CHALEUR RSC

CLIMATE CHANGE ADAPTATION

REGIONAL CLIMATE CHANGE ADAPTATION PLAN

CHALEUR REGION

WSP REF.: 181-12146-01

DATE : 24 MAY 2019

CONFIDENTIAL

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FINAL VERSION

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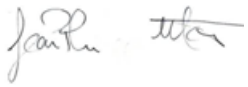
PREPARED BY



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SUMMARY

WSP was mandated to provide Chaleur Regional Service Commission (RSC) a climate change adaptation plan. Using the best practices in building a climate change adaptation plan for the municipal sector (Larrivée, 2010), the plan was built following a climate change risk assessment coherent with ISO 31000 standards and will consist of the following sections.

EXPECTED CLIMATE CHANGE IMPACTS

The mean annual and seasonal temperatures will be subject to an increase of more than 4 °C, with a greater warming during winter. This is consistent with rising summer maximum temperatures, fewer very cold days, more freeze-thaw cycles, more heat waves, and a longer growing season.

The precipitation regime is likely to change overall, but the trend is not as significant as temperatures. However, available data suggest that there will be an increase in the frequency and magnitude of short-duration extreme precipitation events.

With a projected sea level of 1 meter, the plausible upper boundary water level by 2100 during a 100-year period storm surge could be 4.2 meters. This elevation gives a new benchmark in terms of coastal flooding. Along with flooding, coastal erosion already affects Chaleur RSC. At the time of the report, a recent comprehensive study on coastal erosion at the scale of the RSC was still missing. Older results suggest that the highest erosion rates were found around Salmon Beach, although there are many infrastructures that are presently at risk of erosion in Petit-Rocher and Pointe-Verte.

RISK AND VULNERABILITY ASSESSMENT

A vulnerability assessment was conducted at the scale of the RSC to identify vulnerabilities, especially to coastal hazards. Vulnerabilities were discussed with the citizens during two evenings of public consultations, and during a workshop with the Chaleur Regional Advisory Committee on Climate Change and Adaptation (CRACCCA).

Vulnerabilities include:

- impacts on health and safety;
- displacement and property damage;
- loss of livelihood and damage to industries;
- infrastructure damage;
- impacts on social locations and buildings.

ADAPTATION MEASURES

CRACCCA were also consulted to discuss the vision and the selection criteria to prioritize adaptation measures. The preliminary short-term vision is defined through six axes:

- Making individual safety to climate hazards a priority;
- Preserving the aesthetic character of coastal landscape;
- Promoting public access to the coast;

- Developing a coherent regional strategy to favor equity between municipalities;
- Protecting sensitive infrastructure, or infrastructure that can have important environmental effects from coastal hazards;
- Taking advantage of the economic opportunities brought by climate change.

The long-term vision focuses on profound modifications to territorial planning:

- Retreating from the zones exposed to future coastal hazards;
- Developing a holistic vision of territorial planning, integrating the synergies between coastal and watershed processes, ecosystem services to the communities, the quality of life of citizens, and sustainable economic development.

Adaptation measures were then defined and targeted to specific vulnerabilities. These adaptation measures are regrouped in the following categories:

- Education, communication, and awareness;
- Data knowledge and acquisition;
- Planning and regulations;
- Protective measures;
- Emergency planning.

CALENDAR

Based on the vision, targeted sectors at risk, and adaptation measures, an implementation calendar is presented, based on three time-steps with different objectives.

On the short-term (1-5 years), adaptation measures focusing on individual protection and community awareness should be targeted. On the medium-term (5-10 years), measures focusing on changes in regulatory processes and zoning should be implemented. On the long-term (>10 years), Chaleur RSC should focus on integrated development and taking holistic actions that allow to increase ecosystem services.

MONITORING

A monitoring table should be implemented for specific adaptation measures. This table should contain:

- objectives;
- indicators;
- update mechanisms;
- frequency of updates;
- timing of updates.

COMMUNICATION STRATEGY

The communication plan alone, could be a mandate. We provide suggestions to build a communication plan that will maximize social acceptability and engagement towards adaptation. Suggestions touch dissemination outlets, communication targets, when and how to communicate, as well as pitfalls to avoid.

TABLE OF CONTENTS

TABLES

FIGURES

APPENDICES

1 INTRODUCTION

1.1 CONTEXT

There are 12 Regional Service Commissions (RSC) in New Brunswick that are based on a regional-level governance model. They are designed to help communities communicate, collaborate, and plan the future with a common vision of regional development. Located in northeastern New Brunswick, Chaleur RSC takes its name from the Chaleur Bay that runs along its territory. Because of this geographical location in the coastal environment and the growing development and public safety issues that are linked to it, the Chaleur RSCtook the initiative to develop a plan for regional action on climate change adaptation. The Chaleur Regional Advisory Committee on Climate Change and Adaptation (CRACCCA) was formed to oversee this project, with the support of the Coastal Zone Research Institute Inc. (CZRI). The objective of this plan is to gain a better understanding of the impacts of climate change and the role of adaptation to change in the region. The objective is also to recommend actions and solutions to face future changes.

The regional action for the climate change adaptation plan was implemented in two phases. The objectives of the first phase were 1 - to clarify the scope and type of plan to be implemented, 2 - to draw up a state of knowledge on the impacts of climate change and 3 - to analyze risks, vulnerability, and needs at the regional level. The Phase 1 results provided a diagnostic of the current situation, to better understand the climatic hazards. It served to analyze and to assess the risks, the impacts, and the vulnerabilities affecting the populations, the zones, buildings, and the infrastructure at the regional level.

1.2 OBJECTIVES

Phase 2 aims at developing a regional climate change adaptation plan that can be used as a model by other regional service commissions.

Phase 2 objectives are listed below:

- Identify and classify the risks and the vulnerabilities based on their probabilities, frequencies, and the severity of their consequences;
- Prioritize preferred adaptation measures;
- Produce and implement the regional adaptation plan.

1.3 STRUCTURE OF THE REPORT

The report is organized as followed:

- Description of the expected changes in climate and extreme weather events;
- Identification and classification of climate related risks and vulnerabilities;
- Presentation of the results of the public consultations;
- Description of the adaptation plan;

- Proposition of a calendar to implement the adaptation measures;
- Presentation of the communication plan to promote the adaptation plan.

2 REGIONAL CONTEXT

Located on the southern shore of Chaleur Bay in New Brunswick, east of Restigouche, which is south of the border with Québec, Chaleur Region is one of twelve administrative regions within New Brunswick and comprises the municipalities of Bathurst, Beresford, Nigadoo, Petit-Rocher, Point-Verte, Belledune, and the unincorporated areas of the Parishes of Beresford, Bathurst, Allardville, and New Bandon. The region was established under the Regional Service Delivery Act of 2013, to help its communities better communicate and collaborate regionally through a shared vision, and is led by a Regional Service Commission Board comprised of Mayors and Local Service District (LSD) representatives (GNB, 2012).

Chaleur Region covers a territory of 2207 km^2 and boasts a diverse landscape of forests, cliffs, lakes, waterfalls, dunes, and over 30 km of sandy beaches. Because of warm ocean currents entering the bay from the Gulf of the St. Lawrence, Chaleur boasts some of the warmest saltwater beaches in Atlantic Canada, a draw for summer tourism. The bay is also an estuary for seven rivers which run through the region: Tetagouche River, Little River, Middle River, Nepisiguit River, Nigadoo River, Belledune River, and Jacquet River. Dotted around the bay are a series of salt marshes, transitional zones between land and salt water which are among the most productive ecosystems on earth. In addition to acting as a storm buffer, supporting a thriving ecosystem, and detoxifying incoming water, the salt marshes in Bathurst and Beresford are home to the endangered Maritime Ringlet Butterfly, whose territory is limited to a 2 km^2 range surrounding the bay (City of Bathurst, 2013).

The region has a population of 36,000, with 34% of residents concentrated within the City of Bathurst. In the last decades, the region's mean age began to increase. Nowadays, the number of people over the age of 65 surpasses the number of those below 20, a divide that is continuously growing. Demographically, it is one of the oldest regions in Canada, with Bathurst having the oldest mean age of any city with a population of over 10,000 in the country, and the municipality of Petit-Rocher is top five in Canada for populations over 1,000. The average age of the municipalities and parishes is 48.2, compared to the mean provincial average of 43.6, and the mean federal average of 41.2. New Brunswick is the only province in Canada which has both French and English as official languages, and this is reflected in the population of Chaleur, 60% of whom have a working knowledge of both official languages. The population is largely concentrated in coastal regions, specifically the City of Bathurst, Beresford, Nigadoo, Petit-Rocher, and Pointe-Verte which have the highest residential densities in the region. The city of Bathurst is also located 8 km north of the Pabineau First Nations reserve, which holds an average population of 120 accredited band members of the Mi'gmag community (Pabineau First Nation, 2019).

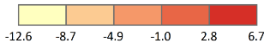
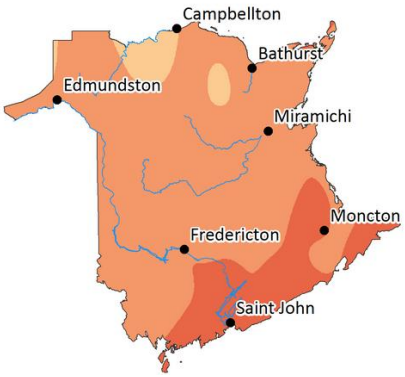
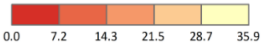
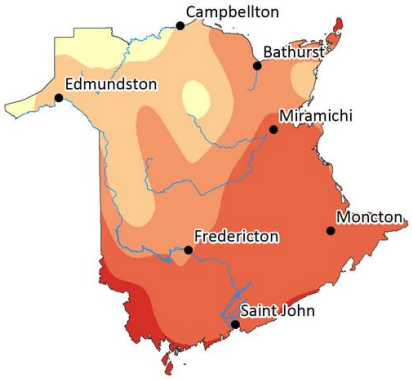
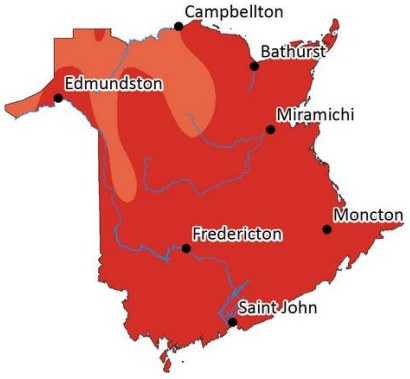
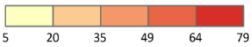
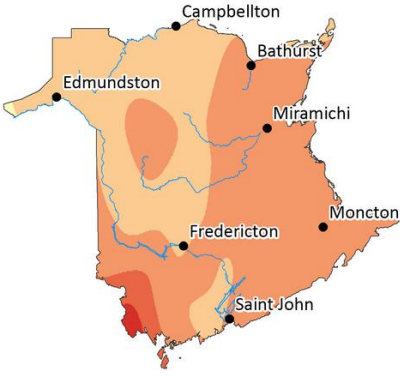
In 2016, the largest economic sectors in Chaleur Region were health care and social assistance (concentrated in the City of Bathurst), retail trade, public administration, and manufacturing. Between 2002 and 2016 construction, health and social assistance, agriculture, forestry, fishing, and hunting were the sectors that experienced the largest economic growth. The region is also home to the strategically important Port of Belledune, a coal-fire electrical generation station, a mining sector, and a fish and seafood processing center. The aging population is a concern for the economy of this region. As of 2007 the workforce in both the region and the province stopped growing and began to decline for the first time in history, partially leading to a provincial economic growth rate of only 0.5% in the past decade (Jupia Consultants Inc, 2018).

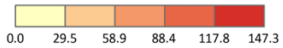
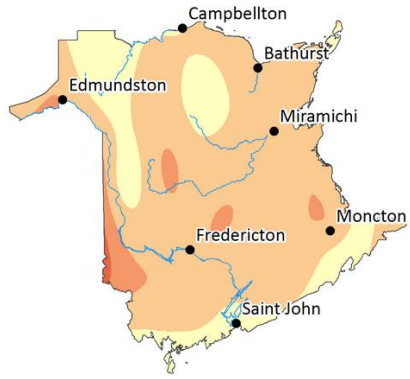
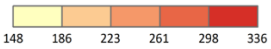
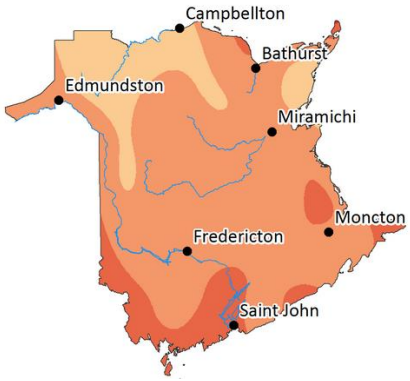
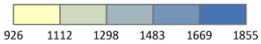
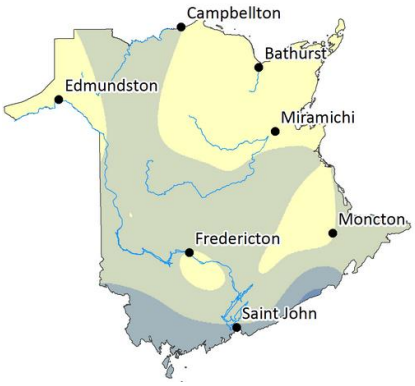
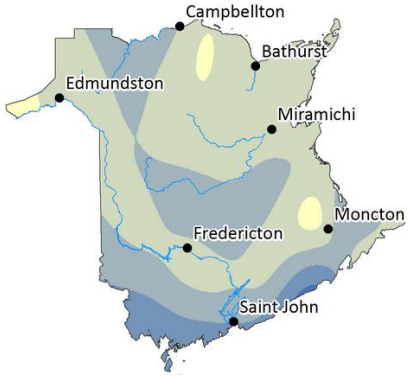
3 EXPECTED CLIMATE CHANGE IMPACTS

3.1 GENERAL TRENDS IN CLIMATE

Table 1 presents the major trends in climate for the region of Chaleur.

Table 1 Projected Climate Trends for the Region of Chaleur (Roy and Huard, 2012)

Variable	Baseline (1981-2010)	Projections for 2080 (RCP8.5)
Winter temperature (°C) 		
Number of days with maximum temperature < -10 °C 		
Winter freeze-thaw day 		

Variable	Baseline (1981-2010)	Projections for 2080 (RCP8.5)
Annual days with maximum temperature > 30 °C 		
Growing season length 		
Annual total precipitation (mm) 		

HIGHLY LIKELY INCREASE IN TEMPERATURE

Winter is the season where the increase of mean temperature will be most significant. The mean winter temperatures are expected to rise from -8.7 °C to -4.8 °C for 2050, and to -2.2 °C for 2080. This is also consistent with rising summer maximum temperatures, but also with fewer very cold days (>14 less days with temperatures below -10 °C per year), more freeze-thaw cycles (15 additional days with winter freeze-thaw cycles), more heat waves (29.5 more days with temperatures above 30 °C annually) and a longer growing season (increase of 75 days). In terms of data quality, the likelihood and confidence levels are very high and high for all the temperature-related variables.

The precipitation regime is likely to change overall, but there appears to be a great variability among the climate models. Overall, the mean annual change corresponds to more than 186 mm per year, until 2080. The maximum increase would occur during spring season. There does not appear to be a trend for the summer season (data not presented). In terms of data quality, the high variability across the models attenuates the ensemble mean, which only provides a moderate likelihood and a medium confidence about the trends.

3.2 SEA-LEVEL RISE AND ICE COVER REDUCTION

3.2.1 COASTAL FLOODING

The upper boundary water level is used to define the coastal flood zone. It is defined by the addition of the higher high water at large tides (HHWLT), the sea-level rise and the 100-year return period storm surge. Table 2 presents the plausible upper water levels for Restigouche and Gloucester counties, with the inclusion of a 0.65 m buffer to account for uncertainties, as proposed by James *et al*. (2014). The upper boundary for a 100-year return period storm surge could be as high as 5.0 and 4.9 m for the two counties, respectively. In that regard, the selection of a 4.2 m water level threshold to define the coastal flood zone by the Chaleur RSC for this project is based on the 1:100 storm surge level by 2100, but does not include the 0.65 m uncertainty.

Table 2 Plausible Upper Water Level (Daigle, 2017)

Coastal Section	HHWLT (m)	Sea-Level Rise in 2100 (m)	100-Year Return Period Storm Surge (m)	Plausible Upper Boundary Water Level by 2100 (m)	Plausible Upper Boundary Water Level by 2100 + 0.65 (m)
Restigouche county	1.8	1.0	1.6	4.3	5.0
Gloucester county western section to Grande-Anse	1.6	1.0	1.6	4.2	4.9

3.2.2 COASTAL EROSION

Historical coastal erosion data shows moderate erosion rates for the coast of the RSC (Figure 1). Over 45 years, coastal marshes and cliffs show the smaller erosion rates (0.17 and 0.18 m/yr, respectively), whereas beaches and dunes show higher, albeit moderate, erosion rates (0.32 and 0.35 m/yr, respectively). However, these rates are not homogeneous, with Salmon Beach recording the highest average historical erosion rate of the RSC, at a rate of 0.6 m per year.

