Hydrology of the Transboundary Rivers of Southern Labrador

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Newfoundland Labrador

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Introduction

Newfoundland and Labrador operates a hydrometric network that measures streamflow at selected stations on an hourly basis. 14 stations are located in watersheds that are shared with the province of Quebec in this region of the province.

The boundary between Labrador and Quebec is based in part by a river watershed divide and the 52nd degree of latitude. Specifically, it is:

> *a line drawn due north from the eastern boundary of the bay or harbour of the Anse au Sablon as far as the fifty-second degree of north latitude, and from thence westward ... until it reaches the Romaine River, and then northward along the left or east bank of that river and its head waters to the source and from thence due northward to the crest of the watershed or height of land there, and from thence westward and northward along the crest of the watershed of the rivers flowing into the Atlantic Ocean until it reaches Cape Chidley (*Hiller, 1997).

The western boundary of Labrador is defined as the crest of the watershed of the rivers that flow into the Atlantic Ocean; therefore, no river systems flow across this shared boundary. There are however a number of rivers systems that flow across the 52nd parallel which forms the southern Labrador / Quebec boundary. The headwaters of these rivers originate in Labrador and flow through the "North Shore" of Quebec into the Gulf of St. Lawrence. The watersheds of these transboundary rivers are very large and combined cover an approximate area of 70,000 km^2.

There are five main transboundary river systems. These rivers, from west to east, are the Romaine River, the Natashquan River, the Little Mecatina River, the St. Augustine River and the St. Paul River. There are also two smaller transboundary river systems. These rivers, the Coxipi River and the Napetipi River, have small portions of their headwaters in Labrador but are primarily located in Quebec. Figure 1 provides an overview of the transboundary watersheds.

Regional Summary

Watershed and River Size

The size of a river's watershed is an important factor as it greater influences characteristics such as streamflow (Bedient and Huber, 2002, pg. 8).The five major transboundary river systems - the Romaine River, the Natashquan River, the Little Mecatina River, the St. Augustine River and the St. Paul River – are very large watersheds. The Coxipi River and the Napetipi River are significantly smaller river systems with much smaller drainage basins.

The watersheds range in size from the Little Mecatina, which is close to 20,000 km^2, to the Napetipi at just over 1, 200 km^2. In fact three of the watersheds are greater than 10,000 km^2 with one approaching this size. All five of the main transboundary rivers are greater than 200 km in length, with two over 500 km. In comparison, the Exploits River which is the largest river on the island of Newfoundland is about 250 km long with a watershed approximately 11,000km^2 (Natural Resources Canada, 2010).

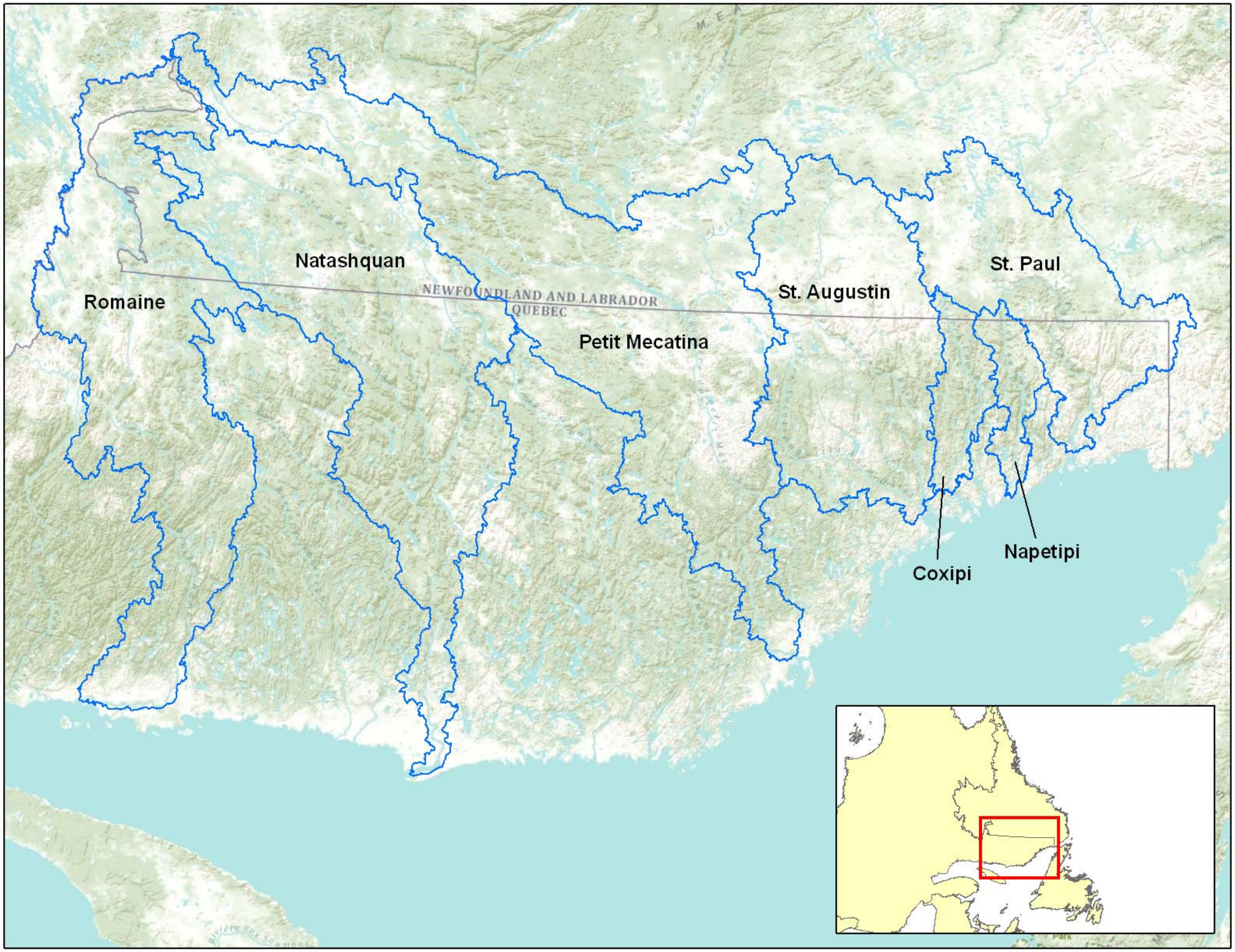
The rivers vary in relation to the proportion of the river that falls within Labrador territory. For example, about 2/3 of the St. Paul River and almost 70% of the watershed are in Labrador. In comparison, just 15% of the Romaine River watershed is in Labrador and the entire river itself is in Quebec. The Coxipi River and Napetipi River have only their headwaters located north of the border with less than 10% of their watersheds in Labrador.

Strahler stream order (see glossary) is a hierarchical method of classifying streams based on the number of tributaries feeding into a river, with headwaters having a value of one and larger streams increasing in order. It is an important means of classifying streams as it gives water resource managers a general idea of the size and strength of a specific channel within a river network (Briney, A., n.d.). All the major transboundary rivers have a stream order of seven indicating they are significant river systems.

Table 1: Watershed Size

Watershed	Area of Watershed (km2)	Area of Watershed in Labrador (km2)	Percent of Watershed in Labrador	Length of Main Channel (km)	Length of Main Channel in Labrador (km)	Percent of Main Channel in Labrador	Strahler Stream Order
Romaine	14,290	2,220	15.5 %	518	0	0 %	7
Natashquan	15,930	6,340	39.8 %	462	169	36.6 %	7
Little Mecatina	19,625	11,035	56.2 %	590	384	65.1 %	7
St. Augustin	9,890	3,995	40.4 %	238	109	45.8 %	7
Coxipi	1,620	130	8.0 %	128	20	15.6 %	6
Napetipi	1,270	60	4.7 %	121	13	10.7 %	5
St.Paul	7,190	5,000	69.5 %	246	164	66.7 %	7

Figure 1: Transboundary Watersheds



Elevation

Elevation is an important feature in influencing the characteristics of a watershed. The topography of a basin can impact the climate, vegetation, stream flow velocity and numerous other factors within a watershed. Additionally, the local wildlife is also influenced by elevation; for example, the woodland caribou found in the region favour the areas of higher elevations (Quebec, 2009, pg.69).

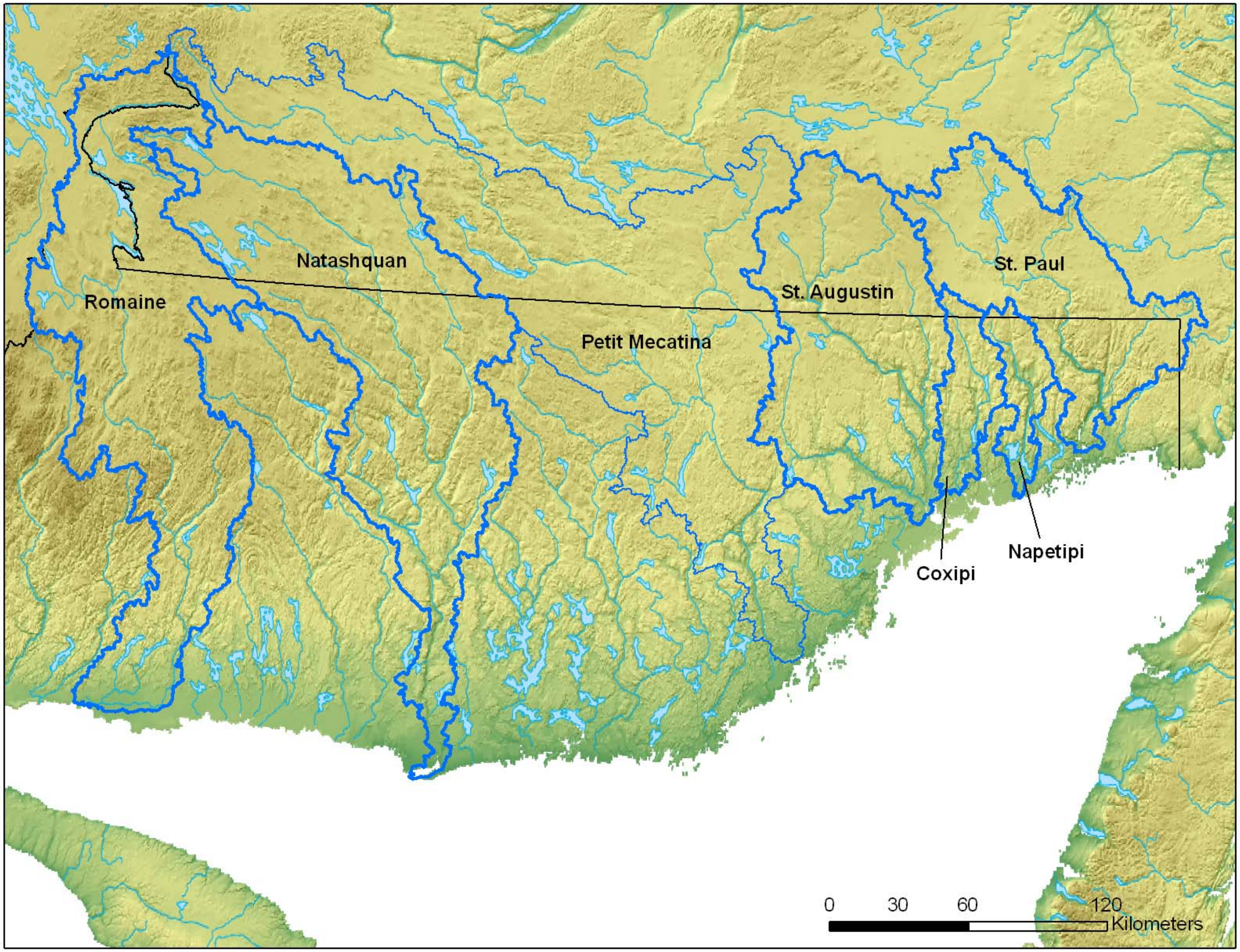
Elevations are generally higher in the western region of the transboundary study area with altitudes over 500 m quite common in the Romaine and Natashquan watersheds. The maximum elevation in the study area, 945 m, is in the Romaine watershed. This is higher than anywhere on the island of Newfoundland. As would be expected, elevations are higher in the upper / northern portions of the watersheds and get lower towards the coast. For example, the average elevation in the Coxipi and Napetipi watersheds, which are located primarily south of the provincial border, is over 100 m less than the adjacent St. Paul and St. Augustin watersheds.

Stream gradient (see glossary) is a measure of the difference in elevation between two points on a stream (Hill, 2009). Stream gradient can greatly influence the velocity of a stream. The average stream gradient shown in the figure below refers to the difference in elevation between the headwaters of the main channel and the outflow to the ocean. While gradient will differ greatly throughout the length of the stream, average gradient provides an overview of the general nature of the river. Average stream gradients vary across the transboundary watersheds, but tend to be higher in the smaller river systems. As well, most rivers display a decrease in gradient in downstream sections (Bedient and Huber, 2002, pg. 8)

Table 2: Elevation

Watershed	Maximum Elevation (m)	Average Elevation (m)	Elevation at Headwaters of Main Channel (m)	Average Stream Gradient (m/km)
Romaine	945	500	730	1.41
Natashquan	765	430	625	1.35
Little Mecatina	766	399	645	1.09
St. Augustin	592	342	570	2.39
Coxipi	503	239	405	3.16
Napetipi	502	233	390	3.22
St.Paul	581	364	410	1.67

Figure 2: Transboundary Watersheds Elevation



Landcover

Landcover is another important aspect when evaluating watersheds. Landcover can greatly influence the amount of precipitation that becomes available as runoff. For example, impervious surfaces such as developed or barren lands will allow more runoff than forested areas sections (Bedient and Huber, 2002, pg. 81). As well, wetlands can serve as a source of retention during major storm events and play an important role in flood control (Maidment, 1993, pg. 13.1). Landcover can also serve as a general indication of the types of land use occurring in an area. Large scale developments or commercial forestry will be quite evident when assessing landcover.

Landcover can be determined by analyzing remotely sensed imagery. Landcover data in the figure below was derived from the Canadian Forest Service Earth Observation for Sustainable Development of Forests (EOSD) Landcover dataset. The EOSD data is a land cover classification based on Landsat imagery circa 2000 and has a spatial resolution of approximately 30 m. The landcover scheme shown is an aggregation of the 23 classes in EOSD.

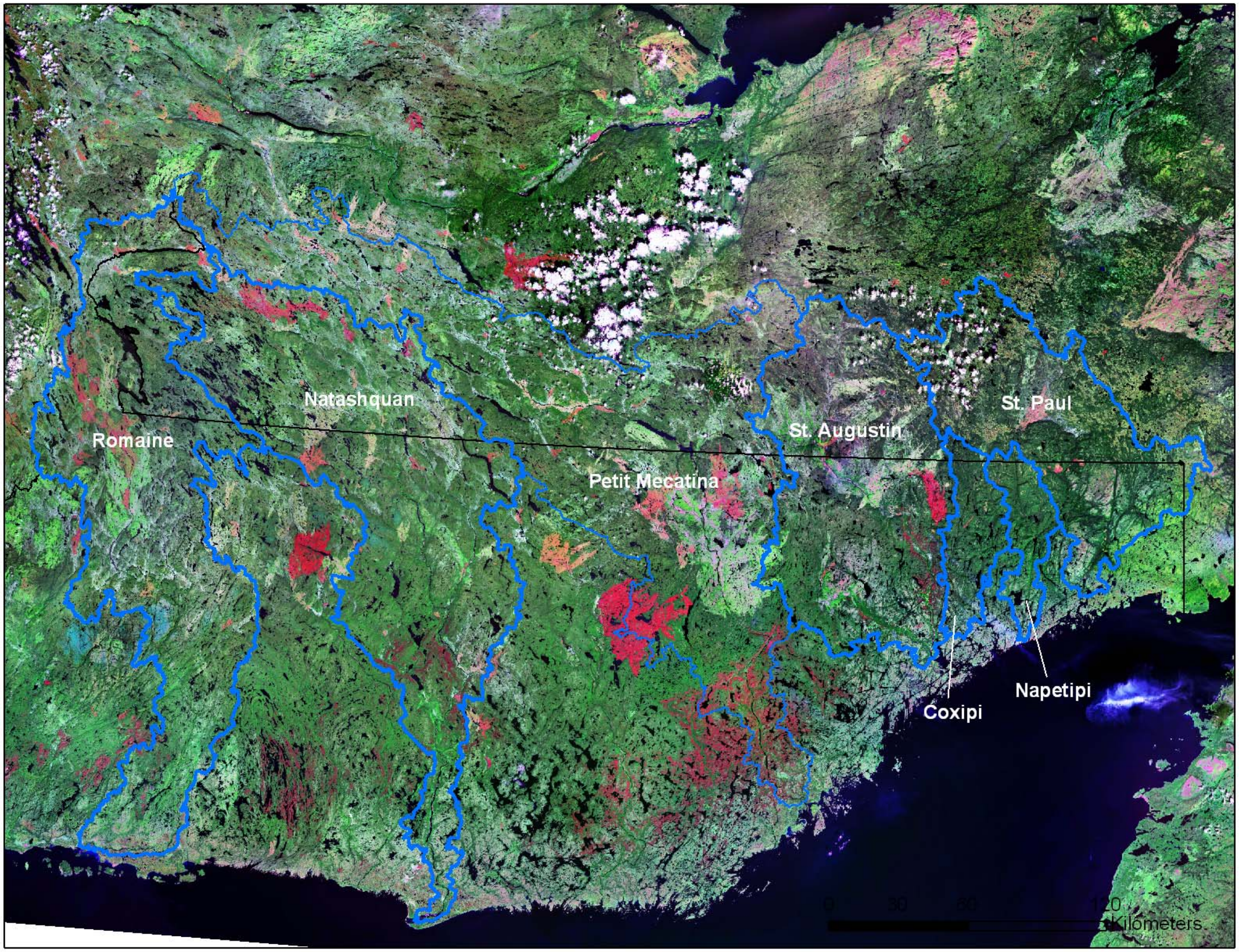
The defining characteristic of the transboundary watershed area is that it is heavily forested, with all the watersheds comprised of at least 65% forest. There is little development in the region, with most of the settlement located near the mouths of the rivers. Wetlands do not comprise a large percentage of the landcover but there are some significant wetland areas near the mouths of several of the rivers.

The landcover in the watersheds of the transboundary rivers is susceptible to change. The Romaine project is expected to lead to a loss in wetlands in its watershed (Quebec, 2009, pg. 57). Further, it is expected that the development would improve access to the region, allowing the commercial forestry to reopen and the tourism industry to expand (Quebec, 2009, pg. 70). Similar impacts may be expected from the Little Mecatina project. It is certain that with development, the landcover will change and so will current rainfall-runoff relationships.

Table 3: Landcover

Watershed	Forest	Non-Forest Vegetation	Barren / Developed	Wetlands	Water	Unclassified
Romaine	69.5 %	14.4 %	3.1 %	1.4 %	10.9 %	0.7 %
Natashquan	71.2 %	13.4 %	3.0 %	0.7 %	10.7 %	1.0 %
Little Mecatina	68.7 %	15.1%	5.3 %	1.2 %	9.0 %	0.7 %
St. Augustin	74.3 %	12.9%	3.1 %	1.3 %	8.0 %	0.4 %
Coxipi	80.6 %	3.1%	0.3 %	1.2 %	9.6 %	5.2 %
Napetipi	85.4 %	3.5%	0.8 %	1.2 %	8.3 %	0.8 %
St. Paul	71.6 %	15.1%	2.0 %	3.7 %	7.2 %	0.4 %

Figure 3: Transboundary Watersheds Landsat Imagery



Short Wave Infrared (bands 7, 4, 2) Landsat Imagery circa 2000. Trees and bushes, crops and wetland vegetation appear as shades of green. Water appears as black to dark blue, urban areas as lavender and bare soil as magenta, lavender, or pale pink.

Ecodistricts

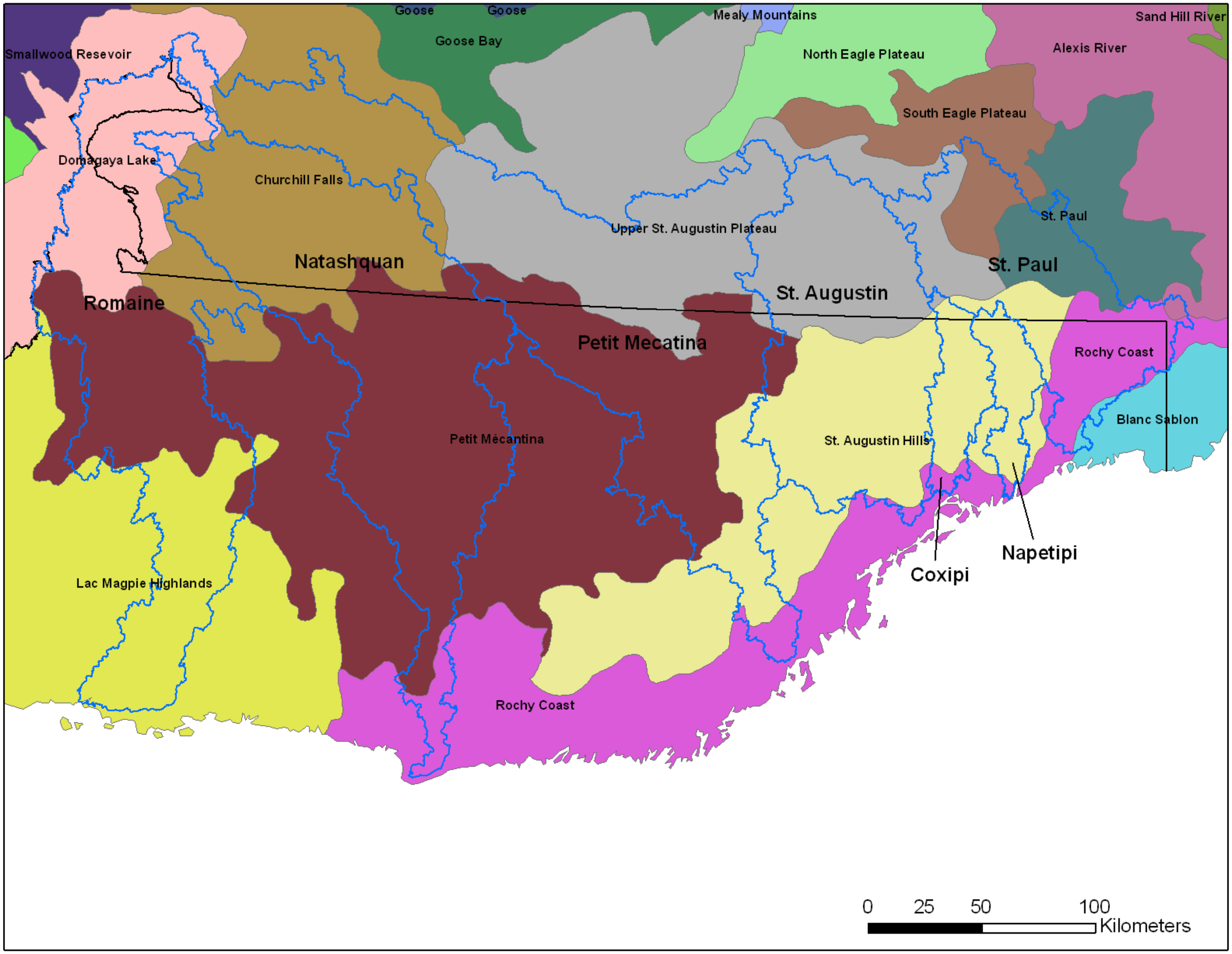
Between 1991 and 1999 the National Ecological Framework for Canada was developed with the goal of creating a series of distinct units to capture the unique ecological systems throughout Canada. The National Ecological Framework for Canada has four levels of generalization with ecodistricts being the smallest. The objective of the ecodistricts, of which there are1,021 in Canada, is to define unique groupings of relief, landforms, geology, soil, vegetation, water bodies and fauna (Agriculture and Agri-Food Canada, 2010).

Ecodistricts are important to this study as they are used as the basis for extracting additional information for this region and the transboundary watersheds. Monthly climatic normals for the 1961-1990 period were compiled for the 1,021 ecodistricts in Canada (see glossary). The climate normals information originated from point-based weather station data obtained from Environment Canada in 1994 (Bootsma and Ballard, 2010). The 1961-1990 climate normals data was used to further characterize watersheds in this study. Climate data is an essential component of any water resources study as factors such as temperature and precipitation are key inputs to the hydrologic processes within the watersheds.

The transboundary watersheds are comprised of ten distinct ecodistricts. They are:

1. Domagaya Lake
2. Churchill Falls
3. Petit Mecatina
4. Lac Magpie Highlands
5. Rochy Coast
6. St. Augustin Hills
7. Upper St. Augustin Plateau
8. South Eagle Plateau
9. St. Paul
10. Blanc Sablon

Figure 4: Transboundary Watersheds Federal Ecodistricts



Climate Normals – Temperature and Windspeed

Temperature can have a major impact on the hydrology of any watershed. Temperature can influence evaporation thereby the amount of available water. Winter temperatures have a significant impact of ice production. As well, temperature plays a key role in the development physical characteristics of the watershed, such as vegetation.

In the transboundary study area average daily mean temperatures are generally warmer near the coast and cooler inland, particularly in the northwest. This pattern is most evident during the winter where there is nearly a 10 °C range from the south east to the northwest. Summer temperatures are generally warmer inland. All of the ecodistricts have large temperature ranges between summer and winter, most over 30°C.

Table 4: Climate Normals – Temperature

Watershed	Annual Daily Mean Temperature (°C)	January Daily Mean Temperature (°C)	July Daily Mean Temperature (°C)
Romaine	-2.8 to 1.4	-20.3 to -13.1	13.8 to 14.7
Natashquan	-2.8 to 1.2	-20.3 to -12.8	13.8 to 14.2
Little Mecatina	-2.8 to 1.2	-20.3 to -12.8	13.8 to15.2
St. Augustin	0 to 1.2	-16.5 to -12.8	13.9 to 15.2
Coxipi	0 to 1.2	-16.5 to -12.8	13.9 to 15.2
Napetipi	1.1 to 1.2	-13.4 to -12.8	13.9 to 14.1
St.Paul	0 to 1.8	-16.5 to -10.6	12.9 to 15.2

Windspeed is another important climatic factor. Wind can influence potential evapotranspiration and is a factor in ice production. It also impacts snow cover and snow water equivalent (Maidment, 1993, pg. 7.5).

In the transboundary study area winds are stronger near the coast, particularly in the south eastern regions where average daily wind speeds are over 20 km/hr.

Table 5: Climate Normals – Windspeed

Watershed	Annual Daily Mean Windspeed (km/hr)	Annual Daily Maximum Windspeed (km/hr)
Romaine	14.8 - 15.9	15.2 - 18.2
Natashquan	14.8 - 18.9	15.2 - 25.6
Little Mecatina	14.8 - 19.0	15.2 - 25.6
St. Augustin	17.1 - 19.0	21.5 - 25.6
Coxipi	17.1 - 19.0	21.5 - 25.6
Napetipi	18.9 - 19.0	22.3 - 25.6
St.Paul	17.1 - 23.8	21.5 - 26.8

Figure 5: Ecodistrict Annual Mean Temperatures for Transboundary Watersheds

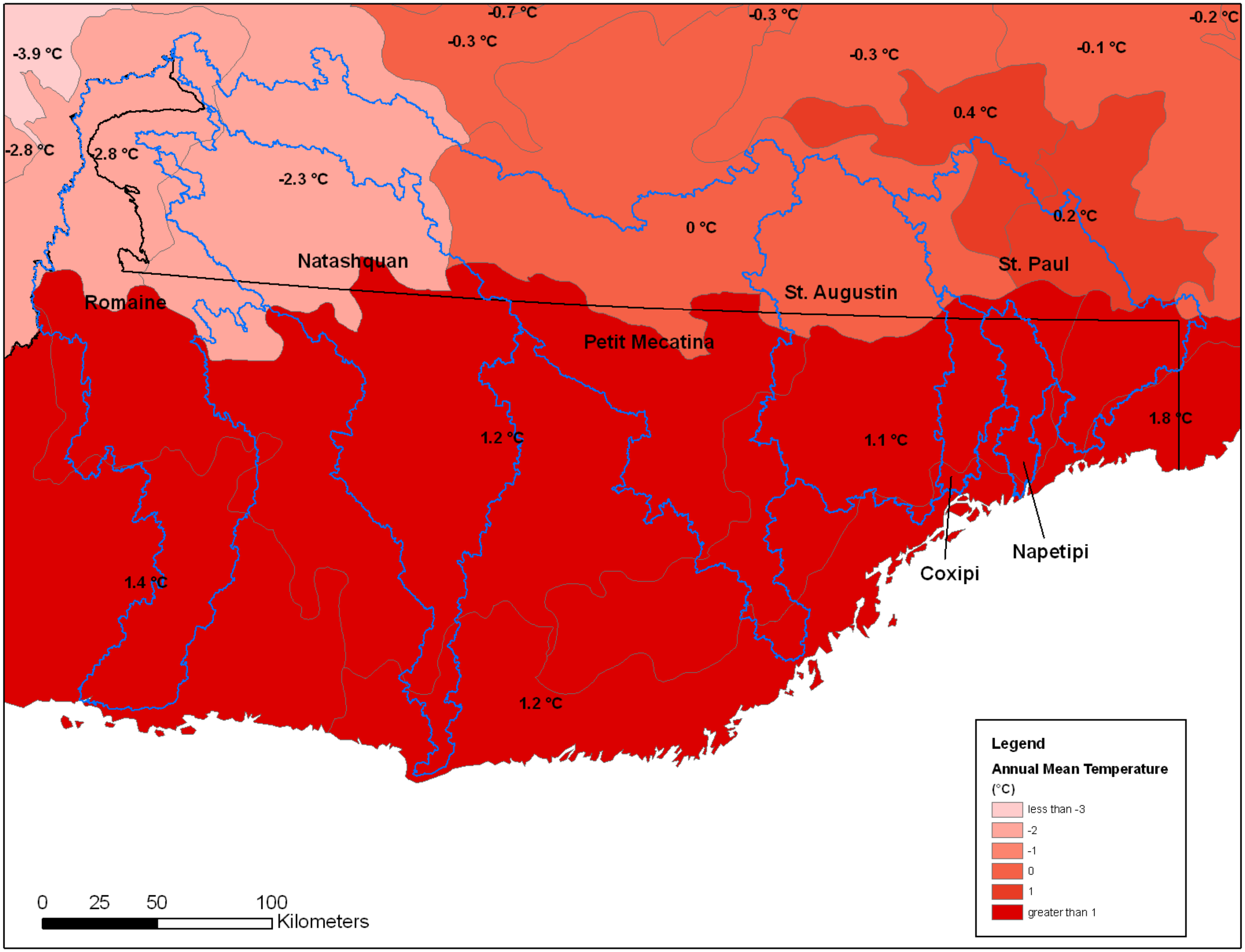


Figure 6: Ecodistrict January Mean Temperatures for Transboundary Watersheds

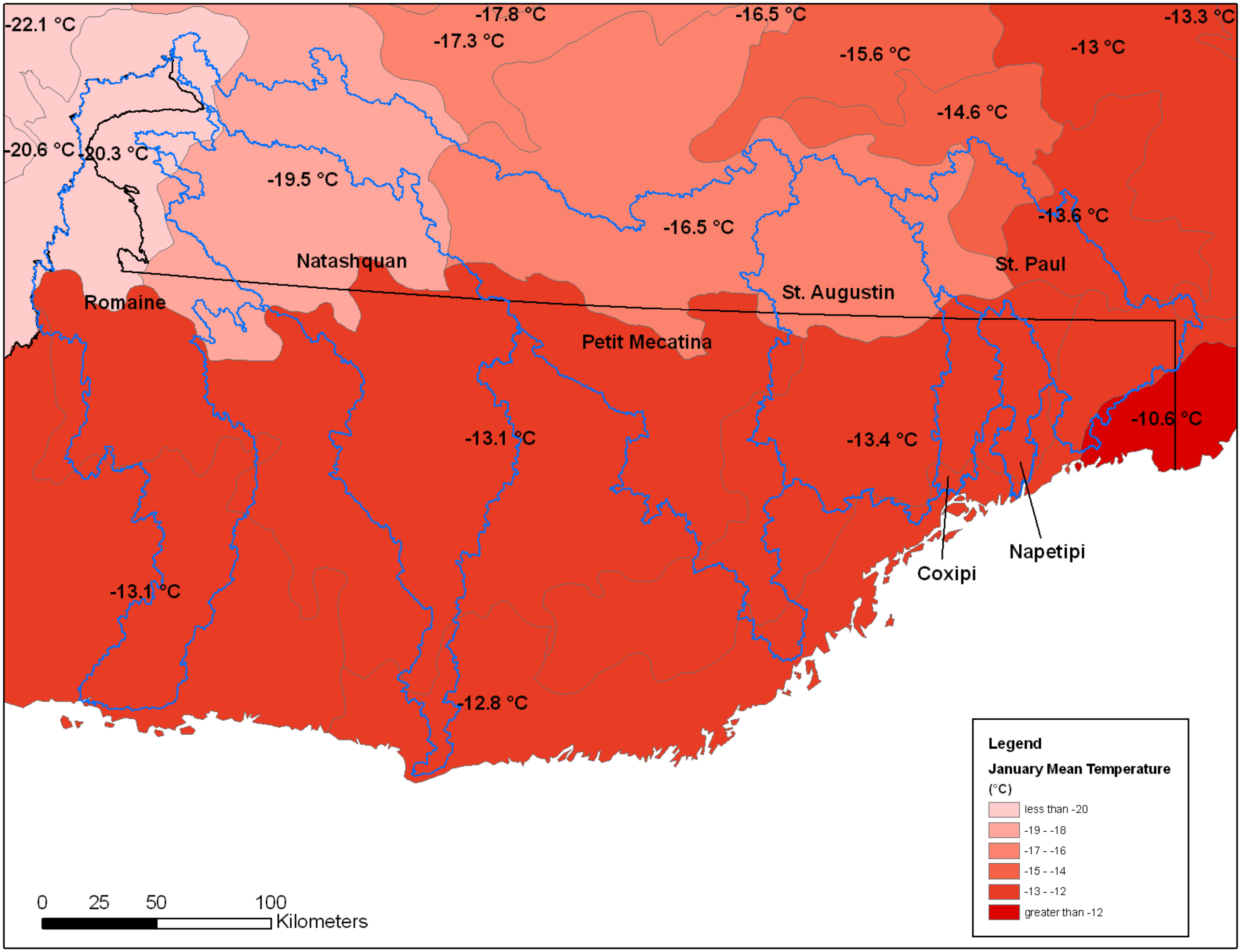


Figure 7: Ecodistrict July Mean Temperatures for Transboundary Watersheds

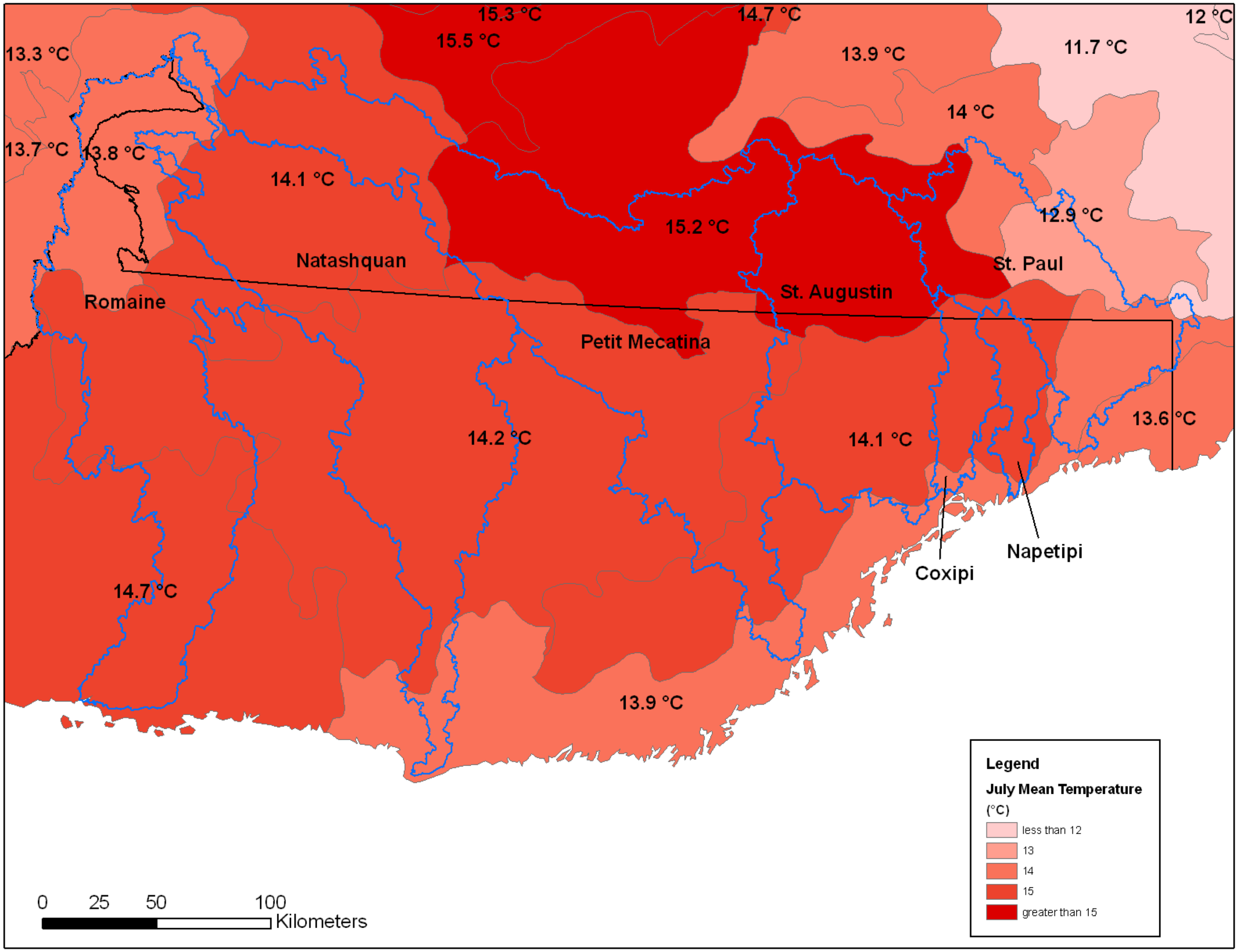
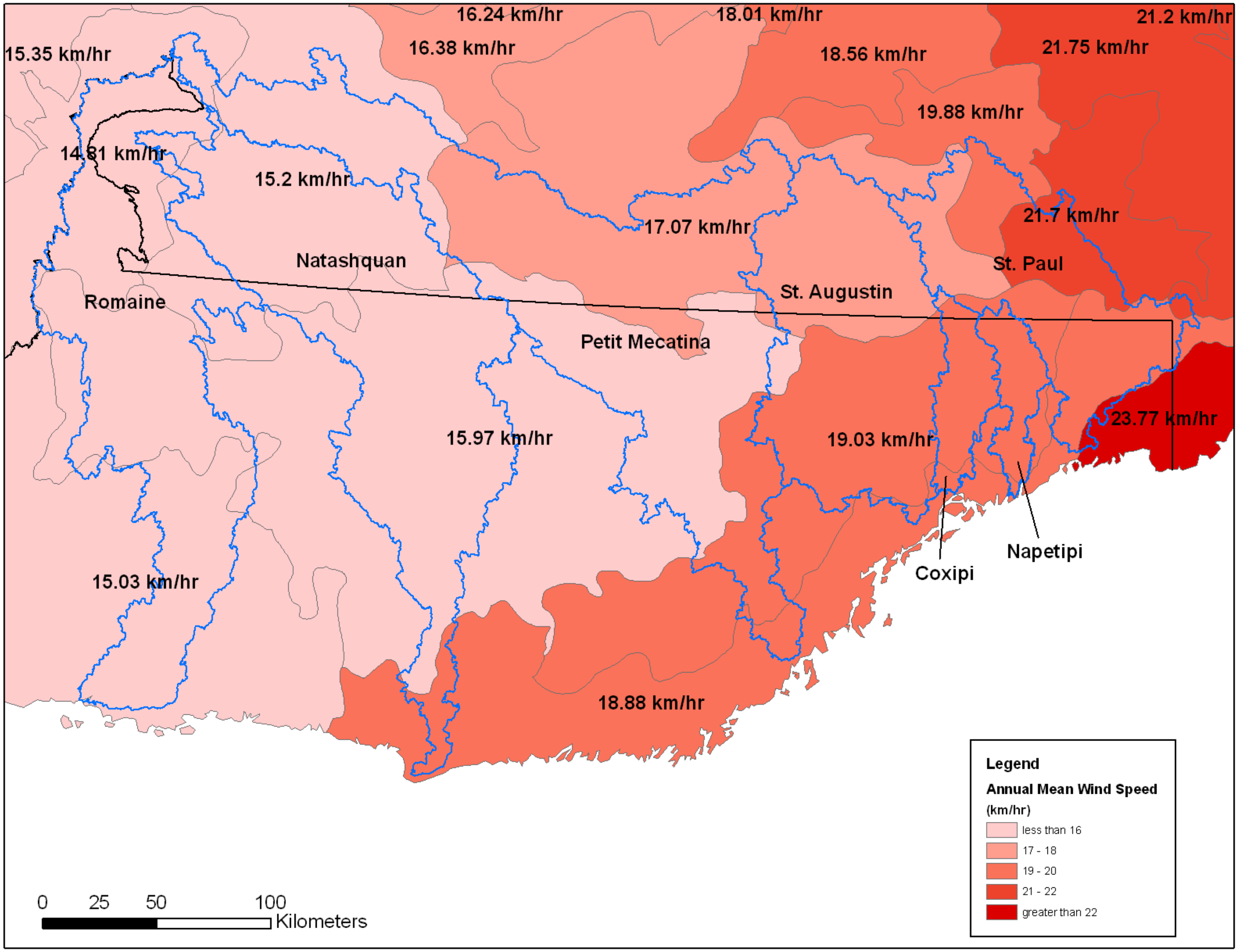


Figure 8: Ecodistrict Annual Mean Wind Speeds for Transboundary Watersheds



Climate Normals – Precipitation

Precipitation is one of the major factors in determining the hydrologic functions of a watershed. The amount of total precipitation available to a watershed will have a direct impact on the amount of runoff and flow in a river system. The form in which precipitation is delivered is important to the hydrology as well. Rainfall may reach a river much quicker as runoff than snowfall which may reach the systems in a delayed fashion during melting periods (i.e. spring). The seasonal melt of snow cover is one of the most important hydrologic events of the year, particularly in northern regions (Maidment, 1993, pg. 7.1). Potential evapotranspiration (see glossary) is another factor influencing hydrology as it defines the amount of evaporation that will occur if sufficient water is available. In the following figures precipitation surplus refers to the annual total precipitation – PE. It provides a measure of how much precipitation is available to "feed" into the river system.

