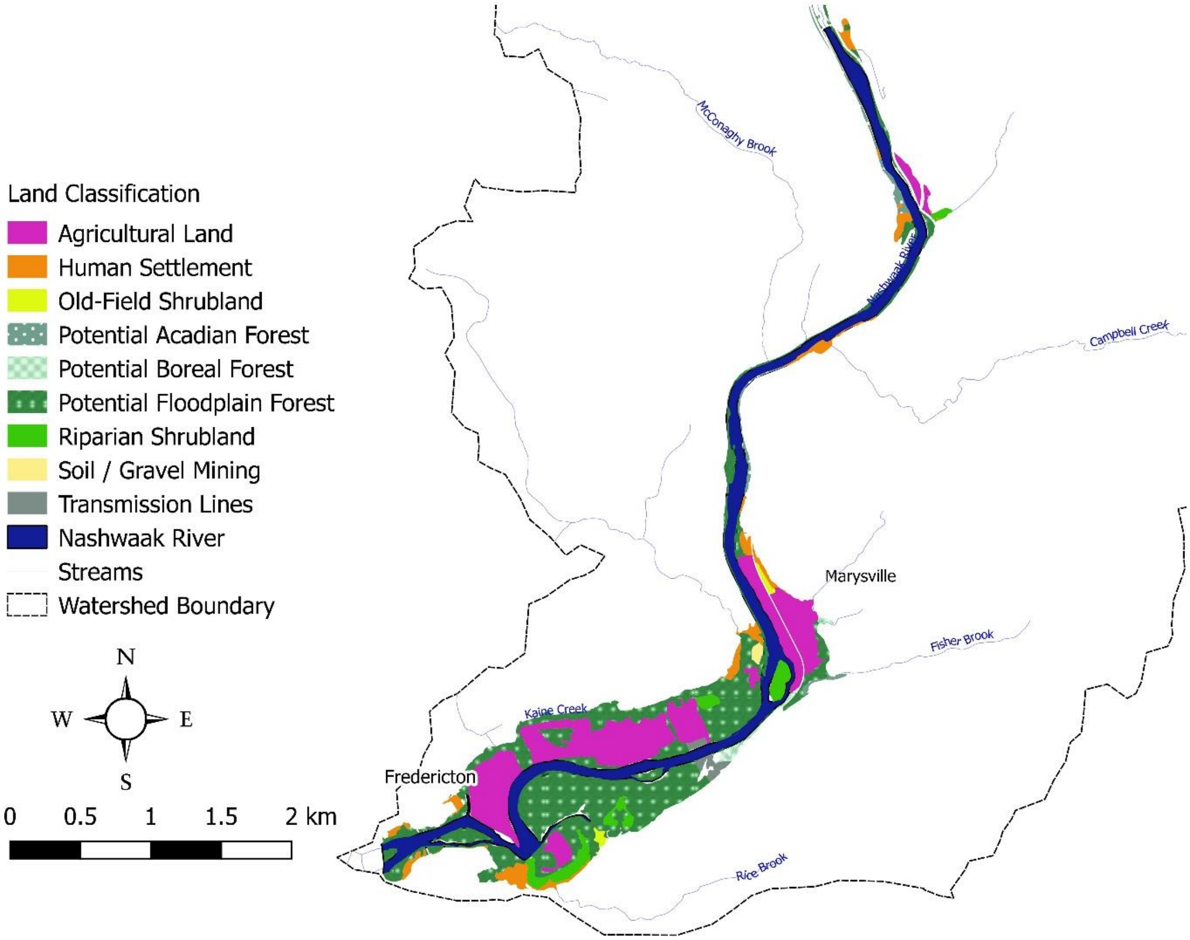


Figure 60 Land use in the lower Nashwaak Greenway. Data source: GeoNB

Table 21 Specific land use in the Nashwaak Greenway. Data source: GeoNB, analysis by Noseworthy (2016b).