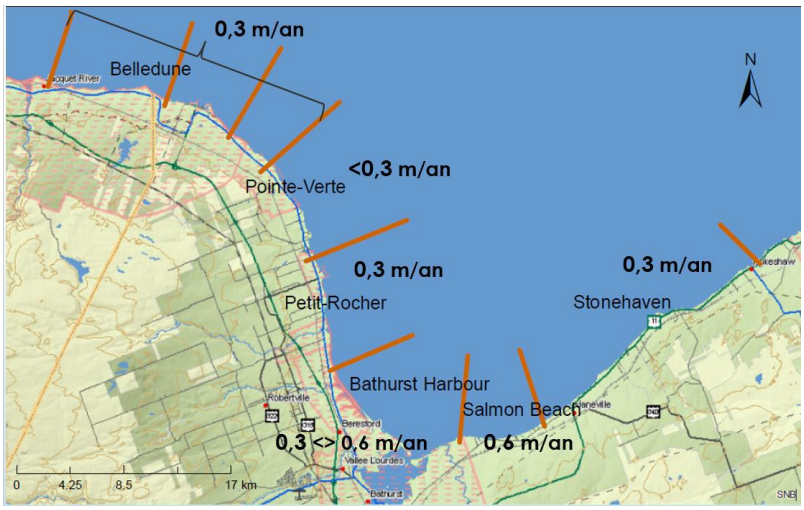


Figure 1 Historical Erosion Rates for Chaleur RSC (Aubé *et al*. 2018)

The Beresford dune showed moderate erosion rates from 1966 to 2002. The shoreline (i.e. the seaward limit of beaches) was eroding at an average rate of -0.28 m/yr, especially in the southern section. The coastline (i.e. the seaward limit of dunes) was eroding at an average rate of -0.21 m/yr, especially in the northern section (Figure 2). Despite the erosion rates being below the provincial averages for dunes and beaches, the gully controlling the water exchange between the lagoon and Chaleur bay migrated southward at a rate of 3.4 m/yr.

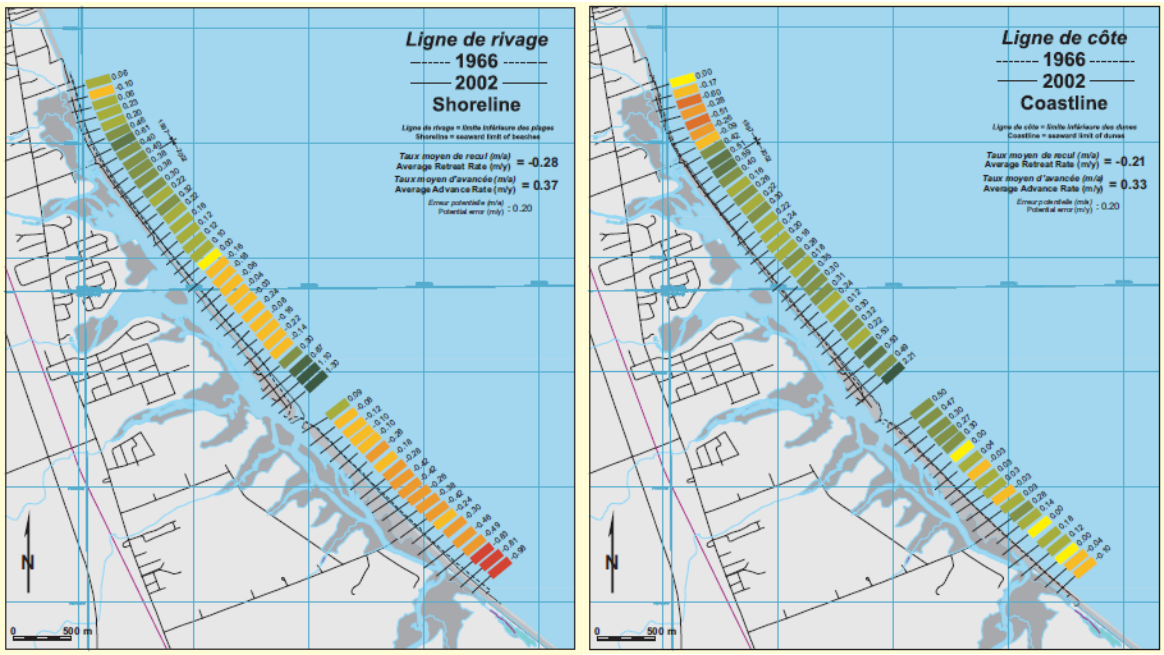


Figure 2 Historical Erosion Rates of the Beresford Dune (Hachey *et al*. 2004)

The analysis of erosion rates is based on historical data and does not consider climate change. These conclusions should be reviewed with the results from the ongoing coastal erosion study mandated by the Chaleur RSC.

3.3 EXTREME EVENTS

The IDF_CC tool was developed by scientists at Western University(Simonovic *et al*. 2016). They provide projected intensity-duration-frequency (IDF) curves for gauged and ungauged locations across Canada, based on 9 global climate models downscaled to a 10-km x 10-km resolution. We based our analysis on the mean of the models adapted to Belledune station.

The IDF_CC provides return periods (2, 5, 10, 25, 50 and 100 years) for total precipitation (mm) or intensity rate (mm/h) for 5, 10, 15, 30 minutes and 1, 2, 6, 12 and 24 hours precipitation events. Data are available for the historical period and for any periods of 50 years from 2006 to 2100.

Historical maximum annual precipitation is presented in Table 3. The projected changes in maximum annual precipitation for the 2050-2100 period, under RCP8.5 emission scenario, is presented in Table 4, in absolute number, and in Table 5 in percentage. Figure 3 summarizes the increase in extreme precipitation events.

Table 3 Maximum Annual Precipitation Based on Historical Data

Duration	Return Period (year)					
	2	5	10	25	50	100
5 min	4.84	6.96	8.44	10.39	11.90	13.45
10 min	6.91	10.74	13.55	17.48	20.68	24.12
15 min	8.07	12.47	15.97	21.19	25.73	30.89
30 min	10.20	14.84	18.77	25.01	30.64	34.19
1 h	13.84	18.91	22.43	27.06	30.64	34.19
2 h	19.98	24.84	27.58	30.57	32.50	34.19
6 h	30.44	38.49	43.32	48.91	52.71	56.22
12 h	37.16	46.57	52.05	58.24	62.35	66.06
24 h	44.83	56.07	62.73	70.34	75.45	80.12

Table 4 Projected Maximum Annual Precipitation for 2050-2100 Under High GHG Emission Scenario

Duration	Return Period (year)					
	2	5	10	25	50	100
5 min	6.60	9.99	12.24	15.13	17.64	20.07
10 min	9.43	15.39	19.56	25.16	30.39	36.31
15 min	11.02	17.94	23.02	30.13	37.20	45.18
30 min	13.88	21.45	27.07	35.65	43.76	50.38
1 h	18.86	27.19	32.60	39.44	45.42	50.65
2 h	27.17	35.56	40.29	45.54	48.97	53.40
6 h	41.41	55.10	63.23	72.67	79.11	87.94
12 h	50.54	66.66	76.03	86.68	93.81	103.27
24 h	60.97	80.29	91.60	104.58	113.33	125.26

Table 5 **Percentage of Increase in Short-Duration Extreme Rainfalls Between Historical and Projected Data**

Duration	Return Period (year)					
	2	5	10	25	50	100
5 min	36.4%	43.5%	45.0%	45.6%	48.2%	49.2%
10 min	36.5%	43.3%	44.4%	43.9%	47.0%	50.5%
15 min	36.6%	43.9%	44.1%	42.2%	44.6%	46.3%
30 min	36.1%	44.5%	44.2%	42.5%	42.8%	47.4%
1 h	36.3%	43.8%	45.3%	45.8%	48.2%	48.1%
2 h	36.0%	43.2%	46.1%	49.0%	50.7%	56.2%
6 h	36.0%	43.2%	46.0%	48.6%	50.1%	56.4%
12 h	36.0%	43.1%	46.1%	48.8%	50.5%	56.3%
24 h	36.0%	43.2%	46.0%	48.7%	50.2%	56.3%

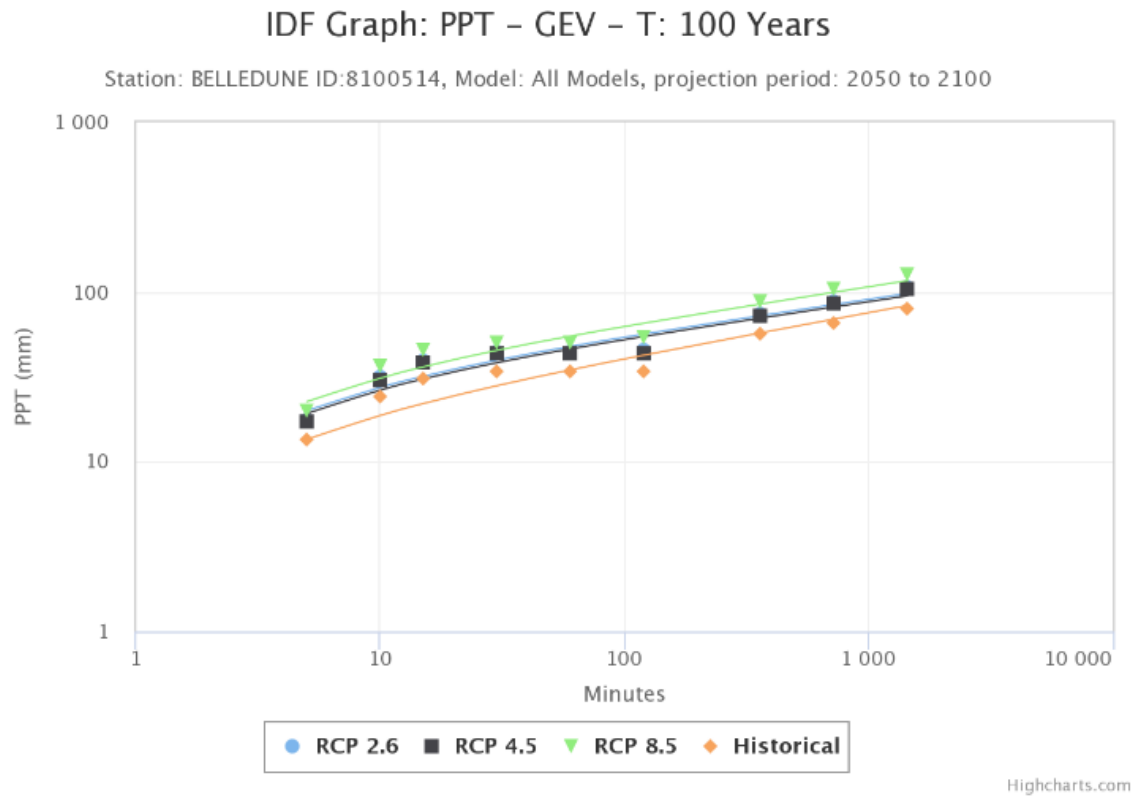


Figure 3 **Comparison of Historical and Projected IDFs for Belledune Station**

HIGHLY LIKELY INCREASE IN EXTREME PRECIPITATION

Low-frequency precipitation events will likely witness the highest increase in their intensity. For example, on average, the projected intensity of 100-year return period precipitation events under the high emission scenario is **up to 56% higher** than the baseline value, based on historical data. For the most catastrophic scenario (maximum projection under the high emission scenario), the increase in intensity of the 100-year return period precipitation events can be 96% higher than the baseline value.

The likelihood and the confidence of witnessing an increase in extreme precipitation events are very high. For example, Figure 4 presents the uncertainties in 100-year return period projected precipitation intensities under high emission scenarios, based on the distribution of the outputs of 9 climate models. For 1440-minute precipitation events (which corresponds to 24 hours), the minimum (101.08 mm) is well above the historical value (80.12 mm).

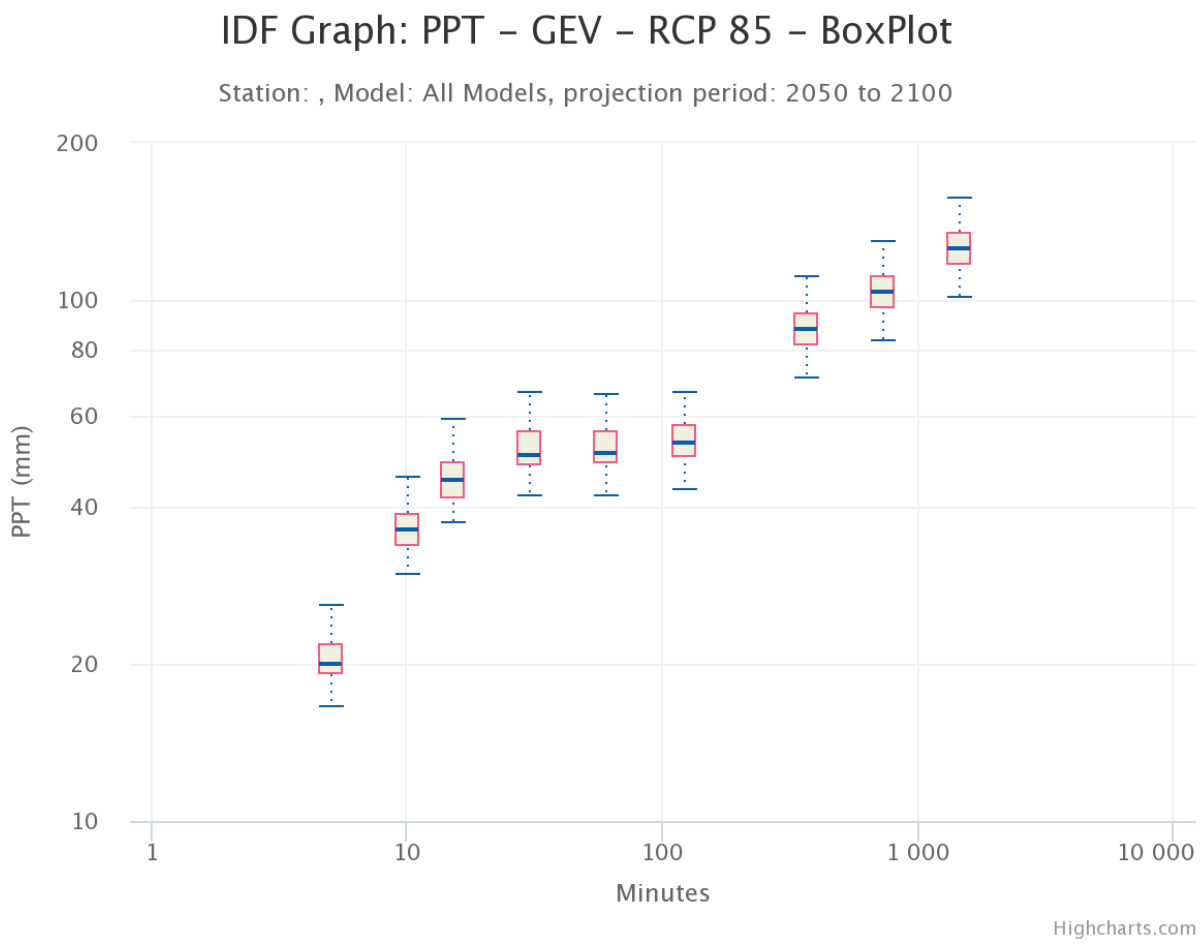


Figure 4 **Distribution of the Model Outputs for the Projected Intensity of 100-Year Return Period Precipitation**

The IDF_CC tool provides ready-to-use IDFs. However, the use of statistical downscaling techniques based on global circulation models, with daily data, to model precipitation at shorter timescales is hazardous. The results presented above must be interpreted cautiously. The key points are that extreme precipitation will increase considerably, and IDF calculations taking climate change into account, that are more adapted to the regional context, are needed.

4 RISK AND VULNERABILITY ASSESSMENT

4.1 CLIMATE EVOLUTION AND HAZARDS

4.1.1 HEAVY PRECIPITATION

Increases in the intensity and duration of precipitation events contribute to increases in overland and river flooding which may negatively impact soil stability, infrastructure, residences, freshwater sources, and pose a risk to public health and safety. Fluvial flooding, or river flooding, occurs when excessive rainfall, snow melt, or ice jams cause a river to exceed its capacity and rise over its banks. This can damage infrastructure, flood residences, destroy or damage riparian ecosystems, and cause human harm or death. It has been estimated that under the effects of climate change the cost of flooding would arguably be the highest, and could increase in the Canadian Maritimes by up to 300% by the end of this century (Thistlethwaite *et al*. 2018). In May 2018, a single flood event in New Brunswick cost upwards of $19 million uniquely for roads and bridges, and displaced hundreds of residents for weeks (Atlantic CTV News, 2018). Flood losses occur due to the damage of both structures and building contents. Within Chaleur region, the Nepisiguit and Middle Rivers are historically the most likely to cause flooding (Aubé *et al*. 2018), with residents of Mathilda Street on the banks of Middle River having to be evacuated almost every year due to flooding. An increase in precipitation could exacerbate these events, increase the areas susceptible to flooding, and drive up the costs, both human and monetary.

During a precipitation event, if the soil is saturated, or the rate of rainfall is greater than the rate at which water can infiltrate into the soil, surface runoff occurs. If there is enough energy in this runoff, loosened sediment will erode and be transported. This sediment may enter the urban sanitation system and cause blockages, pollute waterways, reduce the amount of viable cropland, and reduce the land's capacity to absorb future rain events. In addition, surface runoff may also pick up agricultural pollutants, such as fertilizers and pesticides, and transfer them into salt and freshwater systems, leading to species destruction and water quality reduction. Soil erosion and, on a larger scale, mass wasting can destabilize land and be a threat to human lives and assets.

Both fluvial and coastal flooding pose large risks to human health and safety, and this comes in the form of drownings, hypothermia, bacterial infections, damage from debris, mental health impacts, and waterborne diseases. In addition, flooding can reduce access to first responders, supplies, block evacuation routes, and damage, destroy, or render inaccessible critical health services and infrastructure. According to the Canadian Disaster Database (PSC, 2013), there have been 25 fatalities due to flood related events in New Brunswick on record since 1902, with over 6,500 evacuations.

