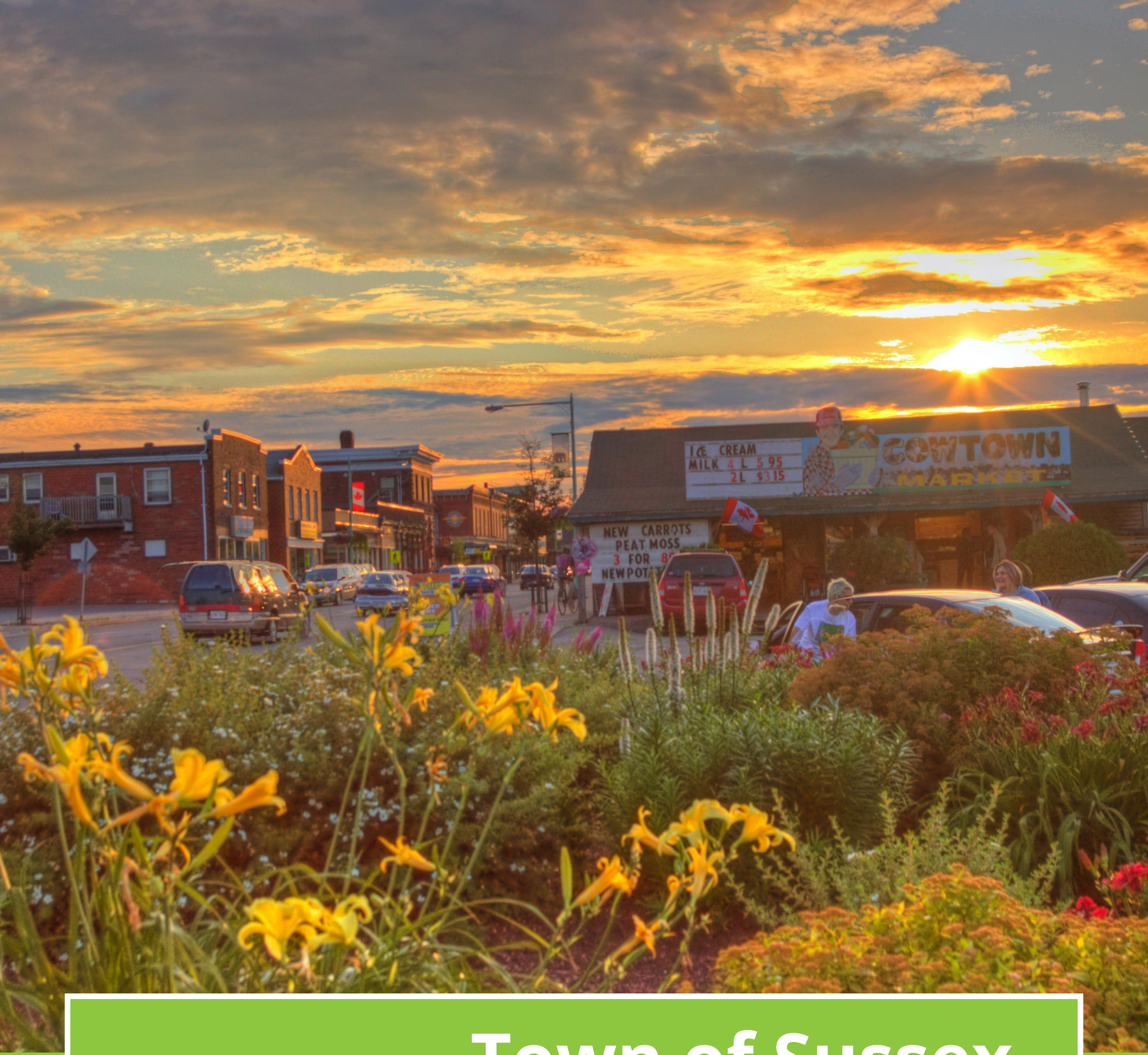

Town of Sussex
Climate Change Adaptation Plan

Phase 1 Final Report

192872.00 • Report • March 2020

Draft Final Report		30/03/2020	
Draft Report	D. Parsons	28/02/2020	L. Wilcott
Issue or Revision	***Reviewed By:***	***Date***	***Issued By:***

CBCL LIMITED
Consulting Engineers

This project was made possible with support from the New Brunswick Environmental Trust Fund

New Nouveau Brunswick
C A N A D A
Your Environmental Trust Fund at work
Votre Fonds en fiducie pour l'environnement au travail

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Solving today's problems with tomorrow in mind

March 30th, 2020

Scott Hatcher, CAO
Town of Sussex
524 Main Street
Sussex, NB
E4E 3E4

Dear Scott:

RE: ***Town of Sussex Climate Change Adaptation Plan- DRAFT FINAL REPORT***

The attached draft final report provides an adaptation plan for the highest ranked climate change and extreme weather-related vulnerabilities in the Town of Sussex. Discussions on historic extreme weather events, such as the 2014 spring flooding, as well as a thorough analysis of future climate change impacts are included.

The risk assessment includes an evaluation of climate change and extreme weather impacts on the Town's infrastructure, assets, and environment. Discussions on potential adaptation measures for each of the top five highest ranked priority vulnerabilities are presented, which include climate change and flooding impacts to (in no order):

1. Sewer Lift Station Flood Vulnerabilities
2. Flood Mitigation for Municipal Drinking Water
3. Flood Mitigation for Key Transportation Routes
4. Municipal Policy Development Update
5. EMO Planning and Emergency Response Plan Update

This report will be finalized following public and stakeholder consultation in Phase 2.

Thank you for the opportunity to work with the Town of Sussex on this important project.

Yours very truly,

CBCL Limited

Prepared by:
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Reviewed by:
David Parsons, P.Eng.
Senior Municipal Engineer

Project No: 192872.00

Contents

Appendices

Executive Summary

The Town of Sussex has received funding from the Environmental Trust Fund (ETF) to complete a Municipal Climate Change Adaptation Plan. All cities and *high-risk* municipalities, who have experienced the impacts of climate change and flooding in their region of New Brunswick, are required to have adaptation plans completed by 2020 as stated in the Government of New Brunswick's Climate Change Action Plan –*"Transitioning to a Low-Carbon Economy"*.

The Town of Sussex engaged CBCL to complete the Town of Sussex Climate Change Adaptation Plan (Plan) to address climate change and extreme weather vulnerabilities for key areas of the Town. Areas of the Town studied in the assessment include municipal infrastructure (sanitary collection system, water distribution systems, transportation systems, and trails), recreational facilities, municipal buildings, emergency services, tourism and economic development, as well as development and planning. The objective of the plan is to identify critical climate change parameters, predict changes to climate and extreme weather over time, and determine the impacts of these predictions on the community.

The Climate Change Adaptation Steering Committee was led by the Town of Sussex, which included Bill Wanamaker (Fire Chief), Rick Horton (EMO Coordinator), Brandon Love (NBDELG), Scott Hatcher (CAO), Jason Thorne (Community Services Director), and Dave Marriott (Water and Wastewater Foreman).

A risk assessment was completed to determine the most vulnerable areas of the Town using a function of severity and probability, with input from members of the Climate Change Adaptation Steering Committee. A thorough analysis of climate change parameters such as temperature, wind, precipitation, and river flooding, among others, are presented. This analysis is complimented with discussions on flood vulnerabilities. The resulting five (5) chosen impacts for adaptation are summarized below:

1. Sewer Lift Station Flood Vulnerabilities.
2. Flood Mitigation for Municipal Drinking Water.
3. Flood Mitigation for Key Transportation Routes.
4. Municipal Policy Development Update.
5. EMO Planning and Emergency Response Plan Update.

Adaptation options and actions are presented for the Town's at-risk infrastructure to prioritize future mitigation and adaptation investments. The Plan will serve to increase community resilience to climate change by assigning mitigation actions with an short-, medium-, and long-term timeframe, a lead department to execute the adaptation actions, and a high level cost or level of effort estimate to assist the Town in securing funding resources and for capital planning purposes.

The next step for the project will be community and stakeholder engagement in Phase II, where the project team will present the major findings of the Plan with Town residents, business owners, special interest groups, and/or developers, to communicate the importance of climate change preparation and adaptation. Engagement activities will also serve to provide the project team with community feedback on the adaptation plan, to be incorporated in Phase II.

CHAPTER 1

Introduction

1.1 Climate Change Adaptation

Image Source: cbc.ca

In the past, Canada has warmed at approximately two-times the magnitude of global warming, this trend is projected to continue into the future (Bush, 2019). Over the period of 1948 to 2016, Canada has experienced a mean annual temperature increase of 1.7°C (Bush, 2019). Atmospheric warming is linked to changes in extreme temperatures, precipitation, sea level, inland water levels, permafrost, and extreme weather events (Palko, K. and Lemmen, D.S., 2016). Climatic variability is creating both opportunities and challenges for Canadian municipalities.

The New Brunswick Climate Change Secretariat (CCS) is a branch in the Department of Environment and Local Government (DELG). They are mandated to develop, implement, and report, in cooperation with other departments, on actions that address Greenhouse Gas (GHG) emissions reductions and climate change adaptation. The CCS works to disseminate climate change awareness programs and share information and best practices with industry and professional organizations. The CCS provides adaptation tools and resources such as climate change indicators, climate change projection data and maps, adaptation planning guidance, coastal and inland flood risk maps, as well as others, to assist communities in completing risks and vulnerability assessments, and adaptation plans. Climate change indicators are measured parameters that depict observed changes in our climate systems. These parameters are analysed over time to detect regional climate trends. Longer time scales (decades) tend to display clearer climate trends whereas over shorter time scales, such as from year to year, weather can be extremely variable.

Climate change can threaten the economic and social benefits of the riverine environment as higher water levels and changing river flow and ice regimes amplify erosion of waterways and cause costly flooding. In comparison, summer heat waves and drought cause low water levels which raise public health concerns for vulnerable populations and threaten groundwater supplies. Similar to changes experienced throughout New Brunswick, Sussex's summers are becoming warmer and extreme temperatures are increasing; extreme storms and power outages are occurring more frequently; and low lying areas are increasingly vulnerable to flooding.

Outdoor recreation, and time spent on and around the Kennebecasis River and its tributaries, such as Trout Creek, are a favorite past time for residents of the Sussex area. In the summer months, people enjoy fishing, canoeing, kayaking and swimming in local waterways. In addition, there are several outdoor events that take place such as the Sussex SummerFEST, Kings County Agricultural Fair, Sussex Flea Market, and most notably the Atlantic International Balloon Fiesta. Other outdoor activities include the weekly Sussex Farmers Market at Leonard's Gate, gardening at the CO-OP Community Garden, events at the Sussex Rotary Amphitheatre, walking along the Sussex Nature Walkway, or enjoying one of the many parks. In the winter, people enjoy the Tree Lighting and Festival of Trees hosted by the Town, as well as snowmobiling and snowshoeing on nearby trials. Poley Mountain, located on the outskirts of Sussex, is a popular tourist destination for downhill skiing and snowboarding. All of these activities will be impacted to some degree in the future by climate change.

Adapting infrastructure and operations to a changing climate and emerging environmental conditions remains a relatively new area of focus for many sectors, despite many Canadian communities reporting vulnerabilities to climate change. (Palko, K. and Lemmen, D.S., 2016). Mitigation and adaptation are the national leading responses to climate change where:

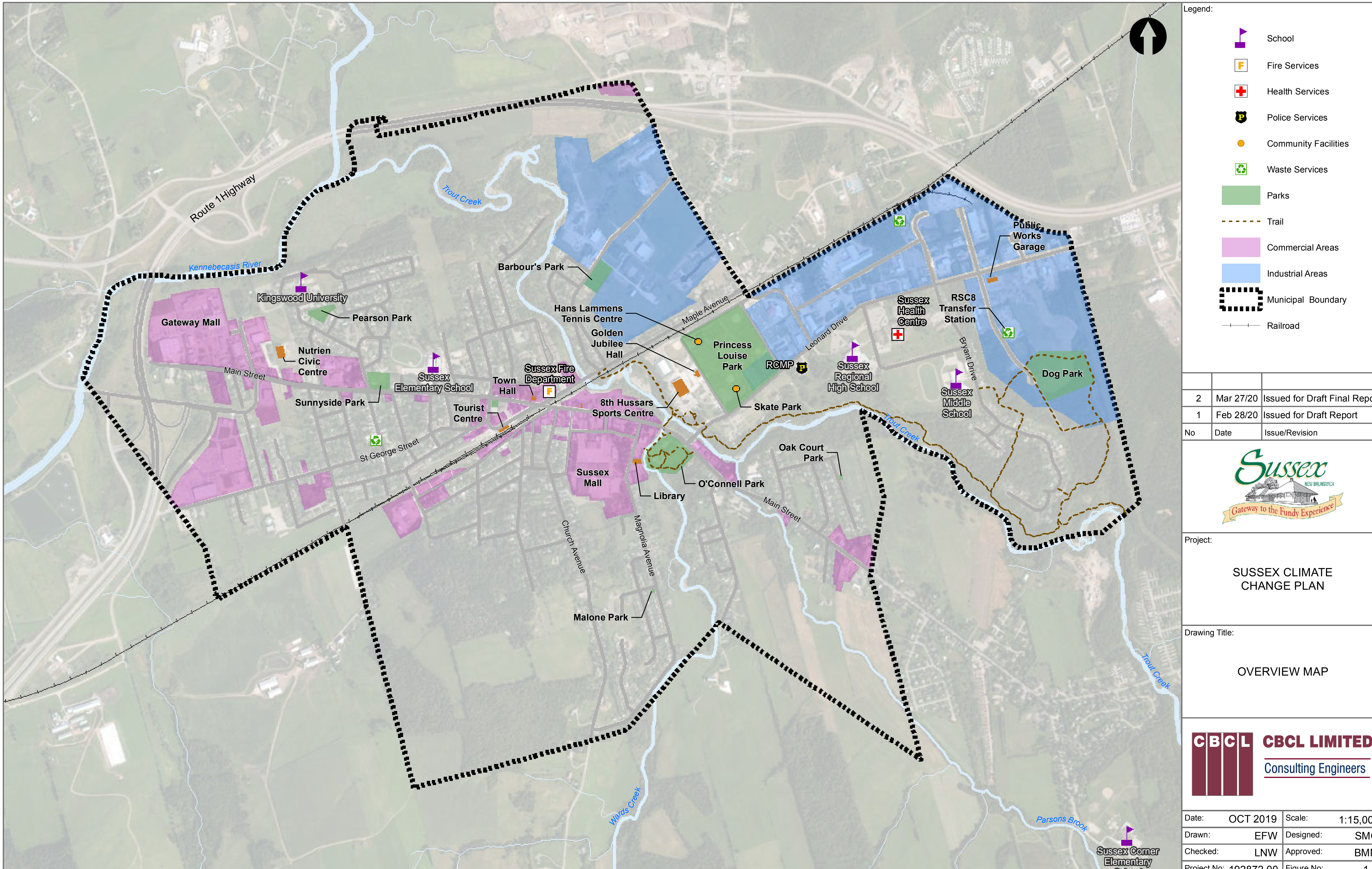
- **Mitigation** refers to actions related to GHG emission reductions; and,
- **Adaptation** refers to any activity that lessens the negative impacts of climate change and/or takes advantage of opportunities created by climate change. This includes actions taken before impacts are observed (anticipatory), and after impacts have been felt (reactive).

This climate change adaptation plan presents local measured, observed and projected impacts of climate change on the community, infrastructure, economy, and environment. The Plan presents options to mitigate and adapt to these changes. Adaptation can take the form of infrastructure resilience to extreme weather, policy implementation, or identifying and taking advantage of the opportunities presented by climate change (i.e. longer growing seasons, reduced winter heating costs and prolonged summer temperatures). The Province of New Brunswick has created a guide to Climate Change Adaptation Planning for New Brunswick Communities (DELG, 2018) which details the methodologies available for executing risk assessments and climate change adaptation plans for various sized communities across the province.

This report outlines the different climate change impacts, vulnerabilities and opportunities that exist for the Town of Sussex, while focusing on increasing community capacity to reduce the adverse impacts of climate change and extreme weather through adaptation planning.

1.2 Background

The Town of Sussex is situated along the Kennebecasis River, in Kings County, New Brunswick. Figure 1.1 on the following page shows the Town's administrative boundary and neighbouring areas with Local Service District (LSD) of Cardwell, LSD of Studholm, LSD of Sussex, and the Village of Sussex Corner. The Town of Sussex was established in 1904 and is known to be located in a rich agricultural area. Currently, the Town of Sussex has a population of 4,282 (2016 Census, Statistics Canada, 2019) and the majority of the population (85%) are predominately English speaking (2016 Census, Statistics Canada, 2019).



No	Date	Issue/Revision
2	Mar 27/20	Issued for Draft Final Report
1	Feb 28/20	Issued for Draft Report

Sussex NEW BRUNSWICK Gateway to the Fundy Experience

Project:

SUSSEX CLIMATE CHANGE PLAN

Drawing Title:

OVERVIEW MAP

CBCL LIMITED Consulting Engineers

Date:	OCT 2019	Scale:	1:15,000
Drawn:	EFW	Designed:	SMO
Checked:	LNW	Approved:	BMM
Project No:	192872.00	Figure No:	1.1

The Town is home to three public schools, hospital, commercial malls, one university, numerous public services (such as the Sussex Regional Library), Sussex Fire Department, and Sussex Solid Waste Transfer Station. The Town also maintains various recreational facilities including: the 8th Hussars Sports Centre, Nutrien Civic Centre, Hans Lammens Tennis Centre, Sussex Skate-park, Sussex Bark Park, Sussex Nature Walkway, various baseball fields, parks, and green spaces. The Town of Sussex has a rich history, featuring several historical sites throughout the Town including; the Intercolonial Railway Station, 8th Hussars Regimental Museum, Agricultural Museum, Sharp's Corner Drug Store, and Sussex Ginger Ale Factory, to name a few. The Town of Sussex has also gained a reputation as being named Communities in Bloom National Champion, and also being the Mural Capital of Atlantic Canada.


Image Source: sussexmurals.com

The Town of Sussex is divided into commercial, industrial, institutional, residential, and park areas. The majority of the commercial development is situated in the western part of the Town, referred to as the Downtown Business district, while one regional mall is located to the west. An industrial park is found in the north eastern side of town and is composed of several different businesses with a range of services.

The Town's economy is heavily influenced by neighboring communities and tourism, where the Town's population has been known to increase considerably during the summer months. Agriculture is a significant economic driver in the region. Often referred to as the Dairy Capital of the Maritimes. Another major contributor to the local economy is the Sussex Sawmill owned by JDI, as well as their woodlands divisions. In the past, two active potash mines were located near the Town, located in Penobsquis and Cassidy Lake. Also located in Penobsquis is the McCully Field, owned by Headwater Exploration Inc. Despite economic changes over the past few years, Sussex remains a hub for small business owners, agriculture, and tourism.

This study aims to assist the Town in proactively addressing climate change by:

- Providing an understanding of riverine flooding vulnerabilities to support developers and residents in reducing the uncertainties related to extreme weather and flooding;
- Determining the impacts of climate change on infrastructure. This allows the Town to perform long-term financial planning and to invest in critical infrastructure that is predicted to be adversely affected by climate change;
- Consulting with various representatives from the Town and other stakeholders to gather useful insights and further enhance the relationship between these groups;
- Performing community engagement in Phase 2 which will serve to enhance relationships between community members and the Town; and,
- Providing a greater understanding of asset vulnerabilities to inform asset management practices and adaptation planning.

Image Source: communitiesinbloom.ca

The Town of Sussex has a transportation network that includes 42 km of road, signalized and unsignalized intersections, street lighting, and signage. The Town is responsible for both maintaining and removing snow from municipal roads. There are four bridges within the municipal boundary; however, these are provincially owned structures. The Town provides infrastructure for active transportation, including sidewalks line the streets in high traffic areas, and numerous trails. Approximately 7 km of gravel trails wind along Trout Creek to the eastern portion of the Town. The municipality maintains the trail system during the summer months, while trails are used for snowshoeing and other winter activities during the winter.

The Town of Sussex treats and supplies potable water from a local groundwater source. Presently, the Town has two production wells within its potable water distribution system; one located on Magnolia Avenue and the other on Jonah Court. These productions wells are capable of each supplying 3,637 L/min to customers within the Town as well as some residents outside its municipal boundaries. Groundwater at the production wells is treated with chlorine and then transported through a 56 km potable water distribution system via watermains to consumers. The Town has two reservoirs located atop a hill at the south end of Pleasant Avenue. The reservoirs have capacities of 5,683 m^3 and 1,137 m^3 respectively.

Stormwater is collected throughout the Town of Sussex via 32 km of storm water piping. The stormwater collection system discharges into local waterways, including; Trout Creek, Parsons Brook, Wards Creek, and the Kennebecasis River. The Town collects and treats wastewater from both residential properties and businesses within the municipality, as well as some residences outside of Town. The wastewater collection system consists of 47 km of gravity sewer, 2 km of force-main, and 6 sewage lift stations (SLSs). Wastewater is treated at the lagoon in the west end of Town, which is comprised of 2 aeration cells.

The Town is responsible for managing its own municipal solid waste. Garbage is collected and transported from Sussex to the Westmorland sorting facility in Moncton. The Town maintains a compost facility for brush and organic products. NB Power supplies electricity to the homes and businesses within the municipal boundaries.

As determined through a recent Asset Management Plan, the majority of Town assets are in good condition and provide a solid foundation for the community to attract business and foster population growth. The Town of Sussex is a resilient community with a vibrant history and a common vision shared by community planners and citizens, attracting new people and business through continued support of sustainable development. This Climate Change Adaptation Plan will support the Town's ongoing initiatives and strategic plans for sustainable and resilient development and growth.

1.3 History of Flooding

Image Source: thestar.com (April 16th 2014)

As recently as the winter of 2019, Sussex experienced flooding that caused evacuations of homes due to high rains. In 2014, the Town of Sussex experienced significant spring flooding that caused substantial damage to businesses and homes. Town residents have also experienced incidents of ground water flooding in basements during the seasonal high groundwater table.

Town leadership has expressed that flooding events experienced in Sussex may be the single most important issue faced by residents and surrounding communities. Mayor Thorne stated in a May 13 2019 press release (sussex.ca) "*I believe there is a need to begin the process of introducing flood mitigation improvements and to explore the development of a Master Plan to attempt to achieve a potential flood solution. There are technical difficulties and difficult approvals for any plan, but a solution is worthy of consideration and to begin the planning and development of the Master Plan/ solution.*"

1.4 Previous Studies

There have been several site specific studies completed for infrastructure that is currently or potentially vulnerable to climate change in the Sussex region. These studies include:

1. Trout Creek Bank Stabilization Assessment (CBCL, 2015).
2. Sussex Flood Study (RVA, 2016).
3. Sussex Region Flood Risk Mitigation Plan (RVA, 2019).

The key findings related to these studies are summarized in the following sections.

1.4.1 Trout Creek Bank Stabilization (CBCL, 2015)

In 2015, CBCL performed a stream bank stabilization assessment for Trout Creek in the Village of Sussex Corner. Due to the local topography, the area surrounding Trout Creek experiences frequent flooding, which causes some of the banks to erode. In total, three locations were identified as having bank erosion that was of concern. These three areas were located just upstream of the Post Road bridge, which included a stream bend at Sullivan Park that previously had riprap installed. A hydrologic assessment was conducted on the area of interest to determine peak flow for the 1-in-100-year flood under current and climate change conditions. It was determined that under current conditions, Trout Creek is estimated to have a flow of 327 m^3/s during a 1 in 100-year flood event.

Climate change is predicted to increase the frequency of high intensity rainfall events in New Brunswick; thus, impacting runoff volumes and peak flows. Environment Canada (EC) estimated changes during 24-hour rainfall events for different return periods at a number of climate stations across the province. It was concluded that the Trout Creek area could experience up to a 30% increase in rainfall in the future. The climate change 1-in-100-year design flow for the project site was estimated to be 425 m^3/s.

A hydrodynamic assessment was performed to using MIKE3 modelling software to compute water levels, flows, and velocities at the project site. The calibrated MIKE3 model estimated peak flows during the 1-in-100-year design flows for existing climate conditions and climate change conditions, respectively. The local 1-in-100-year peak velocities for the three eroded areas was deemed to be up to 3.5 m/s for both design flows. With the above information in mind, erosion protection was evaluated for all three sites. Four erosion protection options were presented including riprap, turf reinforcement mat (TRM), an energy dissipation pool, and a stream diversion. After careful evaluation, riprap or a combination of riprap and TRM were recommended for the sites over energy dissipation pool and stream diversion, due to cost and other site specific factors.

1.4.2 Sussex Flood Study (RVA, 2016)

In 2016, RVA completed a flood study for the Town of Sussex. The study was conducted to review past flooding risk and severity in the area and to determine future risk and severity in order to identify and assess potential mitigation measures. Although flood mitigation measures were restricted to the municipal boundary of the Town, the study area was expanded to include the Kennebecasis River, Trout Creek, Wards Creek, and Parsons Brook watersheds.

The study assessed the land use and development within the watersheds via aerial photographs between 1971 and 2010 for both the Town of Sussex and Village of Sussex Corner. The municipal land was divided into three classifications: urban development, wooded/forest, and agriculture/pasture. Overall, there was an increase in urbanization (+13.2%) followed by a decrease in both wooded/forest (-4.0%) and agriculture/pasture (-9.2%) from 1971 to 2010. As a result, this increase in urbanization has caused an increase in surface runoff and flood flows ranging from less than 0.1% increase in the Kennebecasis River to 1.2% increase in Parsons Brook.

Climate change was also taken into account for future impacts from flooding. The effects of climate change on Eastern Canada in regards to flooding are as follows: changes in the spatial and temporal distribution of precipitation, severity and frequency of large storm events, distribution and amount of snowfall, onset, breakup and thickness of ice covers and the number of ice breakup events. Out of the listed effects, the potential increases in intensity and frequency of severe precipitation events has the greatest impact on flooding. Overall, it is predicted that climate change will cause more noteworthy fall floods and less significant floods due to spring freshets and winter thaws. Likewise, it is projected there will be less floods from ice jams and more due to precipitation.

As a result, Global Circulation Models (GCMs) were used to analyze extreme precipitation. In 2100, Atlantic Canada is estimated to have an increase in severe precipitation events up to a 20% in precipitation intensity. Therefore, the study assumed a 20% increase in precipitation intensity over historical values. This information was used to project climate change flow increases for 1-in-20-year and 1-in-100-year flood. Furthermore, both land use and climate change data were used to determine flood flows, water level elevations, and flood risk mapping for 20 and 100 year return periods.

After analyzing water level elevations and maps for future 20 and 100 year floods, flood risk mitigation was provided for the high impact areas. Flood berms were suggested for the Gateway Mall, Wallace Court, Holman Avenue/McLean Street, and Main Street. A diversion channel was suggested for the eastern part of town to divert water from the upper section of a watercourse to the Kennebecasis River. Realigning and dredging Trout Creek as well as adding flood storage at Parsons Brook was reviewed. Lastly, local drainage improvements and development controls were also suggested.

1.4.3 Sussex Region Flood Risk Mitigation Plan (RVA, 2019)

In 2019, RVA completed a flood risk mitigation plan for the Sussex Region including the Town of Sussex and Village of Sussex Corner. The Town of Sussex secured Federal Funding under the National Disaster Mitigation Program (NDMP) for the completion of this project. The first phase of this project, the Gateway Mall Flood Mitigation Berm Project, had construction begin in late 2019.

The Plan identified 6 high priorities areas within the Sussex region to mitigate flooding. The report includes 6 potential projects including preliminary design details, construction quantities, land acquisition requirements as well as a summary of benefits and risks. The 6 potential projects are as follows: (1) Gateway Mall Flood Mitigation Berm, (2) Trout Creek Flood Mitigation Berm, (3) East Town Limit Flood Flow Diversion Channel, (4) Parson Brook Flood Flow Diversion Channel, (5) Stormwater Infrastructure Upgrades North-West (NW), and (6) Storm Water Infrastructure Upgrades North-East (NE). These projects are further descried below:

- **The Gateway Mall Flood Mitigation Berm** is currently being constructed between the Gateway Mall and the Kennebecasis River at a geodetic elevation of 18m for a length of 400m. In order to provide overland drainage, new dual 1500mm culverts, structures and flap gates are to be installed in the ditch by Route 1. In addition, a new 900mm pipe, structure, and flap gate will be put into the Gateway Mall parking to replace the existing outfall. A shallow storm sewer will be installed into a new manhole with a deep sump to remove surface water. The berm will be vegetated and a 4m wide trail system with an access ramp will be installed for aesthetic purposes. To address backwater, an allowance for a portable pump and generator is provided to lift overland runoff;

- **Trout Creek Flood Mitigation Berm** is to be placed between Main Street and Trout Creek at an elevation of 22m for a length of 700m. This berm will also be vegetated, outfitted with a trail system and access ramp, and will have a portable pump and generator to lift overland runoff. The Trout Creek berm will also have a waterfront park;
- **The East Town Limited Flood Flow Diversion Channel** is set to be constructed between Cougle Road and McLeod Drive for a distance of 1,525m to connect Trout Creek to the Kennebecasis River. The diversion channel will help mitigate flood damage in the Town by diverting water via a weir at the beginning of the diversion channel. In order to assess the risk of implementing this structure, a PCSWMM model was used;
- **The Parson Brook Flood Diversion Channel** is designed to move water between Dutch Valley Road and Trout Creek over the course of 580m to alleviate damages at Parsons Brook during flooding events. On the Dutch Valley Road, a new culvert with a weir will control the water flow. A PCSWMM model was used to assess the risk of implementing the diversion channel;
- **Stormwater Infrastructure Upgrades NW and NE** will include installing new shallow storm sewer system ranging in size from 200mm to 600mm across a length of 1375m and 1480m, respectively. Additionally, storm laterals, catch basins, manholes, and site restoration will also be included. This work will aid in decreasing localized flooding during minor storms.

Given that the Town of Sussex had completed comprehensive flood mitigation studies in these areas of town, CBCL has opted to compliment these study findings with a Climate Change Adaptation Plan that addresses other flood and climate change related risks.

1.5 Key Infrastructure Components

Boundaries are set on the assessment scope which includes defining a set of assets and infrastructure for which climate change vulnerabilities will be assessed and prioritized. A preliminary assessment was completed at a workshop with the Town of Sussex where representatives from the engineering, public works, recreation, fire, EMO, and provincial government provided input on where and when climate risks are believed to be of highest concern, as well as where climate related risks are thought to have a relatively low or negligible impact. This information was used to narrow down an asset inventory of key infrastructure components, outlined below:

1. Engineering & Public Works:

- Sewer Collection System;
- Wastewater Treatment Plant;
- Storm Water Collection and Drainage Systems;
- Storm Water Storage Systems (Detention/Retention/ Underground);
- Water Distribution System;
- Water Treatment & Groundwater Wells;
- Transportation Infrastructure;
- Riverbank Erosion Protection (Ex. Rip-rap, groynes, tree planting, etc.);

- Design Guidelines;
- Storm Water Management Policies;
- Municipal Buildings.

2. Recreation:

- Sports Fields
- Walking Trails
- Winter Recreational Activities/Sites
- Tree Planting and Downtown Beatification (Communities in Bloom)
- Public Spaces
- Arenas/ Indoor Sports Facilities
- Recreation Centers

3. Economic Development & Tourism:

- Events within the Town (Sussex Flea Market/Atlantic International Balloon Fiesta);
- Outdoor Event Facilities (Leonard's Gate/Sussex Rotary Amphitheatre);
- Development Policies;
- Public Spaces;
- Riverfront and Downtown;
- Winter Recreation (Poley Mountain);
- Agriculture (Indirect).

4. Electrical & Power:

- Power;
- Lighting;
- Communications;
- Controls and Instrumentation;
- Backup and Emergency Power.

5. Public Works (Operation & Maintenance)

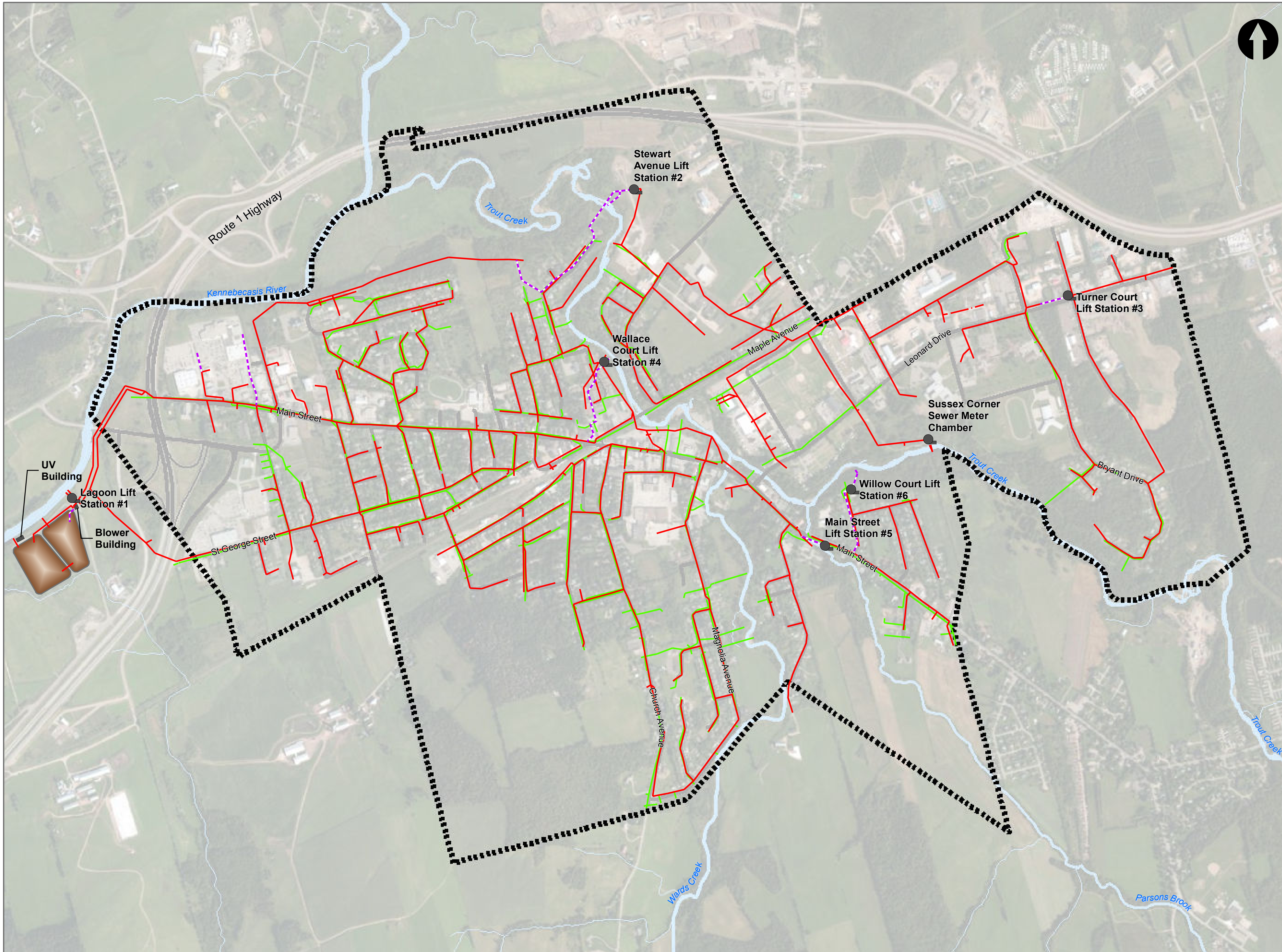
- Snow Clearing;
- Asphalt Re-surfacing and Pothole Maintenance;
- Sewer Collection and Sewage Lift Stations (SLSs);
- Water Distribution and Pumping;
- Treatment Facilities.

6. Environment

- Tree and Plant Health (Communities in Bloom);
- River Erosion Sites;
- Water Quality in River (Monitored by the Kennebecasis Watershed Restoration Committee).

Figures 1.2 through 1.6 on the following page outline key infrastructure across the Town. Other project partners, such as representatives from NBDELG's Climate Change Secretariat, were also contacted to provide useful information and guidance on project scope and climate change impacts.

The preliminary risk assessment identified infrastructure components for which climate change is thought to have negligible or low impacts on operation or infrastructure capacity and these have been discarded from the risk assessment scope. Vulnerabilities with moderate to high impacts are carried through a formal risk assessment process to determine priority ranking. The highest impacts will be analyzed for potential adaptation options.



Legend:

- Sanitary Lift Station
- Sanitary Forcemain
- Sanitary Pipe
- Sanitary Lagoon
- Storm Pipe
- Municipal Boundary

No	Date	Issue/Revision
2	Mar 27/20	Issued for Draft Final Report
1	Feb 28/20	Issued for Draft Report

Sussex
New Brunswick
Gateway to the Fundy Experience

Project:

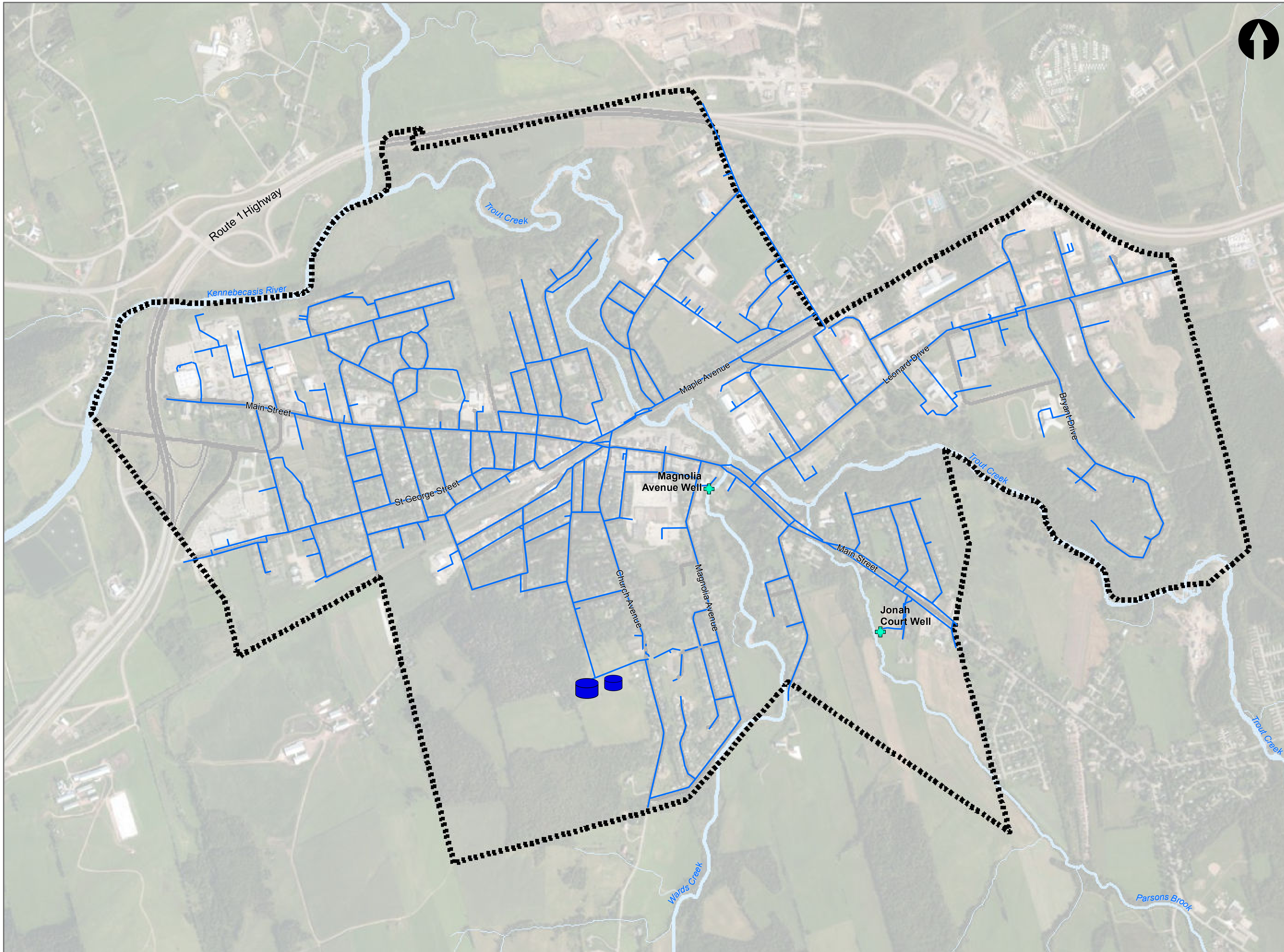
SUSSEX CLIMATE CHANGE PLAN

Drawing Title:

SANITARY AND STORM COLLECTION SYSTEMS

CBCL LIMITED
Consulting Engineers

Date:	OCT 2019	Scale:	1:15,000
Drawn:	EFW	Designed:	SMO
Checked:	LNW	Approved:	BMM
Project No:	192872.00	Figure No:	1.2



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2	Mar 27/20	Issued for Draft Final Report
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Sussex NEW BRUNSWICK Gateway to the Fundy Experience

Project:

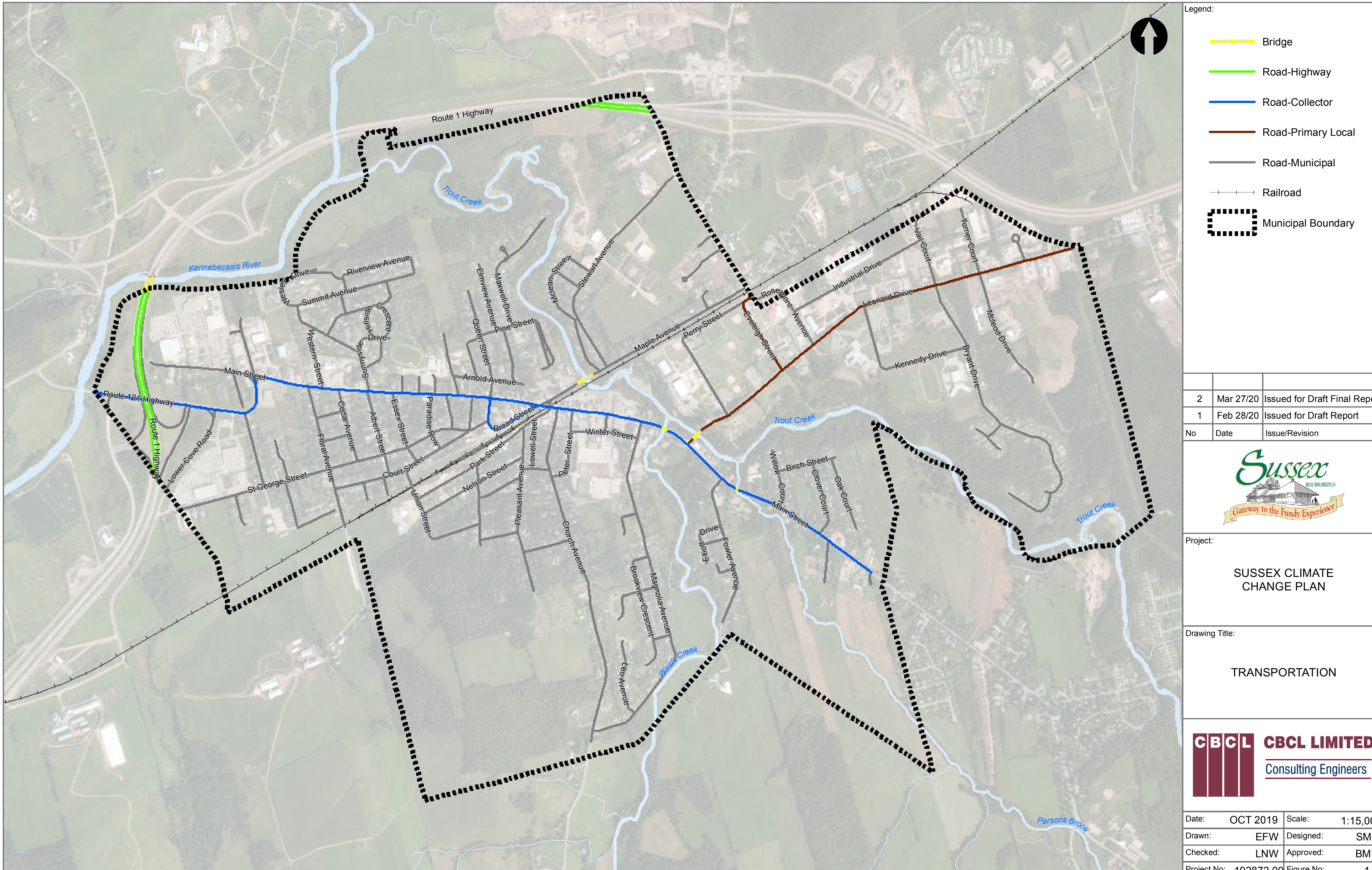
SUSSEX CLIMATE CHANGE PLAN

Drawing Title:

WATER DISTRIBUTION SYSTEM

CBCL LIMITED Consulting Engineers

Date: OCT 2019		Scale: 1:15,000	
Drawn: EFW		Designed: SMO	
Checked: LNW		Approved: BMM	
Project No: 192872.00		Figure No: 1.3	