Classification	Hectares	Acres	%
Agriculture	649.3	1604.4	37.3
Potential Floodplain Forest*	405.5	1002.1	23.3
Riparian Shrubland	159.3	393.5	9.2
Old Field Shrubland	139.3	344.2	8.0
Human Settlement	90.6	223.8	5.2
River Scour	71.0	175.5	4.1
Golf Course	61.1	150.9	3.5
Old Field Forest	56.3	139.1	3.2
Post-Clearcut Forest	55.3	136.6	3.2
Potential Acadian Forest	34.4	85.0	2.0
Soil/Gravel Mining	11.7	29.0	0.7
Transmission Lines	4.4	11.0	0.3
Conifer Plantation	1.9	4.6	0.1
Total	**1740.0**	**4299.6**	**100.0**

*Defined as any hardwood forest within the floodplain. Likely an overestimation of the true extent.

As a forested wetland, the Greenway will greatly increase the flood protection for Marysville and Fredericton, improve our air quality, control erosion, and moderate temperatures. This natural buffer will ensure that future generations can enjoy the Nashwaak River as we do today. The Greenway will help maintain the natural balance required by people and wildlife and to offset the stress on the river induced by growth and development of the landscape.

Based on Noseworthy's (2016b) analysis of the land use in the Nashwaak Greenway, 270 properties were identified as future restoration areas (Figure 61) and 205 properties were identified for conservation (Figure 62). Restoration properties were those that had likely been floodplain forest in the past and had since been converted to agricultural land. Conservation properties were any areas that still contain natural floodplain forest or beach. Beaches were selected for their importance to as habitat for wood turtles or snapping turtles.