In the transboundary study area total precipitation is greatest in the south eastern regions, with totals over 1,000 mm the norm. The majority of this precipitation in the southeast comes as rainfall with amounts greater than 800 mm, more than 300 mm than the average totals in the northwest portions. Snowfall is greater in the northern portions of the watersheds. Over 400 cm of snow is commonly found on the Labrador side of the border, with less than 300 cm near the coast. Potential evapotranspiration is fairly uniform but lowest in the northwest. The highest amounts of precipitation surplus are found along the coast, but over 500 mm surplus are found throughout the region.

Table 6: Climate Normals – Precipitation

Watershed	Annual Total Precipitation (mm)	Annual Rainfall (mm)	Annual Snowfall (cm)	Potential Evapotranspiration (mm)	Precipitation Surplus (mm)
Romaine	943.7 – 1,052.9	532.6 - 774.1	260.4 - 442.9	404.6 - 448.8	532.7 - 609.3
Natashquan	943.7 – 1,098.8	532.6 - 813.5	285.8 - 442.9	404.6 - 443.6	539.0 - 662.5
Little Mecatina	943.7 – 1,122.4	532.6 - 839.3	285.8 - 442.9	404.6 - 444.6	539.0 - 685.0
St. Augustin	1,005.4 – 1,122.4	628.9 - 839.3	292.5 - 426.0	436.3 - 444.6	560.8 - 685.0
Coxipi	1,005.4 – 1,122.4	628.9 - 839.3	292.5 - 426.0	436.3 - 444.6	560.8 - 685.0
Napetipi	1,098.8 - 1122.4	813.5 - 839.3	292.5 - 294 .0	436.3 - 437.4	662.5 - 685.0
St.Paul	1,005.4 – 1,122.4	628.9 - 839.3	292.5 - 426.0	424.5 - 444.6	560.8 - 685.0

Figure 9: Ecodistrict Annual Precipitation for Transboundary Watersheds

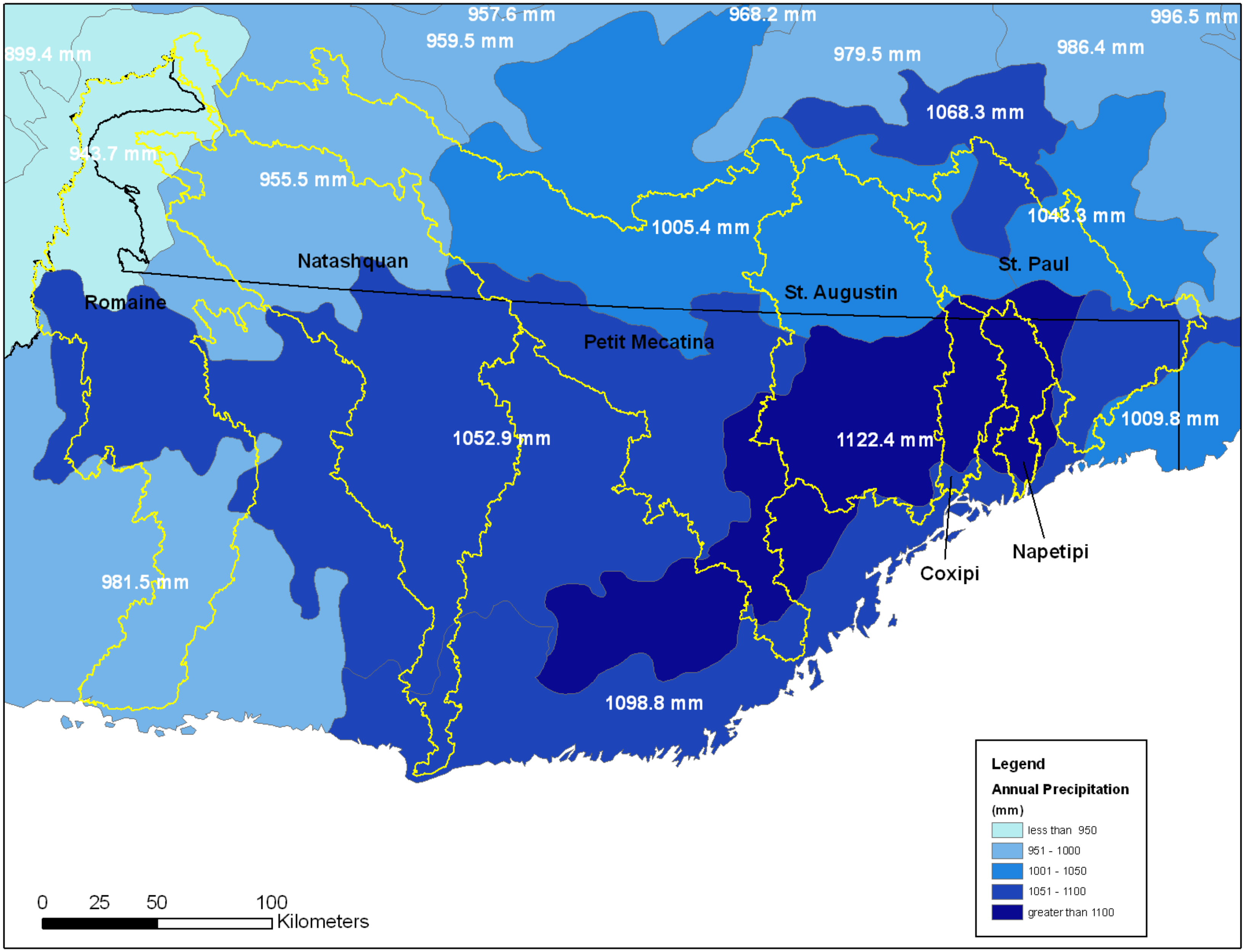


Figure 10: Ecodistrict Annual Rainfall for Transboundary Watersheds

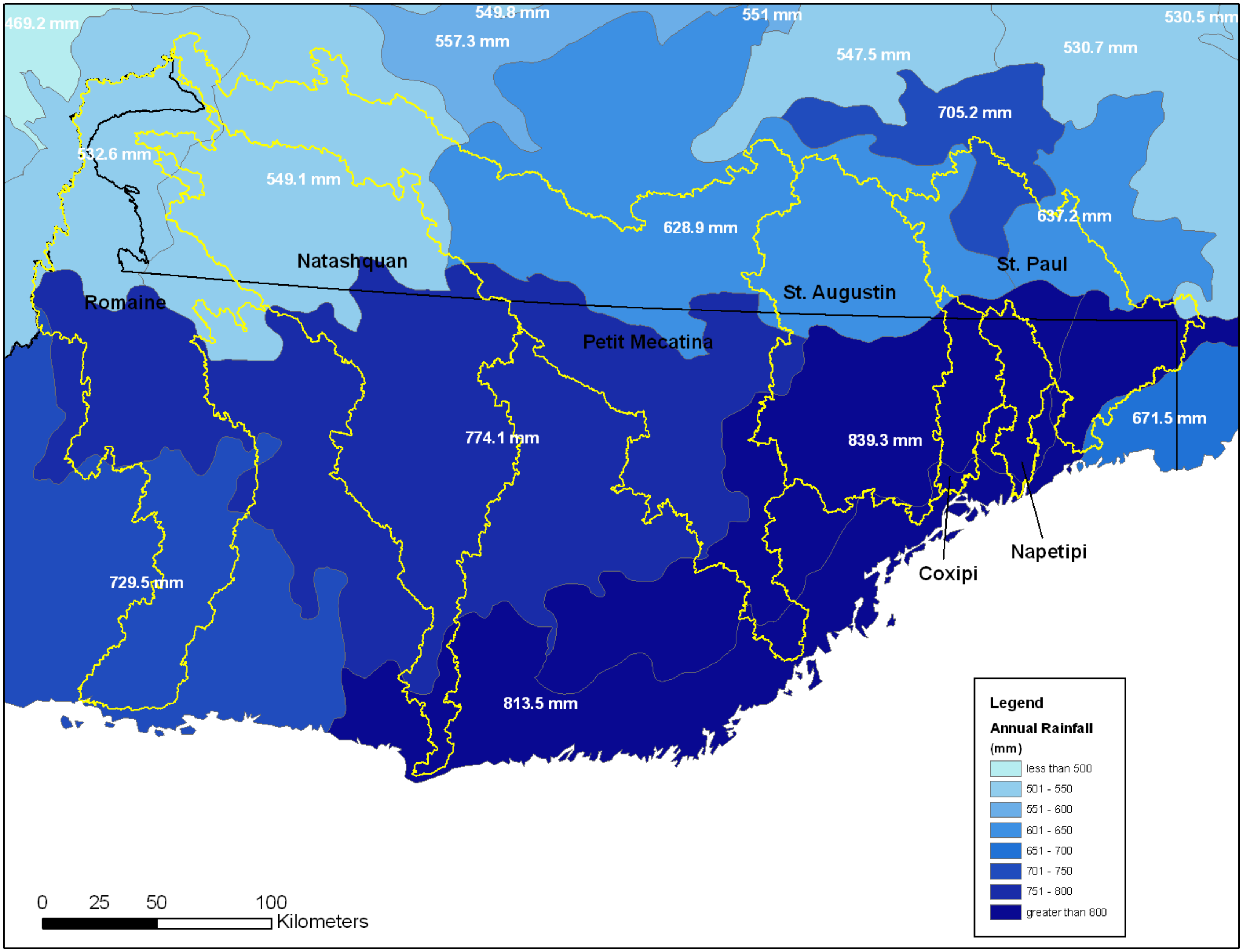


Figure 11: Ecodistrict Annual Snowfall for Transboundary Watersheds

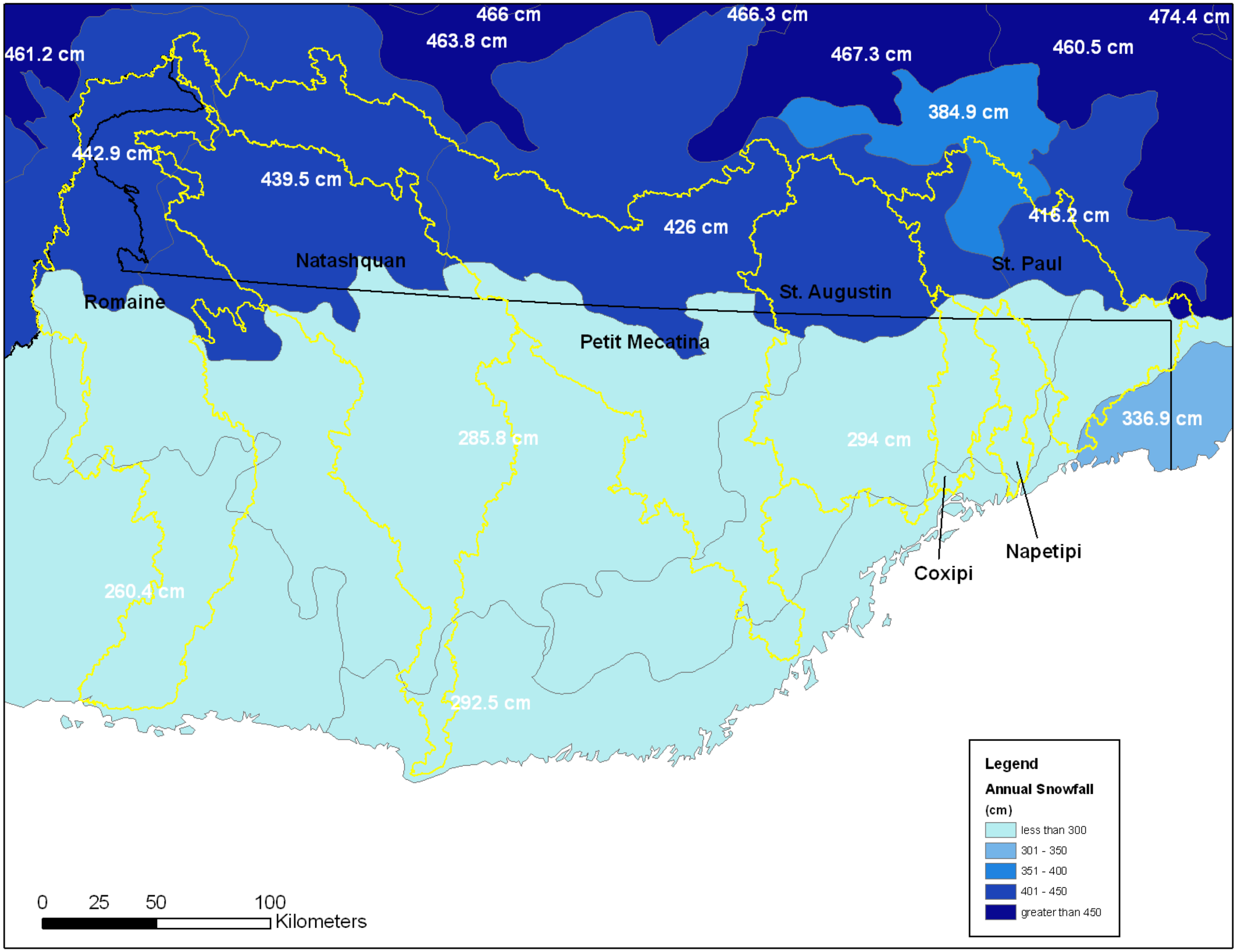


Figure 12: Ecodistrict Annual Potential Evapotranspiration for Transboundary Watersheds

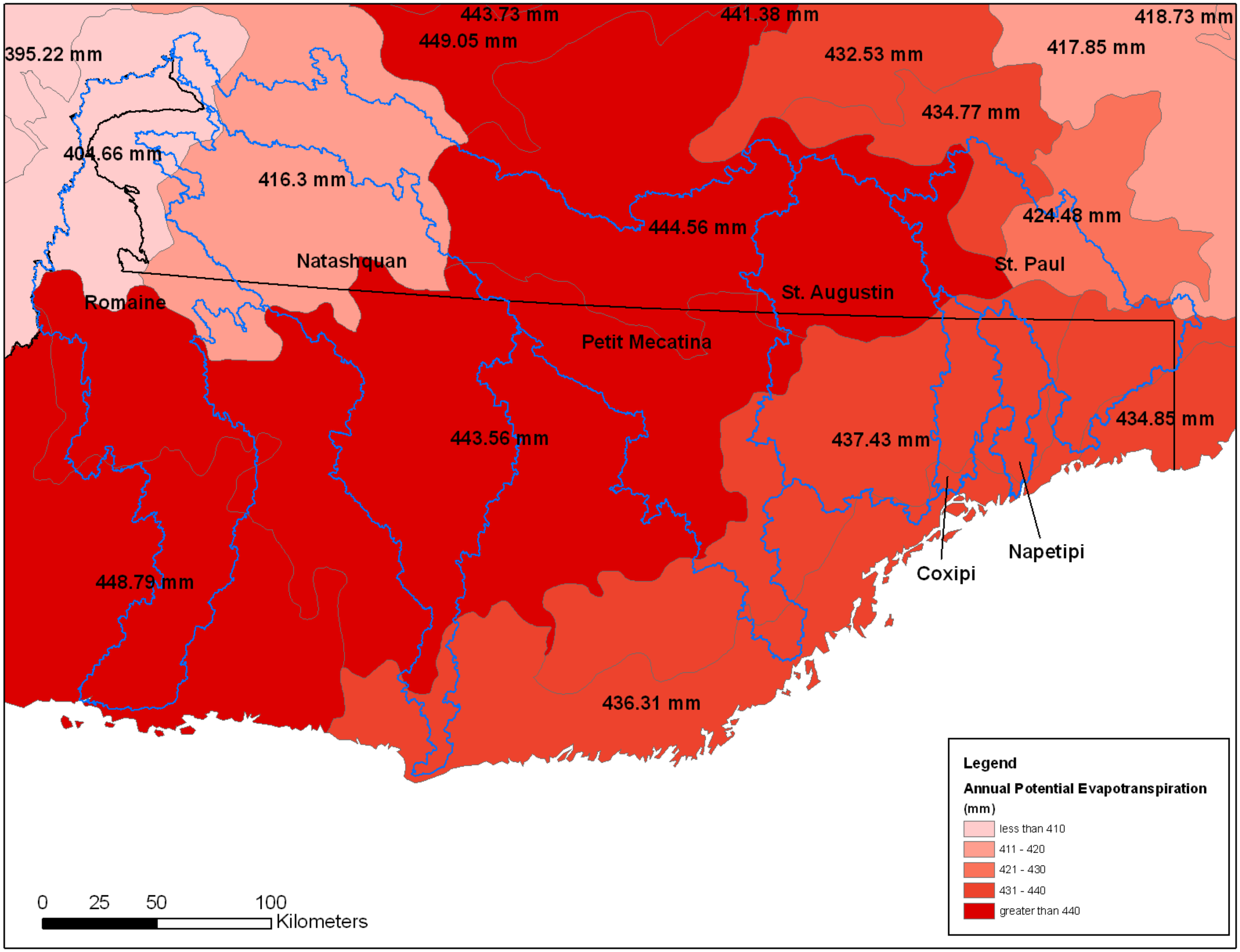
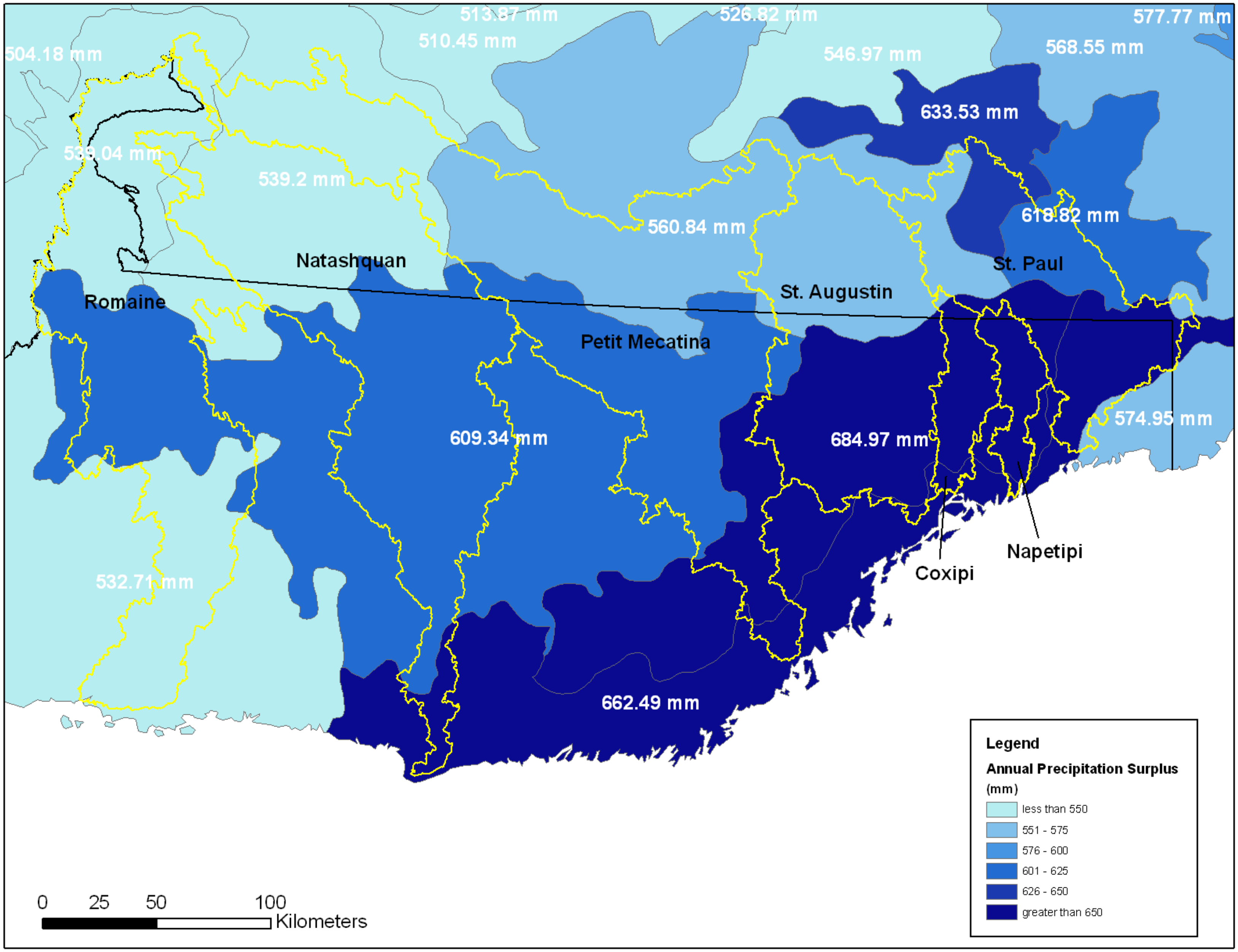


Figure 13: Ecodistrict Annual Precipitation Surplus for Transboundary Watersheds



Hydrometric Data

Water quantity data is essential to the effective management of water resources and the surrounding environment. Hydrometric data has a multitude of uses including flood forecasting, fisheries management, climate change research and hydroelectric power generation (Environment Canada, 2010a). In Canada, hydrometric data is collected and distributed by the Water Survey of Canada.

There are over 2,500 active streamflow / water level stations in Canada although most of these are located in the southern portion of the country where population densities are the highest. As a result, the adequacy of the network to describe hydrologic characteristics, both spatially and temporally, decreases considerably in northern areas such as the transboundary study area (Environment Canada, 2010c). Hydrometric data from Canada's hydrometric network is stored in a relational database called Hydat (Environment Canada, 2010b). Hydat contains streamflow data for both active and inactive hydrometric stations.

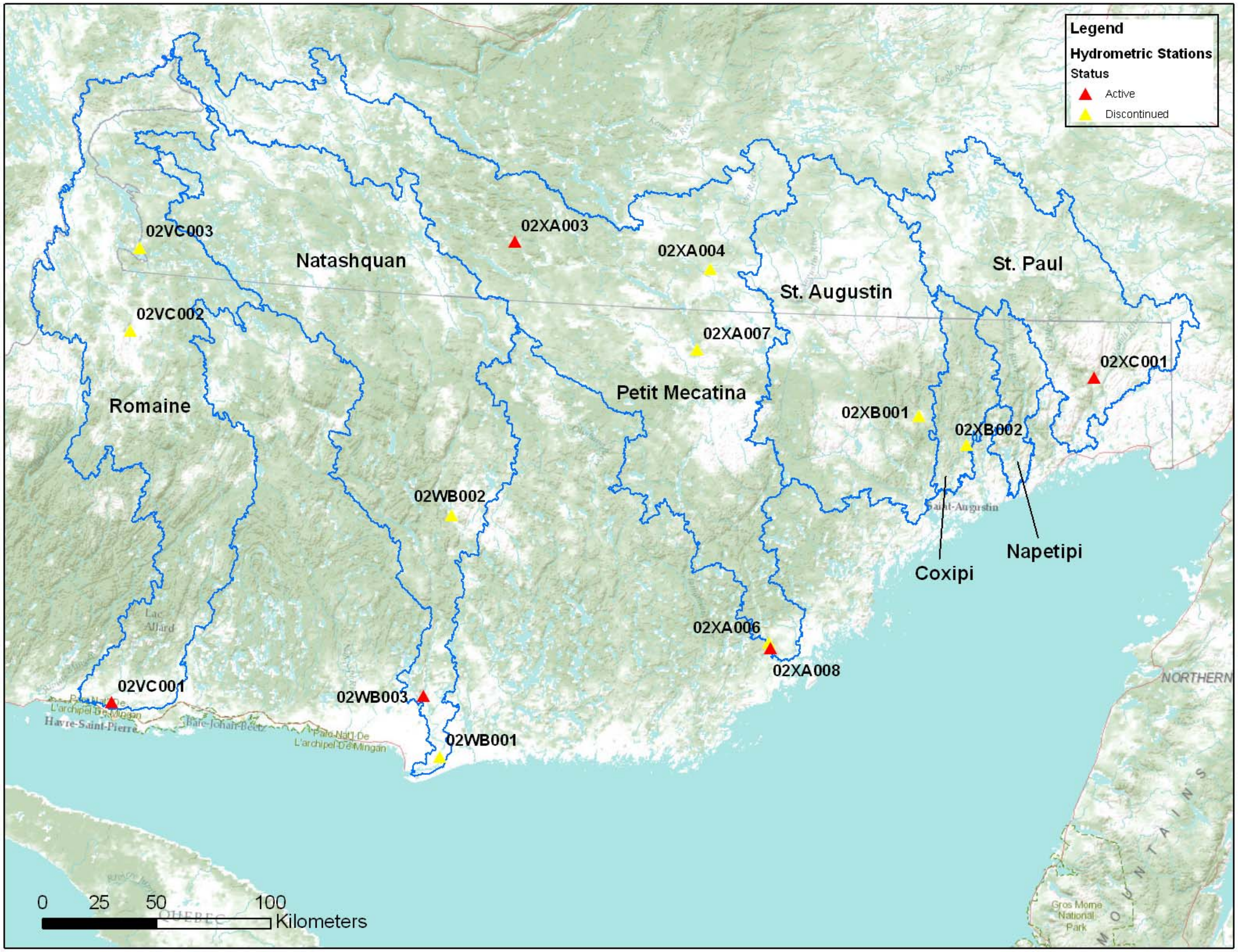
There are 14 hydrometric stations in the transboundary study area with streamflow data in the Hydat database. The period of record for these stations ranges from two years to 46 years. All the transboundary watersheds, with the exception of the Napetipi River, have streamflow data in Hydat. Five of the stations are listed as active and nine as discontinued. Very few of the stations have recent data but they do provide some insight into the flow patterns within these watersheds.

The following sections of the report analyze the data collected from the hydrometric stations which allows for a level of understanding of the hydrodynamics of the region. It is important to note that spatial and temporal data gaps in the network limit the understanding of the hydrodynamics of the region. As with all regions, a continuous long-term period of record for the region is necessary to understand water-use problems and make technical decisions.

Table 7: Period of Record for Hydrometric Stations Located in Transboundary Watersheds

WATERSHED	STATION NUMBER	STATION NAME	FIRST YEAR	LAST YEAR	RECORD LENGTH
Romaine	02VC001	ROMAINE (RIVIERE) AU PONT DE LA Q.I.T.	1956	2001	46
Romaine	02VC002	ROMAINE (RIVIERE) EN AVAL DE LA RIVIERE AUX SAUTERELLES	1972	1982	11
Romaine	02VC003	ROMAINE (RIVIERE) BELOW LAC LAVOIE	1999	2000	2
Natashquan	02WB001	NATASHQUAN (RIVIERE) PRES DE L'EMBOUCHURE	1962	1971	10
Natashquan	02WB002	NATASHQUAN (RIVIERE) EN AVAL DE LA RIVIERE NATASHQUAN EST	1966	1983	18
Natashquan	02WB003	NATASHQUAN (RIVIERE) A 0,6 KM EN AVAL DE LA DECHARGE DU LAC ALIESTE	1980	2001	22
Little Mecatina	02XA003	LITTLE MECATINA RIVER ABOVE LAC FOURMONT	1978	2010	33
Little Mecatina	02XA004	RIVIERE JOIR NEAR PROVINCIAL BOUNDARY	1980	1996	17
Little Mecatina	02XA006	PETIT MECATINA (RIVIERE DU)	1965	1980	16
Little Mecatina	02XA007	PETIT MECATINA (RIVIERE DU) EN AVAL DU LAC BRETON	1978	1993	16
Little Mecatina	02XA008	PETIT MECATINA (RIVIERE DU) A 1,0 KM EN AMONT DE LA NETAGAMIOU	1994	2001	8
St. Augustin	02XB001	SAINT-AUGUSTIN (RIVIERE) EN AVAL DE LA RIVIERE A LAMOUCHE	1967	1982	16
Coxipi	02XB002	COXIPI (RIVIERE) A LA SORTIE DU LAC COXIPI	1980	1993	14
St. Paul	02XC001	SAINT-PAUL (RIVIERE) A 0,5 KM DU RUISSEAU CHANION	1967	2001	35

Figure 14: Hydrometric Stations Located in Transboundary Watersheds



Romaine River

The watershed of the Romaine River, the most westerly of the transboundary rivers, is quite large and covers an area of approximately 14,290 km^2 (Table 1). The majority of the watershed is in Quebec as only 2,220 km^2 (15.5 %) falls within Labrador. The main channel of this watershed is approximately 518 km. While portions of the watershed are in Labrador, none of the actual river is in Labrador as the east bank of the Romaine forms the Quebec / Labrador boundary. The Romaine River has a Strahler stream order of seven (Table 1, Figure 16).

There is a significant elevation range within the watershed, with elevations of over 900 m along the western boundary of the watershed. The maximum elevation within the watershed is about 950 m with an average elevation of 500 m throughout the watershed (Table 2, Figure 17). The elevation at the headwaters of the main channel is approximately 730 m creating an average stream gradient of 1.41 m/km. There are however portions of the river with a much steeper gradient. For example, the river drops over 200 m in the first 50 km. The river profile (Figure 18) provides greater details of the varying gradient along the river system.

The watershed is heavily forested, with about 9,935 km^2 (69.5 %) of the area comprised of forest. There is about 1,555 km^2 (10.9 %) of water within the drainage basin and 2,055 km^2 (14.4 %) of vegetation forms such as shrubs and grasslands. There is 440 km^2 (3.1 %) of barren or developed land within the watershed. There is very little development within the watershed and a large portion of the barren land is located in the upper region of the basin near the provincial border. There is 195 km^2 (1.4 %) of wetlands in the watershed, the majority of which are located in the southern portion of the basin near the mouth of the river. See Table 3, Figure 19 and Figure 20 for more detail.

The Romaine River flows through the federal ecodistricts of Domagaya Lake, Churchill Falls, Petit Mecatina and Lac Magpie Highlands (Figure 4). Monthly climatic normals for the period of 1961 -1990 were compiled for all the ecodistricts of Canada. Annual daily mean temperatures (based on these climate normals of the ecodistricts) range from -2.8 °C to 1.4 °C. Winter daily mean temperatures (January) range from -20.3 °C to -13.1 °C with summer (July) temperatures in the range of 13.8 °C to 14.7 °C. Table 4, Figure 5, Figure 6 and Figure 7 depict temperature normals for the ecodistricts in the study area. Annual daily mean wind speeds range from 14.8 km/hr to 15.9 km/hr (Table 5, Figure 8), with maximum wind speeds ranging from 15.2 km/hr to 18.2 km/hr. Throughout the varying regions of the watershed, yearly precipitation totals range from 943.7 mm to 1,052.9 mm. Annual rainfall amounts range from 532.6 mm to 774.1 mm and snowfall accumulations are generally from 260.4 cm to 442.9 cm. Table 6, Figure 9, Figure 10 and Figure 11 provide more detail on the distribution of precipitation in the region. Depending on the area of the watershed, potential evapotranspiration ranges from 404.66 mm to 448.79 mm (Table 6, Figure 12). This creates precipitation surpluses in the range of 532.7 mm to 609.3 mm a year (Table 6, Figure 13).

There were three hydrometric stations located in the Romaine River watershed, none of which are active (Figure 14). Of these stations 02VC001 has the longest period of record dating from 1956 to 2001, a period of 46 years (Table 7). As shown in Figure 14 it is also the most downstream of the Romaine River stations. Mean Annual Flows for the period of record at this station ranges from 201 m^3/s to 401 m^3/s with a minimum flow of 35.8 m^3/s and a maximum flow of 2,390 m^3/s. Minimum flows generally occur during the winter, largely due to ice conditions.

Maximum flows are usually found in May or June, presumably due to snowmelt. Table 8 and Figure 21 provide greater detail on flows at 02VC001.

Major tributaries of the Romaine River include Riviere de l'Abbe-Huard, Riviere Garneau, Riviere Puyjalon and the Senecal River.