No	Date	Issue/Revision
2	Mar 27/20	Issued for Draft Final Report
1	Feb 28/20	Issued for Draft Report

Sussex NEW BRUNSWICK Gateway to the Fundy Experience

Project:

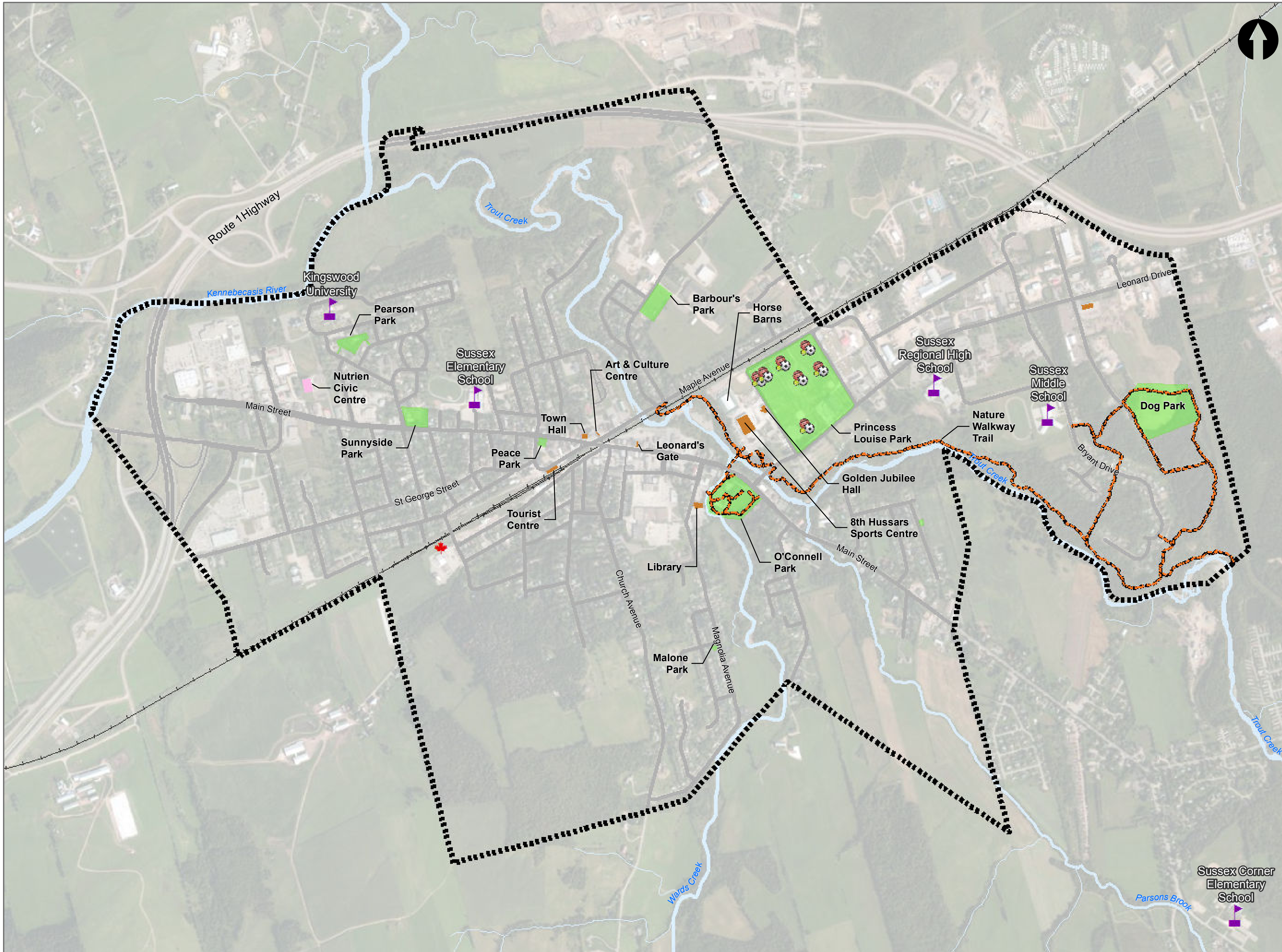
SUSSEX CLIMATE CHANGE PLAN

Drawing Title:

TRANSPORTATION

CBCL LIMITED Consulting Engineers

Date:	OCT 2019	Scale:	1:15,000
Drawn:	EFW	Designed:	SMO
Checked:	LNW	Approved:	BMM
Project No:	192872.00	Figure No:	1.4



Legend:

- School
- Community Garden
- Sports Field
- Nature Walkway Trail
- Parks
- Civic Centre
- Municipal Building
- Railroad
- Municipal Boundary

No	Date	Issue/Revision
2	Mar 27/20	Issued for Draft Final Report
1	Feb 28/20	Issued for Draft Report

Sussex NEW BRUNSWICK Gateway to the Fundy Experience

Project:

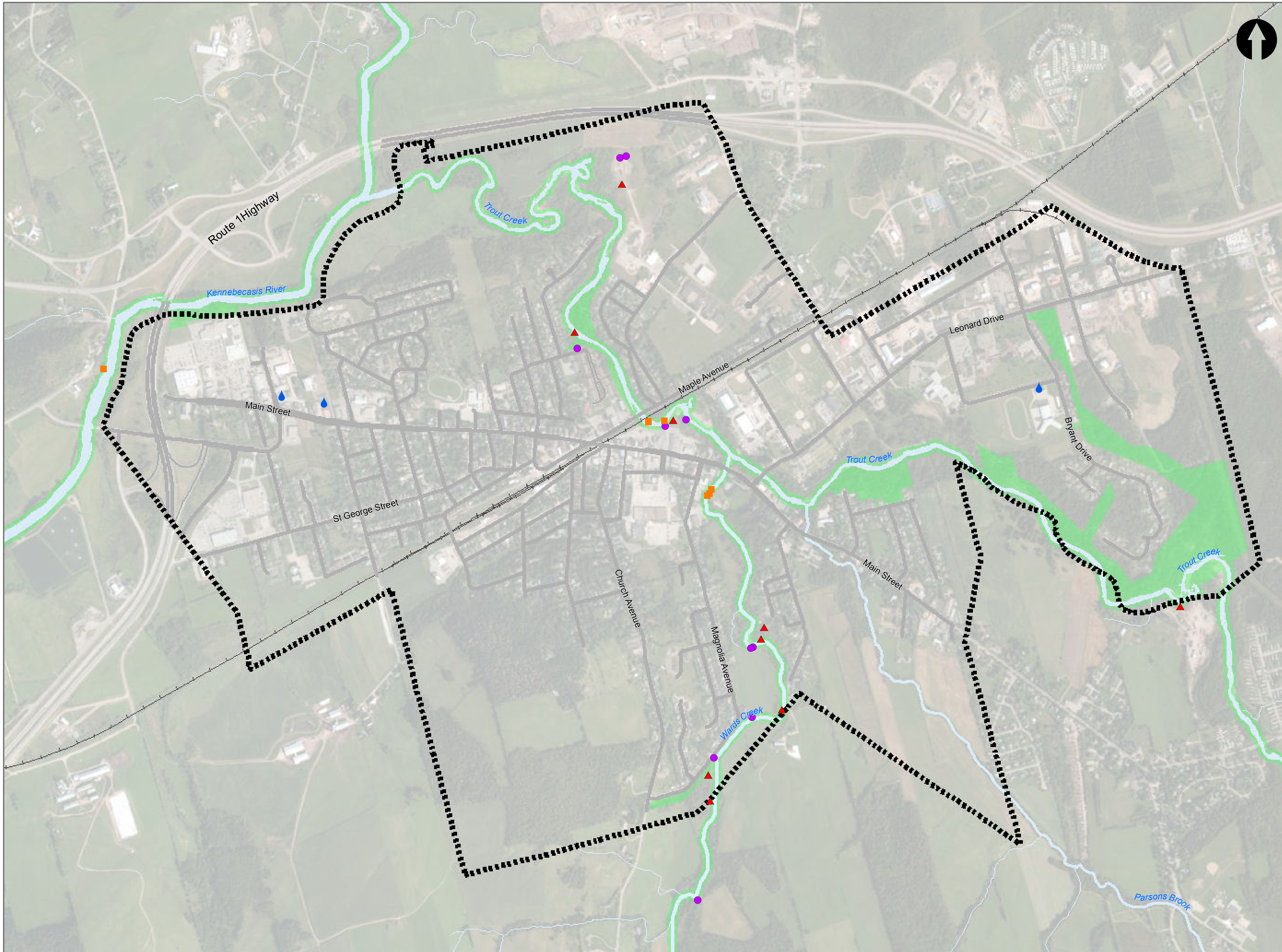
SUSSEX CLIMATE CHANGE PLAN

Drawing Title:

RECREATIONAL FACILITIES

CBCL LIMITED Consulting Engineers

Date:	OCT 2019	Scale:	1:15,000
Drawn:	EFW	Designed:	SMO
Checked:	LNW	Approved:	BMM
Project No:	192872.00	Figure No:	1.5



Legend:

- KWRC Habitat Enhancement
- KWRC Rain Garden
- KWRC Restoration Project
- KWRC Watershed Monitoring Site
- Railroad
- Sussex Green Belt
- Municipal Boundary

KWRC = Kennebecasis Watershed Restoration Committee

No	Date	Issue/Revision
2	Mar 27/20	Issued for Draft Final Report
1	Feb 28/20	Issued for Draft Report

Sussex New Brunswick
Gateway to the Fundy Experience

Project:

SUSSEX CLIMATE CHANGE PLAN

Drawing Title:

ENVIRONMENTAL SENSITIVITIES

CBCL LIMITED
Consulting Engineers

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1.6 Scope and Methodology

The scope of the Climate Change Adaptation Plan includes climate related parameters which are agreed to be changing due to increases global atmospheric carbon emission concentrations as defined by Environment and Climate Change Canada (ECCC). Climate indicators such as temperature, precipitation, sea ice, snow, and wind will be impacted by climate change. Climate change will also increase the occurrence of extreme weather events such as tropical storms. The impacts of climate change on seismic activity is an active field of study for which there is currently no scientific consensus (Canadian Geotechnical Society, 2017). For this reason, earthquakes will not be included in the scope of the assessment as a climate parameter.

The Public Infrastructure Engineering Vulnerability Committee (PIEVC), led by Engineers Canada, created a protocol which acts as a framework to assess engineering vulnerabilities of infrastructure to climate change. The main initiatives of the PIEVC protocol include mitigating the impacts of climate change by providing guidance to support the design, construction, maintenance and regulation of sustainable infrastructure. The PIEVC tool is ideal for assessing infrastructure vulnerabilities to climate change and providing engineers with a process for determining if climate vulnerabilities exist in support of designing more climate resilient infrastructure. Completing a full PIEVC risk assessment is beyond the scope of this project. Rather, a tailored risk assessment methodology has been developed which couples an engineering-based risk assessment methodology (concepts of PIEVC) with a land use planning approach that identifies opportunities to further community resilience to climate change. The PIEVC protocol applies a bottom-up approach to climate vulnerability that starts with a preliminary assessment of the risks. Relevant climate parameters and infrastructure thresholds may be determined based on engineering design, operation and maintenance requirements, and in consultation with relevant groups and stakeholders.

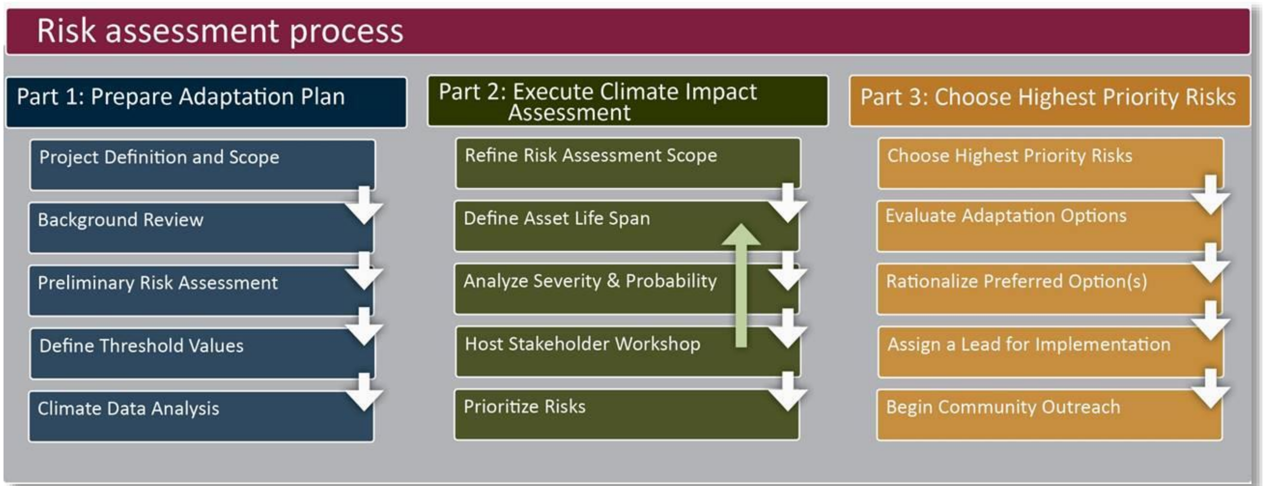
Image Source: cbc.ca

The best available historical climate data and future projections are used to evaluate the likelihood of a climate parameter exceeding a threshold over time within the asset lifecycle. The likelihood of exceeding the infrastructure threshold is assigned based on a score of 1-7, following scoring methodology outlined in the PIEVC protocol. As the score increases, the likelihood of exceedance increases. Where possible, probability of occurrence is established for infrastructure with known threshold values, otherwise likelihood is assigned based on operational experience, observations, histories, and professional judgement. The timescale of a PIEVC risk assessment is based on the expected life span of each major asset and evaluated over specified time frames (time horizons). An example of this is asphalt vulnerabilities to freeze-thaw, increased temperatures and heat waves: as asphalt seal is intended to last for approximately 20-25 years (with periodic maintenance), temperature projections from today to the 2040s-2050s would be applied to the risk matrix.

Likelihood scoring is further described in Appendix A. The associated severity is independently assigned a score of 1-7. Risk is defined at the product of likelihood x severity. The scope of the risk and vulnerability assessment, as well as the analysis of adaptation options, should be relative to:

- The project cost and scope;
- The vulnerability of the asset; and,
- The criticality of the asset.

The summary below highlights each step in the risk assessment process and the general activities/outcomes expected for each step:



Protecting public safety and municipal infrastructure, as well as mitigating economic losses and flooding is considered to be a priority for the Town of Sussex and will be a focus of the risk assessment. Due to the susceptibility of Trout Creek to flooding, preparing for flood-based climate risks will be one notable focus of the adaptation plan. The top five highest priority climate change impacts are brought forward to build adaptation strategies that can be implemented by the Town of Sussex.

Community and stakeholder outreach and education will take place in the second phase of this project. Information sharing on the findings of the assessment will take place in open houses and interactive workshops. Input from local residents and other community members will inform updates to the adaptation plan where appropriate. Companies with infrastructure within the community, such as NB Power, Bell Canada, and Rogers, will also be consulted to solicit their input and share our findings.

CHAPTER 2 Climate Change

New Brunswick has reported an increase in average annual and seasonal temperatures, high intensity precipitation events, rises in sea level, and augmented coastal erosion and flooding. Climate projections indicate that Atlantic Canada will experience increasingly warm and extreme temperatures, increased precipitation and stormier weather in the future as compared to today (Bush, 2019). The length of heat waves and hot spells is also anticipated to increase (Friedel, 2016) Prolonged durations of extremely hot temperatures have not been historically common in the region. Therefore, associated impacts to people, infrastructure, and the environment may present new challenges for municipalities, planners, and emergency responders. Furthermore, projections of increased summer drought conditions may pose a significant threat to the groundwater supply on which the Town relies.

Image Source: weather.com

Historically, measured climate and water trends have been used to predict the probability of extreme weather events occurring in the future using return period statistics on data collected at weather stations and water level gauges. Return period statistics, such as the 1:100 year rainfall, tell us the probability of a certain magnitude event occurring in each year (1:100 year rainfall has a 1% probability of occurring, or being exceeded, in each year). However, historical data is no longer a sufficient representation of future weather due to non-linear climate change. For this reason, modeling software, such as GCM projections, are used to determine regional climate predictions. Climate projection science has progressed in recent years and sophisticated tools for predicting future temperature trends have evolved. Climate model projections for parameters such as precipitation and wind are still evolving, and as the science advances, the models will improve accordingly.

The following chapter presents a summary of the approach and conclusions in the analysis of various climate parameters identified for the Plan. The projected changes from the present until the end of the 21st century (2100) are discussed over specified time periods. The detailed analysis of the climate parameters can be found in Appendix A. Preliminary discussions on impacts are also presented in Appendix A and expanded on in Chapter 3. The following climate indicators were identified to be relevant and representative of climate change impacts within the Town of Sussex:

- Warm Temperatures;
- Cold Temperatures;
- Freeze-Thaw Cycles;
- Snow Accumulation;
- Total Annual and Seasonal Precipitation;
- Precipitation Intensity and High Precipitation Events;
- Freezing Rain;
- Low Precipitation; and,
- Wind.

In addition, other parameters that are not included in the PIEVC matrix, but are discussed include:

- River Ice and Erosion;
- Acid Rain;
- Lightning;
- Forest Fires; and,
- Extreme Storms (Hurricanes).

2.1 Summary of Findings

Climate change has already and will continue to impact the Town of Sussex in numerous ways. Under future climate conditions, warm temperatures, maximum and minimum temperatures, extreme wind gusts, annual and seasonal precipitation, precipitation intensity, freezing rain and growing season length are projected to increase. In contrast, snow and annual freeze-thaw days are predicted to decrease towards the end of the 21st century. Drought conditions are expected to occur more frequently in the future as minimal change in precipitation is projected in the summer months coupled with increasing prolonged and extreme hot temperatures. For additional information on the climate projection analysis completed for the Town of Sussex, refer to Appendix A. The final PIEVC scores determined for climate parameter within each time horizon can be found in Appendix A. Data sources and methodology used to carry out the analysis are detailed in Appendix B.

The climate change projections are summarized as follows:

- **Temperature -** Maximum and minimum temperatures are expected to increase as compared to historically recorded temperatures in the region. As a result, the number of cooling degree days are expected to increase while the number of heating degree days are expedited to decrease. The duration of warm spells and occurrence of extreme heat is expected to increase over the

21st century. Drought conditions are expected to increase in the region during the summer months due to expected decrease in seasonal precipitation and increases in extreme heat. The length of the growing season is expected to increase as a result of increasing monthly temperatures. Overall, temperature projections are relatively well characterized because changes occur on larger spatial and temporal scales, which means that they are more easily modelled by GCMs. The findings are consistent with statements from the IPCC that it is “very likely the warming signal will be large compared to natural variability in all North American regions throughout the year by mid-century.”;

- **Freeze Thaw –** The annual number of freeze-thaw days is expected to decrease over the course of the 21st century. This is due to the mean and minimum annual rise in temperatures throughout the region resulting in below freezing temperatures occurring less frequently. A shift in freeze thaw cycles is expected as warmer temperatures are projected to occur earlier in the seasons. While warmer temperatures expected in the colder months may extend the number of freeze-thaw cycles typically observed in a year in the short-term, the overall number will decrease according to CMIP5 GCM projections;
- **Snow -** Atlantic Canada may have experienced some increases in snow over the historical period, but future projections are for significant decreases in snow by mid-century. These findings are consistent with the IPCC statement that it is “very likely that snow cover will reduce as temperatures rise over the next century”. The Sussex location showed greater trends than at more northerly sites, where rising temperatures are still conducive to snow formation**;**
- **Annual and Seasonal Precipitation –** An increase in annual and seasonal precipitation is expected as a result of climate change. This is due to the increased capacity of the atmosphere and potential of the water cycle as a result of increasing temperatures. According to CMIP5 ensemble GCM model projections for the Town of Sussex, annual precipitation in wet days is expected to increase approximately 15% over the 21st century. Due to projected decreases in annual snow amount over the 21st century as a result of rising temperatures, the increase in precipitation may be attributed to increases in rainfall;
- **Precipitation Intensity** - An increase in the frequency and intensity of extreme precipitation events is expected at the site. The magnitude of increase for a 24-hour 1 in 100 year precipitation event is 15-20% over the 21st century based on the IDF-CC Tool. According to monthly GCM projections of extreme precipitation indices the largest increases are expected to occur during the winter and spring months. The findings are consistent with the process understanding of an accelerated water cycle under a future climate, and statements from the IPCC that “extreme precipitation events will very likely be more intense and more frequent.”;
- **Flooding** - Climate projections show an increase in the duration and frequency of extreme precipitation events, which are expected to cause sudden increases in river flows and runoff therefore increasing flood risk. Increasing temperatures may impact the formation and breakup of river ice, which impacts the likelihood of flood events as a result of ice jams, the extent of this impact is currently not well defined at the present time;
- **Low Precipitation** – The IPCC AR5 report states low confidence in observed drought trends. However, drought conditions may be expected to increase in the summer months due to minimal change in precipitation projected during the summer months concurrent with increases in the occurrence and duration of extreme and hot temperatures. Results of a Hydrometric trend analysis show a significant decreasing trend in the mean daily summer flows within the

Kennebecasis River near the region of Sussex. Furthermore, an increasing frequency of precipitation events leads to increased runoff and decreased infiltration to recharge aquifers or water supplies. This may lead to a higher likelihood in the occurrence of drought conditions within the region;

- **Freezing Rain** - For the Town of Sussex, the projected increase in freezing rain is of up to 10-20% in January and February. Although there is no readily available model output or data for freezing rain, and while literature is limited, there is some quantification of trends available from more detailed studies reported in the literature. Predictions of general trends are robust due to a fairly good process-based characterization of changes;
- **Wind** - The evidence to support changes in trends in wind speeds is not very strong. The sources of information used include projections of hourly wind gusts reported in literature. It is likely that extreme wind speeds will increase under a future climate. Wind gusts above 90km/hr are projected to increase up to 130% around mid-century for the region. Furthermore, projections show a percent increase in wind gusts above 40 km/hr and 70km/hr of approximately 10% and 20%, respectively. It is emphasised that the uncertainty associated with wind modelling is high. The IPCC states that winds are modelled with "low confidence." It is therefore good practice to have allowance for this uncertainty when assigning probabilities to wind predictions;
- **River Ice and Erosion** - Sudden increases in water levels from large precipitation events causes increased flooding potential to surrounding areas. The formation of ice jams as a result of melting river ice are known to cause flooding impacts to the Town of Sussex. There are a multitude of ways in which climate changes are predicted to, and have been observed to, affect river ice behaviour. Increasing seasonal temperatures may impact ice accumulation and formation processes which impact ice jam frequency and formation. Due to the complex and interactive nature of these processes, it is difficult to predict overall trend that can be expected in the Town of Sussex. It is reasonable to expect increased variability of river ice processes upstream and changes to ecosystems and sediment transport processes;
- **Acid Rain** - The interactions between acid rain, UV radiation and climate change can magnify the impacts of acid rain. Atmospheric concentrations of chemicals contributing to acid rain have decreased approximately 40% (1970-2000) since legislation controlling emissions came into effect in the 1970's. However, CO_2 can still cause some acid rain (a weaker acid), and increasing concentrations may increase rain acidity in the future. The combination of many changing processes makes it difficult to assess the impacts of climate change on acid rain in ecosystems;
- **Air Quality** - Globally, a decrease in air quality is expected due to increased rates of emissions from urbanization and increasing populations;
- **Lightning and Forest Fires** - Presently, there is little scientific consensus on how the frequency and intensity of lightning storms will be impacted by climate change. However, studies have identified that increasing temperatures and moisture in the atmosphere would lead to increased frequency of conditions conductive to produce lightning. Possible increases in lightning concurrent with projected increased summer temperatures and drier conditions is also conductive to natural ignition of wildfires;
- **Extreme Storms** – The IPCC AR5 states that a "shift to more intense individual storms and fewer weak storms is likely", and that "extreme precipitation events will very likely be more intensity and more frequent". Due to a potential decrease in atmospheric currents as a result of increasing global temperatures, hurricanes may travel slower across regions; thus, compounding

their effect through increase rainfall amounts over a longer period of time (NRDC, 2018). There is evidence to support a northward shift of storm tracks over the North Atlantic Ocean, this trend is projected to continue into the future.

CHAPTER 3

Risk & Vulnerability Assessment

Image Source: thestar.com

The purpose of a risk and vulnerability assessment is to identify locations, individuals, or infrastructure that are already (from a past weather event) or may become vulnerable to climate change and extreme weather. The assessment scope includes determining the highest ranked vulnerabilities through a risk prioritization process (consequence/severity rating x probability/likelihood rating). The province has allowed municipalities to determine the scope of their climate change adaptation plans based on need and capacity. A community can choose to focus on one or two climate impacts that are considered to be the most important at the time of the assessment to address adaptation actions, or alternatively, a community may address all potential impacts at once.

In consultation with the Town, it was determined that the adaptation plan for the Town of Sussex will focus on the key climate change impacts which have caused, have the potential to cause the greatest impacts, or are considered to be important to the community. This was determined to be the top 5 highest ranked climate change and extreme weather vulnerabilities. Both the economic and social implications of extreme weather events were considered in the risk assessment process. As the impact of riverine flooding and potential mitigation measures had previously been investigated in the Sussex Region Flood Risk Mitigation Plan, focus was directed at the potential impacts to physical municipal assets and planning tools.

3.1 Risk Workshop

A brainstorming workshop was held with representatives from various town departments and stakeholders to better understand where and what weather-related vulnerabilities exist today and what potential impacts could be reasonably expected in the future. The following key questions were discussed:

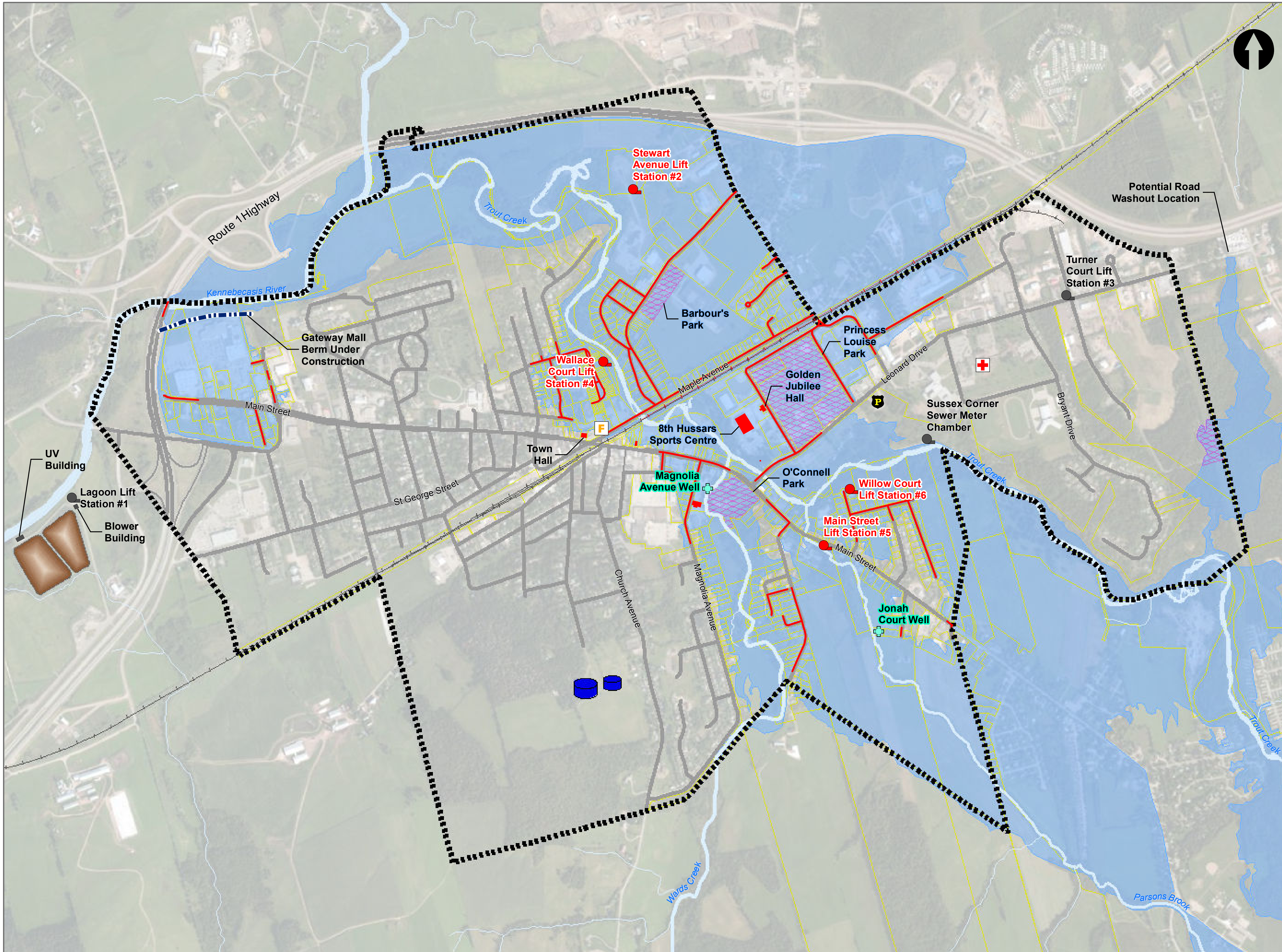
1. Has climate change or extreme weather impacted the Town in the past?
2. What types of climate threats are most likely to impact the Town and how?
3. Where do we expect extreme weather to impact the Town in the future?
4. How likely are these threats to occur and how often are they expected?
5. If an event did occur (regardless of the likelihood), which areas of the community and what infrastructure would be impacted? How severe is the impact?

The age, condition, and performance of infrastructure can influence vulnerability and therefore assets in need of repair or replacement were identified and discussed. The Town assets expected to be affected by the 2100 1:100 year flood line are shown in Figure 3.1.

3.2 Assigning Thresholds

Vulnerability assessment is an integrated approach that includes evaluating climatic conditions, sensitivities of infrastructure, and the built-in capacity of infrastructure. If a gap between infrastructure capacity and forecasted load is predicted, a potential future failure condition is identified. In vulnerability assessments, the point where the climate load exceeds capacity is called the threshold value. Different thresholds lead to different asset outcomes. Small climate changes above critical thresholds have the potential for extreme damage. For this project, the assessment team carefully considered the pros and cons of each of the threshold characterization methods and determined the most optimal threshold value based on professional judgment, operator experience, and site observations where appropriate.

Typically, the most severe climate impacts are accounted for in codes and standards (e.g. wind load in building code). Whereas less severe impacts, such as snowfall removal requirements (ongoing maintenance) are based on the owner and operator’s ability or appetite for the maintenance cost and level of effort. The current approach to engineering in building design is based on historical data, thus the climate loads as presented in National Building Code (NBC), are derived from measured data from the closest weather station and converted to a 50 year return period load. The National Research Council (NRC), who is responsible for updates to the NBC, recently determined



NOTE: The 2100 1:100 year flood line was digitized from the 2016 Sussex Flood Report By R.V. Anderson Associates Limited

No	Date	Issue/Revision
2	Mar 27/20	Issued for Draft Final Report
1	Feb 28/20	Issued for Draft Report

Sussex NEW BRUNSWICK Gateway to the Fundy Experience

Project:

SUSSEX CLIMATE CHANGE PLAN

Drawing Title:

FLOODED INFRASTRUCTURE 100 YEAR EVENT IN 2100

CBCL LIMITED Consulting Engineers

Date: OCT 2019		Scale: 1:15,017	
Drawn: EFW		Designed: SMO	
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that historical climate data is no longer sufficient for building design as it is not representative of future climate trends due to climate change.

Image Source: cbc.ca

Due to the generalized nature and interconnected consequences of climate change impacts to the Town of Sussex, the change in probability of the occurrence of climate parameters over time were assessed based on reference to historical data. This is supported by the common practice in Canada that infrastructure is designed to thresholds withstanding the historical climate. Therefore, the subsequent magnitude of change in the probability of a climate parameter is relevant to the baseline likelihood. Baseline conditions were assessed at the site through available historical and hindcast data and assigned a baseline probability score relevant to the parameter. For example, buildings are designed to accommodate drainage of annual precipitation amounts, which have a 'normal' likelihood of occurring within any given year. This corresponds to a 20-40% probability with an associated score of 4 within the PIEVC scoring matrix. Subsequent change in likelihood of the climate parameter is then assessed within each time horizon relevant to the baseline and scores are assigned accordingly.

3.3 Risk Assessment

There are many vulnerability assessment tools and templates available, such as: community, engineering, land-use, or emergency management-based. The strengths of each of these methodologies depend on the type of infrastructure being assessed. For this assessment, a hybrid approach to risk assessment was developed which relates to the engineering/public works philosophy following the PIEVC protocol, where an engineering solution is the ideal adaptation outcome. In other circumstances, the ideal solution to a vulnerability is non-structural (policies, plans, protocols, zoning), operational, or maintenance based.

The climate impact assessment presented in this chapter generally follows the processes outlined in the PIEVC protocol. An infrastructure risk assessment for climate change and extreme weather should answer three main questions: **What can happen? (Scope)**, **How likely is it to happen? (Likelihood)**, and **Given that it has happened, what are the consequences? (Severity).**

The risk matrix uses the concepts of severity and probability ratings to determine risk. Severity and probability scores are assigned from 1 -7 based on site specific analysis and professional judgment of the assessment team and are then validated during a risk assessment workshop involving the infrastructure owners, managers, design team, and operators (etc.). Table 3.1 outlines the probability and severity scores used for this assessment with their qualitative definitions. Risk is computed as the product of likelihood (1 – 7) and severity (1 – 7) for each item identified in the risk assessment matrix. Table 3.2 highlights the risk matrix format and the colours outlined in the risk assessment matrix are explained in Table 3.3.

Table 3.1: Risk Assessment Matrix Ratings

Likelihood (Probability)	Severity	Score
Negligible Not Applicable (Above 1:100 years/ <1%)	Negligible or Not Applicable	0
Highly Unlikely Improbable (1:100 years/ 1%)	Very Low or Some Measurable Change	1
Remotely Possible (1:20 – 1:50 years/ 2-4%)	Low or Slight Loss of Serviceability	2
Possible Occasional (1:5 – 1:20 years/ 4-20%)	Moderate Loss of Serviceability	3
Somewhat Likely Normal (1:2 – 1:5 years/ 20-50%)	Major Loss of Serviceability or Some Loss of Capacity	4
Likely Frequent (1:1, Annually)	Loss of Capacity or Some Loss of Function	5
Probable Often (<1:1 /Multiple times per year)	Major or Loss of Function	6
Highly Probably Approaching Certainty (Daily - Monthly)	Extreme or Loss of Asset	7

Table 3.2: Risk Assessment Matrix

	LIKLIHOOD							
S		1	2	3	4	5	6	7
E	1	1	2	3	4	5	6	7
V	2	2	4	6	8	10	12	14
E	3	3	6	9	12	15	18	21
R	4	4	8	12	16	20	24	28
I	5	5	10	15	20	25	30	35
T	6	6	12	18	24	30	36	42
y	7	7	14	21	28	35	42	49

Table 3.3: Risk Descriptions

Risk	Color	Description
Extreme Risk		Highest priority. Controls required.
High Risk		High priority. Controls required.
Moderate Risk		Some controls required to reduce risk.
Low Risk		Controls likely not required. At owner's discretion.
Negligible Risk		No further consideration.

The risk assessment considers the impact to people (health and safety, displacement, loss of livelihood, social implications, and reputation), the economy (infrastructure damage, financial impact), and the environment (air, water, land, ecosystems). The completed risk assessment matrix is outlined in Appendix C. When prioritizing adaptation efforts, the following considerations were applied in order of importance within the severity classification:

- Public safety;
- The protection and continued delivery of public drinking water and other essential services such as electricity, sewerage treatment and conveyance, transportation, emergency response, and health care services; and,
- The protection of buildings and infrastructure that support the community and local economy.

Multiple impacts have been grouped where the impacts and/or adaptation strategies coincide. The resulting 5 chosen impacts for adaptation are summarized below

1. Sewer Lift Station Flood Vulnerabilities.
2. Flood Mitigation for Municipal Drinking Water.
3. Flood Mitigation for Key Transportation Routes.
4. Municipal Policy Development Update.
5. EMO Planning and Emergency Response Plan Update.

CHAPTER 4 Adaptation Plan

This chapter outlines a series of adaptation actions for the top priority vulnerabilities determined though a risk assessment process documented in Chapter 3. The purpose of each recommended action is to improve community resilience to climate change. Adaptation actions presented in this chapter vary in size and complexity.


Image Source: cbc.ca

4.1 Priority Based Adaptation Actions

Options to deal with each priority impact are presented with a high level cost or level of effort for each option. The preferred adaptation method(s) for each impact was developed following consultation with Town representatives. The time needed for implementation and resources required are discussed for each impact where appropriate. The following adaptation actions are presented in no particular order.

There are other high-risk activities highlighted in Chapter 3 which are not addressed in this section of the report.

4.1.1 Sewage Lift Station Vulnerabilities

A number of the Sewage Lift Station (SLS) within the Town are vulnerable to flooding. To observe the impact of flooding on SLS assets, predicted flood levels were interpolated from the 2016 Flood Risk Assessment Report. CBCL examined the impacts of the 2100 1:100 flood line on each SLSs in the field. The potential impacts of flooding on the SLS building, as well as electrical equipment and pumps, were analyzed to develop appropriate flood mitigation options and Class D Estimates. Mitigation options considered include:

1. Raising electrical equipment on site; or
2. Completely rebuilding or relocating the lift station on higher ground.

The Class D opinions of probable cost were developed based on costs of previously constructed SLSs of similar size. Several assumptions were made to develop the costs, such as:

- New SLSs would be constructed adjacent to the existing ones, to allow the existing SLSs to remain in operation during construction, and to not require extensive realignment of sewer piping if the station were required to be relocated;
- All SLSs would be rebuilt 300mm above the predicted flood elevation at each site; and,
- Costs are represented in 2020 dollars, although construction may not be completed until a time in the future.

Where the Town had previously completed engineering cost study to rebuild of one of their SLSs, the probable cost determined in the study were used in place of our Class D opinion of probable cost. Operational information were also obtained from the Town for each SLS.

4.1.1.1 Stewart Avenue Lift Station

The Stewart Avenue Lift Station was constructed in 1984, and is equipped with two 150mm lift-pumps that transport all the wastewater east of Trout Creek, including wastewater from the Village of Sussex Corner. The 2100 flood line will impact select electrical equipment, although most of the equipment and pump motors are above the flood line. The pumps currently in use are no longer manufactured, and only wearable parts are available for maintenance. For this reason, the Town is considering rebuilding the SLS. The Stewart Avenue SLS it is one of the Town's critical stations, and its continued

Figure 4.1: Exterior of Stewart Avenue Lift Station, with predicted 2100 1:100 flood elevation of 18.86m.

operation is imperative for collecting wastewater over a 2.5km distance to the lagoon.

Due to the age and condition of the Stewart Avenue Lift Station, as well as the flood risk, rebuilding the SLS is the preferred approach. A previously completed engineering cost study for the complete rebuild of this SLS was estimated in 2019 to be $750,340, inclusive of engineering and unrecoverable HST (Crandall, 2019). A complete rebuild of this station would be expected to take 1.5 years, from the initial detailed design phase to construction. There may be additional vulnerabilities of the storm or sanitary sewer collection system, or ditches and culverts, related to flooding and extreme rainfall. A comprehensive review of the capacity of collection system infrastructure (and to determine the current level of service for each pipe) would require a computer modelling software to simulate the various systems in the Town.

4.1.1.2 Wallace Court Lift Station

The Wallace Court Lift Station was constructed in 1966, and is equipped with three 150mm lift-pumps, although one is currently offline for maintenance. The station is also equipped with an external generator mounted on a concrete pad immediately adjacent to the SLS building, and electricity supplied to the building is serviced via underground lines. The lift station is located in a low lying region of town and has been subjected to flooding in the past.

Figure 4.2: Exterior of Wallace Court Lift Station, with the predicted 2100 1:100 flood line limits of 20.03m (lower limit) and 21.09m (upper limit) shown.

The interpolation exercise to identify the flood line at the Wallace Court Lift Station produced varying elevations that were greater than 300mm in difference. Therefore, the lower and upper limits of the interpolation were identified, as shown in Figure 4.2, to represent the predicted flood line limits. A detailed assessment of the most recent flood model should be conducted prior to determining course of action for this SLS.

Where the upper limit of the flood line was approaching the roof of the building, simply raising the electrical equipment above this flood line is not feasible at this station. A Class D opinion of probable cost of $750,000 was developed to represent the cost to completely rebuild and raise the new station, which includes contingency and engineering. As this SLS is similar in size to the Stewart Avenue Lift Station, an entire rebuild of the station would be expected to take 1.5 years.

4.1.1.3 Main Street Lift Station

The Main Street Lift Station was constructed in mid-1960, and is an in-ground chamber with no building sheltering the SLS. It is the oldest in-ground lift station in the town, as evident from much of the metal fixtures within the chamber experiencing extensive rust.

Figure 4.3: Main Street Lift Station, with predicted 2100 1:100 flood elevation of 22.91m.

The Town had also expressed that this lift station is well past its useful life and is due for a complete rebuild. While the flood level marked at this position indicates the electrical equipment is at least partly submerged by the 2100 flood line, the current station has outlived its useful life expectancy, and therefore a rebuild is recommended. A Class D opinion of probable cost of $460,000 was developed to represent the cost to completely rebuild and raise the new station, which includes contingency and engineering. It was assumed that since an in-ground chamber already exists at this location, that a similar structure would be rebuilt in its place. A complete rebuild of the in-ground chamber would be expected to take 1.5 years.

4.1.1.4 Willow Court Lift Station

The Willow Court Lift Station was constructed in approximately 1988, and is an in-ground chamber with no building sheltering the lift station. Where the lift station is relatively new, there has been no reported operational challenges at this SLS, with the exception of it being overwhelmed by surface water during flood events. A flooding event may cause issues for operators to access the station. Only the chamber itself would be submerged by the 2100 flood line and no electrical equipment would be affected. As the SLS would not be

Figure 4.4: Willow Court Lift Station, with predicted 2100 1:100 flood elevation of 22.19m.

significantly adversely impacted by the 2100 year flood, a flood-resilient rebuild is not required for this site.

4.1.1.5 Lagoon Lift Station

The flood boundary developed as part of the 2016 Sussex Flood Report did not encompass the area around the lagoon cells or the Lagoon Lift Station. Since a model had not been created to quantify the extent of flooding at this location, it was excluded from the analysis. However, it was noted by the Town that the area surrounding this lift station has flooded in the past. Since there is potential of flooding at this SLS, it is recommended that further study be performed to extend the flood model to include this Lagoon Lift Station, and the lagoon cells. A flood risk analysis should also be completed for the lagoon to determine its vulnerability to flooding, while at the same time considering the remaining useful life of the asset.

4.1.2 Municipal Drinking Water

The Town is fortunate to be situated nearby plentiful groundwater aquifers that supply municipal drinking water to residents and businesses. While there have been no historical issues with the municipal drinking water, it does not rule out the possibility of impacts during a flooding event or other operational issues caused by climate change.

4.1.2.1 Projected 2100 1:100 Year Flood Line

The flood lines were also identified in the field for two municipal well houses to visualize the effect of the projected 2100 1:100 flood line at the two well sites. The well houses where marked in the field to identify the 2100 1:100 year flood line inside the buildings and to quantify the level damage to pumps and electrical equipment. The impact to electrical equipment and pumps were also analyzed to develop Class D Opinions of Probable Cost to raise the electrical equipment within the buildings, where applicable. Operational information was also obtained from the Town at each of the well buildings.

Jonah Court Well

The Jonah Court Well house was constructed in 1989, and it is equipped with a generator and on-site fuel storage located within the building. It is the larger of the two well houses in Town. The projected 2100, 1 in 100 year flood line shown inside the well building is below all electrical equipment, and only rising partly up the steel frame for the generator. The only major piece of equipment affected would be the fuel storage tank, and it would be submerged by approximately 200mm. As there is minimal impact to the well components and electrical systems inside the building itself, no major flood mitigation is recommended. The fuel storage tank could be raised above the flood line to limit risk.

Figure 4.5: Exterior of Jonah Court Well House, with predicted 2100 1:100 flood elevation of 25.20m shown.

Magnolia Avenue Well

The Magnolia Avenue Well house was constructed in 1976, and recently had a motor and frequency drive replaced in late 2019. The projected 2100 flood lines shown inside the well building are below all electrical equipment, except for the electrical service into the building, as seen in Figure 4.6 on the exterior of the well house. A Class D opinion of probable cost was developed to install expansion fittings to raise the conduit of the service and reconnect to the disconnect switch at approximately $5,000.

Figure 4.6: Exterior of Magnolia Avenue Well House, with predicted 2100 1:100 flood elevation of 21.61m shown.