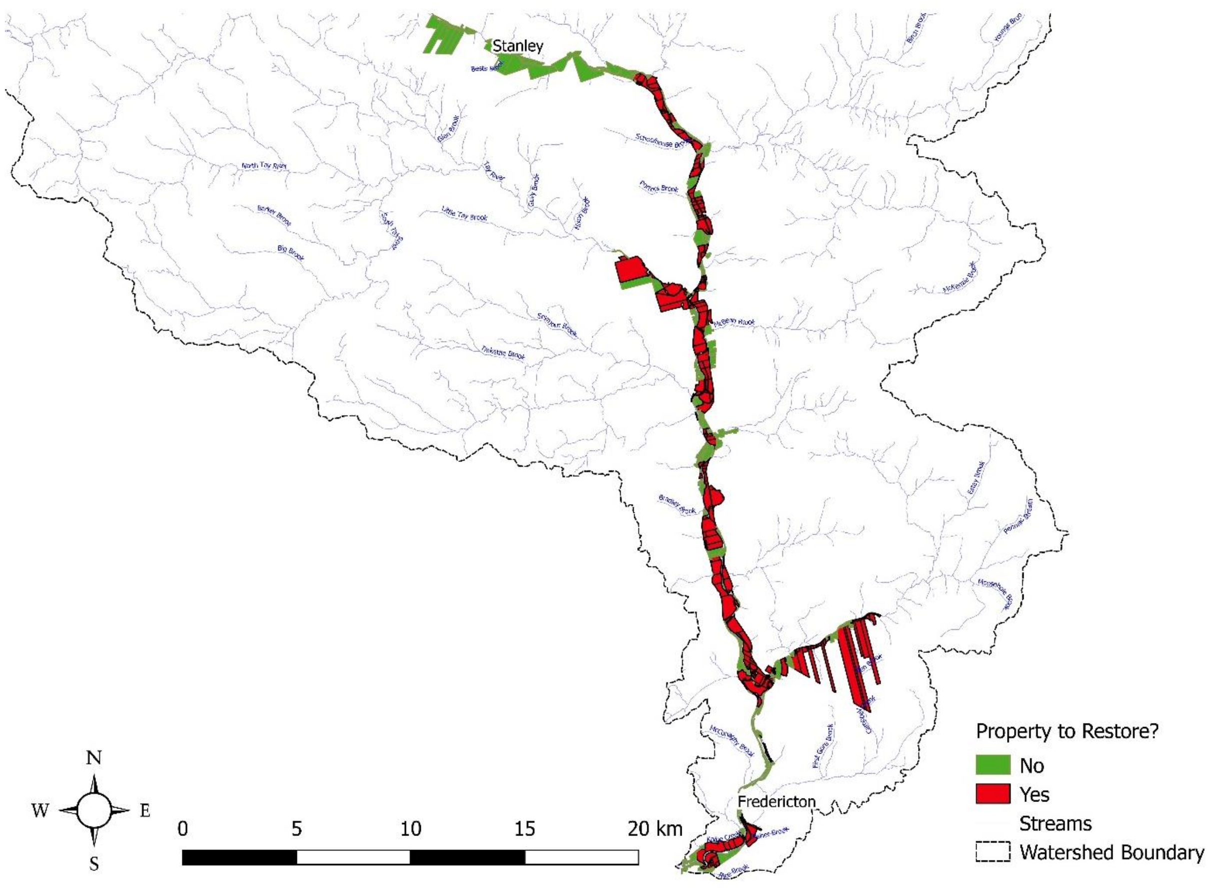


Figure 61 Properties in the Nashwaak Greenway defined as potential restoration properties (red). Data source: GeoNB.