4.1.2 SEA LEVEL RISE

Rising sea levels expose coastlines to greater risks of flooding, erosion, storm surges, coastal wetland destruction, and salt water intrusion. A storm surge is the rise in seawater levels caused solely by a storm, and is higher than the normal high tide. It is often the greatest threat to life and property during major storm events, and can greatly increase the area damaged by a hurricane. It is estimated that because of the global rising sea levels, storm surges today are 20 cm higher than they were in 1900 (US Climate Resilience Toolkit, 2017). Rising sea levels also increase rates of coastal erosion which decrease the stability of land and endanger property, infrastructure, and residents located in coastal areas. In addition to built infrastructure and property, coastline ecosystems, namely wetlands, such as salt marshes, can be destroyed by a sudden or gradual influx of salt water which diminishes their capacity to filter water and provide valuable habitats and flood barriers.

Lastly, a large segment of the Chaleur Region's population relies, to some extent, on well water drawing from freshwater aquifers. As sea levels rise, the rates of salt water intrusion, and the movement of saline water into freshwater aquifers, increase. This can lead to contamination of drinking water sources and eliminate a source of drinking water. Sea level rising is a concern for the Chaleur Region due to the population being heavily concentrated on coastal regions surrounding the bay, and to the elevation of the area being relatively low.

4.1.3 HEAT WAVES

In Canada, a heat wave is generally considered a period of 3 or more consecutive days with temperatures of 32 °C or higher. It is a period of excessive heat, which may be accompanied by high humidity and little to no wind. While high heat can have impacts on infrastructure and physical assets, including reducing the ability of planes to takeoff and warping metal in extreme cases, the focus of the hazard is often on the impacts to human health. During a heat wave it becomes harder for a human body to cool and maintain its temperature within normal limits (Government of Québec, 2019). This may cause headaches, muscular cramps, swollen hands, feet, and ankles, fatigue, mild to severe dehydration, loss of consciousness, heat stroke, and death. In addition, during heat waves, air becomes stagnant and traps emitted pollutants, often resulting in increases in ground levels of ozone, a health hazard to those with pre-existing respiratory and cardiac conditions (NOAA, 2019). Since 1912 there have been 1,658 recorded cases of heat wave deaths in Canada, with 8 located in eastern Canada and the Maritimes (Public Safety Canada, 2013). While the temperate climate of Chaleur reduces the likelihood of severe impacts from heat waves, the number of days with temperatures over 30 °C are expected to increase to 29.5 by 2080, under RCP8.5, which increases the likelihood of this hazard. In addition, Chaleur Region's population is an aging demographic, and seniors are at much greater risk of developing complications if exposed to oppressive or extreme heat. The most vulnerable to heat wave hazards are the young, seniors, those with pre-existing medical conditions, the economically vulnerable, and those who live alone or in isolated areas.

A secondary hazard resulting from heat waves is the stress they put on electrical systems. Electricity usage surges during times of extreme heat, which puts pressure on the supply and transmission systems, and can cause power failure and leave thousands without access to cool centers or other essential services.

4.1.4 FREEZE-THAW EVENTS

A freeze-thaw event is when the temperature of the air fluctuates between freezing and non-freezing temperatures (Climate Atlas of Canada, 2019). This type of event can become a hazard because of the influence it has on infrastructure damage and lifespans. When water enters cracks or pores in materials such as roadways or building cement, and then freezes and expands, causing the crack or pore to expand as well. If this process is repeated multiple times during a season, it can cause significant damage to any outdoor structures, with a most notable example being potholes which form during spring or mid-winter melts. This creates both dangerous driving conditions and incurs a significant cost in infrastructure and personal vehicle damage and maintenance. In addition to built infrastructure, freeze-thaw cycles can also accelerate the rates of coastal erosion and aid in the creation of dangerous ice jams.

4.1.5 SPECIES MIGRATION

A slower onset hazard of climate change comes in the form of species migration which can have numerous health, economic, and ecosystem impacts. Changing temperatures and precipitation regimes can cause the natural zone of animal and plant species to shift. Often species are shifting northwards as temperatures increase, and their habitat ranges increase, though this is also contingent on other factors such as food sources, habitat availability, and precipitation, among others. Migrating species may act as disease vectors or become threats to native ecosystems. Two predominant examples in Canada are ticks bringing Lyme Disease up from the United States, and Emerald Ash Borers who are highly destructive to Ash trees and have been recently found in southern New Brunswick (NRCAN, 2019).

4.1.6 STORM EVENTS

While Climate Change has not been found to increase the frequency of storm events, it will increase the intensity of existing events including wind gusts, hail and ice storms, snow storms, and heavy precipitation events. In Eastern Québec, since 2000 we observe an increase in the frequency of effective storms, i.e. storms that have significant impacts on the coast in more than one region (Bernatchez *et al*. 2012). The effects of this may include direct damage to infrastructure, power outages, flooding, health and safety impacts, reduced mobilities, and access to aid and supplies. In 2018, over 92,000 residents in New Brunswick lost power from a single wind storm, and the region is already susceptible to large winter and summer storms.

4.2 RISK AND VULNERABILITY ASSESSMENT AND EVALUATION

4.2.1 RISK AND VULNERABILITY ASSESSMENT

The vulnerability assessment was built directly on the Vulnerability and Risk Assessment conducted in Phase 1. The objective of this task was to apply the results of the assessment to specific systems at risk within the region to classify the level of risk and vulnerability based on probability, frequency, and consequence. Risks to selected systems were determined by assessing their exposure to climate change impacts, as determined in the Phase 1 Risk and Vulnerability Assessment. This involved a systematic assessment of the expected frequency, probability, and consequence of climate impacts such as temperature increases, changes in precipitation regimes, sea level rise, and extreme events. The vulnerabilities of high priority risk systems, and regions identified, were further assessed using information provided by the CRACCCA, knowledge of the region, and professional knowledge of systems in general. Risk levels were classified for each system and region investigated based on occurrence probability, from rare to certain, frequency, and the severity of their consequences from low to catastrophic.

The vulnerability assessment began by compiling a list of consequence areas to examine in detail:

- Health and Safety;
- Displacement;
- Loss of livelihood;
- Social health;
- Infrastructure damage;
- Damage to industry;
- Property Damage;
- Environmental damage: air;
- Environmental damage: water;
- Environmental damage: land;
- Environmental damage: ecosystems.

These were compared against the climate impacts from the Phase 1 Risk and Vulnerability Assessment:

- Temperature increases and changes to precipitation regimes;
- Increased frequency of heavy rain events;
- Heat waves;
- Droughts;
- Increased frequency of freeze-thaw episodes;
- Forest fires;
- Species movement;
- Sea level rising and ice cover reduction;
- Risks of salt water intrusion into drinking water sources;
- Increased coastal flooding;
- Increased coastal erosion;
- Extreme events;
- Strong winds, freezing rain, snowfalls, fires, floods, and droughts.

The consequences and climate impacts were compiled in a matrix for each individual region. They included general risks to the regions, as well as specific risks derived from the information provided by CRACCCA, the public consultation workshop, and the CRACCCA stakeholders workshop and questionnaire. Table 6 gives a simplified example of two consequence categories compared against three climate hazards.

This list of risks did not include the likelihood or consequence levels of each risk, but rather acted as a catch all to ensure a comprehensive assessment.

Table 6 Examples of Consequences Attributed to Different Climate Hazards

Climate Hazard	Health and Safety	Displacement
Heat waves	Heat exhaustion, heat stroke, death, dehydration, fainting, dizziness, and more, especially among vulnerable populations Increased mental illness Increased risk of forest fires	Temporary relocation of those in residential or work buildings without air conditioning
Heavy rain events	Dangers due to flooding Increased risk of car accidents Emergencies	Displacement from homes, cottages, and workplaces in flood zones
Droughts	Reduction in water availability Increase in food prices Increase in risks of forest fires	

4.2.2 QUALITATIVE MEASURE OF CONSEQUENCE

Each risk was given a consequence rating of low, medium, or high, based on criteria presented in Table 7.

Table 7 Criteria to Define the Severity of Consequences

Risk	Low	Medium	High
Health and safety	First aid required	Minor to serious injury, with restricted work or loss of work	Major or multiple injuries, permanent disability or injury
Displacement	No displacement	Temporary displacement during an event	Long term displacement or permanent relocation
Loss of livelihood	No or minor effect on the broader community	High impact on the local economy with some effects on the wider economy	Serious effects to the local economy spreading to the wider economy
Social health	No impacts or localized temporary social impacts	Localized long term social impacts	Failure to protect poor or vulnerable groups National long term social impacts
Infrastructure damage	Localized infrastructure service disruption No permanent damage Some minor restoration work required An adverse event which can be absorbed through business continuity actions	Limited infrastructure damage and loss of service Damage recovery by maintenance and minor repair A serious event which requires additional emergency business continuity actions	Extensive infrastructure damage requiring major repair Major loss of infrastructure service A critical event which requires extraordinary/emergency business continuity actions
Damage to industry	Localized disruption to industry with no permanent damage and minor restorative work. No work time lost.	Limited disruption to industry and loss of service Recoverable by maintenance and minor repair Minor work time loss	Extensive damage to industry requiring major repair and work time loss
Property damage	Damage requiring no or minor repair.	Damage requiring moderate to significant repair	Damage requiring significant repair, abandonment, or demolition of the property
Environment damage (air, land, water, and ecosystems)	Minimal effects on the natural environment. Localised within site boundaries. Recovery measurable within 1 month of impact.	Some damage to the environment, including local ecosystems Some remedial action mat be required Recovery in 1 year	Significant effects on the environment and local ecosystems Remedial action likely to be required Recovery longer than 1 year Failure to comply with environmental regulations/consents

4.2.3 QUANTITATIVE MEASURES OF LIKELIHOOD

Risk is the product of the severity of consequences and the likelihood of occurrence of a given hazard. Table 8 explains how we quantitatively assessed the level of likelihood for different hazards.

Table 8 Criteria to Define the Level of Likelihood

Rating	Description	Recurrent Event Risks	Long Term Risks
High (almost certain)	Could occur several times per year or has already begun	Has happened several times in the past 5 years	Has a greater than 75% change of occurring in the identified period, if the risk is not mitigated
Moderate (possible/likely)	Maybe a couple times in a generation	Has happened at least once in the past 5 years	Has a 25%-75% chance of occurring in the identified period, if the risk is not mitigated
Low (rare/unlikely)	Maybe once in a lifetime	Has not occurred in the past five years	Has less than a 25% chance of occurring in the identified period, if the risk is not mitigated

4.2.4 RISK RATING ASSESSMENT

Coupling the severity of consequences with the likelihood of occurrence allowed to define three levels of risks. High risk occurs for highest likelihood of occurrence or highest severity of consequences, as illustrated in Table 9.

Table 9 Likelihood-Consequence Risk Matrix

Consequences	**High**	Moderate	High	High
	Moderate	Low	Moderate	High
	Low	Low	Low	Moderate
		Low	**Moderate**	**High**
		Likelihood		

Below are the high and moderate risks identified for Chaleur Region.

4.2.4.1 IMPACTS ON HEALTH AND SAFETY

The primary climate risks for coastal areas, in respect to the climate vulnerabilities identified in Phase 1, comprise:

- drowning, injury, illness, or death from coastal flooding;
- injury, illness, or death from coastal erosion;
- injury, illness, or death from an increase in extreme events such as storms, strong winds, freezing rain, snowfalls, floods, fires, and drought;
- injury, illness, or death from temperature increases;
- illness or death from vector-borne diseases;
- injury, illness, or death from forest fires;
- injury, illness, or death from salt water intrusion into drinking wells.

From a health and safety perspective, the population of Chaleur is vulnerable because the population is densely concentrated along coastal and riparian regions, notably on the western side of the region, and is statistically one of the oldest regions in the country and province, with an average age over 50.

Coastal Flooding, Erosion, and Storm Events

There are 431 residential buildings with 1-2 units and 5 residential buildings with 3-5 units within a 4.2 m flood level. These populations are vulnerable to all the associated health impacts from flooding including mental health impacts, hypothermia, bacterial disease, injury, illness, and death. In addition, during storms a higher sea level increases the range of a storm surge which often causes the greatest casualties during a flood event. Within the Chaleur Region, Beresford has the greatest concentration of residences within this zone (255), and the Beresford Dune is a concern due to its high density of inhabitants, low-lying geography, and history of being flooded during storms (Phase 1). There are 12 residential buildings with 1-2 units in the 25 m coastal erosion buffer zone. Coastal erosion can weaken the structure of soils and cause sudden destabilization which is a danger to nearby structures and people. Due to the geography of Nigadoo Bay, New Brandon-Salmon-Beaches are the most vulnerable with a total of 12 residences in this area.

Temperature Increases and Heat Waves

The average number of annual days with temperatures over 30 °C are expected to increase from the current 0-29.5 days to 29.5-58.9 days by 2080, under high greenhouse gas emission scenarios. While Chaleur Region experiences temperate weather because of its coastal location, an increase in temperature may still become a health hazard for its aging population. Pointe-Verte, Belledune, Petit Rocher, and New-Brandon-Salmon Beach are areas of concern where the population aged >65 comprises 27-31.4% of the population. Increases in temperatures may cause heat exhaustion, stroke, death, dehydration, fainting, and dizziness, and may exacerbate pre-existing conditions.

Vector Borne-Diseases

Changes in precipitation and temperature regimes shift the ranges of disease carrying vectors such as ticks, mosquitoes, and rodents. From a health perspective, in Canada and New Brunswick, the greatest concern is the tick bug whose range has been moving upwards and who carries Lyme disease, a bacterial infection by *Borrelia burgdorferi* which if left untreated can cause arthritis, nervous system problems, and immune suppression. Research done by the Lyme Research Network at Mount Allison University modelled current and future probability of tick presence in the Maritimes and Chaleur Region (Figures 5).

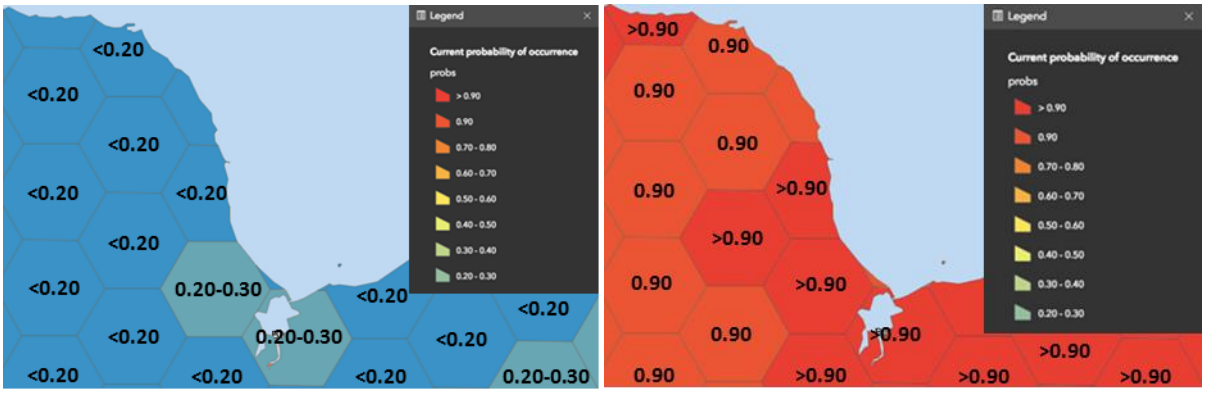


Figure 5 Probability of Occurrence of Lime Disease for Chaleur, Present-Day (left) and Projected (right)

Probabilities for each grid point are written to facilitate the reading (Lyme Disease Research Network, 2019).

In the last years, four ticks were collected and tested positive to *B. burgdorferi*, two in 2013 and two in 2016. All the ticks were collected near Bathurst.

Salt Water Intrusion

The region's proximity to a large salt water body, lack of a regional water distribution and sanitation network, and the dependence of many citizens on wells in conjunction with a projected rise in sea level, increase their vulnerability to salt water intrusion. While expected to a certain degree in coastal communities, an increase in saltwater levels in private wells may contaminate the water and eliminate a source of freshwater for citizens. This problem is pronounced in Beresford, Pointe-Verte, and Salmon Beach where maps indicate that there are wells at risk of coastal flooding (Aubé *et al*. 2018). In addition, some wells in Point-Verte and Salmon Beach already have sodium concentrations >500mg/L, above the guideline of less than 200mg/L.

4.2.4.2 DISPLACEMENT AND PROPERTY DAMAGE

Within a 4.2 m flood level and a 25 m erosion buffer zone, there is a total of 2106 buildings and structures (Table 10). Of these, 455 are residential buildings, predominantly 1-2 units. The area most vulnerable to forced displacement and property damage is Beresford, which has a total of 1345 buildings and structures, and 255 residential buildings. There is also the Petit-Rocher Cemetery which is partly within the 4.2 m flood level zone.

Table 10 Infrastructure Located Within the 4.2 m Flood Level or 25 m Erosion Buffer Zone

Infrastructure	Belledune	Pointe-Verte	Petit Rocher	Nigadoo	Beresford	New Brandon-Salmon Beach
Camp/Cottage/Recreation vehicle[1]	13	25	43	8	153	55
Agriculture/Farm/Cropland/Cultivated field	1	-	-	-	-	-
Heavy industrial	9	-	-	-	-	-
Residential: 1-2 units	14	64	80	8	252	20
Residential: 3-5 units	-	-	2	-	3	-
Small retail service/Office (< 200 m^2)	1	-	-	-	-	-
Accessory	59	75	95	2	908	53
Pumping station	-	2	3	1	4	-
Seaport/Wharf/Marina	-	2	2	-	-	2
Campground (number of structures in campgrounds)	-	-	6	-	-	-
Hotel/Motel/Inn	-	-	11	-	-	-
Mini and mobile homes (not in park)	-	-	3	-	4	-
Public park/Playground	-	-	4	-	16	-
Treatment plant (sewage)/ Lagoon	-	-	1	-	-	-
Education	-	-	1	-	-1	-
Indoor recreation	-	-	-	-	2	-
Large retail service/Office (> 200 m^2)	-	-	-	3	2	-
Children camp	-	-	-	-	-	1
Retail area with large outdoor storage areas	-	-	-	-	-	2

[1] Recreational vehicles were not discriminated from camp and cottages in the regional database.