4.1.2.2 Flood Risks - Groundwater

Groundwater sources may be at risk during severe flooding. The presence of surface water in areas normally below the flood line can mobilize pathogens and could lead to the release of chemical contaminants. Flooding of sewage infrastructure (lagoons and lift stations), sewage backflows, or direct overflows associated with sanitary and storm water infrastructure could add significantly to the pathogen load of the floodwater. Inundation of fuel tanks and chemical storage areas could likewise release petroleum hydrocarbons into the environment. Once mobilized, contaminants typically spread over a large area. If the flooded area included a well head, mobilized pathogens and chemical contaminants could find a short-circuit pathway into the well. Contaminants that have entered a well casing may not only affect the water supply, but could infiltrate into the aquifer creating a longer-lasting source zone.

In addition to a direct short-circuit pathway via a well head, contaminants transported by surface water could have the potential to pool and infiltrate into the ground as flood waters recede. The increased hydraulic head associated with the flood event will tend to increase the rate of infiltration of contaminants. If the zone of infiltration is in a source water area for a well, there is a risk of exposure over time as the water is drawn toward the well by pumping. Flooding may furthermore interrupt power to well pumps and booster stations.

4.1.2.3 Well Field Setting

The Sussex aquifer is a buried channel deposit of sand and gravel underlying the Trout Creek Valley. The aquifer is approximately 30m deep, overlain by a unit of low permeability clay and silt. This clay unit may provide some protection to the Town's two wells that are screened in the confined aquifer. The confined aquifer exhibits high transmissivities, which allows the Town's two wells to be pumped at a combined rate of approximately 615igpm during typical operation, 18 hours per day. The direction of flow in the aquifer is predominantly from east to west. There is a shallow, unconfined sand and gravel aquifer overlying the clay unit, reported to show a direct connection to local surface water bodies (Aqua Terra et. al., 1999).

The clay confining unit is discontinuous in some locations, providing a direct connection and pathway for contaminant transport between the shallow and deeper aquifer. The high transmissivity of the aquifer implies potential for rapid transport of contaminants that reach the aquifer. In areas where the deeper clay confining unit is absent, the deeper aquifer could be vulnerable to pathogens originating at the ground surface or in surface water (i.e. Groundwater Under the Direct Influence of surface water [GUDI]). The aquitard was noted to be absent near the intersection of Summer Street and Main Street, approximately 200 metres west of the Magnolia Avenue Well. A former production well on Albert Street Well was abandoned due to contamination by dry cleaning chemicals (perchloroethylene, PCE), demonstrating the vulnerability of the aquifer to contaminant releases at the ground surface.

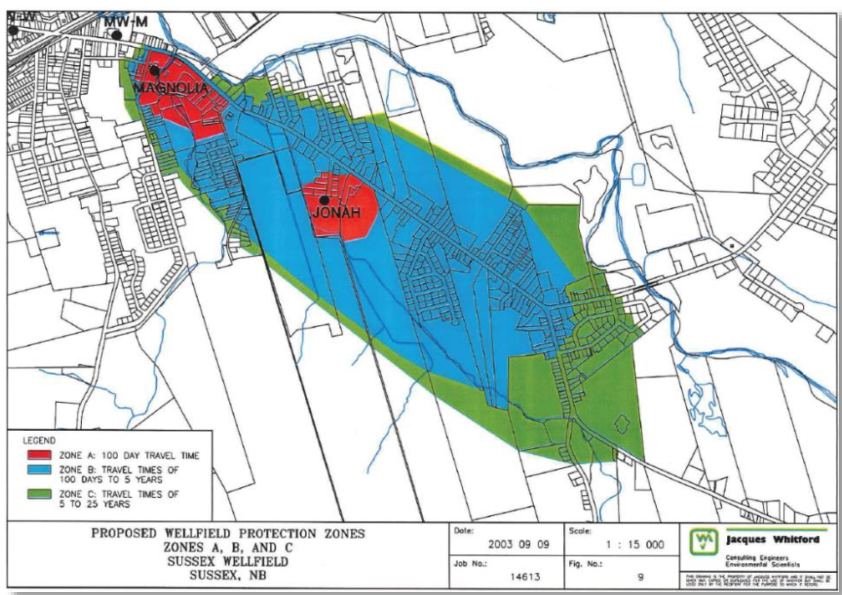


Image Source: Wellfield Protection Study, Jacques Whitford Environment Ltd.

4.1.2.4 Potential Contaminant Sources

Flood risk mapping for Sussex indicates that both the Magnolia Avenue and Jonah Court wells could become covered by water. In addition to the background pathogen load associated with runoff and surface water bodies, the following potential sources were identified for the Magnolia Avenue Well site:

- SLSs (Wallace Court, Main Street, and Willow Court);
- A dry cleaner on Winter Street; and,
- A gas station at 653Main Street (includes buried underground storage tanks).

For the Jonah Court Well site:

- SLSs (Main Street, and Willow Court);
- Possible manure spreading on agricultural land; and,
- A car care business at 1012 Main Street.

Provincial mapping furthermore shows Source Water Protection Areas (SWPAs) within the flood risk zone. SWPAs are associated with the Town's wells and with wells serving the Village of Sussex Corner.

4.1.2.5 Mitigation Measures

Under flooded conditions exposure of the water supply to pathogens represents the greatest and most immediate threat. As the wells may exhibit GUDI conditions in the absence of flooding, the further mobilization of pathogens into the aquifer or directly to a well head would represent an acute threat to life and health. Measures to improve the resiliency of the groundwater supply to pathogens should be a priority. These measures could include:

- **Install a UV light:** UV irradiation provides inactivation of protozoa and is relatively inexpensive to add to existing disinfection systems;
- **Seal of well cap:** Check and ensure an excellent seal of well cap and replace/renew as needed;
- **Confirm casing is in excellent condition**: Perforations may develop in older casings, and represent a short-circuit pathway for pathogens;
- **Vent Pipe and Screen:** Consider extending well vent pipe above the flood line elevation and ensure that the opening is screened. Ensure that the vent screen is checked annually and replaced as needed;
- **GUDI Investigation:** Initiate a GUDI investigation, including seasonal samples for Microscopic Particulate Analysis (MPA);
- **Well head protection planning:** Follow up on well head protection planning and inspections to ensure that there is no open storage of manure on agricultural land within the SWPA;
- **Consider restrictions:** Such as on manure storage and spreading within SWPA during periods of highest risk for flooding; and,
- **Construct new wells** with an enhanced annular seal and apron at the ground surface. Although the Town has been actively studying alternate water sources, aside from their existing wells.

The vulnerability of the aquifer to chemical contamination has been demonstrated. The release of chlorinated solvents and/or petroleum hydrocarbons could cause long-term and potentially irreversible damage to the aquifer. Groundwater affected by these contaminants is likely to exceed drinking water guidelines due to long-term and chronic exposure risks. Mitigation measures could include:

- Require that all liquid contaminants within the SWPA are stored above ground in sealed containers;
- Avoid storage of bulk PCE and TCE within the SWPA (dry cleaning operation);
- Conduct regular inspection of dry cleaner and service stations; and,
- Require preparation of site-specific flood risk mitigation plan by dry cleaner and service stations.

4.1.3 Key Transportation Routes

There are certain areas of the town that are susceptible to riverine flooding that can cause roads to be impassable, as shown in Figure 3.1. Maintaining emergency access for first responders during a flooding event was considered the primary focus of this section. There are additional vulnerabilities to walking trails from flooding and erosion along the river as well as the impacts of high ground water table and freeze-thaw cycles on road life expectancy and early deterioration.

4.1.3.1 Critical Flooded Routes- Inside Town Boundary

A major concern would be two critical corridors, Leonard Drive and Maple Avenue. When flooded, these two streets essentially cut the town in half. Flooding of these critical routes can cause certain areas to become isolated within the town boundary, and restrict travel for residents and emergency response personnel. This would be especially concerning with regard to the impediment to emergency services between the western portion of town and the eastern portion, where access to the hospital, RCMP, and EMO centre would be obstructed.

Critical transportation routes that were identified in the Town's Asset Management Plan, such as Main Street, Leonard Drive, Eveleigh Street, and Rosemount Drive, were analyzed at a conceptual level to investigate the potential of raising the roads above the 2100 1:100 year flood event. The flooded sections of these roads include:

- **Leonard Drive**: Trout Creek bridge to Civic 30;
- **Main Street**: Summer Street to Wards Creek bridge;
- **Eveleigh Street**: Entire length from railroad tracks to Leonard Drive; and,
- **Rosemount Avenue**: Railroad tracks to 50 Leonard Drive's driveway on Rosemount Avenue.

Image Source: NBDELG

A Class D Estimate of $4.0 million was developed to raise the finished ground elevations of these streets 300mm above the predicted 2100 1:100 year flood level. Table 4.1 below summarizes the routes affected by flooding and the proportion of the estimate for each.

Table 4.1: Opinion of Probable Costs for Critical Routes Affected by Flooding

Route Name	Leonard Drive	Main Street	Rosemount Avenue	Eveleigh Street
Length (m)	360m	350m	400	460
Class D Estimate	$900,000	$1,100,000	$900,000	$1,100,000
TOTAL	**$ 4,000,000**			

While the costs pertinent to municipal infrastructure were considered in the Class D opinion of probable cost, several aspects were not considered at this conceptual level of planning, including:

- Legal and potential land acquisition;
- NB Power utilities;
- The need to raise the railroad tracks at the intersection of Maple Avenue and Marble Street;
- Possible adjustments to buildings.

4.1.3.2 Critical Flooded Routes - Outside Town Boundary

In addition to the risk of flooding within the Town boundary, there are routes outside of town limits that would also be susceptible to flooding. Two critical routes, outside the Town's boundary, that are within the 2100 1:100 flood zone are:

- The section of Main Street within the Village of Sussex Corner; and,
- Marble Street.

The flooded section of Main Street within the Village of Sussex Corner, from the Town's east limit to the intersection with Post Road and Needle Street, also both within the Village of Sussex Corner, would restrict access to the Town. While this section of road is within the Village of Sussex Corner, it is a critical corridor that provides access to rural areas east of the Village of Sussex Corner, and also access to the TransCanada Highway (Route 1) to the northeast. In the event of flooding along this section of road, residents on Willow Court, Clover Court, and Jonah Court may become stranded during the 2100 1:100 flood event.

The second route, Marble Street, is another critical corridor in terms of access between the Town and Route 1. While Marble Street is a provincial road, it is a critical route between the Town and rural areas north of the LSD of Cardwell. Relatively new roads within the Town, such as Azalea Lane and Carriage Lane, would be flooded themselves, and also would not have access to the Town or Route 1 to the north.

4.1.3.3 Implementing Mitigation Measures

Raising the critical sections of roads within the Town would require a great level of effort, both in terms of cost and planning. Once sufficient funding has been acquired, the time to handle any potential land acquisition, develop detailed design drawings, and complete construction, could take upwards of 3 years to complete.

4.1.4 Municipal Policy Development

As outlined in the recently updated Municipal Plan By-law #704-20, the Town has undertaken considerable effort to develop adaptation plans and strategies to prepare for the potential impacts of climate change. These plans, including the flood risk assessments, asset management plans, and this Climate Change Adaptation Plan (once adopted), will provide Town staff with the knowledge and direction to make informed decisions for a sustainable future. The Town is expecting to adopt the proposed updates to the Municipal Plan By-law #704-20 and this Climate Change Adaptation Plan in it draft final. This will allow the Town to leverage the shared vision between these key documents in future endeavours.

One of the key points of interest that arose during community engagement in developing the Municipal Plan was “the desire to be prepared for and adapt to the effects of climate change”. This is echoed by the vision portrayed in section 4.5 Environment and Climate Change of the Municipal Plan, specifically with the following points concerning flooding and development:

- ECC-2 Council shall consider the recommendations of their Climate Change Adaptation Plan when processing application for development and in the issuance of any municipal permits;
- ECC-3 Council shall consider the recommendations of the Flood Master Plan when processing application for development and in the issuance of any municipal permits; and,
- ECC-4 Council shall ensure a developer, when making an application for development, is made aware of flooding potentials at the proposed site and that any proposed development may require a Wetland and Watercourse Permit from the Province of New Brunswick. Council shall ensure an approved Wetland and Watercourse Permit is a condition of the development.

These policies relate primarily to identifying whether a development proposal is situated within a flood plain, as per the flood boundary developed in the 2016 Sussex Flood Study, and informing developers should this be the case. The Building Inspector in charge of the development application’s permitting will determine whether the lowest building floor elevation of the proposed development is below 1:100 year flood elevations, and note so on the issued Building Permit. In such cases, building plans must show how the structure has been designed for potential flooding.

Zoning By-law 1350-10.40.2 restricts building of structures on sites when, in the opinion of the Planning Advisory Committee, the site is marshy or subject to flooding. However, there is no mechanism to restrict such building below flood elevation. The closest such restriction is provided by Building By-Law 151-16 Section 7.3, which stipulates that the lowest elevation of the top of the foundation have a minimum elevation of 0.46 m above the centreline of the affronting street.

Taking this recommendation a step further, the first task of an effective flood management strategy would be to identify and understand the flood risks facing the municipality. The Province of New Brunswick references a two-zone strategy with regards to floodplain: the floodway and the flood fringe. Floodway refers to the area serving the conveyance of watercourses and corresponds to a flood return of a 1:20 year event, meaning that the area has a 5% chance of flooding any given year. Flood Hazard Areas refer to areas outside of the floodway that will see a 1:100 year event or have a 1% chance of flooding any given year. The flood fringe consists of the Flood Hazard Area, and includes the Flood Risk Area corresponding to historical flood levels. CBCL is recommending that the

Town of Sussex consider incorporating the following into future development policies and zoning by-laws:

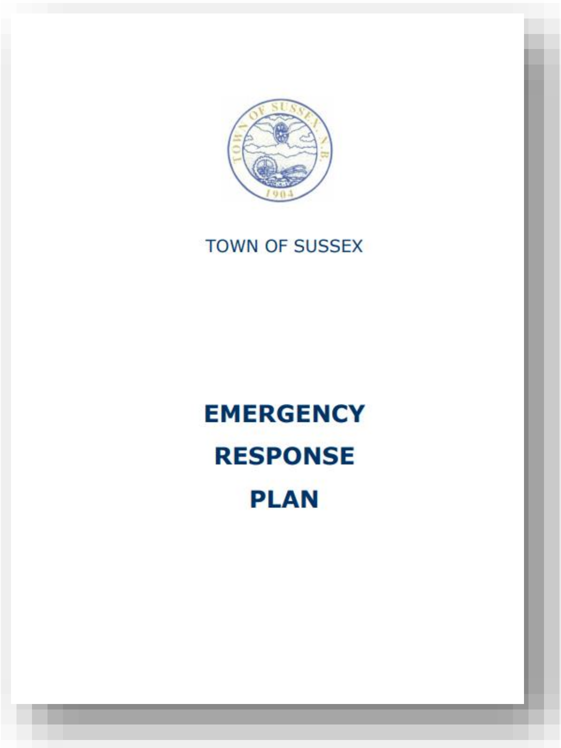
1. Restrict alterations to existing properties located below the 2100 1:100 year flood line that could cause additional flood damages (i.e. finished basements); and
2. Prohibit construction of new buildings below the predicted 2100 1:100 year flood line, subject to exceptions (discussed below).

Designated “special policy areas” (SPA) can be enacted, where development below the 2100 1:100 year flood line can proceeded if flood proofing or protection measures are incorporated. This is commonly referred to as “flood resilient construction”. These and other recommendations must be formulated for inclusion in the Town’s ongoing Municipal Plan Review. The Town may also wish to ask residents who choose to develop within the flood line to sign a waiver indicating their understanding of the flood risk.

4.1.5 EMO Planning and Emergency Response Plan Update

The Town’s emergency planning capabilities have become sophisticated over the years, as they have needed to respond and manage several severe flooding events. The Town has developed an Emergency Response Plan to coordinate the various aspects of planning and responding to an emergency, which is comprised of:

- **Emergency Measures Committee**: The committee is comprised of the Mayor and members of Council. They are responsible for the management of the municipal emergency operations and possess the authority for decision making during an emergency;
- **Emergency Operations Control Centre (EOC)**: The Town’s EOC centre is currently located on the second floor of the Sussex Fire Hall. It provides a central location for emergency response personnel to gather when responding to a community threat;
- **Emergency Operations Control Group (EOCG):** This group is responsible for the planning, response and monitoring of emergencies. The organizational structure of the group has the ability to fluctuate its staff according to the level of response needed during a particular emergency. The group can also recommend to the Mayor and Council that a state of local emergency be declared when a particular emergency reaches a level where additional support is necessary.



The combined efforts of these measures in the Emergency Response Plan allow for the prompt, coordinated, and effective response to an emergency. While the Town’s Emergency Response Plan has become quite sophisticated, its current form is general in outlining procedures to respond to a variety of emergencies, and not specific to certain events that would have a high level of risk associated (flooding, train derailment, etc.). Additional aspects of the plan to be expanded upon to prepare for more frequent and severe climate events could include the following:

- **Warming and Cooling Centre**. Designate a facility to be used as a warming and cooling centre for residents during an emergency. Also consider the location of the designated facility, as some municipal buildings would be susceptible to emergencies (8th Hussars Sports Centre and Golden Jubilee Hall both fall within projected 2100 1:100 year flood line);
- **Extended Power Outages**. Establish a plan to handle extended power outages during extreme temperature seasons. In the winter, a heating centre would be needed to be designated if residents are without power for a significant length of time (48 hours or more). Similarly, in the summer, a cooling centre would be needed if the outage coincided with a prolonged heat wave;
- **Backup Power**. Equip designated warming and cooling centre with electrical connection for a generator to be installed. A portable generator could also be considered if the warming and cooling centre was unavailable and it was required to be relocated to another facility (designated centre is flooded);
- **Designate EOC Outside of Vulnerable Areas**. The current location of the Fire Hall is positioned near the projected 2100 1:100 year flood line, which could create concern for maintaining access to the building during a significant flood event. Moreover, where the Fire Hall is positioned adjacent to the CN railroad, if an incident were to occur involved dangerous good being transported by rail, the EOC would be inaccessible;
- **Specific Plans**. Consider creating emergency specific plans tailored to events that have a high level of risk associated with them, in addition to the “Hazard and Response Actions” appended to the Emergency Response Plan. For example, where Sussex has been vulnerable to extreme flooding in recent years, it could be beneficial to have a plan in place outlining specific planning, management, and operational procedures during a flood event;
- **Evacuation Plan**. Consider creating an evacuation plan for residents in certain regions of the Town (residents living east and west of Trout Creek, and/or north and south of railroad tracks). Look into developing a procedure of how to inform residents of an evacuation and advise them to travel to safe locations either within or outside of the Town.

4.2 Action Summary Table

As described in the Priority Based Adaptation Actions, the five impacts that were analyzed and mitigation measures developed for, are summarized in Table 4.5. Timeframes are based on periods less than 1 year, between 1 and 10 years, and greater than 10 years for short, medium, and long-term, respectively. The level of difficulty represents the total level of resources required to mitigate each impact, shown here as a combination of time and cost.

Table 4.5: Summary of Priority Based Adaptation Actions

Priority Number	Description of Vulnerability	Timeframe	Estimated Cost	Level of Difficulty	Lead Department
1	Sewer Lift Station Vulnerabilities	Medium-term to Long-term	$1.9 million	High	Works Department/ Town Hall
2	Municipal Drinking Water Vulnerabilities	Medium-term	-	Moderate	Works Department/ Town Hall
3	Key Transportation Routes	Long-term	$4.0 million	High	Town Hall
4	Municipal Policy Development	Short-term	-	Moderate	Town Hall
5	EMO Planning and Emergency Response Plan Update	Short-term	-	Low	EMO

CHAPTER 5

Next Steps

The results of the risk and vulnerability assessment presented in this Town of Sussex Climate Change Adaptation Plan are reflective of input from Town staff. Contributions from the Town departments and officials allowed for a comprehensive assessment that is tailored to the needs of the Town of Sussex. The Adaptation Plan presented has been designed with flexibility to allow the Town to tackle and support these resilience initiatives as project budgets and personnel schedules allow.

This completed report represents Phase I of a two phase project. In Phase II of the Climate Change Adaptation Plan project, the Town will begin to implement recommendations presented in this Plan and will perform public outreach and education. Public and stakeholder consultation will include information on the findings of this report as well as public meetings, interactive workshops, and presentations with residents and community groups, which will ultimately assist to validate the information and priorities identified in this report.

DRAFT FINAL

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Appendix A

Climate Change Projection Analysis

CHAPTER A Climate Change Analysis

The following sections detail the climate change analysis and PIEVC scoring results on identified relevant climate parameters outlined in Chapter 2. The analysis is based on PIEVC methodologies as described in Chapter 1.6 and Chapter 2.

A.1 Warm Temperature

Increasing temperatures have a variety of impacts on municipal systems, including water systems, land use, and emergency services. Extreme hotter temperatures and increased duration of days with warmer temperatures may lead to increased energy demand for mechanical and electrical systems, increased water demand, and pose a safety risk to vulnerable persons in the community such as children and the elderly. Furthermore, growing season lengths may be extended due to the prolonged seasonal time frame of warm temperatures within the region.

A.1.1 Climate Change Processes

The main climate processes that are leading to changes in global temperatures are the modification of the earth's energy balance at different scales, as greenhouse gases reflect more shortwave radiation back to Earth. Therefore, temperature changes are affected by relatively large-scale processes (e.g., compared to precipitation). Due to the increase of radiative forcing, global temperatures are increasing, with more significant warming trends projected in northern regions.

A.1.2 Sources of Climate Information

The sources of climate information used to characterise trends in temperature at this site were obtained from GCMs. Since temperature is relatively well modelled at larger scales, the analysis made use of the large number of GCM projections available, including CMPI5 ensemble GCM model projections, which allows relative change to be estimated more accurately. CMIP5 GCM results were obtained from multiple sources including:

- Raw data obtained from the Canadian Center for Climate Modelling and Analysis, processed using Climdex indices to produce plots.
- *Future Climate Scenarios – Province of New-Brunswick* report published in 2016 by Roy and Huard. The box-plot figures were derived from projections of the CMIP5 ensemble GCM results statistically downscaled using observed records from selected meteorological stations.

- Provincial maps generated from CMIP5 ensemble GCM results presenting in the *Future Climate Scenarios – Province of New-Brunswick* report published in 2016 by Roy and Huard available through the Atlantic Climate Adaptation Solutions Association.

The CMPI5 GCM results were used to obtain projected trends of:

- Warm Spell Duration Index
- Monthly Maximum Value of Daily Maximum Temperature
- Monthly Minimum Value of Daily Maximum Temperature
- Number of Days where the Maximum Temperature is greater than 30 °C
- Number of Days where the Maximum Temperature is greater than 35 °C
- Growing Season Length
- Cooling Degree Days above 18°C

The uncertainty in projections is indicated by the skew of the different GCMs to the ensemble mean or represented by box plots. Uncertainty increases as the projection year increases.

A.1.3 Background Information

Temperature data is recorded at weather stations across New Brunswick. Daily records of temperature are typically available from Environment Canada weather data stations. Over the period of 1948 to 2016 Canada has experienced a mean annual temperature increase of 1.7°C (Bush, 2019). Spring, summer, fall, and winter average temperatures have increased in all parts of New Brunswick and average temperatures across the province are expected to increase by 3.5°C by the end of the century (2080-2100) (DELG, 2018). This predicted increase is almost two and half times greater than the relatively gradual change we have experienced over the past 100 years, the largest of which was observed between the 1980s and 2000s as determined using average decadal variation in average temperature from Environment Canada's historical records for New Brunswick (shown on the temperature dial to the right by DELG).

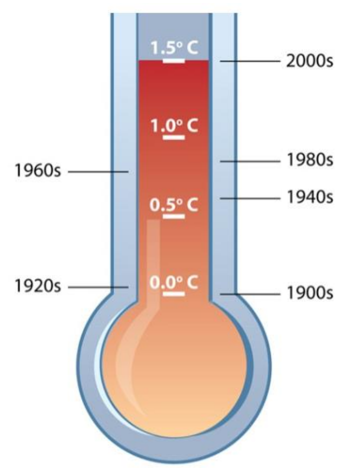


Figure A-1: Increase in Global Average Temperatures due to Climate Change

The impacts of increasing temperatures are most drastically observed during the winter and summer months. Nationally, hot summer days have become more frequent since 1950, while the frequency of cold nights has decreased. The following image show the spatial distribution of average temperature for winter 2016/2017 in relation to the baseline average, which is defined as the mean over the 1961–1990 reference period. In New Brunswick, the average increase was 2.5°C above baseline.

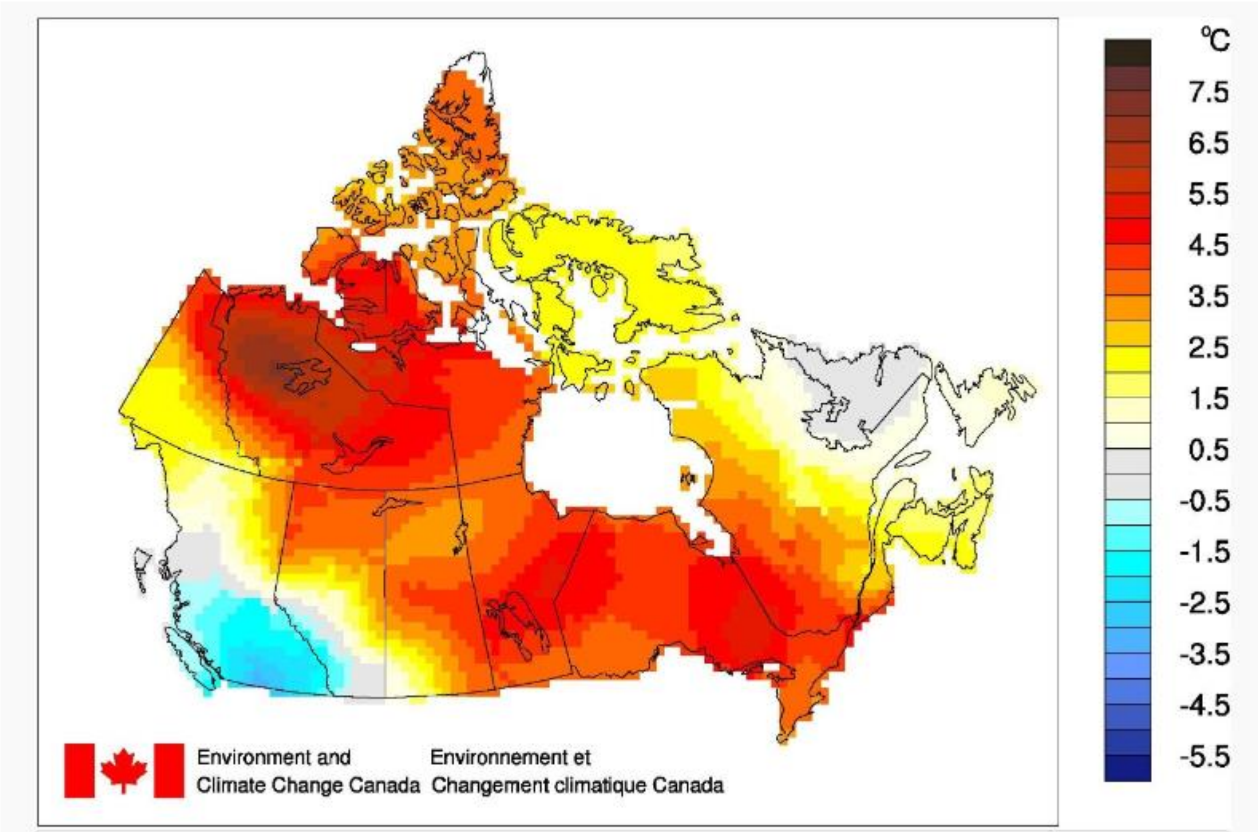
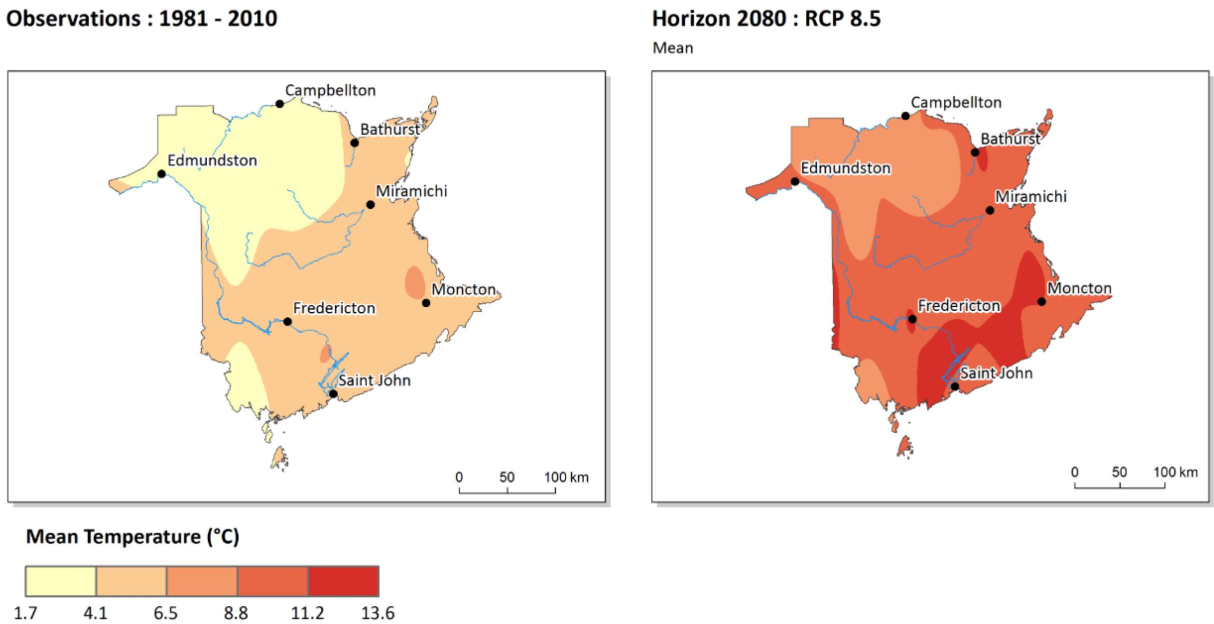


Figure A-2: National Average Temperature in Relation to Baseline for the Winter of 2016/2017

Heat warnings are issued in New Brunswick when 2 or more consecutive days of daytime maximum temperatures are expected to reach 30°C or warmer and nighttime minimum temperatures are expected to fall to 18°C or warmer. Heat warnings are also issued when 2 or more consecutive days of humidex values are expected to reach 36°C or higher.

The magnitude of projected warming varies substantially with the emission scenario. Extreme maximum and minimum temperatures are projected to increase in the region over the 21st century due to climate change. Furthermore, the duration and frequency of extreme temperatures are projected increase. The number of warmer days are projected to increase throughout the 21st century, with a rising in minimum temperatures diurnally, decreasing the opportunity for nighttime cooling. By mid-century, a 1:20 year extreme hot day is projected to become a 1:5 year event over most of Canada. Figure A-3 shows the projected spatial distribution of average temperatures across the province from the historical period to the 2080 time horizon. An ensemble of global climate models were used to reproduce some of the trends reported by DELG, but specifically looking at the parameters important to this study (Figure A-1 and Figure A-2)



A.1.4 Findings

Figure A-3: New Brunswick's predicted mean temperature trends for the historical period and 2080 under the RCP 8.5 emission scenario (Ouranos, 2016)

Figure A-4 presents the CMIP5 ensemble GCM model projections for Monthly Maximum value of daily maximum temperature. The warmest temperatures occur during the summer months at the site, both July and August historically experience maximum temperatures of approximately 30 °C, this extreme temperature is projected to increase approximately 5% by 2100 at the site. Extreme temperatures are projected to increase during each month of the year over the 21st century. Increases in extreme temperatures are projected to occur within the range of 5 - 10 degrees, with most of the largest increases occurring in the summer, spring and winter months.

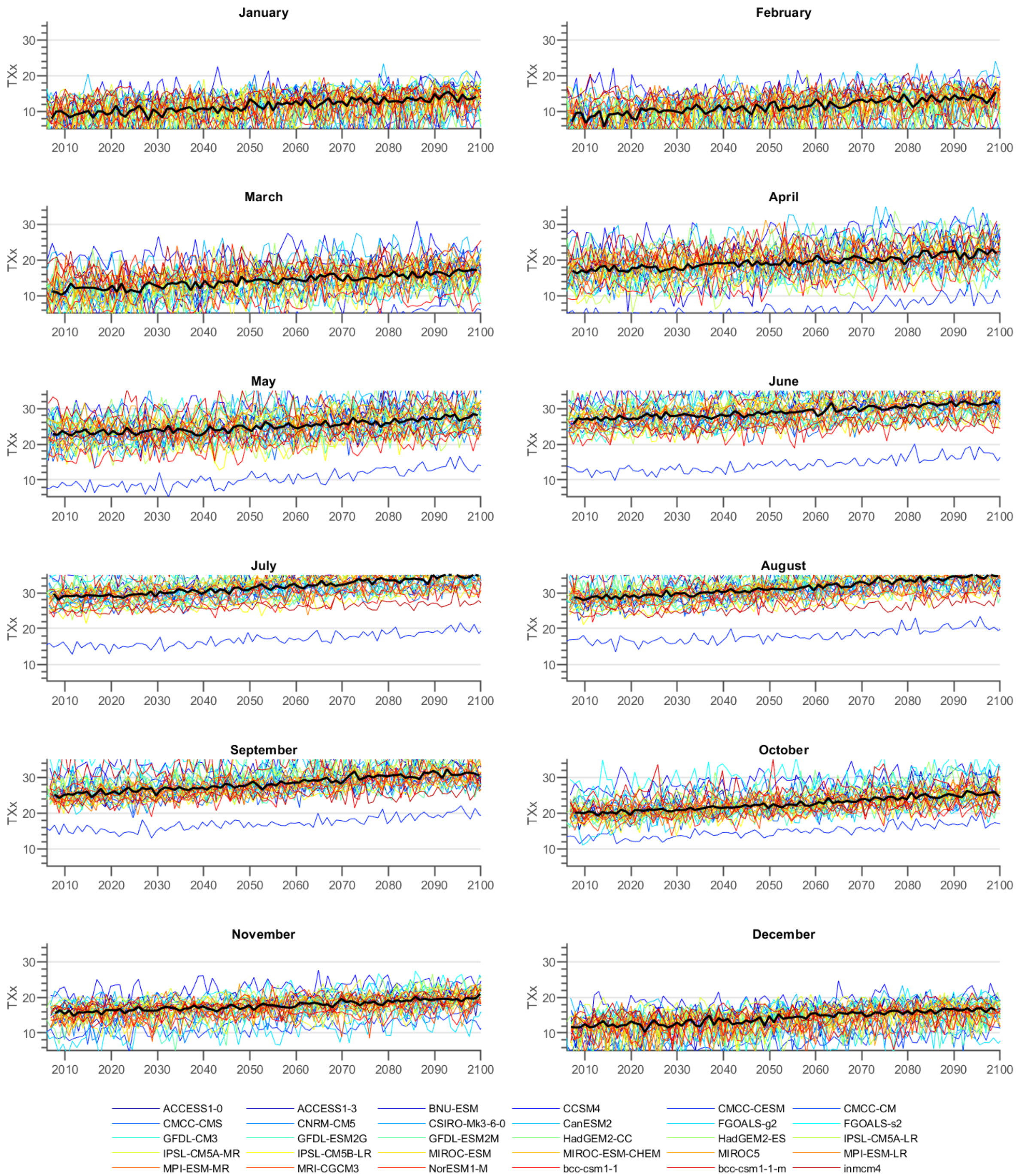


Figure A-4: CMIP5 ensemble GCM model projections for Monthly maximum value of daily maximum temperature.

According to downscaled CMPI5 ensemble GCM projections at the Moncton, NB climate station (Figure A-5) there is an increase in the frequency of annual number of days where the maximum temperature is greater than 30 °C. Historically, the region does not experience many days (less than 5 days annually) above the threshold temperature. A significant increase is depicted within the long term time horizon for RCP 8.5 as compared to increases within the near and mid-term time horizons. Projections of frequency of days above 30 °C within the near and mid-term depict increases of approximately 5-10 and 15-20 days annually, respectively. In comparison, RCP 8.5 projections within the long term horizon shown an increase to approximately 30-40 days annually where the maximum temperature is greater than 30°C. The maps presented in Figure A-6 show the projected change over the 21st century in annual number of days with the maximum temperature greater than 30 °C across regions in New Brunswick in comparison to the reference period. The maps depict the region of Sussex within the mid-range of the increasing trend as compared to other regions within the province. The largest increasing trends are seen inland and along the western border of the province.

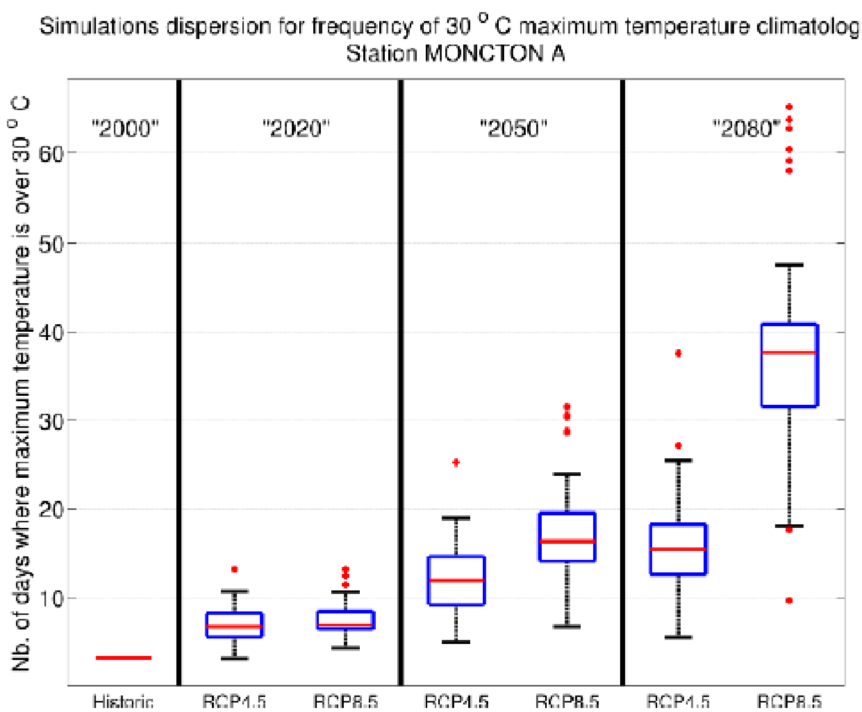


Figure A-5: CMIP5 ensemble GCM model projections for Number of Days where the Maximum Temperature is greater than 30 °C in Moncton, NB.

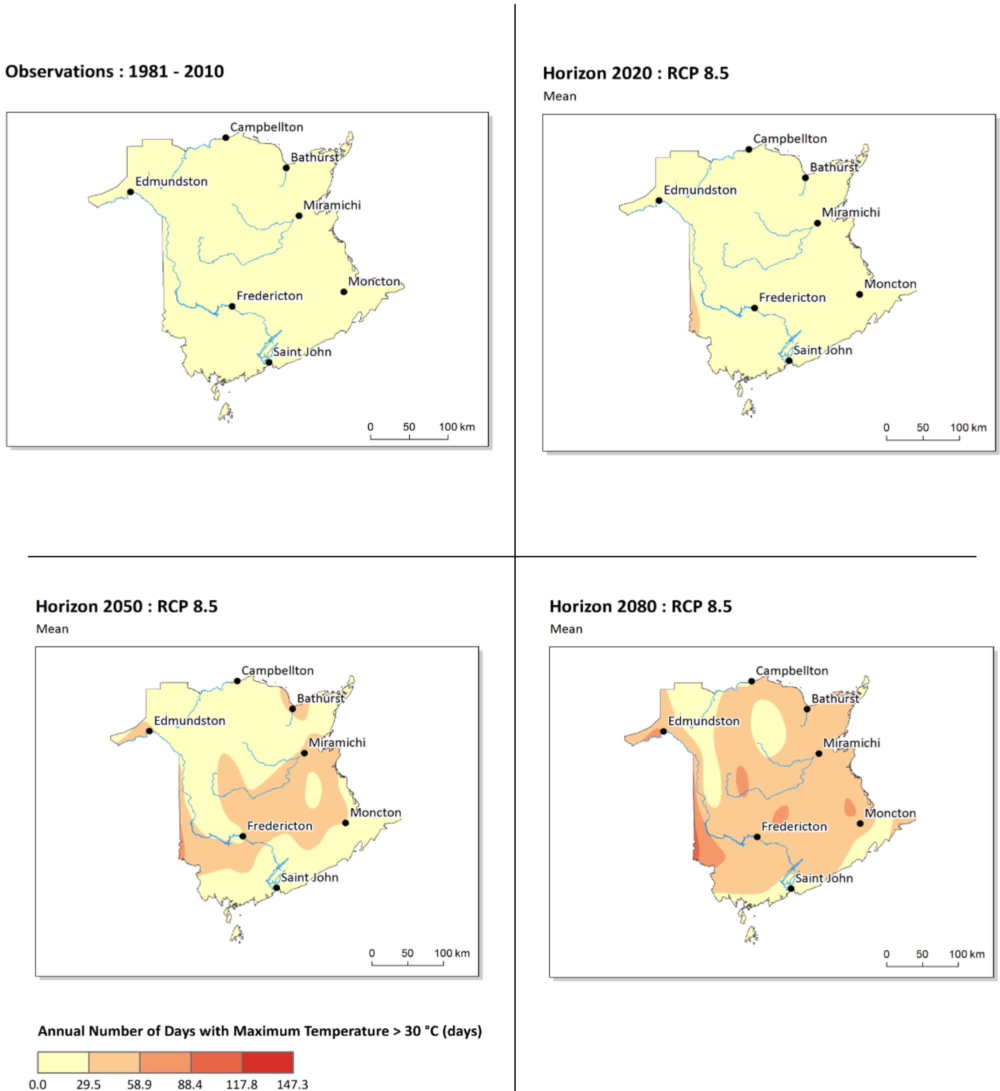


Figure A-6: New Brunswick Climate Futures CMIP5 ensemble GCM model projections for Annual Number of Days with Maximum Temperature greater than 30 °C in Regions across New Brunswick.

Figure A-7 presents the number of days where the maximum temperature is greater than 35°C based on downscaled CMIP5 ensemble GCM projections. Historical values presented show that temperatures within the regional climate rarely exceed 35°C. Slight increases in the frequency of temperatures above the threshold are projected within the near and mid time horizon for both RCP scenarios. Projected treads for RCP 4.5 are relatively linear over the 21st century whereas there is an exponential increasing trend projected for RCP 8.5. Within the long term for RCP 8.5 projected treads indicate an increase to approximately 5-10 days annually with temperatures exceeding the threshold value. The maps presented in Figure A-8 show a larger increase in the number of days where the maximum temperature is greater than 35°C within the mid latitudes of the province as compared to more southerly and northerly regions, with the largest increases occurring along the western border of the province.

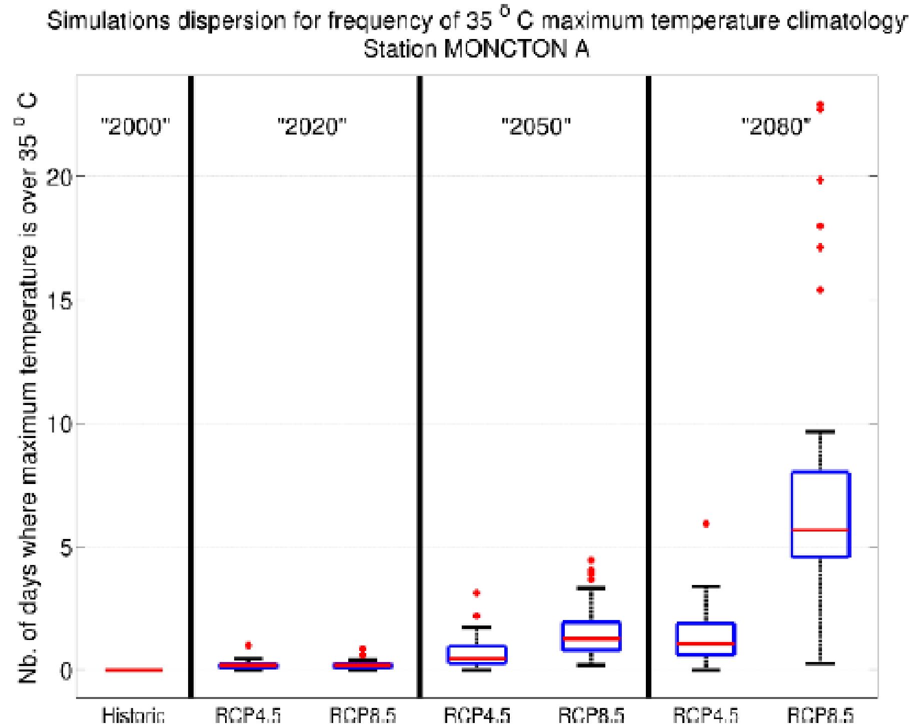


Figure A-7: CMIP5 ensemble GCM model projections for Number of Days where the Maximum Temperature is greater than 35 °C in Moncton, NB.