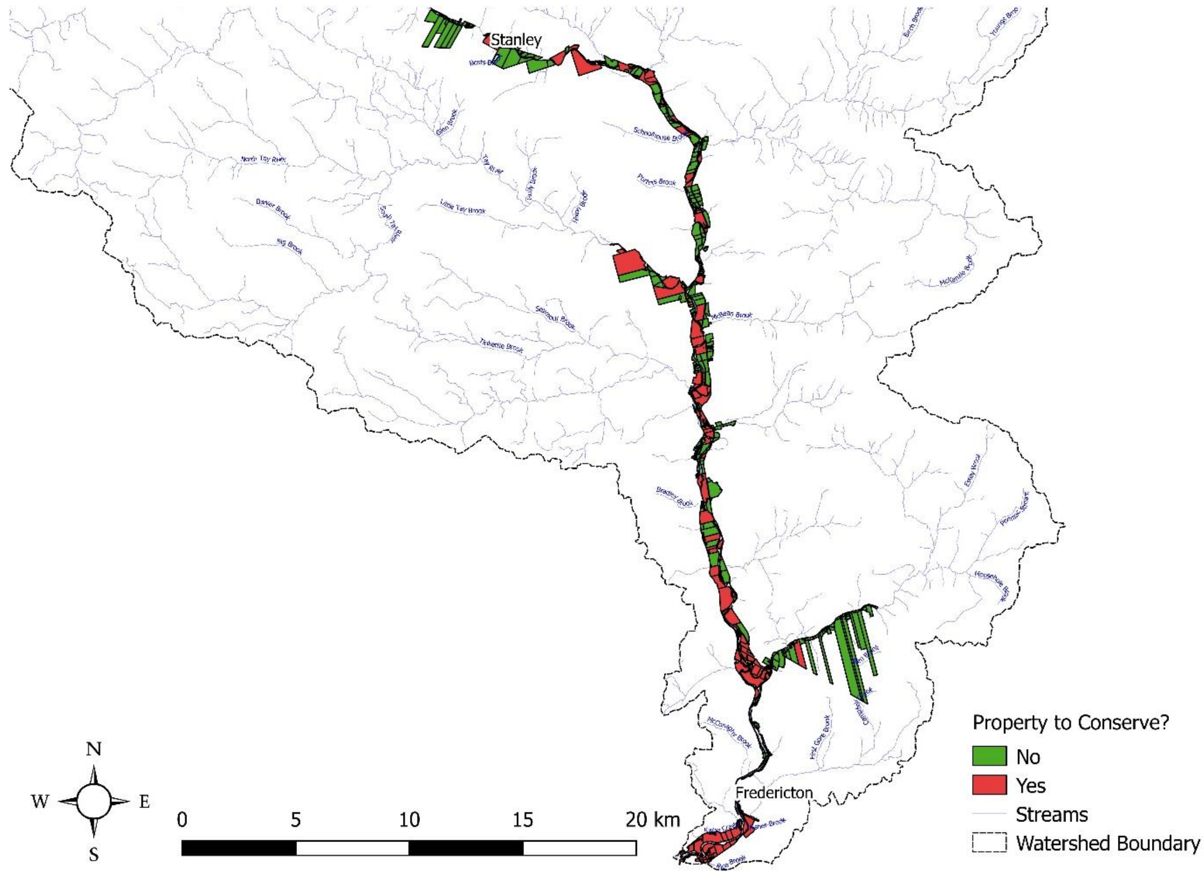


Figure 62 Properties in the Nashwaak Greenway defined as potential conservation properties (red). Data source: GeoNB.

Though only 2% of the province is covered by fresh water, the value of this resource is immeasurable. The protection and management of ground and surface water resources is crucial to safeguarding their future. Previous, lack of management has lead to declining fish stock, polluted water, contaminated wells, and increased levels and frequency of flooding. The 1973 flood, for example, cost the province $12 million dollars (the equivalent of $63 million in 2016) in damages. An ice jam that caused a flood in Stanley in 2013 cost the village $350,000 in damages (DELG, 2017). As the climate becomes more unpredictable, these costs will only rise unless work is done to repair degraded ecosystems and restore their functions.

18 OUTREACH AND EDUCATION

In order to inform the general public of the work that NWAI is doing, the organization produces an annual newsletter that is mailed to ~4,400 addresses in the watershed and select addresses in downtown Fredericton. The newsletter informs residents about our annual general meeting, usually held in November, and provides updates on that year's projects and programs.

We have also focused on educating elementary school students within the watershed in a program we now call "Upstream/Downstream", which began in 2015. Our program targets grades three and four students at schools within the Nashwaak Watershed (Stanley, Nashwaak Valley, Gibson-Neill, and Barker's Point Elementary Schools and Fredericton Christian Academy). We deliver interactive classroom presentations followed by a field trip. The program aims to tie into the current grades three and four curriculums, in particular, the grade three unit on plants and habitat and the grade four unit on soils and erosion. Grade three field trips involve tree planting activities to help re-establish a silver maple wetland forest while grade four field trip sites will focus on an area of eroding riverbank along the Marysville Flats.

This project will help build a sustainable and educated community within the Nashwaak Watershed. Elementary students will develop a connection to the natural world and the Nashwaak River. Students who participate in the *Upstream/Downstream* education program will learn about how science and engineering can be used to help restore rivers and improve habitat for wildlife. Students will develop a broader understanding of how a watershed works and a specific understanding of the Nashwaak Watershed.

19 WHAT CAN YOU DO?

There are things that each of us, as residents of the Nashwaak River watershed, can do to protect the river's health for now and for the future.

1. *Green the shoreline*: Maintaining and planting native vegetation along watercourses provides a home for wildlife, shades the water, reduces erosion, and filters pollutants.
2. *Fence watercourses near farms*: Livestock are a major source of E. coli contamination and can erode riverbanks. Fencing the watercourse is better for both the river and the animals.
3. *Conserve water*: Install low flow appliances and collect rain water for gardening. Rivers rely on groundwater inputs to maintain flow during the dry season.
4. *Keep sewage out of the river:* Ensure that your domestic septic tanks are regularly maintained.
5. *Reduce chemical inputs*: Use phosphate-free and biodegradable cleaning products and personal care products. Reduce the use of pesticides on lawns and gardens and clean up pet waste.
6. *Reduce impervious surfaces*: Use porous alternatives and collect runoff.
7. *Learn more about your watershed and its issues*.