4.2.4.3 LOSS OF LIVELIHOOD AND DAMAGE TO INDUSTRY

The western side of Chaleur Region is heavily dependent on Management, Business, Finance and Administration, Health, Sales and Services, and Trades, Transport, and Equipment Operators and Related. The eastern labour force has a much higher dependence on Natural and Applied Sciences as well as Manufacturing and Utilities. 4.2 m flood levels and a 25 m erosion buffers endanger various employment venues including agriculture, heavy industrial, small and large retail, pumping stations, marinas, campgrounds and children's camps, and hotels/motels/inn. The largest area of concern is Belledune which houses 9 heavy industrial areas and the only agricultural area.

4.2.4.4 INFRASTRUCTURE DAMAGE

Within the 4.2 m flood zone there are 24,614 m (24.6km) of linear infrastructure including:

- 14828 m of roadway;
- 2638 m storm water infrastructure;
- 7148 m sanitary systems.

The greatest impact is along the western coastline in Belledune, Pointe-Verte, Petit-Rocher, and Beresford. In addition, in those areas there are eight pumping stations, 6 wharf/marina structures and 2 treatment plants (sewage)/lagoons.

4.2.4.5 SOCIAL IMPACTS

Several social locations and buildings are at risk of a 4.2 m sea level rise as well as the 25 m erosion buffer. This includes 289 camp sites/cottages/recreational vehicles as well as 6 campgrounds, 20 public parks and playgrounds, 2 educational centers, 2 indoor recreation centers, and one children's camp.

4.2.5 COMMUNITY BASED ASSESSMENTS

Public consultations were facilitated by WSP on December 7 and 8. The first evening targeted the communities west of Bathurst and the second evening targeted the communities east of Bathurst. The major objectives of these consultations were:

- to present the regional climate change context and associated hazards and vulnerabilities for every community;
- to conduct an interactive community mapping exercise to identify other vulnerabilities and to evaluate which hazards were most concerning for the citizens;
- to gather the inputs of the citizens regarding the representation of the profile, the most pressing issues and the acceptability of adaptation measures.

4.2.5.1 VULNERABILITY MAPPING

The exercise allowed to gather and map the comments presented in Table 11. These comments underlined the following considerations:

- Need to consider the synergy between storm surges and fluvial flooding;

- Many public and private infrastructures are vulnerable to coastal floods (pumping stations, roads, and wells);
- Coastal erosion affects the RSC west of Bathurst sector;
- Forest fires can be an issue, albeit only one major event affected the region from this exercise;
- Need to assess the vulnerability of agricultural land.

Table 11 Comments Gathered During the Community-Based Assessment Mapping Exercise

ID	Site	Comment
1	Petit-Rocher	Storms fill the outlet of the brook with sand and debris, blocking flow
2	Petit-Rocher	Water and debris during storms goes onto road
3	Nigadoo	5-6 feet of land lost in the last 30 years
4	Belledune	Pumping station affected by flooding of 4.2 m will affect industrial area and the one street that has water
5	Belledune	General request to know how much agricultural land is affected by flood scenarios in Belledune
6	Belledune	Well only 25 ft deep
7	Pointe-Verte	There was once a wagon road from here to du Ruisseau along the coast, now gone due to erosion
8	Petit-Rocher	October 2016 accessory building moved by storm over 18 feet
9	Belledune	Community could be affected by salt water intrusion at a water source pumping station on the Jacquet River
10	Beresford Parish	1950's major fire in Nicholas-Denys, Sormnay, Ste-Rosette (Beresford Parish) going in the direction of Robertville
11	Robertville	Hard Water

4.2.5.2 COMMUNITY PREOCCUPATIONS

The discussions with the citizens from the western sector targeted coastal and wind-induced hazards, whereas the discussions with the citizens from the eastern sector targeted mostly construction permits and deforestation.

The key messages of these discussions touched three major components:

1. Climate change awareness and citizen involvement:
   - **a** Sense of urgency is not as strong in the eastern sector;
   - **b** Need for the communities to understand the decision-making process in selecting adaptation measures;
   - **c** Need to acquire knowledge on the impact of climate change on wind related hazards;
   - **d** Importance of scientific outreach activities to build community knowledge on coastal dynamics and its interaction with protective structures.
2. Adaptation measures:
   - **a** Curiosity of the citizens regarding the different engineering measures to protect coastal assets;
   - **b** High acceptability for regulatory measures.

3 Planning and integrated management:

a Worries regarding deforestation of coastal areas and the necessity to integrate watershed management into coastal management in the adaptation plan.

4.3 PRIORITY ZONES

The higher risk zones have been identified and are presented in Appendix A. For every adaptation measure presented in section 5, an example of a high-risk zone that could benefit from the measure is added.

5 ADAPTATION MEASURES

5.1 CRACCCA CONSULTATIONS

A workshop and a survey were conducted with the CRACCCA to discuss their needs, their vision, their preferred adaptation strategies and the selection criteria for adaptation measures. The following section presents the results. During the workshop, mind maps were produced for the different topics that were addressed (Appendix B).

5.1.1 WORKSHOP

5.1.1.1 PRIORITIES

The first activity was a discussion with the CRACCCA regarding the vision of their community.

Three priorities were obtained from the discussion:

1. Public access to the coast;
2. The need for region-based regulatory measures;
3. The importance of preserving the aesthetic aspect of the landscape.

5.1.1.2 VULNERABILITY ASSESSMENT

The second activity was to confirm our vulnerability assessment. The discussion outlined two concerns for the CRACCCA: civil security and sustainability of economic activities.

The consultations with the CRACCCA were an opportunity to validate the priority of vulnerabilities. Most of the vulnerabilities were already addressed, except for the Petit-Rocher Cemetery and the trailers on Beresford dune.

5.1.1.3 COMMUNITY NEEDS FOR A SUCCESSFUL ADAPTATION

The next activity was about their needs in terms of adaptation. Two priorities were obtained from the discussion:

1. The need for mechanisms to clarify the responsibility of the different stakeholders;
2. The creation of a web mapping portal to promote awareness and the development of a risk culture.

5.1.1.4 ADAPTATION STRATEGIES

The objective of this activity was to discuss their preferred adaptation strategies. Three strategies were more thoroughly discussed.

1. Retreat from zones exposed to future coastal hazards was considered a long-term objective. Meanwhile, it is imperative to stop the transformation of secondary homes into principal residencies within the zone exposed to coastal hazards, especially on Beresford dune.

2 Accommodation was perceived as an appropriate strategy to retrofit buildings located in the flood zone.

3 Protection was considered an appropriate short-term solution to protect industrial contamination. However, certain members of the committee raised concerns regarding the level of responsibility in the implementation of hard engineering solutions, as well as their impacts on access to the coast.

5.1.1.5 INLAND HAZARDS AND VULNERABILITIES

The committee also shared its points of view on different inland hazards:

- Forest fires;
  - Many unlisted camps located in the forest;
  - A lot of residential developments in forested areas;
  - The lack of volunteer firefighters is a major problem rather than the distance between the residences in forested areas and fire stations;
- Droughts;
  - Issues with wells drying up;
- Storms;
  - Problems getting gas to use for generators when power is out, as gas stations need electricity to function;
  - The idea of having a priority retail network with generators was brought up.

5.1.2 CRACCCA SURVEY

A survey was conducted amongst the members of the CRACCCA. 6 people answered the survey. The results of the survey are summarized in Appendix C. The key results are presented below.

5.1.2.1 DECISION-MAKING TOOLS TO PROMOTE ADAPTATION

The favored decision-making tools to promote adaptation can be regrouped in the following categories:

- Maps;
- Planning and regulatory tools;
- Communication.

Knowledge acquisition, concertation and citizen involvement were considered secondary.

5.1.2.2 SELECTION CRITERIA

Selection criteria were grouped in three categories: implementation, direct impacts and indirect impacts. In terms of implementation, the most important selection criteria are related to the ease of implementation and their social and temporal extension:

- Feasibility;
- Cost;
- Equity;
- Sustainability.

Criteria related to effectiveness (robustness, efficiency, flexibility) came in second.

Regarding direct impacts, the respondents preferred adaptation measures that improved **safety** (public and first respondent safety), **sociosanitary conditions** (drinking water and sanitary conditions) and **infrastructure resilience. Social and environmental benefits** were considered more important indirect impacts than economic benefits.

5.1.2.3 PRIORITY OF NON-COASTAL HAZARDS

The CRACCCA members were asked to rank the priority of non-coastal hazards from 1 to 5. Scores were then averaged to provide a general picture of the importance of the different hazards for the committee. According to the survey, fluvial flooding should be considered as the main inland hazard to focus on, followed by pluvial flooding, forest fires and ice storms. Vector-borne diseases were considered less important. Table 12 summarizes the results of the survey questions related to these hazards.

Table 12 Priority Level and Adaptation Vision for Different Non-Coastal Climate Induced Hazards

Hazard	Average Score	Strategy 1	Strategy 2	Measure 1	Measure 2
Fluvial flooding	2	Retreat	Others equally	Planning	Education Emergency measures
Pluvial flooding	3	Accommodate Protect	Procedural Retreat	Light engineering Emergency measures	Education
Forest fires	3	Protect	Others equally	Education	Planning Emergency measures
Ice storms	3,2	Accommodate Protect		Emergency measures	Education Light engineering
Vector borne disease	3,8	Protect	Accommodate	Education	Emergency measures

Emergency measures and education were considered the most important adaptation measures to include for most hazards. For geographically constrained hazards, the committee considered planning as an appropriate measure. Light engineering was deemed appropriate for precipitation-related hazards.

5.2 ADAPTATION PLAN

5.2.1 VISION

The following section proposes elements to include to the RSC vision, regarding adaptation. As climate change is a gradual process, it is possible to develop a vision of resilient communities at different time steps. Given the fact that discussions with communities or the CRACCCA regarding the vision still need to intensify, the vision presented here describes a guiding principle of measures to consider and to deepen further.

5.2.1.1 SHORT-TERM VISION

The short-term vision (2019-2030) is defined through these six axes:

- Make individual safety to climate hazards a priority;
- Preserve the aesthetic character of coastal landscape;
- Promote public access to the coast;
- Develop a coherent regional strategy to favor equity between municipalities;
- Protect sensitive infrastructure, or infrastructure that can have important environmental effects from coastal hazards;
- Take advantage of the economic opportunities brought on by climate change.

5.2.1.2 LONG-TERM VISION

On the longer term, as sea-levels rise and coastal hazards being of higher magnitudes, profound modifications to the following territorial planning should lead to a more resilient society:

- Retreat from the zones exposed to future coastal hazards;
- Develop a holistic vision of territorial planning integrating the synergies between coastal and watershed processes, ecosystem services to the communities, the quality of life of citizens, and sustainable economic development.

While these profound modifications are undertaken, measures described for the short-term vision should still be considered to enable a safe access to and healthy habitats near coastlines.

5.2.2 ADAPTATION MEASURES

The following section presents the adaptation measures that were selected to build resiliency for Chaleur region. Measures were divided in to different categories: i) education, communication and awareness, ii) data and knowledge acquisition, iii) planning and regulatory measures, iv) emergency planning and v) protective measures. In each group, a set of measures is presented, including targeted actions and best practices where applicable. Examples of implementation of similar practices are also presented at the end of each category. Next to most measures, the number in a red box refers to priority zones where the measure should be developed.

5.2.2.1 EDUCATION, COMMUNICATION AND AWARENESS

1 Promote public and small business awareness and understanding of climate impacts.

Public engagement in decision making and planning is a central component of a successful adaptation plan (Serrao-Neumann *et al*. 2015). One of the barriers to public participation in adaptation is the complexity of the available scientific data. Indeed, climate change information can be structured and downscaled to the community level using concrete risks to the community and coherent scenarios at the regional scale (Sheppard *et al*. 2011). Two means of communication have been identified by the communities and the CRACCCA: information sessions and a climate change data portal. In that regard, we propose six actions to promote awareness and understanding of climate change impacts:

#33

a Propose targeted awareness activities regarding general information about climate change to promote citizen engagement, especially in the eastern sector.

The lack of participation from the eastern sector during the public consultations suggests a lesser sense of urgency. In addition, present citizens did demonstrate an interest in better understanding climate change in a general sense.

#23

b Realize awareness activities regarding coastal dynamics, coastal protection structures, including technical aspects and interactions with natural environments.

Coastal dynamics is complex, from an hydraulic, geomorphologic or engineering standpoint. Acceptability of the selected adaptation solutions regarding coastal flooding and erosion depends upon the understanding of coastal processes and engineering processes. The understanding that individual choices regarding coastal management can affect the coast at the community level is paramount to proper and integrated planning and collective management of coastal hazards.

#38

c Collaborate in the creation of a portal to promote awareness and the development of a risk culture.

During the CRACCCA consultations, one member mentioned that a data portal with hazards maps at the scale of the RSC would raise awareness towards the issues at stake, promote the development of a risk culture and favor accountability at the individual and collective levels. Similar websites exist at different spatial scales, from municipal to national (example below). The creation and maintenance of such a website might necessitate a computer infrastructure and capacity that exceed the resources of the RSC. There is therefore an opportunity to collaborate with other RSC or the provincial government on this project.

#24

d Determine and target the most vulnerable and most motivated audience.

The public consultations allowed us to observe a discrepancy in the level of understanding of the impacts of climate change and a contrasting sense of urgency between the western and the eastern sectors. In the first phase, targeting the most motivated audience has the potential to provide legwork to implement adaptation and to improve awareness of less motivated audience. Targeting the most vulnerable can increase social acceptability of the adaptation plan and ensures a democratic access to resiliency building.

e Determine the most locally relevant communication networks to reach the population.

Communication networks can be social media, websites, flyers, public forums, etc. It is important to select the network depending on the aim of the communication (awareness, education, outreach, etc.). It is also important to tailor the message to the selected network.

f Identify partners to best disseminate the information.

Depending on the targeted hazard, institutional partners will already have mechanisms to disseminate the information to the right population or already have the expertise to prepare the communication. For example:

i general climate change communication: CRACCCA members and academics of nearby universities;

ii Forest fires: municipal fire departments and volunteer firefighters' brigades;

iii Vector-borne disease: public health New Brunswick and Jacquet River Health Center should be involved in awareness campaigns regarding Lyme disease. As for insect outbreaks affecting crops or commercial forests, the National Farmers Union, the Agricultural Alliance, the New Brunswick Federation of Woodlot Owners and the Ministry of Natural Resources can possibly be strategic partners to disseminate information.

2 Provide public and small businesses with personal actions and public policy options available to respond to climate change.

Building resilient communities starts with personal actions that can decrease the vulnerabilities of households and small businesses. It is imperative to empower citizens by providing tools to help them prevent and prepare to climate change induced hazards.

#36

a Promote the elaboration of a Family Safety Plan (FSP).

A FSP is a good way to make sure that households are ready to react in case of an emergency. The RSC should partner with local first responders to promote the elaboration of a FSP, especially for households located in zones exposed to natural hazards, especially for riparian and coastal communities sensitive to flooding, as well as isolated communities in forested areas of the RSC that are prone to forest fires. However, given the frequency of storm-induced power outages and the likelihood of severe ice storms, every household of the RSC should elaborate a FSP. The Ministry of Public Safety of Québec proposes that these elements be covered in a FSP (SPQ, 2017).

i Always have an emergency kit in your home to contain all the necessities to provide for your family's basic needs for 72 hours. Appendix D lists the essential items to keep in your emergency kit.

ii List the contact information of the persons that you will need to reach in case of an emergency: family members, daycare, school, municipality, first responders, employers, etc.

iii Prepare your home evacuation plan, a sketch of each floor of your home that simplifies the evacuation of the residence in case of an emergency by showing the evacuation route. This plan must be practiced once every year.

iv Learn how to shut off water, electricity and gas in your home.

v Plan the emergency route if you need to evacuate the neighborhood. This emergency route should contain a principal route and alternate options in case of road closures.

vi Prepare an inventory of all belongings, including proofs of purchase, photographs or videos. A copy of these documents, along with copies of your government issued documents (e.g. passports) and your home and automobile insurance policies should be kept outside your home in a secure location (e.g. office, home of a relative living at a safe distance from your household).

b Provide information about insurance coverage available.

Insurance companies are adapting to climate change by modifying the hazards that are covered. However, clauses in an insurance contract can be intricate and overwhelming. In that regard, the RSC should provide a list of insurance companies covering different climate-related hazards (flood, snow load, ice damming, forest fires, etc.) and to what conditions. For example, retrofitting measures can make a building insurable. To promote personal accountability, people located in zones that cannot be covered by insurance policies regarding climate-induced hazards (e.g. residences in the 20-year floodplain generally cannot be covered for fluvial flooding damages) should be formally warned.

c Provide information about circumstances and programs under which financial aid is available.

Following a disaster, financial aid programs are often set up to help affected citizens. For example, following the floods in 2018, the New Brunswick government launched a disaster financial aid program. However, during recovery, many victims are overwhelmed and struggle to understand if they are eligible to financial aid programs. The RSC should make sure that the information about financial aid programs (list of programs, eligibility criteria, and process to obtain funding) is available to the citizens through the best means of communication to reach the communities (example #2).