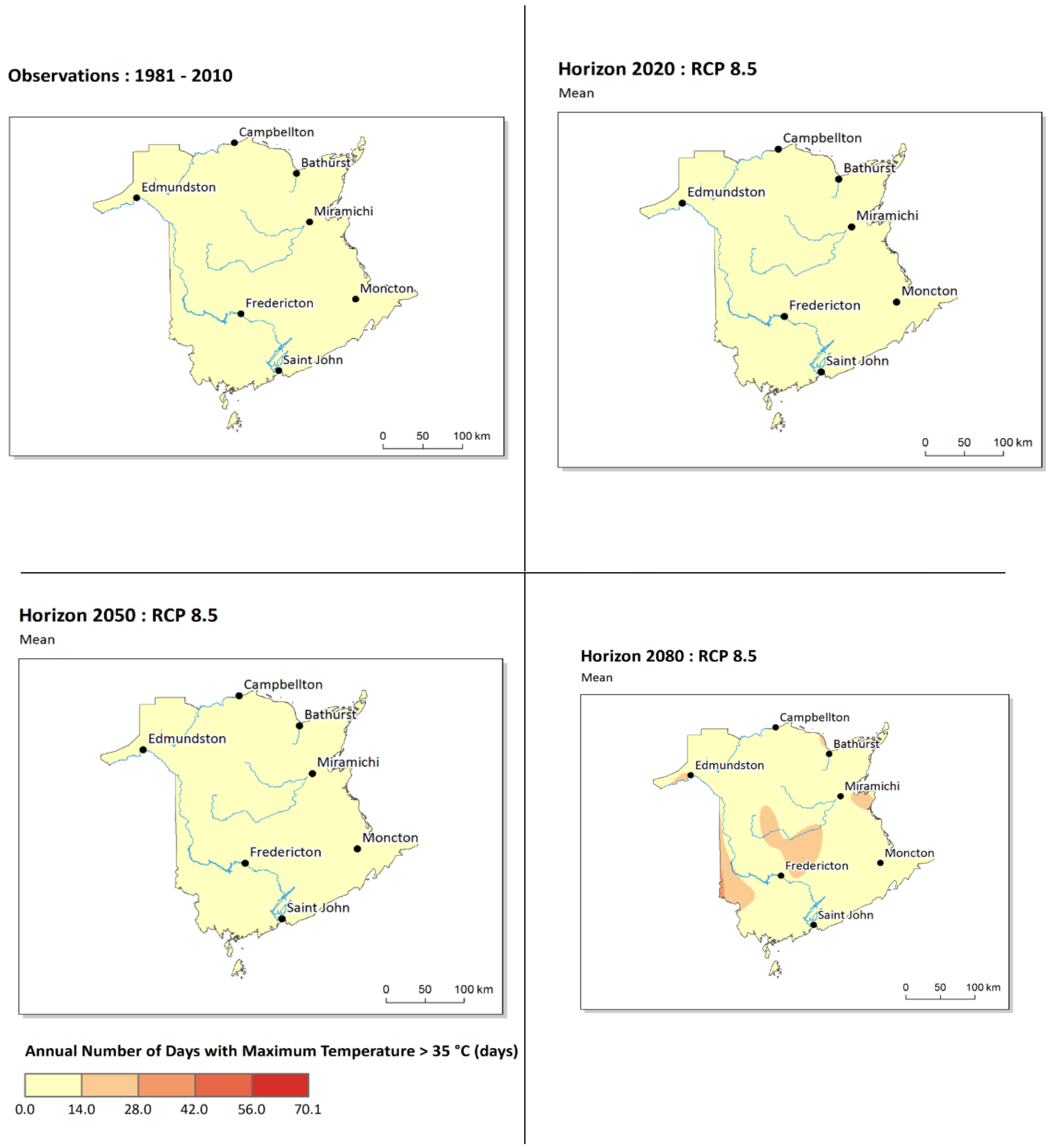


Figure A-8: New Brunswick Climate Futures CMIP5 ensemble GCM model projections for Annual Number of Days with Maximum Temperature greater than 30 °C in Regions across New Brunswick.

CMIP5 ensemble GCM model projections for Warm Spell Duration Index (WSDI) (Figure A-9) depicts an apparent exponential increase in the number of occurrences of days with at least 6 consecutive days with temperatures above the 90th percentile over the 21st century. The annual sum of days within a warm spell increases from historically less than 5 days to approximately 50-150 days near the end of the 21st century. It is noted that there is high intermodal variability among GCM projections during the end of the 21st century.

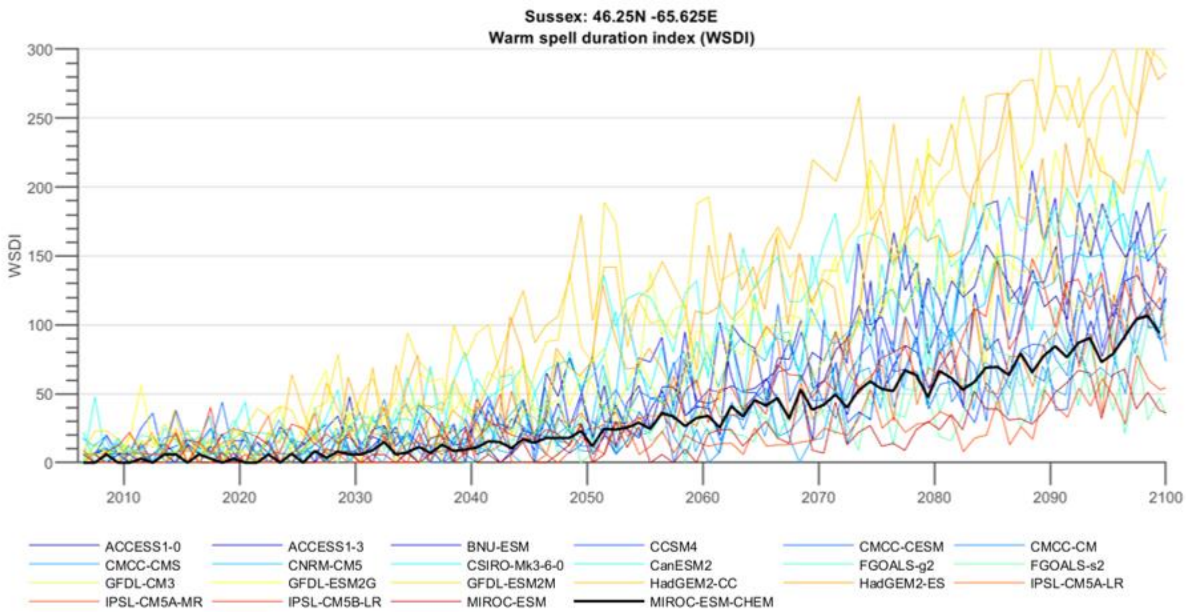


Figure A-9: CMIP5 ensemble GCM model projections for Warm spell duration index (annual count of days with at least 6 consecutive days when Tx >90th percentile).

According to CMIP5 ensemble GCM model projections (Figure A-10) the number of Cooling Degree Days (Base 18 °C) is expected to increase relatively linearly throughout the near and midterm time horizons with a significant increase depicted in the long term for RCP 8.5 between the mid and long term. Regional climatology shows an historic value of approximately 50 cooling degree days, increasing approximately 100% and 300% within the near-term and mid-term respectively. Subsequently, an increase in the number of cooling degree days to approximately 350-400 is projected within the long-term. The greatest discrepancy between the RCP scenarios is projected over the long term, where RCP8.5 projected increased warming to 350-400 degree days and RCP 4.5 projected approximately 150-200 degree days; almost half the projected increase. The maps presented in Figure A-11 show a greater near term increase in the number of Cooling Degree Days within the region of the site as compared to more northerly regions in the province. A higher frequency in the increase of cooling degree days are projected in the southerly mid latitudes of the province, which is therefore regionally significant to the project site.

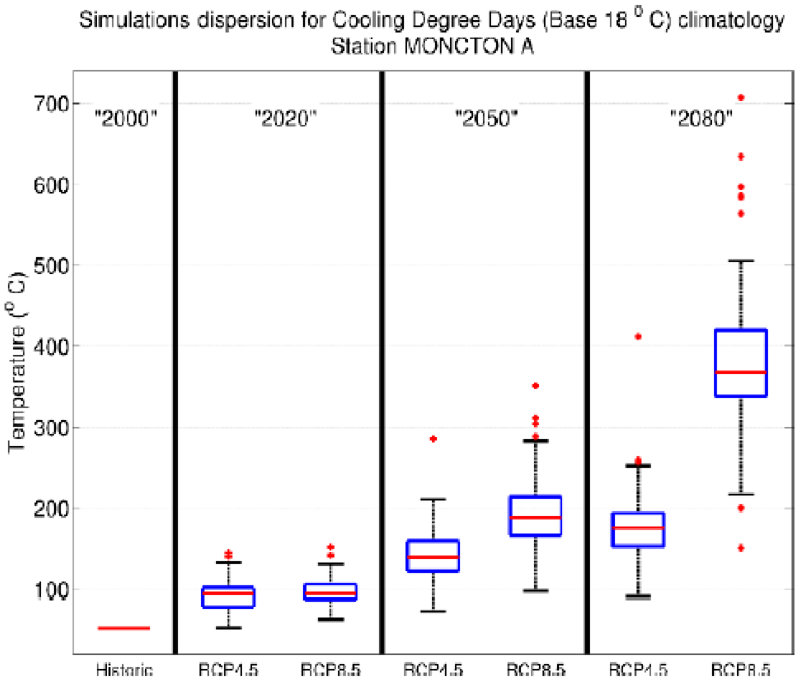


Figure A-10: CMIP5 ensemble GCM model projections for Degree Days above 18°C for Moncton, NB. An increasing trend in the number of Cooling Degree Days is projected with the largest increase depicted in the timeframe "2080" projected year for RCP 8.5.

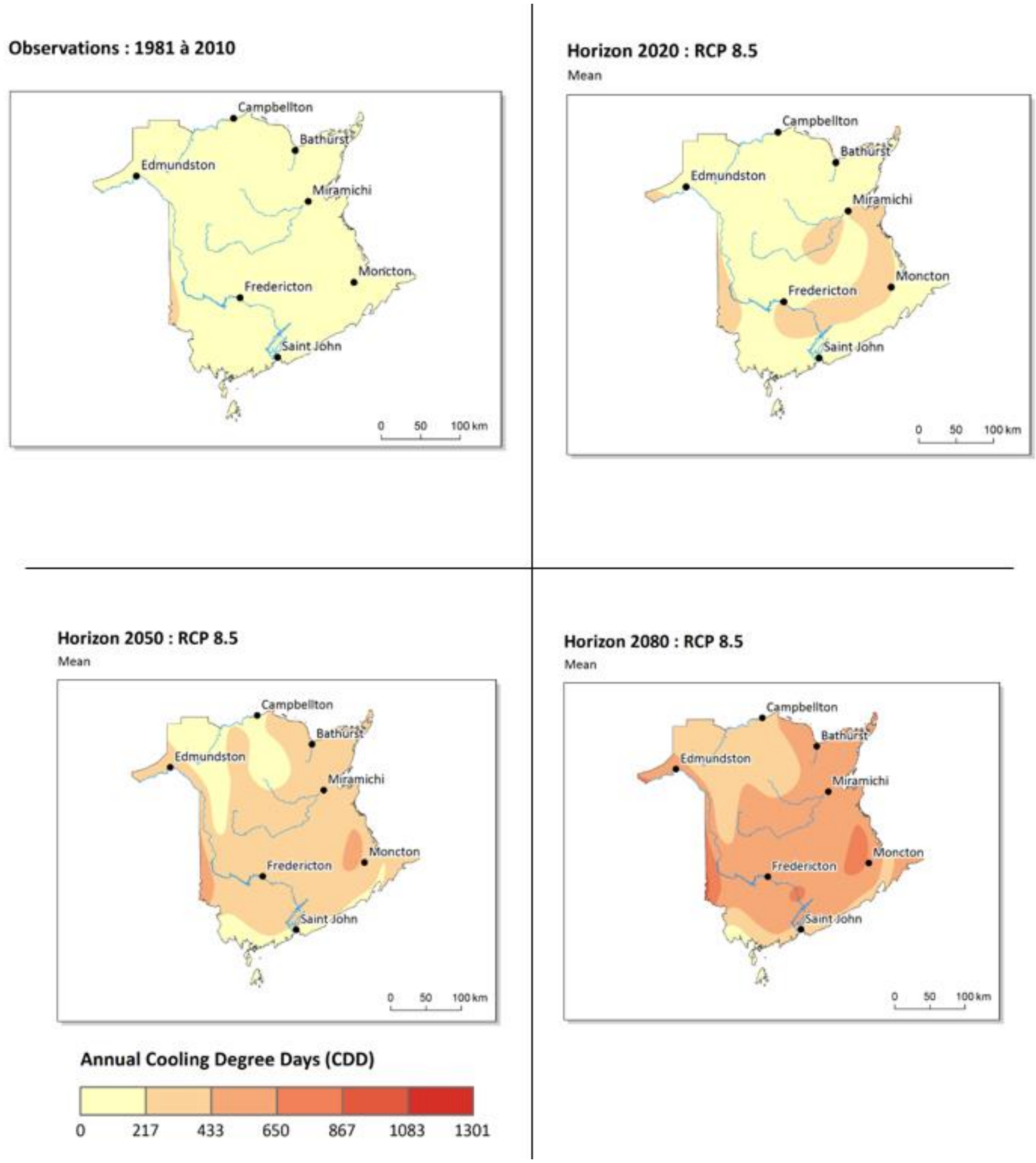


Figure A-11: New Brunswick Climate Futures CMIP5 ensemble GCM model projections for Annual Cooling Degree Days in Regions across New Brunswick.

Figure A-12 presents the CMPI5 ensemble GCM projections for Growing Season Length. A relatively linear increase in the growing season length is projected throughout the 21st century for both RCP scenarios. A projected increase in the growing season length of approximately 30% between the historical and long term RCP 8.5 scenario is depicted. Historically, the site experienced a growing season of approximately 160-165 days; the growing season is projected to increase within the region approximately 5-10%, 10-15% and 10-15% over the near, mid, and long term time horizons, respectively. The maps presented in Figure A-13 show a larger increase in the growing season length within more southerly regions, including the region of the project site, as compared to the mid and northern latitudes.

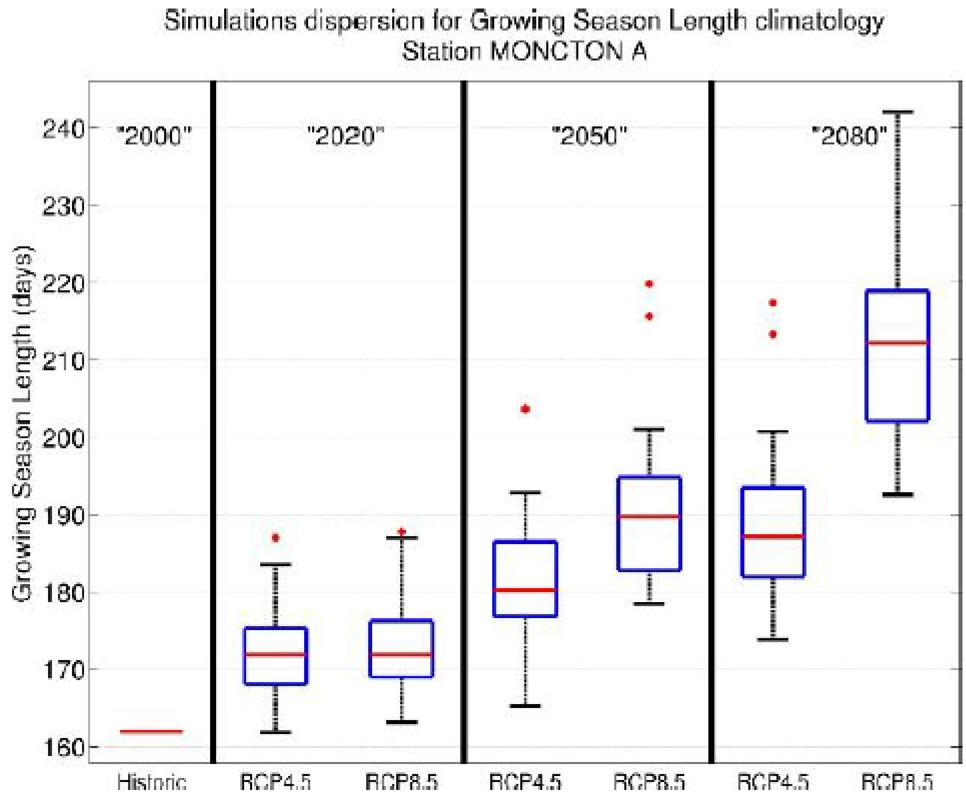


Figure A-12: CMIP5 ensemble GCM model projections for Growing Season Length in Moncton, NB.

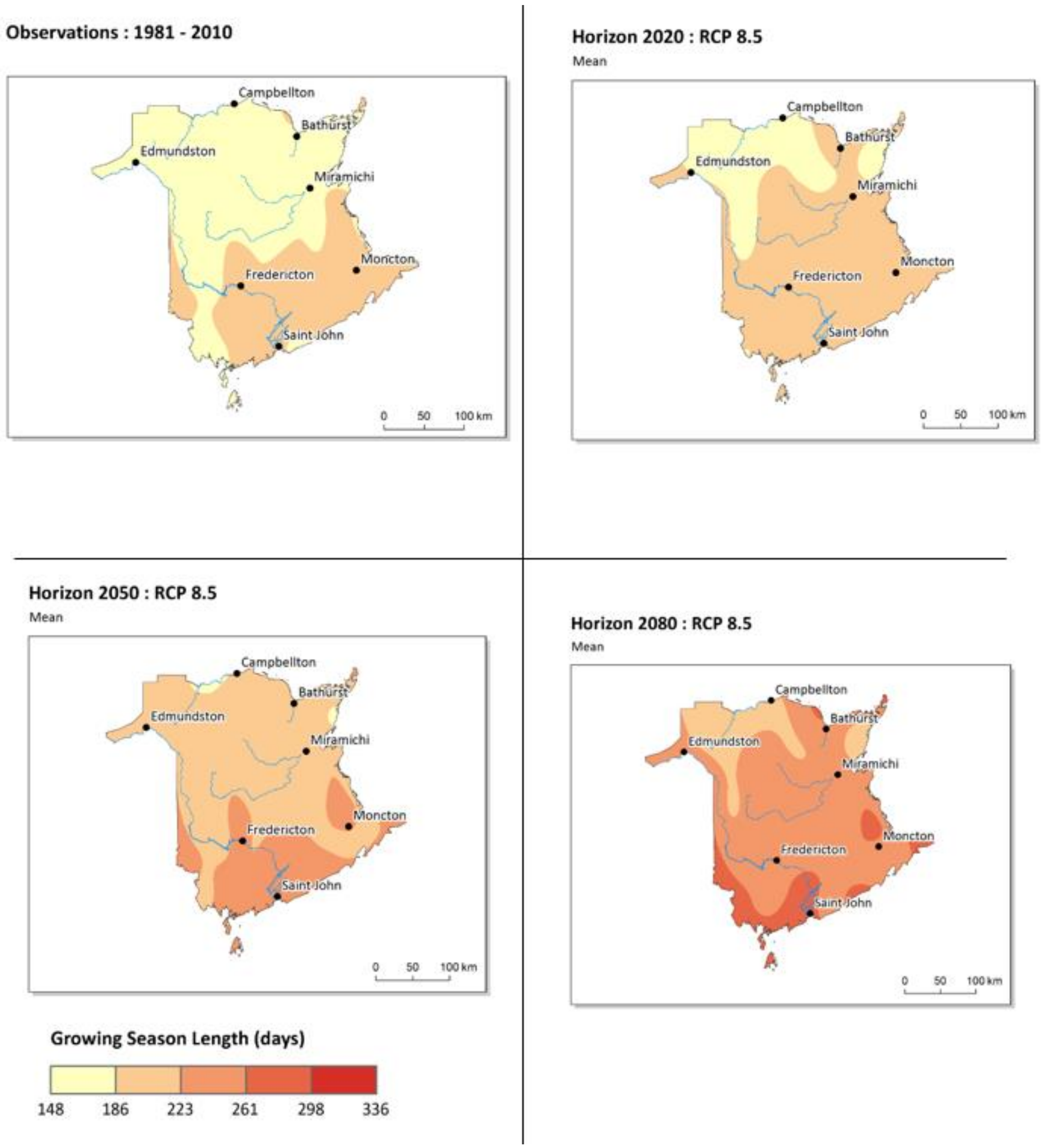


Figure A-13: New Brunswick Climate Futures CMIP5 ensemble GCM model projections for Growing Season Length in Regions across New Brunswick.

A.1.5 Probability Scores

A multitude of warm temperature indicators and extreme hot temperature indices were evaluated in order to determine the magnitude of increase in high temperatures at the site. The PIEVC scores were based off of a baseline score of 4 representing the normality of mean and extreme temperatures experienced within the historical period. From a baseline score of 4, subsequent scoring for the time horizons were determined to represent the probability that the historical baseline of warm temperature indices and extreme hot temperatures would be exceeded within the representative time frame. Temperatures are modelled with high confidence and each index indicated an increase in the frequency and magnitude of extreme temperatures and the duration of hotter temperatures within the region. Temperature increases were depicted for all months of the year at the project site, and are projected to occur at magnitudes larger than experienced in more northern regions of the province. Due to these projected increases and the confidence of CMIP5 GCM temperature projections, it is highly probable that within the long-term historical temperature normals will be exceeded within daily or monthly time frames. Therefore, the long term was assigned a probability score of 7. To reflect the linearity of the majority of the climate projections, scores of 5 and 6 were assigned to the near and mid-term time horizons, respectively. Within the near term it is expected that temperature extremes and historically experienced values will be exceeded on an annual basis, increasing to multiple times a year within the mid-term.

Table 1: Probability Scores for Warm Temperatures at the Town of Sussex

Time Horizon	Baseline	Near-Term	Mid-Term	Long-Term
Probability Score	4	5	6	7

A.1.6 Summary

Overall, temperature projections are relatively well characterized because changes occur on larger spatial and temporal scales, which means that they are more easily modelled by GCMs. Trends were therefore reproduced with multiple sources of climate information and CMIP5 GCM models. The findings based on manipulation and plotting of measurements and model output are consistent with statements from the IPCC that it is "very likely the warming signal will be large compared to natural variability in all North American regions throughout the year by mid-century."

A.2 Cold Temperature

A.2.1 Climate Change Processes

The main climate processes that are leading to changes in temperature are the modification of the energy balance of the earth at different scales, as greenhouse gases reflect more shortwave radiation back to Earth. Therefore, temperature changes are affected by relatively large-scale processes (e.g., compared to precipitation). Due to the increase of radiative forcing, an increase in minimum and mean temperatures is projected, with more significant trends occurring in northerly regions.

A.2.2 Sources of Climate Information

The sources of climate information used to characterise trends in temperature at this site were obtained from GCMs. Since temperature is relatively well modelled at larger scales, the analysis made use of the large number of GCM projections available, including CMPI5 ensemble GCM model projections, which allows relative change to be estimated more accurately. CMIP5 GCM results were obtained from multiple sources including:

- Raw data obtained from the Canadian Center for Climate Modelling and Analysis, processed using Climdex indices to produce plots.

- *Future Climate Scenarios – Province of New-Brunswick* report published in 2016 by Roy and Huard. The box-plot figures were derived from projections of the CMIP5 ensemble GCM results statistically downscaled using observed records from selected meteorological stations.
- Provincial maps generated from CMIP5 ensemble GCM results presenting in the *Future Climate Scenarios – Province of New-Brunswick* report published in 2016 by Roy and Huard available through the Atlantic Climate Adaptation Solutions Association.

The CMPI5 GCM results were used to obtain projected trends of:

- Mean Winter Temperature
- Number of Icing Days
- Number of Frost Days
- Monthly Minimum value of daily minimum temperature
- Cold spell duration index
- Percentage of days when minimum temperature is greater than 90th percentile
- Heating Degree Days below 18°C

The uncertainty in projections is indicated by the skew of the different GCMs to the ensemble mean. Uncertainty increases as the projection year increases.

A.2.3 Findings

In terms of the presented climate indices for cold temperatures, projections with respect to RCP 4.5 represent the “worst case” scenario where temperatures have a less significant increasing trend as compared to RCP 8.5. As a conservative approach, RCP 4.5 was used to evaluate the cold temperature climate indices at the project site in order to encapture the potential probability of colder temperatures within the scoring.

According to CMIP5 ensemble GCM model projections for Mean Winter Temperature (Figure A-14), there is an increasing temperature trend projected throughout the 21st century at the Town of Sussex. According to the reference period, mean winter temperatures average approximately - 12°C at the site. This value is projected to increase approximately 30-35% at the end of the 21st century. In terms of RCP 4.5, temperature increases of 10-15% between respective time horizons are projected over the duration of the 21st century. Furthermore, the maps presented in Figure A-15 show more predominant increases of mean winter temperature in southerly regions of the province along the Bay of Fundy, reaching further inland, including regions encompassing the Town of Sussex as compared to more northerly regions of New Brunswick.

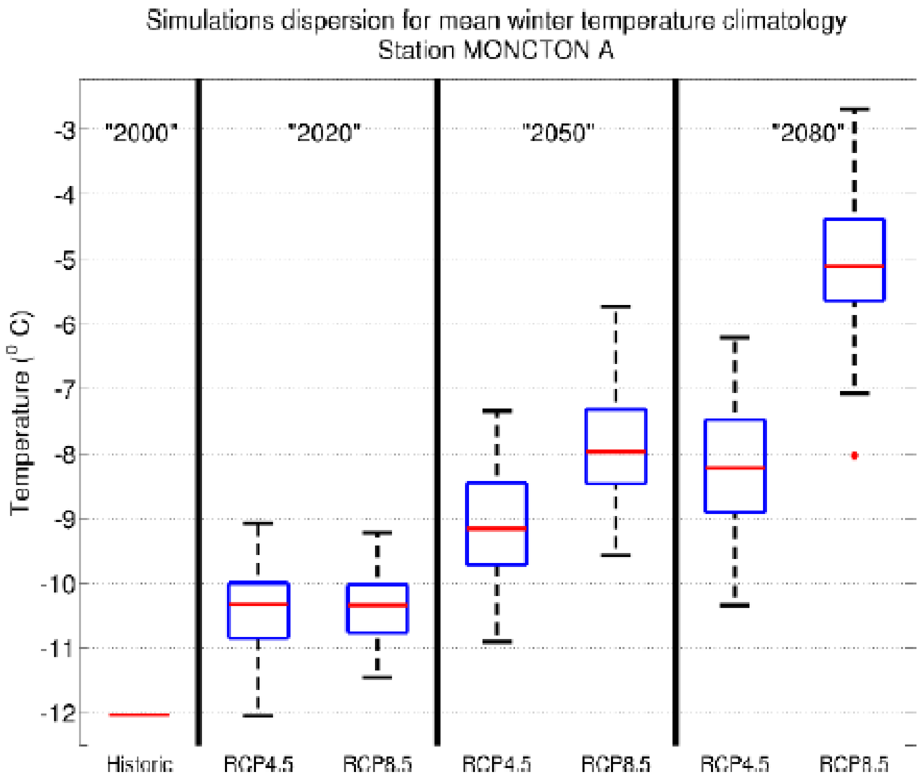


Figure A-14: CMIP5 ensemble GCM model projections for Mean Winter Temperature in Moncton, NB.

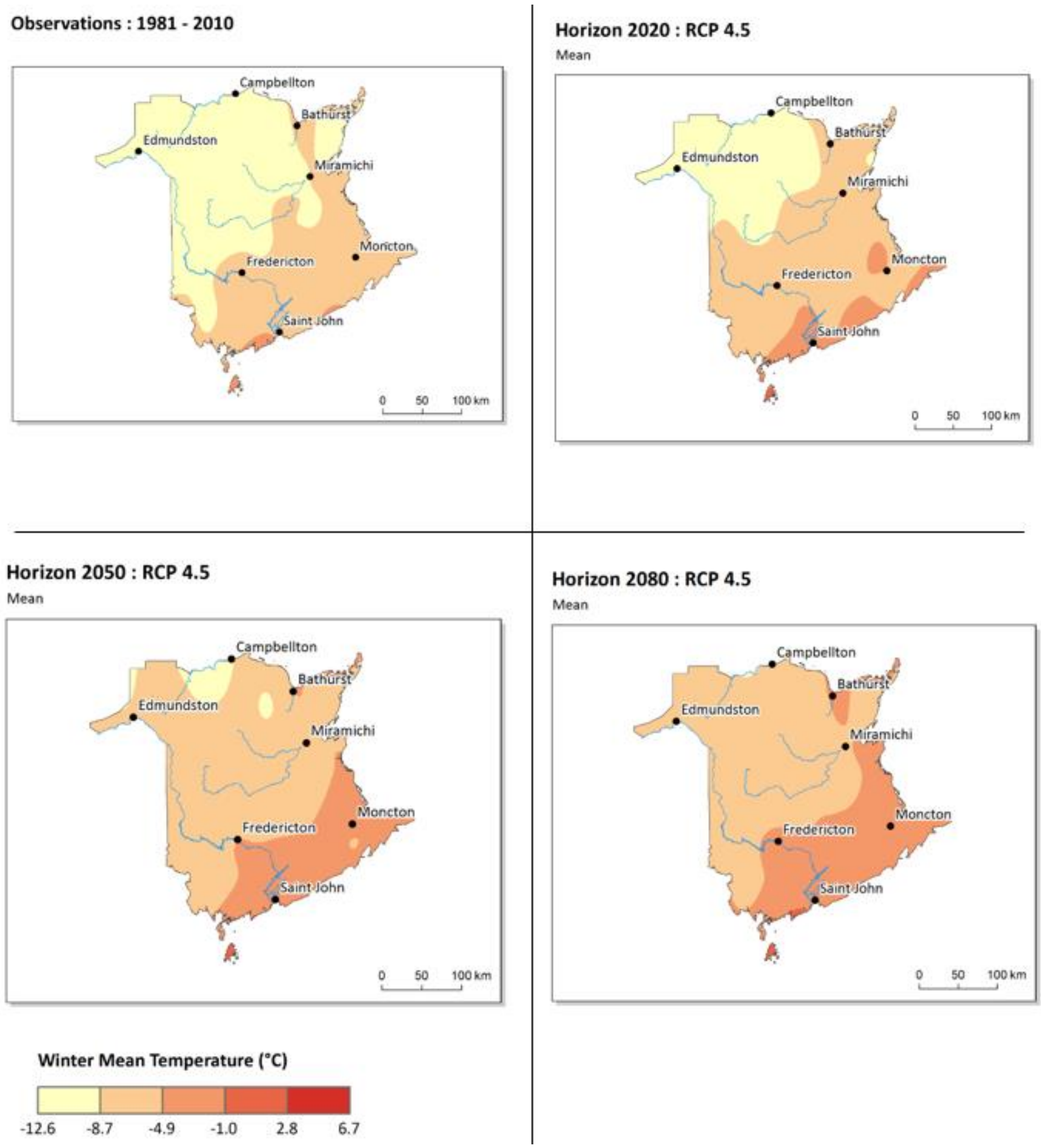


Figure A-15: New Brunswick Climate Futures CMIP5 ensemble GCM model projections for Mean winter Temperature in Regions across New Brunswick.

Figure A-16 and Figure A-17 presents the CMIP5 ensemble GCM projections for the number of frost days and the number of icing days, respectively. Historically, the Town of Sussex experiences approximately 120 frost days and 45 icing days. In both cases, the number of days with minimum and maximum daily temperatures less than 0 °C is projected to decrease over the 21st century. The trend is more significant in the number of icing days, meaning the number of days where the maximum temperature is less than 0 °C will become significantly less frequent near the end of the century. Frost days are projected to decrease approximately 60% over the 21st century, decreasing approximately 25% between subsequent time horizons. Similarly, the number of icing days are projected to decrease approximately 80% from the historical value to the end of the century. The largest decreases in the number of icing days occurs within the mid and long term time horizons at a magnitude of approximately 60% within each time frame.

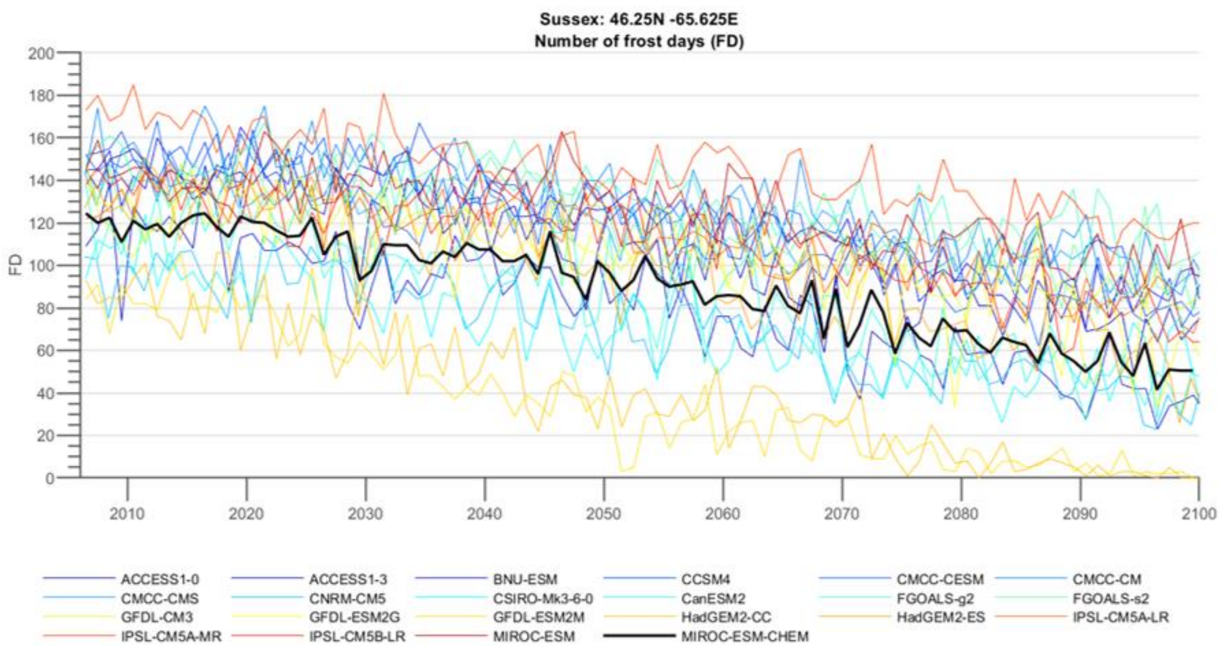


Figure A-16: CMIP5 ensemble GCM model projections for Number of Frost Days. A frost day is defined by when the daily minimum temperature is less than 0°C

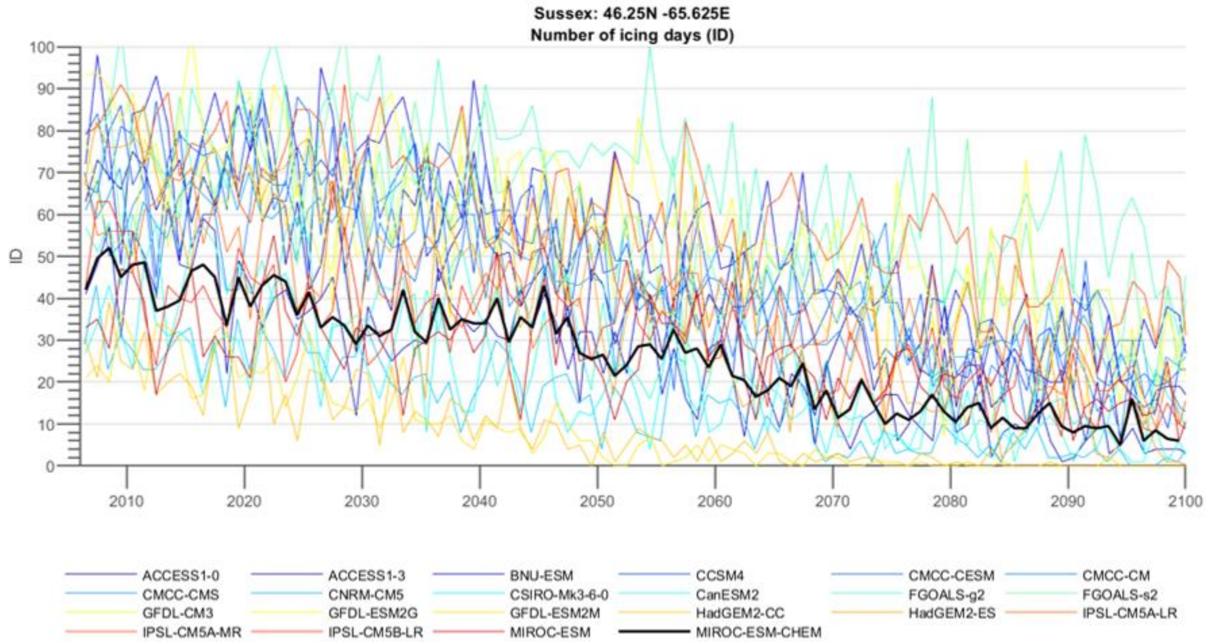


Figure A-17: CMIP5 ensemble GCM model projections for Number of Icing Days. An icing day is defined by when the daily maximum temperature is less than 0°C

CMIP5 ensemble GCM projections for the monthly minimum value of daily minimum temperature are presented in Figure A-18. The coldest temperatures experienced in the Town of Sussex occur during January and February, historically recording minimum temperatures of approximately -0 °C. According to the climate projections, the minimum temperature experienced during each month of the year is expected to increase relatively linearly throughout the 21st century. Increasing trends are greatest during the winter months, in contrast the summer months experience a lower increasing trend. The temperature projections indicate a decrease in the occurrence of extreme minimum temperatures in the Town of Sussex.

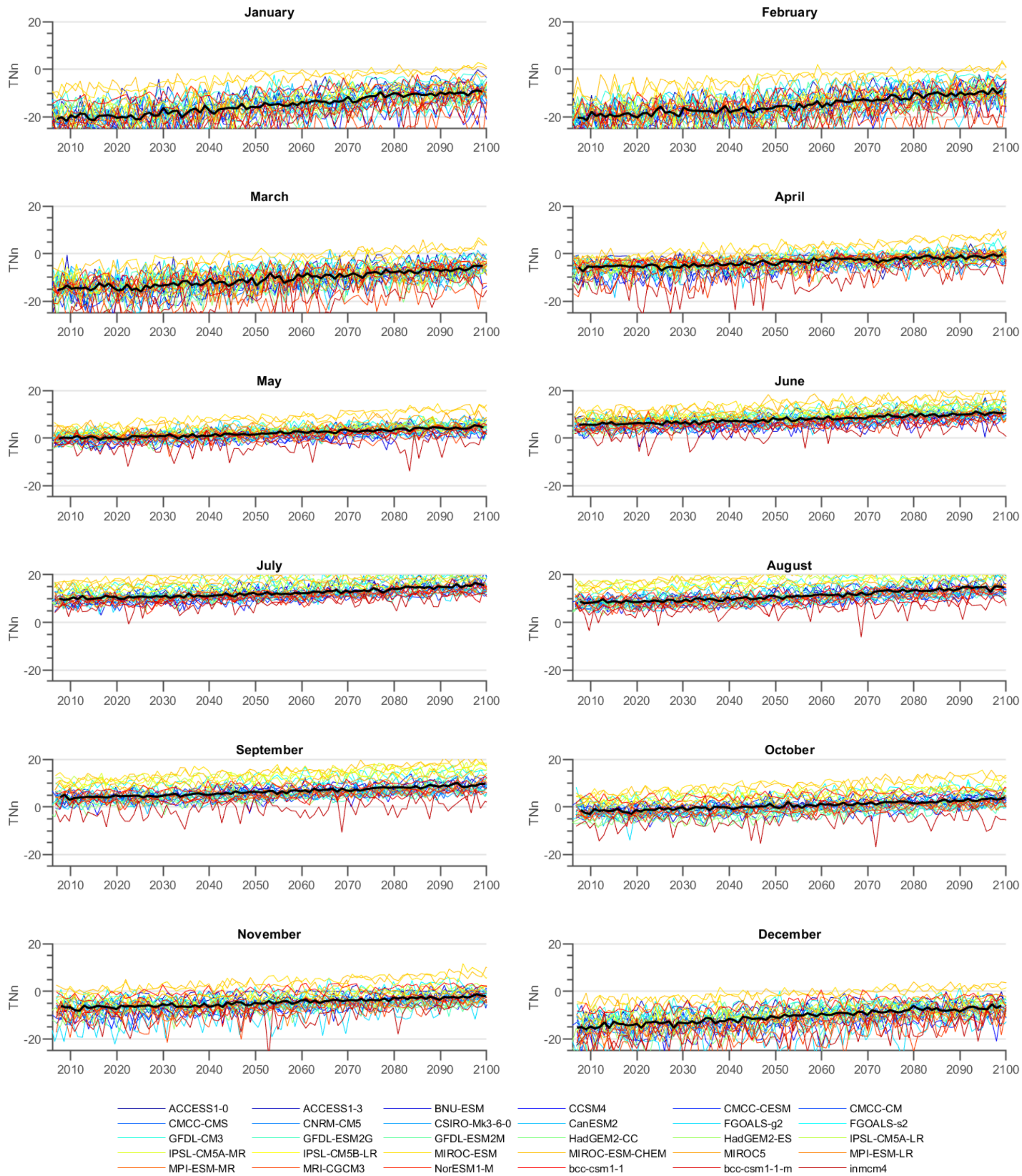


Figure A-18: CMIP5 ensemble GCM model projections for monthly minimum value of daily minimum temperature.

Figure A-19 presents CMIP5 ensemble GCM projections for Heating Degree Days (base 18°C). A relatively linear decreasing trend in the number of heating degree days is depicted at the site throughout the 21st century. This means that in the future, days where the temperature is below 18 degree will become less frequent, indicating an annual rise in temperatures. Historically, the site experiences approximately 5900 degree days, a decrease of approximately 5-10% is expected over each time horizon with respect to RCP 4.5.

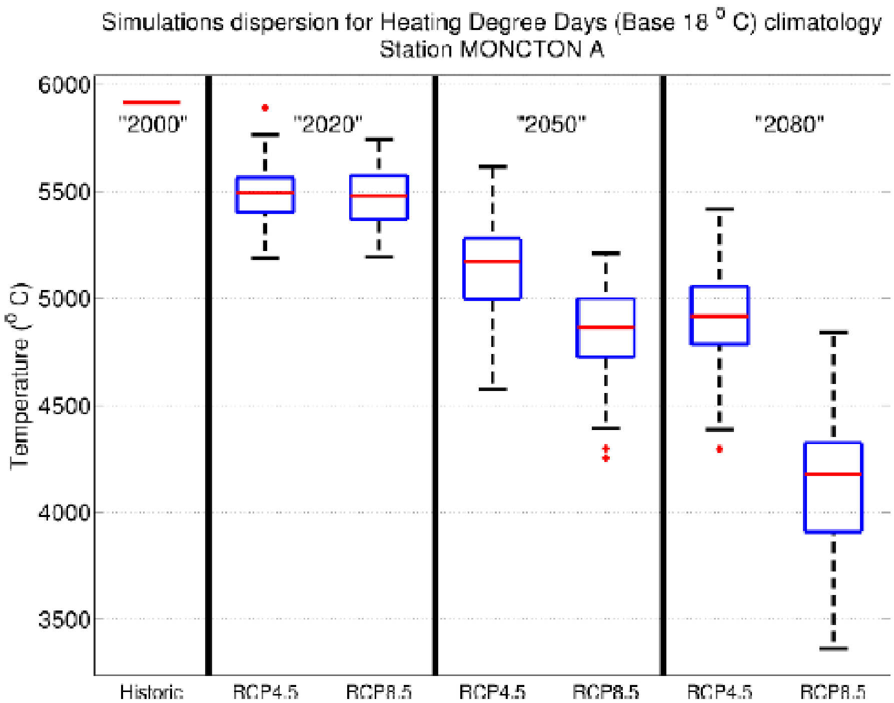


Figure A-19: CMIP5 ensemble GCM model projections for Degree Days below 18°C for Moncton, NB. A decreasing trend in the number of Heating Degree Days is projected with the largest decrease depicted in the timeframe "2080" projected year for RCP 8.5.

Furthermore, the maps presented in Figure A-20: New Brunswick Climate Futures CMIP5 ensemble GCM model projections for Heating Degree Days in Regions across New Brunswick.Figure A-20 show the projected decrease of heating degree days throughout New Brunswick. The map indicates that the southern regions of the province, including the region of the Town of Sussex, experiences a decrease in Heating Degree Days and overall experiences the less heating degree days as compared to more northern regions of New Brunswick.