20 LONG TERM WATERSHED GOALS

The Nashwaak Watershed Association Inc.'s long term goal and mandate are to manage the Nashwaak watershed as a healthy ecosystem that balances a variety of economic, recreational, social, and landowner interests so that it will serve the community while maintaining a healthy resource for generations to come. We will strive towards this goal so that eventually:

- Healthy natural areas are protected and expanded through acquisition and restoration projects;
- The Nashwaak River and its tributaries are green corridors of connected tree canopies that connect to forested upland areas;

- Pollution sources are addressed;
- Native fish species thrive and anadromous salmonids return in greater numbers; and
- The Nashwaak River becomes a model for how people, wildlife, and the river can live in harmony.

This technical report compliments the NWAI's *2017-2020 Action Plan*, which outlines

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22 APPENDIX A

Table i WQIs per site per year, along with rating, for NWAI's historical data.

Station	Index Period	CCME WQI	Rating	Problems	Data Points
NASH-A Barkers Point	1999	95.3	Excellent		3
	2000	93.7	Good	Al	1
	2001	95.7	Excellent		4
	2002	100.0	Excellent		3
NASH-B Marysville	1998	92.6	Good	Hg	2
	1999	73.3	Fair	Cd, Ni	3
	2000	93.7	Good	Al	1
	2001	100.0	Excellent		5
	2002	100.0	Excellent		5
	2003	100.0	Excellent		2
	2004	100.0	Excellent		5
	2005	68.7	Fair	Al, TP-L	7
	2006	95.4	Excellent		4
	2007	100.0	Excellent		4
	2008	95.4	Excellent		4
	2009	91.4	Good		4
	2010	95.7	Excellent		7
	2011	90.9	Good		8
	2012	91.6	Good		8
	2013	95.8	Excellent		5
	2014	91.5	Good		8
	2015	95.7	Excellent		8
	2016	95.4	Excellent		5
NASH-C Below Penniac Brook	1999	100.0	Excellent		1
	2000	93.7	Good	Al	1
	2001	100.0	Excellent		4
	2002	100.0	Excellent		3
NASH-D Penniac Stream	1988	46.1	Marginal	Pb, Al, TP-L, Zn	4
	1999	90.6	Good	Al	3
	2000	88.7	Good	Al, TP-L	2
	2001	91.6	Good	Al	5
	2002	90.6	Good	Al, TP-L	4
	2005	52.0	Marginal	Al, Cd, Cu	2
	1980	100.0	Excellent		4
	1988	56.3	Marginal	Pb, Cu,	5
	1995	45.8	Marginal	Cu, pH, Zn	2
	1996	43.4	Poor	Pb, Cd, Zn,	1

NASH-E Durham Bridge	1997	42.5	Poor	Al, Cd, Cu, TP-L	3
	1998	93.7	Good	Al	4
	1999	100.0	Excellent		3
	2000	93.7	Good	Al	1
	2001	100.0	Excellent		5
	2002	100.0	Excellent		4
	2005	100.0	Excellent		2
NASH-F Dunbar Stream	1988	79.3	Fair	TP-L	4
	1999	95.3	Excellent		3
	2000	100.0	Excellent		1
	2001	100.0	Good		4
	2002	100.0	Good		3
	2005	100.0	Excellent		2
NASH-G Tay River	1988	83.8	Good	Al, Pb	3
	1999	100.0	Excellent		3
	2000	100.0	Excellent		1
	2001	100.0	Excellent		5
	2002	100.0	Excellent		4
	2005	100.0	Excellent		6
NASH-H Taymouth	1988	67.3	Fair	Pb, TP-L, Zn	3
	1999	100.0	Excellent		3
	2000	86.9	Good	Al, Zn	1
	2001	95.8	Excellent		5
	2002	100.0	Excellent		5
NASH-I Youngs Brook	1988	67.7	Fair	Pb, Al, TP-L, Zn	5
	1999	100.0	Excellent		3
	2000	93.7	Good	Al	1
	2001	95.7	Excellent		4
	2002	100.0	Excellent		4
	2005	95.4	Excellent		4
NASH-J Cross Creek	1999	100.0	Excellent		3
	2000	100.0	Excellent		1
	2001	95.6	Good	DO	4
	2002	100.0	Good	DO	4
	2005	100.0	Excellent		2
NASH-K McLaggon Bridge	1988	69.4	Fair	Pb	4
	1998	92.6	Good	Hg	2
	1999	95.3	Excellent		3
	2000	87.3	Good	Zn, Al	1
	2001	95.6	Excellent	Al	5
	2002	100.0	Excellent		4