There are also funding opportunities for institutions and municipalities. For example, the Federation of Canadian Municipalities have ongoing funding programs that can contribute to climate change adaptation, such as the Municipalities for Climate Innovation Program, a five-year, $75 million program that will support more than 600 municipalities to address climate change. Therefore, a list of funding opportunities for individuals, business owners, industries, institutions and municipalities should be gathered and shared to the community.

d Partner with the public health sector to prepare communication materials about human health risks of climate change.

Climate change will have both direct and indirect impacts on human health. Human health risks of climate change can be grouped in three categories:

i Vector-borne disease. There is a high likelihood that the citizens of the RSC will be exposed to ticks carrying Lyme disease in the following years (Figure 5, section 4.2.4).

ii Heat illness. With rising temperatures, heat illness could become more frequent.

iii Floodwater pathogens and contaminants. With increasing flood hazards in the region, and given that floodwater can contain infectious organisms (e.g. *E.Coli*, Salmonella or Hepatitis) and chemicals, it is important to promote sanitary practices amongst flood cleanup crew members to limit their exposition to health hazard.

The RSC should partner with the public health sector to promote prevention practices to limit exposure to these human health risks, as well as to raise awareness and capacity regarding these health issues amongst staff of regional clinics, health centers and hospitals.

EXAMPLE #1: WEBSITES TO COMMUNICATE RISK

Many communities and countries communicate information to their citizens regarding their exposure to natural hazards through websites. Hawke's Bay is a region of New Zealand with similar scale as Chaleur region, that possesses a website about emergency management (Hawke's Bay Emergency Management Group, 2019). It is an example of good practice given the thoroughness of information that is well classified.

Like Hawke's Bay website, a portal addressed to the communities should contain the following sections: i) a general description of natural hazards affecting the concerned territory to increase general awareness, ii) maps allowing citizens to appreciate to which natural hazards (and to what probability) their property is exposed, iii) information about getting ready to face disasters for home and small businesses, iv) awareness and methods to build a resilient community, and v) alerts about the ongoing and expected emergencies. For the latter component, the Chaleur region website could relay the alerts from Environment Canada.

EXAMPLE #2: THE WEBSITE OF THE TOWN OF RIGAUD INDICATES HOW TO RECEIVE FINANCIAL AID

The Town of Rigaud (Québec) was heavily affected by floods in Spring 2017. The disaster financial aid program launched by the provincial government was complex and novel. Moreover, given the high number of victims at the provincial scale, the government had a hard time responding to every inquiry. The Town of Rigaud took two main actions to accelerate the recovery of their citizens:

1. Provide information about financial aid on the municipal website, including the provincial guide to financial aid, the provincial bylaws that control the development in the flood zones, the provincial order declaring the zones that were eligible to financial aid and especially flowcharts to understand the eligibility criteria and steps to realize before starting the rebuilding (Figure 6).

2. Open a recovery office in Rigaud, aiming at processing every financial aid requests produced by the flood victims, with a strategy based on meeting, informing, accompanying and giving responsibility to the citizens. They receive the jurisdiction to receive and process the demands on behalf of the Ministry of Public safety to accelerate the process.

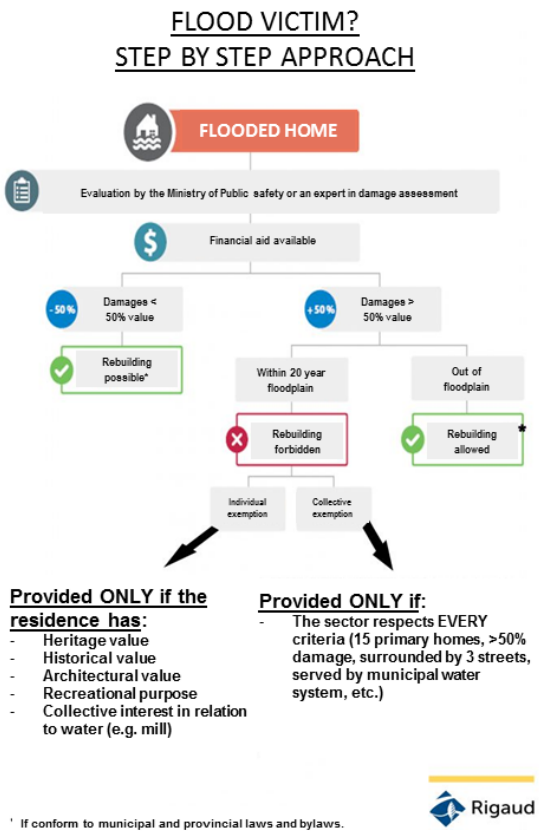


Figure 6 Example of a Flowchart Produced by the Town of Rigaud

5.2.2.2 DATA AND KNOWLEDGE ACQUISITION

#43

3 Create a data portal (cf 1c) and make it available to the public, landowners, asset owners and businesses.

The creation of a data portal was mentioned earlier, but as data collection and gathering will be a large part of the process and will provide support in deciding for the region and municipalities, we emphasize the importance of the measure by including it in this section. This data portal should include:

- coastal erosion and inland flood risk maps;
- fluvial flooding risk maps;
- salt water intrusion and well salinity data;
- individual grant and funding opportunities;
- fire prone zones;
- vector-borne disease zones.

4 Gather and maintain a regional inventory of assets and demographics vulnerable to climate change to facilitate sustainable asset management.

Integrating asset management in climate change adaptation is key to building resilience, since climate change threatens sustainable service delivery. Asset management is a three-step process: assess, plan and implement (Figure 7).

Figure 7 **Example of an Asset Management Framework (BC Ministry of Municipal Affairs and Housing, 2018)**

In terms of data acquisition, the following measures should be implemented:

#8

a Coordinate among regional government public works agencies in tandem with businesses and the public to develop and maintain local and regional inventories of local infrastructure and natural assets vulnerable to climate change.

The first step towards sustainable asset management practices is to assess the current states of assets, including:

i water utilities, stations, treatment and distribution centers;

ii power utilities, stations and distribution centers;

iii wastewater treatment, collection infrastructure and septic tanks;

iv drinking water infrastructure and wells;

v ecological sites of community, economic or environmental significance;

vi public health;

vii linear infrastructure (roadways, bridges, and power lines).

There are a myriad of tools and guidelines to produce asset inventories. The Government of Ontario (no date) proposes the following checklist to validate that the inventory is up to date and contains the relevant information.

- The asset inventory is complete. All the major asset classes are included. Land should be included in the inventory for completeness even though it is not depreciated or replaced. (e.g. does the net book value of assets in the AMP approximate the value in the financial statements?);
- The inventory contains all the relevant information for asset management and for undertaking analysis. Such information could include: asset class, asset description (e.g. for pipes this might include pipe material, location, length, and depth), in service year, life expectancy, net book value, replacement value, annual depreciation, condition rating, and risk rating;
- Asset rehabilitation/replacement strategy for the assets. Will you:

  (1) replace the asset with a new identical asset?

  (2) Do nothing?

  (3) Replace the asset with a different asset?

  (4) Extend the life of the asset without replacing it (e.g. pipe lining)?
- The asset inventory grows in the future as per the capital plan. Assets that are expected to be added in the future can be incorporated into the AMP and budget forecasts prior to their actual emplacement.
- The inventory contains information that reflects the way the asset is managed vs the way it might be treated in financial statements (e.g. statements might deal with buildings on a "whole asset" approach and contain a cost for a building and a life expectancy. The building will not necessarily be demolished at the end of its life and replaced. This is not how buildings are managed. The various components such as heating, elevators, windows, roof, etc. are maintained and upgraded. These "betterments" extend the life of the asset. The AMP should include costs for component replacement/rehabilitation and not simply assume that the building will be replaced entirely in 50 years).
- There is an established process for bringing new assets into the inventory and removing old assets:

b Make a GIS inventory of assets located within areas vulnerable to climate change. #55

Facilitate the combination of spatial information with GIS tools, such as location of buildings and exposure to hazards (example #3).

c Coordinate among regional government public works agencies in tandem with businesses and the public to develop and maintain local and regional maps of demographics vulnerable to climate change.

When a disaster occurs, first responders should target the most vulnerable population first, as these people are the most susceptible to be heavily affected by the so-called disaster (example #4).

5 Develop and monitor regional indicators of climate change impacts and adaptation action. #1

Climate change induced processes and impacts are accompanied by a high level of uncertainty. As much as it is possible to identify trends, in terms of management, having more accurate data can help prioritize actions. In that regard, continuous monitoring will favor proactive responses from the municipalities and the region. Subjects that can benefit from this measure are:

i coastal erosion zones;

ii coastal flood zones;

iii salt water intrusion;

iv fluvial flood zones;

v fire zones;

vi invasive species range.

a Develop citizen based data gathering and monitoring programs.

Research shows that involving citizens in data gathering and monitoring in environmental science allows to improve data sufficiency, raises awareness regarding the issue at stake and increases scientific literacy. Citizen based data gathering includes the following tasks.

i Ask citizens to periodically collect water from their wells or provide citizens with water testing kits. This measure would promote access to safe drinking water;

ii Monitor the shoreline and gather evidence of coastal erosion to record changes that occur along the coast over the years (example #5). As coastal erosion is likely to speed up in the following year, gathering data with the help of volunteers is less cost extensive than using remote sensing techniques (LIDAR, aerial photos, etc.);

iii Organize community mapping exercises following flooding events to validate the extent of the flood and the associated water levels;

iv Track the migration of invasive species with deleterious effects on endemic ecosystems.

6 Undertake a comprehensive evaluation of climate change risks and hazards and improvements necessary to adapt critical infrastructure, homes, ecological sites, and businesses, to climate change.

#21

a Partner with academics to increase the knowledge regarding climate change hazards.

Climate change information is getting more accessible, although getting reliable and practical information on some aspects is hard. The region should partner with researchers and academics to broaden their knowledge on the following domains that can have implication on risk assessment, planning and adaptation.

i IDF curves. Intensity duration frequency curves present the expected return period for extreme precipitation events. They provide key information regarding pluvial water management. Despite the availability of IDF curves that consider climate change for Canada such as the one presented above, this product is of low practical utility given the issues with statistical downscaling. IDF curves should be modeled based on dynamic downscaling of regional climate models, and should be developed as part of research projects.

ii Synergies in watershed management and coastal management. As expressed by a citizen, there are synergies between fluvial and coastal processes. These synergies act upon and are highly dependant on the regional context and therefore should garner a study of their own.

#9

b Evaluate stormwater management practices necessary to expand surface water storage, enhance water quality treatment and reduce stormwater discharges.

With the expected increase in pluvial, fluvial and coastal flooding hazards, proper storm water management practices should be implemented to facilitate water drainage and enhance water quality. Existing infrastructure may be under-designed, might necessitate more frequent maintenance and the region should therefore seize retrofitting opportunities. New infrastructure might be designed with increased pipe diameters or increased water storage capacity. The evaluation of current storm water design infrastructure can be carried out using the Public Infrastructure Engineering Vulnerability Committee (PIEVC) protocol, a step by step method to assess the climate change vulnerability of infrastructure developed by Engineers

Canada (Figure 8). The vulnerability to climate change of new infrastructure can be assessed using the Climate Lens from Infrastructure Canada.

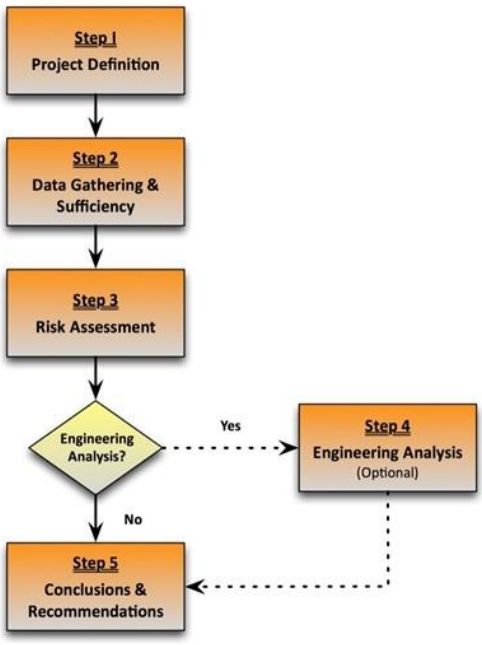


Figure 8 Stepwise Method of the PIEVC Protocol

c Make a GIS inventory of every house, cottage, cabin or trailer located in forested areas.

There are a lot of residential assets in forested areas that serve as vacation houses and that are not inventoried. To ensure systematic evacuation and proper emergency responses, first responders need to know where to look for individuals.

d Assess the potential impacts of invasive species, vector-borne disease, parasites and pathogens on public health and economic activities.

As climate change and associated migration of species will have profound impacts on human health and agriculture, the RSC should partner with public health institutions and environmental health academics to:

i evaluate the impacts of vector-borne disease, parasites and pathogens on public health;

ii evaluate the impacts of invasive species and parasites on agriculture and commercial forests;

iii identify human diseases exacerbated by climate change.

This assessment would allow to plan targeted actions to promote human resilience (e.g. Lyme disease) and economic resilience (e.g. emerald ash borer outbreak effect on commercial forest).

#45

e Evaluate climate change risks and opportunities to agriculture, forestry and tourism.

The economy of the region will be affected by climate change. A full assessment of the impact of climate change on the different sectors can help in adapting and seizing opportunities to develop.

i Agriculture: calculate and map the agricultural land sensitive to coastal flooding, identify crops that could benefit future climate conditions;

ii Forestry: adapt yield calculations of commercial forests to changing climate conditions;

iii Tourism: evaluate the impact of winter warming on the snowmobile industry.

EXAMPLE #3: OUR ASSETS MANAGEMENT APPLICATION – RICHMOND, QUÉBEC

Asset management is a challenge for the human and financial capacity of small municipalities. WSP developed a GIS-based application named *Our Assets* which provides the municipalities with a spatial database of every asset owned by the municipality, along with the major land-use constraints (wetlands, flood zones, etc.). On the field or at his desk, the asset manager can fill information on every asset, including the state of the asset, the planned management, etc. There are many query options so the managers can take informed decisions when planning operations. Figure 9 provides an example of the application of *Our Assets* in the city of Richmond, Québec.

Figure 9 Our Asset Application Interface

EXAMPLE #4: MAPS OF VULNERABILITY TO URBAN HEAT ISLAND EFFECTS - MONTRÉAL

With increasing summer temperatures, the effects of heat waves are amplified by the urban heat island effects in densely urbanized contexts such as the City of Montréal. The City already had different measures to mitigate the impacts of heat waves (e.g. extending the opening hours of public pools). One of the measure was for first-responders to visit residences of targeted neighborhoods to check on the citizens and give tips to protect themselves against the effets of heat. However, the lack of a methodology to map the vulnerability to heat made the zones to visit too large for the capacity of the first responders.

Researchers from the Université du Québec à Montréal (UQAM) further refined the map by creating an index of risks using the following data:

- Exposure: ground temperature satellite imagery;
- Vulnerability: % of population > 65 years of age;
- Adaptation capacity: material and social deprivation index based on:
  - persons living alone;

- single-parent households;
- employment rate;
- level of education;
- average income;
- Dissemination area (area with a population between 400 and 700 people) from the 2006 census.

— Land use to keep only residential areas.

This method allowed to target small zones of priority intervention for first responders. The map (Figure 10) is now used by the civil security of Montréal, and different cities in Québec adapted the method to their needs.

Figure 10 Map of the Priority Intervention Zones for Heat Hazards in Montréal (Lareau & Beaudoin, 2015)

EXAMPLE #5: RÉSEAU D'OBSERVATEURS SUR LE MILIEU CÔTIER – EASTERN QUÉBEC

Université du Québec à Rimouski (UQAR) developed a network of citizens who document processes and human or natural transformations of the coast in eastern Québec, whether it relates to coastal hazards, weather or landscape evolution. These citizens are the eyes of the land, as they are well positioned to witness the ongoing changes.

Sharing documents, archives, photographs and testimonies of the coastal zone allows UQAR to feed an important database that is precious to further increase knowledge and promote the integrated management of the coastal zone. It allows to include coastal citizen knowledge in their analysis and to identify discrete events with their impacts on the coastal systems. This precious information can feed research projects directly or allow the scientists to target priority study sites. Figure 11 shows the location of the data that was acquired by this network.

With few guidelines to make sure that the information is transferable the needs of scientists, citizens can provide information on:

— the impacts of coastal storms;

- the impacts of sea ice on the coast;
- length of annual ice cover;
- coastal erosion processes;
- landscape evolution;
- human activity on the coast;
- ecosystem transformation;
- historical photos of the coast;
- any other phenomenon that is of interest for the citizens.

Figure 11 Map of the Inputs from Communities to Coastal Hazard Studies

5.2.2.3 PLANNING AND REGULATIONS

Planning is an important part of adaptation. During the consultations with the CRACCCA, planning and regulatory measures were often considered as essential to building resilience to climate induced hazards. In that regard, the following section describes targeted zoning and regulatory changes, as well as best practices to inspire planning of the RSC.

7 Implement specific zoning, policies and regulations within high-risk areas that require certain measures to be undertaken by developers and landowners.

#24

a Evaluate the possibility to adopt a coastal regulation to limit the residential spread within the exposed zones.

The residential spread in the coastal area is a major issue within the CSR. For instance, the transformation of cabins into permanent residences on the Beresford Dune is a problem from a civil security standpoint, but also from an economic standpoint, as this spread causes an increase in the value of the assets in a zone frequently exposed to storm surges and potentially sensitive to coastal erosion. The New Brunswick Coastal Areas Protection Policy separates the coast in three distinct zones from zone A (more stringent regulation)

to zone C (less stringent regulation). However, according to the CRACCCA, the policy was never implemented, and it is impossible to implement considering the local context.