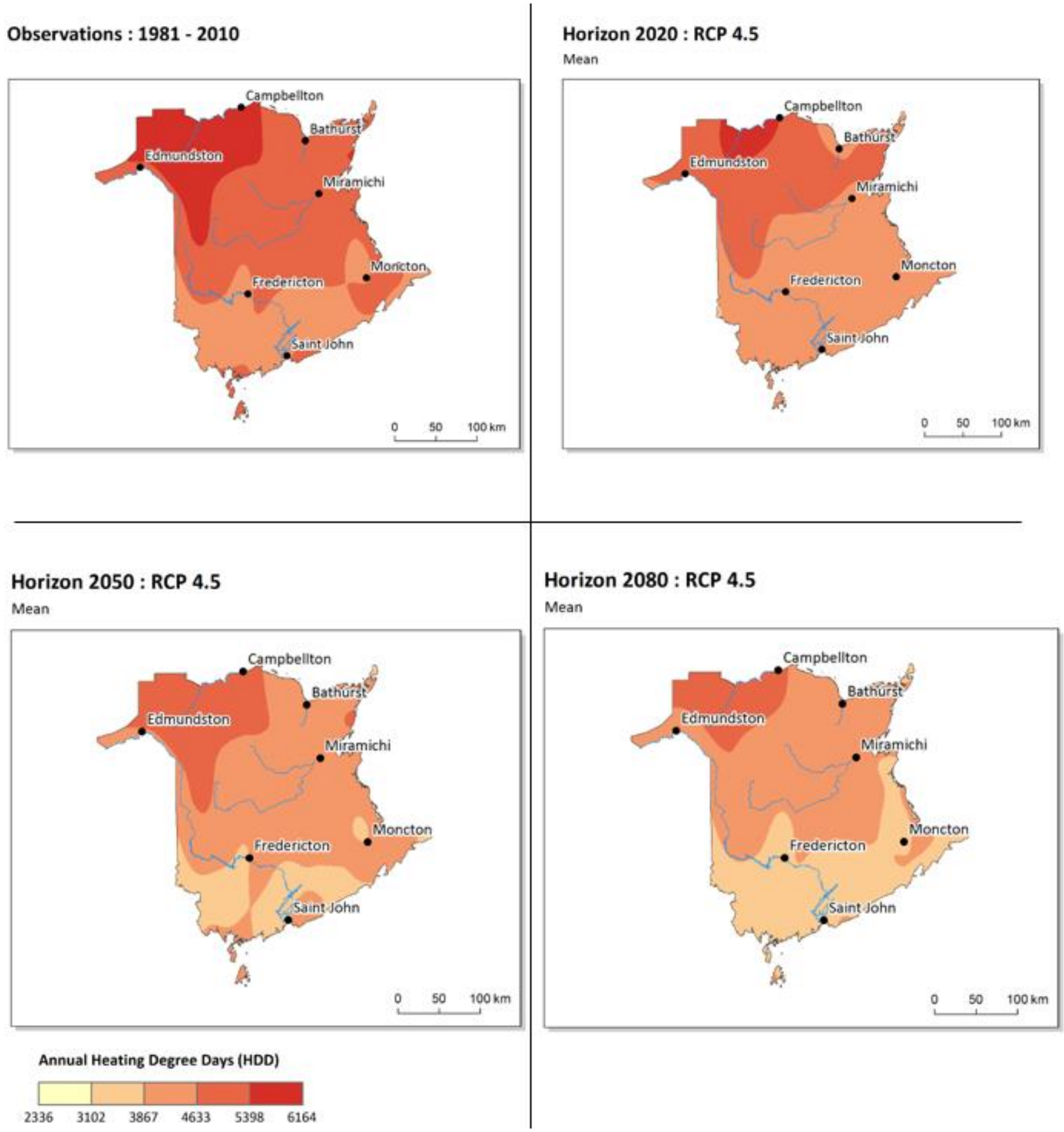


Figure A-20: New Brunswick Climate Futures CMIP5 ensemble GCM model projections for Heating Degree Days in Regions across New Brunswick.

A.2.4 Probability Scores

A probability score of 4 was assigned to the baseline because recorded historical temperatures represent the normal conditions experienced at the site from which change will occur over the 21st century as a result of climate change. Due to the binned nature of the PIEVC scoring, a score of 4 was assigned to the near-term as a conservative approach where cold temperatures experienced at the site may occur within the likelihood of historically experienced temperatures at the site. The mid-term was assigned a score of 3 to reflect the significant trends of increasing minimum temperatures and decreasing number of days with maximum and minimum freezing temperatures. Finally, the long-term was assigned a score of 2 because based on projections near the end of the 21st century it becomes remotely possible that the cold temperatures experienced within the historical period at the site will occur.

Table 2: Probability Scores for Cold Temperature for the Town of Sussex

Time Horizon	Baseline	Near-term	Mid-Term	Long-Term
Probability Score	4	4	3	2

A.2.5 Summary

According to climate projections, there will be a decrease in the frequency and magnitude of minimum temperatures experienced within the region of the Town of Sussex. Trends of increasing minimum temperatures are most significant during the winter months at the site. A decreasing trend of both days with maximum and minimum temperatures of 0 °C is projected for the site. Furthermore, projections of increases in annual and winter temperatures are modelled with high confidence within the province. There is strong evidence derived from projected modelled with high confident that overall colder temperatures will increase and become less frequent at the Town of Sussex over the 21st century.

A.3 Freeze-Thaw Cycles

Freeze-thaw cycles are a frequent occurrence in temperate climates, where temperature extremes can vary significantly. The effect of these cycles are most notably observed during the spring time, when the frozen ground is starting to thaw and temperatures fluctuate above and below 0°C. Temperature is known to have a variety of impacts on infrastructure, including weathering of concrete and pavement. Rapid changes in temperature (e.g., freeze-thaw cycles) cause additional weathering. Freeze-thaw cycles limit spring weight restrictions as temperature variability across the freezing mark can accelerate roadway damage. As these cycles decrease on average, opportunities for earlier or longer construction seasons may be presented. In the short term however; no significant change is anticipated.

A.3.1 Sources of Climate Information

The sources of climate information used to characterise trends in temperature at this site were obtained from GCMs. Since temperature is relatively well modelled at larger scales, the analysis made use of the large number of GCM projections available, including CMPI5 ensemble GCM model projections, which allows relative change to be estimated more accurately. CMIP5 GCM results were obtained from multiple sources including:

- *Future Climate Scenarios – Province of New-Brunswick* report published in 2016 by Roy and Huard. The box-plot figures were derived from projections of the CMIP5 ensemble GCM results statistically downscaled using observed records from selected meteorological stations.

- Provincial maps generated from CMIP5 ensemble GCM results presenting in the *Future Climate Scenarios – Province of New-Brunswick* report published in 2016 by Roy and Huard available through the Atlantic Climate Adaptation Solutions Association.

A.3.2 Findings

As the mean annual and winter temperature continues to increase throughout the region of Sussex, an annual decrease in the number of freeze thaw cycles is expected (Figure A-21). The historical and projected distribution within New Brunswick of the number of seasonal freeze-thaw days with respect to RCP 4.5 and RCP 8.5 can be seen in Figure A-22 and Figure A-23. The largest projected number of annual freeze thaw days occurs in the south-western region of the province adjacent to the Atlantic Ocean. A large portion of the southern latitude regions experience the least amount of freeze-thaw cycles as compared to mid-latitudes regions. It is noted that the most northern latitudes of the province also experience significantly less freeze thaw cycles than the south western region of the province.

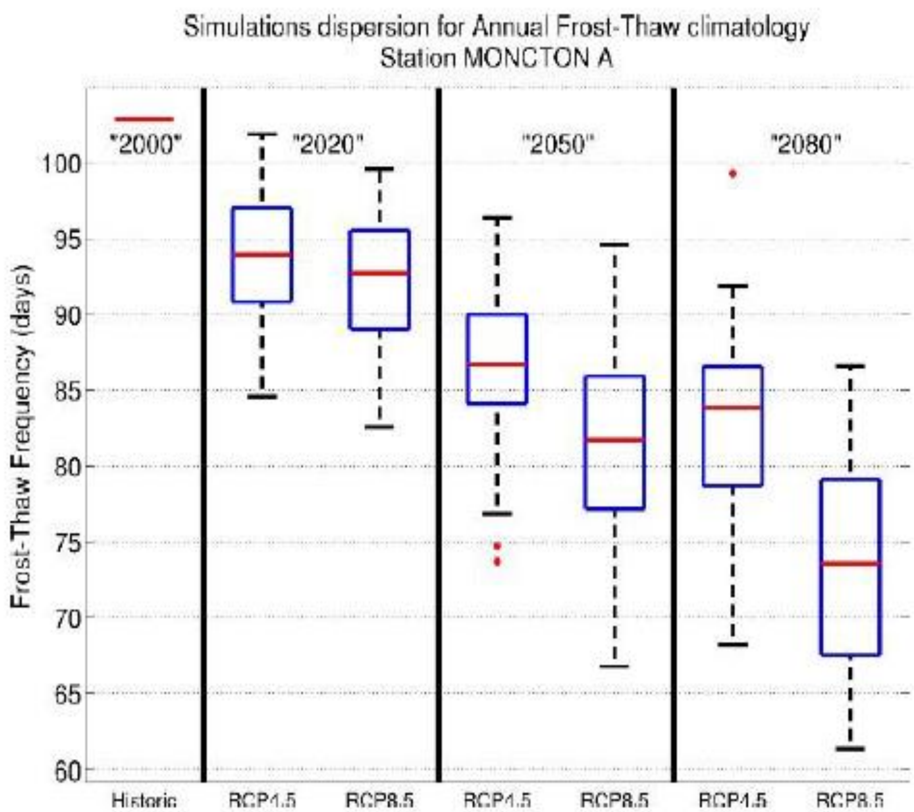


Figure A-21: CMIP5 ensemble GCM model projections for Annual Freeze-Thaw Days for Moncton, NB. A decreasing trend in the number of freeze-Thaw Days is projected with the largest decrease occurring during the time frame "2080" for RCP 8.5.

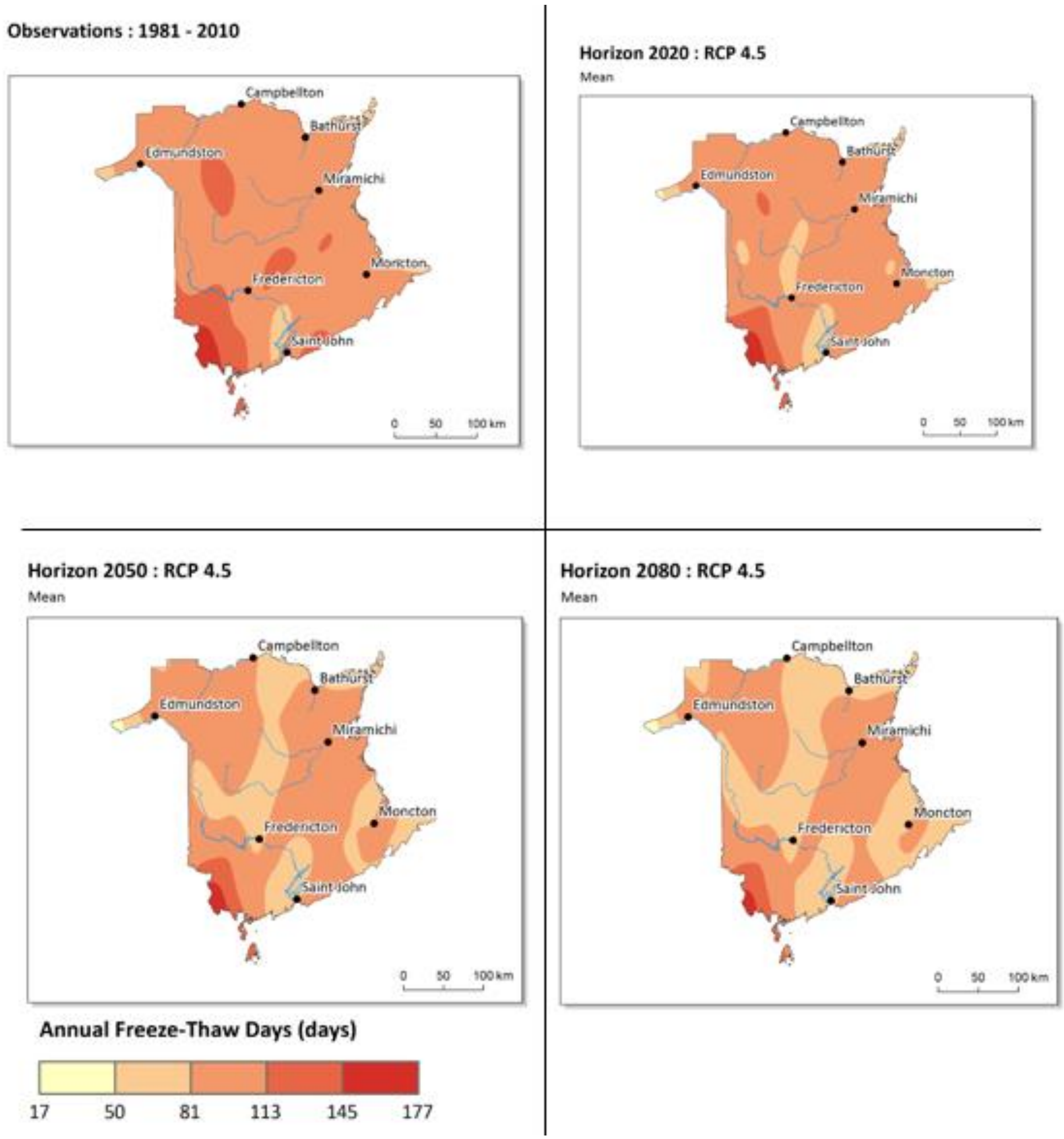


Figure A-22: New Brunswick Climate Futures CMIP5 ensemble GCM model projections for Annual Freeze Thaw Days in Regions across New Brunswick under RCP 4.5.

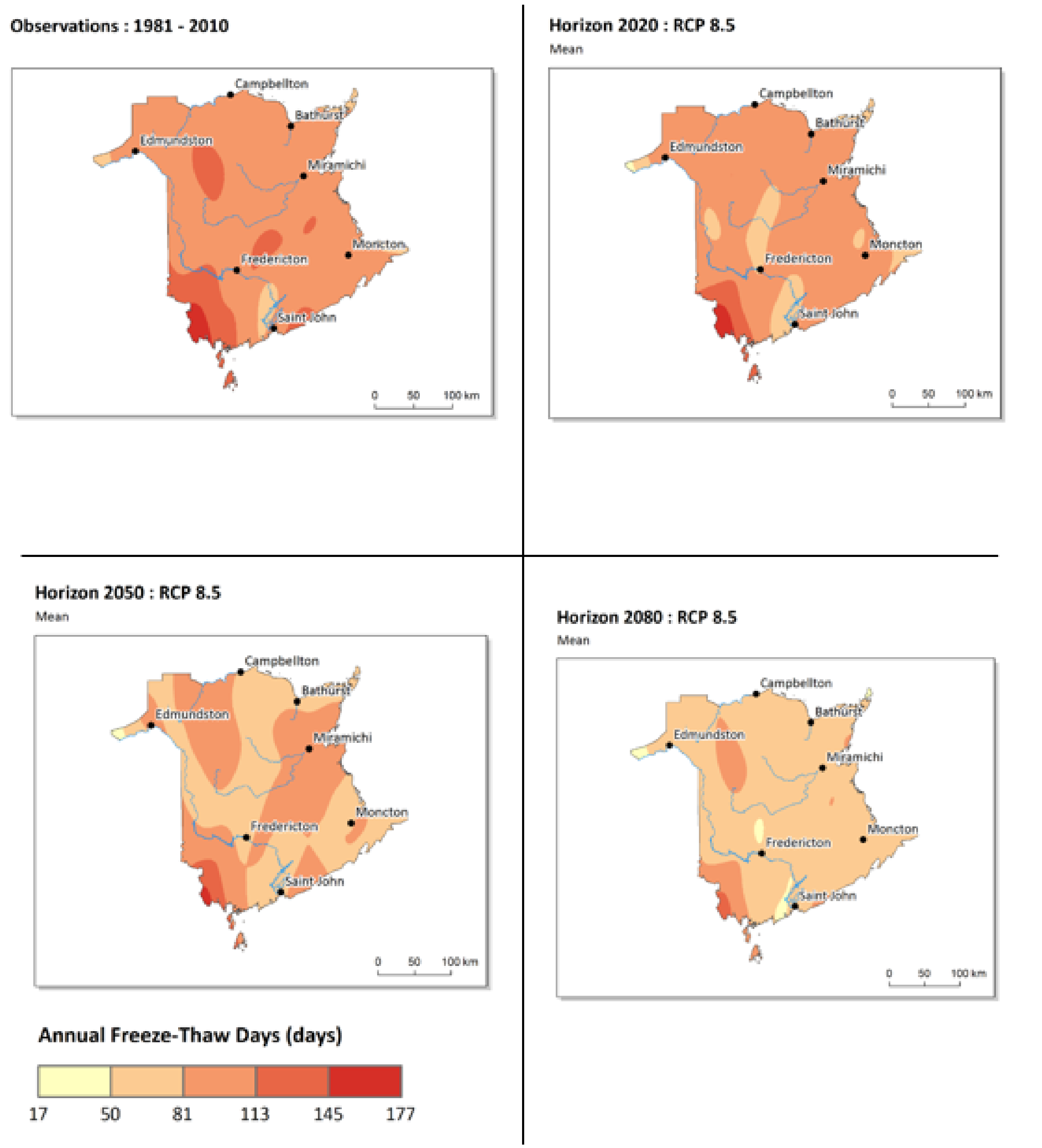


Figure A-23: New Brunswick Climate Futures CMIP5 ensemble GCM model projections for Annual Freeze Thaw Days in Regions across New Brunswick under RCP8.5.

Although the annual number of freeze-thaw cycles is decreasing due to increasing mean temperatures a seasonal shift in the occurrence of freeze thaw cycles is expected. The shifting seasonal frequency of freeze thaw cycles is depicted in Figure A-24. While the number of freeze thaw cycles occurring in the spring months is projected to decrease, an increase is projected during the winter months due to warmer temperatures arriving earlier.

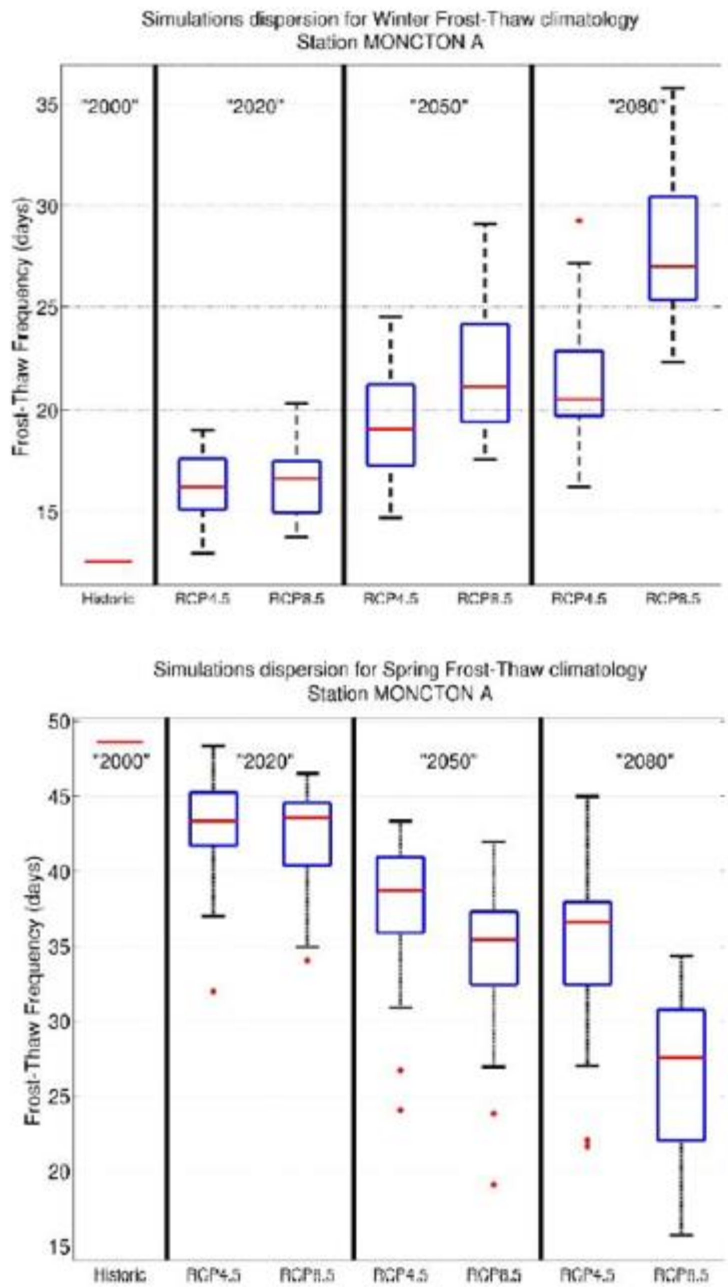


Figure A-24: CMIP5 ensemble GCM model projections for winter and spring (top and bottom frames respectively) Freeze-Thaw Days for Moncton, NB. A decreasing trend in the number of freeze-Thaw Days is projected with the largest decrease occurring during the time fram

Figure A-25 to Figure A-28 shows the largest number of winter freeze thaw days occurring in the south-western region and along the eastern regions of the province. According to RCP 4.5 CMIP5 ensemble GCM projections there is a projected 15-20% decrease in the annual number of freeze thaw cycles over the course of the 21st century. Decreases in the annual number of freeze-thaw cycles within the region of 5-10%, 5-10%, and 0-5% are projected for the near-term, mid-term, and long-term time horizons respectively in terms of RCP 4.5. Spring freeze thaw cycles are projected to decrease at rates of 10-15%, 1--15% and 0-5% over the subsequent time horizons with respect to RCP 4.5, with an overall decrease of approximately 25% over the course of the 21st century. Concurrently, the number of winter freeze thaw cycles is projected to increase at rates of 30-35%, 15-20% and 10-15% over the near-term, mid-term, and long-term time horizons.

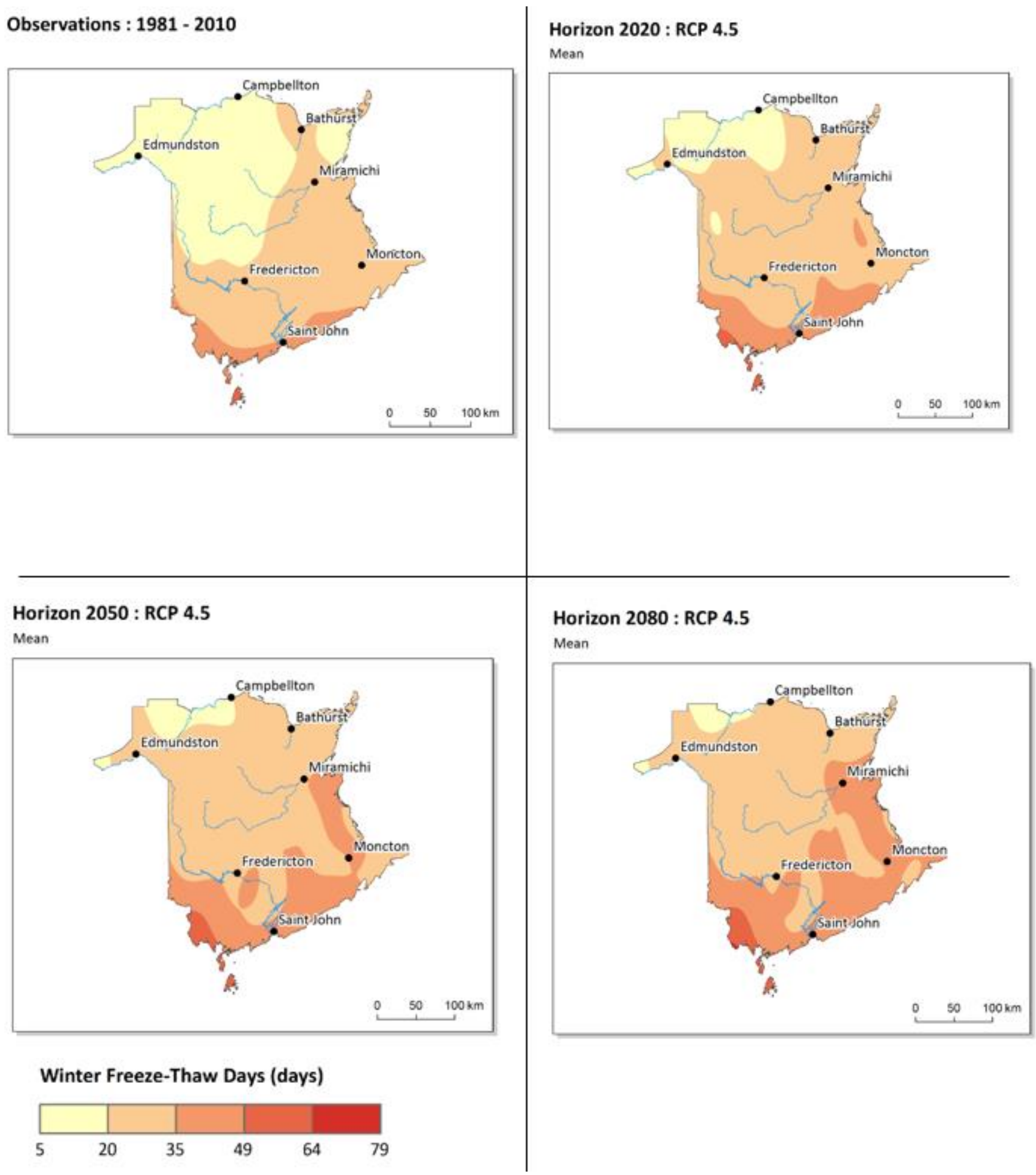


Figure A-25: New Brunswick Climate Futures CMIP5 ensemble GCM model projections for Winter Freeze Thaw Days in Regions across New Brunswick under RCP 4.5.

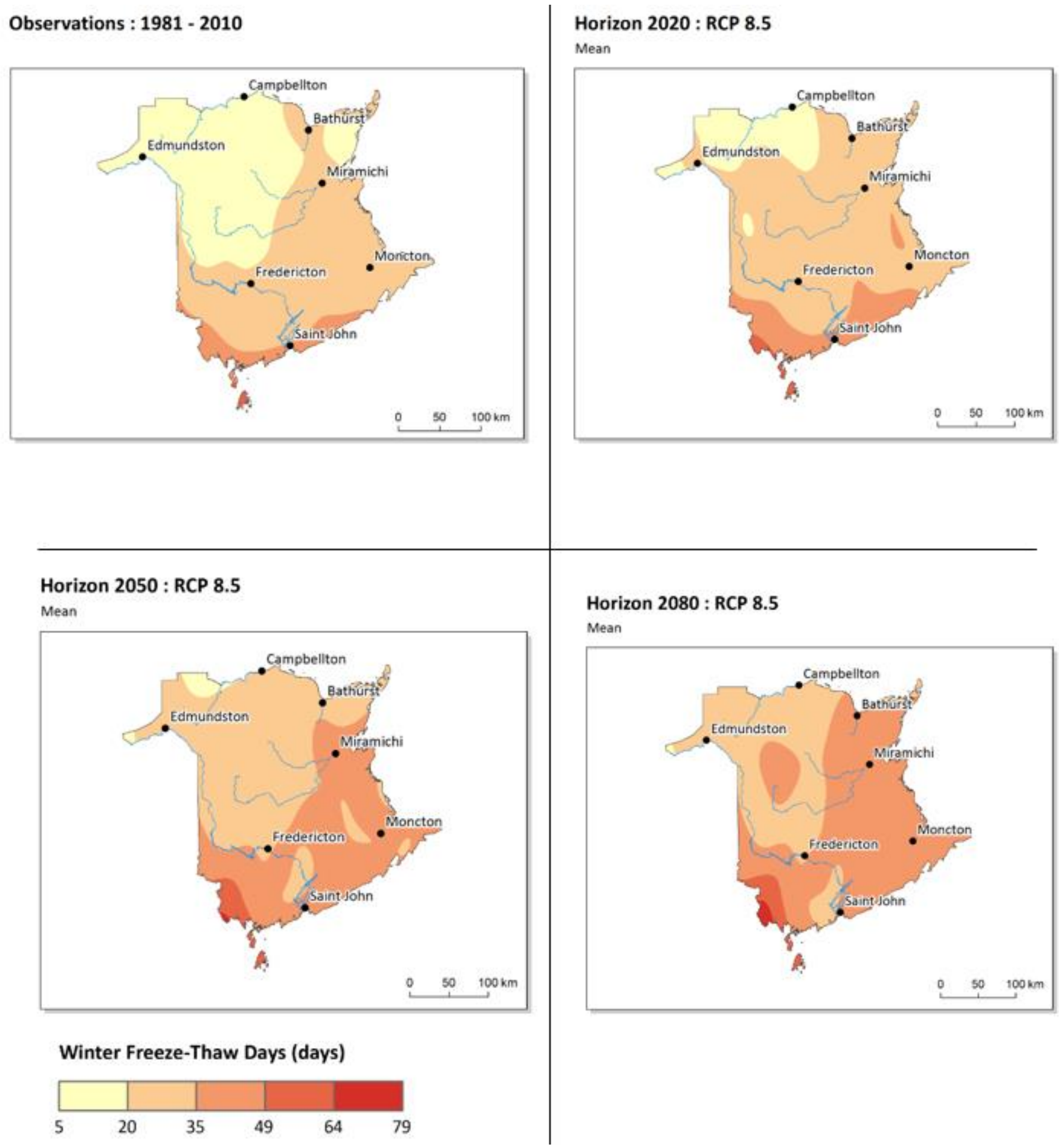


Figure A-26: New Brunswick Climate Futures CMIP5 ensemble GCM model projections for Winter Freeze Thaw Days in Regions across New Brunswick under RCP 8.5.

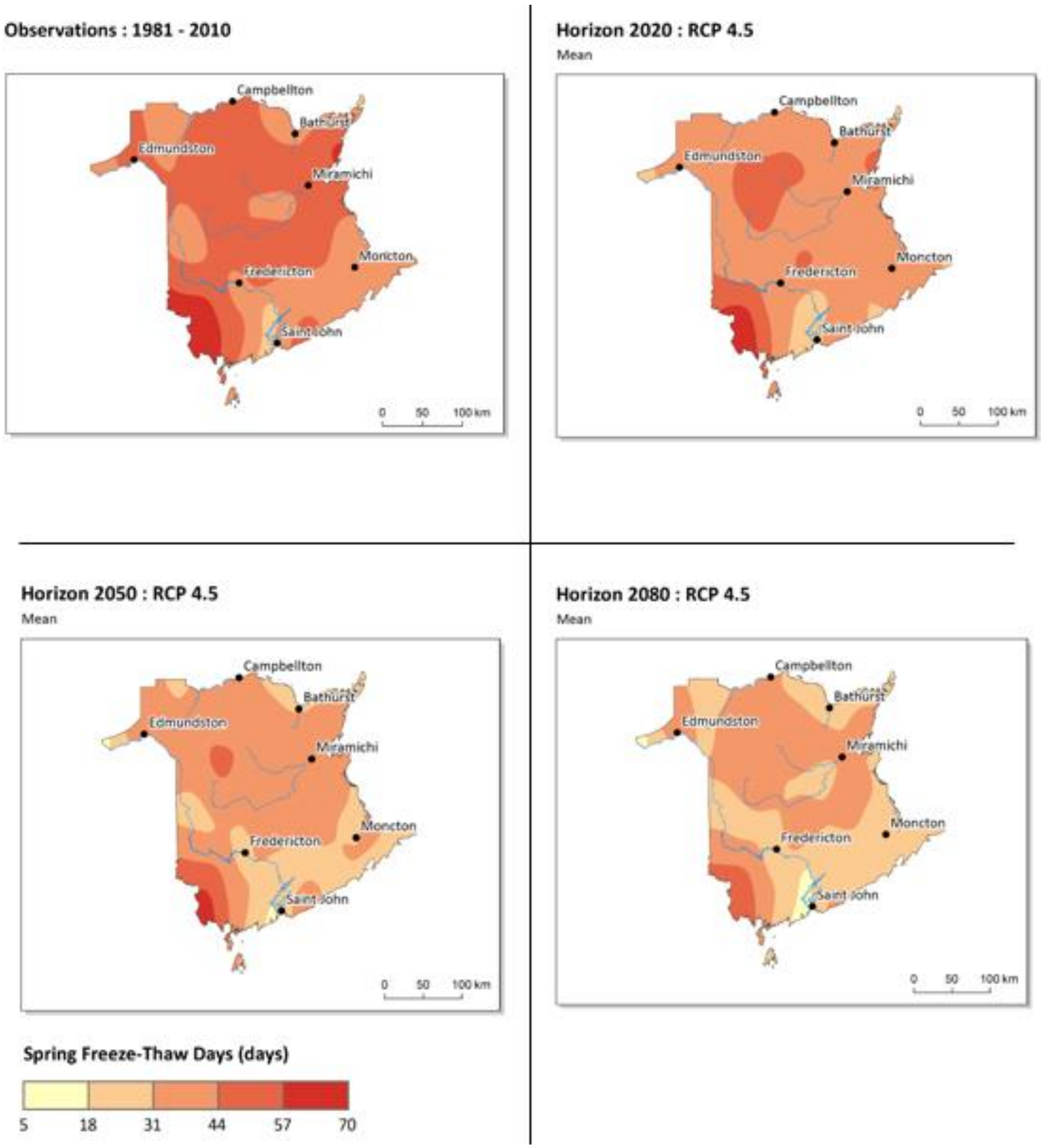


Figure A-27: New Brunswick Climate Futures CMIP5 ensemble GCM model projections for Spring Freeze Thaw Days in Regions across New Brunswick under RCP 4.5.

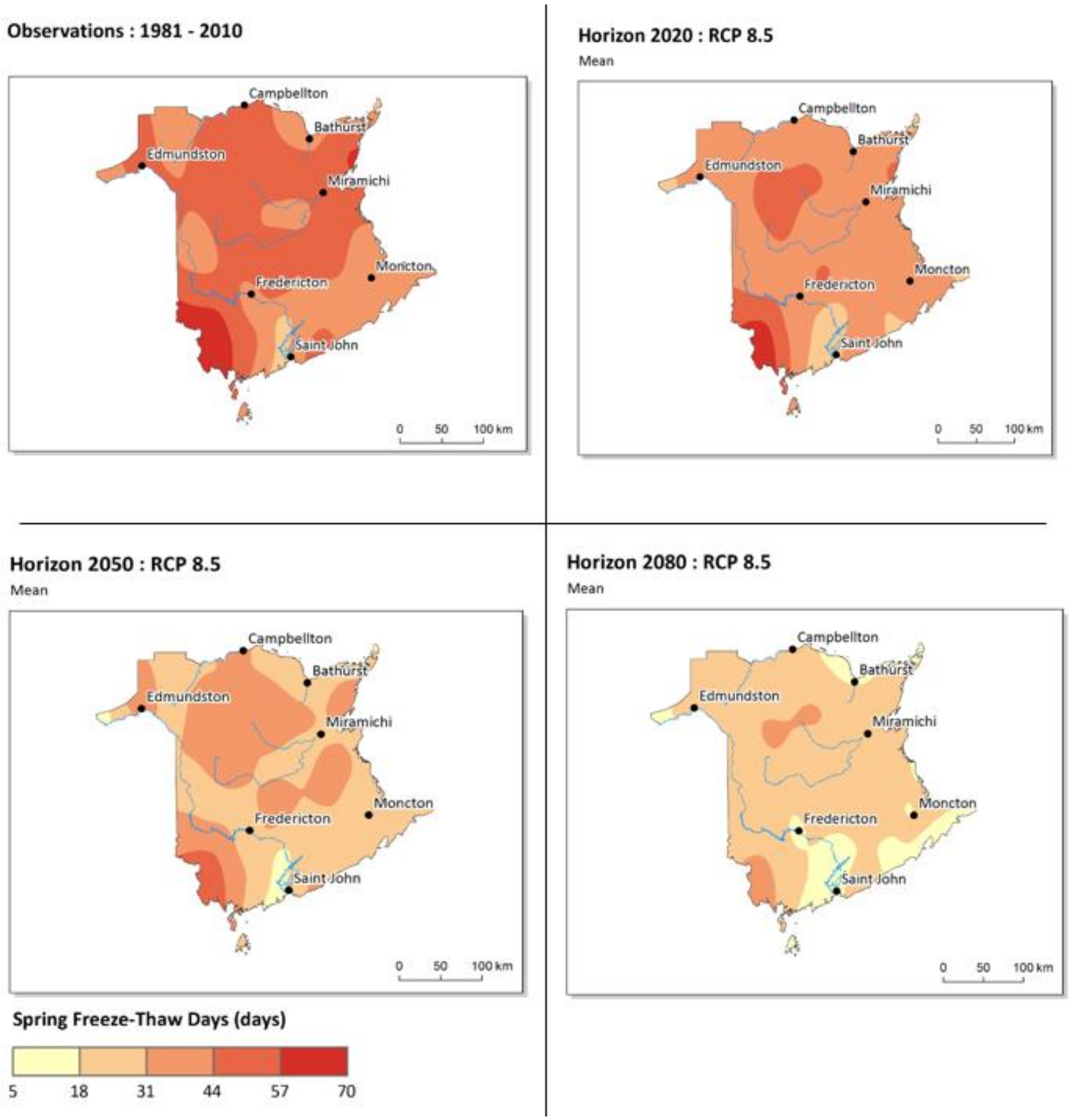


Figure A-28: New Brunswick Climate Futures CMIP5 ensemble GCM model projections for Spring Freeze Thaw Days in Regions across New Brunswick under RCP 8.5.

A.3.3 Probability Scores

The climate indices were evaluated and scored within the PIEVC matrix in terms of RCP 4.5, this is due to the climate scenario projecting less significant decreasing trends than RCP 8.5; this was done as a conservative scoring approach to capture the worst case event likelihood within the matrix.

The baseline was assigned a score of 4 due to the historical measurements representing normal conditions at the site. Near-term projected decrease in the annual number of freeze thaw cycles was determined to be not significant enough to decrease the score from the baseline due to the binned nature of the PIECV matrix. Finally the mid-term and long-term time horizons were assigned scores of 3 to account for increasing temperature projections, decreasing number of days where minimum temperatures reach freezing and an overall decreasing trend of annual freeze thaw cycles.

Table 3: Probability Scores for Number of Annual freeze-Thaw Days at the Town of Sussex.

Time Horizon	Baseline	Near-term	Mid-term	Long-term
Probability Score	4	4	3	3

A.3.4 Summary

The annual number of freeze-thaw days is expected to decrease over the course of the 21st century. This is due to the mean, and minimum annual rise in temperatures throughout the region. While the warmer temperatures expected in the colder months could extend the number of freeze-thaw cycles typically observed in a year in the short term, the overall number will decrease according to CMIP5 GCM projections. This annual trend obscures seasonal patterns. In many regions, shoulder seasons (spring and fall) are experiencing a decrease in freeze thaw cycles as minimum daily temperatures rise above 0˚C. However, in some localities winter freeze thaw cycles are actually increasing as maximum daily temperatures rise above 0˚C.

A.4 Snow Accumulation

Snow can impact municipal infrastructure in terms of direct loading on buildings and seasonal recreational activities. Snow affects operations and accessibility during the winter months and impacts maintenance requirements, such as snow removal and de-icing.

A.4.1 Climates Change Processes

There are several climate change processes which may result in potential changes in snow accumulation:

- Firstly, the increased air temperature will allow for the atmosphere to hold more moisture and therefore more precipitation.
- In addition, a poleward shift of extratropical cyclone activity is expected with climate change, which may result in greater storm activity in Atlantic Canada.
- Lastly, increased temperatures affect snow accumulation both by increasing rates of snow melt and causing precipitation that may have historically fell as snow to fall as rain.

A.4.2 Sources of Climate Information

The sources of climate information used as part of this analysis are:

- Trends in snow water equivalent were obtained from Mudryk et al. (2018, Figure 3.7.1), with trends in observations from re-gridded data (CANGRD), and CMIP5 ensemble GCM model projections for the years 2020-2050.
- Environment Canada “White Christmas” indices obtained from the New Brunswick Government website.
- CMIP5 GCM results were obtained from multiple sources including:

- *Future Climate Scenarios – Province of New-Brunswick* report published in 2016 by Roy and Huard. The box-plot figures were derived from projections of the CMIP5 ensemble GCM results statistically downscaled using observed records from selected meteorological stations.
- Provincial maps generated from CMIP5 ensemble GCM results presenting in the *Future Climate Scenarios – Province of New-Brunswick* report published in 2016 by Roy and Huard available through the Atlantic Climate Adaptation Solutions Association.

A.4.3 Findings

The overall conclusions from this analysis were that in Eastern Canada, snow accumulation is dominated by temperature trends, and a net decrease in snow accumulation is expected throughout the 21st century. It is noted that this is not the case everywhere (e.g., some regions further north may experience an increase in snow before a decrease occurs, as seen in Figure A-29). CMIP5 ensemble GCM model projections shown in Figure A-30 depict a decrease of approximately 10-15% in the annual number of snow days in the long term for RCP 8.5 and approximately 5% for RCP 4.5 as compared to historical values.

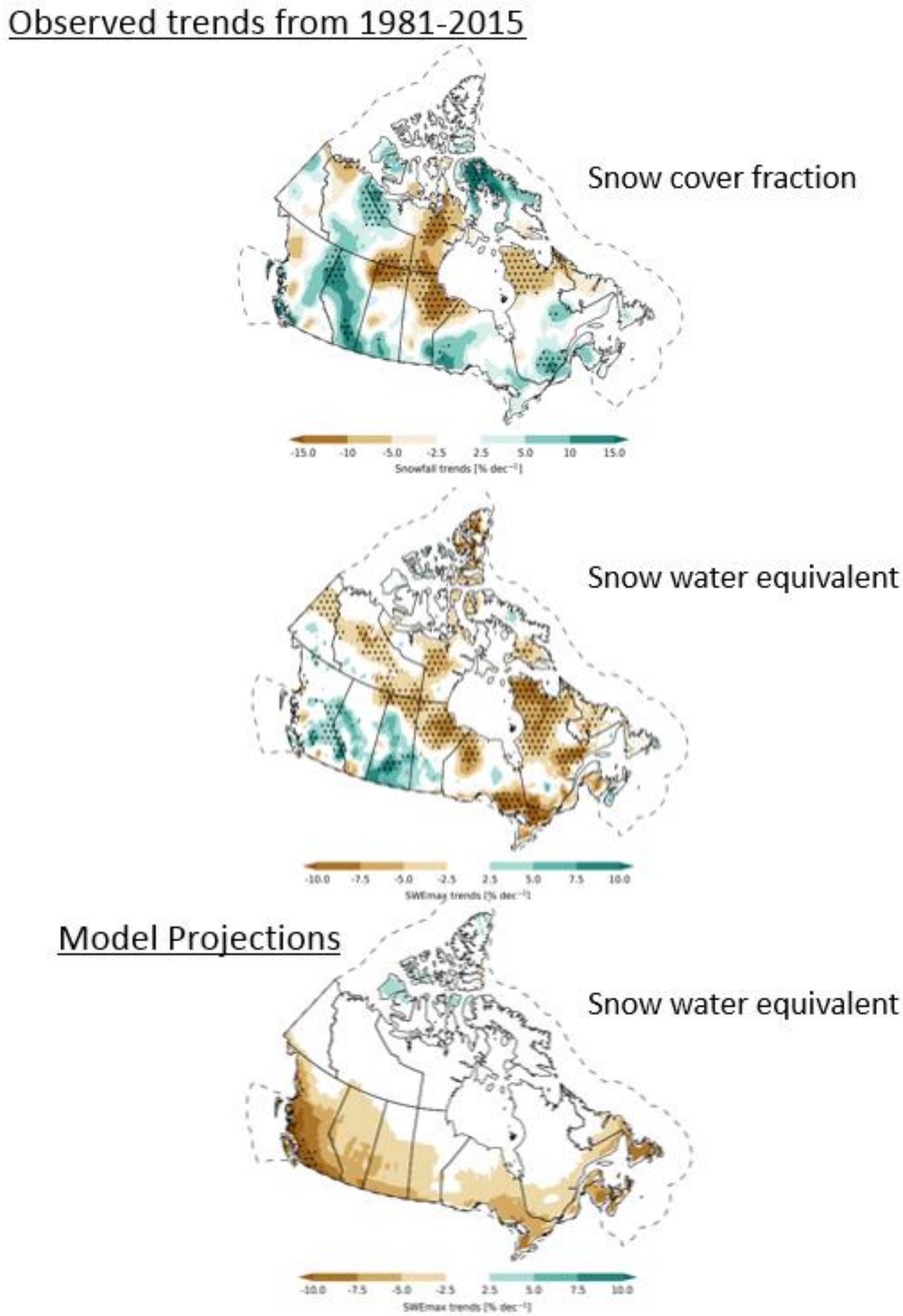


Figure A-29: Trends in observed snow cover and snow water equivalent (top frames), and projected changes in snow water equivalent (bottom frames). Observations are based on regridded data (CANGRD). Model projections are for 2020-2050, shown as percent change relative to the 1981-2015 mean, and are based on the CMIP5 ensemble. Blue colors show an increase in snow; brown colors show a decrease. Stippling indicates pointwise significance at the 90th percentile (from Mudryk et al. 2018). This figure shows that Atlantic Canada may have experienced some increases in snow over the historical period, but that future projections are for decreases in snow throughout the region.