	2005	95.0	Excellent	Al	2
NASH-L Curriebürg	1999	100.0	Excellent		3
	2000	87.4	Good	Zn, Al	1
	2001	95.6	Excellent		6
	2002	100.0	Excellent		3
NASH-M Napadogan Brook	1999	90.0	Good	Al, TP-L	2
	2000	88.8	Good	Zn, Al	2
	2001	100.0	Excellent		1
NASH-N Narrows Mountain	1999	90.0	Good	Al, TP-L	2
	2000	93.4	Good	Al	1
	2001	95.4	Excellent	Al	5
	2002	100.0	Excellent	Al	5
NASH-O McBean Brook	2000	86.9	Good	Zn, Al	1
	2001	91.0	Good	Al	5
	2002	94.8	Good	Al	4
NASH-P South Sisters Brook	1999	90.0	Good	Al, TP-L	2
	2000	86.8	Good	Zn, Al	1
	2001	95.5	Excellent		5
	2002	95.7	Excellent		3
NASH-Q Gorby Gulch	1999	89.9	Good	Al, TP-L	2
	2000	93.0	Good	Al	1
	2001	94.5	Good	Al	4
	2002	90.5	Good	Al	3
NASH-T Napadogan Haul Road	2001	91.4	Good	Al	5
	2002	100.0	Excellent		4
	2005	95.4	Excellent		4

Table ii. Annual mean, maximum daily, and minimum daily discharge data for Station #01AL002 at Durham for 1962 to 2013.

	Overall Mean (m^3/s)	**Max. Daily (m^3/s)**	**Min. Daily (m^3/s)**	**Total Annual Discharge (m^3)**	**Annual Precipitation at Fredericton (mm)**
1962	31	148 on Nov 23	3.88 on Aug 4	11,311.49	943.1
1963	54	467 on May 1	7.02[B] on Mar 17	19,712.86	1,243.4
1964	23.9	408 on Apr 17	2.61 on Jul 20	8,758.51	1,020.7
1965	26	123 on May 5	3.14 on Aug 7	9,503.55	790.1
1966	25.2	200 on Nov 4	2.94 on Sep 13	9,214.48	796.7
1967	35	247 on May 4	3.68[B] on Mar 11	12,775.80	1,181.3
1968	30.5	254 on Apr 15	2.75 on Oct 16	11,172.87	907.4
1969	38.4	255 on Apr 18	3.71 on Sep 5	14,017.70	1,086.3
1970	39.5	827[B] on Feb 4	8.78[B] on Feb 2	14,402.98	1,178.4
1971	25.3	311 on May 5	3.23 on Oct 5	9,219.91	1,041.5
1972	36	334 on May 16	5.35[A] on Sep 26	13,183.79	1,364.3