As the Beresford Dune sector is a dune extending beyond the Higher High Water Large Tide (HHWLT), it should be considered not prompt for residential development. Specifically, development of principal residences on the Beresford Dune should be banned, at least until the RSC gains a better understanding of the coastal erosion dynamics.

i Implement coastal zoning based on future sea level. With the expected sea level rise of 1.31 m in Gloucester county, many sectors have the potential to become within the HHWLT level. Coastal zoning should be based on future sea levels to make sure that the coastal development is coherent with the future coastal landscape. Analog to common practices in floodplain mapping, we recommend using data from Daigle (2017) to define and map coastal flood zones based on the return period of different storm surges by 2100:

(1) The 1-year return period would correspond to the HHWLT level + Sea Level Rise + the 1-year surge (3.4 m);

(2) The 25-year return period would correspond to the HHWLT level + Sea Level Rise + the 25-year return period storm surge (4.0 m);

(3) The 100-year return period would correspond to the HHWLT level + Sea Level Rise + the 100-year return period storm surge (4.2 m).

Zoning regarging coastal erosion should follow the zones identified by Chelbi et al. (2019), which are:

(1) Presently at risk of erosion would correspond to the 1-year return period zone;

(2) At risk of erosion by 2050 would correspond to the 25-year return period zone;

(3) At risk of erosion by 2100 would correspond to the 100-year return period zone.

ii Propose a more severe regulation regarding coastal development than the New Brunswick Coastal Areas Protection Policy (example #6).

(1) 1-year zone: no development should be allowed;

(2) 25-year zone: before having a better understanding of coastal hydrogeomorphological dynamics at the scale of the RSC, impose a moratorium in the development inside the 30 m buffer beyond the 25-year zone. Major retrofits of permanent structures in this zone should include immunization measures to make it is resilient to flooding and erosion;

(3) 100-year zone: allow for development depending on the sensitivity to storm surges. The policy states that all permanent structures should be built at an elevation of 2 m above HHWL. However, we recommend that all permanent structures be built at an elevation above the 100-year return period storm surge in 2100. New permanent structures located below that line should be built with immunization measures that make them resilient to storm surges.

iii Propose a more severe regulation regarding retrofitting in the coastal flood zone:

(1) Forbid retrofitting or reconstruction of infrastructure in the 25-year zone when the damages to the infrastructure caused by coastal flooding or erosion exceed half of the real value attributable to the real property (Gazette Officielle du Québec, 2017);

(2) Allow retrofitting or reconstruction of infrastructure in the 100-year zone when the damages to the infrastructure caused by coastal flooding or erosion exceed half of the real value attributable to the real property (Gazette Officielle du Québec, 2017). Reconstruction should include immunization measures to make them resilient to coastal hazards.

On the long term, measure 7.a.iii will promote the relocation of citizens towards safer zones. However, relocation of the citizens is a complex process that needs thorough preparation, as there are many stakes involved (example #7).

b Modernize permitting, planning, and design standards to incorporate future climate considerations into land use and building regulations. #38

For the infrastructure and assets that will be remaining in zones exposed to coastal and fluvial hazards, the following set of measures will contribute to increasing their individual and collective resilience.

i Establish set future climate scenarios to establish design standards and analyze the resilience of existing infrastructure (e.g. which storm frequency to be built to?);

ii Incorporate unified sea level rise projections, by reference, into all city and regional agency comprehensive plans, transportation and other infrastructure plans, and capital improvement plans;

iii Include a clause explaining risk acceptance regarding coastal and fluvial hazards for every permit demand in zones exposed to these hazards (100-year zone);

iv Relocate, retrofit, and/or protect properties and infrastructure vulnerable to climate change impacts (e.g., move infrastructure located in areas vulnerable to erosion, flood proof homes located in food risk zones, and protect scenic routes).

8 Plan new developments with climate change in mind.

As municipalities and DSL seek to increase the commercial, industrial or residential areas, new developments should be planned to avoid exposure to the main hazards, especially in the case where cascading effects can occur between natural and technical hazards (e.g. industrial toxic waste spreading in the environment following a storm surge).

#24

a Avoid areas in climate projected coastal erosion or flood zones.

Refer to measures 7 and 8 regarding zones to avoid or zones to promote resilient development. #36

b Establish criteria to new development in forested zones.

Criteria to plan development in forested areas are available through the FireSmart awareness program (FireSmart Canada, 2018).

9 Promote the protection and restoration of vulnerable and / or socially, economically or environmentally significant areas.

Natural ecosystems provide key services to the population. For example, wetlands will contribute to increase water quality and to decrease flood magnitude by retaining water. A vegetated coast will prevent erosion and promote slope stability.

#21

a Zone key social, economic, or environmentally significant sites, as conservation areas.

b Preserve public access to the coast by restricting public ownership of the beaches.

Consultations with the public and the CRACCCA brought out the population's concern to preserve access to the coast. In that regard, it is important that development be planned with this objective in mind. In that regard, public access to beaches should be included in zoning of each municipality to make sure that private ownership does not block access. To achieve this, we propose the addition of bylaws to require easements or right of ways from private owners to make public access to beaches permanent.

c Adopt local estate tax incentives for protecting and conserving vulnerable and significant ecosystems.

d Acquire conservation easements or conservation land for critical wetland and coastal zones.

e Promote the creation of living shorelines and riverbanks at the regional scale.

Living shorelines are ecological engineering techniques that use native vegetation, optionally combined with traditional engineering designs, to stabilize the shoreline. They provide numerous advantages: pollution remediation, habitat provision for species, and buffering the shoreline from wave action. Figure 12 illustrates the benefits of a living shoreline.

Riverbanks naturally migrate horizontally. Land use planning of riverbanks should consider the flood zone, migration zone and wetlands to increase resilience and take advantage of the floodplain's ecosystem services. To achieve this, an hydrogeomorphological analysis of the floodplains should be carried out. This novel river management practice has been demonstrated to provide economic benefits in addition to promote public and infrastructure safety (example #8).

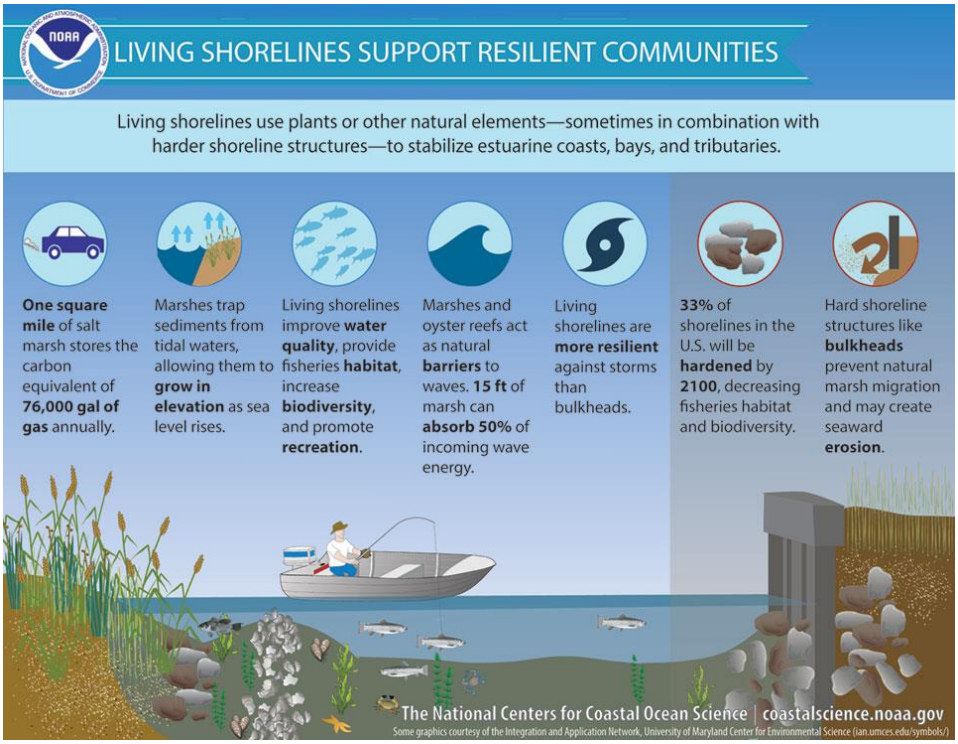


Figure 12 Benefits of a Living Shoreline (NOAA, 2017)

10 Assist the municipalities in reviewing all local comprehensive, transportation, infrastructure and capital improvement plans and determine the gaps in asset planning for projected climate changes.

As climate change will affect infrastructure, it is necessary to plan for projected climate vulnerability. Municipalities should review their most critical assets (built or planned) and use existing methods to assess their vulnerability. For example:

- Infrastructure Canada implemented the requirements for a Climate Lens assessment as a prerogative to receive funding for important infrastructure projects;
- Engineers Canada provide the Public Infrastructure Engineering Vulnerability Committee (PIEVC) protocol to evaluate vulnerability to climate change.

EXAMPLE #6: THE RIPARIAN RESILIENCY REGULATION PROJECT – ILE-BIZARD – SAINTE-GENEVIÈVE

Following the 2017 Spring floods in Québec, the Montréal's neighborhood of Ile-Bizard – Sainte-Geneviève asked WSP to suggest regulatory modifications to increase the resiliency of their riverbank populations. After conducting an inventory of public and private assets located within the flood ore riverbank erosion zones, the regulatory proposal was coherent with the laws and bylaws of Montréal and with Québec's policy on the protection of the riparian zone. The regulation targeted four principal aspects:

- Forbid new construction in the 100-year floodplain;
- Forbid any volume increase of buildings located in the 100-year floodplain;
- Define the regulatory requirements for any permanent anti-flood structures;
- Require retrofitting of the mobile homes by increasing the spacing from the ground.

EXAMPLE #7: HOW TO MAKE CHANGES ACCEPTABLE FOR COASTAL ZONING

Coastal zoning solutions may be considered publicly unfavorable as they may place limitations on homeowners, developers, and businesses, undue interference and regulation. Below are some suggested solutions to create more favorable conditions for zoning implementation and earn public acceptance.

Timing

Research has shown that awareness and concern among the general public are heightened immediately after a disaster (Baker, 1977). Individuals are most likely to adopt mitigating actions such as new zoning or legislation soon after a disaster. For example, during hurricane forecasts evacuation rates tend to be the highest in places with recent disasters (Baker, 1977). Introducing new zoning measures soon after a coastal-based disaster such as a storm event or flooding may increase public acceptability of more restrictive actions.

Education and Partnerships

Research has found that while most people believe that climate change is a significant problem, far fewer consider themselves personally vulnerable (Lieske *et al*. 2015). In addition, there is often a gap between council and legislative reasoning and the understanding of the public. This sometimes creates a misunderstanding of the reasons behind the motivations of restrictive actions such as zoning and invites contravening. Ensuring that the public affected is properly aware of the problem and the intentions behind the solutions will help ease public adoption of solutions (McInnes, 2006). In addition, ensuring that the public and relevant stakeholders are active and engaged members of the solution throughout the process minimizes chances for backlash.

Accountability

Those who benefit from underdeveloped zoning do not bear the full cost when disaster strikes. Establishing and framing zoning as an accountability method where the costs of individual decisions are not the responsibility of the community may discourage living in those zones or personal investment in retrofitting and other adaptation methods without impacting the entire community (Pawlukiewicz *et al*. 2007).

Market-based incentives

Shifting the burden of new zoning onto new development reduces the impacts on the existing public and property. Tax incentives, preferred treatment for timely regulatory approvals, density bonuses, and public investment into projects not in sensitive areas or those with above-standard coastal protection may shift development without strict restrictions (Pawlukiewicz et al. 2007).

EXAMPLE #8: THE FREEDOM SPACE FOR RIVERS IS AN ECONOMICALLY VIABLE CONCEPT

Buffin-Bélanger *et al*. (2015) have conducted a cost-benefit analysis of forbidding development in a delineated buffer zone around rivers that includes the potential mobility of meanders and flood zones. Zones were determined with a hydrogeomorphologic approach where floodplain landforms are indicative of flood hazards. Costs included were the loss of construction rights and loss of farming rights, whereas benefits included were avoided costs for bank protection, avoided costs for flood protection, wetland ecosystem services and riparian buffer ecosystem services. Ratios of benefits over costs range between 1.5:1 and 4.8:1 over a 50-year period.

5.2.2.4 PROTECTIVE MEASURES

It is beyond the scope of the project to define the engineering method to protect coastal assets. This section defines good practices that will increase collective resiliency to climate change.

11 Target strategic infrastructure that will necessitate short term protection.

#46
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Consultations with the CRACCCA underlined that retreating from the coast was a favored strategy than protecting the coastline, but the members acknowledged that this objective was feasible on the long-term. On the short-term, there are many sensitive infrastructures located in the coastal flood zone for which a protection strategy should be implemented. Notable sites located within the 4.2 m projected flood zone are:

- Beresford dune;
- Belledune Port;
- New Brunswick Power generating station;
- the Belledune heavy industries (9);
- pumping stations (8);
- treatment plants (2);
- educational buildings (2).

As these infrastructures are near the coast, an update of coastal erosion data will likely suggest that some of these infrastructures will also be vulnerable to the later process. These buildings should be targeted in priority for implementing protection measures.

The CRACCCA recognized that hard engineering solutions have the potential to modify significantly the hydrogeomorphological dynamics of the coast, especially due to end effect and the modification of the sediment yield. The region should raise stakeholders' awareness regarding the regional impact of local protection measures and promote solutions with minimal impacts for the neighbors.

The intensive use of hard engineering structures has the potential to limit access to the coast and affect negatively the aesthetics of the coastal landscape. To insure social acceptability of these measures, the region should promote the importance of these two criteria amongst the stakeholders.

12 Require the deposition of a collective coastal management plan by municipalities.

The coastal environment works as a complex system where every coastal unit interacts in terms of sediment yield, maritime hydrology and hydraulics. The principle of integrated coastal management should be prioritized to make sure that single measures do not disturb the coast at a wider scale. The application guide of the *Politique de Protection des Rives, du Littoral et de la Plaine Inondable* (MELCC, 2015) provides guidelines to apply a collective management unit to coastal and riparian communities and could be transferred to the local context of Chaleur Region. Fisheries and Ocean Canada (2006) also made an inventory of the coastal integrated management initiatives in Québec where key elements of the process are underlined.

#37

5.2.2.5 EMERGENCY PLANNING

13 Determine the current resilience of evacuation routes.

An important aspect of resilience is the ability of citizens to leave the hazardous zone quickly. Evacuation routes should be accessible even in the occurrence of climate-change induced increased coastal or fluvial flooding.

By mapping the routes against projected climate impacts, the region will be able to observe which evacuation routes are threatened by climate change and need redesign.

An example of an evacuation route needing rethinking is the access to Dunlop area. Residents of this zone can be cut off if the bridges traversing Middle River Road become impassible. Access to the Panibeau Indigenous Reserve has also been an issue in the past.

14 Create a regional emergency preparedness plan framework.

The region should coordinate with municipalities, so they follow a similar framework in creating or updating their emergency preparedness plan. The emergency response plan provided by the provincial government (GNB – 2008) describes the operational protocol and capacity, but should be supplemented by adding the following information:

i List of vulnerable groups (geographically and demographically), critical infrastructure, land use, housing, economic development, and public health;

ii Integration of climate projection data into planning (i.e. considers higher levels of flooding when creating evacuation routes);

iii Inclusion of neighborhood, business, and government accelerated recovery and resilience plans;

iv Map of safe spaces within communities and a plan to communicate these to the public before/during/and after an event.

Building the emergency management plan should include citizen committees to increase the public engagement and acceptability of the plan. This will facilitate the response during an emergency, especially in the case of evacuations, for example. Including representatives from vulnerable communities in emergency management decision-making processes, will help in building trust between these communities and institutions.

15 Conduct training exercises involving emergency services and local responders to respond to severe, wide area flooding, erosion, storm events, fires and improve delivery of services and response times.

These training exercises provide the additional benefit of raising awareness regarding natural hazards. Cross-region events where every municipality conducts a training exercise simultaneously followed by a short workshop to share lessons learned can increase the efficiency of operations during an emergency.

16 Create programs for vulnerable populations to prepare for and prevent additional impacts, and prepare for and mitigate the need for additional recovery efforts.

Having the programs in place before an emergency will allow the response to be proactive regarding vulnerable populations and will prevent additional impacts such as health issues induced by a sinister. The rule of thumb stipulates that each dollar spent in prevention allows to save six to ten dollars in response and recovery.

17 Develop incentives to favor the citizen involvement in first responders volunteering.

During consultations with the CRACCCA, the members mentioned that the distance of the most remote houses in forested areas from fire stations is not as problematic as the lack of volunteer firefighters. Having a strong network of first responders is important in making sure that emergency response is adequate. For example, the state of Pennsylvania passed a law that will give volunteer firefighters tax credits.

6 CALENDAR

We propose an implementation of the adaptation measures in a three-step process to increase its social acceptability and maximize public safety: short (1-5 year), medium (5-10 year), and long (>10 year) terms.

6.1 SHORT-TERM: INDIVIDUAL PROTECTION AND AWARENESS

The most important objective is individual protection of the public and should be targeted first. As social acceptability is harder to attain regarding regulatory or planning modifications, in the first step, we included education and outreach measures. It has extensively been shown that providing information to the public about climate change and its impacts goes a long way in easing the implementation of adaptation measures. Reducing the uncertainties about climate change impacts will also allow to better tailor the measures to the regional context. In that regard, data and knowledge acquisition should be conducted in this phase.