Figure 15: Romaine River Watershed

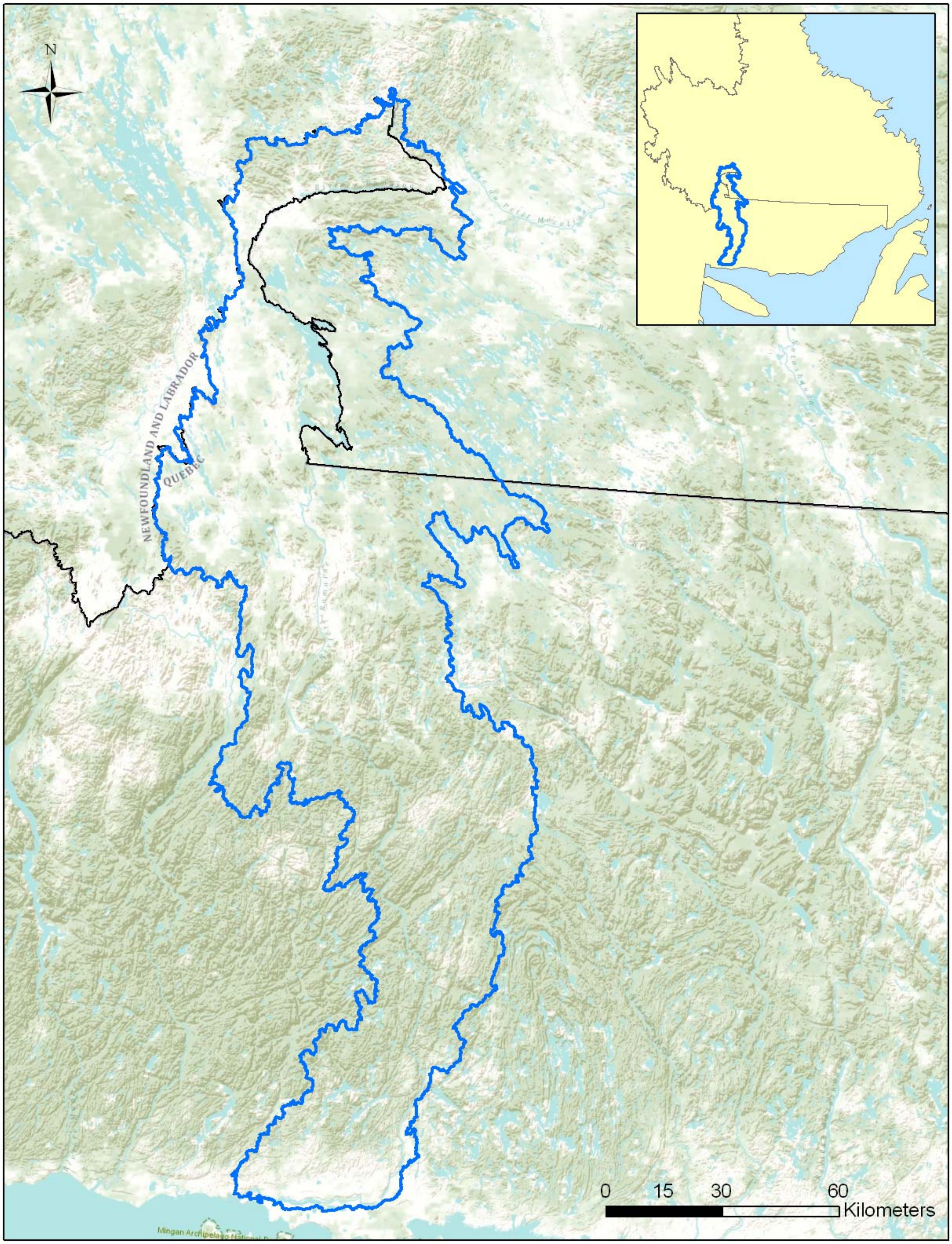


Figure 16: Romaine River Stream Order

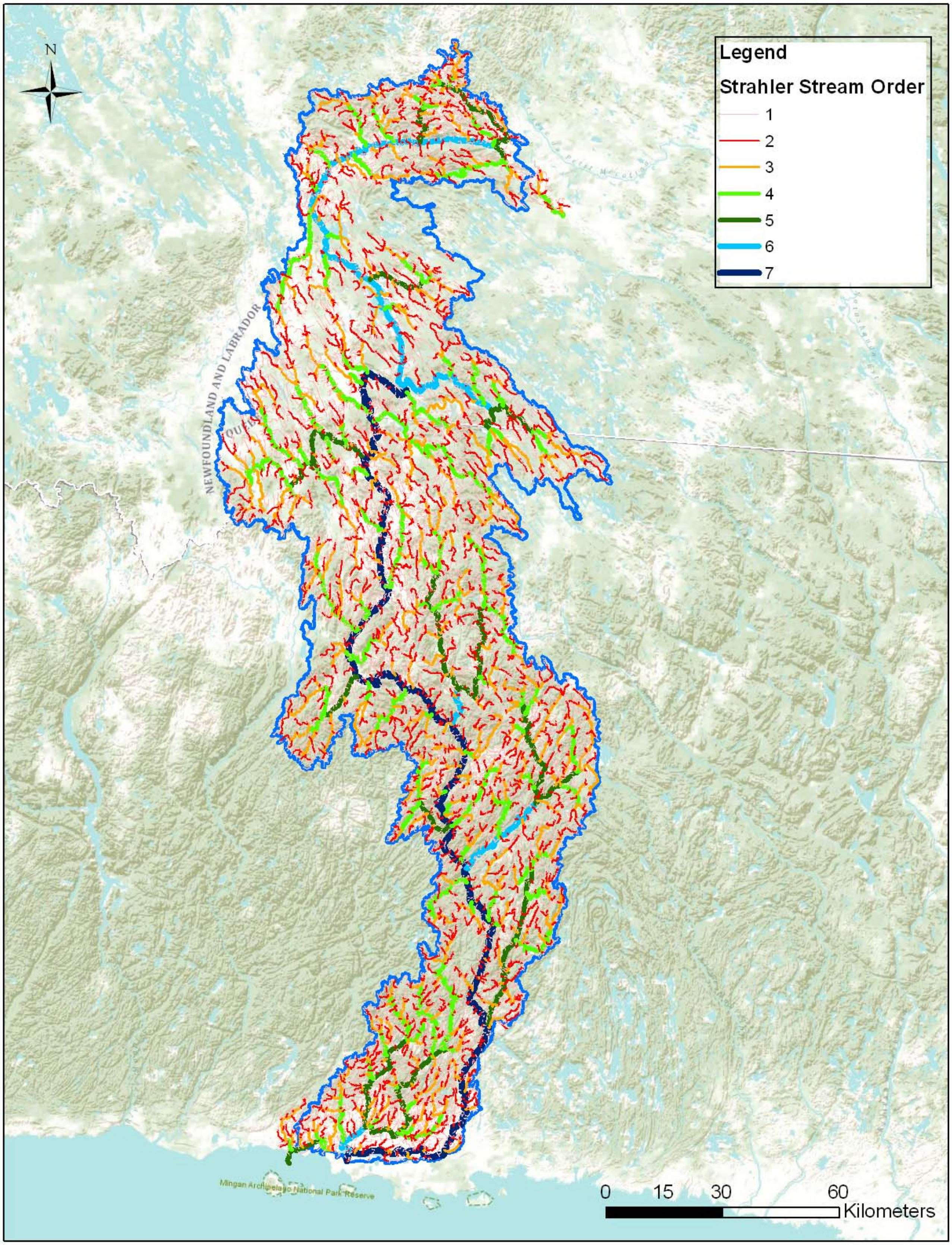


Figure 17: Romaine River Watershed Elevation

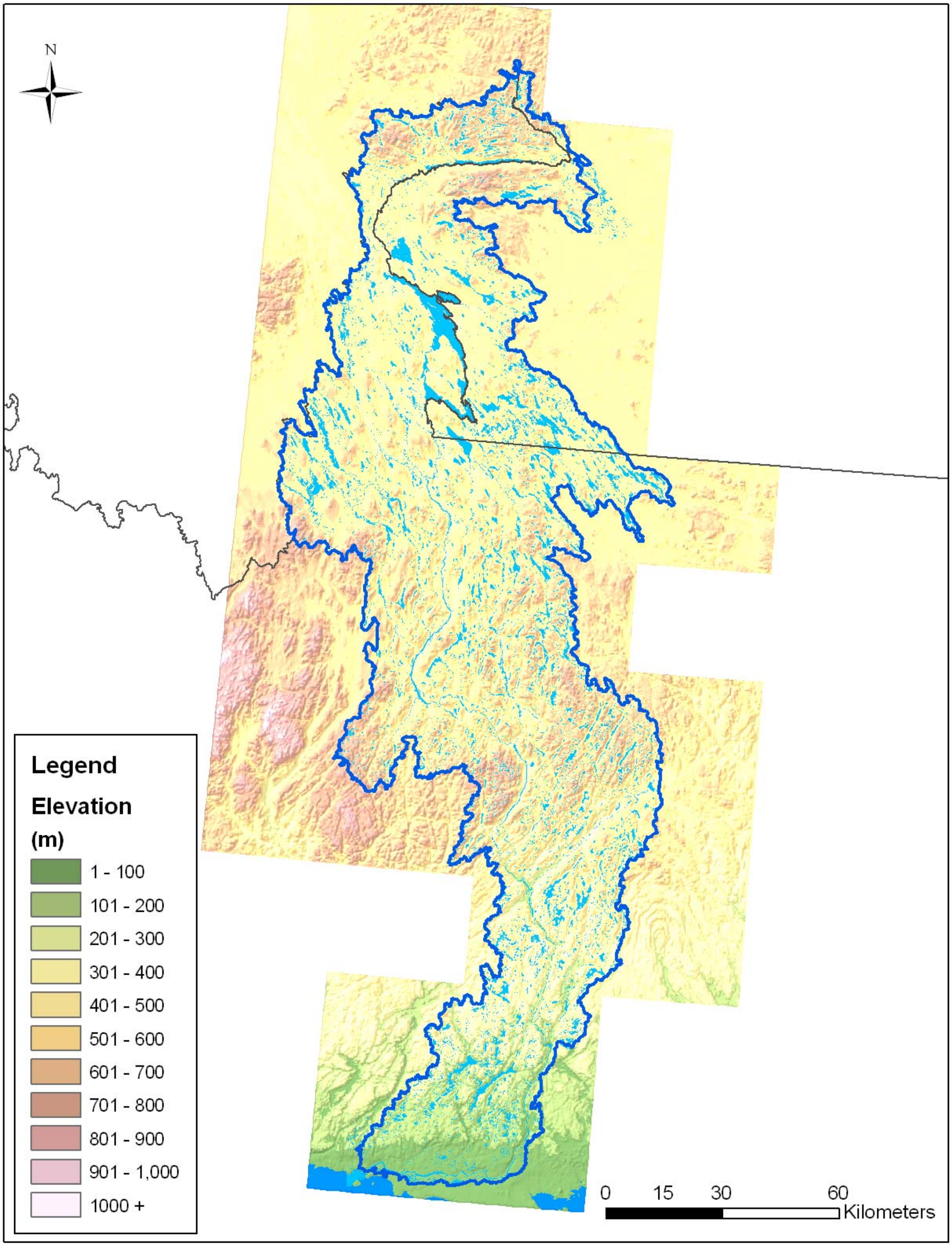


Figure 18: Romaine River Elevation Profile

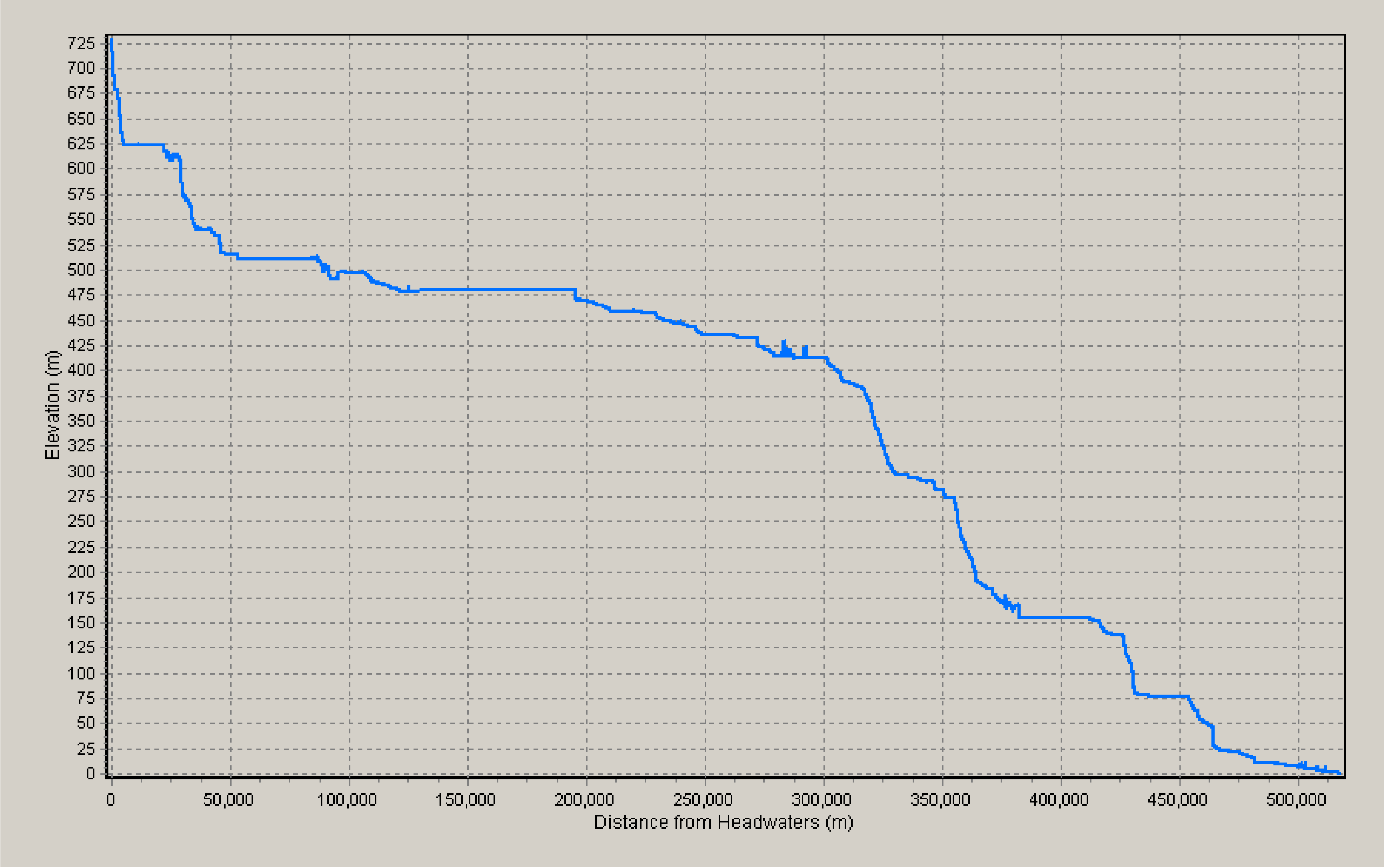
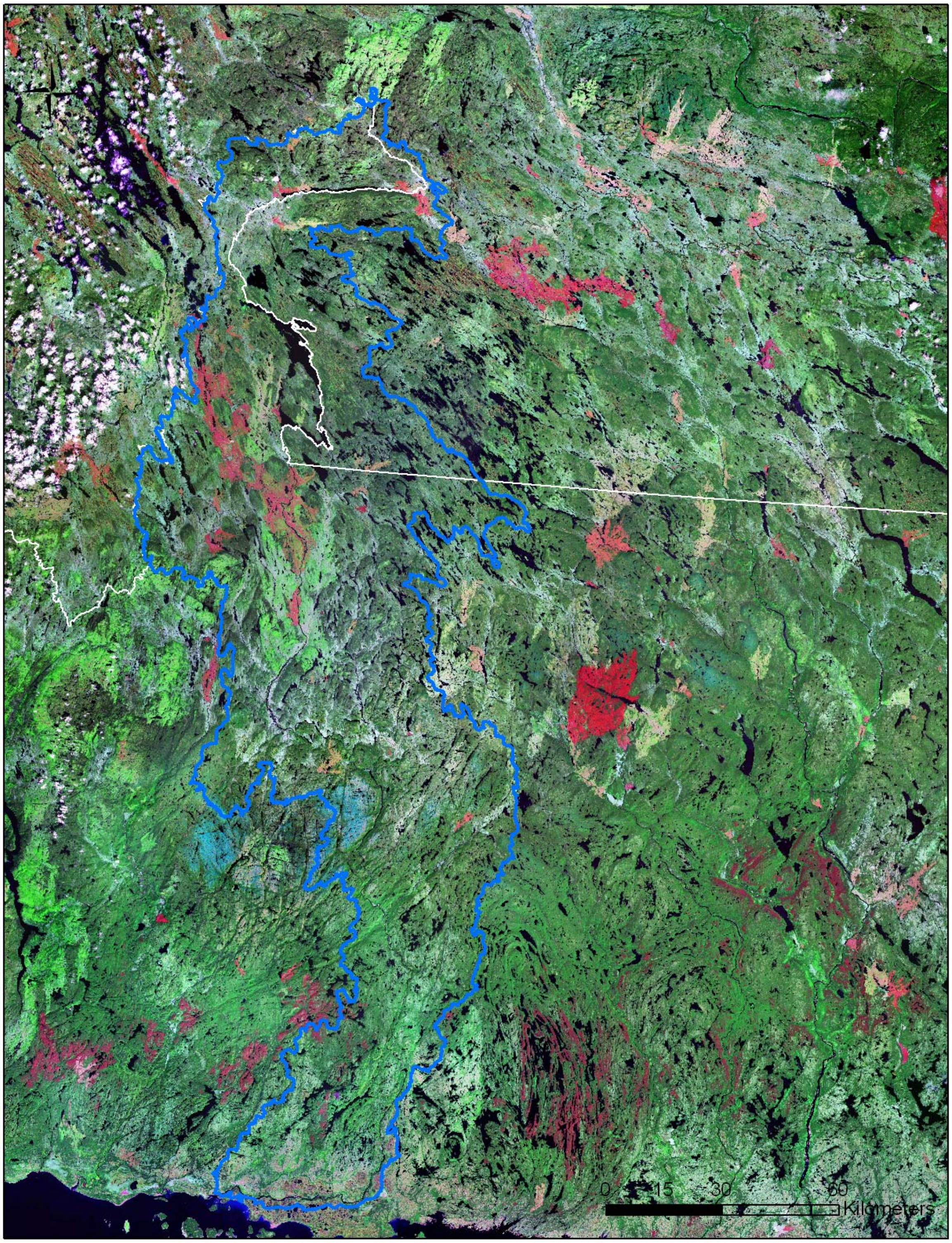


Figure 19: Romaine River Watershed Landsat Imagery



Short Wave Infrared (bands 7, 4, 2) Landsat Imagery circa 2000. Trees and bushes, crops and wetland vegetation appear as shades of green. Water appears as black to dark blue, urban areas as lavender and bare soil as magenta, lavender, or pale pink.

Figure 20: Romaine River Watershed Landcover

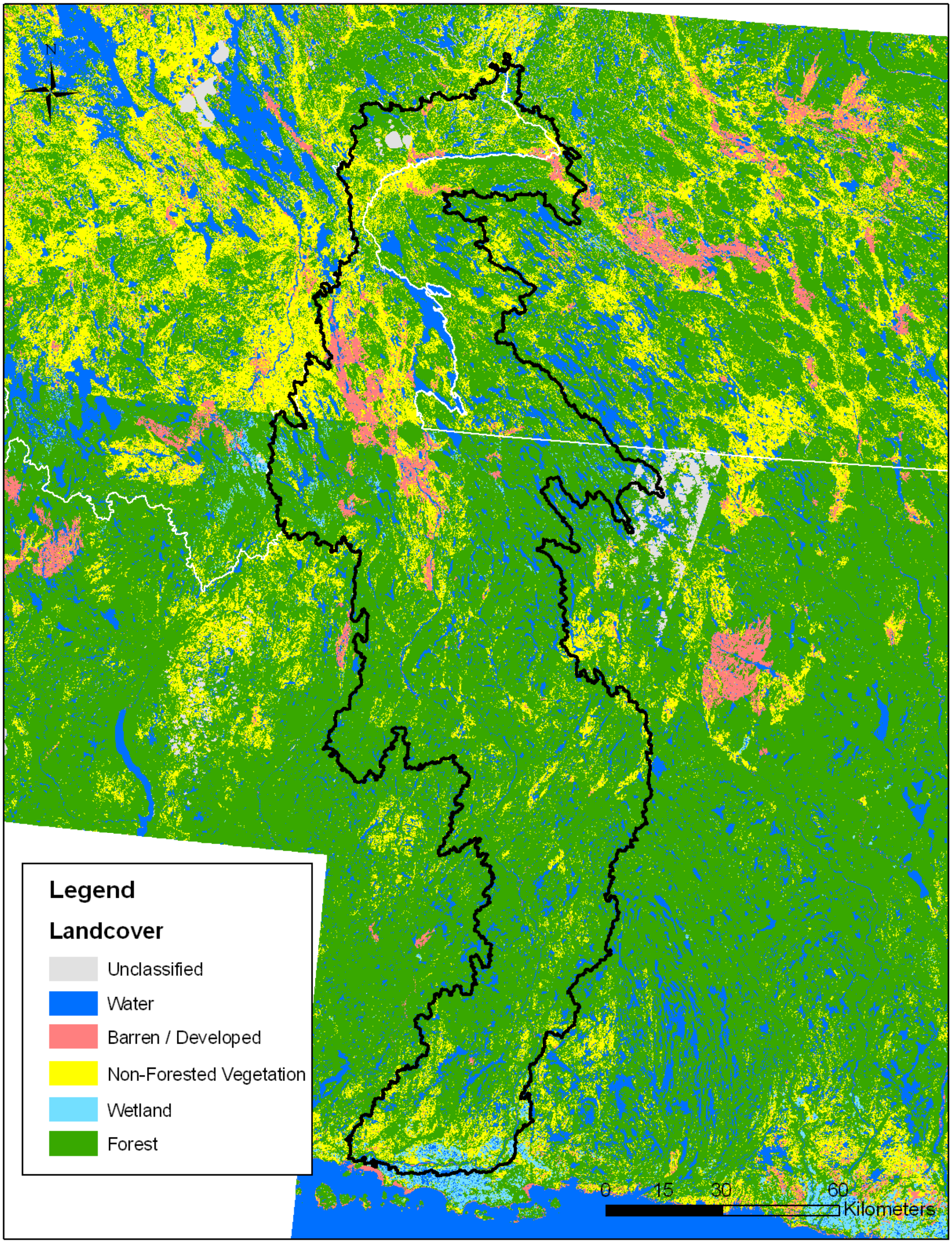


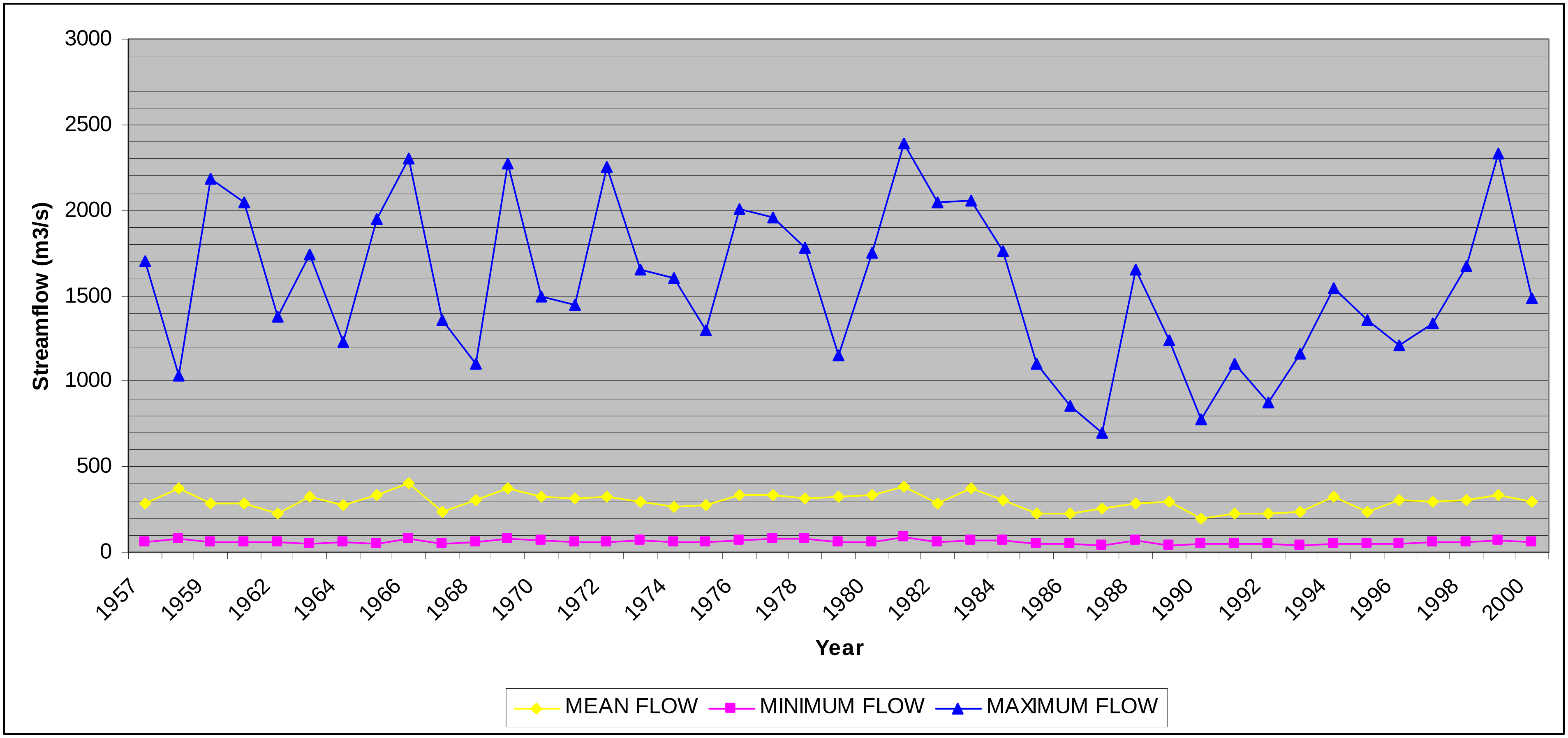
Table 8: Annual Flow Statistics for 02VC001 Hydrometric Station

YEAR	MEAN FLOW	MIN_MONTH	MIN_DAY	MINIMUM FLOW	MIN_SYMBOL	MAX_MONTH	MAX_DAY	MAXIMUM FLOW	MAX_SYMBOL
1957	281	4	6	57.8	B	6	5	1,700	
1958	370	1	8	83.5	B	5	31	1,030	
1959	287	3	1	61.2	B	10	28	2,180	E
1961	287	3	1	60	B	6	1	2,050	
1962	230	2	13	62.3	B	6	2	1,380	E
1963	327	3	9	46.4	B	5	28	1,740	
1964	276	3	14	54.4	B	5	31	1,230	
1965	330	4	17	45.3	B	6	9	1,950	
1966	401	3	6	75		6	6	2,300	
1967	240	5	1	53.5	B	6	10	1,360	E
1968	304	3	15	61.7	B	6	5	1,100	E
1969	373	4	29	81.8	B	6	9	2,270	
1970	322	12	25	68	B	5	22	1,500	A
1971	318	3	31	54.4	B	5	15	1,450	
1972	322	3	15	59.2	B	6	6	2,250	
1973	298	4	16	66.5	B	5	25	1,650	
1974	264	3	24	62.3	B	6	6	1,600	
1975	274	2	23	63.4		6	4	1,300	
1976	332	3	19	73.3	B	5	24	2,010	
1977	334	3	25	75.6	B	5	26	1,960	
1978	316	4	5	75	E	5	21	1,780	E
1979	322	3	1	60.5	B	5	7	1,150	
1980	337	4	14	56.2	B	5	23	1,750	
1981	380	2	2	84.8	B	6	2	2,390	
1982	283	3	27	56	B	6	4	2,050	
1983	375	3	21	65	B	5	4	2,060	E
1984	303	4	4	67.5	B	5	26	1,760	
1985	231	4	6	53.7	B	6	3	1,100	
1986	231	4	11	46.2	B	5	17	855	
1987	258	3	15	39.1	B	10	31	703	
1988	283	3	18	66	B	5	24	1,650	

YEAR	MEAN FLOW	MIN_MONTH	MIN_DAY	MINIMUM FLOW	MIN_SYMBOL	MAX_MONTH	MAX_DAY	MAXIMUM FLOW	MAX_SYMBOL
1989	292	3	20	43.4	B	5	21	1,240	
1990	201	3	5	45.4	B	5	13	778	
1991	228	4	13	51.6	B	5	27	1,100	
1992	229	3	25	45.9	B	5	16	872	
1993	237	3	22	35.8	B	5	23	1,160	
1994	324	3	10	50.2	B	5	22	1,540	
1995	240	4	11	50	B	5	25	1,360	
1996	309	2	20	51.3	B	5	25	1,210	
1997	296	4	15	57.2	B	5	24	1,339	
1998	304	2	25	59.7	B	5	17	1,675	
1999	332	3	1	66.4	B	5	12	2,329	
2000	293	3	16	59.4	B	6	3	1,488	

Note: For Minimum and Maximum Symbols: B = Ice Conditions; E = Estimated, A= Partial Day

Figure 21: Annual Flow Graph for 02VC001 Hydrometric Station



Romaine River Watershed Data Summary:

Watershed Area: 14,290 km^2
% in Labrador: 2,220 km^2 (15.5 %)

Main Channel Length: 518 km
% in Labrador: 0 (east bank forms boundary)

Main Channel Elevation: 730 m
Stream Gradient: 1.41 m/km

Strahler Stream Order: 7

Elevation Range: 0 – 945 m
Avg Elevation: 500 m
Median Elevation: 538 m

Landcover:
Barren / Developed: 440 km^2 (3.1 %)
Forest: 9,935 km^2 (69.5 %)
Non-Forest Vegetation: 2,055 km^2 (14.4 %)
Water: 1,555 km^2 (10.9 %)
Wetland: 195 km^2 (1.4 %)
Unclassified: 110 km^2 (0.7 %)

Climate Normals:

Temperature:
Annual Daily Mean Temperature: -2.8 °C to 1.4 °C
January Daily Mean Temperature:-20.3 °C to -13.1 °C
July Daily Mean Temperature: 13.8 °C to 14.7 °C

Wind:
Annual Daily Mean Windspeed: 14.8 km/hr to 15.9 km/hr
Annual Daily Maximum Windspeed: 15.2 km/hr to 18.2 km/hr

Precipitation:
Annual Total Precipitation: 943.7 mm to 1,052.9 mm
Annual Rainfall: 532.6 mm to 774.1 mm
Annual Snowfall: 260.4 cm to 442.9 cm
Potential Evapotranspiration: 404.66 mm to 448.8 mm
Precipitation Surplus: 532.7 mm to 609.3 mm

Natashquan River

The Natashquan River watershed is the second largest of the transboundary rivers with an area of approximately 15,930 km^2 (Table 1). A significant portion of the watershed is within Labrador, roughly 6,340 km^2 (39.8 %). The main channel of this watershed is approximately 462 km, with 36.6 % (169 km) of river on the Labrador side of the boundary. The Natashquan River has a Strahler stream order of seven (Table 1, Figure 23).

Elevations in the Natashquan River watershed are highest in the northwestern portion of the basin as altitudes are over 500 m in this area. The maximum elevation within the watershed is about 765 m with an average elevation of 430 m throughout the watershed (Table 2, Figure 24). The elevation at the headwaters of the main channel is approximately 625 m creating an average stream gradient of 1.35 m/km. The gradient is much steeper on the Labrador portion of the river as the river drops over 400 m in the first 150 to 170 km. The river profile (Figure 25) provides greater details of the varying gradient along the river system.

The Natashquan is adjacent to the Romaine watershed and as such they have very similar landcover. The watershed is dominated by forest cover, with about 71.2 % (11, 345 km^2) of the area comprised of forest. There is about 1700 km^2 (10.7 %) of water within the drainage basin. There is approximately 2,130 km^2 (14.4 %) of vegetation forms such as shrubs and grasslands, mainly in the northern portions of the watershed. There is 475 km^2 (3.0 %) of barren or developed land within the watershed. The majority of barren land is located near the headwaters of the basin and there is limited development within the watershed. There is 115 km^2 (0.7 %) of wetlands in the watershed and, similar to the Romaine, the majority of these are located in the southern portion of the basin near the mouth of the river. Table 3, as well as Figure 26 and Figure 27, provide additional details.

The Natashquan River flows through the federal ecodistricts of Domagaya Lake, Churchill Falls, Petit Mecatina and Rochy Coast (Figure 4). Monthly climatic normals for the period of 1961 - 1990 were compiled for all the ecodistricts of Canada. Based on the climate normals of these ecodistricts, annual daily mean temperatures in the watershed range from -2.8 °C to 1.2 °C. Winter daily mean temperatures (January) range from -20.3 °C to -12.8 °C with summer (July) temperatures in the range of 13.8 °C to 14.2 °C. Temperature normals for the ecodistricts in the study area can be seen in Table 4 and Figure 5, Figure 6 and Figure 7. Annual daily mean wind speeds range from 14.8 km/hr to 18.9 km/hr (Table 5, Figure 8), with maximum wind speeds ranging from 15.2 km/hr to 25.6 km/hr. Yearly precipitation totals range from 943.7 mm to 1,098.8 mm in the various ecodistricts in the watershed. Annual rainfall amounts range from 532.6 mm to 813.5 mm and snowfall accumulations are generally from 285.8 cm to 442.9 cm. Table 6, Figure 9, Figure 10 and Figure 11 provide more detail on the distribution of precipitation in the region. Depending on the area of the watershed, potential evapotranspiration ranges from 404.6 mm to 443.6 mm (Table 6, Figure 12). This creates precipitation surpluses in the range of 539.0 mm to 662.5 mm a year (Table 6, Figure 13).

There were three hydrometric stations located in the Natashquan River watershed, none of which are active (Figure 14). Of these stations 02WB003 has the longest period of record dating from 1980 to 2001, a period of 22 years (Table 7). Mean Annual Flows for the period of record at this station ranges from 271 m^3/s to 427 m^3/s with a minimum flow of 44.8 m^3/s and a maximum flow of 2,795 m^3/s. Minimum flows generally occur during the winter, largely due to ice conditions. Maximum flows are usually found in May or June, presumably due to snowmelt. Table 9 and Figure 28 provide greater detail on flows at 02WB003.

A significant portion of the Quebec portion of Natashquan River watershed, an area of 4,089 km^2, has been proposed as a biodiversity reserve. With protected status, the area would be protected from hydroelectric development (Quebec, 2009, pg. 181).

Major tributaries of the Natashquan River include Riviere Le Dore, Riviere Natashquan Est and Riviere Natashquan Ouest.