1973	47.4	665 on Apr 29	4.87 on Oct 30	17,285.39	1,211.8
1974	36.8	399 on May 1	5.04 on Sep 2	13,441.21	1,045.9
1975	32	200 on May 7	3.26 on Sep 2	11,668.15	1,128.1
1976	44.5	343 on Apr 4	7.70 on Jul 11	16,289.64	1,312.1
1977	39.6	279 on Apr 23	3.37 on Sep 5	14,441.82	1,261.1
1978	27.6	242 on May 10	2.92 on Aug 25	10,057.66	1,009.7
1979	50.9	623 on Mar 27	4.88 on Jul 26	18,593.18	1,520.7
1980	31.4	186 on Apr 16	3.65^{B} on Mar 5	11,487.11	1,159.5
1981	43.2	289 on Apr 6	5.18 on Sep 8	15,772.81	1,473.6
1982	34.3	331 on Apr 28	5.53 on Jul 16	12,504.56	1,167.0
1983	40	602 on Nov 26	4.47 on Aug 26	14,588.65	1,191.3
1984	40.8	300 on Apr 17	2.94 on Nov 9	14,936.30	1,288.3
1985	22.6	149 on Apr 17	2.58 on Sep 24	8,254.52	949.1
1986	31	244 on Apr 24	5.22 on Jul 13	11,297.48	1,056.8
1987	24.3	281 on Apr 2	2.71 on Sep 6	8,881.84	979.9
1988	25.6	304^{B} on Mar 28	3.64 on Aug 3	9,378.80	1,008.7
1989	32.1	399 on Apr 7	3.83 on Jul 27	11,722.32	1,177.3
1990	45.8	351 on Oct 25	4.89 on Jul 22	16,731.46	nd
1991	38.6	292 on Apr 23	3.31 on Jul 31	14,106.89	1,137.0
1992	27.6	177 on Apr 22	4.88 on Oct 9	10,116.85	994.7
1993	40.6	571 on Dec 12	5.31 on Sep 1	14,815.03	1,141.5
1994	38.3	725 on Apr 17	3.64 on Oct 18	13,964.49	1,116.9
1995	30.3	236 on Apr 22	2.94^{A} on Sep 7	11,056.93	1,117.2
1996	46.5	314 on Jan 28	4.92 on Sep 8	17,030.40	1,035.8
1997	28.9	353 on May 2	3.69 on Oct 26	10,536.00	844.8
1998	40.7	423^{E} on Mar 11	4.33 on Aug 10	14,867.25	1,036.9
1999	35.3	265 on Dec 8	2.33 on Sep 6	12,873.03	1,103.0
2000	30.8	404 on Apr 10	3.60 on Sep 12	11,285.85	1,122.0
2001	20.8	364 on Apr 25	2.16 on Sep 20	7,591.94	690.3
2002	31.2	328 on Apr 14	2.33^{B} on Feb 10	11,405.59	nd
2003	39.9	443 on Oct 30	4.79^{B} on Feb 28	14,578.33	1,047.8
2004	23.1	253 on Apr 15	4.26 on Aug 29	8,439.13	779.9
2005	54.6	560 on Nov 23	3.67 on Aug 20	19,934.37	1,190.1
2006	39.6	473^{B} on Jan 15	3.02^{B} on Mar 12	14,471.37	1,029.8
2007	28.6	266 on Apr 24	3.37 on Oct 8	10,422.38	907.4
2008	52.8	471 on Apr 30	6.12 on Sep 26	19,314.52	nd
2009	48.4	485 on Apr 23	4.95 on Sep 23	17,670.64	nd
2010	44.4	1150 on Dec 14	3.29 on Sep 3	16,221.94	nd
2011	46.8	263 on May 5	8.29^{B} on Mar 5	17,093.17	957.7
2012	37.6	513 on Apr 24	4.73 on Aug 27	13,744.50	922.2
2013	43.3	375 on Nov 28	-	15,805.92	990.4
Average	36.21	-	-	13,229.87	1,077.9

A=Partial Day, B=Ice Conditions, E=Estimated
Data source: (WSC, 2017)