The following list identifies the measures to implement in the first phase. In bold are measures that should be targeted in priority.

- **1a: propose targeted awareness activities regarding general information about climate change to promote citizen engagement, especially in the eastern sector;**
- **1b: carry out awareness activities regarding coastal dynamics, coastal protection structures, including technical aspects and interaction with natural environments;**
- **1d: determine and target the most vulnerable and most motivated audience;**
- 1e: determine the most locally relevant communication networks to reach the populations;
- **1f: identify partners to best disseminate the information;**
- **2a: promote the elaboration of a Family Safety Plan (FSP);**
- 2b: provide information about available insurance coverage;
- **2c: provide information about circumstances and programs under which financial aid is available;**
- 2d: partner with the public health sector to prepare communication materials about human health risks from climate change;
- 4a: coordinate among regional government public works agencies in tandem with businesses and the public to develop and maintain local and regional inventories of local infrastructure and natural assets vulnerable to climate change;
- 4**b: make a GIS inventory of assets located within areas vulnerable to climate change;**
- 4c: coordinate among regional government public works agencies in tandem with businesses and the public to develop and maintain local and regional maps of demographics vulnerable to climate change;
- **6a: partner with academics to increase the knowledge regarding climate change hazards;**
- **6c: make a GIS inventory of every house, cottage, cabin or trailer located in forested areas;**
- 6d: assess the potential impacts of invasive species, vector-borne disease, parasites and pathogens on public health and economic activities;

- 6e: evaluate climate change risks and opportunities to agriculture, forestry and tourism;
- **8a: avoid climate projected coastal erosion or flood zone areas;**
- 8b: establish criteria to new development in forested zones;
- **11: target strategic infrastructure that will necessitate short term protection;**
- **13: determine the current resilience of evacuation routes;**
- 17: develop incentives to favor citizen involvement in first responders volunteering.

6.2 MID-TERM: REGULATORY PROCESSES AND COLLECTIVE ACTION

As climate change adaptation gains acceptability, it is possible to implement measures that can appear more stringent in terms of individual choices. The objective is to move beyond individual protection towards collective measures of adaptation. The following list focuses mainly on regulatory modifications and the implementation of collective action. In bold are measures that should be targeted in priority.

- **1c: collaborate in the creation of a portal to promote awareness, and in the development of a risk culture;**
- **3: create a data portal and make it available to the public, landowners, asset owners and businesses;**
- 5a: develop citizen-based data gathering and monitoring programs;
- 6b: evaluate storm water management practices necessary to expand surface water storage, enhance water quality treatment and reduce storm water discharges;
- **7a: evaluate the possibility of adopting a coastal regulation to limit the residential spread within the exposed zones;**
- **7b: modernize permitting, planning, and design standards to incorporate future climate considerations into land use and building regulations;**
- **10: assist the municipalities in reviewing all local comprehensive, transportation, infrastructure and capital improvement plans and determine the gaps in asset planning for projected climate changes;**
- **12: require the deposition of a collective coastal management plan by municipalities;**
- **14: create a regional emergency preparedness plan framework;**
- 15: conduct training exercises involving emergency services and local responders to respond to severe, wide area flooding, erosion, storm events, fires, and improve delivery of services and response times;
- **16: create programs for vulnerable populations, to prepare for and prevent additional impacts, and to prepare for and mitigate, the need for additional recovery efforts.**

6.3 LONG-TERM: INTEGRATED DEVELOPMENT AND HOLISTIC ACTION

The following actions are proposed for the long-term and mainly pertain to ecosystem services and planning. While their implementation could be planned as early as in the first phase, their widespread implementation and consequences will extend on the longer term.

- 9a: zone key social, economic or environmentally significant sites as conservation areas;
- 9c: adopt local estate tax incentives for protecting and conserving vulnerable and significant ecosystems;
- 9d: acquire conservation easements or conservation land for critical wetland and coastal zones;
- 9e: promote the creation of living shorelines and riverbanks at the regional scale.

7 MONITORING

7.1 GENERAL EVALUATION

The implementation of institutional mechanisms to monitor and update the adaptation plan is essential to demonstrate that the plan provides the expected outcomes or to be proactive in doing the necessary adjustments. Monitoring consists in:

- the progress of measures;
- reviewing assumptions;
- updating the plan.

Here is a list of questions to help measure progress:

- Are local authorities, populations, and other stakeholders concerned by climate change adaptation (survey)?
- Did you improve your technical capacity to face climate change impacts?
- Are the different aspects of climate change being addressed in decision-making?
- Did the actions that were undertaken increase the adaptation capacity of infrastructure, social systems, and natural systems that were targeted by the plan?
- Are the different stakeholders engaged in the implementation of the adaptation plan (Climate Impacts Group King County, 2007)?

7.2 SPECIFIC MONITORING

Every measure that is implemented should be monitored using Table 13. Monitoring should cover the following aspects:

- The objectives of the measure;
- A list of indicators to evaluate the efficiency of the measures;
- A mechanism to include new information regarding climate change;
- Frequency of updates;
- Timing of the first evaluation.

Table 13 Example of a Monitoring Table for Specific Adaptation Measures

Measure Number	Objective	Indicator	Update Mechanism	Frequency of Update	Timing of First Evaluation
1a	Improve citizen knowledge regarding climate change	Number of public sessions Participation rate to the public sessions	Partner with academics to prepare or review information provided	Upon completion of the coastal erosion study or in 1 year	2 years

Note that a single measure can have many objectives, indicators, and update mechanisms.

8 COMMUNICATION STRATEGY

This section presents different considerations to promote good communication of the adaptation plan and measures, to maximize the outreach, and to favor social acceptability.

8.1 GENERAL RECOMMENDATIONS

- Communications should be made available in French and English;
- Include easy to understand graphics;
- Use accessible font styles and sizes;
- Limit the use of overly scientific language;
- Use consistent terminology throughout;
- Focus on actions and steps forward;
- Use site-specific examples when possible;
- Frame the problem in a way that overlaps the values of the target audience.

8.2 DISSEMINATION OUTLETS

- Traditional Media;
- Radio;
- Television;
- Newspapers;
- Community areas;
- Schools;
- Community centers;
- Sports venues;
- Issue and Policy Briefs;
- Community Workshops and Seminars;
- Social Media;
  - Facebook groups;
  - Twitter.

8.3 COMMUNICATION TARGETS

- **Government leaders and policy makers:** this includes the leaders of the municipalities and the local service districts. They decide local policy and have knowledge and access to their local communities.
- **Public health officials:** those in the public health field are themselves an effective tool for disseminating information and often have an established network of highly vulnerable groups. In addition, as climate change can often lead to health impacts, they are directly impacted by the effects.
- **Vulnerable groups**: this includes those that are geographically vulnerable, such as the residents of Beresford Dune who are located directly in the projected flood plain, and those who are demographically vulnerable: seniors, those with young children, those with pre-established conditions, and those who are economically unstable.
- **General public**: everyone who lives within Chaleur Region and those who may be temporary residents such as tourists.

8.4 WHEN TO COMMUNICATE

Communication can be strategically timed to coincide with specific events such as a severe storm event. For example, releasing information on adapting to higher flood levels right after a heavy rainfall may help create a connection in a user's mind between the event, climate change, and adaptation measures. In addition, adaptation measures that are season dependent may be released during or prior to the season to stay fresh in the public's mind.

8.5 HOW TO COMMUNICATE

To effectively communicate adaptation options, information must be disseminated in a way that is accurate, succinct, and that connects with the values and emotions of the recipient. The downfall is that the perception of climate change impacts is global, in the future, and far away, therefore adaptation is not an immediate need. To combat this, communications should highlight:

- the risks of inactions;
- local impacts;
- short-term effects.

Creating a narrative that this problem will have near-term local consequences and warrants public attention will help convince an audience that action is necessary. In addition, when it is possible for communications to coincide with audience values and concerns, use the examples provided in the following table.

Table 14 Different Audience Values and Concerns

Business and Economic-Focused Groups	Government and Public Policy Audiences	Public Audiences
– Risks to company profits or business models – Adaptation measures can create resiliency and long-term prospects for growth and stability – Assessing climate change may demonstrate s long-term vision to shareholders – Adapting increases competitiveness and avoids stranded assets	– Climate change will undermine the achievements of major public policy goals – Cost prevention is demonstrably less expensive than reaction – With proper adaptation there are opportunities that can be exploited	– Risks to health and well-being of family and friends – Action will prevent the loss of livelihoods and assets – Adaptation will save money in the long term – Adapting will protect the community – Climate change is a social issue that will affect the local culture

8.6 PITFALLS TO AVOID

When promoting adaptation options, communications should not be focused on uncertainty, the negative impacts of climate change, or using overly scientific language. While uncertainty is a necessary part of climate projections and risk assessments, the public will often unnecessarily concentrate on the uncertainty of an occurrence over its high probability. This translates into the wording of material. For example, stating that there is a 70% probability of an occurrence will resonate better than saying that the uncertainty is 30%. Focusing on the “doom and gloom” of climate change has been shown to create anxiety and not encourage action. Instead, emphasizing the benefits of climate adaptation policies and creating a call to action has been shown to be more effective in encouraging action. Lastly, all communications should be easy to understand by the non-technical layperson with no background in climate change.

9 CONCLUSION

Climate change is already ongoing and the coastal communities from Eastern Canada will be amongst the populations mostly affected by sea level rising and modifications to coastal dynamics. At the local or regional scale, communities have the responsibility to act now to adapt to tomorrow's changes.

In Chaleur RSC, sea level rising will cause major impacts in terms of flood frequency, the rate of coastal erosion or saltwater intrusion in drinking wells. Inland hazards, such as fluvial flooding, pluvial flooding, storms, forest fires or vector-borne diseases will also affect populations.

Elaborating an adaptation plan is a complex task that must be coherent with the human and physical geography, but also with policies and regulations at different levels (municipal, provincial and national). Moreover, it must be accepted by the citizens to make sure that they are engaged in the process. The implementation should be carried out by a team with multidisciplinary expertise.

The present document listed the main climate trends, climate-induced hazards and associated risks that were targeted by the adaptation measures. The latter were divided in five categories:

1. Education and awareness;
2. Knowledge and data acquisition;
3. Planning and regulation;
4. Protective measures;
5. Emergency planning.

Every measure is coherent with the vision that was formulated following consultations with the communities and the CRACCCA, and can be implemented on three different timeframes.

Adaptation requires investment, therefore as the investments mitigate the severity of the expected consequences, and allow to occupy the new opportunity niches brought by the changing climate, they will also be profitable for the region.

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APPENDIX

A HIGH RISK ZONES

	Region	Site	Climate				Issue, Risk, Description, Impact	Vulnerabilities							Risk Level			Adaptation measures
			Coastal Flooding	Coastal Erosion	Inland Flooding	Other (specify)		Health and Safety	Social Health	Loss of livelihood	Infrastructure Damage	Property Damage	Damage to Industry	Environmental	Likelihood	Consequences	Risk	
1	Belledune	Gagnon Street		X			Erosion of road infrastructure.				X				High	Moderate	High	3, 4, 5
2	Belledune	Fenderson Street		X			Erosion of road infrastructure.				X				High	Moderate	High	3, 4, 5
3	Belledune	Two cemeteries		X			Erosion of cemetery. Cemeteries have been losing ground and graves.					X			High	Low	Moderate	1(b), 3, 4, 5
4	Belledune	Roherty Point		X			Has been experiencing coastal erosion. Roherty point is a natural area with a marine estuary.							X	High	Low	Moderate	3, 4
5	Belledune	Big Hole Brook			X		Flooded twice and destroyed a section of the road and a bridge in the past two years	X			X				High	High	High	3, 4, 5, 13
6	Belledune	Ocean Drive	X				Coastal Flooding	X			X				High	Moderate	High	1, 2, 3, 5, 7
7	Belledune	Belledune Port	X			Storm events	Several terminal buildings are within the 4.2m projected flood zone			X	X	X			High	High	High	1, 3, 5, 7
8	Belledune	New Brunswick Power Generating Station	X			Storm events	Secondary structures and smelter outbuildings are within the 4.2m projected flood zone. In addition, NB Power has expressed concern that reduced sea ice will increase the intensity of storm events.			X	X	X			High	High	High	1(b), 3, 7, 11
9	Belledune	Storm water management systems				Storm events and precipitation	It has been suggested that storm water management systems are inadequate for projected trends	X			X				Moderate	Moderate	Moderate	3, 4, 6(b)
10	Pointe-Verte	Cemetery		X			Erosion of cemetery. Cemeteries have been losing ground and graves.				X				High	Low	Moderate	1(b), 3, 4, 5
11	Pointe-Verte	Chalets Street	X				Coastal flooding (required police attention)	X			X				High	Moderate	High	1, 2, 3, 4, 5, 7
12	Pointe-Verte	Parc Est Street	X				Coastal flooding (required police attention)	X			X				High	Moderate	High	1, 2, 3, 4, 5, 7
13	Petit-Rocher	Coast from Beach park to the wharf		X			Has been experiencing coastal erosion.							X	High	Low	Moderate	1, 3, 4, 5
14	Petit-Rocher	Streets between Arseneau and Maurice Street		X							X				High	Moderate	High	1, 2, 3, 4, 5
15	Petit-Rocher	Doucet Street to du Havre Street	X				Sections of the sewer have been affected during storms.	X			X				High	Moderate	High	1, 3, 4, 5, 6(b)
16	Petit-Rocher	Maurice Street	X				Coastal flooding (rebuilt after 2010 flood)	X			X				Moderate	Moderate	Moderate	1, 2, 3, 4, 5, 7
17	Petit-Rocher	Arsenault Street	X				Coastal flooding	X			X				High	Moderate	High	1, 2, 3, 4, 5, 7
18	Petit-Rocher Nord	Camp Ectus Road	X				Coastal flooding	X			X				High	Moderate	High	1, 2, 3, 4, 5, 7

19	Nigadoo	Chaleur Street		X			Erosion of road infrastructure.				X				High	Moderate	High	3, 4, 5
20	Beresford	Beaches (North, East, West)		X			The total area of the beach has decreased by 51% from 1934 to 2002							X	High	Low	Moderate	1(a,b), 3, 5
21	Beresford	Salt Marshes	X	X			The total area of salt marshes has decreased by 2% from 1934 to 2002. Salt marshes are among the most productive ecosystems in the world, protect from coastal impacts, and those in Beresford are one of the few habitats of the endangered Maritime Ringlet Butterfly.							X	Moderate	Moderate	Moderate	1(a,b), 3, 5, 9
22	Beresford	Martin Street		X			Erosion of road infrastructure.				X				High	Moderate	High	3, 4, 5
23	Beresford	Beach		X			Erosion of dune. The dune must be built up every year to be conserved.		X		X			X	High	Moderate	High	1, 3, 5, 9
24	Beresford	Beresford Dune	X				Coastal flooding.	X			X				High	High	High	1, 2, 3, 4, 5, 7, 11
25	Beresford	John Cormier Street	X				Residents previously flooded during storm events.	X				X			High	High	High	1, 2, 3, 4, 5, 7
26	Beresford	Jacques Cartier Street	X				Road flooding	X			X				High	Moderate	High	1, 3, 4, 5, 7, 13
27	Beresford	Lent Lodge Street bridge	X				Flooded, making street impassible	X			X				High	High	High	1, 2(a), 3, 4, 5, 7, 13
28	Beresford	Beach Park Street	X				Flooding	X			X				High	Moderate	high	1, 2, 3, 4, 5, 7
29	Beresford	Des Chalet Street	X				House flooding	X				X			High	Moderate	High	1, 2, 3, 4, 5, 7
30	Beresford	Baie Street	X				House flooding	X				X			High	Moderate	High	1, 2, 3, 4, 5, 7
31	Beresford	Thomas and Bel-Air Street Intersection	X				House have been flooded here	X				X			High	Moderate	High	1, 2, 3, 4, 5, 7
32	Salmon Beach	Miller Brook Wharf		X			Erosion has been notes on the west side of the wharf.				X				Moderate	Low	Low	1(b), 3, 4, 5
33	Eastern Chaleur	Salmon Beach to Grande-Anse		X			More frequent freeze thaw episodes are accelerating cliff erosion. Increased cliff erosion poses a public safety threat and may limit developmental and economic activities.	X						X	High	Moderate	High	1(a,b,), 3, 5
34	Allardville	Little Bass River			X		Washed away a bridge	X			X				High	High	High	3, 4, 13
35	Allardville	Bass River			X		A bridge is often close to being submerged	X			X				High	Moderate	High	3, 4, 13
36	Allardville, St.Sauveur, Tétagouche-Nord	Nepisiguit Falls				Increased temperatures and changes to precipitation regimes	Isolated areas surrounded by trees (fire risk) 70 principle residences isolated	X			X	X		X	Low	High	Moderate	1(a,c,f), 2(a,b), 3, 4, 6(c), 13, 17
37	Dunlop	Middle River			X	Ice jams	Risk of isolating residents if bridges crossing Middle River Road were to become impassible	X			X				High	Moderate	High	1(a,c,e), 2(a), 3, 4, 13
38	Middle River	Mathilda Street and Theriault Road			X		Residents have had to be evacuated practically every year because of river overflow.	X				X			High	High	High	1, 2, 3, 4, 5, 13
39	Pabineau Reserve	Nepisiguit River and Pabineau River			X		Bridge across floods almost every spring. Has previously destroyed a section of the road.	X			X				High	High	High	1, 2(a), 3, 4, 5, 13