Figure 22: Natashquan River Watershed

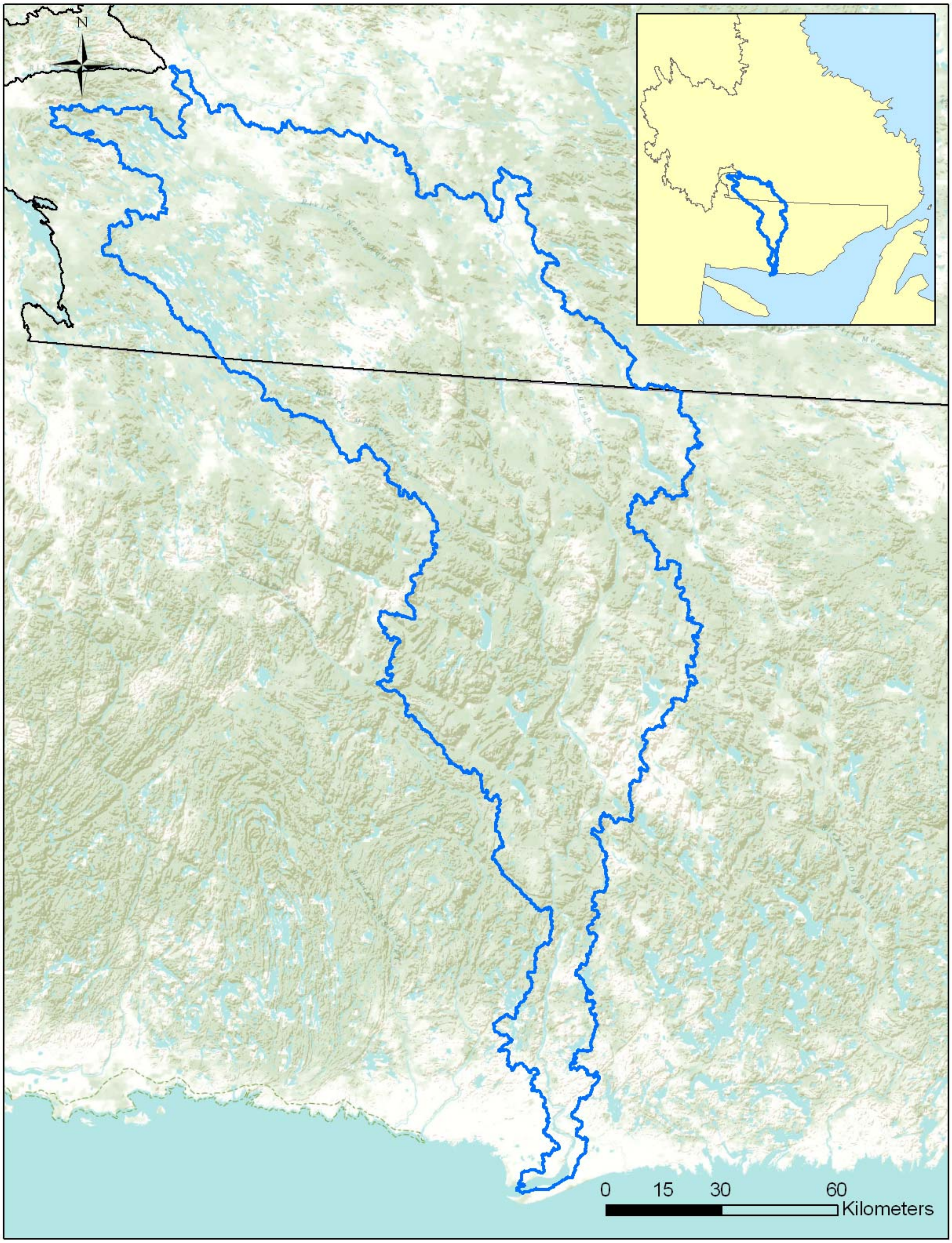


Figure 23: Natashquan River Stream Order

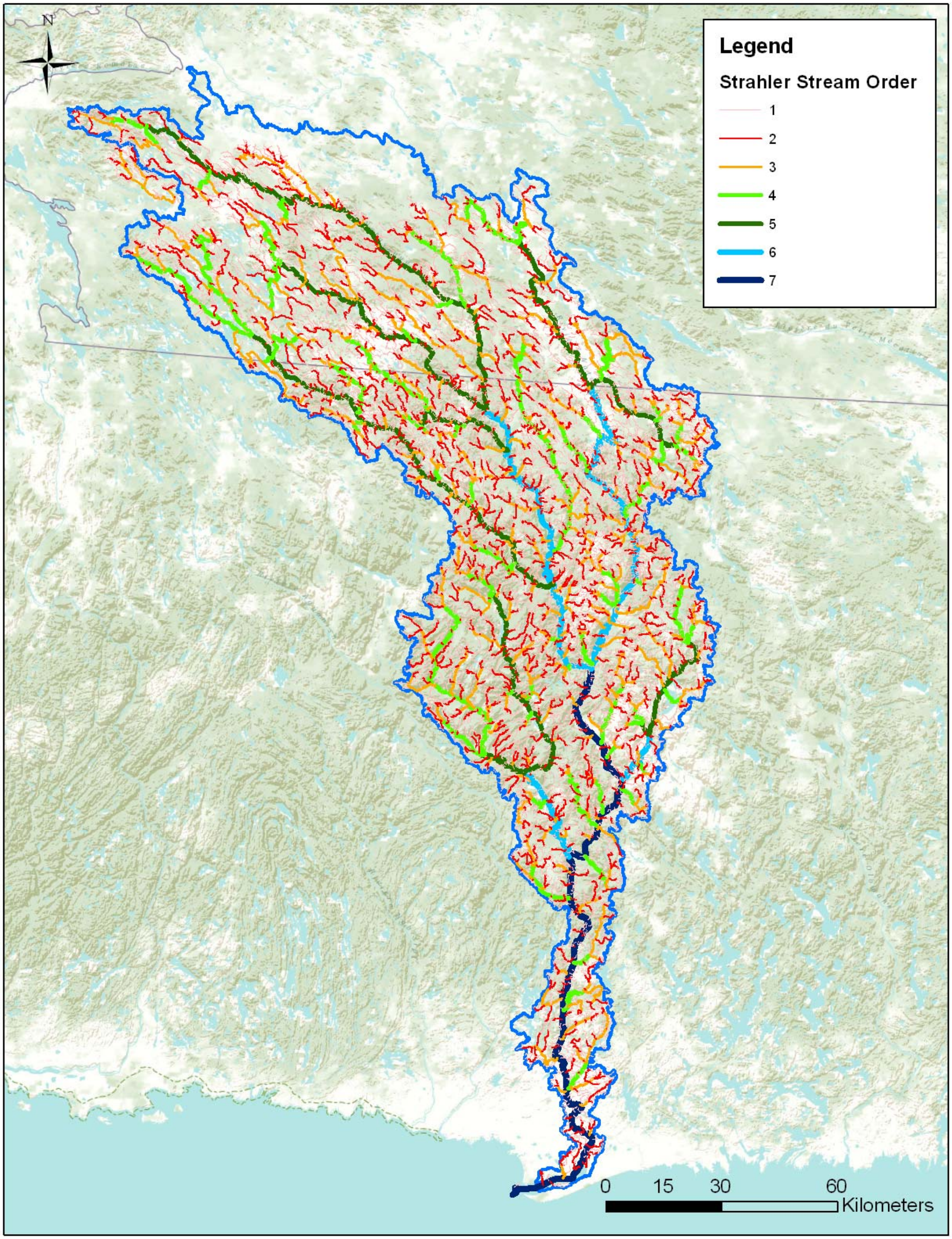


Figure 24: Natashquan River Watershed Elevation

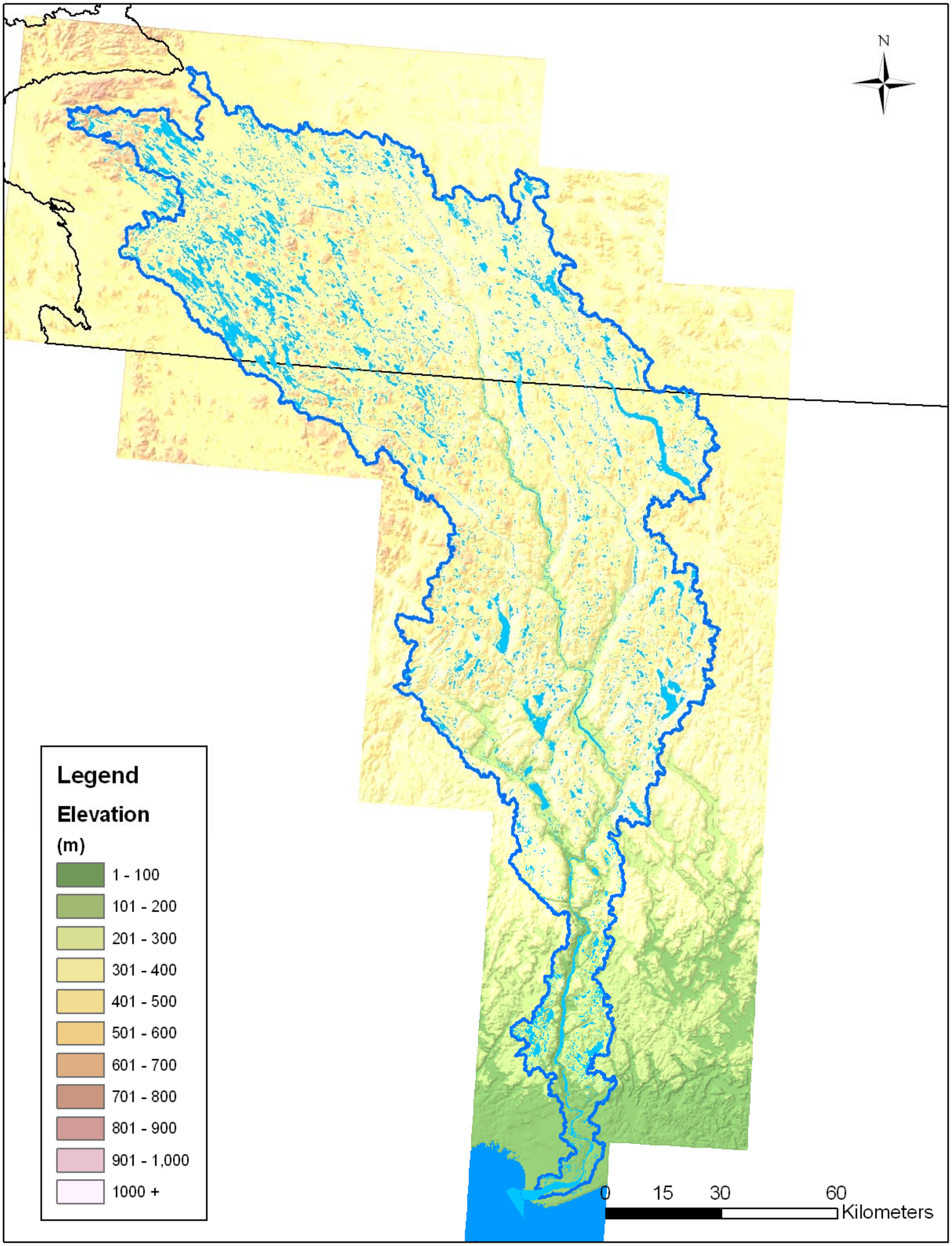


Figure 25: Natashquan River Elevation Profile

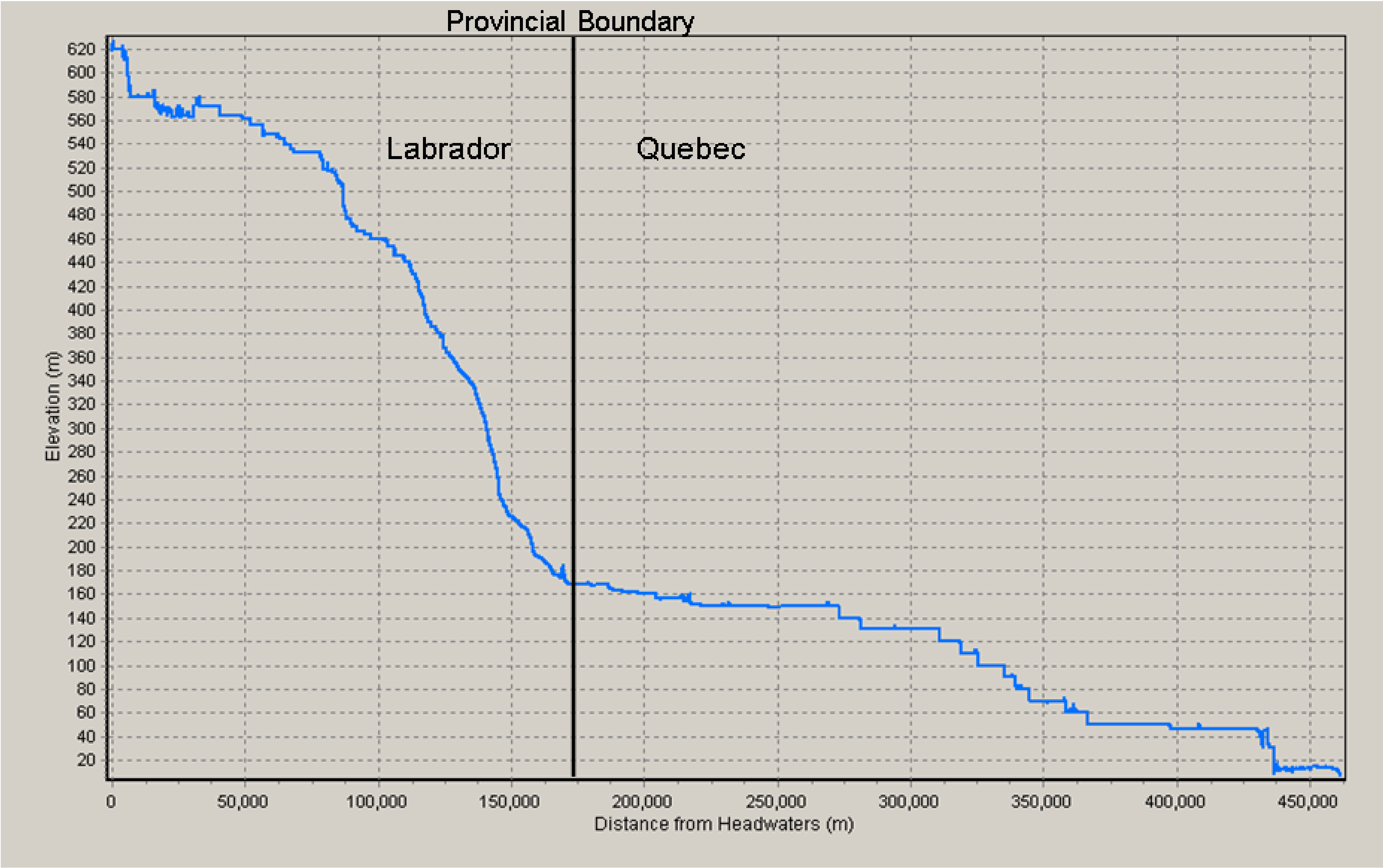
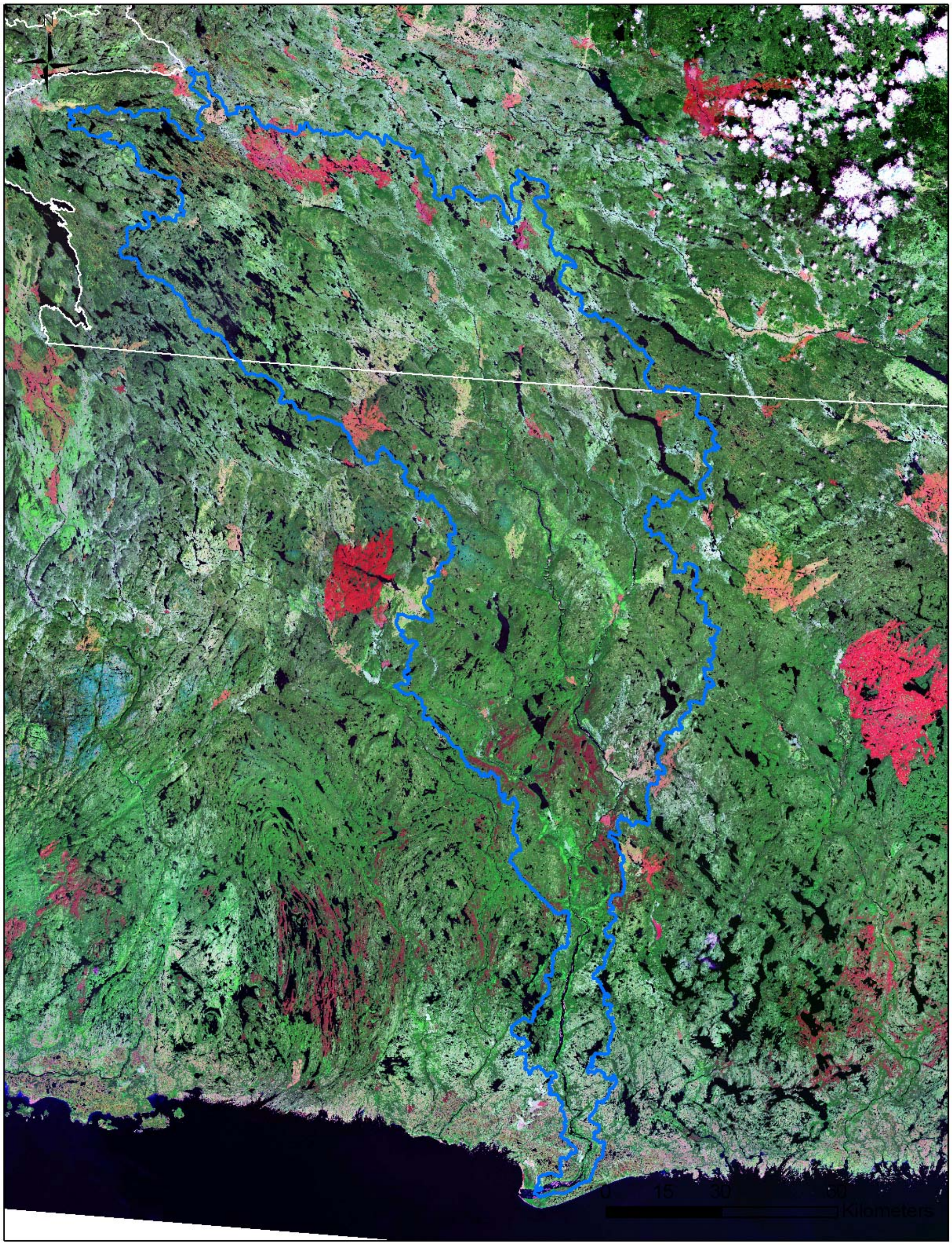


Figure 26: Natashquan River Watershed Landsat Imagery



Short Wave Infrared (bands 7, 4, 2) Landsat Imagery circa 2000. Trees and bushes, crops and wetland vegetation appear as shades of green. Water appears as black to dark blue, urban areas as lavender and bare soil as magenta, lavender, or pale pink.

Figure 27: Natashquan River Watershed Landcover

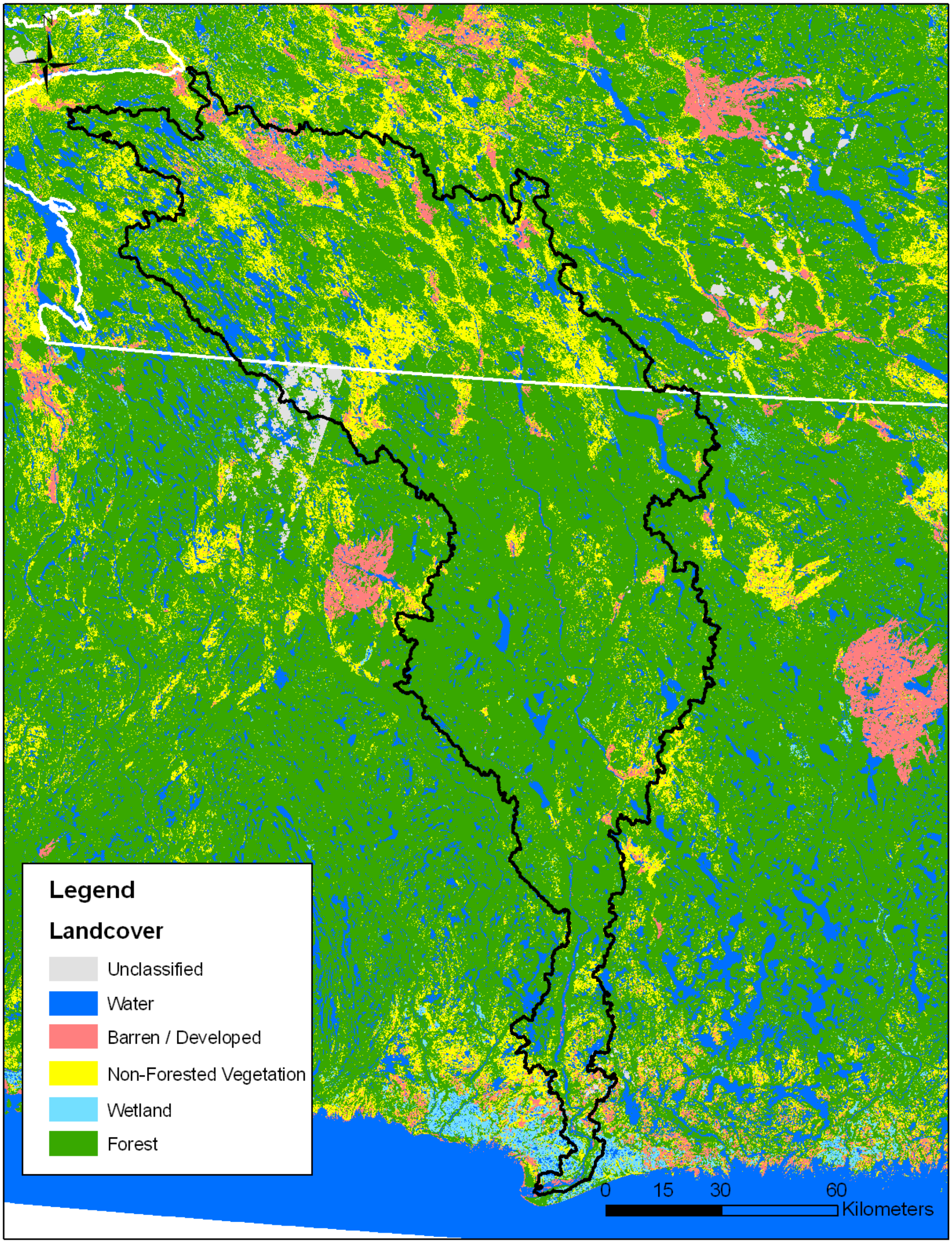
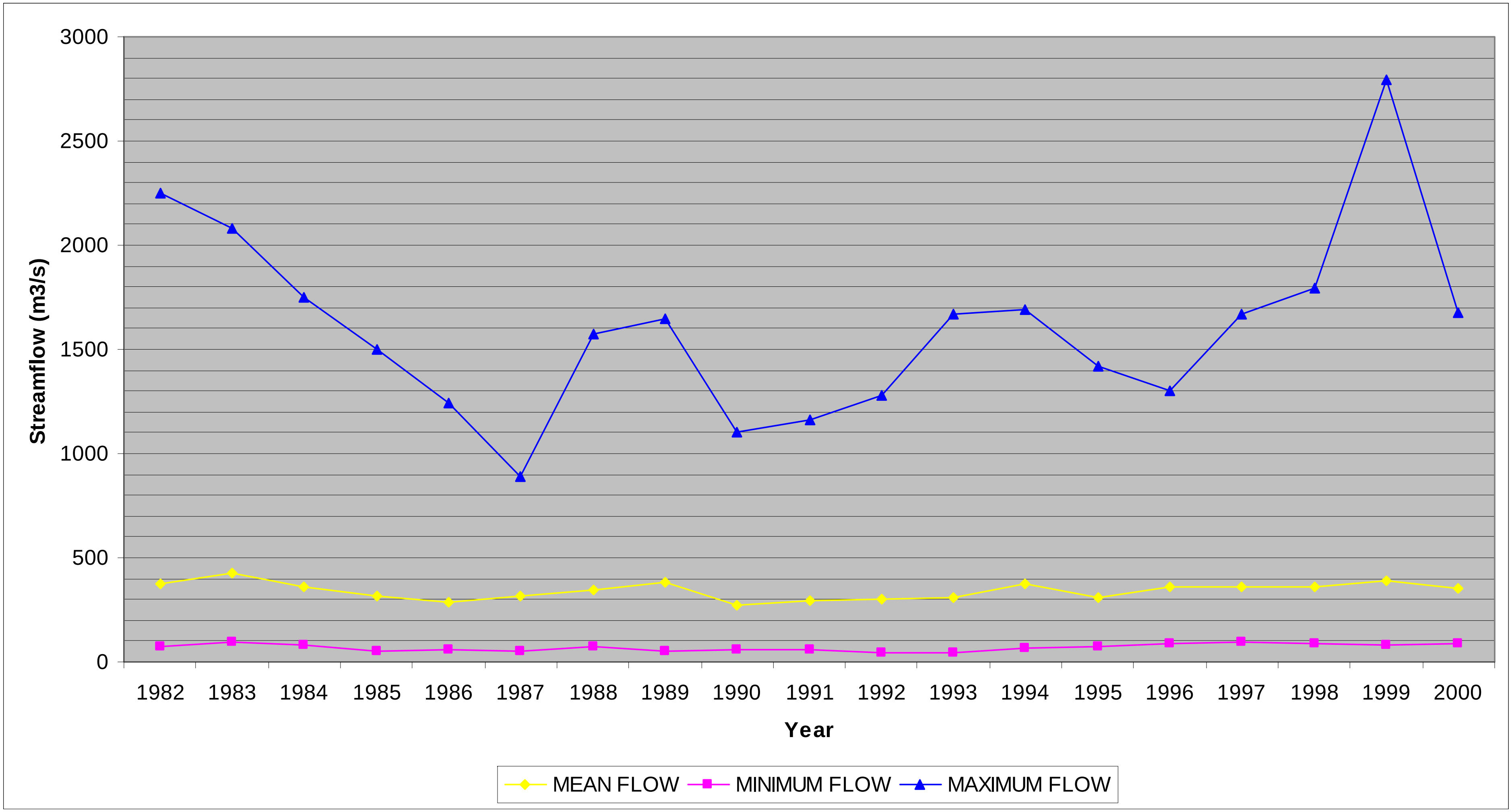


Table 9: Annual Flow Statistics for 02WB003 Hydrometric Station

YEAR	MEAN	MIN_MONTH	MIN_DAY	MIN	MIN_SYMBOL	MAX_MONTH	MAX_DAY	MAX	MAX_SYMBOL
1982	375	3	25	73.5	B	6	5	2,250	E
1983	427	3	11	96.2		5	1	2,080	E
1984	357	3	12	80.4	B	5	17	1,750	
1985	318	4	4	55	B	5	25	1,500	
1986	284	3	25	62	B	5	5	1,240	A
1987	316	3	15	49.7	B	4	23	893	
1988	343	3	2	77	B	5	23	1,570	
1989	386	3	30	50.1	B	5	31	1,650	
1990	271	3	14	58.1	B	5	24	1,100	
1991	296	4	19	59.8	B	5	28	1,160	
1992	300	3	27	45.2	B	5	16	1,280	
1993	306	4	7	44.8	B	5	24	1,670	
1994	376	4	14	68.7	B	5	23	1,690	
1995	306	3	17	75.7	B	5	26	1,420	
1996	363	1	20	90.2	B	5	5	1,300	
1997	362	4	20	97.3	B	5	23	1,672	
1998	358	2	14	87.2	B	5	16	1,797	
1999	393	2	28	80.3	B	5	12	2,795	
2000	355	3	27	90.4	B	6	3	1,679	

Note: For Minimum and Maximum Symbols: B = Ice Conditions; E = Estimated, A= Partial Day

Figure 28: Annual Flow Graph for 02WB003 Hydrometric Station



Natashquan River Watershed Data Summary:

Watershed Area: 15,930 km^2
% in Labrador: 6,340 km^2 (39.8 %)

Main Channel Length: 462 km^2
% in Labrador: 169 km^2 (36.6 %)

Main Channel Elevation: 625 m
Stream Gradient: 1.35 m/km

Strahler Stream Order: 7

Elevation Range: 0 – 765 m
Avg Elevation: 430 m
Median Elevation: 466 m

Landcover:
Barren / Developed: 475 km^2 (3.0 %)
Forest: 11,345 km^2 (71.2 %)
Non-Forest Vegetation: 2,130 km^2 (13.4 %)
Water: 1,700 km^2 (10.7 %)
Wetland: 115 km^2 (0.7 %)
Unclassified: 165 km^2 (1.0 %)

Climate Normals:

Temperature:
Annual Daily Mean Temperature: -2.8 °C to 1.2 °C
January Daily Mean Temperature:-20.3 °C to -12.8 °C
July Daily Mean Temperature: 13.8 °C to 14.2 °C

Wind:
Annual Daily Mean Windspeed: 14.8 km/hr to 18.9 km/hr
Annual Daily Maximum Windspeed: 15.2 km/hr to 25.6 km/hr

Precipitation:
Annual Total Precipitation: 943.7 mm to 1,098.8 mm
Annual Rainfall: 532.6 mm to 813.5 mm
Annual Snowfall: 285.8 cm to 442.9 cm
Potential Evapotranspiration: 404.6 mm to 443.6 mm
Precipitation Surplus: 539.0 mm to 662.5 mm

Little Mecatina River

With a watershed of approximately 19, 625 km^2, the Little Mecatina River watershed is the largest of the transboundary rivers (Table 1). Over half of the watershed is located within Labrador, about 11,035 km2 (56.2 %). An even greater proportion of the main channel of the river is on the Labrador side of the boundary. Approximately 384 km of the 590 km main channel (65.1 %) is north of the border. The Little Mecatina River has a Strahler stream order of seven (Table 1, Figure 30).

The western regions of the Little Mecatina watershed exhibit the highest elevations as altitudes often exceed 500 m in this area. The maximum elevation within the watershed is about 766 m with an average elevation of 399 m throughout the watershed (Table 2, Figure 31). The elevation at the headwaters of the main channel is approximately 645 m creating an average stream gradient of 1.09 m/km. The gradient does vary greatly throughout the river showing several distinct changes. The headwaters are quite steep, dropping about 220 m in the first 100 km. The river then flattens out in the middle sections but displays another sharp drop about 140 km from the mouth of the river. The river profile (Figure 32) provides greater details of the varying gradient along the river system.

The Little Mecatina watershed, like the other transboundary watersheds, is dominated by forest cover. Approximately 13,480 km^2 (68.7 %) of the watershed is comprised of forest (Table 3). There is about 1,775 km^2 (9.0 %) of water within the drainage basin. There is roughly 2,955 km^2 (15.1 %) of vegetation forms such as shrubs and grasslands, mainly in the middle to northern sections of the watershed. There is 235 km^2 (1.2 %) of wetlands and 1,035 km^2 (5.3 %) of barren or developed land within the watershed. There is very little development within the watershed. A large portion of the barren land is located near the western boundary of the basin and is a distinct feature as seen in Figure 33 and Figure 34.

The federal ecodistricts of Churchill Falls, Upper St. Augustin Plateau, Petit Mecatina, St. Augustin Hills and Rochy Coast are all found within the Little Mecatina watershed (Figure 4). Monthly climatic normals for the period of 1961 -1990 were compiled for all the ecodistricts of Canada. Annual daily mean temperatures (based on these climate normals of the ecodistricts) range from -2.8 °C to 1.2 °C. Winter daily mean temperatures (January) range from -20.3 °C to -12.8 °C with summer (July) temperatures in the range of 13.8 °C to 15.2 °C. Table 4, Figure 5, Figure 6 and Figure 7 depict temperature normals for the ecodistricts in the study area. Annual daily mean wind speeds range from 14.8 km/hr to 19.0 km/hr (Table 5, Figure 8), with maximum wind speeds ranging from 15.2 km/hr to 25.6 km/hr. Throughout the varying regions of the watershed, yearly precipitation totals range from 943.7 mm to 1,122.4 mm. Annual rainfall amounts range from 532.6 mm to 839.3 mm and snowfall accumulations are generally from 285.8 cm to 442.9 cm. Table 6, Figure 9, Figure 10 and Figure 11 provide more detail on the distribution of precipitation in the region. Potential evapotranspiration ranges from 404.6 mm to 444.6 mm (Table 6, Figure 12) which results in precipitation surpluses in the range of 539.0 mm to 685.0 mm a year (Table 6, Figure 13).

There have been five hydrometric stations located in the Little Mecatina River watershed. These stations are distributed throughout the watershed, with two near the mouth of the river and two on the Labrador side of the boundary (Figure 14). Of these stations 02XA003 has the longest period of record dating from 1978 to 2010, a period of 33 years (Table 7). Of the two stations located in the downstream portion of the watershed, 02XA006 has the longest period of record. Mean Annual Flows for the period of record at this station ranges from 406 m^3/s to 595 m^3/s with a minimum flow of 58.3 m^3/s and a maximum flow of 3,770 m^3/s. Minimum flows generally occur during the winter, largely due to ice conditions. Maximum flows are usually found in May or June, presumably due to snowmelt. Table 10 and Figure 35 provide greater detail on flows at 02XA006.

Major tributaries of the Little Mecatina River include Rivière Joir, Rivière Piakuakamit and Rivière Mongeaux.

Figure 29: Little Mecatina River Watershed

Figure 30: Little Mecatina River Stream Order

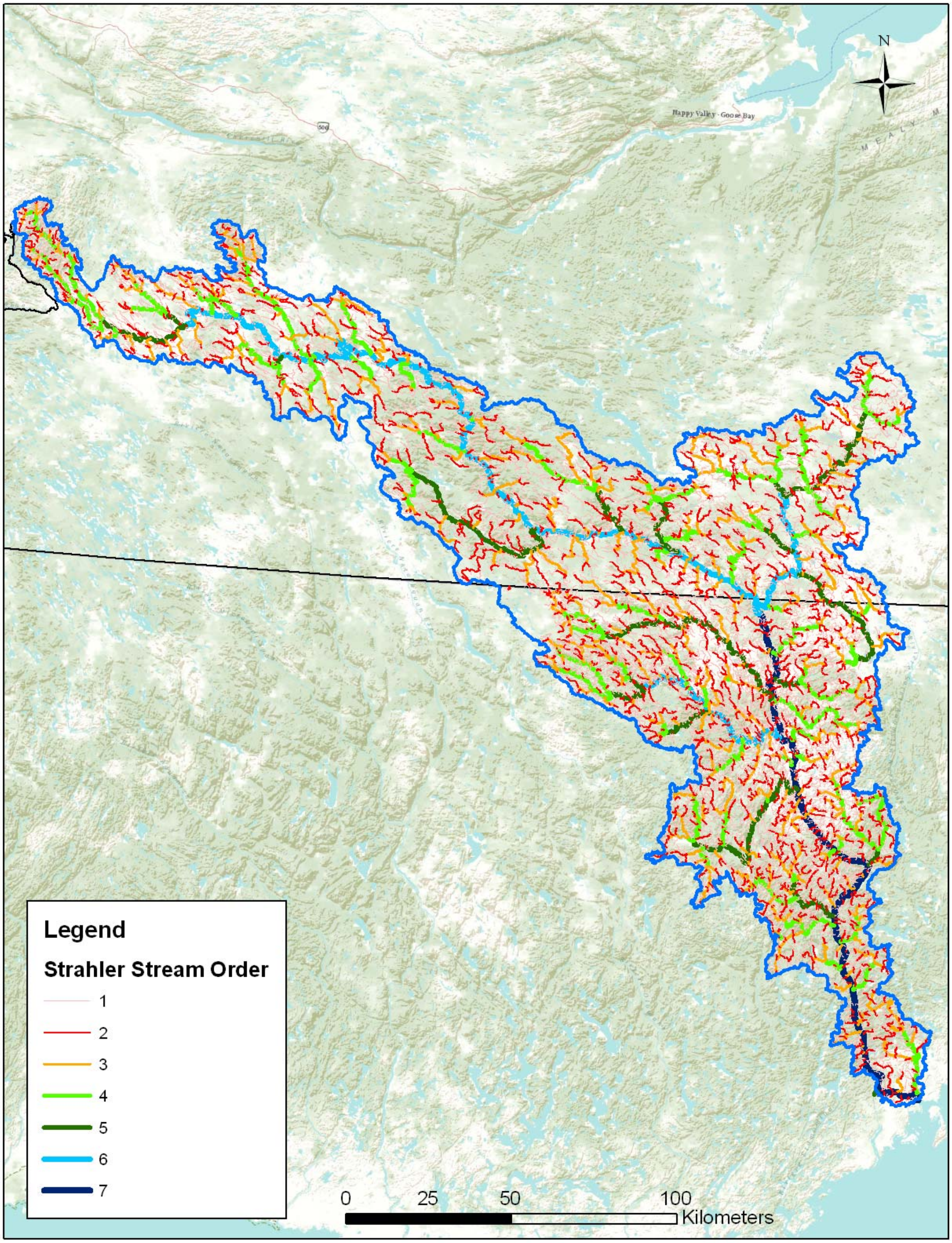


Figure 31: Little Mecatina River Watershed Elevation

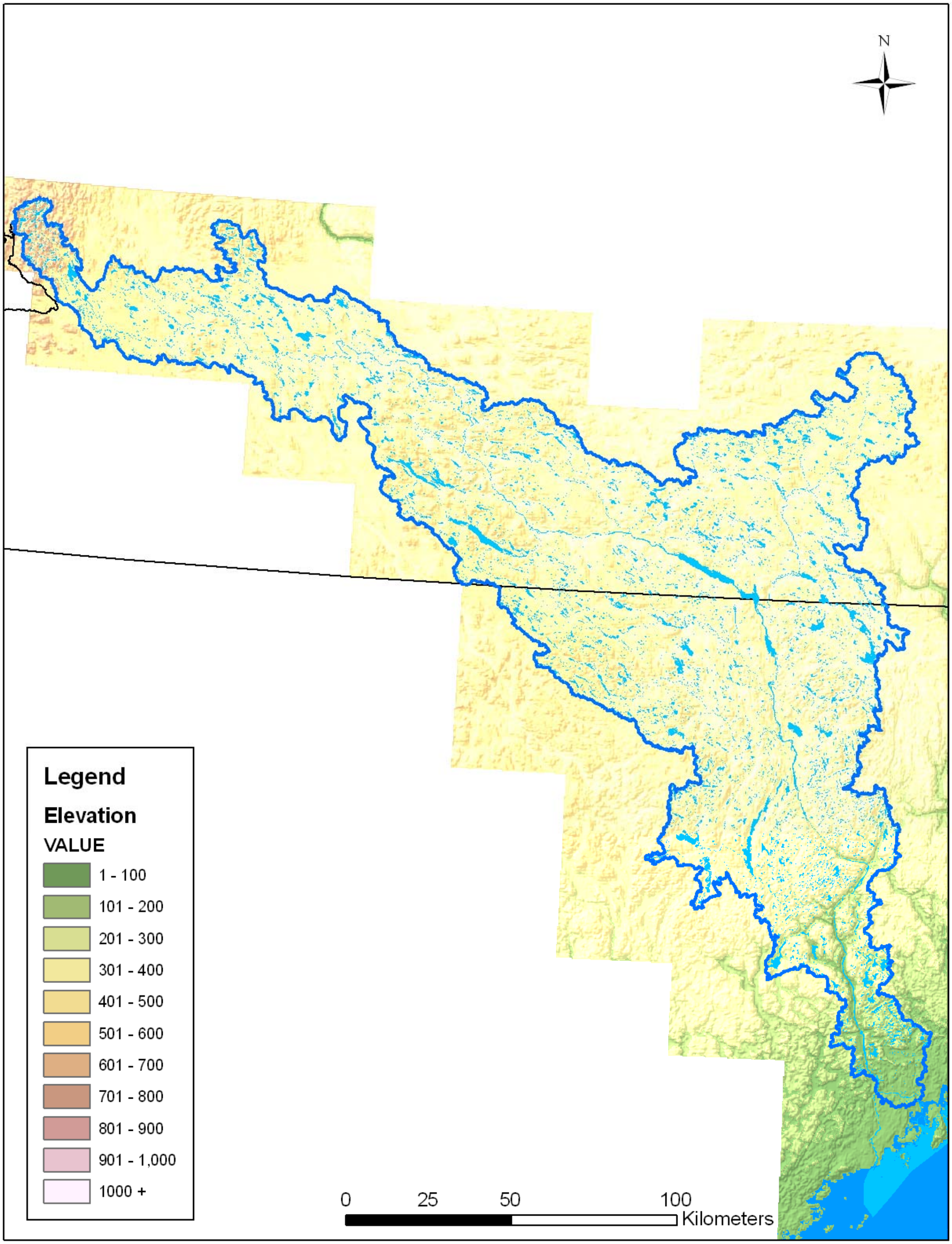


Figure 32: Little Mecatina River Elevation Profile

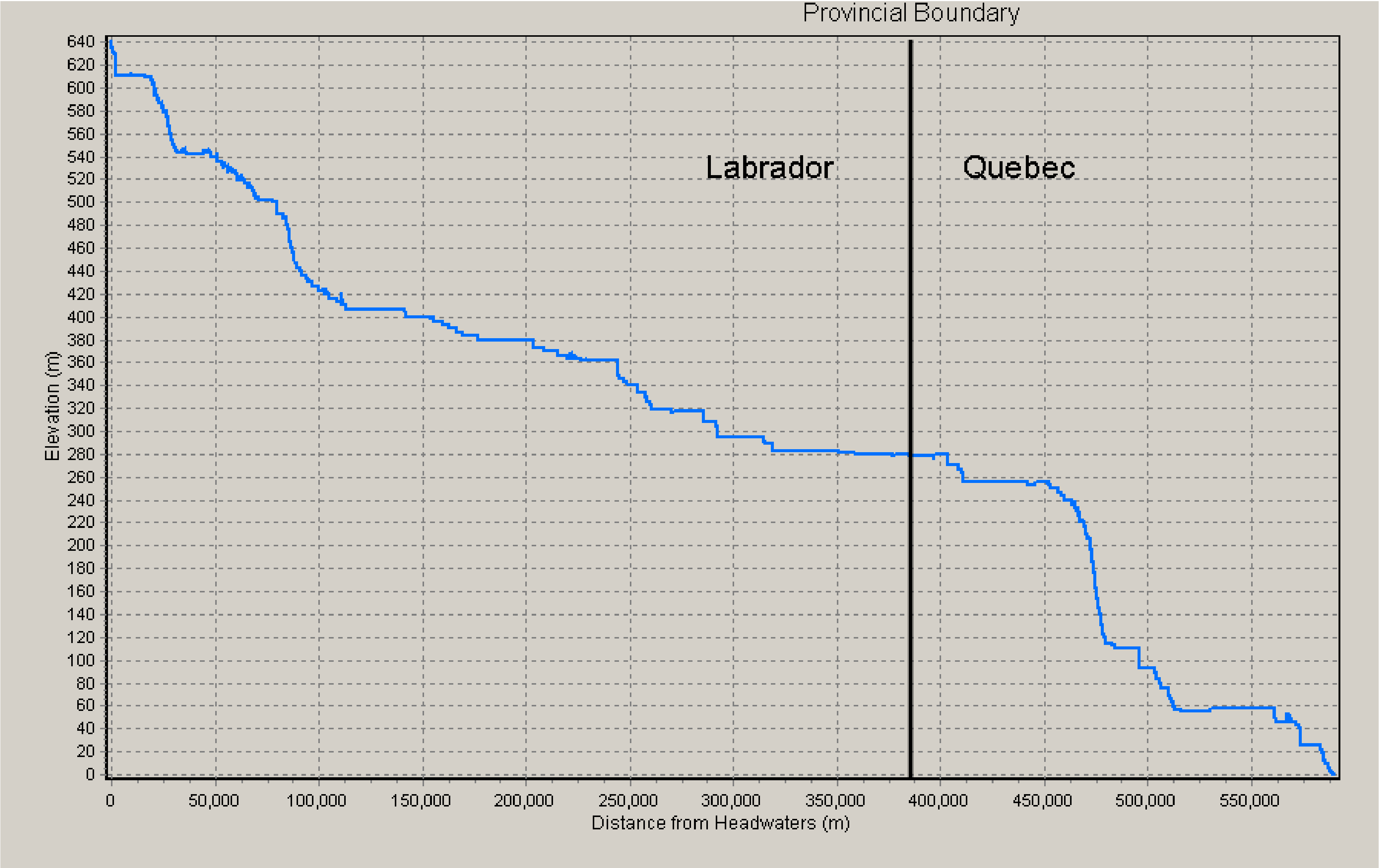
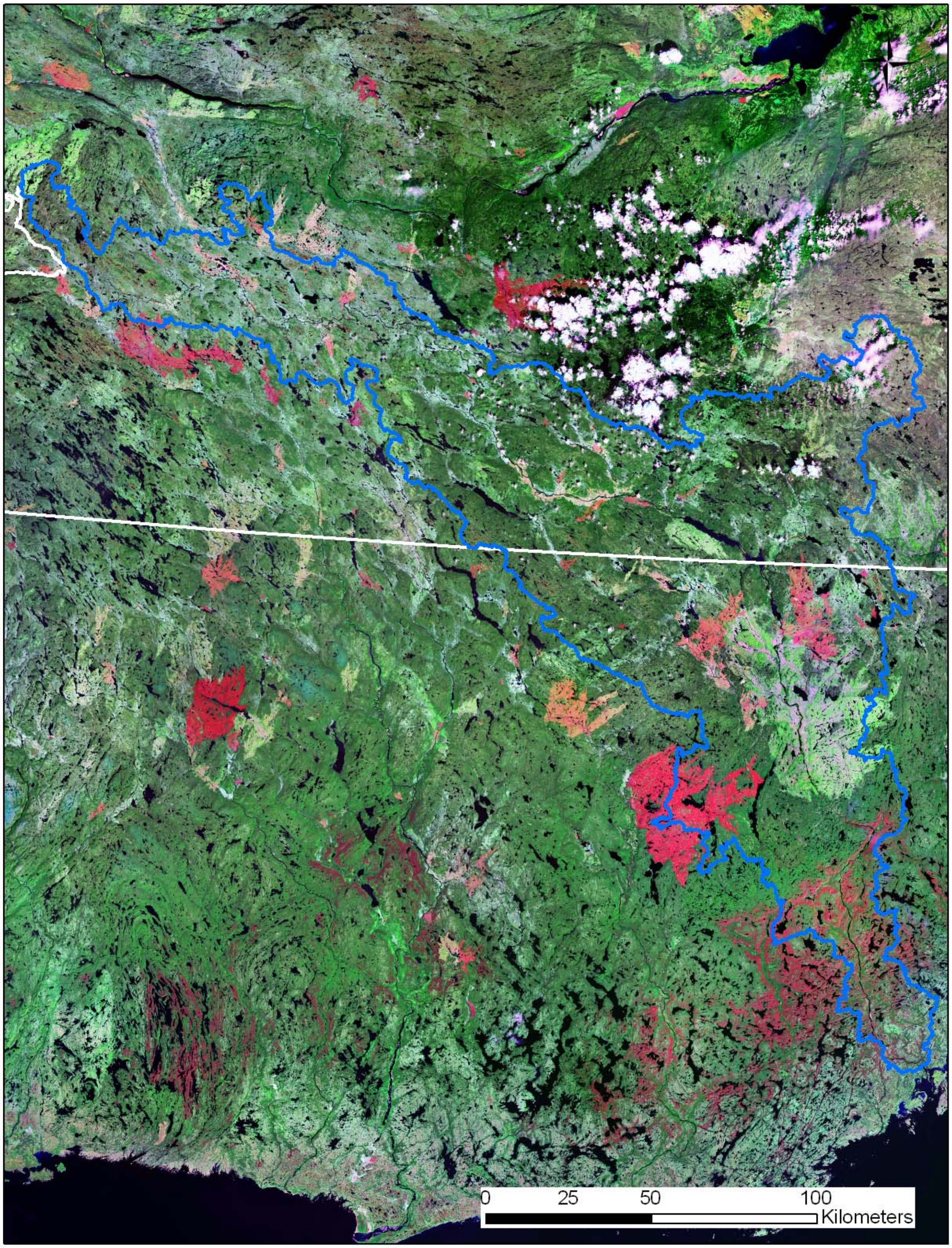


Figure 33: Little Mecatina River Watershed Landsat Imagery



Short Wave Infrared (bands 7, 4, 2) Landsat Imagery circa 2000. Trees and bushes, crops and wetland vegetation appear as shades of green. Water appears as black to dark blue, urban areas as lavender and bare soil as magenta, lavender, or pale pink.