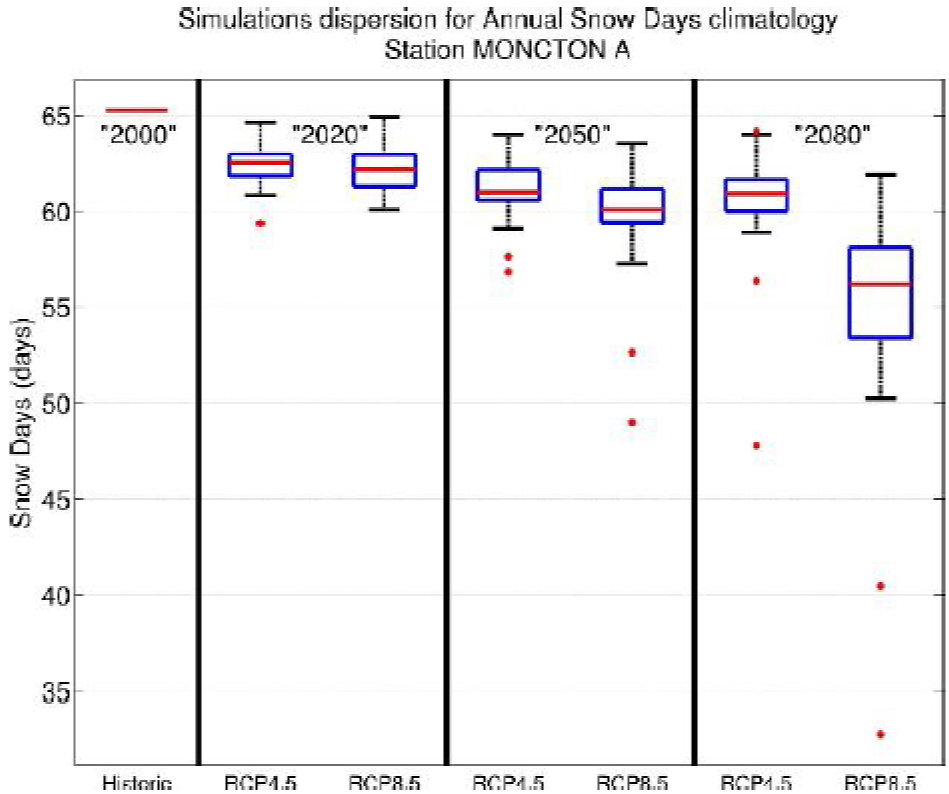


Figure A-30: CMIP5 ensemble GCM model projections for Annual Snow Days for Moncton. An decrease in number of snow days is projected with the largest decrease occurring during the time frame "2080" for RCP 8.5.

A climate change indicator for snowfall used by DELG is the White Christmas indicator. In the past, it was typical for snow to be on the ground during the Christmas time throughout New Brunswick; however, White Christmases are becoming less likely. Data has been collected from six municipalities across the province since 1960, and it's evident that the probability of these communities seeing a White Christmas is decreasing, especially in the southern regions of the province, including the area of Sussex.

Figure A-31: Environment Canada measurements of the probability of a "White Christmas" occurring in a given decade in Regions across New Brunswick.

A.4.4 Probability Scores

There are many aspects of snowfall which can impact infrastructure. The rate of snow fall, the total amount over different durations, or even the characteristics of the snow can be determining key factors. Furthermore, snow impacts maintenance requirements, planning, transportation, as well as seasonal recreational activities within the Town.

The baseline was assigned a score of 4 due to historical measurements representing normal conditions at the site. The probability scores for subsequent time horizons where assigned in relation to the baseline score based on an understanding of overall changes in snow processes. Studies show that there may be increased variability of snow fall in the short-term which is difficult to quantify, with a significant decrease in snow fall by late-century. Towards the end of the century within the mid-term is it expected that due to the known impacts of increased temperatures on snow fall amount it is unlikely for the threshold to be exceeded as a probability than what is currently expected. Furthermore, at the end of the century, it becomes improbable that the threshold will be exceeded due to projected increases in mean and minimum temperatures within the region.

Table 4: Probability Scores for Snow at the Town of Sussex

Time Horizon	Baseline	Near-term	Mid-term	Long-term
Probability Score	4	4	3	2

A.4.5 Summary

Atlantic Canada may have experienced some increases in snow over the historical period, but future projections are for significant decreases in snow by mid-century. These findings are consistent with the IPCC statement that it is "very likely that snow cover will reduce as temperatures rise over the next century". Compared to other sites, Sussex showed greater trends compared to more northerly sites, where rising temperatures are still conducive to snow formation.

A.5 Total Annual and Seasonal Precipitation and Rainfall

In New Brunswick, the total annual precipitation is expected to increase according to model GCM projections. Total annual precipitation reports the general amount of rainfall and snowfall the region experiences. Total precipitation can provide a basis for understanding how precipitation events may change on an annual basis at the site when compared to precipitation and snowfall historical and projection data. Total Annual and seasonal precipitation may impact agriculture and water availability for crops during growing seasons, water supply and natural resources.

A.5.1 Climate Change Processes

There are several processes driving potential changes in precipitation quantities:

- A warmer atmosphere is able to hold more moisture, which leads to more precipitation (accelerated water cycle).
- Anticipated changes to atmospheric circulation and synoptic (large-scale) weather patterns which will affect the locations of storm tracks and may affect precipitation in Eastern Canada.
- Changes to aerosol distribution.
- Changes to cloud formation processes.
- Shift from snowfall to rainfall.

A.5.2 Sources of Climate Information

Findings were obtained from literature and CMIP5 GCM results were obtained from multiple sources including:

- Raw data obtained from the Canadian Center for Climate Modelling and Analysis, processed using Climdex indices to produce plots.
  Future Climate Scenarios – Province of New-Brunswick report published in 2016 by Roy and Huard. The box-plot figures were derived from projections of the CMIP5 ensemble GCM results statistically downscaled using observed records from selected meteorological stations.
- Provincial maps generated from CMIP5 ensemble GCM results presenting in the *Future Climate Scenarios – Province of New-Brunswick* report published in 2016 by Roy and Huard available through the Atlantic Climate Adaptation Solutions Association.

A.5.3 Findings

Based on the IPCC AR5, average precipitation has already increased and is expected to keep increasing globally. However, regional trends are spatially variable, with some regions becoming wetter and others becoming dryer. Projections for NB show increasing total annual precipitation for the region.

In Figure A-32 CMIP5 ensemble global climate model projections for annual total precipitation on wet days are shown for the location of Sussex. Raw data from the models was combined to produce a plot of all the models together. The black line shows the ensemble median, and the scatter of models shows the level of uncertainty associated with the projection of different GCMs. This figure also shows that total annual precipitation is expected to increase within the region of Sussex over the 21st century. CMIP5 ensemble GCM projections for annual total precipitation in wet days for Sussex indicate increases of approximately 5-10%, 5%, and 5% for the near-term, mid-term, and long-term time horizons, respectively. Overall an increase of approximately 15% is projected at the site over the 21st century.

A relatively linear increase in annual precipitation is expected over the 21st century at the site according to the CMIP5 ensemble GCM projections as seen in Figure A-33. Annual Precipitation at the site is projected to increase approximately 10-15%. Overall, southerly regions experience higher total precipitation compared to north-eastern regions in the province as depicted on the provincial maps presented in Figure A-34.

CMIP5 ensemble GCM projections for the annual number of rain days are presented in Figure A-35. The results suggest a decrease in the annual number of days from the historical to the near-term and increasing over subsequent time horizons thereafter.

Figure A-36 depicts a relatively linear increase in the total precipitation during the winter and spring months over the 21st century. Figure 3.10.9 shows an overall increase in summer precipitation over the 21st century, however, the trend is less significant as compared to the spring and winter months. Overall, an increase of approximately 25% and 30% is expected for the spring and winter months respectively while an increase of approximately 5% expected during the summer over the 21st century with respect to RCP 8.5.

The maps presented in Figure A-37 show that a significant amount of winter precipitation occurs over the western and southern regions of the province, however, the largest precipitation amounts occur in the north-east. Figure A-38 shows significant precipitation amounts occurring in the south-western and north-eastern regions of the province. Spring precipitation amounts within the mid to upper range occur within the region of the site, as compared to other regions in New Brunswick throughout the 21st century. Figure A-39 shows summer precipitation occurs predominately in the south and north-western regions of the province; the least amount of summer precipitation is depicted to occur in a region near to the project site.

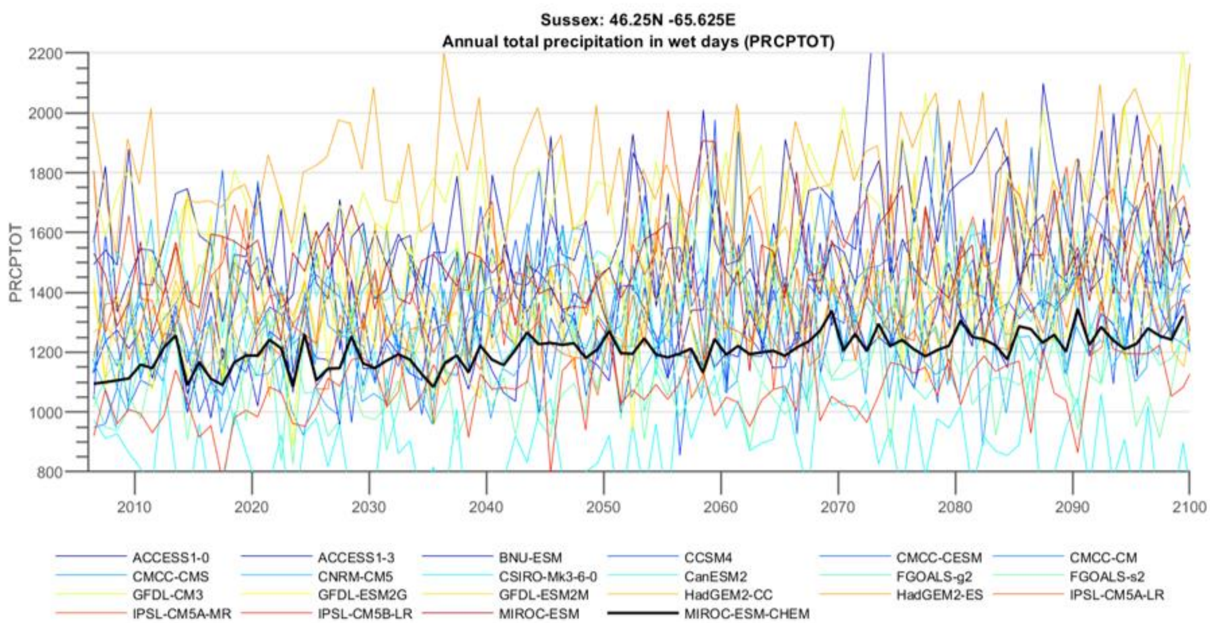


Figure A-32: CMIP5 ensemble GCM model projections for total annual precipitation on wet days. Although the inter-model variability is high, there is an apparent increase in this parameter. It is noted that GCMs have spatial resolutions much larger than the scale of some precipitation processes. The median is shown in black.

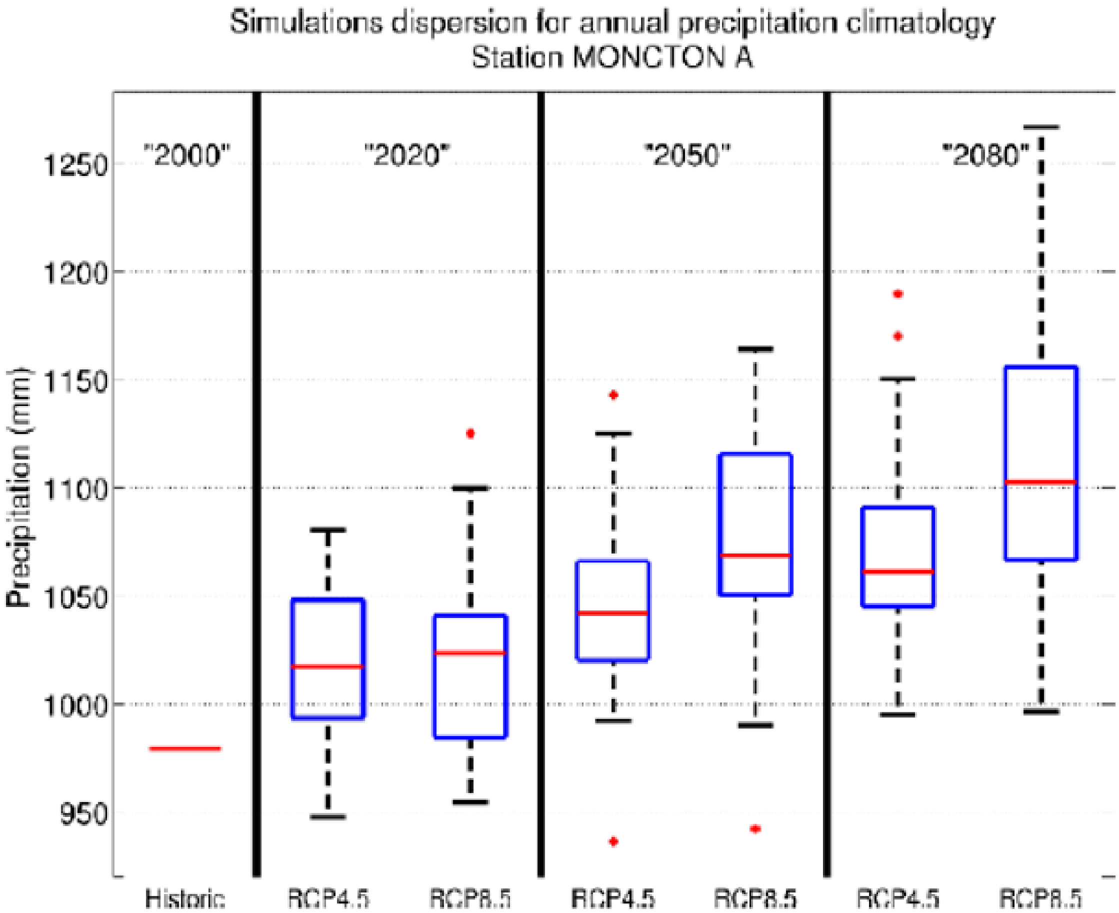


Figure A-33: CMIP5 ensemble GCM model projections for Annual Precipitation Accumulation in Moncton, NB. The figure project an increase in annual precipitation, with the largest increase depicted in the "2080" projected year for RCP 8.5.

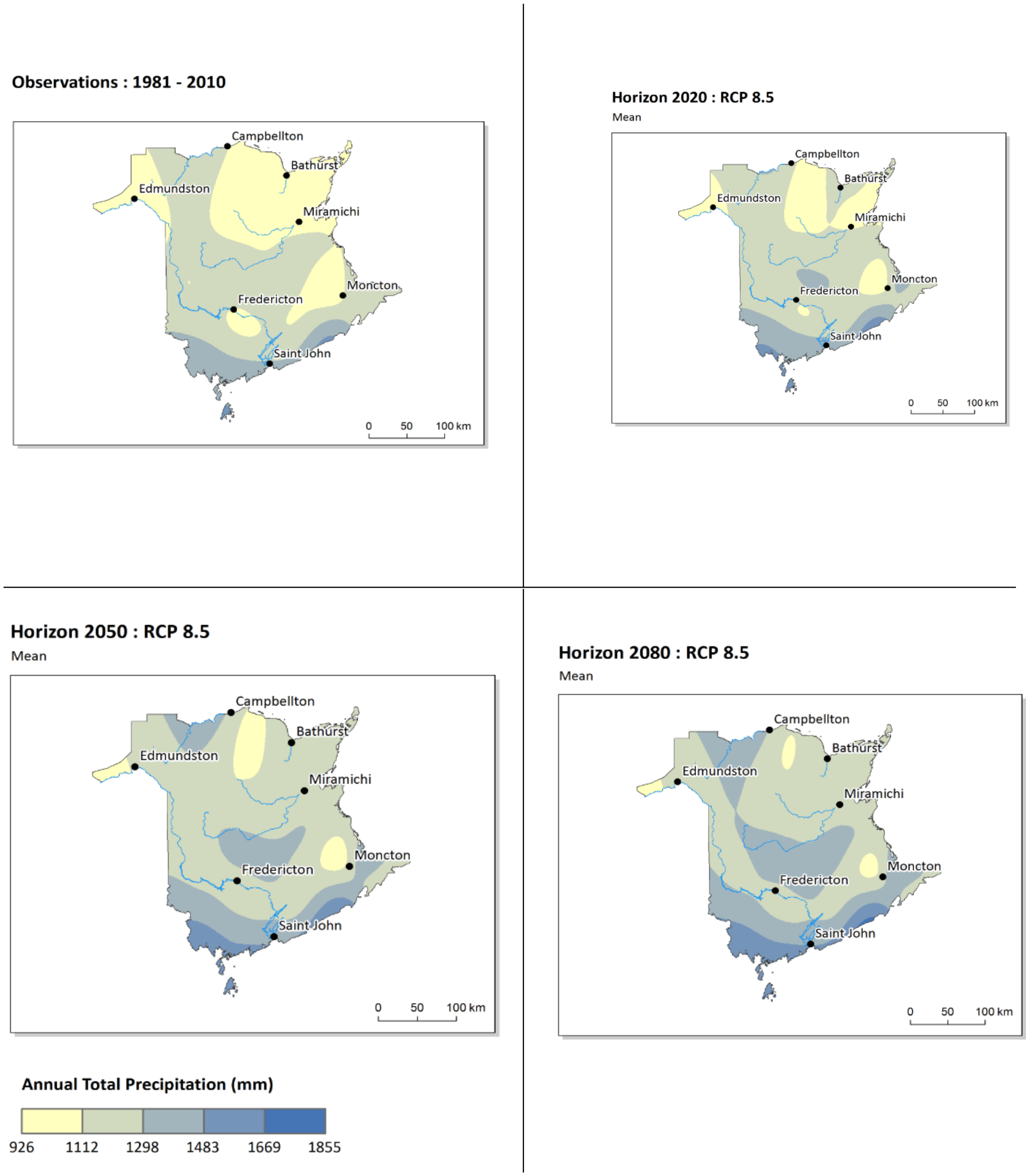


Figure A-34: New Brunswick Climate Futures projections Historical and future projections of Annual Precipitation Accumulation in Regions across New Brunswick under RCP 8.5

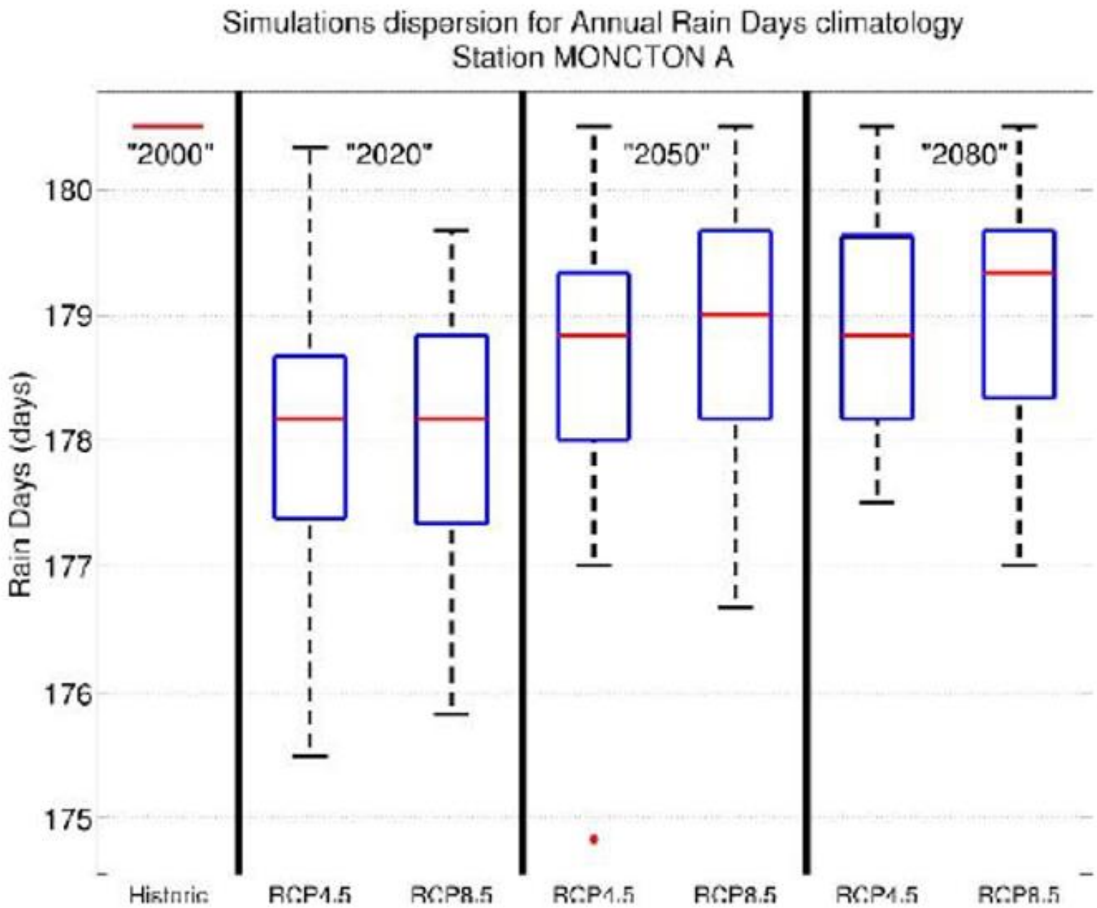
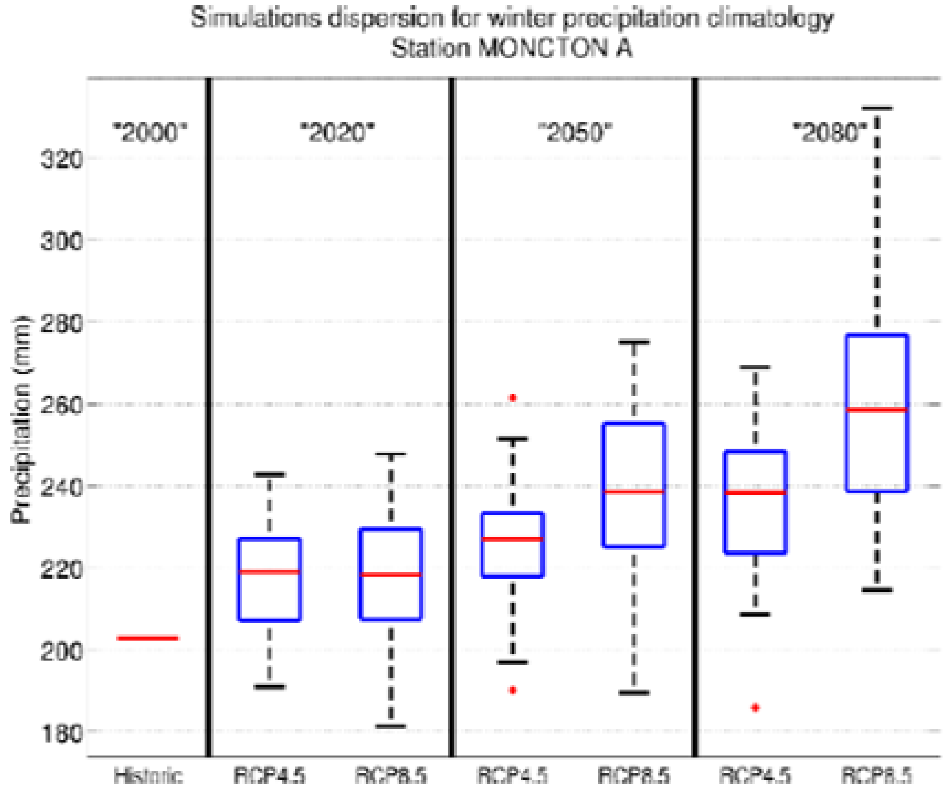


Figure A-35: CMIP5 ensemble GCM model projections for Annual Rain Days in Moncton, NB. A slight projected decrease in the number of rain days in the near term time frame and then increasing thereafter towards the end of the century is depicted.



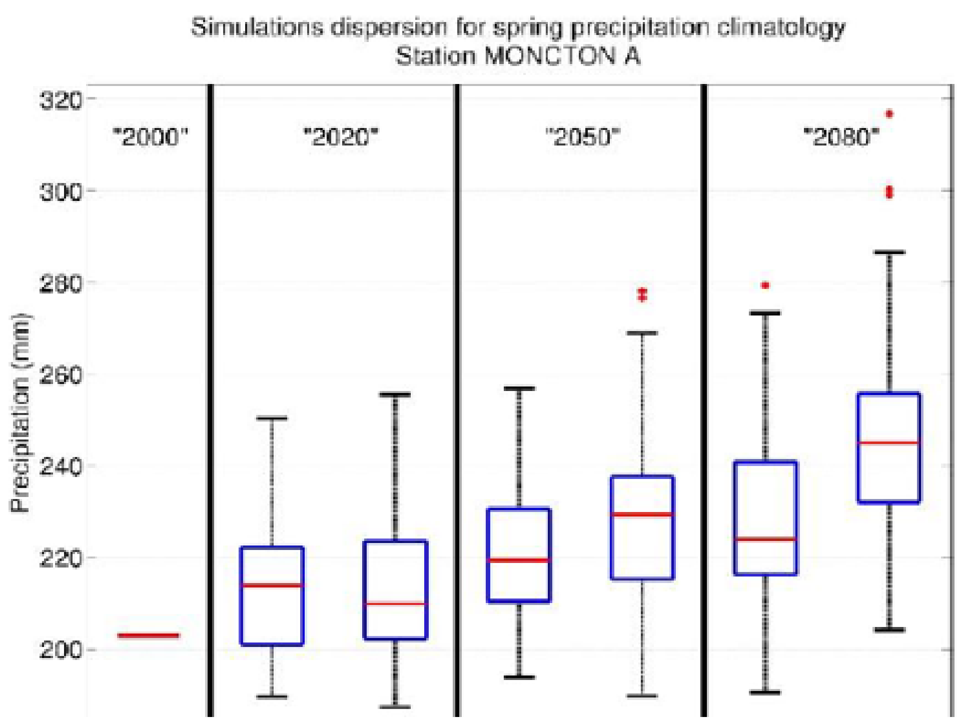


Figure A-36: CMIP5 ensemble GCM model projections for Winter and Spring (top and bottom frames respectively) Precipitation Accumulation in Moncton, NB. The figure project an increase in annual precipitation, with the largest increase depicted in the "2080" projection year under RCP 8.5

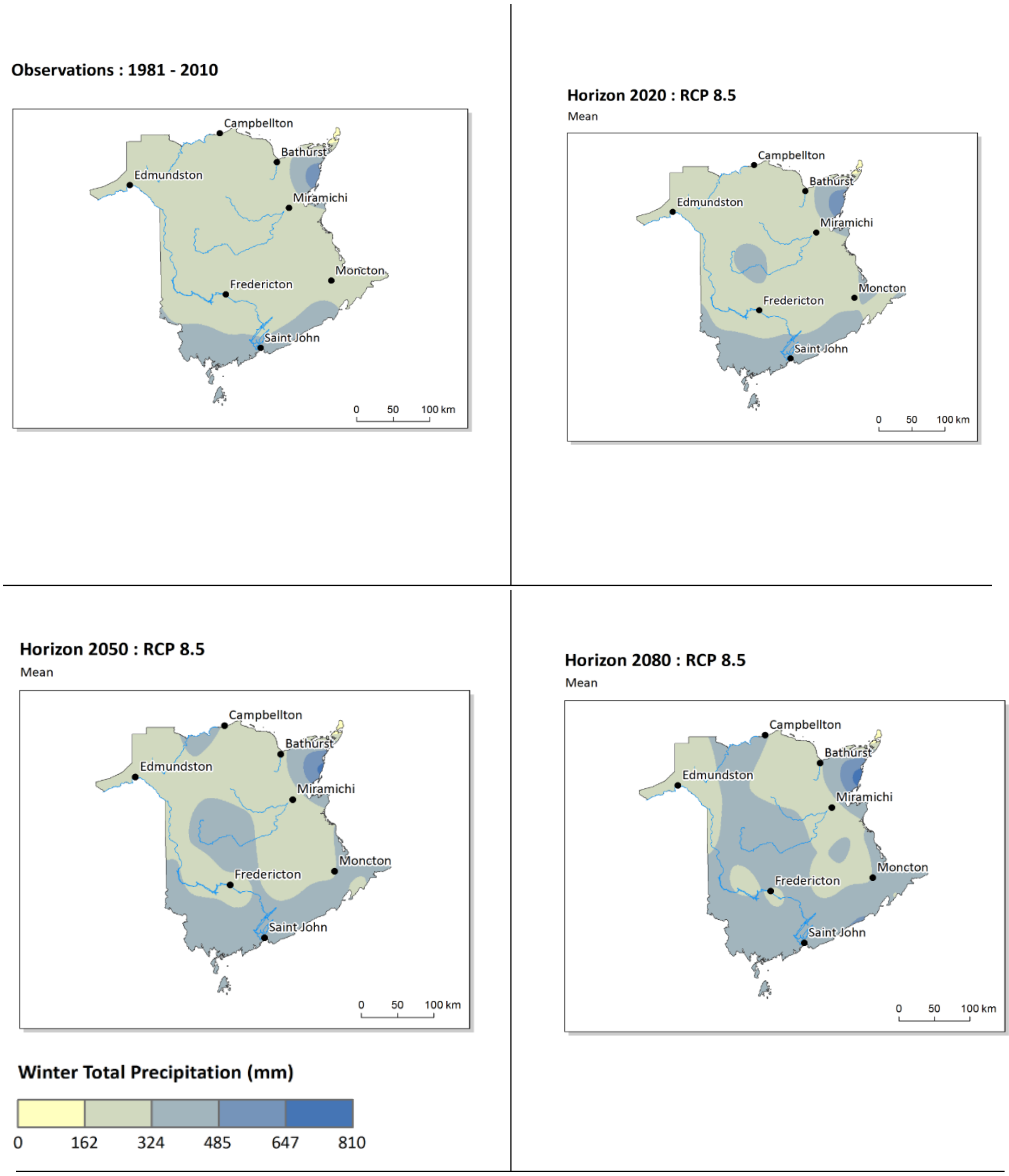


Figure A-37: New Brunswick Climate Futures CMIP5 ensemble GCM model projections for Winter Precipitation Accumulation in Regions across New Brunswick under RCP 8.5.

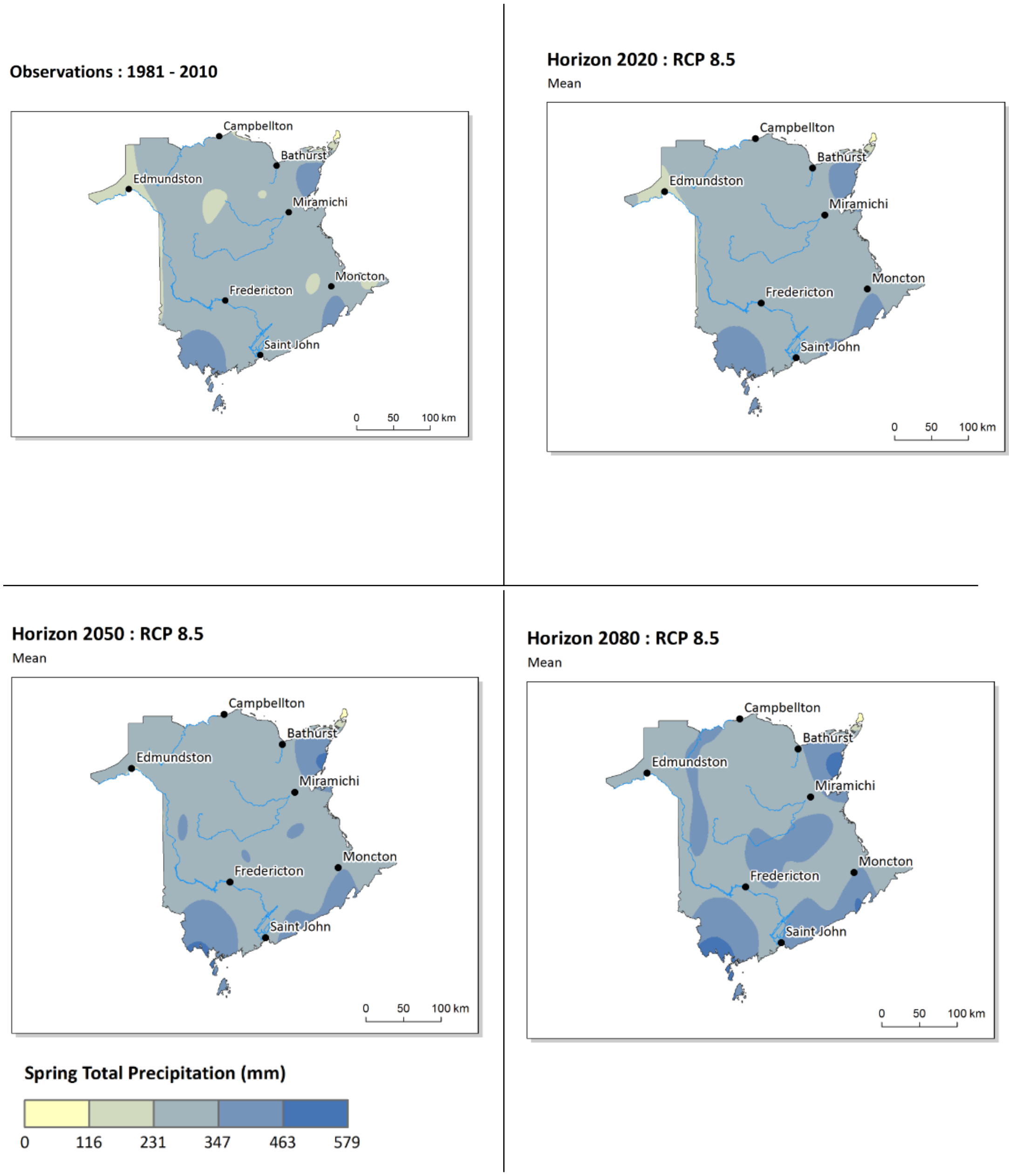


Figure A-38: New Brunswick Climate Futures CMIP5 ensemble GCM model projections for Spring Precipitation Accumulation in Regions across New Brunswick under RCP 8.5.

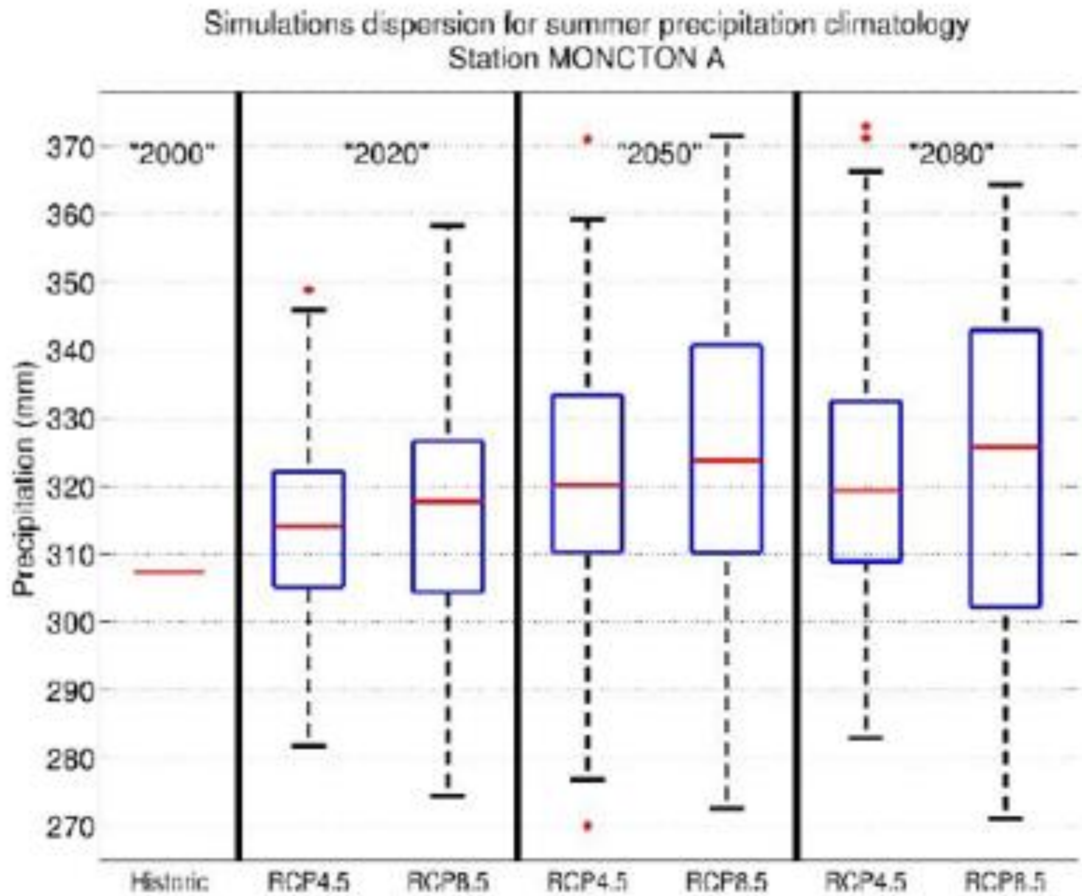


Figure A-39: CMIP5 ensemble GCM model projections for Summer Precipitation Accumulation in Moncton, NB. The figure project an increase in annual precipitation, with the largest increase depicted in the "2080" projected year for RCP 8.5.

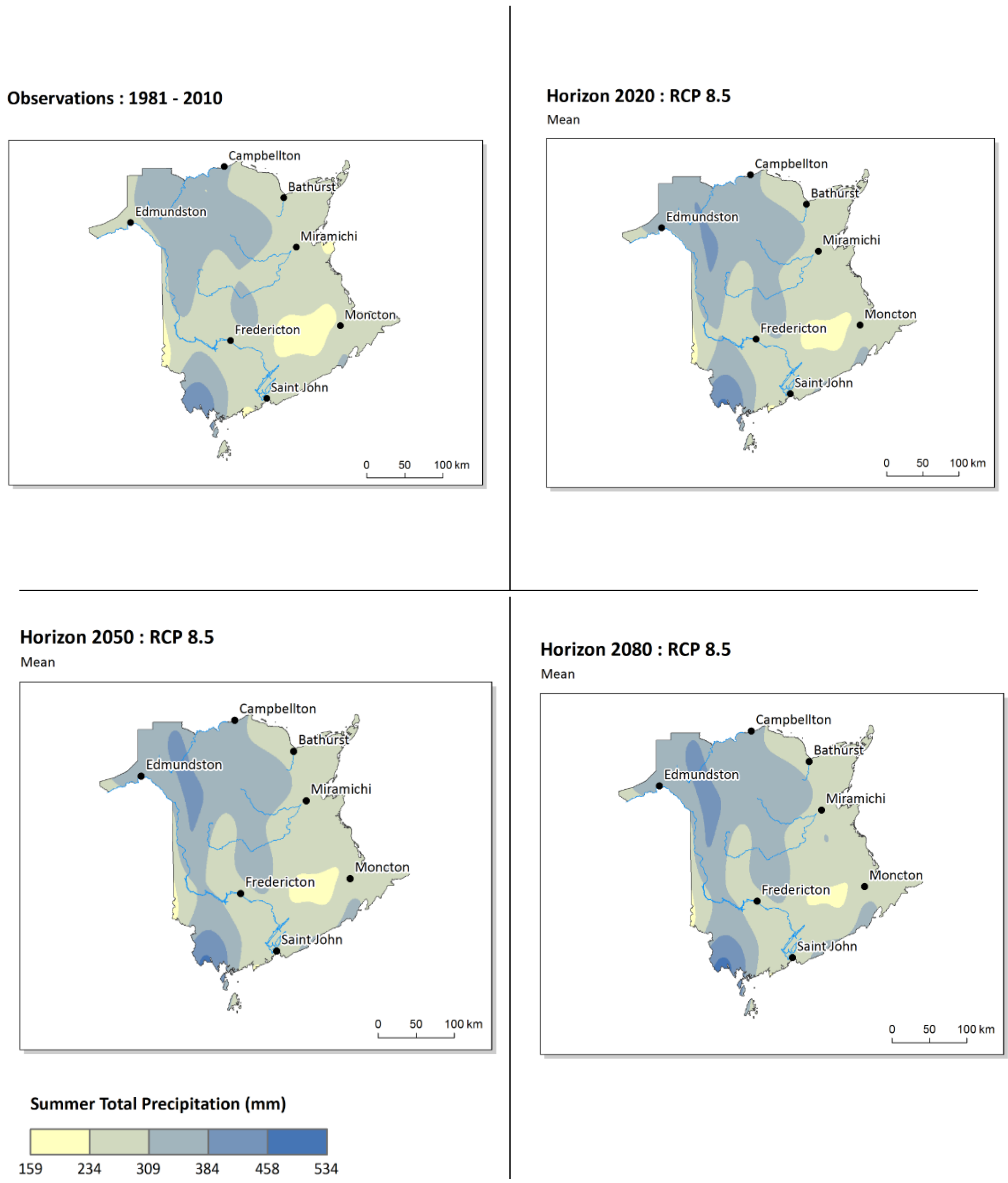


Figure A-40: New Brunswick Climate Futures CMIP5 ensemble GCM model projections for Future Summer Precipitation Accumulation in Regions across New Brunswick under RCP 8.5.

A.5.4 Probability scores

A probability score of 4 was assigned to the baseline due to historical measurements representing normal condition at the site. The near-term was assigned a similar scoring as the baseline due to the binned nature of the PIEVC matrix. The projected likelihood of annual precipitation being exceeded on a frequent basis was determined to be significantly possible within the mid-term time horizon, therefore a score of 5 was assigned. Increasing precipitation trends are more significant in northerly and north-eastern regions of the province. Therefore, although annual precipitation will increase over the course of the 21st century, within the general region of Sussex the likelihood of exceeding the baseline value was scored a 5.

Table 5: Probability Scores for Annual Precipitation at the Town of Sussex

Time Horizon	Baseline	Near-term	Mid-term	Long-term
Probability Score	4	4	5	5

A.5.5 Summary

An increase in annual precipitation and rainfall is expected at the Town of Sussex. The magnitude of increase for annual precipitation increases over the course of the 21st century. CMPI5 ensemble GCM results indicate an increase in annual precipitation of approximately 15% from the historical period to the end of the 21st century within the region of Sussex. Additionally, significant increases in precipitation were projected for the fall and winter months towards the end of the century. The findings are consistent with the process understanding of an accelerated water cycle under a future climate due to increased temperatures and the Coriolis-Columbus effect.

A.6 Precipitation Intensity

The IPCC states that a “shift to more intense individual storms and fewer weak storms is likely”, and that “extreme precipitation events will very likely be more intensity and more frequent” (IPCC AR5). While total annual and monthly precipitation data is important for understanding the total amount of precipitation (rain and snow) that a local site may receive and how that may change in the future, extreme precipitation is the crucial factor for designing infrastructure drainage capacities.

Extreme precipitation may impact municipal infrastructure in a number of ways, including surface drainage capacity and material selection for repairs (e.g. roofing). Extreme precipitation events may cause flooding or “surface ponding” which may impact accessibility to the building and potentially damage exterior infrastructure assets if accumulation persists and increase the potential for interior flooding risks due to capacity exceedances. Extreme rainfall events can also increase demand transportation infrastructure and storm water collection systems. Large storm events may induce flooding conditions, increase river erosion and negatively impact crops.

A.6.1 Sources of Climate Information

There were several sources of climate information used for this assessment:

- One way of representing precipitation intensity is through the use of IDF curves. These are plots with event duration on the x-axis and precipitation intensity on the y-axis, with different frequencies (return periods) plotted as separate lines. The University of Western Ontario IDF-CC Tool was used to obtain ‘updated’ IDF curves under multiple RCP scenarios projected for the years 2025-2100.
- CMIP5 GCMs
- Literature

A.6.2 Findings

Figure A-41 presents extreme precipitation estimate for the 24-hour duration 1 in 100 year storm event across Eastern Canada for spatial context in extreme precipitation across the region. The region of Sussex, NB falls within the low-mid range of magnitude events in Eastern Canada. Extreme precipitation events are depicted to occur more predominantly in southerly latitudes as compared to more northern regions of the eastern provinces.