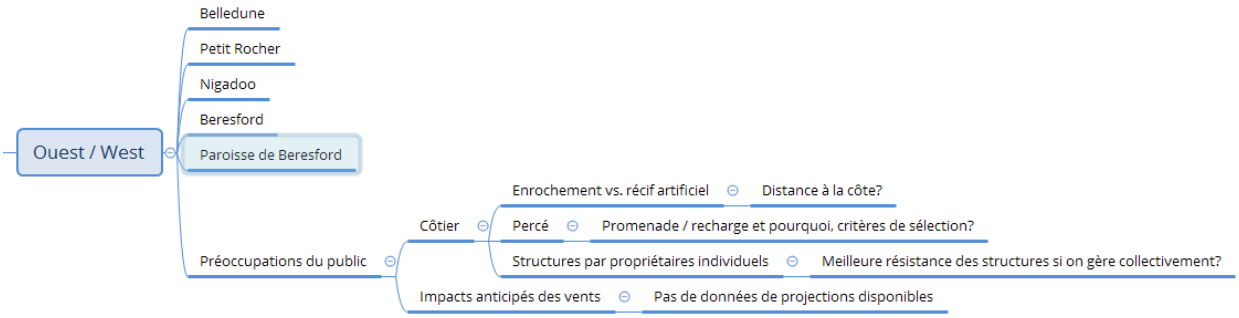
40	South Tétagouche	Bathurst Regional Airport				Storm events	Increase storm events risk endangering flights and damaging airport infrastructure.	X		X	X	X			Moderate	High	High	3, 4, 11
41	Chaleur Region	Nepisiguit River			X	Ice jams and increased precipitation	Several buildings and mines have sustained damage, nearby roads have been flooded, the bride across the Pabineau River flooded, and the Nepisiguit River Camp terrains sustained damage.	X	X		X	X			High	High	High	1, 2, 3, 4, 5, 13
42	Chaleur Region	Millstream River			X		River has flooded about fifteen houses in the past. Road flooding, evacuation for 6 days. Basements flooded.	X				X			High	High	High	1, 2, 3, 4, 5, 13
43	Chaleur Region (excluding Bathurst, Beresford, and Petit-Rocher)	Drinking wells	X			Shifts in precipitation regimes	Risk to wells from precipitation regime changes, sea level rise and salt water intrusion.	X							Moderate	High	High	1(b), 3, 4, 5a
44	Chaleur Region	Camp/Cottage/Recreational vehicle	X	X			There are 289 camp/cottages within the 4.2m flood zone and 25m coastal erosion buffer zones.	X				X			High	Low	Moderate	1, 2(a, b,c), 3, 5, 7
45	Chaleur Region	Agricultural/Farm/Cropland	X				There is 1 farm within the 4.2m flood zone. Located in Belledune.			X			X		High	Low	Moderate	2, 3, 4, 5, 6(e)
46	Chaleur Region	Heavy Industrial	X				There are 9 heavy industrial buildings in the 4.2m projected flood zone, including smelter outbuildings. These are concentrated in Belledune.			X	X	X	X		High	High	High	1, 3, 4, 11
47	Chaleur Region	Residential Units	X	X			There are 436 residential units within the 4.2m flood zone and 25m coastal erosion buffer zone.	X				X			High	High	High	1, 2, 3, 4, 5, 7
48	Chaleur Region	Small Retail Services/Office (<200m^2)	X				There is 1 small retail office within the 4.2m flood zone.			X		X			High	Low	Moderate	1, 2, 3, 4, 5, 7
49	Chaleur Region	Accessory Buildings	X	X			There are 1184 Accessory Buildings within the 4.m flood zone and 25m erosion buffer zone.					X			High	Low	Moderate	3, 4, 5
50	Chaleur Region	Pumping station	X	X			There are 8 pumping stations within the 4.2m flood zone and the 25m erosion buffer zone.				X	X	X		High	High	High	3, 4, 5, 6(b), 11
51	Chaleur Region	Seaport/Wharf/Marina	X	X			There are 6 such structures within the 4.2m flood zone and the 25m erosion buffer zone (this includes the Port of Belledune)				X				High	High	High	3, 4, 5, 11
52	Chaleur Region	Campgrounds	X				There are 6 campgrounds within the 4.2m flood zone	X	X	X		X			High	Low	Moderate	1, 3, 4, 5
52	Chaleur Region	Hotel/Motel/Inn	X				There are 11 Hotel/Motel/Inns within the 4.2 flood zone.	X		X		X			High	Moderate	High	1, 2, 3, 4, 5, 7
53	Chaleur Region	Mini and Mobile Home (not in park)	X				There are 7 of these structures within the 4.2m flood zone.	X		X		X			High	Low	Moderate	1, 2, 3, 4, 5, 7
54	Chaleur Region	Public Park/ Playground	X				There are 20 public parks and playground within the 4.2m flood zone.		X			X			High	Moderate	High	3, 4
55	Chaleur Region	Treatment plant (sewage, lagoon)	X				There are two of these structures located within the 2.4m flood zone.	X			X	X		X	High	High	High	3, 4, 11

56	Chaleur Region	Education	X				There are two educational buildings within the 4.2m flood zone. One is in Petit-Rocher and one is in Beresford		X						High	High	High	1, 2(a), 3, 4, 5, 11
57	Chaleur Region	Indoor Recreation	X				There are two indoor recreation buildings within the 4.2m flood zone, both in Beresford.		X						High	Moderate	High	1, 2(a), 3, 4
58	Chaleur Region	Large retail service/office	X	X			There are three large retail buildings located within the 4.2m flood zone and 25m erosion buffer zone. There are concentrated in Salmon Beach New Bandon and Nigadoo.			X		X			High	Moderate	High	1, 2(a,b), 3, 4, 5, 7
59	Chaleur Region	Children’s Camp	X				There is one children’s camp located within the 4.2m flood zone.		X						High	Low	Moderate	1, 2(a), 3, 4

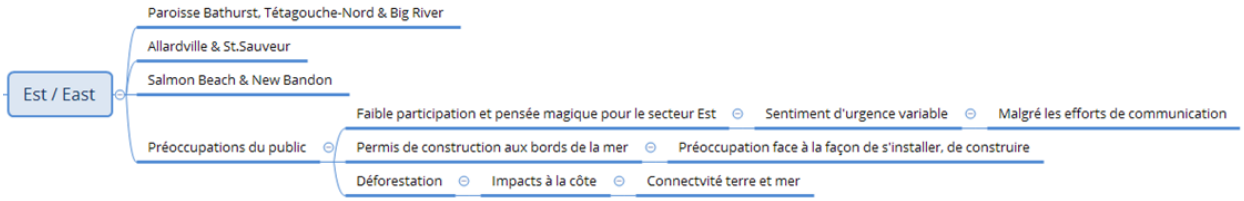
APPENDIX

B MIND MAPS

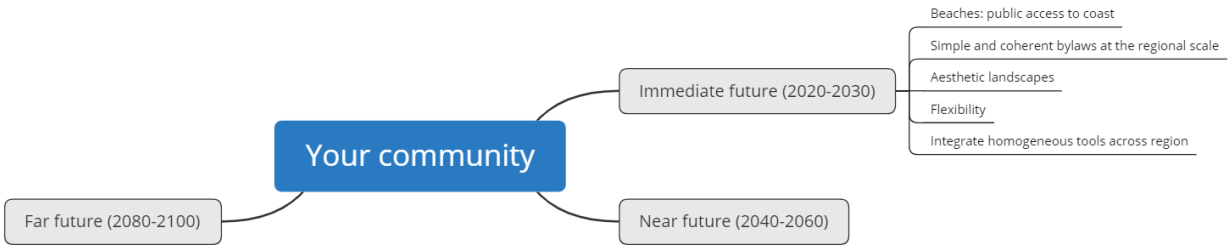
Mind map summarizing the exchanges between WSP and citizens from the western sector.



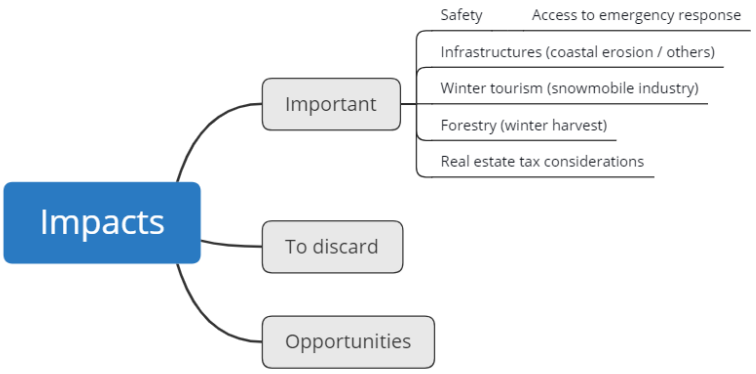
Mind map summarizing the exchanges between WSP and citizens from the eastern sector.



Mind map summarizing the vision of the CRACCCA.

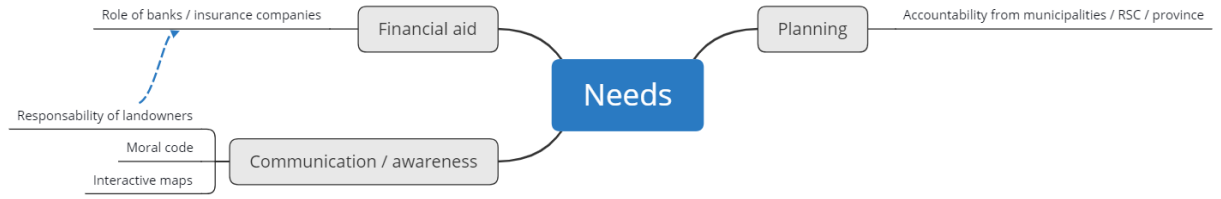


Mind map summarizing vulnerability identification by the CRACCCA.

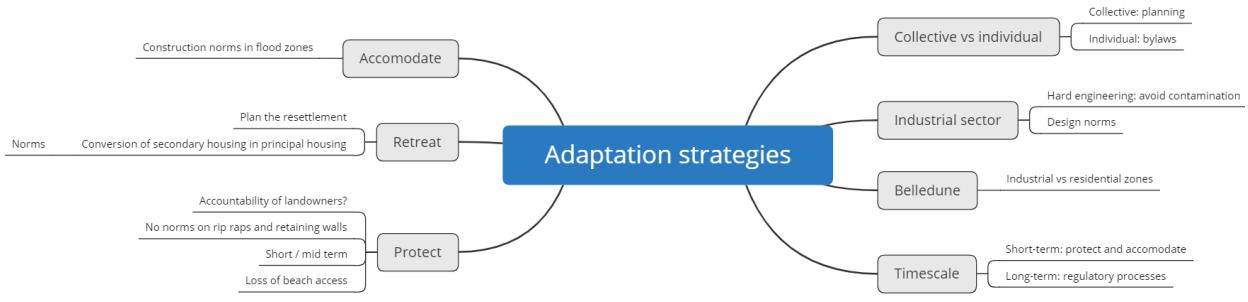


Mind map summarizing vulnerability priorities by the CRACCCA.

Mind map summarizing needs for adaptation by the CRACCCA.



Mind map summarizing the preferred adaptation strategies by the CRACCCA



APPENDIX

C 72-HOUR KIT

Always have the following items in your home. Ideally, they should be placed in a backpack or a storage bin:

- Drinking water — two litres per person per day, for at least 3 days;
- Non-perishable food — enough for at least 3 days;
- Manual can opener;
- Battery-operated radio — spare batteries;
- Flashlight or headlamp — spare batteries, or a hand-crank flashlight or headlamp;
- Lighter or matches and candles;
- First Aid kit — antiseptic, pain medication, adhesive bandages, sterile gauze pads, scissors, etc.;
- Whistle — to signal your presence to rescuers;
- Dust masks — to filter contaminated air;
- Map or GPS;
- Compass;
- Sunglasses and sun lotion;
- Pocketknife;
- Small toolbox;
- Tent, sleeping bag and foam mat;
- Camping stove, fuel and kitchen utensils;
- Personal care items;
- Over-the-counter medications (antihistamine, ibuprofen, acetaminophen, etc.);
- Prescription medications (prescribed by your doctor);
- Garbage bags;
- Hiking shoes or boots;
- Waterproof clothing;
- Spare clothes;
- A deck of cards, books, magazines.

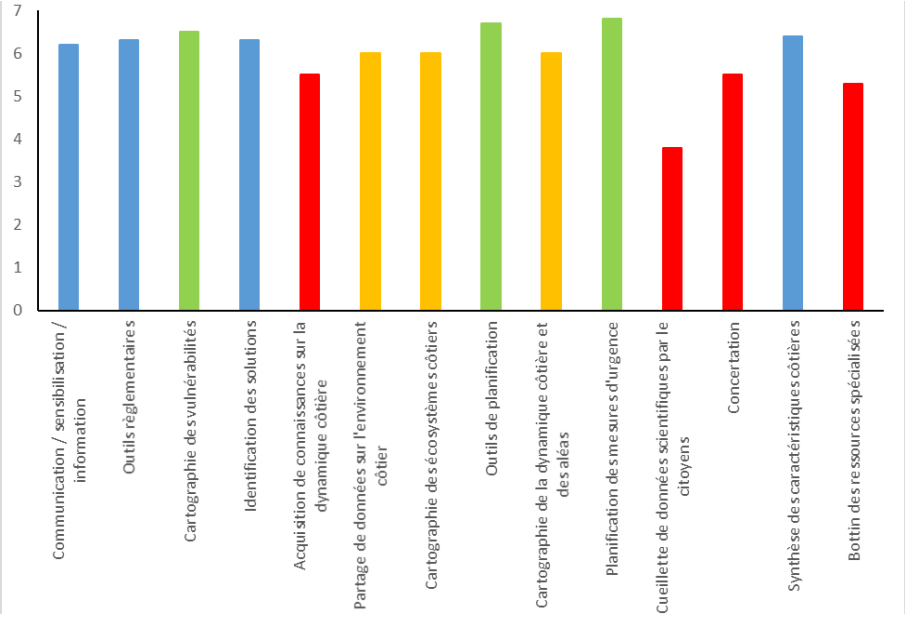
The first seven items will make it possible for you and your family to survive during the first 3 days of an emergency, while you wait for rescue or for essential services to be re-established. They should be stored together and be updated every year to replace perishable items (batteries, medication, etc.).

APPENDIX

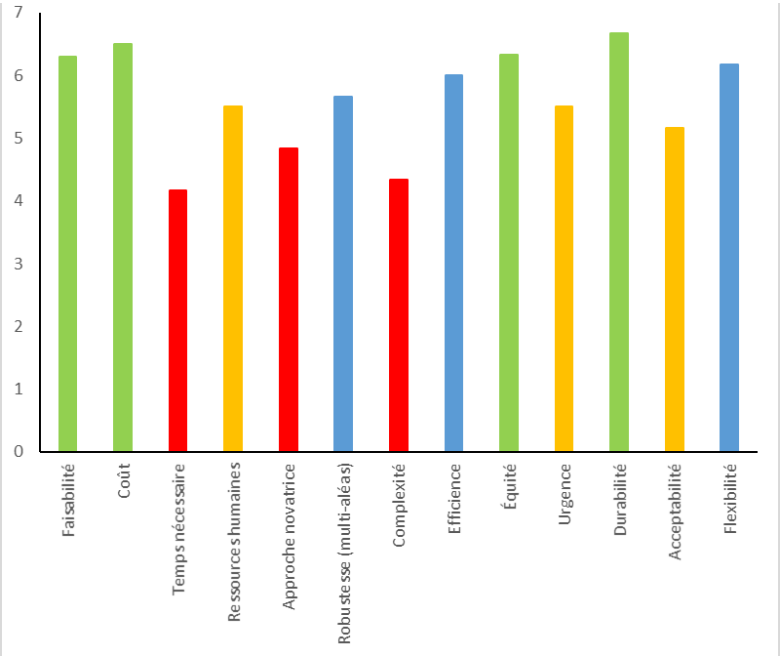
D SURVEY RESULTS

For each question, respondents had to attribute a score from 1 to 7 to each answer. The results present the average score for every answer. Green: 1st quantile. Blue: 2nd quantile. Yellow: 3rd quantile. Red: 4th quantile.

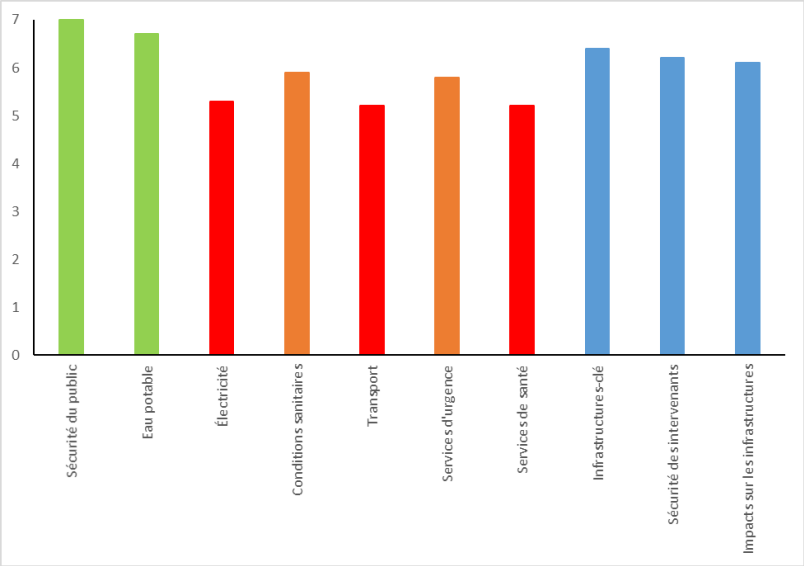
Preferred decision-making tool for a successful adaptation.



Importance of the implementation criteria to select adaptation measures



Importance of the direct impact criteria to select adaptation measures



Importance of the indirect impact criteria to select adaptation measures