Figure 34: Little Mecatina River Watershed Landcover

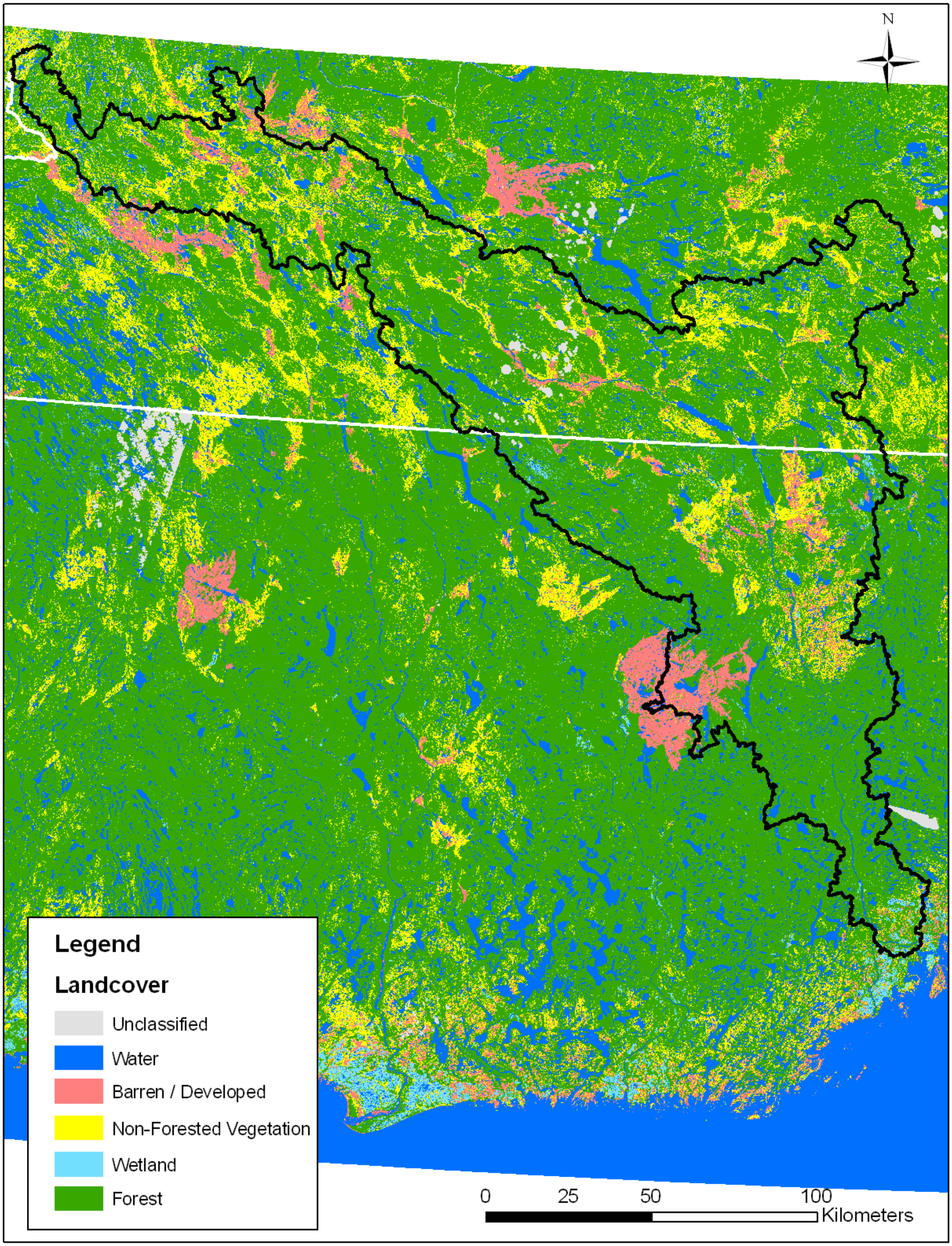
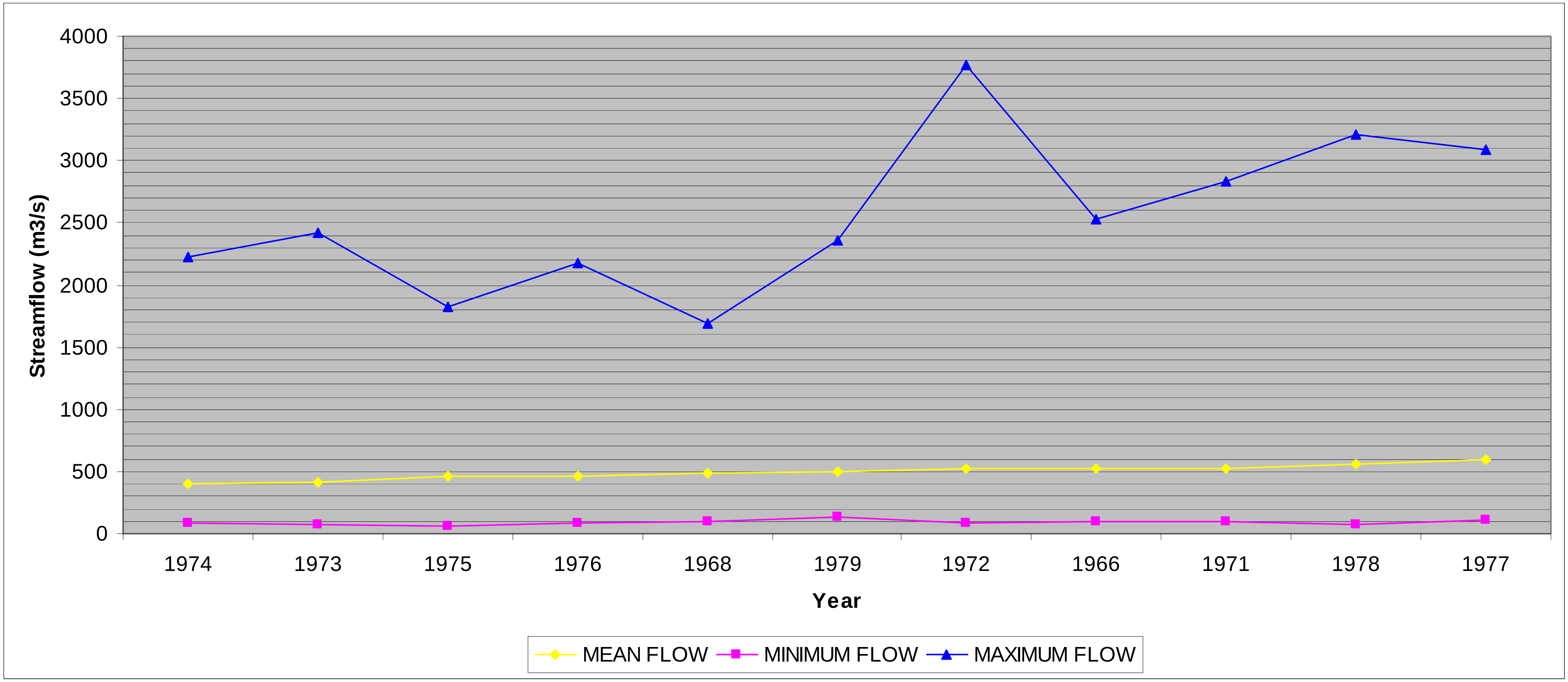


Table 10: Annual Flow Statistics for 02XA006 Hydrometric Station

YEAR	MEAN	MIN_MONTH	MIN_DAY	MIN	MIN_SYMBOL	MAX_MONTH	MAX_DAY	MAX	MAX_SYMBOL
1974	406	3	20	87.8	B	6	8	2,230	
1973	410	4	7	76.7	B	5	20	2,420	
1975	465	3	20	58.3	B	5	26	1,820	
1976	466	3	22	85	B	5	22	2,180	
1968	488	3	30	99.1		5	15	1,690	
1979	503	12	31	138	B	5	8	2,360	
1972	518	3	14	79.6	E	6	10	3,770	
1966	518	3	21	91.5	E	6	1	2,530	
1971	522	4	8	91.2	B	5	23	2,830	A
1978	558	4	21	72.2	B	5	22	3,210	
1977	595	3	23	107	B	6	11	3,090	E

Note: For Minimum and Maximum Symbols: B = Ice Conditions; E = Estimated, A= Partial Day

Figure 35: Annual Flow Graph for 02XA006 Hydrometric Station



Little Mecatina River Watershed Data Summary:

Watershed Area: 19,625 km^2
% in Labrador: 11,035 km^2 (56.2 %)

Main Channel Length: 590 km^2
% in Labrador: 384 km^2 (65.1 %)

Main Channel Elevation: 645 m
Stream Gradient: 1.09 m/km

Strahler Stream Order: 7

Elevation Range: 0 – 766 m
Avg Elevation: 399 m
Median Elevation: 407 m

Landcover:
Barren / Developed: 1,035 km^2 (5.3 %)
Forest: 13,480 km^2 (68.7 %)
Non-Forest Vegetation: 2,955 km^2 (15.1%)
Water: 1,775 km^2 (9.0 %)
Wetland: 235 km^2 (1.2 %)
Unclassified: 145 km^2 (0.7 %)

Climate Normals:

Temperature:
Annual Daily Mean Temperature: -2.8 °C to 1.2 °C
January Daily Mean Temperature:-20.3 °C to -12.8 °C
July Daily Mean Temperature: 13.8 °C to 15.2 °C

Wind:
Annual Daily Mean Windspeed: 14.8 km/hr to 19.0 km/hr
Annual Daily Maximum Windspeed: 15.2 km/hr to 25.6 km/hr

Precipitation:
Annual Total Precipitation: 943.7 mm to 1,122.4 mm
Annual Rainfall: 532.6 mm to 839.3 mm
Annual Snowfall: 285.8 cm to 442.9 cm
Potential Evapotranspiration: 404.6 mm to 444.6 mm
Precipitation Surplus: 539.0 mm to 685.0 mm

St. Augustin River

The St. Augustin River has a watershed of approximately 9,890 km^2 with roughly 40.4% (3,995 km^2) of the watershed within Labrador. The main channel of the St. Augustin is about 238 km. Approximately 109 km of the main channel (45.8 %) is north of the provincial boundary. Similar to the other large transboundary rivers, the St. Augustin has a Strahler stream order of seven (Table 1, Figure 37).

The maximum elevation within the watershed is about 592 m with an average elevation of 342 m throughout the basin (Table 2). The northeastern portions of the watershed contain the highest elevations as altitudes often surpass 500 m in this area (Figure 38). The elevation at the headwaters of the main channel is approximately 570 m creating an average stream gradient of 2.39 m/km. This is the steepest average gradient of any of the five large transboundary rivers. The majority of this elevation drop is found within the Labrador section of the river. The river drops about 460 m before the border then flattens out and drops only 100 m in the final 120 km. The river profile (Figure 39) provides greater details of the varying gradient along the river system.

The St. Augustin River watershed is also heavily forested. Approximately 7,345 km^2 (74.3 %) of the watershed is comprised of forest (Table 3). There is roughly 1275 km^2 (12.9 %) of vegetation forms such as shrubs and grasslands, much of which is found in the Labrador portion of the watershed. There is about 795 km^2 (8.0 %) of water and 130 km^2 (1.3 %) of wetlands within the drainage basin. There is and 310 km^2 (3.1 %) of barren / developed land within the watershed. There is very little development within the watershed. A large portion of the barren land is located near the eastern boundary of the basin just south of the provincial boundary and is a distinct feature as seen in Figure 40 and Figure 41.

Within the St. Augustin River watershed there are areas defined as the federal ecodistricts of Upper St. Augustin Plateau, Petit Mecatina, St. Augustin Hills and Rochy Coast (Figure 4). Monthly climatic normals for the period of 1961 -1990 were compiled for all the ecodistricts of Canada. Annual daily mean temperatures (based on these climate normals of the ecodistricts) range from 0 °C to 1.2 °C. Winter daily mean temperatures (January) range from -16.5 °C to -12.8 °C with summer (July) temperatures in the range of 13.9 °C to 15.2 °C. Table 4 and Figure 5, Figure 6 and Figure 7 depict temperature normals for the ecodistricts in the study area. Annual daily mean wind speeds range from 17.1 km/hr to 19.0 km/hr (Table 5, Figure 8), with maximum wind speeds ranging from 21.5 km/hr to 25.6 km/hr. Yearly precipitation totals range from 1005.4 mm to 1122.4 mm. As in the other watersheds, the form this precipitation falls in (i.e. rain or snow) varies throughout the drainage basin. Annual rainfall amounts range from 628.9 mm to 839.3 mm and snowfall accumulations are generally from 292.5 cm to 426.0 cm. Table 6, Figure 9, Figure 10 and Figure 11 provide more detail on the distribution of precipitation in the region. Depending on the area of the watershed, potential evapotranspiration ranges from 436.3 mm to 444.6 mm (Table 6, Figure 12). This creates precipitation surpluses in the range of 560.8 mm to 685.0 mm a year (Table 6, Figure 13).

There has only been one hydrometric station, 02XB001, located in the St. Augustin River watershed. This station has a period of record of 16 years, dating from 1967 to 1982 (Table 7). Mean Annual Flows for the period of record at this station ranges from 146 m^3/s to 207 m^3/s with a minimum flow of 10.8 m^3/s and a maximum flow of 2,040 m^3/s. Minimum flows generally occur during the winter, largely due to ice conditions. Maximum flows are usually found in May or June, presumably due to snowmelt. Table 11 and Figure 42 provide greater detail on flows at 02XB001.

Major tributaries of the St. Augustin River include Matse River, Michaels River, Rivière à la Mouche and Rivière Saint-Augustin Nord-Ouest.

Figure 36: St. Augustin River Watershed

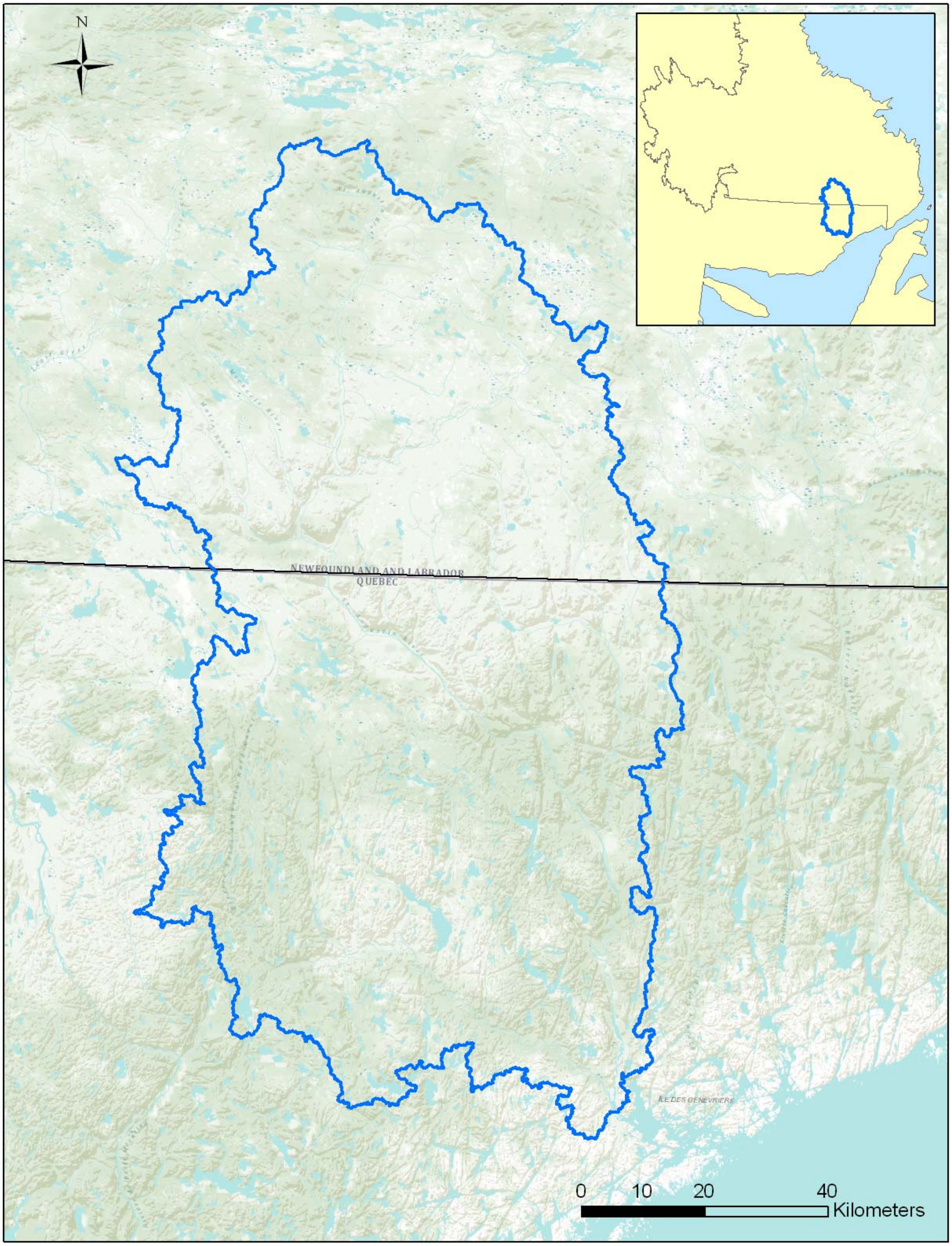


Figure 37: St. Augustin River Stream Order

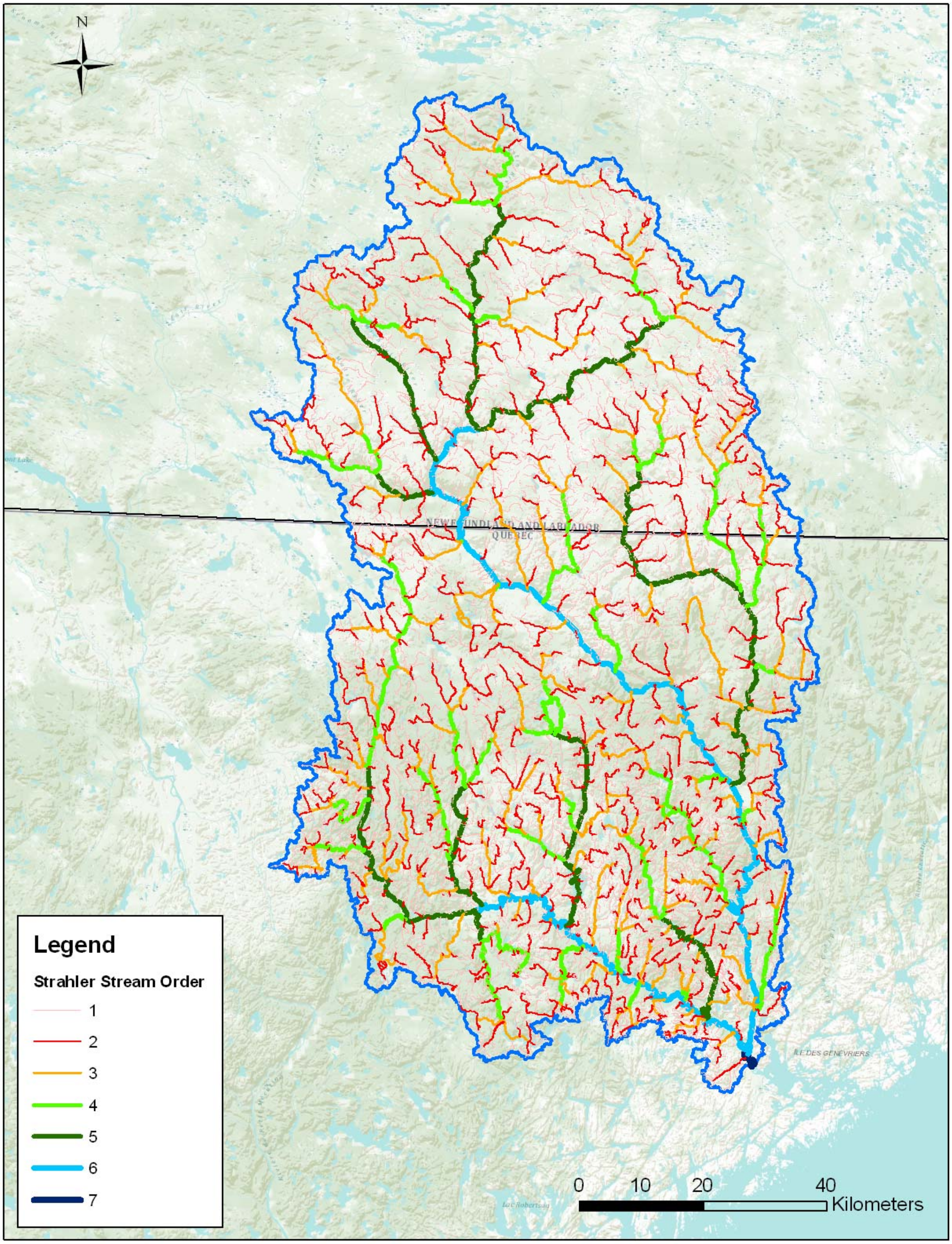


Figure 38: St. Augustin River Watershed Elevation

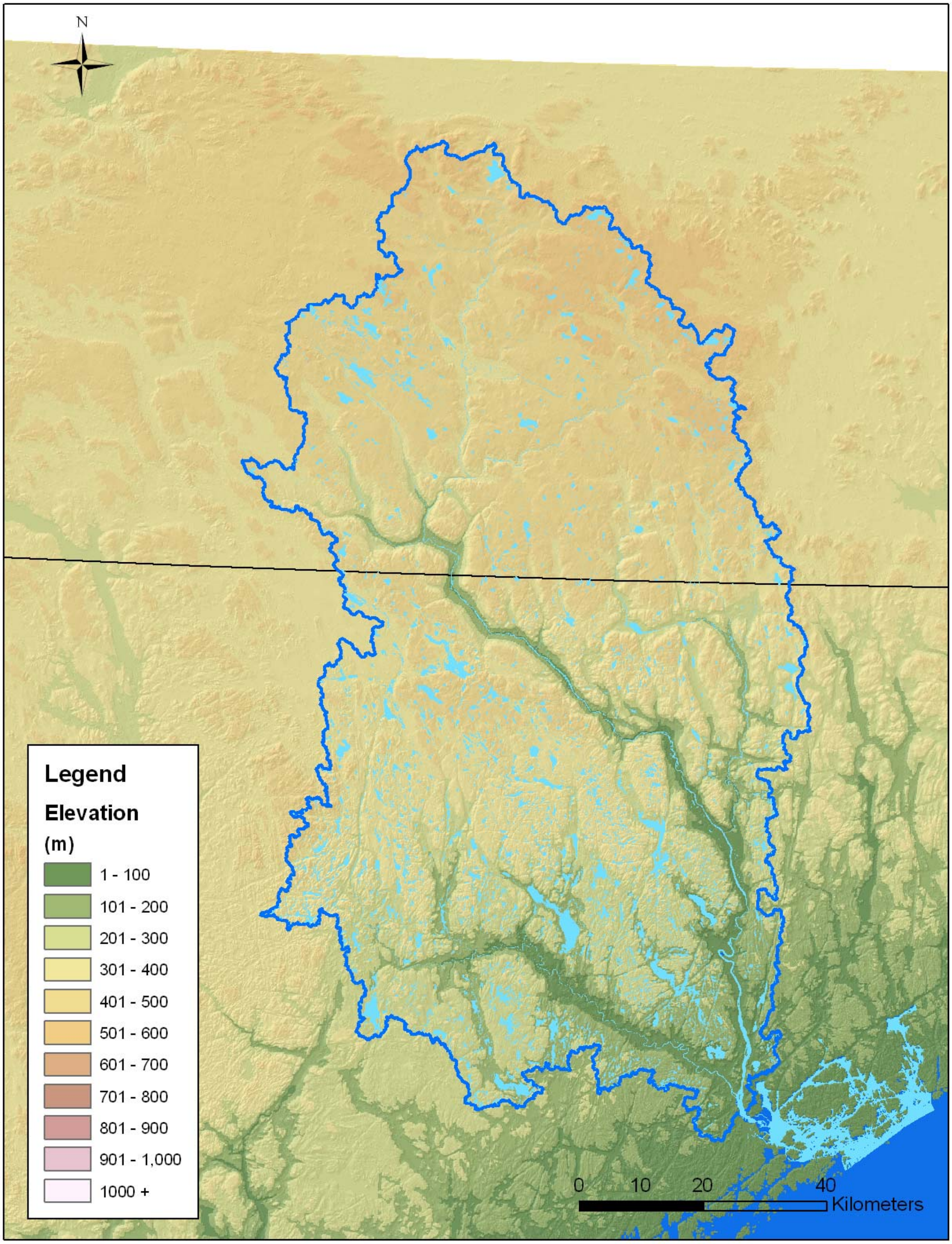


Figure 39: St. Augustin River Elevation Profile

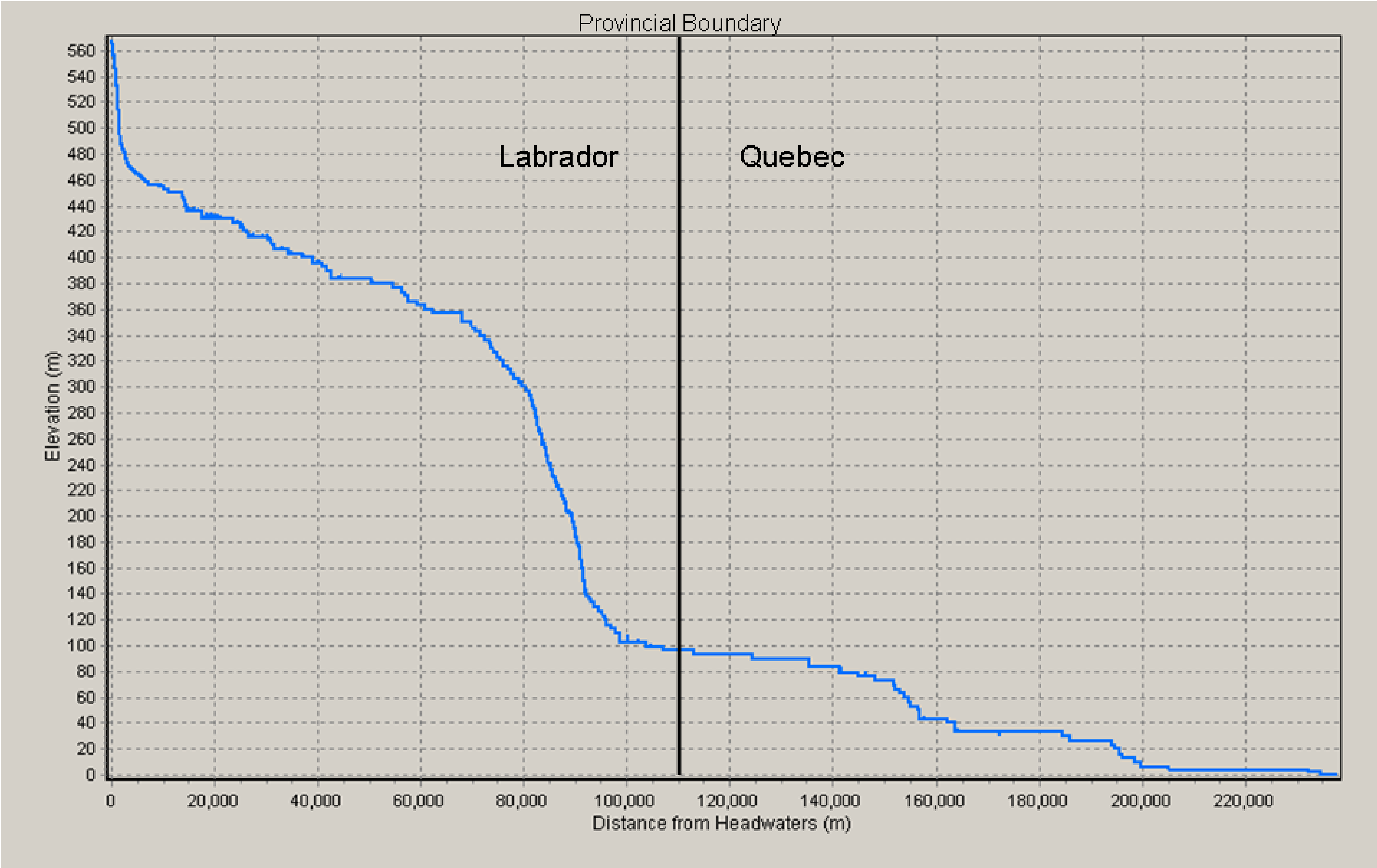
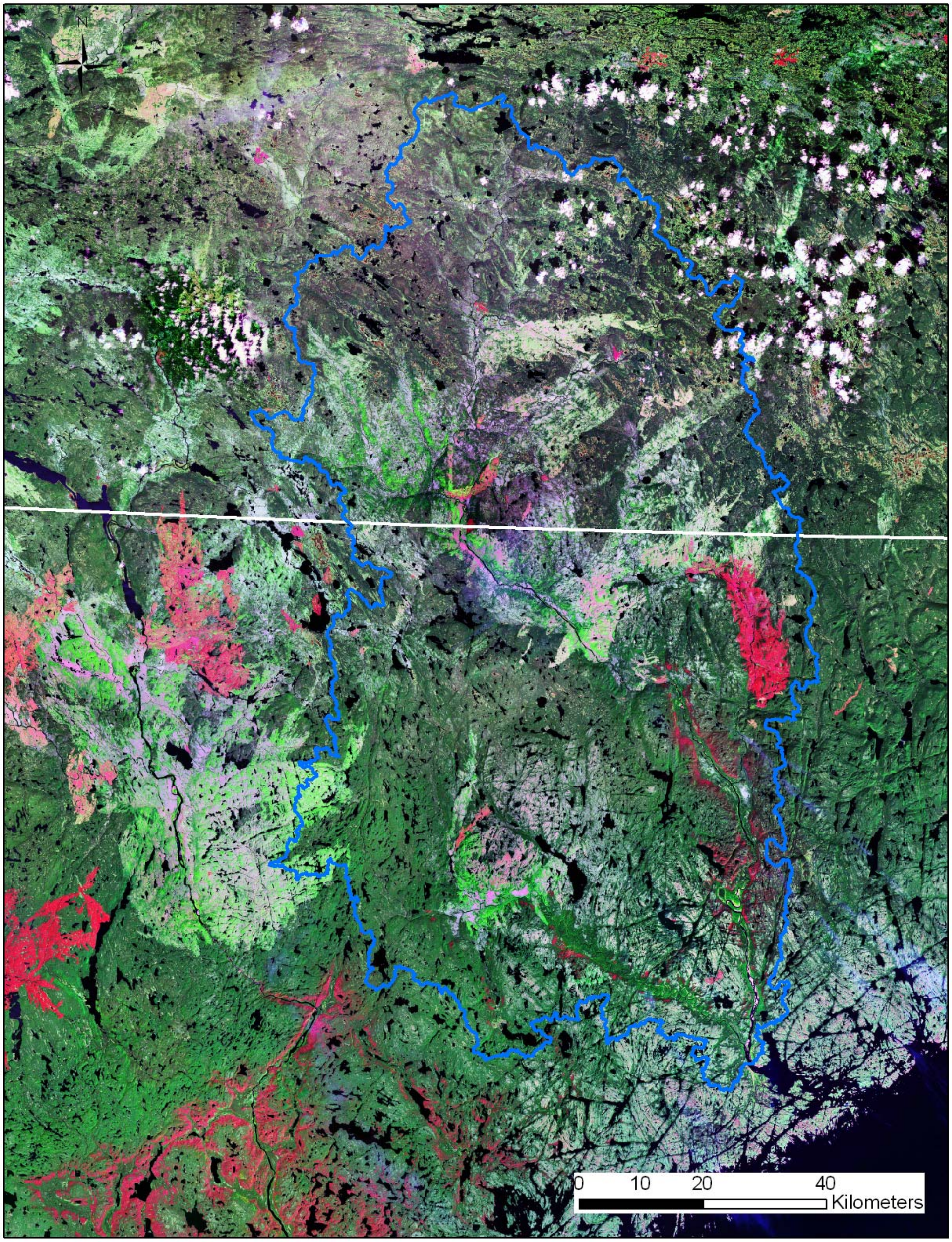


Figure 40: St. Augustin River Watershed Landsat Imagery



Short Wave Infrared (bands 7, 4, 2) Landsat Imagery circa 2000. Trees and bushes, crops and wetland vegetation appear as shades of green. Water appears as black to dark blue, urban areas as lavender and bare soil as magenta, lavender, or pale pink.