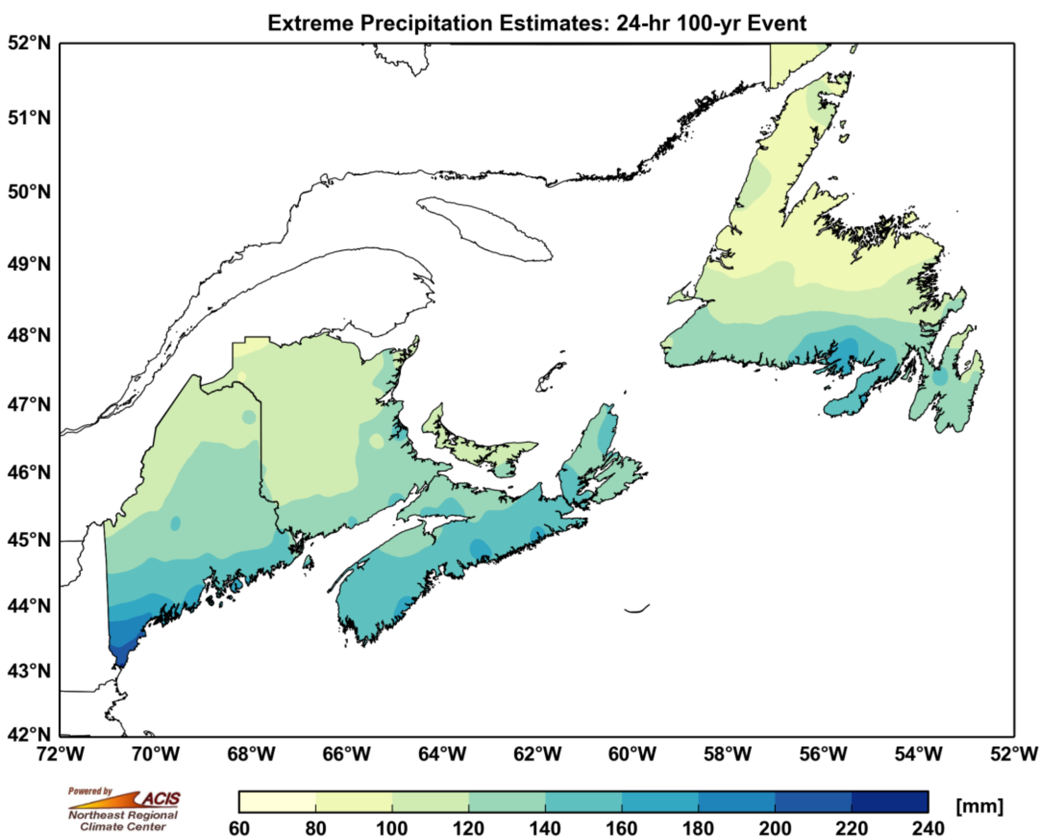


Figure A-41: This figure is based on the sample principle as the IDF but only shows results for the 24 hour duration and 100-yr frequency. The precipitation intensity is totalled over a 24-hour period. Hence, this figure gives spatial context for variation in 24-hour period. Hence, this figure gives spatial context for variation in 24-hour extreme precipitation across Eastern Canada under the existing climate.

CMIP5 ensemble GCM projections presented as a 30-year moving average in Figure A-42, show an increase in monthly maximum 1-day precipitation during most months of the year, with exception during the summer months. Therefore, the intensity of the most extreme 24-hour precipitation event is increasing. The largest magnitude of increase is approximately 10.0 mm occurring in March and May.

Figure A-43 presents CMIP5 ensemble GCM projections for the monthly maximum consecutive 5-day precipitation shown as a 30-year moving average. The projections show increases in the intensity of longer duration storm events; notably during the winter and spring months.

CMIP5 ensemble GCM projections for annual total precipitation when the daily precipitation is greater than the 95th and 99th percentile are presented in Figure A-44 and Figure A-45, respectively. An increase is projected for both percentiles, with a larger increase projected for the 95th percentile. Therefore, extreme precipitation events occurring over a 24-hour period are projected to increase in frequency over the 21st century. The magnitude of increase per the raw model data is approximately 40% from the historical period to the end of the century.

The IDF CC Tool was used to generate intensity duration frequency curves in order to assess the change in the intensity of storms with different return periods over the 21st century with respect to climate change. The IDF curve based on historical data for reference was reproduced and is presented in figure 3.11.5. The IDF CC tool requires a minimum of 50 years of data in order to generate the curves, therefore, the projection dates of the curves were selected in order to best capture the mid-range of the defined time horizons. Figures 3.11.7 - 3.11.9 were projected for the time frames; 2010-2060, 2030-2080, and 2050-2100, respectively. The Town of Sussex has a gauged weather station, however, within the tool the station has insufficient recorded data to produce an IDF Curve. Therefore, the site was treated as ungauged, in which case the IDF_CC Tool interpolates data from the nearest climate stations to produce the 'updated' IDF for that location. The IDF curves produced under the RCP 8.5 scenario were selected for analysis based upon it representing the "worst case scenario" for emission increases in which radiative forcing reaches greater than 8.5 W m–2 by 2100 and continues to rise for some time.

As seen in the IDF figures, the intensity of storms for all durations and return periods is increasing over the 21st century. The largest increase occurs in the near term (2010-2060), as the magnitude of increase of a 24-hour storm with a return period of 100 years is approximately 12% from the historical. Subsequent increases in intensity are approximately 5% for the time horizons 2030-2080 and 2050-2100 respectively. Furthermore, it is seen that the historical 1 in 100 year storm intensity becomes the 1 in 50 year storm intensity within the near term. Therefore, storms are becoming both more intense and more frequent as a result of climate change.

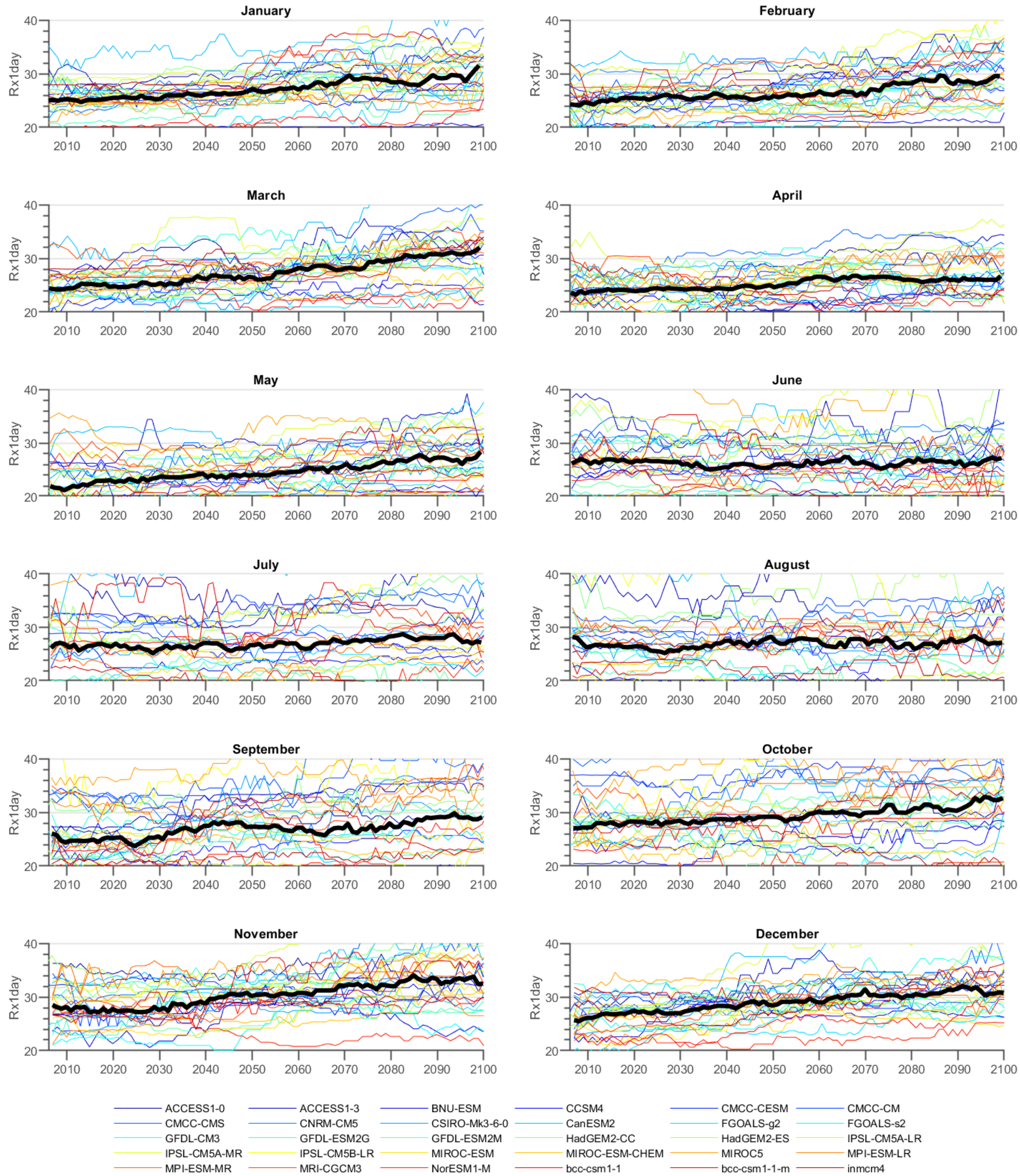


Figure A-42: CMIP5 ensemble GCM model projections for Monthly maximum 1-day precipitation shown with a 30-year moving average. The projections may show an increase in monthly precipitation during most months of the year.

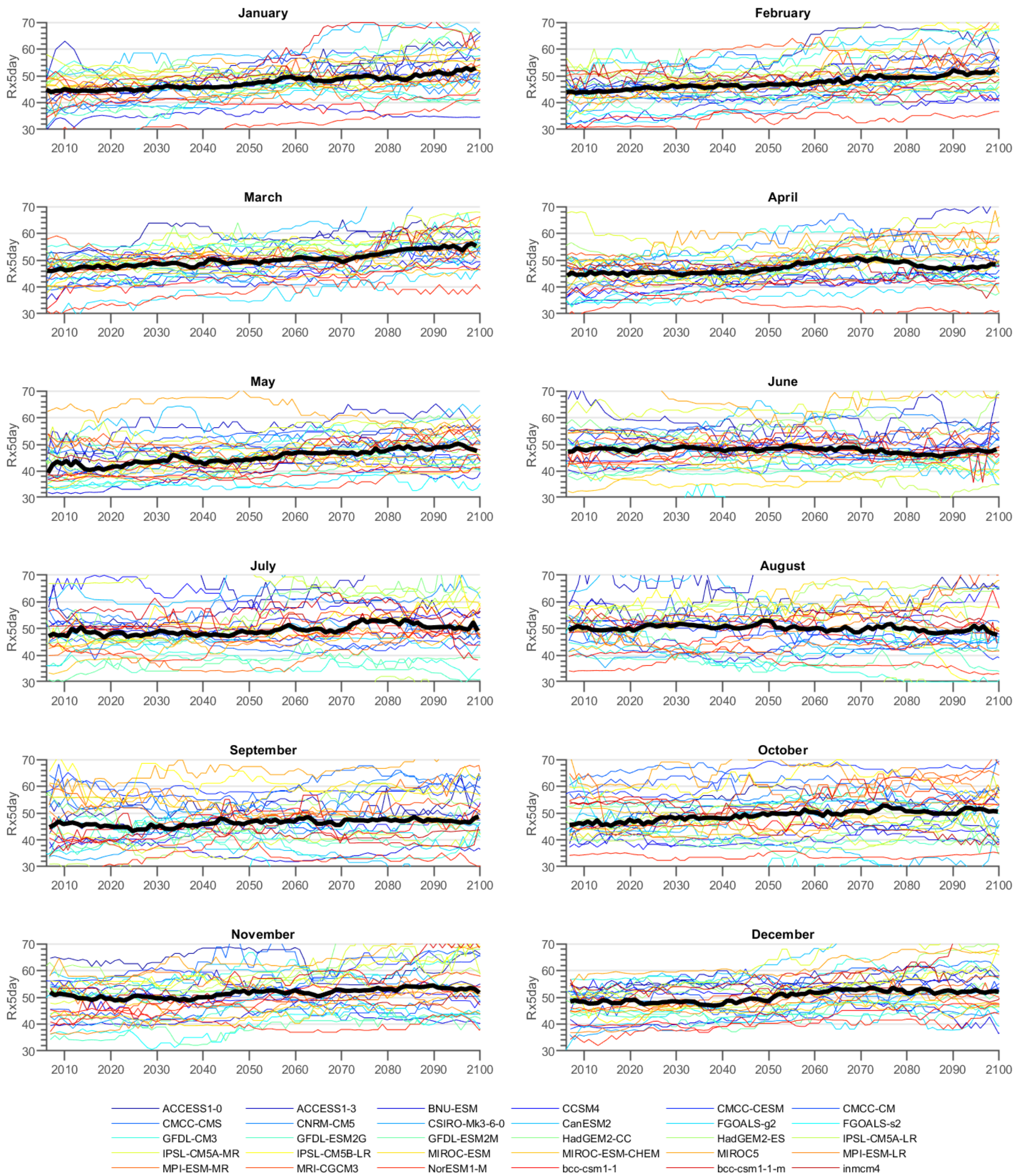


Figure A-43: CMIP5 ensemble GCM model projections for Monthly maximum consecutive 5-day precipitation shown with a 30-year moving average. The projections may show an increase in monthly precipitation during most months of the year.

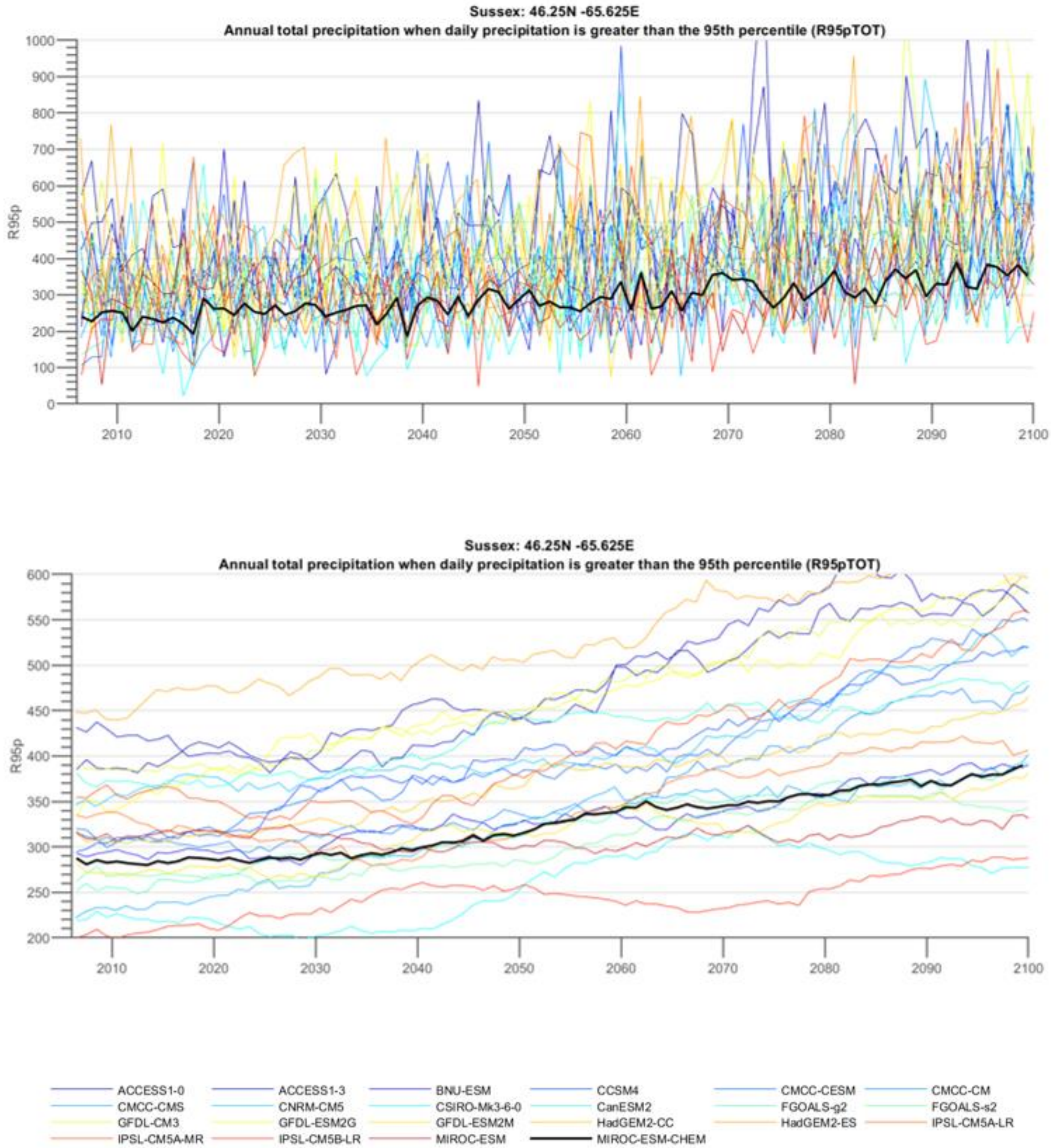


Figure A-44: CMIP5 ensemble GCM model projections for Annual total precipitation when daily precipitation is greater than the 95th percentiles. The figure presents the raw model data to represent the variability (top frame) and a 30-year moving average (bottom frame) to depict trends within the data.

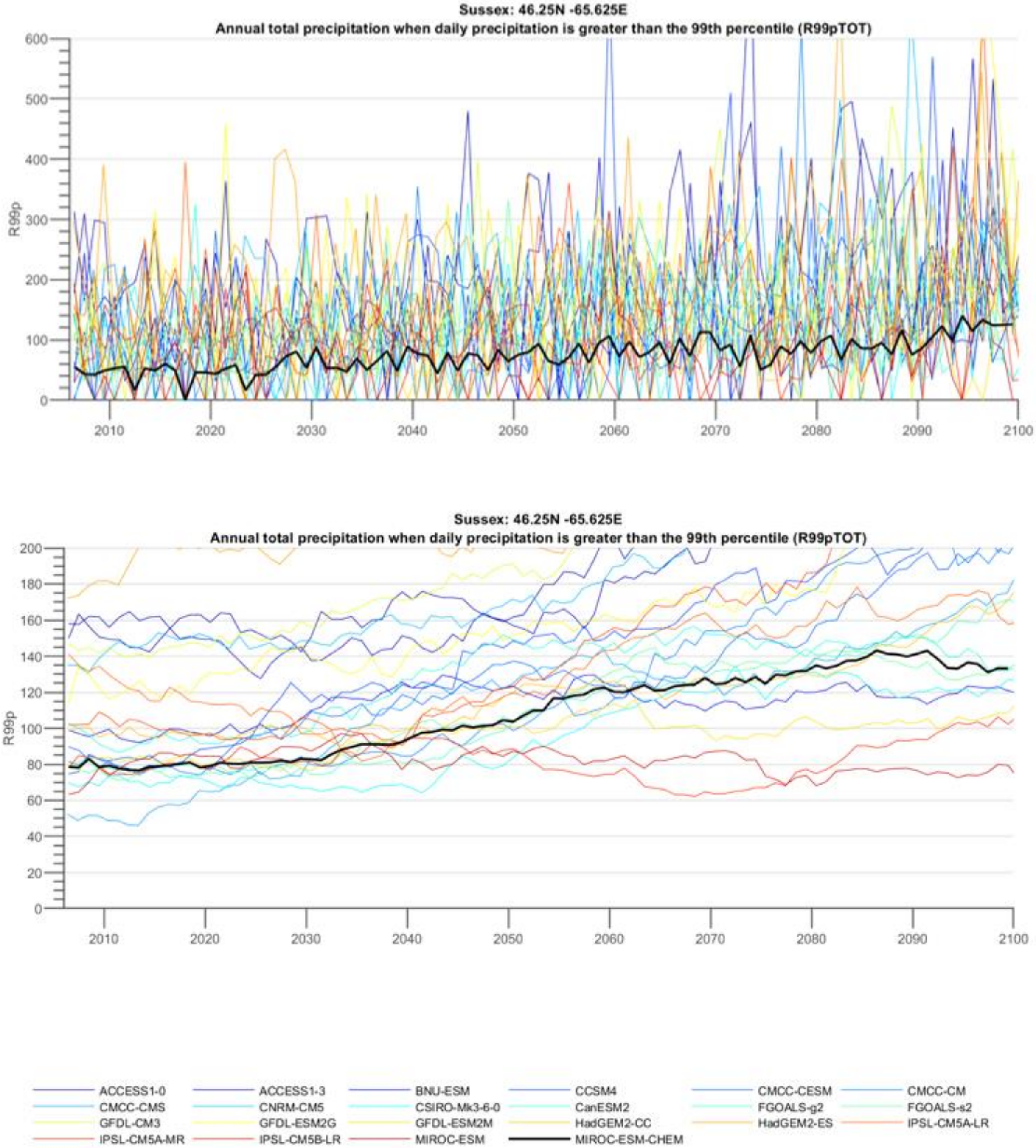
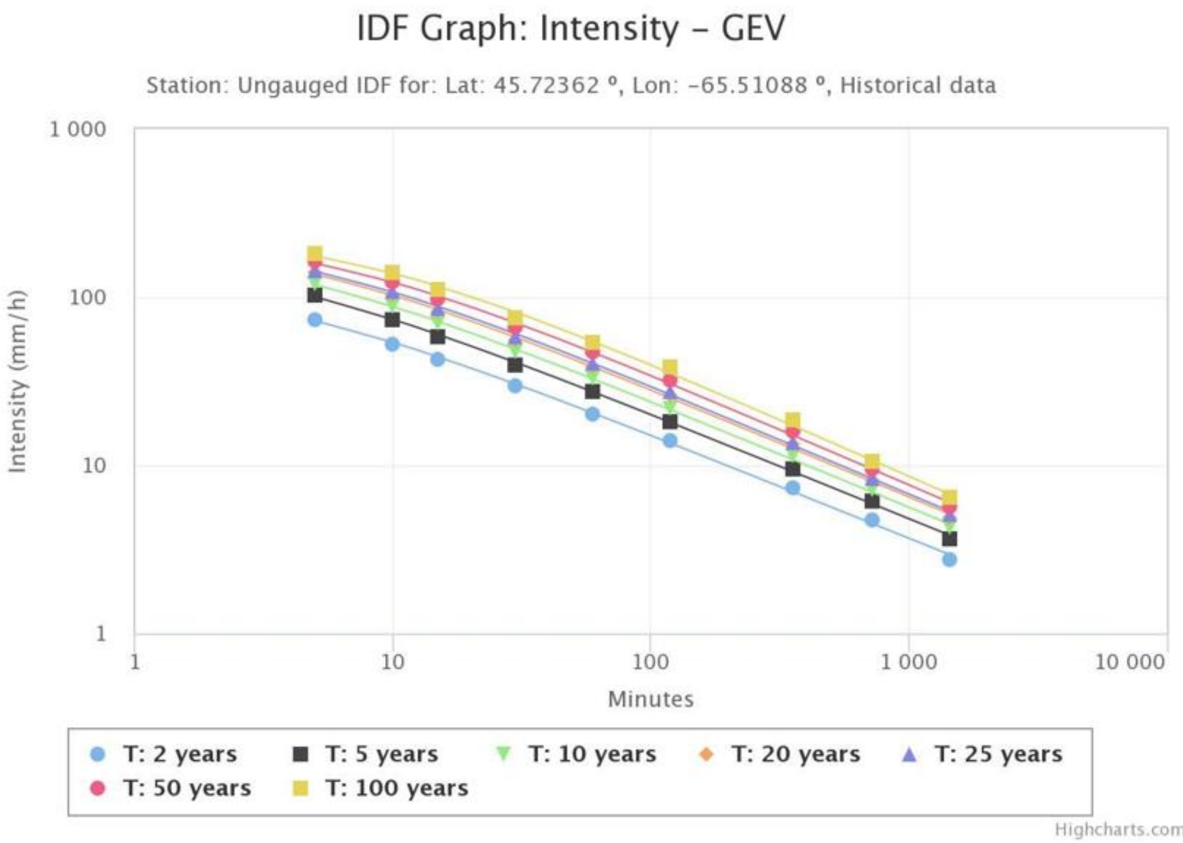
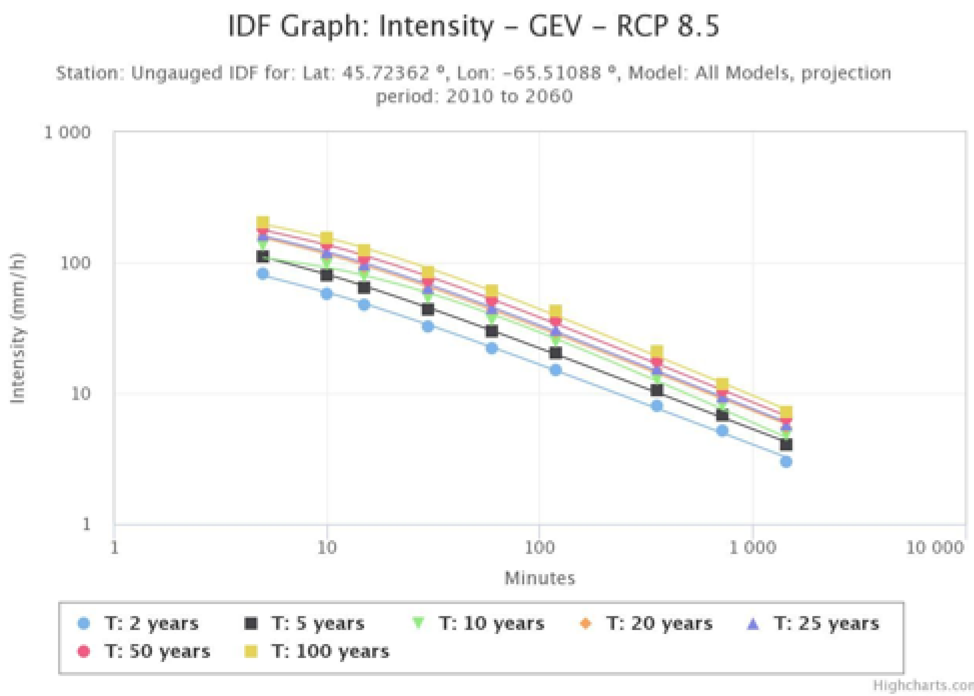


Figure A-45: CMIP5 ensemble GCM model projections for Annual total precipitation when daily precipitation is greater than the 99th percentiles. The figure presents the raw model data to represent the variability (top frame) and a 30-year moving average (bottom frame) to depict trends within the data.



T (years)	2	5	10	20	25	50	100
5 min	74.13	101.94	120.81	139.74	145.24	163.84	182.72
10 min	52.53	72.71	87.15	102.18	106.73	122.31	138.74
15 min	42.97	58.40	69.57	81.30	84.89	97.20	110.29
30 min	29.41	39.71	47.23	55.19	57.64	66.07	75.11
1 h	20.16	27.11	32.46	38.36	40.22	46.82	54.19
2 h	13.84	18.21	21.79	25.96	27.30	32.25	38.03
6 h	7.37	9.57	11.26	13.19	13.79	16.03	18.65
12 h	4.70	6.11	7.09	8.11	8.41	9.44	10.51
24 h	2.73	3.61	4.22	4.86	5.05	5.70	6.38

Figure A-46: Intensity-Duration-Frequency curves are plotted with duration on the x-axis and intensity on the y-axis, with different frequencies (return period) plotted as separate lines (top panel). This can also be represented as a table (bottom panel). This figure shows an IDF curve for the site based on historical data. The figure was created using the IDF-CC tool from the University of Western Ontario. It is noted that the validity of the curve depends on the availability of local data. This station was ungauged, therefore the IDF_CC tool interpolates data from the nearest climate stations to produce the IDF.



T (years)	2	5	10	20	25	50	100
5 min	81.84	112.92	135.55	158.70	164.24	183.61	205.01
10 min	57.99	80.54	97.78	116.04	120.69	137.08	155.66
15 min	47.43	64.68	78.06	92.33	95.99	108.93	123.74
30 min	32.47	43.99	52.99	62.68	65.17	74.05	84.27
1 h	22.26	30.04	36.42	43.57	45.48	52.47	60.80
2 h	15.28	20.17	24.45	29.48	30.88	36.14	42.67
6 h	8.14	10.60	12.64	14.98	15.60	17.97	20.93
12 h	5.19	6.77	7.96	9.21	9.51	10.58	11.80
24 h	3.02	4.00	4.74	5.52	5.71	6.38	7.15

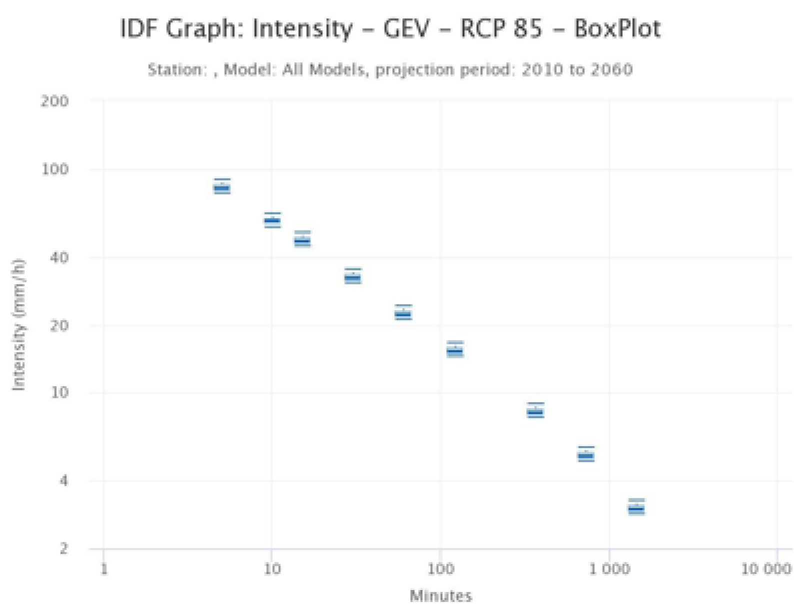
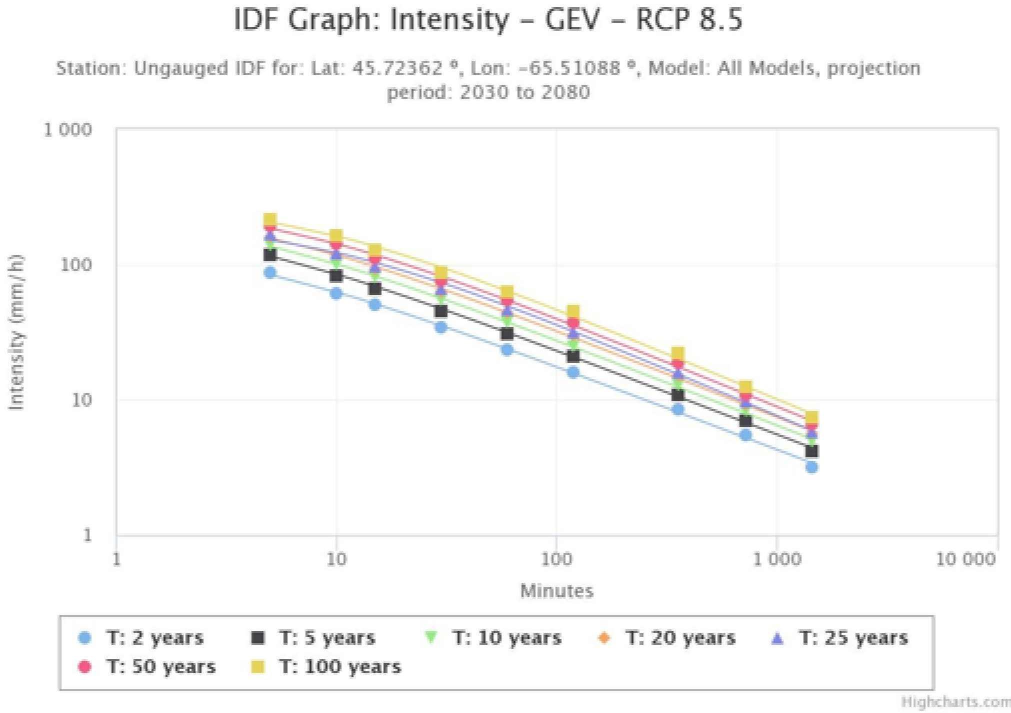


Figure A-47: IDF curves obtained from the University of Western Ontario IDF-CC tool, for 2010-2060 using RCP 8.5. An ensemble of GCM models was used to generate future precipitation, which was then downscaled spatially and temporally to produce the curves. The top plot and table show results for all return periods, based on the ensemble mean of the GCMs. The bottom plot shows results for the 1 in 100 year return period only, with the box plot representing the spread among all the models. This can be interpreted as a measure of uncertainty.



T (years)	2	5	10	20	25	50	100
5 min	86.08	117.27	138.71	160.19	167.11	190.51	214.34
10 min	60.99	83.64	100.06	117.13	122.81	142.23	162.75
15 min	49.89	67.17	79.88	93.20	97.67	113.02	129.37
30 min	34.15	45.68	54.23	63.27	66.31	76.83	88.11
1 h	23.41	31.19	37.27	43.98	46.28	54.44	63.57
2 h	16.07	20.95	25.02	29.76	31.42	37.50	44.62
6 h	8.56	11.01	12.93	15.12	15.87	18.64	21.88
12 h	5.46	7.03	8.14	9.29	9.67	10.98	12.33
24 h	3.17	4.15	4.85	5.57	5.81	6.62	7.48

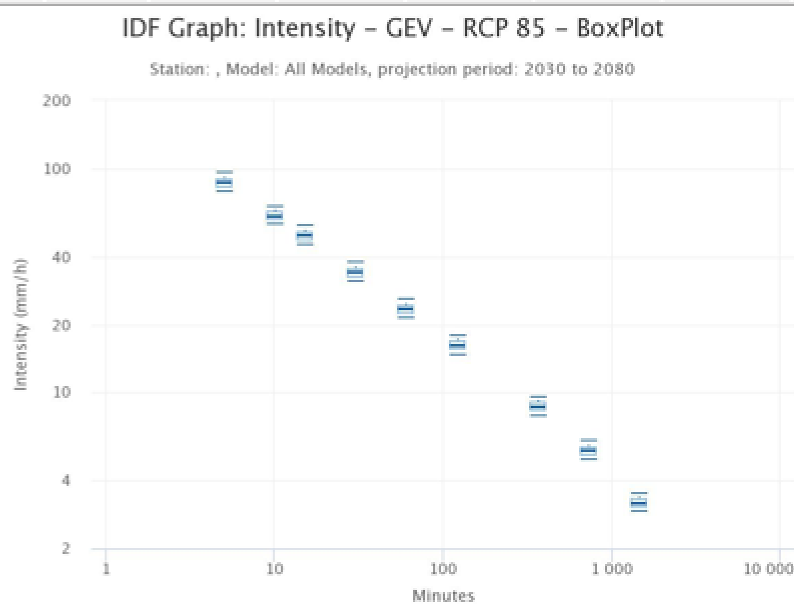
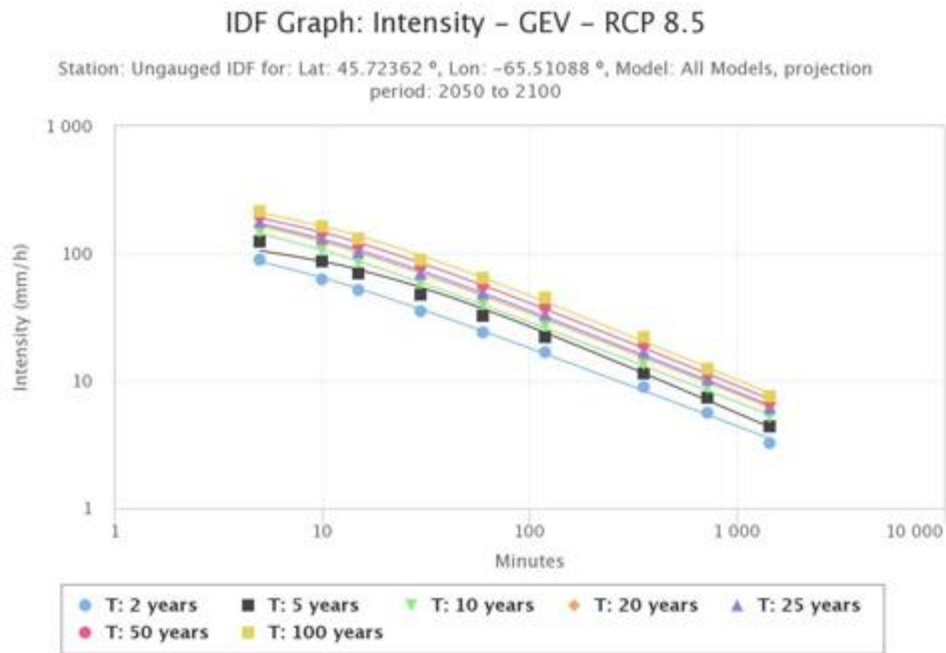


Figure A-48: IDF curves obtained from the University of Western Ontario IDF-CC tool, for 2030-2080 using RCP 4.5. An ensemble of GCM models was used to generate future precipitation, which was then downscaled spatially and temporally to produce the curves. The top plot and table show results for all return periods, based on the ensemble mean of the GCMs. The bottom plot shows results for the 1 in 100 year return period only, with the box plot representing the spread among all the models. This can be interpreted as a measure of uncertainty.



T (years)	2	5	10	20	25	50	100
5 min	89.38	123.53	146.95	170.13	176.79	197.09	217.51
10 min	63.33	88.11	106.00	124.40	129.91	147.14	165.15
15 min	51.80	70.76	84.62	98.99	103.32	116.93	131.29
30 min	35.46	48.12	57.45	67.20	70.15	79.48	89.41
1 h	24.31	32.86	39.48	46.71	48.96	56.32	64.51
2 h	16.69	22.07	26.51	31.61	33.23	38.80	45.28
6 h	8.89	11.59	13.70	16.06	16.79	19.29	22.20
12 h	5.67	7.40	8.63	9.87	10.23	11.36	12.52
24 h	3.29	4.37	5.14	5.91	6.14	6.85	7.59

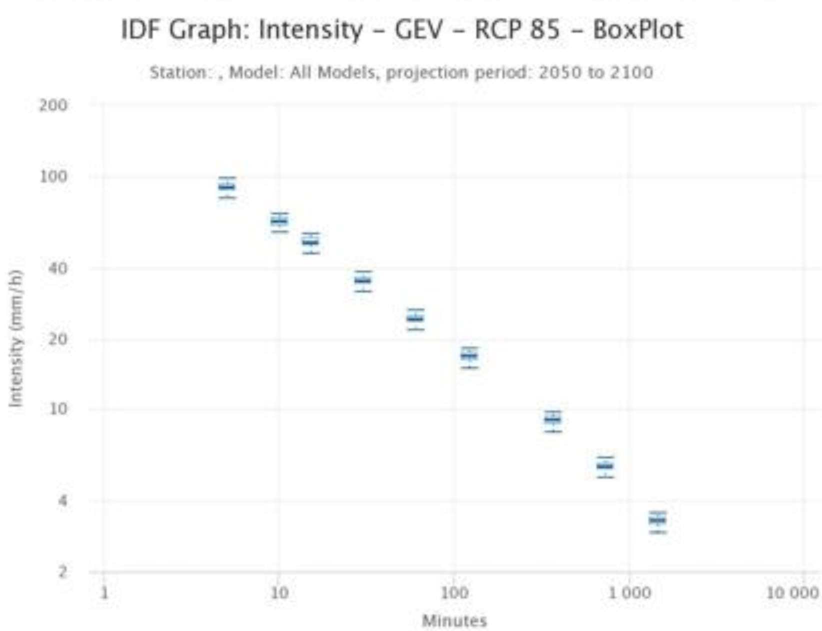


Figure A-49: IDF curves obtained from the University of Western Ontario IDF-CC tool, for 2050-2100 using RCP 4.5. An ensemble of GCM models was used to generate future precipitation, which was then downscaled spatially and temporally to produce the curves. The top plot and table show results for all return periods, based on the ensemble mean of the GCMs. The bottom plot shows results for the 1 in 100 year return period only, with the box plot representing the spread among all the models. This can be interpreted as a measure of uncertainty.

A.6.3 Probability Scores

A probability score of 4 was assigned to the baseline because historically recorded events depict the normal climatology experienced at the site. Due to significant trends of increased extreme precipitation events modelled with high certainty over the course of the 21st century, the long-term time horizon was assigned a score of 7 where it is highly probable that the frequency and magnitude of extreme events experience within the baseline period will be exceeded. The near-term and mid-term time horizons or assigned score of 5 and 6 respectively to encapture the increasing likelihood in the occurrence of extreme events as well as the increasing magnitude of extreme events over the 21st century.

Table 6: Probability Scores for Precipitation Intensity at the Town of Sussex

Time Horizon	Baseline	Near-term	Mid-term	Long-term
Probability Score	4	5	6	7

A.6.4 Summary

An increase in the frequency and intensity of extreme precipitation events is expected at the site. The magnitude of increase for a 24-hour 1 in 100 year precipitation event is 15-20% over the 21st century based on the IDF-CC Tool. According to monthly GCM projections of extreme precipitation indices the largest increases are expected to occur during the winter and spring months. The findings are consistent with the process understanding of an accelerated water cycle under a future climate, and statements from the IPCC that “extreme precipitation events will very likely be more intense and more frequent”.

A.7 Low Precipitation

Low precipitation refers to periods of drought which occur during periods of extended abnormally low rainfall. This leads to shortages of water which can impact supply, water quality, and public health and safety.

A.7.1 Sources of Climate Information

The sources of climate information used as part of this analysis are CMPI5 ensemble GCM projections from the Climdex index of maximum length of dry spell.

A.7.2 Findings

The IPCC AR5 report states that there is low confidence in observed trends in drought. However, increased temperatures within the summer months may lead to seasonality dryer conditions. Furthermore, an increasing frequency of precipitation events leading to increased runoff and decreased infiltration to recharge aquifers or water supplies may lead to a higher likelihood in the occurrence of drought conditions within the region.

A Hydrometric trend analysis completed in 2001 investigated potential patterns in flood frequency over time. Results show a significant decreasing trend in the mean daily summer flows within the Kennebecasis River near the region of Sussex.

CMIP5 ensemble GCM model projections for maximum length of dry spell are presented in Figure A-50. Upon analysis of the projections, no trend is apparent over the 21st century, however, it is noted that the model variability is high. However, with minimal precipitation increases during the summer months in the area over the 21st century, concurrent with rises in mean and extreme temperatures, drought conditions may be expected to increase during the summer.

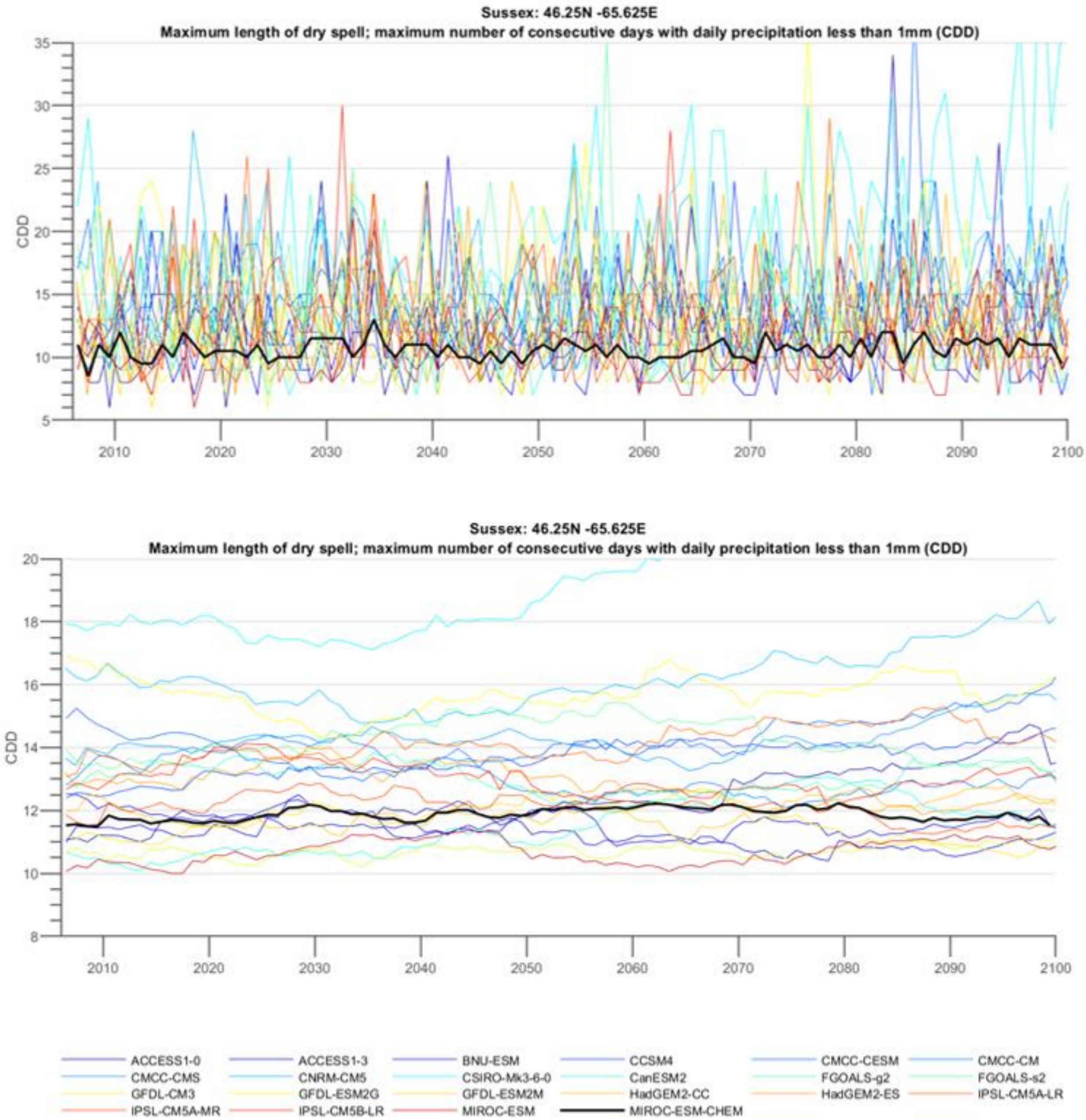


Figure A-50: CMIP5 ensemble GCM model projections for maximum length of dry spell. No trend is apparent based on projections over the 21st century, however, it is noted that there is high model variability.