Figure 41: St. Augustin River Watershed Landcover

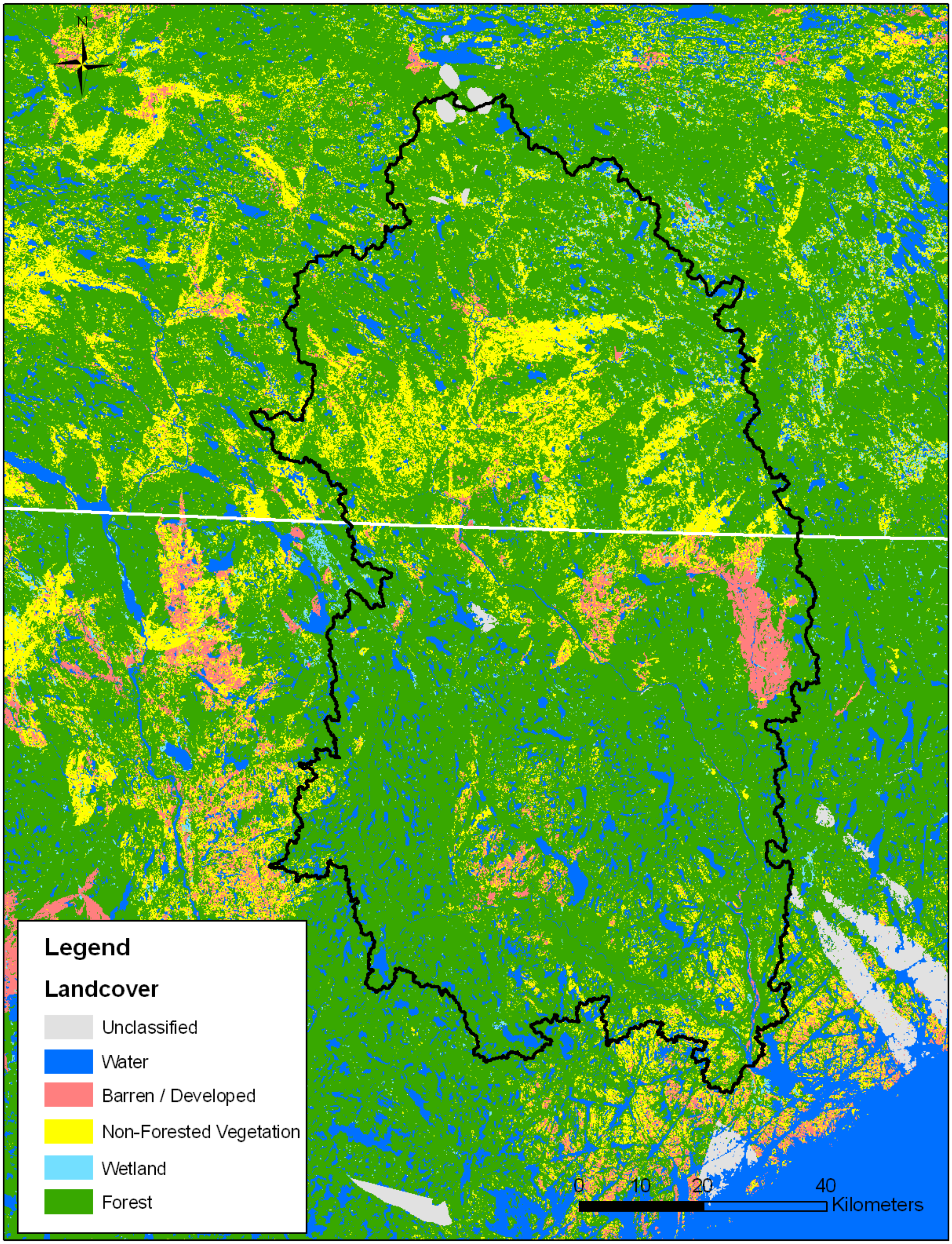
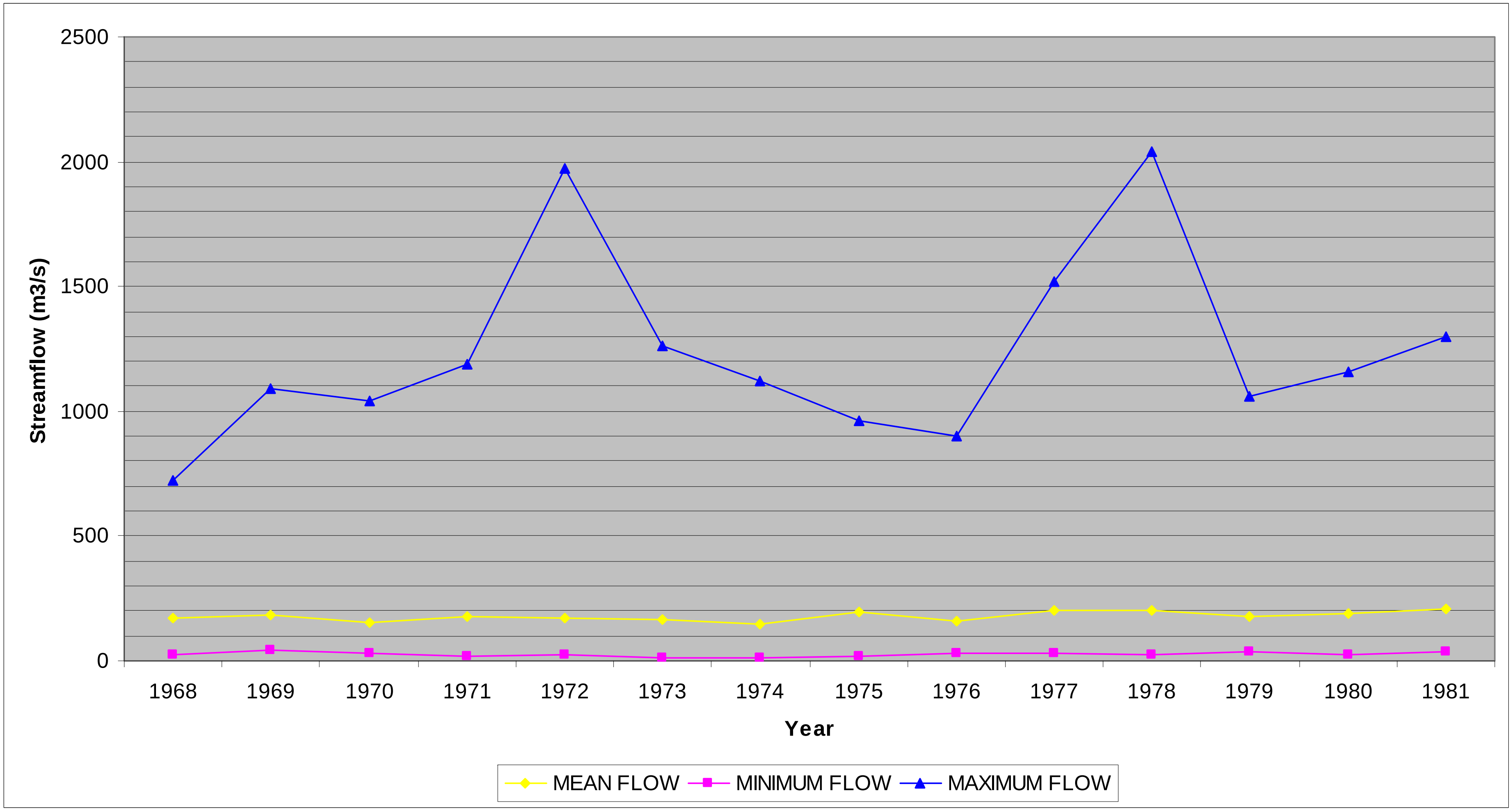


Table 11: Annual Flow Statistics for 02XB001 Hydrometric Station

YEAR	MEAN	MIN_MONTH	MIN_DAY	MIN	MIN_SYMBOL	MAX_MONTH	MAX_DAY	MAX	MAX_SYMBOL
1968	171	4	6	24.3	B	5	4	722	
1969	185	4	16	39.9	B	6	9	1,090	
1970	151	4	5	33.4	B	5	21	1,040	
1971	176	4	1	18.1	B	5	25	1,190	
1972	172	12	31	23.4	B	6	5	1,970	
1973	164	4	19	10.8	B	5	20	1,260	E
1974	146	3	17	15.1	B	6	6	1,120	
1975	194	3	4	15.9	B	11	20	963	E
1976	161	3	29	32	B	5	15	898	E
1977	201	3	28	28	B	6	5	1,520	
1978	204	4	18	22.8	B	5	19	2,040	E
1979	177	12	31	34.8	B	5	4	1,060	
1980	189	4	8	24	B	5	23	1,160	
1981	207	2	1	39	B	5	19	1,300	

Note: For Minimum and Maximum Symbols: B = Ice Conditions; E = Estimated, A= Partial Day

Figure 42: Annual Flow Graph for 02XB001 Hydrometric Station



St. Augustine River Watershed Data Summary:

Watershed Area: 9,890 km^2
% in Labrador: 3,995 km^2 (40.4 %)

Main Channel Length: 238 km
% in Labrador: 109 km (45.8 %)

Main Channel Elevation: 570 m
Stream Gradient: 2.39 m/km

Strahler Stream Order: 7

Elevation Range: 0 – 592 m
Avg Elevation: 342 m
Median Elevation: 369 m

Landcover:
Barren / Developed: 310 km^2 (3.1 %)
Forest: 7,345 km^2 (74.3 %)
Non-Forest Vegetation: 1,275 km^2 (12.9%)
Water: 795 km^2 (8.0 %)
Wetland: 130 km^2 (1.3 %)
Unclassified: 35 km^2 (0.4 %)

Climate Normals:

Temperature:
Annual Daily Mean Temperature: 0 °C to 1.2 °C
January Daily Mean Temperature:-16.5 °C to -12.8 °C
July Daily Mean Temperature: 13.9 °C to 15.2 °C

Wind:
Annual Daily Mean Windspeed: 17.1 km/hr to 19.0 km/hr
Annual Daily Maximum Windspeed: 21.5 km/hr to 25.6 km/hr

Precipitation:
Annual Total Precipitation: 1,005.4 mm to 1,122.4 mm
Annual Rainfall: 628.9 mm to 839.3 mm
Annual Snowfall: 292.5 cm to 426.0 cm
Potential Evapotranspiration: 436.3 mm to 444.6 mm
Precipitation Surplus: 560.8 mm to 685.0 mm

Coxipi River

The Coxipi River is one of the two smaller transboundary rivers and has a watershed of approximately 1,620 km^2 (Table 1). The majority of the river is in Quebec as only about 8.0 % (130 km^2) of the watershed is within Labrador. The main channel of the Coxipi is roughly 128 km with 20 km (15.6 %) in Labrador territory. The Coxipi has a Strahler stream order of six (Table 1, Figure 44).

The maximum elevation within the Coxipi watershed is about 503 m with an average elevation of 239 m (Table 2). The northern portions of the watershed contains the highest elevations and almost all the watershed within Labrador has an elevation over 350 m (Figure 45). The elevation at the headwaters of the main channel is approximately 405 m creating an average stream gradient of 3.16 m/km. This is a steeper average gradient than any of the five large transboundary rivers but this is often the case in shorter rivers. The river drops over 240 in the first 30 – 40 km but displays are fairly consistent gradient in the remaining sections as well. The river profile (Figure 45) provides greater details of the varying gradient along the river system.

The Coxipi River watershed is dominated by forest cover. Approximately 1,305 km^2 (80.6 %) of the watershed is comprised of forest. Only 3.1% (50 km^2) of the watershed is consists of vegetation forms such as shrubs and grasslands, a much lower percentage than some of the larger watersheds. There is about 155 km^2 (9.6 %) of water and 20 km^2 (1.2 %) of wetlands within the drainage basin. There is very little barren or developed land within the watershed, just 5 km^2 (0.3 %). See Table 3 , Figure 47 and Figure 48 for additional detail.

The Coxipi River is adjacent to the St. Augustin and shares many of its climatic characteristics. The federal ecodistricts of Upper St. Augustin Plateau, St. Augustin Hills and Rochy Coast are found within the Coxipi River watershed (Figure 4). Monthly climatic normals for the period of 1961 -1990 were compiled for all the ecodistricts of Canada. Annual daily mean temperatures (based on these climate normals of the ecodistricts) range from 0 °C to 1.2 °C. Winter daily mean temperatures (January) range from -16.5 °C to -12.8 °C with summer (July) temperatures in the range of 13.9 °C to 15.2 °C. Table 4 and Figure 5, Figure 6 and Figure 7 depict temperature normals for the ecodistricts in the study area. Annual daily mean wind speeds range from 17.1 km/hr to 19.0 km/hr (Table 5, Figure 8), with maximum wind speeds ranging from 21.5 km/hr to 25.6 km/hr. Throughout the varying regions of the watershed, yearly precipitation totals range from 1005.4 mm to 1122.4 mm. Annual rainfall amounts range from 628.9 mm to 839.3 mm and snowfall accumulations are generally from 292.5 cm to 426.0 cm. Table 6, Figure 9, Figure 10 and Figure 11 provide more detail on the distribution of precipitation in the region. Depending on the area of the watershed, potential evapotranspiration ranges from 436.3 mm to 444.6 mm (Table 6, Figure 12). This creates precipitation surpluses in the range of 560.8 mm to 685.0 mm a year (Table 6, Figure 13).

There has only been one hydrometric station, 02XB002, located in the Coxipi River watershed. This station has a period of record of 14 years, dating from 1980 to 1993 (Table 7). Mean Annual Flows for the period of record at this station ranges from 21 m^3/s to 33 m^3/s with a minimum flow of 3.8 m^3/s and a maximum flow of 157 m^3/s. Minimum flows generally occur during the winter, largely due to ice conditions. Maximum flows are usually found in May or June, presumably due to snowmelt. Table 12 and Figure 49 provide greater detail on flows at 02XB002.

A portion of the Coxipi River watershed that is in Quebec has been proposed as a biodiversity reserve (Quebec, 2007, pg. 5). With the protected status, the area would be protected from hydroelectric development.

Figure 43: Coxipi River Watershed

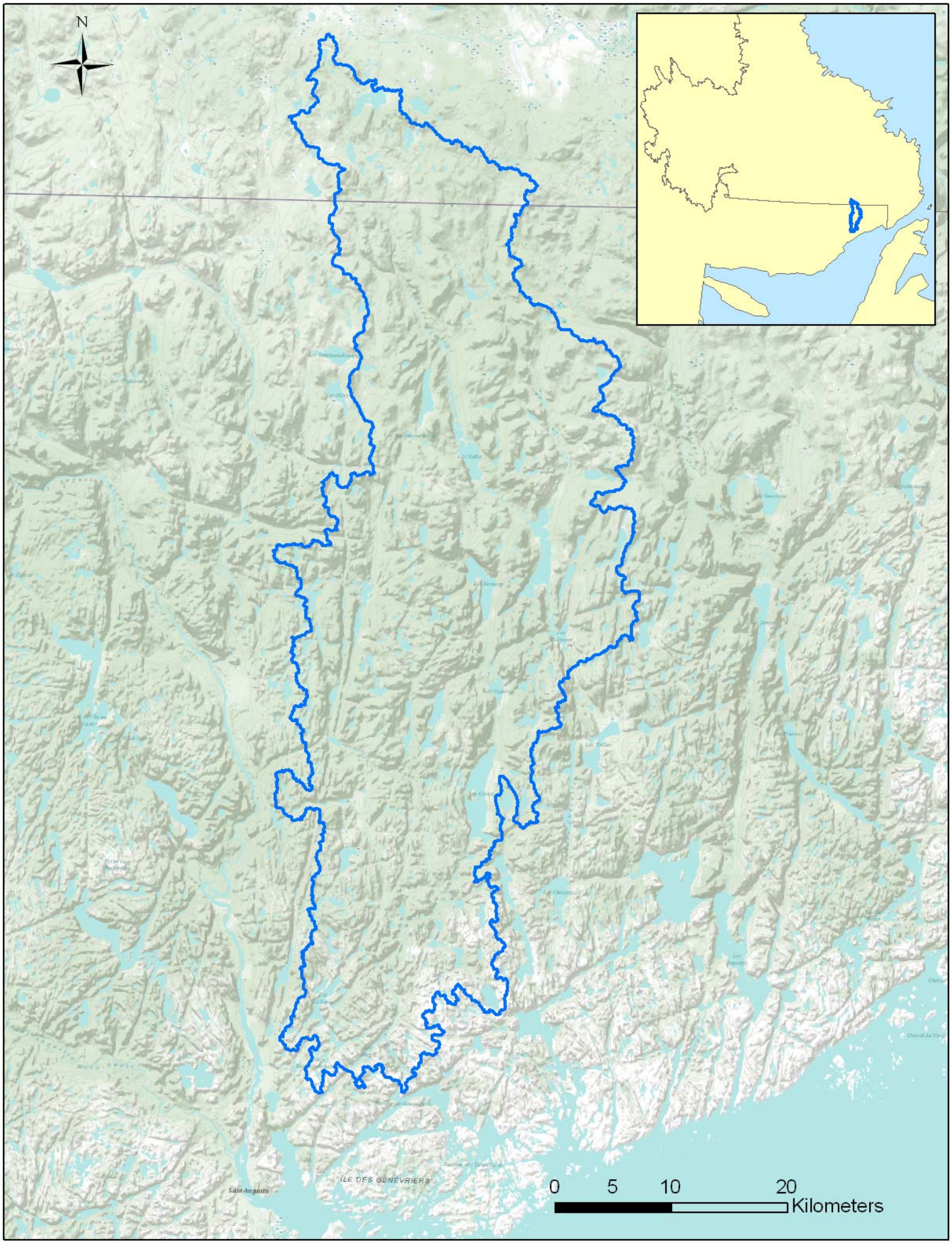


Figure 44: Coxipi River Stream Order

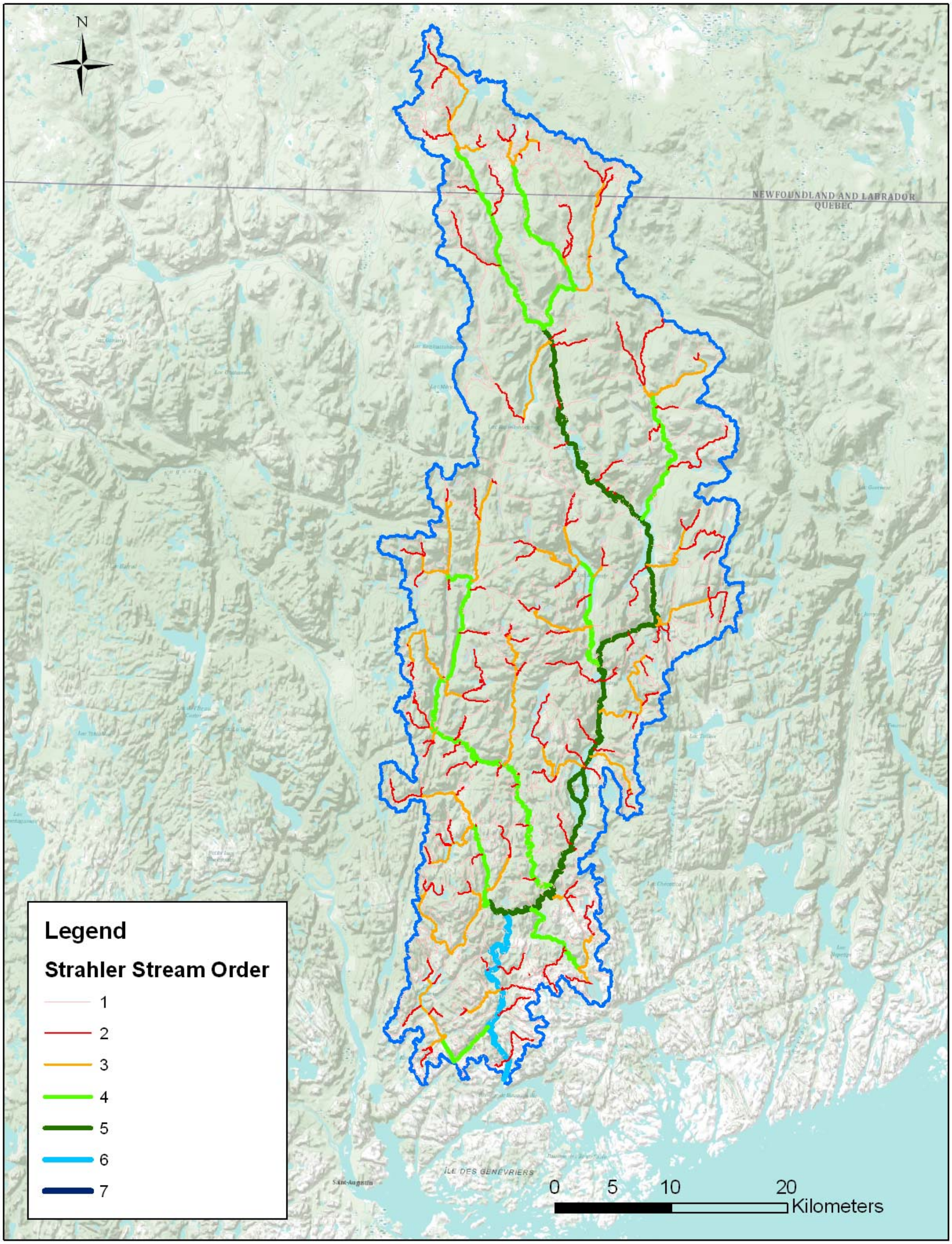


Figure 45: Coxipi River Watershed Elevation

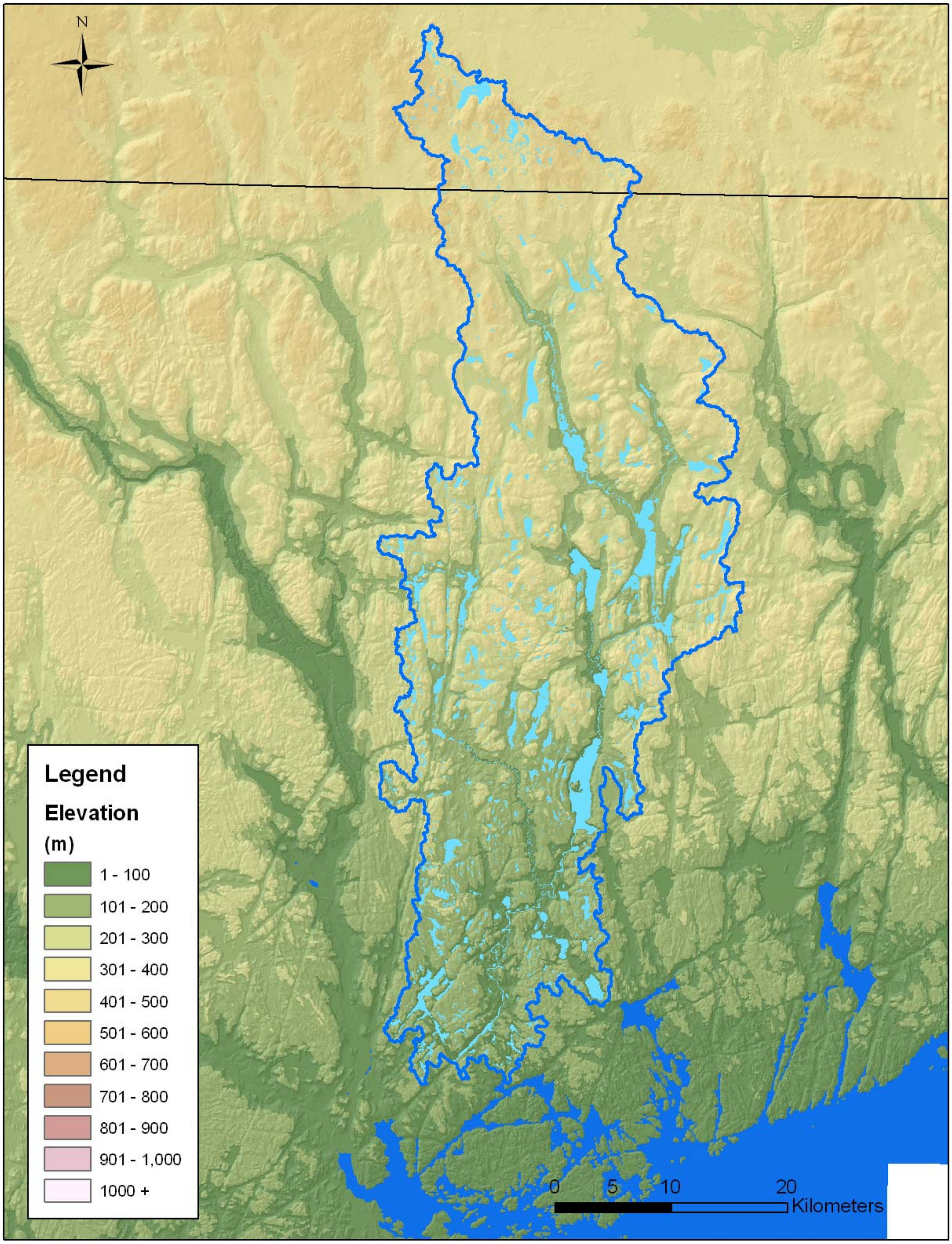


Figure 46: Coxipi River Elevation Profile

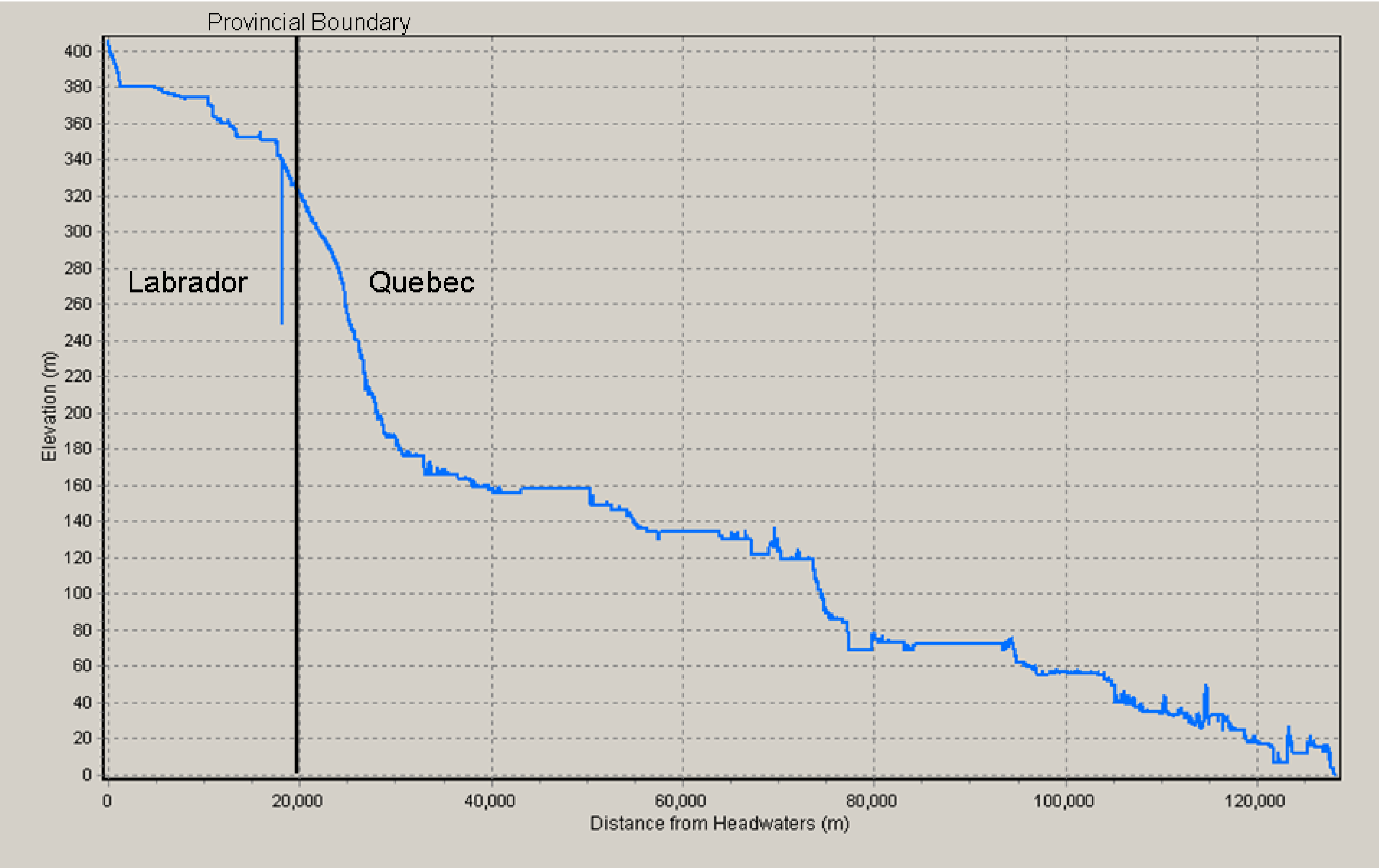
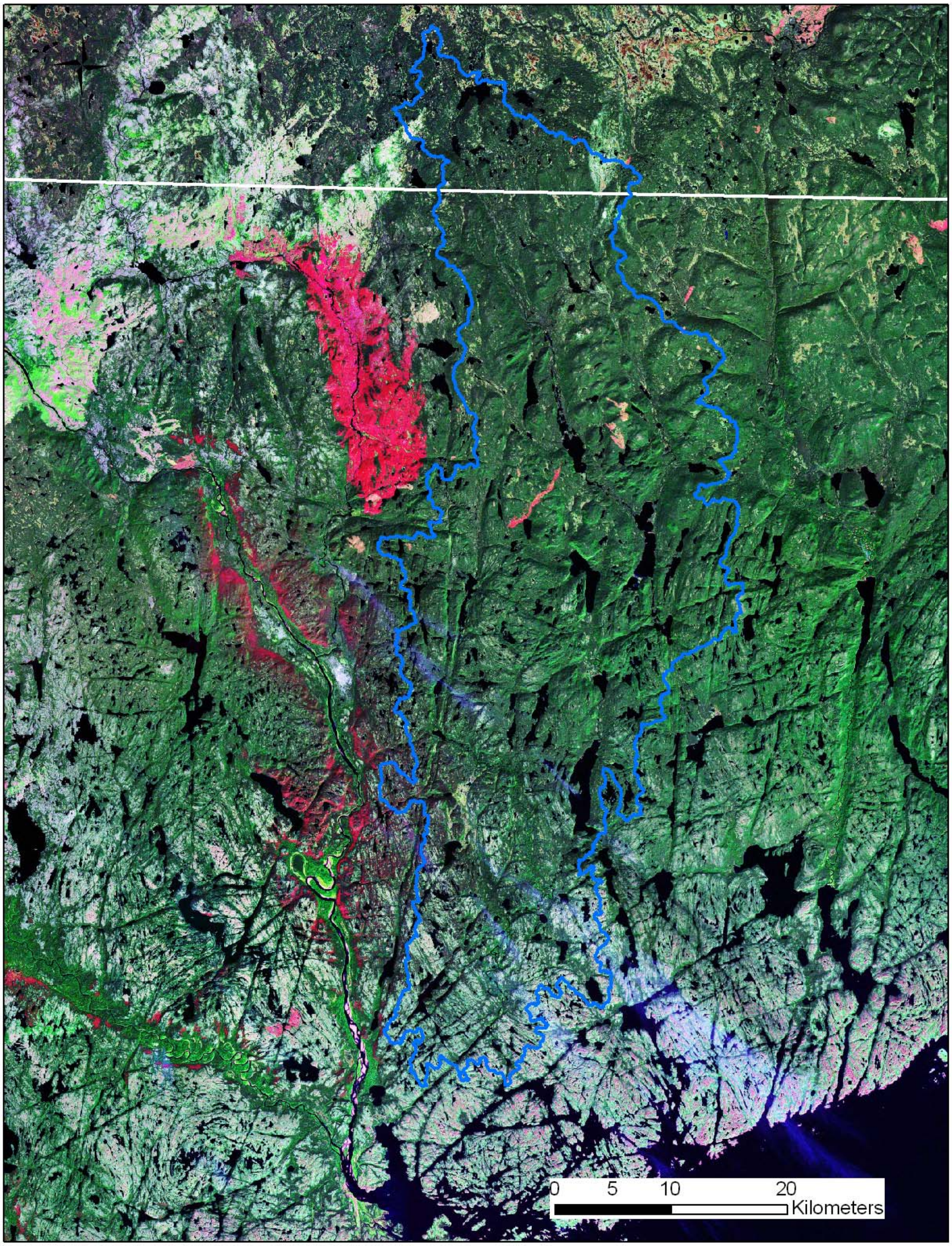


Figure 47: Coxipi River Watershed Landsat Imagery



Short Wave Infrared (bands 7, 4, 2) Landsat Imagery circa 2000. Trees and bushes, crops and wetland vegetation appear as shades of green. Water appears as black to dark blue, urban areas as lavender and bare soil as magenta, lavender, or pale pink.

Figure 48: Coxipi River Watershed Landcover

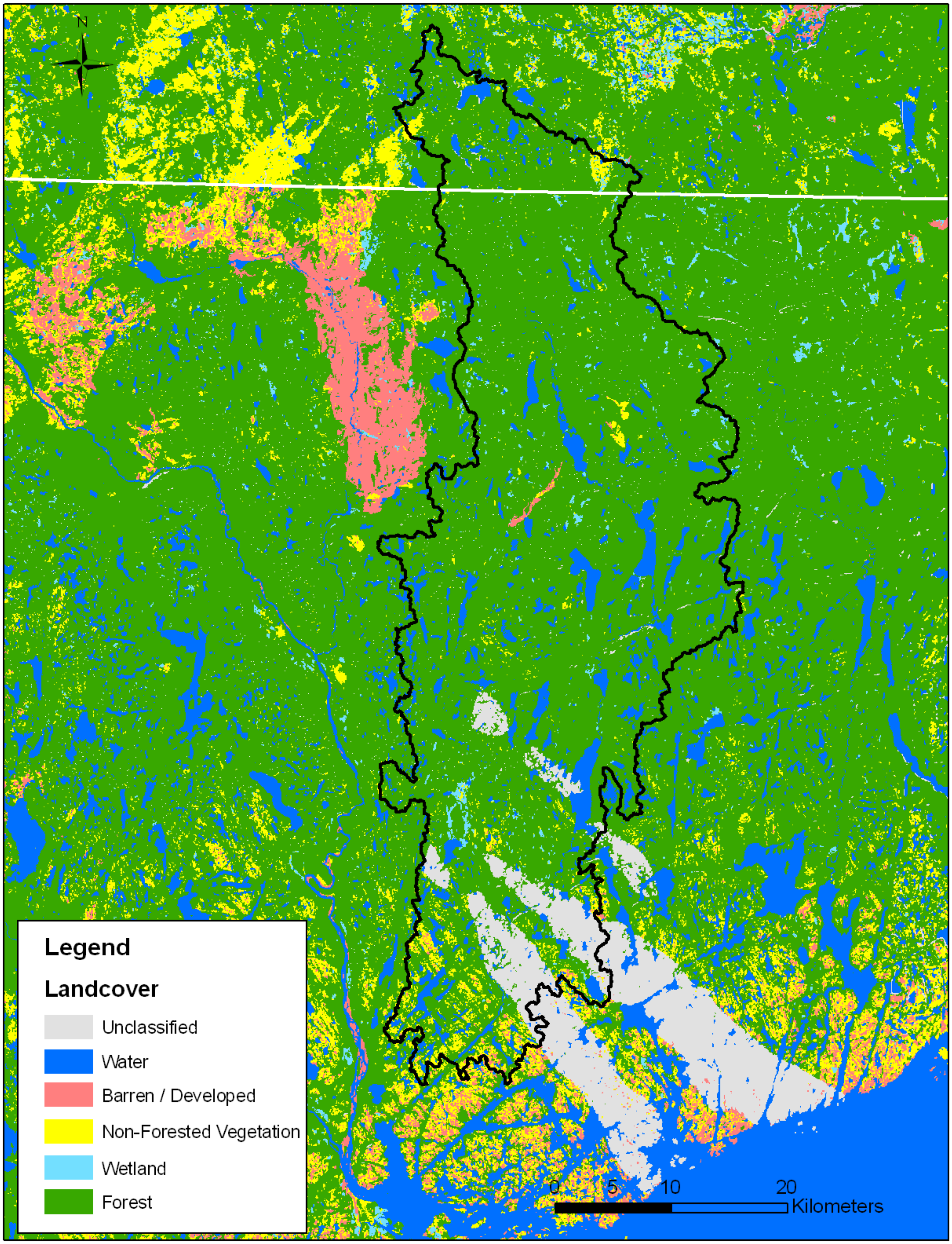
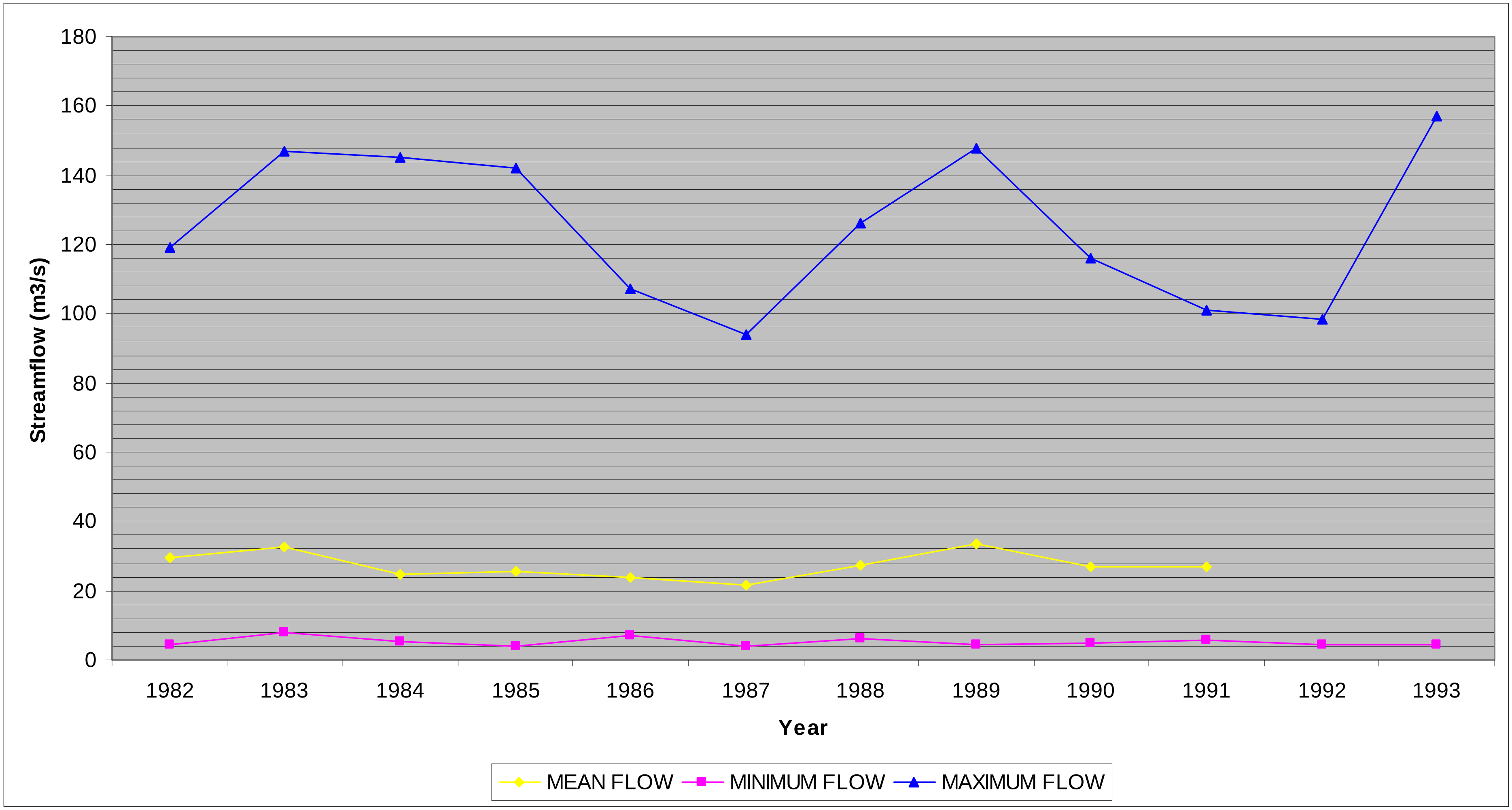


Table 12: Annual Flow Statistics for 02XB002 Hydrometric Station

YEAR	MEAN	MIN_MONTH	MIN_DAY	MIN	MIN_SYMBOL	MAX_MONTH	MAX_DAY	MAX	MAX_SYMBOL
1982	29.6	3	7	4.49		6	6	119	
1983	32.7	1	10	8.04		5	1	147	
1984	24.8	3	9	5.3	E	5	18	145	
1985	25.4	3	28	3.8	B	6	6	142	
1986	23.8	4	3	7.15	B	5	5	107	
1987	21.4	3	14	4	B	5	12	93.9	
1988	27.4	2	26	6.3		5	17	126	
1989	33.4	4	5	4.42	B	5	14	148	
1990	27.1	3	17	4.96	B	6	1	116	
1991	27	4	23	5.79	B	5	24	101	
1992		3	10	4.39	B	5	22	98.2	
1993		4	13	4.34	B	5	26	157	

Note: For Minimum and Maximum Symbols: B = Ice Conditions; E = Estimated, A= Partial Day

Figure 49: Annual Flow Graph for 02XB002 Hydrometric Station



Coxipi River Watershed Data Summary:

Watershed Area: 1,620 km^2
% in Labrador: 130 km^2 (8.0 %)

Main Channel Length: 128 km
% in Labrador: 20 km (15.6 %)

Main Channel Elevation: 405 m
Stream Gradient: 3.16 m/km

Strahler Stream Order: 6

Elevation Range: 0 – 503 m
Avg Elevation: 239 m
Median Elevation: 239 m

Landcover:
Barren / Developed: 5 km^2 (0.3 %)
Forest: 1,305 km^2 (80.6 %)
Non-Forest Vegetation: 50 km^2 (3.1%)
Water: 155 km^2 (9.6 %)
Wetland: 20 km^2 (1.2 %)
Unclassified: 85 km^2 (5.2 %)

Climate Normals:

Temperature:
Annual Daily Mean Temperature: 0 °C to 1.2 °C
January Daily Mean Temperature:-16.5 °C to -12.8 °C
July Daily Mean Temperature: 13.9 °C to 15.2 °C

Wind:
Annual Daily Mean Windspeed: 17.1 km/hr to 19.0 km/hr
Annual Daily Maximum Windspeed: 21.5 km/hr to 25.6 km/hr

Precipitation:
Annual Total Precipitation: 1,005.4 mm to 1,122.4 mm
Annual Rainfall: 628.9 mm to 839.3 mm
Annual Snowfall: 292.5 cm to 426.0 cm
Potential Evapotranspiration: 436.3 mm to 444.6 mm
Precipitation Surplus: 560.8 mm to 685.0 mm

Napetipi River

The Napetipi River is the smallest of the transboundary rivers with a watershed of approximately 1,270 km^2 (Table 1). Only a small portion of the headwaters of the watershed, just about 60 km^2 (4.7 %), is within Labrador. Approximately 10.7 % (13 km) of the 121 km main channel is in Labrador territory. The Napetipi has a Strahler stream order of five (Table 1, Figure 51).

The Napetipi watershed shares similar elevation characteristics to the neighbouring Coxipi River. The maximum elevation within the Napetipi watershed is about 502 m with an average elevation of 233 m (Table 2). The northern portions of the watershed contain the highest elevations, generally above 300 m. The elevation at the headwaters of the main channel is approximately 390 m creating an average stream gradient of 3.22 m/km. This is the steepest average gradient of any of the transboundary rivers. The upper reaches of the river are much steeper than the downstream section. The river drops almost 320 m in the first 40 km but then flattens out and drops only about 60 m in the final 80 km. The river profile (Figure 53) provides greater details of the varying gradient along the river system.

The Napetipi River is the most heavily forested of the transboundary rivers watersheds. Approximately 1085 km^2 (85.4 %) of the watershed is comprised of forest. Only 45 km^2 (3.5%) of the watershed is consists of vegetation forms such as shrubs and grasslands, a much lower percentage than some of the larger watersheds. There is about 105 km^2 (8.3 %) of water and 15 km^2 (1.2 %) of wetlands within the drainage basin. There is very little barren or developed land within the watershed, just 10 km^2 (0.8 %). See Table 3, Figure 54 and Figure 55 for additional detail.

There are two federal ecodistricts within the Napetipi River watershed, St. Augustin Hills and Rochy Coast (Figure 4). Monthly climatic normals for the period of 1961 -1990 were compiled for all the ecodistricts of Canada. As the Napetipi is a smaller watershed and contains only two ecodistricts there is less variation in climatic conditions than some of the other watersheds. Annual daily mean temperatures (based on these climate normals of the ecodistricts) range from 1.1 °C to 1.2 °C. Winter daily mean temperatures (January) range from -13.4 °C to -12.8 °C with summer (July) temperatures in the range of 13.9 °C to 14.1 °C. Table 4 and Figure 5, Figure 6 and Figure 7 depict temperature normals for the ecodistricts in the study area. Annual daily mean wind speeds range from 18.9 km/hr to 19.0 km/hr (Table 5 ,Figure 8), with maximum wind speeds ranging from 22.3 km/hr to 25.6 km/hr. Throughout the varying regions of the watershed, yearly precipitation totals range from 1,098.4 mm to 1,122.4 mm. Annual rainfall amounts range from 813.5 mm to 839.3 mm and snowfall accumulations are generally from 292.5 cm to 294.0 cm. Table 6, Figure 9, Figure 10 and Figure 11 provide more detail on the distribution of precipitation in the region. Depending on the area of the watershed, potential evapotranspiration ranges from 436.3 mm to 437.4 mm (Table 6, Figure 12). This creates precipitation surpluses in the range of 662.5 mm to 685.0 mm a year (Table 6, Figure 13).

There have been no hydrometric stations located in the Napetipi River watershed.

A portion of the Napetipi River watershed that is in Quebec has been proposed as a biodiversity reserve (Quebec, 2007, pg. 5). With the protected status, the area would be protected from hydroelectric development.

Figure 50: Napetipi River Watershed

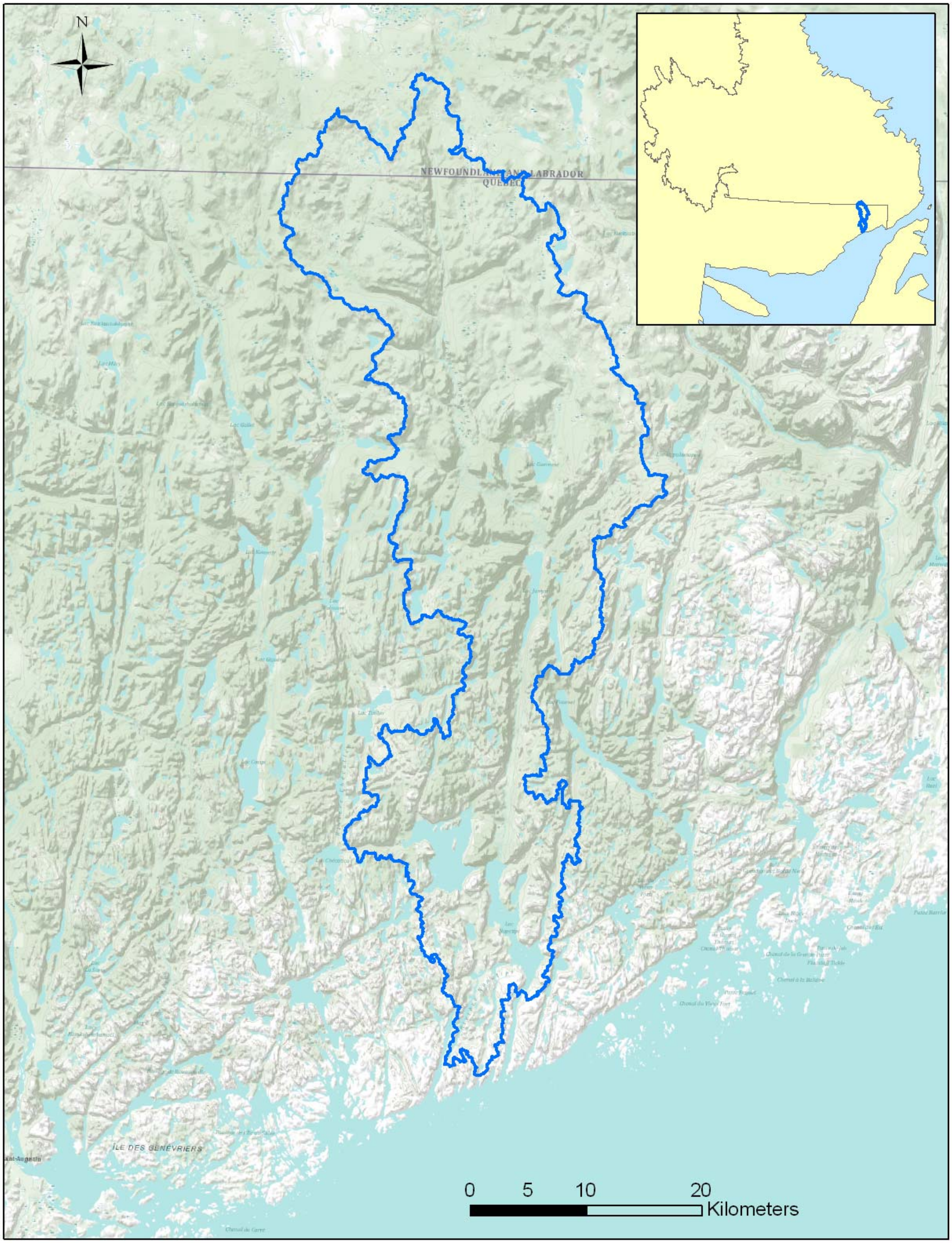


Figure 51: Napetipi River Stream Order

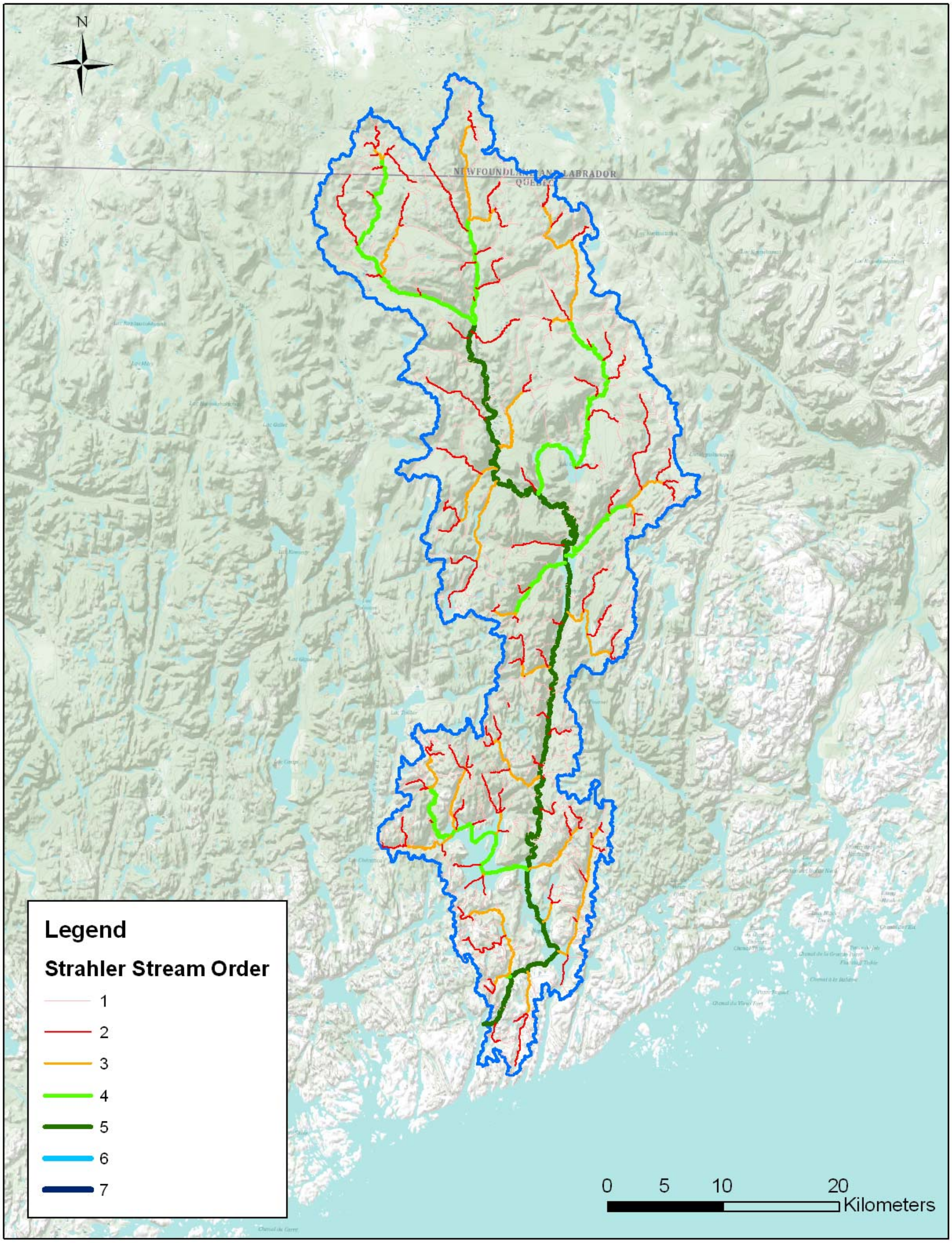


Figure 52: Napetipi River Watershed Elevation

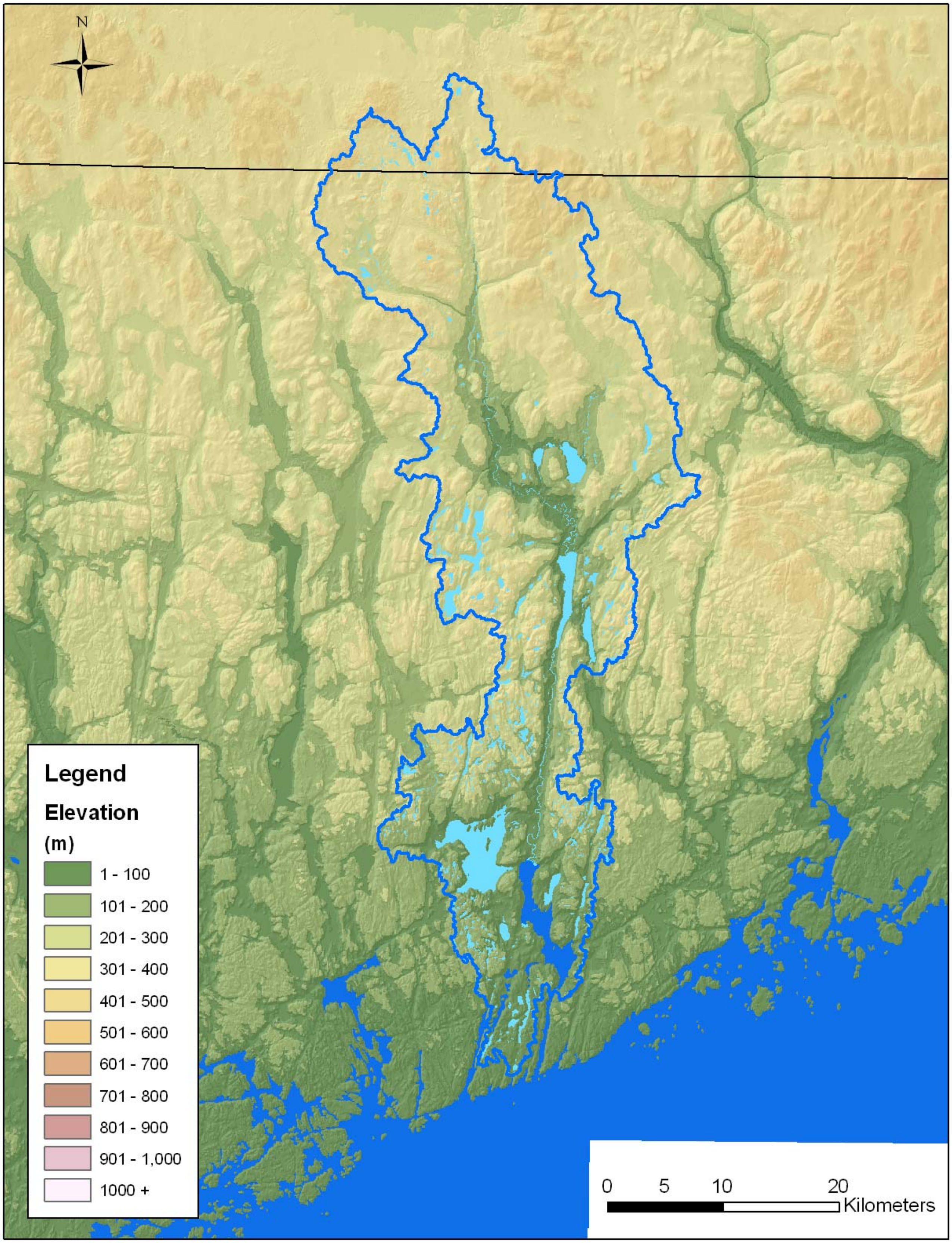


Figure 53: Napetipi River Elevation Profile

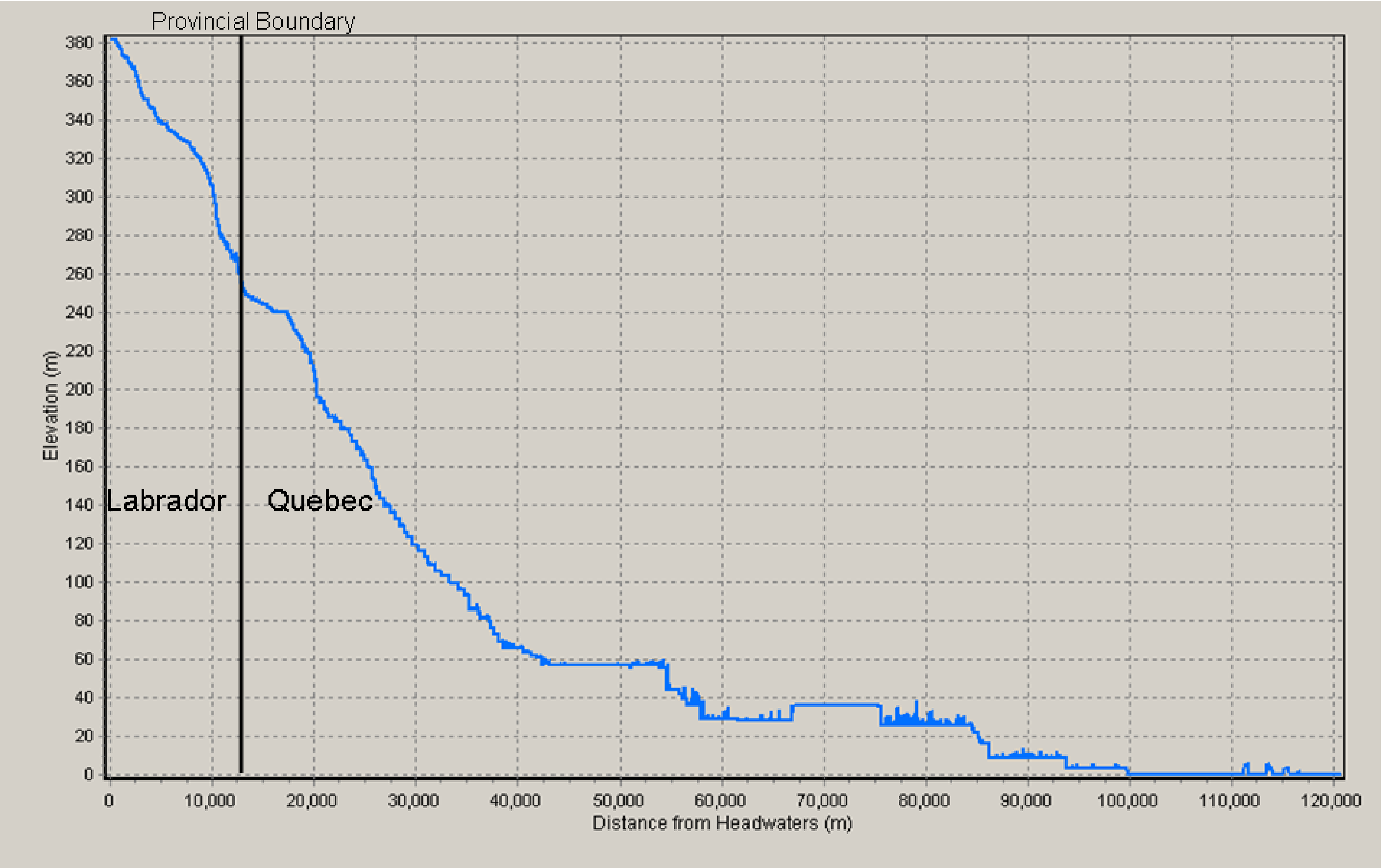
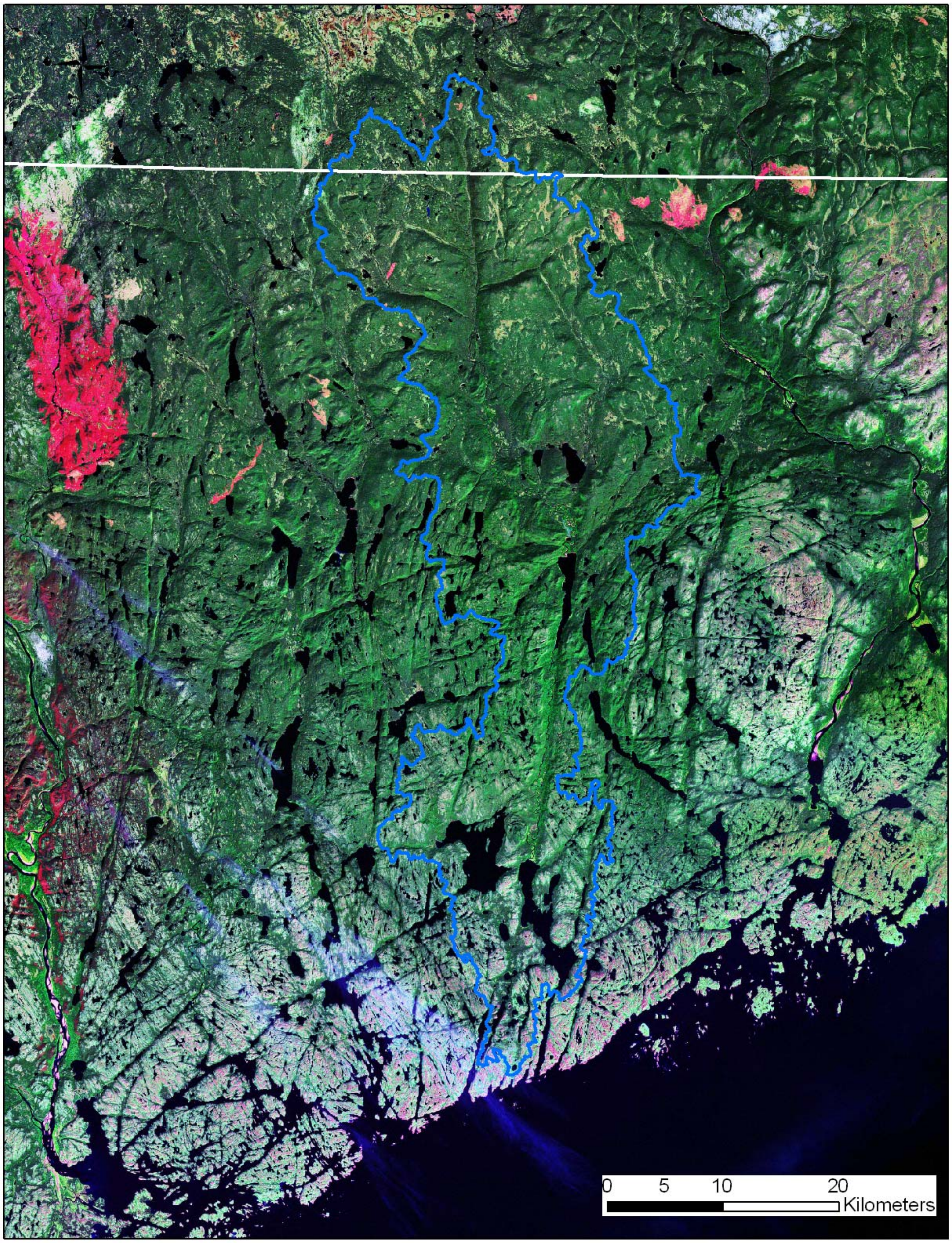
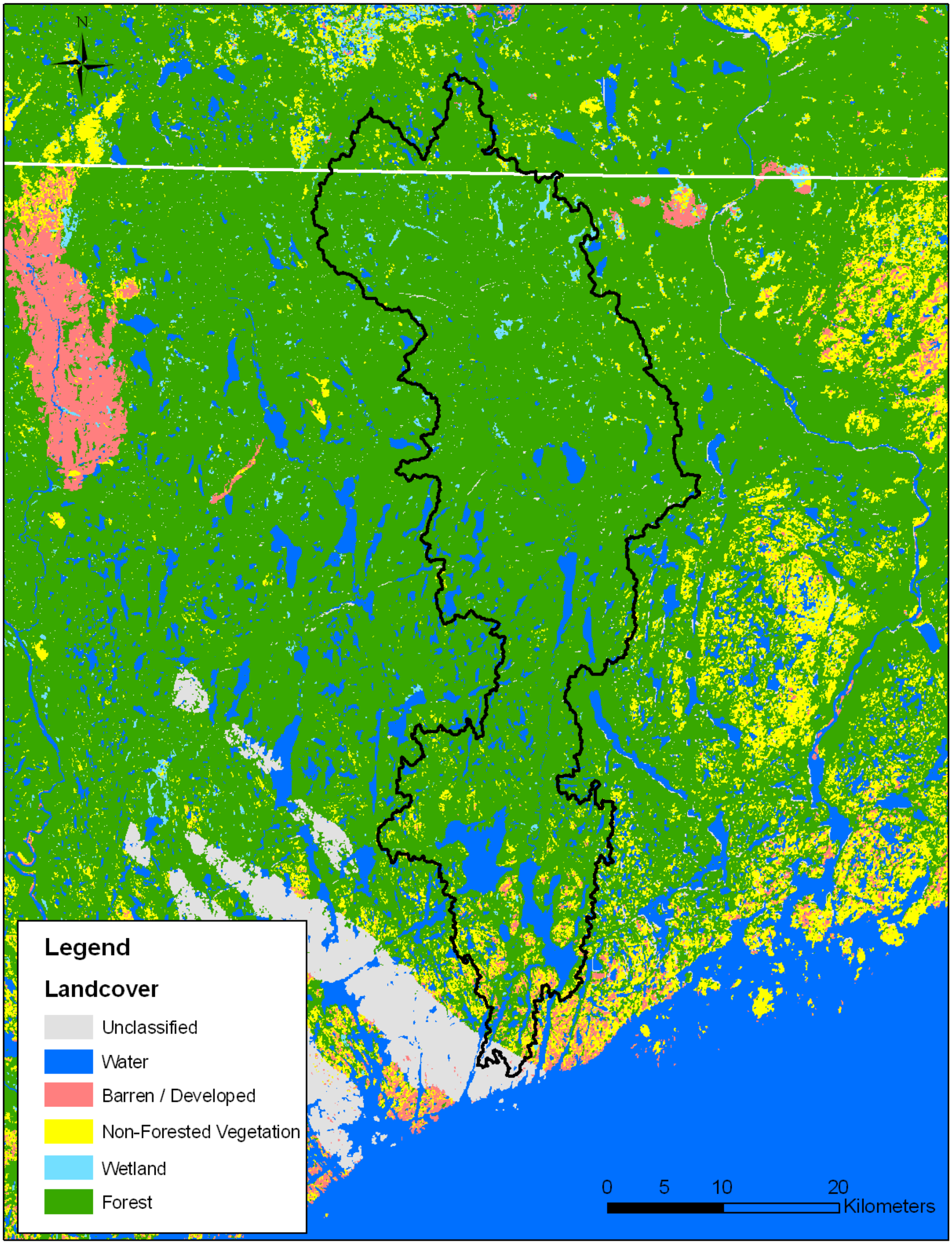


Figure 54: Napetipi River Watershed Landsat Imagery



Short Wave Infrared (bands 7, 4, 2) Landsat Imagery circa 2000. Trees and bushes, crops and wetland vegetation appear as shades of green. Water appears as black to dark blue, urban areas as lavender and bare soil as magenta, lavender, or pale pink.

Figure 55: Napetipi River Watershed Landcover



Napetipi River Watershed Data Summary:

Watershed Area: 1,270 km^2
% in Labrador: 60 km^2 (4.7 %)

Main Channel Length: 121 km
% in Labrador: 13 km (10.7 %)

Main Channel Elevation: 390 m
Stream Gradient: 3.22 m/km

Strahler Stream Order: 5

Elevation Range: 0 – 502 m
Avg Elevation: 233 m
Median Elevation: 247 m

Landcover:
Barren / Developed: 10 km^2 (0.8 %)
Forest: 1,085 km^2 (85.4 %)
Non-Forest Vegetation: 45 km^2 (3.5%)
Water: 105 km^2 (8.3 %)
Wetland: 15 km^2 (1.2 %)
Unclassified: 10 km^2 (0.8 %)

Climate Normals:

Temperature:
Annual Daily Mean Temperature: 1.1 °C to 1.2 °C
January Daily Mean Temperature:-13.4 °C to -12.8 °C
July Daily Mean Temperature: 13.9 °C to 14.1 °C

Wind:
Annual Daily Mean Windspeed: 18.9 km/hr to 19.0 km/hr
Annual Daily Maximum Windspeed: 22.3 km/hr to 25.6 km/hr

Precipitation:
Annual Total Precipitation: 1,098.8 mm to 1,122.4 mm
Annual Rainfall: 813.5 mm to 839.3 mm
Annual Snowfall: 292.5 cm to 294 cm
Potential Evapotranspiration: 436.3 mm to 437.4 mm
Precipitation Surplus: 662.5 mm to 685.0 mm

St. Paul River

The St. Paul River is the most eastern of the transboundary rivers and has a watershed of approximately 7,190 km^2. The St. Paul River is also the river with the greatest proportion of its watershed in Labrador with roughly 69.5% (5,000 km^2) of the watershed north of the provincial boundary (Table 1). The main channel of the St. Paul is about 246 km with approximately 66.7 % (146 km) of the channel in Labrador. The St. Paul River has a Strahler stream order of seven (Table 1, Figure 57).

The maximum elevation within the St. Paul River watershed is about 581 m with an average elevation of 364 m (Table 2, Figure 58). The elevation at the headwaters of the main channel is approximately 410 m. The average stream gradient is 1.67 m/km with the middle sections of the river displaying the highest slope. The river drops about 50 m in the first 10 to 15 km then flattens out significantly. There is a relief change of just 10 m or so for the next 75 – 80 km before the gradient then becomes much steeper. The final 70 to 80 km then become quite flat, dropping just over 20 m. The river profile (Figure 59) provides greater details of the varying gradient along the river system.

With approximately 5,145 km^2 (71.6 %) of the watershed comprised of forested land the St. Paul River is similar to the other transboundary watersheds in terms of the dominant landcover feature (Table 3). There is roughly 1,085 km^2 (15.1%) of vegetation forms such as shrubs and grasslands, much of which is found in the southeastern portion of the watershed. About 7.2 % (520 km^2) of the watershed is water and 2.0% (145 km^2) is barren / developed land. There are 265 km^2 (3.7 %) of wetlands within the drainage basin, the highest percentage of wetlands in any of the watersheds. Unlike some of the other rivers where most of the wetlands are close to the mouth of the river, a large portion of the wetlands in the St. Paul watershed are located in the upper sections of the basin. Greater detail can be seen in Figure 60 and Figure 61.

The St. Paul River watershed is quite ecologically diverse. It is comprised of the federal ecodistricts of Upper St. Augustin Plateau, South Eagle Plateau, St. Augustin Hills, St. Paul, Blanc Sablon and Rochy Coast (Figure 4). Monthly climatic normals for the period of 1961 - 1990 were compiled for all the ecodistricts of Canada. Based on the climate normals of these ecodistricts, annual daily mean temperatures in the watershed range from -0 °C to 1.8 °C. Winter daily mean temperatures (January) range from -16.5 °C to -10.6 °C with summer (July) temperatures in the range of 12.9 °C to 15.2 °C. Table 4 and Figure 5, Figure 6 and Figure 7 depict temperature normals for the ecodistricts in the study area. Annual daily mean wind speeds range from 17.1 km/hr to 23.8 km/hr (Table 5 ,Figure 8), with maximum wind speeds ranging from 21.5 km/hr to 26.8 km/hr. Throughout the varying regions of the watershed, yearly precipitation totals range from 1,005.4 mm to 1,122.4 mm. Annual rainfall amounts range from 628.9 mm to 839.3 mm and snowfall accumulations are generally from 292.5 cm to 426.0 cm. Table 6, Figure 9, Figure 10 and Figure 11 provide more detail on the distribution of precipitation in the region. Depending on the area of the watershed, potential evapotranspiration ranges from 424.5 mm to 444.6 mm (Table 6, Figure 12)). This creates precipitation surpluses in the range of 560.8 mm to 685.0 mm a year (Table 6, Figure 13).

There has only been one hydrometric station, 02XC001, located in the St. Paul River watershed. This period of record for this station is 1967 to 2001 (Table 7). Mean Annual Flows for the period of record at this station ranges from 89.5 m^3/s to 192 m^3/s with a minimum flow of 11.1 m^3/s and a maximum flow of 2,440 m^3/s. Minimum flows generally occur during the winter, largely due to ice conditions. Maximum flows are usually found in May or June, presumably due to snowmelt. Table 13 and Figure 62 provide greater detail on flows at 02XC001.

A portion of the St. Paul River watershed, that is in Quebec, has been proposed as a biodiversity reserve (Quebec, 2007, pg. 5). With protected status, the area would be protected from hydroelectric development.

Major tributaries of the St. Paul River include Rivière Bujeault (Bujeault River), Ruisseau Chanion and Ruisseau Uahatu.

Figure 56: St. Paul River Watershed

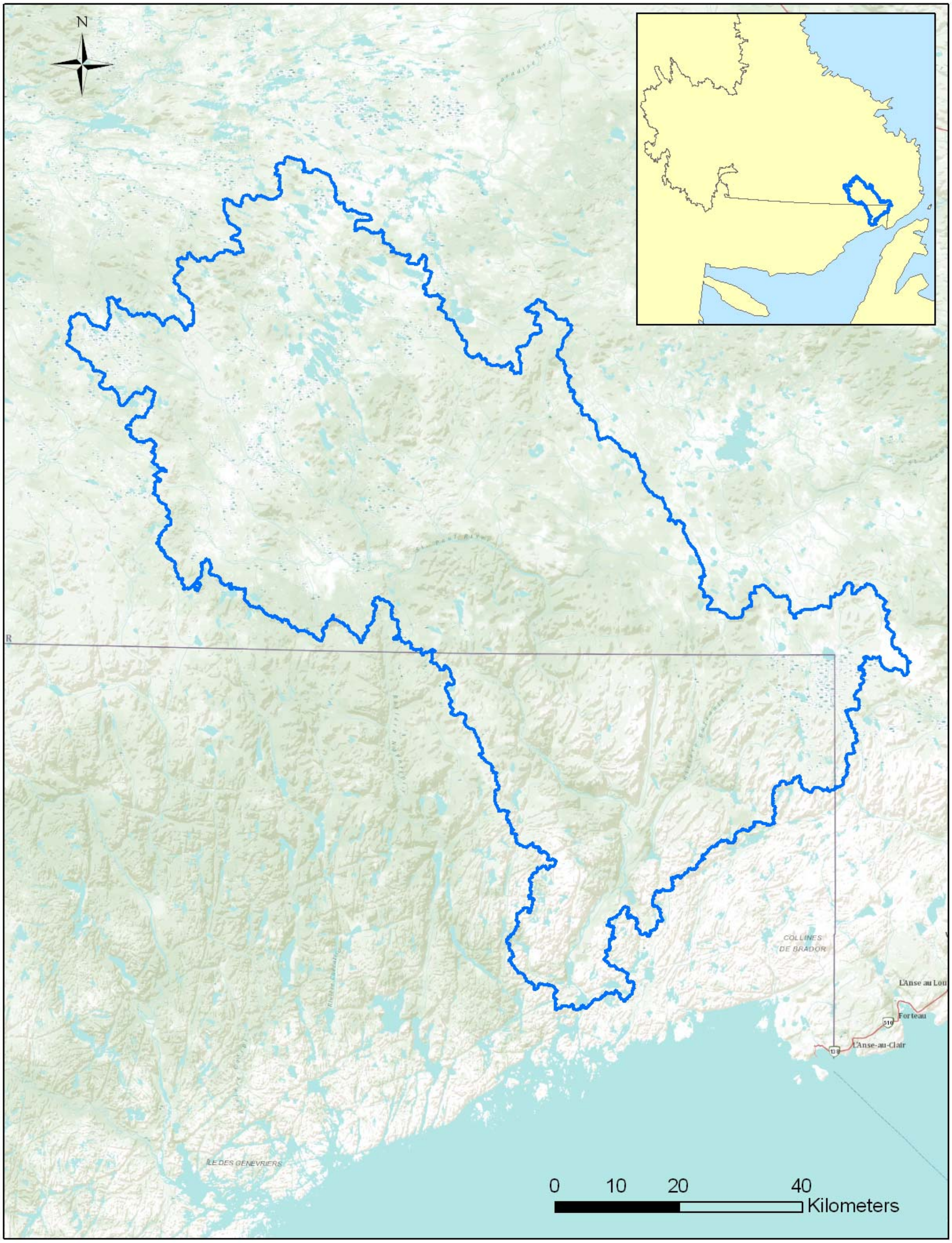


Figure 57: St. Paul River Stream Order

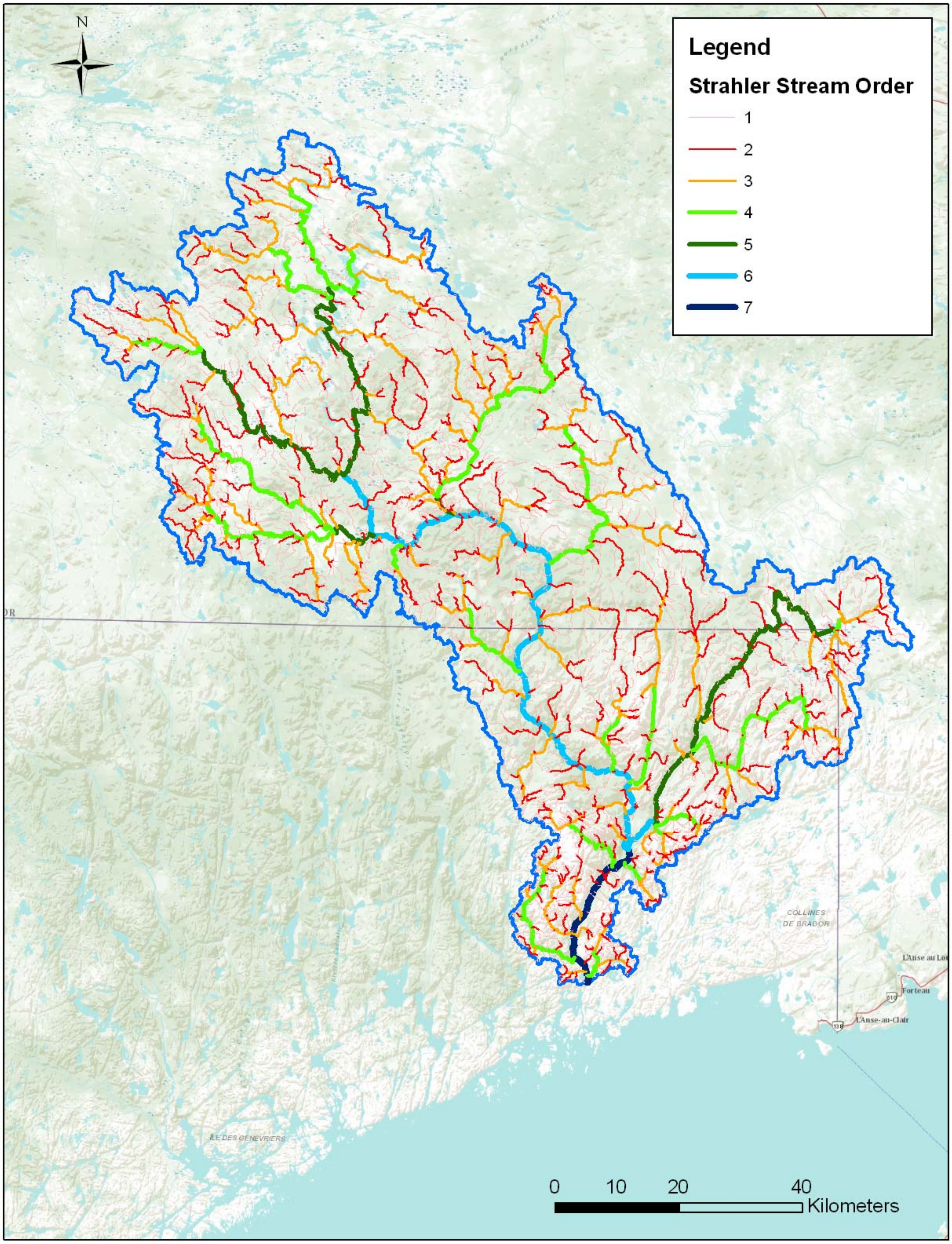


Figure 58: St. Paul River Watershed Elevation

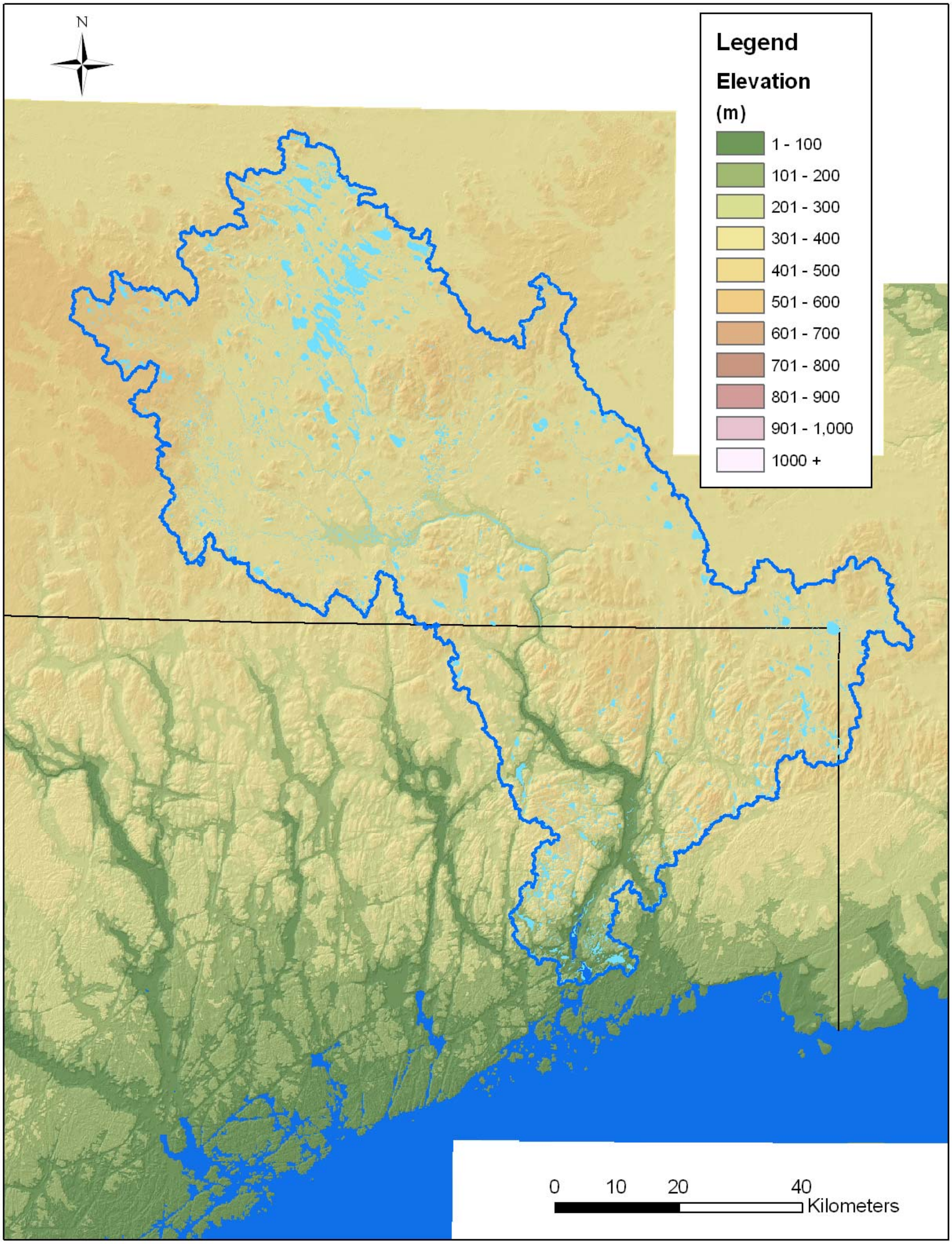


Figure 59: St. Paul River Elevation Profile

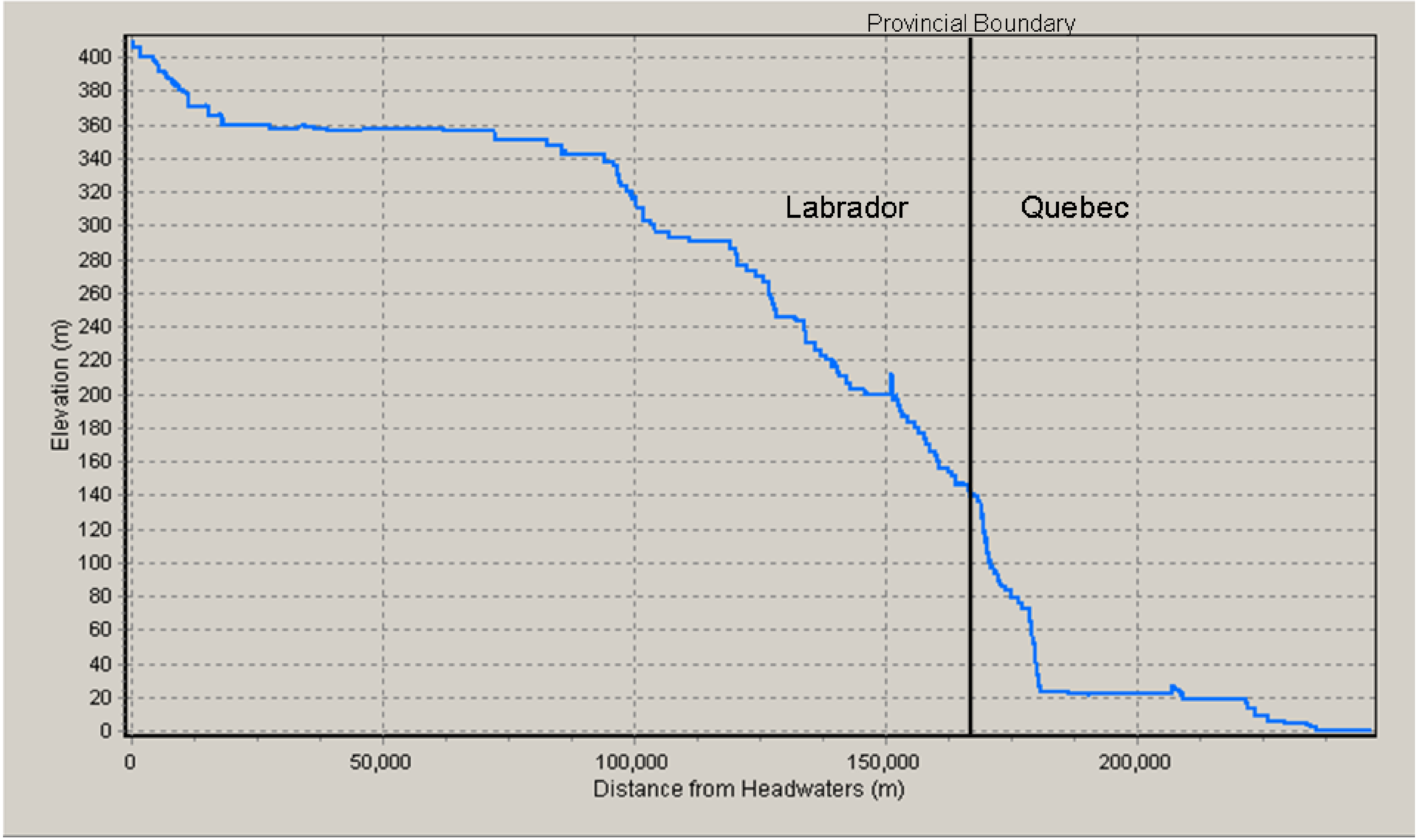
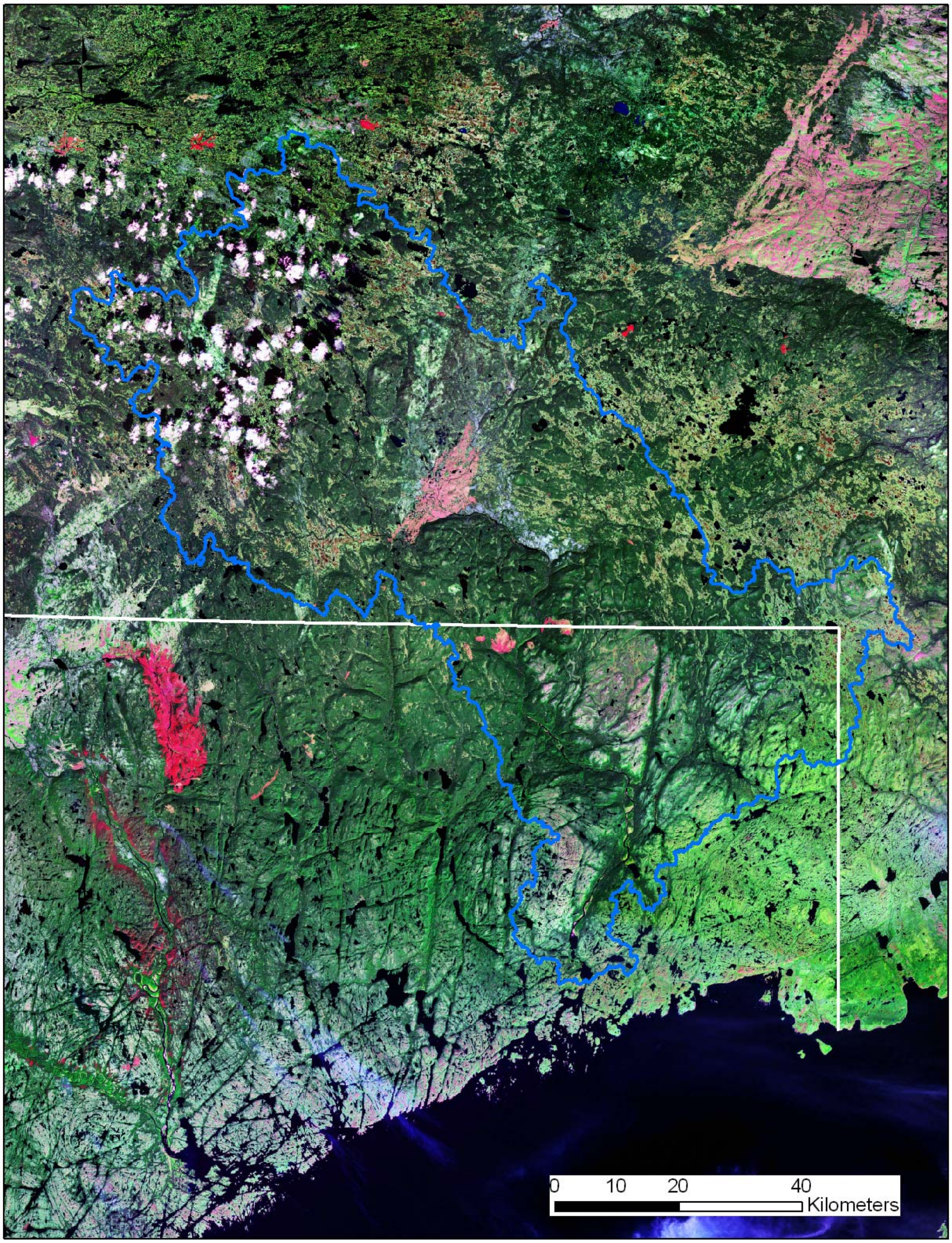


Figure 60: St. Paul River Watershed Landsat Imagery



Short Wave Infrared (bands 7, 4, 2) Landsat Imagery circa 2000. Trees and bushes, crops and wetland vegetation appear as shades of green. Water appears as black to dark blue, urban areas as lavender and bare soil as magenta, lavender, or pale pink.

Figure 61: St. Paul River Watershed Landcover

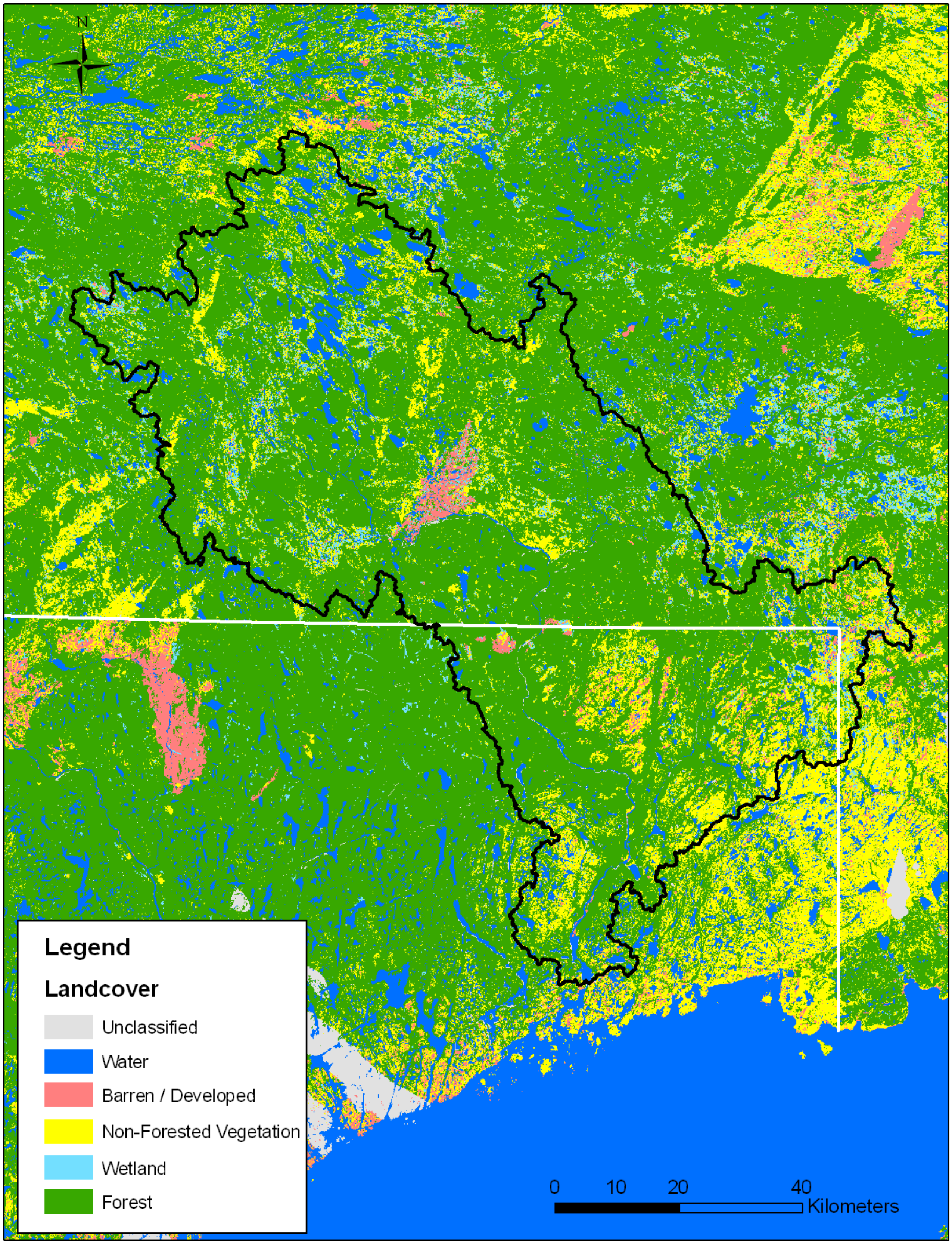
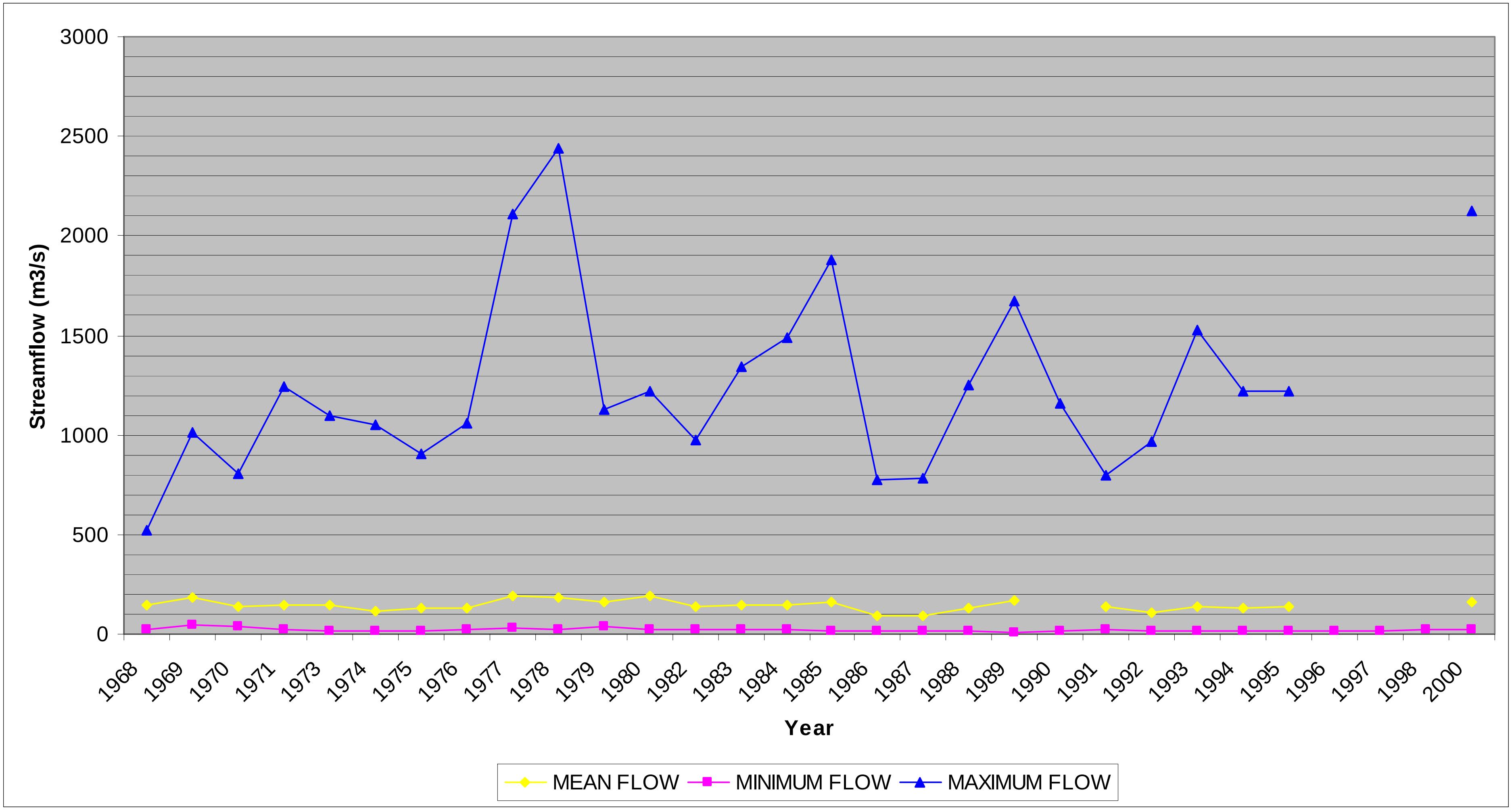


Table 13: Annual Flow Statistics for 02XC001 Hydrometric Station

YEAR	MEAN	MIN_MONTH	MIN_DAY	MIN	MIN_SYMBOL	MAX_MONTH	MAX_DAY	MAX	MAX_SYMBOL
1968	147	4	4	22.7	B	5	12	521	E
1969	182	1	25	45.6	B	6	9	1,010	E
1970	139	3	1	34.8	B	10	18	807	
1971	145	3	27	24.3	B	5	25	1,240	
1973	148	4	22	13.1	B	5	20	1,100	E
1974	118	3	16	16.1	B	6	7	1,050	E
1975	131	3	1	12.5	B	5	24	906	E
1976	132	3	27	21.5	B	5	15	1,060	
1977	192	3	28	28.9	B	6	4	2,110	
1978	186	4	16	21.8	B	5	19	2,440	
1979	160	1	2	36.3	B	5	1	1,130	
1980	188	4	13	23.7	B	5	22	1,220	
1982	141	3	1	19.6	B	7	25	973	
1983	147	3	19	22.1	B	4	30	1,340	
1984	147	3	18	25.2	B	5	16	1,490	
1985	164	4	4	15.7	B	6	5	1,880	
1986	89.5	12	31	15	B	5	4	775	
1987	91.4	3	17	11.7	B	5	9	781	
1988	130	2	22	16.5	B	5	15	1,250	
1989	166	3	25	11.1	B	5	11	1,670	
1990		4	15	17.9	B	5	30	1,160	
1991	136	12	31	19.4	B	5	22	801	
1992	105	3	11	13.9	B	6	1	963	
1993	135	2	20	14.7		5	25	1,530	B
1994	130	3	4	15.9	B	5	20	1,220	B
1995	135	3	13	19.1	B	5	14	1,220	
1996		2	15	18.3	B				
1997		3	28	16.1	B				
1998		2	23	21.3	B				
2000	163	3	18	21.4	B	6	2	2,126	

Figure 62: Annual Flow Graph for 02XC001 Hydrometric Station



St. Paul River Watershed Data Summary:

Watershed Area: 7,190 km^2
% in Labrador: 5,000 km^2 (69.5 %)

Main Channel Length: 246 km
% in Labrador: 164 km (66.7 %)

Main Channel Elevation: 410 m
Stream Gradient: 1.67 m/km

Strahler Stream Order: 7

Elevation Range: 0 – 581 m
Avg Elevation: 364 m
Median Elevation: 371 m

Landcover:
Barren / Developed: 145 km^2 (2.0 %)
Forest: 5,145 km^2 (71.6 %)
Non-Forest Vegetation: 1,085 km^2 (15.1%)
Water: 520 km^2 (7.2 %)
Wetland: 265 km^2 (3.7 %)
Unclassified: 30 km^2 (0.4 %)

Climate Normals:

Temperature:
Annual Daily Mean Temperature: 0 °C to 1.8 °C
January Daily Mean Temperature:-16.5 °C to -10.6 °C
July Daily Mean Temperature: 12.9 °C to 15.2 °C

Wind:
Annual Daily Mean Windspeed: 17.1 km/hr to 23.8 km/hr
Annual Daily Maximum Windspeed: 21.5 km/hr to 26.8 km/hr

Precipitation:
Annual Total Precipitation: 1,005.4 mm to 1,122.4 mm
Annual Rainfall: 628.9 mm to 839.3 mm
Annual Snowfall: 292.5 cm to 426.0 cm
Potential Evapotranspiration: 424.5 mm to 444.6 mm
Precipitation Surplus: 560.8 mm to 685.0 m

Summary

There are five large rivers which originate in southern Labrador and flow through the “North Shore” of Quebec into the Gulf of St. Lawrence. These five rivers: the Romaine River, the Natashquan River, the Little Mecatina River, the St. Augustin River and the St. Paul River are long river systems with large watersheds. Several of the rivers have significant portions of their watersheds in Labrador. The Coxipi River and Napetipi River have small sections of their headwaters north of the Labrador and Quebec border and are considerably smaller watersheds. All together the transboundary watersheds cover an area of approximately 70,000 km^2.

The transboundary watershed area is heavily forested with very little development. There are areas with significant elevation changes and various sections of the rivers display steep gradients. There is some degree of ecological diversity within the region as it encompasses ten federal ecodistricts. There is considerable range in temperature throughout the year, often exceeding 30 °C between summer and winter. Temperature ranges in the coastal sections of the watersheds are often less than the northern (Labrador) sections due to the moderating impact of the ocean. The region does get significant amounts of precipitation with most areas exceeding 1,000 mm annually. Potential evapotranspiration rates are much lower creating precipitation surpluses of greater than 400 mm a year. Coastal areas receive more precipitation in the form of rainfall while northern sections receive greater amounts of snowfall.

Snowfall is an important feature in the region as high flows are usually found in May or June which would coincide with spring melt off of snow pack. Low flows are usually found during winter and could be the result of ice conditions. While streamflow data monitoring in the area has been sporadic, the data available reveals several of the rivers to have significant flows. The high flows combined with some sections of rivers with steep slopes have made the area of interest for hydro power generation.

As indicated to in the previous paragraph, streamflow data monitoring in the area has been sporadic. Over the years, a number of hydrometric stations have been discontinued. Further, there is only limited climate and water quality monitoring taking place in the area. An established monitoring network collecting climate, water quality, and water quantity data is required for the transboundary rivers.

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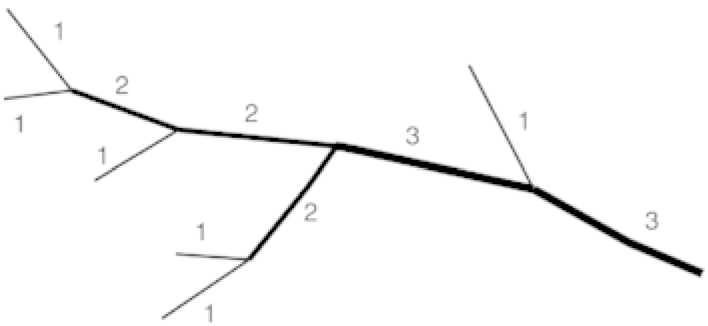
Appendices

Appendix 1 – Glossary

Strahler Stream Order:

A classification system used to define stream size based on a hierarchy of tributaries. A stream with no tributaries (headwater stream) is considered a first order stream. When two first-order streams come together, they form a second-order stream. When two second-order streams come together, they form a third-order stream. Streams of lower order joining a higher order stream do not change the order of the higher stream. Thus, if a first-order stream joins a second-order stream, it remains a second-order stream. It is not until a second-order stream combines with another second-order stream that it becomes a third-order stream.



ftp://frap.cdf.ca.gov/pub/incoming/TAC/ISOR%20references%201-139%20%20KIRSTEN/Strahler,%201957,%20Quantitative%20Analysis%20of%20Watershed%20Geomorphology.pdf

Stream Gradient

Stream gradient is the grade measured by the ratio of drop in a stream per unit distance, usually expressed as feet per mile or meters per kilometer.

A high gradient indicates a steep slope and rapid flow of water (i.e. more ability to erode); whereas a low gradient indicates a more nearly level stream bed and sluggishly moving water. The gradient influences the velocity of the stream. The steeper the gradient, the higher the velocity will be (if all other factors are held constant).

Ecodistricts

The National Ecological Framework for Canada was developed between 1991 and 1999. The fundamental basis for delineation of ecological units is to capture the major ecological composition and the linkages between the various components (e.g., landforms, soils, water, and vegetation) rather than treating each component as a separate characteristic of the landscape. The National Ecological Framework for Canada has four levels of generalization ranging from Ecozone (largest – 15 in Canada) to ecodistrict (smallest – 1021 in Canada).

Ecodistricts are defined as a subdivision of an ecoregion characterized by a distinctive assemblages of relief, landforms, geology, soil, vegetation, water bodies and fauna.

http://sis.agr.gc.ca/cansis/nsdb/ecostrat/1999report/framework.html

Climate Normals

Monthly climatic normals for the 1961-1990 normals period were compiled for the 1022 Ecodistricts in Canada. The climate normals information originated from point-based weather station data obtained from Environment Canada (1994). The average monthly and annual climate variables were estimated from monthly and annual climatic normals for each ecodistrict . In the source data, monthly normals were provided for each month plus an annual normal. Each of the 13 values were aggregated to the ecodistrict spatial framework independently. In some cases this results in the annual value for an ecodistrict not equaling the sum of the 12 monthly values. The annual values for an ecodistrict were not calculated as the sum of the 12 monthly values, but as an area weighted average of the annual values from source weather stations.

http://sis.agr.gc.ca/cansis/nsdb/ecostrat/1999report/climate_normals_1961-90_compilation.html

Potential Evapotranspiration

Potential evapotranspiration (PET) is the amount of evaporation that would occur if a sufficient water source were available. If the actual evapotranspiration is considered the net result of atmospheric demand for moisture from a surface and the ability of the surface to supply moisture, then PET is a measure of the demand side. Surface and air temperatures, insolation, and wind all affect this.

http://www.unc.edu/courses/2007fall/geog/801/001/www/ET/Thornthwaite48-GeogrRev.pdf

Average monthly and annual potential evapotranspiration (PE) were estimated from monthly climatic normals for each Ecodistrict (Appendix 1) using the Penman and the Thornthwaite methods. Average monthly and annual Thornthwaite Potential Evapotranspiration (PE) values and Water Deficits (WD) were computed using methods described by Thornthwaite and Mather (1957).

Thornthwaite values were used in this report.

http://sis.agr.gc.ca/cansis/nsdb/ecostrat/1999report/climate_normals_1961-90.html#pe

Precipitation Surplus

A precipitation surplus/deficit was computed by subtracting the PE from Total Precipitation (i.e. TOTALP-PE) using both the Penman and the Thornthwaite PE calculations.

Thornthwaite values were used in this report.

http://sis.agr.gc.ca/cansis/nsdb/ecostrat/1999report/climate_normals_1961-90.html#pe

Appendix 2 – Mapping and Analysis Data Sources

As the area of interest for this report includes portions of two provinces, all data sources used in the analysis for this report are where possible derived from federal data sets.

Mapping Data sources for report are as follows:

National Hydro Network (NHN)
http://www.geobase.ca/geobase/en/data/nhn/index.html
The National Hydro Network (NHN), for which the standard was officially adopted by the Canadian Council on Geomatics (CCOG) in August 2004, focuses on providing a quality geometric description and a set of basic attributes describing Canada's inland surface waters. It provides geospatial vector data describing hydrographic features such as lakes, reservoirs, rivers, streams, canals, islands, obstacles (e.g. waterfalls, rapids, rocks in water) and constructions (e.g. dams, wharves, dikes), as well as a linear drainage network and the toponymic information (geographical names) associated to hydrography.
The NHN is a vector, topographic data product primarily designed to allow hydrographic network analysis. It is intented for water flow analysis, water and watershed management, environmental and hydrographical applications, as well as for a multitude of cartographic applications.

Land Cover, Circa 2000 – Vector
http://www.geobase.ca/geobase/en/data/landcover/index.html
Land Cover information is the result of vectorization of raster thematic data originating from classified Landsat 5 and Landsat 7 ortho-images, for agricultural and forest areas of Canada, and for Northern Territories. The forest cover was produced by the Earth Observation for Sustainable Development (EOSD) project, an initiative of the Canadian Forest Service (CFS) with the collaboration of the Canadian Space Agency (CSA) and in partnership with the provincial and territorial governments. The agricultural coverage is produced by the National Land and Water Information Service (NLWIS) of Agriculture and Agri-Food Canada (AAFC). Northern Territories land cover was realized by the Canadian Centre of Remote Sensing (CCRS).
This product aims to offer a Canadian integrated Land Cover base produced from various available classified satellite data. The Land Cover base dating extended from 1996 to 2005 nevertheless 80% of the Land Cover base come from 1999 to 2001 defined by circa 2000.

Canadian Digital Elevation Data
http://www.geobase.ca/geobase/en/data/cded/index.html
The Canadian Digital Elevation Data (CDED) consists of an ordered array of ground elevations at regularly spaced intervals. The source digital data for CDED at scales of 1:50,000 and 1:250,000 is extracted from the hypsographic and hydrographic elements of the National Topographic Data Base (NTDB) or various scaled positional data acquired from the provinces and territories.
CDED are used in geographic information systems (GIS) for land-management applications. CDED plays the same role as contours and relief shading on conventional paper maps but is more powerful analytically. In addition to providing estimated values of elevation points, CDED can be used to determine orientation and the slope of each point when used in GIS applications.

CDED can also be used for terrain modeling, for calculating the influence of the terrain on line-of-sight, for radar imaging, for simulating flooding, and similar applications.

Landsat GeoCover ETM+ 2000 Edition Mosaics
http://www.glcf.umd.edu/data/mosaic/index.shtml
The Landsat GeoCover collection of global imagery was merged into mosaics by the Earth Satellite Company (now MDA Federal). The result was a series of tiled imagery that is easier to wield than individual scenes, especially since they cover larger areas than the originals.
Spectral Bands: Three Landsat ETM+ bands, each sharpened with the panchromatic band.
• Band 7 (mid-infrared light) is displayed as red
• Band 4 (near-infrared light) is displayed as green
• Band 2 (visible green light) is displayed as blue
Pixel size: 14.25 m

Short-Wavelength Infrared, or SWIR: Band 2 is displayed in blue, band 4 is displayed in green, and band 7 (or 5) is displayed in red. This rendition looks like a jazzed up true color rendition - one with more striking colors.

This is the band combination was used in the GeoCover data set. It is built into the GeoCover data and cannot be changed. Further, the contrast and brightness have been altered in the GeoCover data set to make a more consistent overall mosaic.

	True Color **Red: Band 3** **Green: Band 2** **Blue: Band 1**	**False Color** **Red: Band 4** **Green: Band 3** **Blue: Band 2**	**SWIR (GeoCover)** **Red: Band 7** **Green: Band 4** **Blue: Band 2**
Trees and bushes	Olive Green	Red	Shades of green
Crops	Medium to light green	Pink to red	Shades of green
Wetland Vegetation	Dark green to black	Dark red	Shades of green
Water	Shades of blue and green	Shades of blue	Black to dark blue
Urban areas	White to light blue	Blue to gray	Lavender
Bare soil	White to light gray	Blue to gray	Magenta, Lavender, or pale pink

Toporama Web Map Service
(http://geogratis.cgdi.gc.ca/geogratis/en/service/toporama.html).
The Toporama Web Map Service (Toporama WMS) of the Earth Sciences Sector (ESS) at Natural Resources Canada (NRCan) is an Internet service that is intended mainly for online map application users and developers. This service is compliant with the Open Geospatial Consortium's (OGC) Web Map Service Implementation Specification, version 1.1.1.
This service can be used to build a customized map using the best baseline data from the ESS for a given scale. These data are known for being accurate and up-to-date. They are grouped together under 16 information themes developed, depending on the scale, using CanVec 1:50,000, the National Topographic Data Base (NTDB) 1:250,000 and baseline data from the Atlas of Canada (1:1,000,000 to 1:30,000,000 scales).

National Ecological Framework for Canada
http://sis.agr.gc.ca/cansis/nsdb/ecostrat/intro.html
The National Ecological Framework for Canada was developed between 1991 and 1999 by the Ecosystems Science Directorate of Environment Canada, and the Center for Land and Biological Resources Research, of Agriculture and Agri-Food Canada. Over 100 federal and provincial agencies, non-governmental organizations, and private sector companies contributed to its development. The underlying principle for the initiative was the commitment and need to think, plan, and act in terms of ecosystems. The principle required people to move away from an emphasis on individual elements that comprise an ecosystem to a perspective that is more comprehensive - a holistic approach. This required an national ecological framework to provide a consistent, national spatial context within which ecosystems at various levels of generalization can be described, monitored, and reported on. The use of such a framework of standard ecological units provides for common communication and reporting between different jurisdictions and disciplines. The working group focused on three priority levels of stratification, namely ecozones, ecoregions, and ecodistricts.

Monthly climatic normals for the 1961-1990 normals period were compiled for the 1022 Ecodistricts in Canada. The climate normals information originated from point-based weather station data obtained from Environment Canada (1994). The average monthly and annual climate variables were estimated from monthly and annual climatic normals for each ecodistrict. In the source data, monthly normals were provided for each month plus an annual normal. Each of the 13 values were aggregated to the ecodistrict spatial framework independently. In some cases this results in the annual value for an ecodistrict not equaling the sum of the 12 monthly values. The annual values for an ecodistrict were not calculated as the sum of the 12 monthly values, but as an area weighted average of the annual values from source weather stations.

HYDAT Database (National Water Data Archive)
http://ec.gc.ca/rhc-wsc/default.asp?lang=En&n=9018B5EC-1
Hydrometric data are collected and compiled by Water Survey of Canada’s eight regional offices. The information is housed in two centrally-managed databases: HYDEX and HYDAT.

HYDEX is the relational database that contains inventory information on the various streamflow, water level, and sediment stations (both active and discontinued) in Canada. This database contains information about the stations themselves such as; location, equipment, and type(s) of data collected.

HYDAT is a relational database that contains the actual computed data for the stations listed in HYDEX. These data include: daily and monthly means of flow, water levels and sediment concentrations (for sediment sites). For some sites, peaks and extremes are also recorded.

WSC now offers hydrometric data and station information in a single downloadable Microsoft Access Database file. This file is updated on a quarterly basis.

Appendix 3 – GIS Methodology

Watersheds:
Watersheds delineated using Hydrologically Conditioned 50k DEMs. See attached document on WRMD semi-automated watershed delineation process.
Manual editing done using NHN and Toporama Web Mapping Service (a topographic base mapping service) provided by NRCan. Accessed via GeoGratis (http://geogratis.cgdi.gc.ca/geogratis/en/service/toporama.html).

Landcover:
Landcover was derived from Landcover data from Geobase. The 44 landcover classes in original Geobase layer were combined into 6 classes. Processsing was completed in ArcGIS using the following set of steps:

- Merge landcover data for the transboundary watershed area.
- Clip to watershed.
- Calculate area for each cover type.
- Combine cover types into six major types.
- Calculate area.

An ArcGIS model was developed to assist in automation of this processing.

Elevation
DEMs were created by creating a mosaic of individual Geobase 50 k DEMs for each NHN work Unit. Elevation stats derived from the mosaiced DEMs using zonal stats function of Spatial Analyst.

Stream Order
Stream Order derived from NHN "Primary Directed flow" layer in file geodatabase using Rivex extension.

Main Channels
Main Channels were determined by:
- Selecting features with appropriate river name from NHN geodatabase
- Finding longest flow path for watersheds
- Use utility network extension to trace downstream from most upstream point and selecting features

Elevation Profiles
Elevation profiles were created by dissolving the main channel layer to create a single feature. Dissolved main channel was then converted to a 3D feature using the 50k DEMs.

Stream Gradient
Stream Gradient calculated by determining elevation of source / headwaters of main channel and dividing by channel length.

Possible errors etc.:
1. Gap between Natashquan and Romaine
2. Petit Natashquan
3. Little Mecatina near Dominion Lake – edge of NHN unit, water running in two directions.
4. Several areas on boundary of Little Mecatina and St. Augustin where lakes drain two ways
5. Gap between Little Mecatina and Romaine