A.7.3 Probability Scores

Probability scores were assigned to the time horizons based both on projected data as well as process based understanding. Furthermore, due to drought being a season occurrence, scoring was determined on a seasonal basis when the impact of drought conditions would be relevant.

A baseline score of 4 was assigned within the matrix because the historical period represents conditions normally experienced at the site. Within the near-term it was determined that the likelihood of low precipitation events exceeding currently experienced events falls within the same range of probability of a score of 4, due to the binned nature of the PIEVC matrix.

Large bodies of water provide sources for precipitation and have an impact on climatology of a region. The Town of Sussex is located inland approximately 35 km from the coast. As a result, there is a decreased potential for convective rainfall during the dry season because there are no large bodies of water regionally available to provide sources for precipitation. Furthermore, the increase of extreme precipitation events can lead to flooding and increasing amount off runoff which decreases the amount of rainfall able to absorb into the ground and recharge groundwater sources such as aquifers. This, in conjunction with increasing temperatures, and increased duration of days with extreme temperatures indicate a potential increase for drought condition within the region. Therefore, the mid-term and long-term time horizons were increased to a score of 5 to reflect this.

Table 7: Probability Scores for Low Precipitation at the Town of Sussex

Time Horizon	Baseline	Near-term	Mid-term	Long-term
Probability Score	4	4	5	5

A.7.4 Summary

According to the IPCC AR5 report there is low confidence in the global-scale impact of climate change on drought conditions. However, trends of certain climate indices may indict in the increase for drought conditions with the region of Sussex. The summer months are projected to experience increasing frequency and duration of warm temperatures. Low summer flows and potentially decreasing levels of infiltration to recharge groundwater supplies may lead to an increased potential for drought conditions within the Sussex area.

A.8 Freezing Rain

Freezing rain impacts infrastructure in several ways, including ice accretion on buildings, and mechanical or electrical equipment which may cause failures or power outages.

A.8.1 Definition

The formation of freezing rain, sleet, and hail depends primarily on the vertical profile of atmospheric temperature (Figure A-51). Freezing rain forms if liquid raindrops fall from a warm layer through a layer of cold air that is too thin for the drops to have time to freeze. Water then freezes on contact with the surface. Sleet and hail occur when the layer of cold air is thick enough for the water to start to freeze before it reaches the ground. This inversion in the vertical temperature profile can occur for example on the leading edge of a warm front that is overtaking a cold front (warm air is located above cold air).

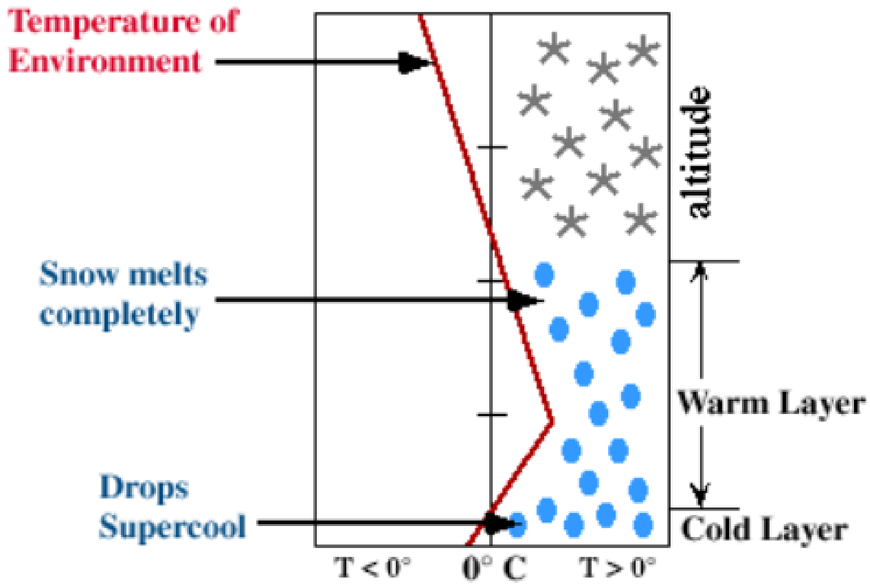


Figure A-51: Diagram illustrating a vertical temperature profile of the atmosphere and the formation of freezing rain. For freezing rain to occur, liquid raindrops must fall from a warm layer through a thin layer of cold air. Water then freezes on contact with the surface (reference: University of Illinois http://ww2010.atmos.uiuc.edu/(Gh)/wwhlpr/zr_profile.rxml)

A.8.2 Sources of Climate Information

Due to the complexity of the atmospheric phenomena involved in freezing rain occurrence, there are few studies that investigate the potential impacts of climate change on future freezing rain events. Previous studies on freezing rain have focused on the development of statistical models to improve short-term weather forecasts, as well as case studies of individual freezing rain events. Nonetheless, baseline conditions and future projections of freezing rain for this assessment were obtained from the literature:

- Lambert and Hansen (2011) used statistical downscaling from one global climate model (CGCM3) to characterize potential changes over North America, with a focus on 12-hour events (Figure A-52). Environment Canada completed a climatological research study to investigate climate change and freezing rain, as reported in Cheng *et al.* (2011). The purpose was to characterize the atmospheric conditions under which freezing rain occurs ("weather typing"), which was used to downscale region-specific freezing rain predictions using eight GCMs (Figure A-53).

A.8.3 Findings

Freezing rain affects all of Eastern Canada although the region of Sussex experiences less freezing rain events than other regions (e.g., Newfoundland). Both the severity and frequency of future freezing rain events in Eastern Canada is expected to increase compared to average historical conditions, as freezing rain-related weather systems move N/ NE over North America under a changing climate. The seasonal timing of impacts varies across the region. The relative increase in magnitude during the warmest months is much less than during the coldest months.

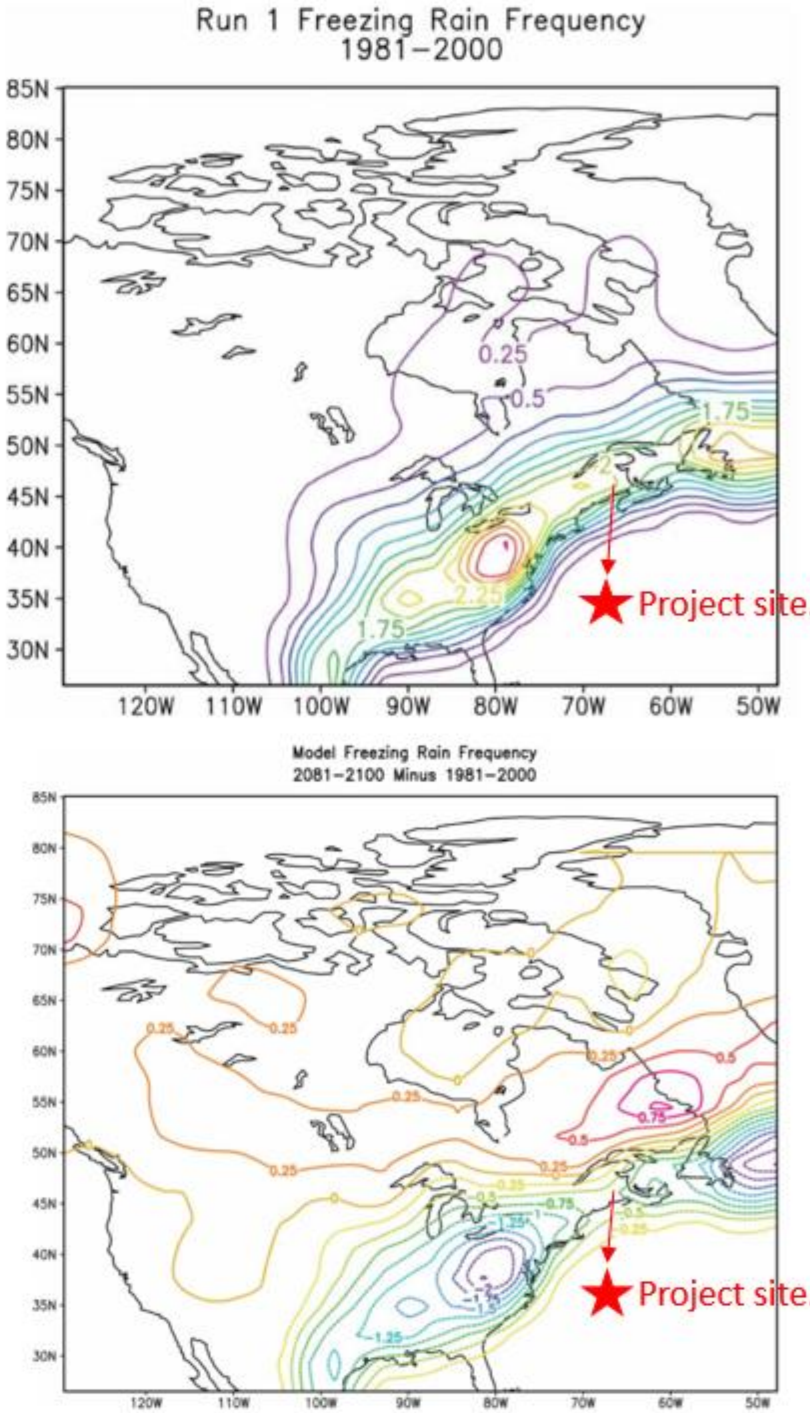


Figure A-52: Annual mean number of observed (top frame) and projected changes (bottom frame) in freezing rain occurrences over North America obtained from Lambert and Hansen 2011. Values are shown for the 12-hour freezing rain; the contour interval is 5.

Projections for the occurrence of freezing rain provided by Cheng et al. (2011) depict increases of up to 10-20% in January and February for all durations over the 21st century within the region of the site. Other months have lower projected increases, although increases of up to approximately 15% are projected for durations greater than 6 hours for March and December. Sussex is located in the region of Eastern Canada which actually has the smallest projected increases in freezing rain, according to Cheng et al. (2011). For comparison, the adjacent region (part of Cape Breton and most of Newfoundland) is projected to have 30-50% increases to 6 hourly freezing rain.

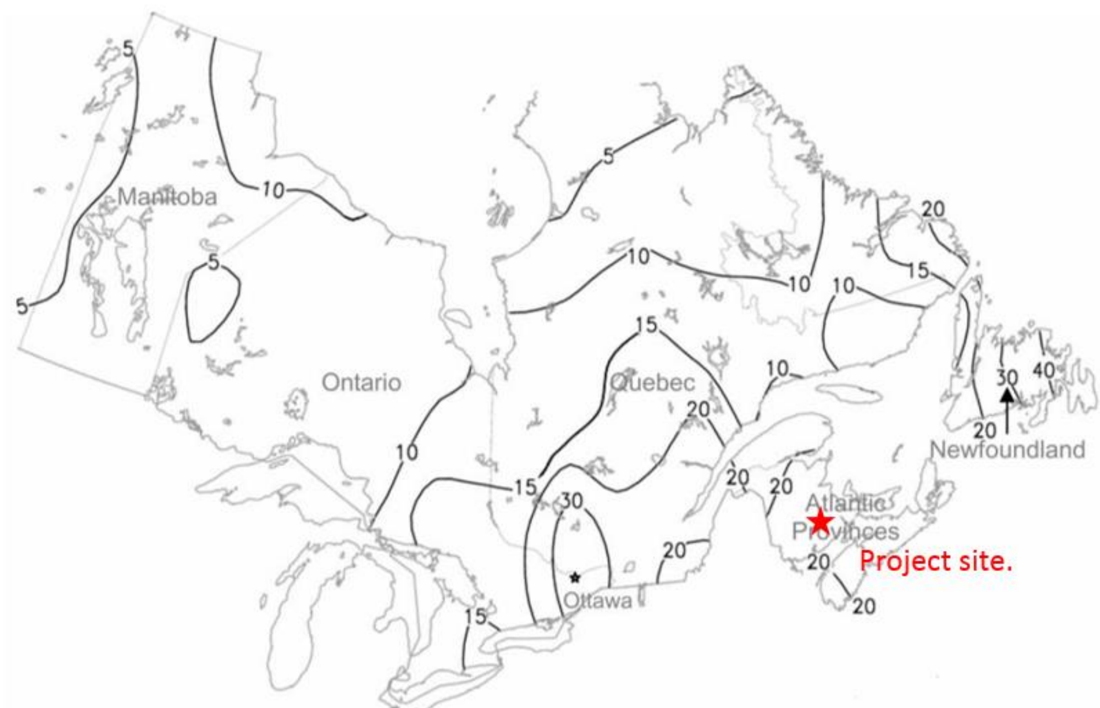


Figure A-53: Observed total hours of seasonal freezing rain (Oct-May 1953-2007). The greatest amounts of freezing rain have been observed in Newfoundland (Cheng et al. 2011).

It is noted that short duration events are the most difficult to model and could be underrepresented in these results. Also, the studies did not assess changes to ice accretion amounts, which are very difficult to predict.

A.8.4 Probability Scores

A baseline probability score of 4 was assigned based on historically plotted freezing rain observations depicting similar frequency of occurrence at the site. Projections indicate an increase in the number of freezing rain events within the long term. As a conservative approach, based on climate process understanding and model projections, scores were increased in the mid- and long term time horizons.

Table 8: PIEVC Scores for Freezing Rain in the Town of Sussex

Time Horizon	Baseline	Near-term	Mid-term	Long-term
Probability Score	4	4	5	5

A.8.5 Summary

Although there is no readily available model output or data for freezing rain, and although literature is limited, there is some quantification of trends available from more detailed studies reported in the literature, and predictions of general trends are robust due to a fairly good process-based characterization of changes. For the Town of Sussex, the projected increase in freezing rain is of up to 10-20% increase in January and February over the 21st century.

A.9 Wind

Strong winds and wind gusts have the potential to cause damage to buildings and other above-ground infrastructure. Winds that accompany intense storms, such as tropical storms, have the strength to lift roof structures or remove siding from buildings (envelope damage), and can blow debris to further damage above-ground infrastructure. Impacts of high winds include:

- Building envelope damage (windows, roofs, etc.)
- Building structural damage
- Fallen trees causing obstruction.

Within the following section wind speed refers to the velocity of wind over the specified time scale (e.g. m/s or km/hr). Extreme winds and wind gusts are closely related within the context of building design; wind gusts are defined as the occurrence of extreme winds within smaller time scales than average winds would be measured. An extreme wind may be defined based upon the application in which it referring. An extreme wind is a wind speed exceeding a threshold for which the wind is strong enough to be dangerous to people, or cause significant damage to buildings or property. In general, extreme winds may be classified as sustained winds of speeds greater than 70 km/hr and wind gusts of 90 km/hr.

A.9.1 Climate Change Processes

Processes impacting winds are complex, with different processes having contrasting effects. Changes are therefore difficult to project and are anticipated to be non-linear. The main processes driving potential changes in winds are as follows:

- A change in the location of regional storm tracks (e.g., northward movement of extratropical cyclones).
- The displacement and intensification of mid-latitude westerlies.
- The potential increase in localized convection caused by heating of the ground surface.

A.9.2 Sources of Climate Information

Literature on wind gusts was used to characterize and explore potential changes in extreme winds such as projections published by Cheng and Lopez (2014) for North America.

A.9.3 Findings

A downscaling study by Cheng and Lopes (2014) reveals that wind gusts of differing thresholds are expected to increase, with gusts above the highest thresholds expected to increase the most (Figure A-55) The region of Sussex is located on the border of two defined wind gust regions as seen in Figure A-54 (A1 and C3) therefore, the results of both regions are presented. According to region A1, a percent increase in wind gusts above 40 km/hr and 70 km/hr of approximately to 10% and 20% respectively is expected for the region of Sussex. An increase in extreme winds (90 km/hr) of up to 130% is projected for the years 2046-2065 and up to 75% for the years 2081-2100 in region A1. According to region C3, a percent increase in wind gusts above 40 km/hr and 70 km/hr of approximately to 15% and 20% respectively is expected for the region of Sussex. An increase in extreme winds (90 km/hr) of up to 200% is projected for the years 2046-2065 and up to 200% for the years 2081-2100 in region C3. Hence, even if there were no clear trends in hourly winds, there could still be trends in wind gusts. In other words, the relationship (and conversion factor) between hourly winds and wind gusts may change in the future.

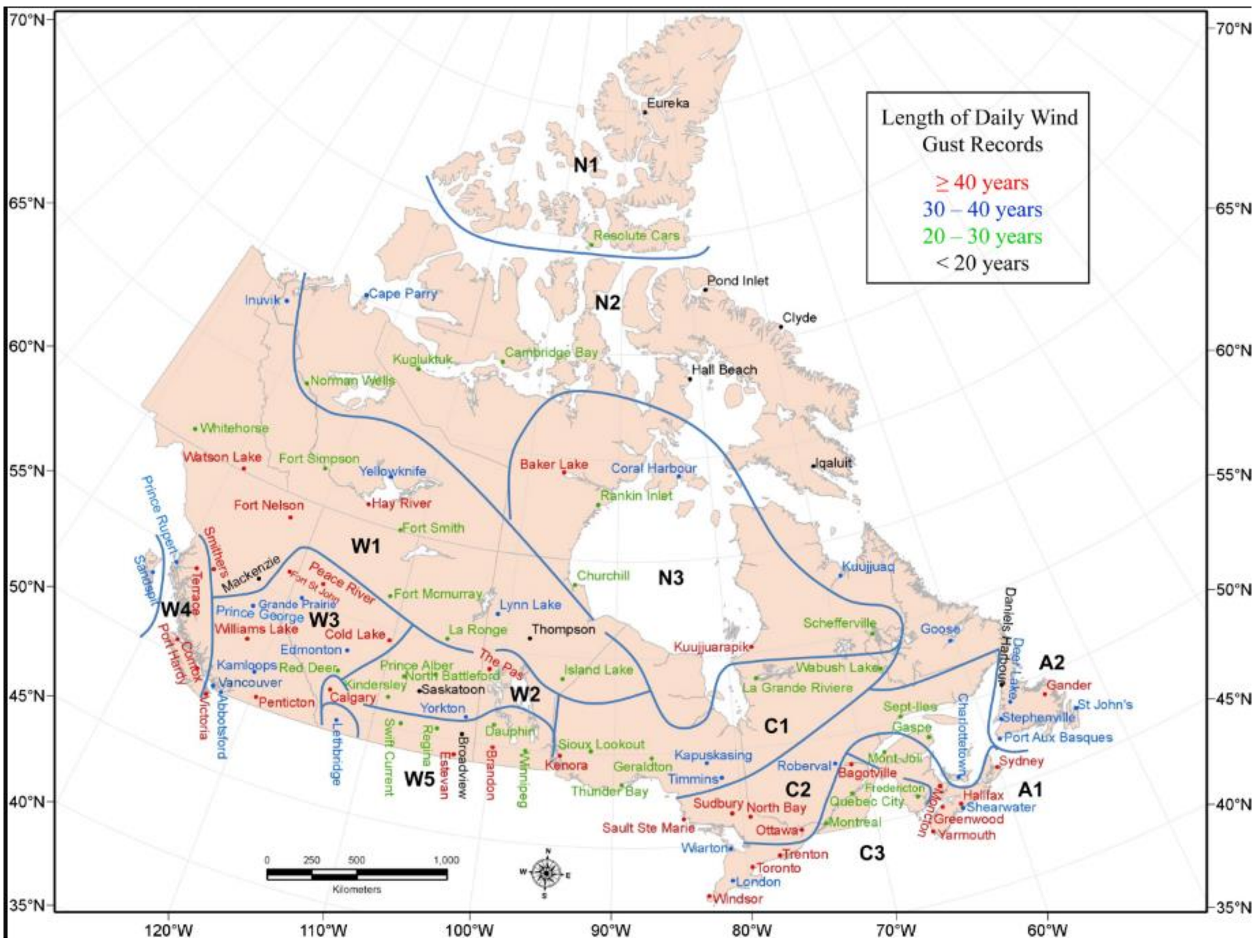


Figure A-54: Wind Gust Regions as defined in Cheng and Lopez (2014) for North America.

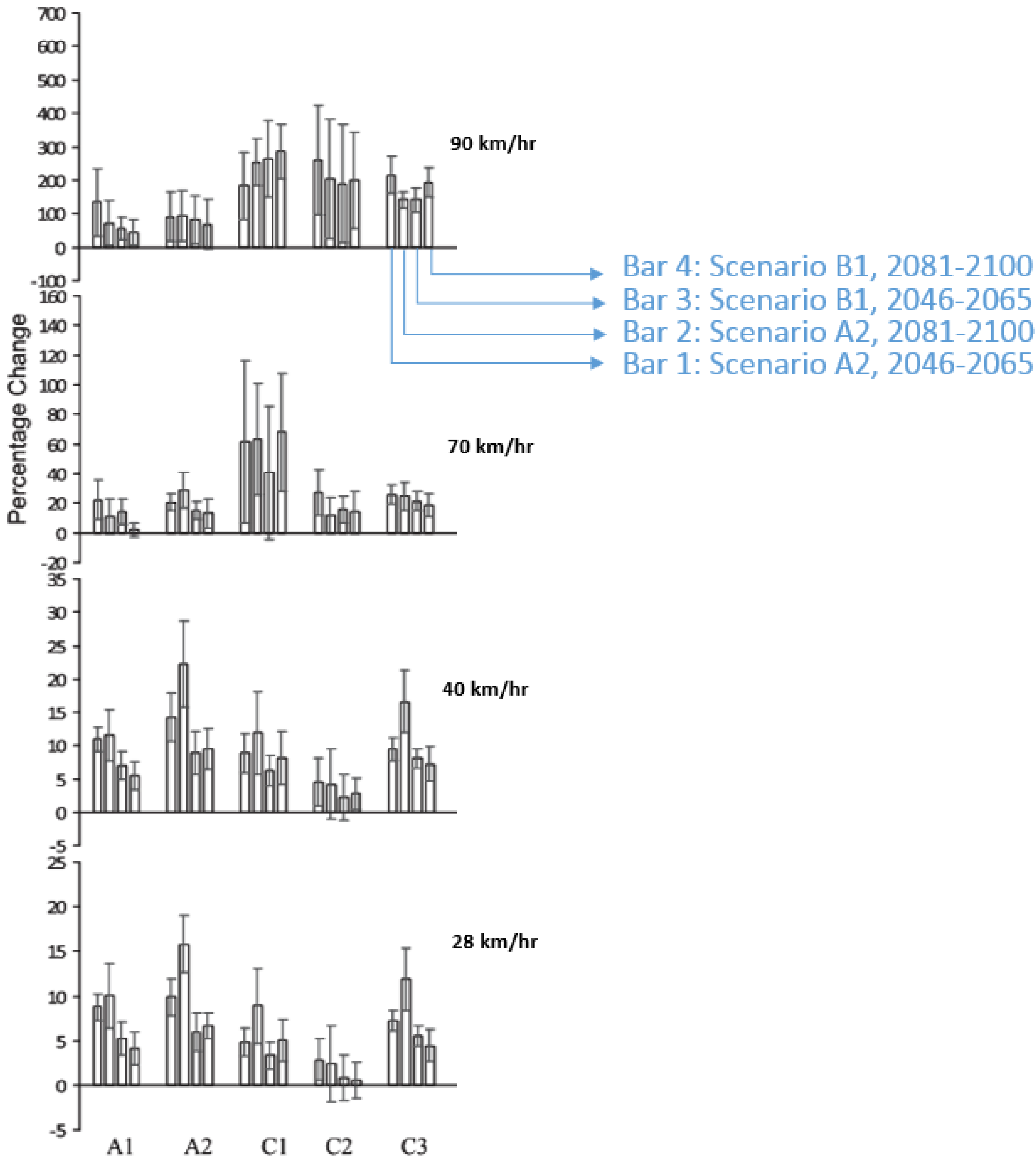


Figure A-55: This figure shows the percent change in hourly wind gusts (Cheng and Lopes 2013). The projections were statistically downscaled from an ensemble of 8 GCMs. The emission scenarios used (B1, A2) are from the Intergovernmental Panel on Climate Change (2007).

A.9.4 Probability Scores

Probability scores were assigned for each time horizon using projections for wind gusts and projected impacts of storm shifts within the region. Wind gusts are different than wind speeds therefore the projected increases cannot be directly applied; however, they can be used as a reference to determine the overall magnitude of potential increases in winds under future conditions. It is noted that due to the non-linear nature of wind processes, in some cases RCP4.5 showed a more significant trend than RCP8.5. Both the inter-annual variability and the difference between the two RCP scenarios were considered as part of the PIEVC scoring.

It is possible that winds will increase in the region, due to the northern shift of storm tracks. However, although research has shown an increase in wind gusts, there is not high confidence in the projections due to the difficultly of wind modelling and their relationship to extreme winds.

A probability score of 4 was assigned to the baseline to reflect the normal conditions at the site and characterize the likelihood of extreme winds on a historical basis. Projections for wind gusts do not include the near-term time frame, therefore, a score of 4 was assigned similar to the baseline. The mid-term time horizon was scored a 5 to reflect projected increases in extreme wind gusts within the region. The mid-term is projected to experience a larger percent increase in wind gusts as compared to the long-term, therefore the long-term was scored a 5 as well to reflect the uncertainty of wind projections near the end of the 21st century.

Table 9: PIEVC Scores for Wind Gusts in the Town of Sussex

Time Horizon	Baseline	Near-term	Mid-term	Long-term
Probability Score	4	4	5	5

A.9.5 Summary

The evidence to support changes in trends for hourly wind speeds is not very strong. Literature on extreme wind gusts was the primary source of climate projections for evaluation of climate change impacts within the region. It is likely that high wind speeds will increase under a future climate, and the site may experience an increase in the occurrence of extreme winds. It is emphasised that the uncertainty associated with wind modelling is high. The IPCC states that winds are modelled with “low confidence.” It is therefore good practice to have allowance for this uncertainty when assigning probabilities to wind predictions.

A.10 Other Parameters

A.10.1 Flooding

The Town of Sussex is located near four main watercourses: The Kennebecasis River, Trout Creek, Parsons Brook, and Wards Creek. Impacts of Flooding to Municipal infrastructure as a result of flooding include; property damage, transportation delays and service disruptions. A Sussex Flood Study was completed in 2016 for the Town. The report incorporates land use development and climate change into the assessment of Flooding risks within the Town (R.V.A. Limited, 2016).

Historically, “newsworthy” floods were characterized to be caused by 50% spring freshets, 40% winter thaws, and 10% fall floods (ADI, 1982). Furthermore, the 1982 Hydrotechnical Study determined that approximately 75% of floods were related to rainfall and snowmelt, while 25% are the result of ice jams. (R.V.A. Limited, 2016)

Climate projections show an increase in the duration and frequency of extreme precipitation events which are expected to cause sudden increases in river flows and runoff therefore increasing flood risk. Increasing temperatures may impact the formation and breakup of river ice which impacts the likelihood of flood events as a result of ice jams. This impact to flooding is discussed in Section A.10.2.

Figure 3.1 (attached) outlines the projected flood plain delineation and impacted infrastructure for a 1 in 100 year flood event in 2100. A 1 in 100 year flood water level has a 1% change of occurring in any given year. The flood lines were determined by digitally tracing the flood lines produced by RVA in the Sussex Flood Study of 2016. The following infrastructure is predicted to be impacted by a 1 in 100 year flood event in 2100: four sanitary lift stations, both municipal wells, thirty eight streets (approximately 10.02 km), eight community buildings, and four parks.

A.10.2 River Ice and Erosion

According to the Government of New Brunswick, approximately 70% of flood damages are a result of ice jams. According to the river ice manual, ice jams form as a result of ice breakup due to warming winter or spring temperatures and rapid accumulation downstream. Subsequently, sudden increases in water levels from large precipitation events causes increased flooding potential to surrounding areas.

The Town of Sussex is located near four main watercourses: The Kennebecasis River, Trout Creek, Parsons Brook, and Wards Creek. The formation of ice jams as a result of melting river ice is known to cause flooding impacts to the Town of Sussex.

Ice jams are historically known to impact the area of Sussex. The New Brunswick River Ice Manual noted an extreme flooding event which occurred in the Sussex Area in February 1981 due to a severe ice jam along the Kennebecasis River. A Sussex Flood Study completed in, 2016 reports the Sussex area as having underlying sediment of sand and gravels which result in highly erodible channel banks and high rates of sediment transport. In particular, these processes were evident in Trout Creek and were noted to increase local flood levels and flooding risks as a result.

The ice regime in the region is described in the NB River Ice Manual (2011) as follows:

- The region of Sussex has approximately an average of 800 freezing degree days.
- The regions reported has thin to average ice cover and a much lighter snow cover than northern areas.
- Mid-winter thaws and rain events are more common within the region than within the rest of the province. This results in early breakup and sometimes severe ice jams.

In addition to being the cause of major flooding hazards via ice jams, river ice has several other important impacts (Beltaos and Prowse 2001).

- **Channel morphology and sediment transport**. Surges during ice jam release are associated with large pulses of sediment transport.
- **Biological effects**. River ice affects ecosystems through the creation of unique in-channel and riparian habitats, the modification of aquatic and floodplain vegetation. River ice is a major factor in the life cycle of many aquatic and other species.
- **Engineering design parameters.** For example, for riprap design, river ice plucking forces often exceed forces calculated from open water flows.
- **Socioeconomic impacts.** Includes impacts via transportation (shipping), flooding, fishing, and recreational activities.

The main effects of climate change on ice jams are through (1) changes to the flow hydrograph (through changes in both rain and snow), and (2) changes in air temperature and ice formation.
Climate projections show increases in rainfall intensity, decrease in the fraction of precipitation that falls as snow, and increase in the overall variability in precipitation (and therefore flows) throughout the ice season as well as inter-annually. One consequence of these changes is a possible increase to flows during freeze up. This would raise the water level at which freeze-up occurs, hence raising the potential ice accumulation thickness (and increase the potential severity of ice jams). On the contrary, if flows increase during break-up, this would not change the damage potential of ice jams (which is constrained by ice thickness), but could increase their frequency, including an increase in potentially damaging mid-winter events as opposed to spring events (Beltaos and Prowse 2001).

For example, a study of the upper reach of the Saint John River showed that small perturbations in winter temperature can produce major changes in the incidence of breakup and ice jams, by altering snowstorms into rainfall events. Increased rainfall in the winter has resulted in augmented flows during the winter, which are lately becoming capable of effecting breakup of the river-ice cover (Beltaos 2002).

In addition to changes in precipitation, climate changes to temperature will decrease ice cover thickness and the timing of ice formation. Temperature trends have been correlated to reduced length of the ice season, with later freeze-ups and earlier break-ups, and increased variability in river ice coverage. Lastly, other indirect climate influences to river ice include impacts via channel morphology, river basin characteristics, and groundwater supplies, which are factors that are closely linked to regional climate changes(Beltaos and Prowse 2001).

In summary, there are a multitude of ways in which climate changes are predicted to, and have been observed to, affect river ice behaviour. Due to the complex and interactive nature of these processes, it is difficult to predict overall trend that can be expected at the Town of Sussex. It is reasonable to expect increased variability of river ice processes upstream and changes to ecosystems and sediment transport processes.

A.10.3 Acid Rain

The deposition of acid rain accelerates corrosion of materials including rocks, mortar and metals. The interactions between acid rain, UV radiation and climate change can magnify the impacts of acid rain.

The most problematic emissions for acid rain are not the same gases that cause the most warming (carbon dioxide and methane). In fact, due to 1970's legislation controlling acid emissions, sulfate and nitrate in precipitation has decreased by 40% from 1970-2000 in Canada (Driscoll *et al.* 2001). That said, CO_2 can still cause some acid rain (a weaker acid), and increasing concentrations may increase rain acidity in the future. Furthermore, climate change affects precipitation characteristics, and this will change acid rain impacts (e.g., changes to timing, and more acid snow falling as acid rain). The combination of many changing processes makes it difficult to assess the impacts of climate change on acid rain in ecosystems.

A.10.4 Air Quality

Poor air quality may negatively impact visibility conditions which may limit transportation operations. Furthermore, increasing concentrations of airborne particulates may negatively impact mechanical systems through infiltration and deposition. Globally, a decrease in air quality is expected due to increased rates of emissions from urbanization and increasing populations.

A.10.5 Lightning and Forest Fires

Lightning is the product of positive and negative charges in clouds making contact with the positive charges on the ground to create what we perceive as a lightning strike. Lightning can be spectacular to watch, but can also be dangerous due to the unpredictability of where and how the strike will connect with the ground. Lightning strikes have the potential to damage buildings, electrical systems, wind turbines, and infrastructure that is not equipped with mitigating grounding devices. Control measures, such as lightning rods and grounds, can attract lightning strikes to a localized point, which will then dissipate the charge. The magnitude of changes in lightning depends on season, location and even time of day, and is very difficult to predict.

Presently, there is little scientific consensus on how the frequency and intensity of lightning storms will be impacted by climate change.

- A 1993 study projected that the annual mean number of lightning induced fires would increase by 44% in the United States based on modelling a doubling of atmospheric CO_2 emissions (Price and Rind, 1993).
- Price (2009) suggested that global lightning rates will increase approximately 5-6% per degree Celsius rise in global temperatures, due to increased moisture content in the air from increased evapotranspiration rates.
- Effects of climate change lead to increased occurrence of thunder clouds due to increased convection; this also leads to an increase in frequency and intensity of lightning generation.
- However, a study from the Institute for Climate and Atmospheric Science found that by 2100, global temperature rises will impact the formation and movement of cloud ice particles, leading to a significant drop in lightning occurrence (University of Leeds, 2018).

Wildfires can be ignited by both natural and man-made sources, although over half of all wildfires are caused by lightning strikes. Conditions such as dry forests, high temperatures, and low humidity, are favourable for wildfires to ignite in forested areas. It is estimated that nearly 2.5 million hectares of forests are destroyed each year from wildfires (Government of Canada, 2018).

The spring and summer of 2018 was characterized as hot and dry across the province of New Brunswick with higher than usual winds. By May of that year, New Brunswick firefighters had already put out more than three times the number of fires as at the same point the year before (comparing 2018 to 2017) (Global News, 2018). The provincial Forest Fire Watch was monitoring 6 active fires in New Brunswick during this wildfire, 3 in the Fredericton, 2 in Miramichi, and 1 in the Bathurst area (CBC, 2018).

Presently, there is little scientific consensus on how the frequency and intensity of lightning storms will be impacted by climate change. A 1993 study projected that the annual mean number of lightning induced fires would increase by 44% in the United States based on modelling a doubling of atmospheric CO_2 emissions (Price and Rind, 1993). However, a study from the Institute for Climate and Atmospheric Science found that by 2100, global temperature rises will impact the formation and movement of cloud ice particles, leading to a significant drop in lightning occurrence (University of Leeds, 2018).

Although the link between climate change and lightening isn't straight forward, there is clear evidence of the impacts of climate change on forest fires, or rather on temperature and precipitation. By the year 2040, forests fires are anticipated to last on average 30 days longer, happen 25% more often, and burn a 46% larger areas then in the 1990s (ECCC, 2018). While the greatest risk of forest fires are in Central and Western Canada, there is still a risk of wildfires occurring in New Brunswick. It is anticipated that other climate change effects, such as increased summer temperature and drought, will help facilitate conditions favourable for wildfires to occur and sustain in Sussex, and increase the associated risk.

The following figure depicts the change in forest fire severity levels based on circulation model projections across Canada. The seasonal severity rating (SSR) is a measurement of fire danger conditions over a complete fires season (The Atlas of Canada, 2009).

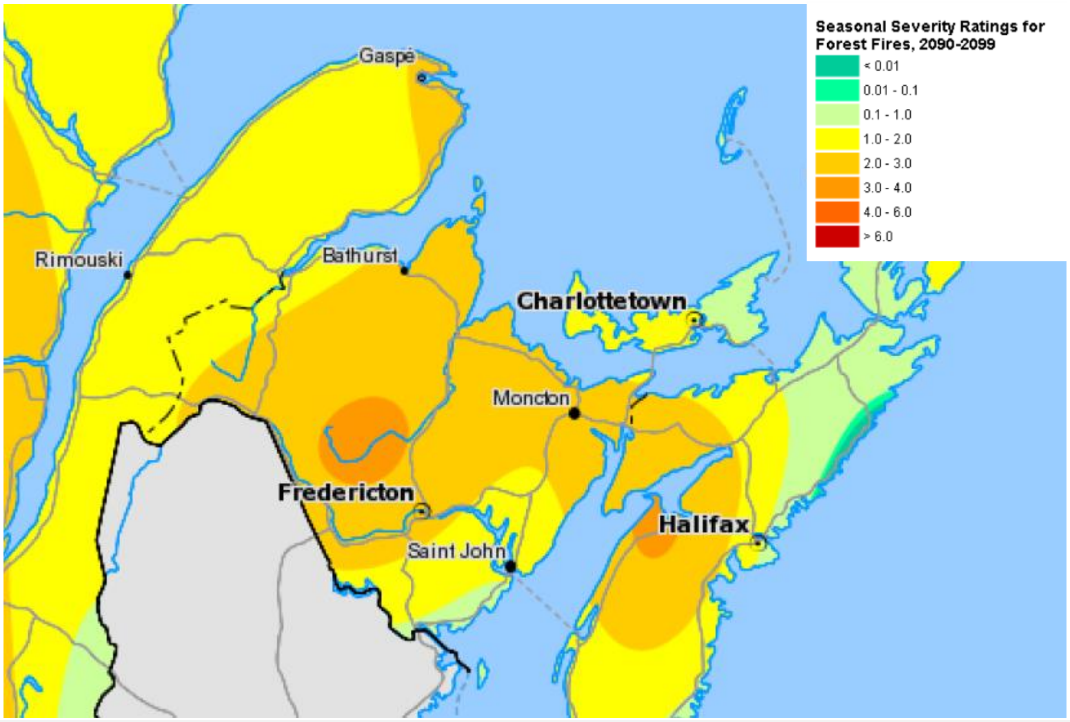


Figure *2.35*: **Forest Fire Severity Level for 2090-2100 (Natural Resources Canada, 2009)**

The land surrounding Sussex is residential areas and is forested to the east with no dedicated fire breaks currently in place to prevent the spread of a wildfire, if one were to occur. Although relatively rare, a wildfire in the Sussex area could have significant impacts, including: public safety concerns, loss of potentially large areas of forest, danger to wildlife, health concerns due to smoke produced from wild fire, and infrastructure damage.

A.10.6 Extreme Storms

Hurricanes are a result of convective forces acting between the warm layer of air above the ocean and the colder temperature within the upper atmosphere. Clouds are generated within this system due to high relative humidity, while areas of low pressure generate lateral movement. As the system gains energy, it grows and rotates at a faster rate developing into a tropical storm.

New Brunswick has historically experienced hurricanes within the province, notably a recent category 1 hurricane, Igor, in 2010 which caused $200 million in damage and lead to one death. The occurrence of hurricanes within the region are known to cause flooding form high intensity rains, power outages, and damage to infrastructure.

CMIP5 GCM projects increases in extreme weather events such as extreme rainfall and winds over the 21st century. This indicates an increase in the number of extreme storms for the region. An extreme rainfall event is defined within the 'New Brunswick Climate Change Action Plan 2014-2020' as 50 millimetres or more of rain over a 24-hour period. The report indicates that Fredericton and Moncton experienced more extreme rainfall events that during any other decade on record during the 2000s (Province of New Brunswick, 2014). The IPCC states that a "shift to more intense individual storms and fewer weak storms is likely", and that "extreme precipitation events will very likely be more intensity and more frequent" (IPCC AR5).

The oceans have absorbed an approximate 90% of heat generated though global warming, becoming warmer as a result. This increase in temperature correlates to an increased energy potential for hurricanes which causes their severity to increase. Due to a potential decrease in atmospheric currents as a result of increasing global temperatures, hurricanes may travel slower across regions; thus, compounding their effect through increase rainfall amounts over a longer period of time (NRDC, 2018).

The IPCC states that no increasing trend in hurricane frequency was depicted over the past century. However, the United Nations body has reported an increase in the frequency and intensity of hurricanes within the North Atlantic. It is noted that this increase may be due to the improvement to monitoring practices. Towards the end of the 21st century the IPCC states that although there is projected trends of decreasing hurricane frequencies, the storms are more likely to be more intense (category 4 or 5) with increase wind and rain amounts (NRDC, 2018).

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Appendix B

Methodology and Data Sources

Appendix B: Key Methodological Considerations

The following factors are considered when choosing appropriate sources of climate change information:

1. **Spatial Resolution** – Global climate models (GCMs) have grid cells that are typically several hundred km wide (very course grid size) as seen in Figure 2.1. This figure illustrates the spatial resolution of the associated GCM model. Some parameters can only be predicted at a higher resolution (e.g., convective storms which cause high-intensity precipitation, as shown in Figure 2.2. Therefore, these parameters would be better obtained from downscaled GCMs, downscaling tools such as the University of Western Ontario Intensity-Duration-Frequency Climate Change Tool (IDF-CC Tool), or analyses of historical measurements.
2. **Stationarity Assumption** – Both statistical downscaling and extrapolation of trends based on historical measurements have the advantage of capturing local effects, which is key. However, they rely on the "stationarity assumption" because they ignore known changes in processes and non-linearity. The stationary assumption is characterized by a time invariant interval of the difference between the modeled and the observed value. This assumption is not validated in the context of climate change as natural systems are known to have non-stationary. Therefore local, small-scale dynamics between changing climate parameters and feedbacks are not simulated.
3. **Need to characterize uncertainty** – There are several major sources of uncertainty in climate modelling, including natural variability, emission scenarios, and inter-model variability, as shown in Figure 2.3. For this reason, the Intergovernmental Panel on Climate Change (IPCC) recommends in their most recent Fifth Assessment Report (AR5) that an ensemble or range of models be considered, because individual models may be less accurate on their own. There are more than 30 internationally accepted GCMs in the Coupled Model Inter-comparison Project (CMIP5), which is many more than the number of available RCMs. Therefore, the GCMs were used to provide a range of predictions.
4. **Availability of parameters** – GCMs provide a limited set of parameters as output. Therefore, other sources of information, such as literature, were selected for particular parameters that are not available from GCMs.
5. **Process-based understanding** – For the parameters that are not readily available in GCM outputs, information was obtained from literature (e.g., process-based understanding from measurement or modelling study conducted elsewhere).

These considerations result in several trade-offs for sources of climate information since no single approach is ideal for all parameters, time horizons, locations, or purpose. As a result, best practice is to vary the sources of climate information depending on the quality of available data and characteristics of the climate parameter.

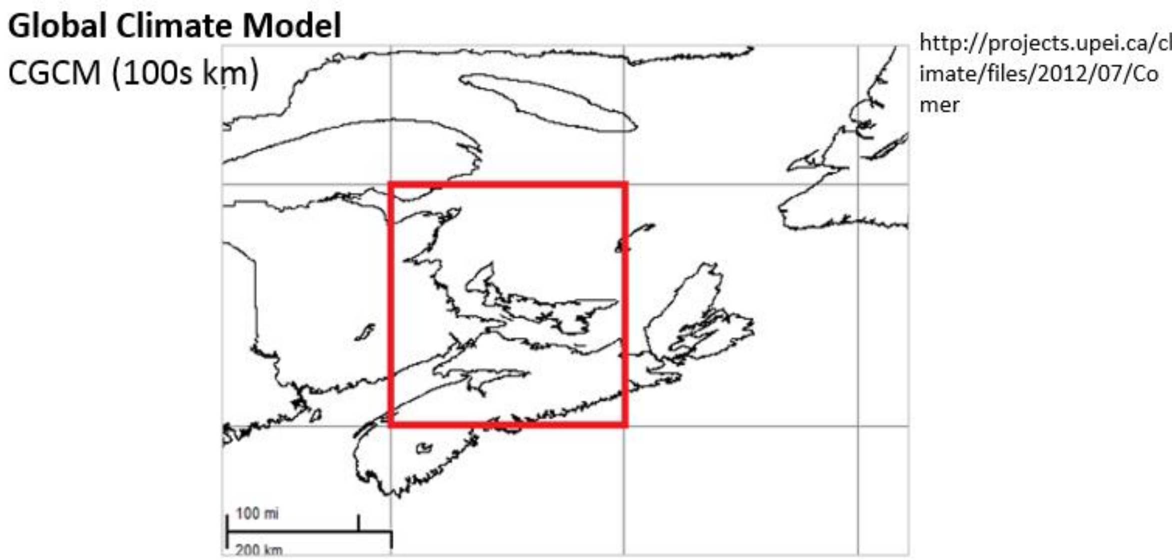


Figure Error! No text of specified style in document.**.1: Modelling domains for our Global Climate Model (CGCM). This figure illustrates the large spatial resolution of GCM models**

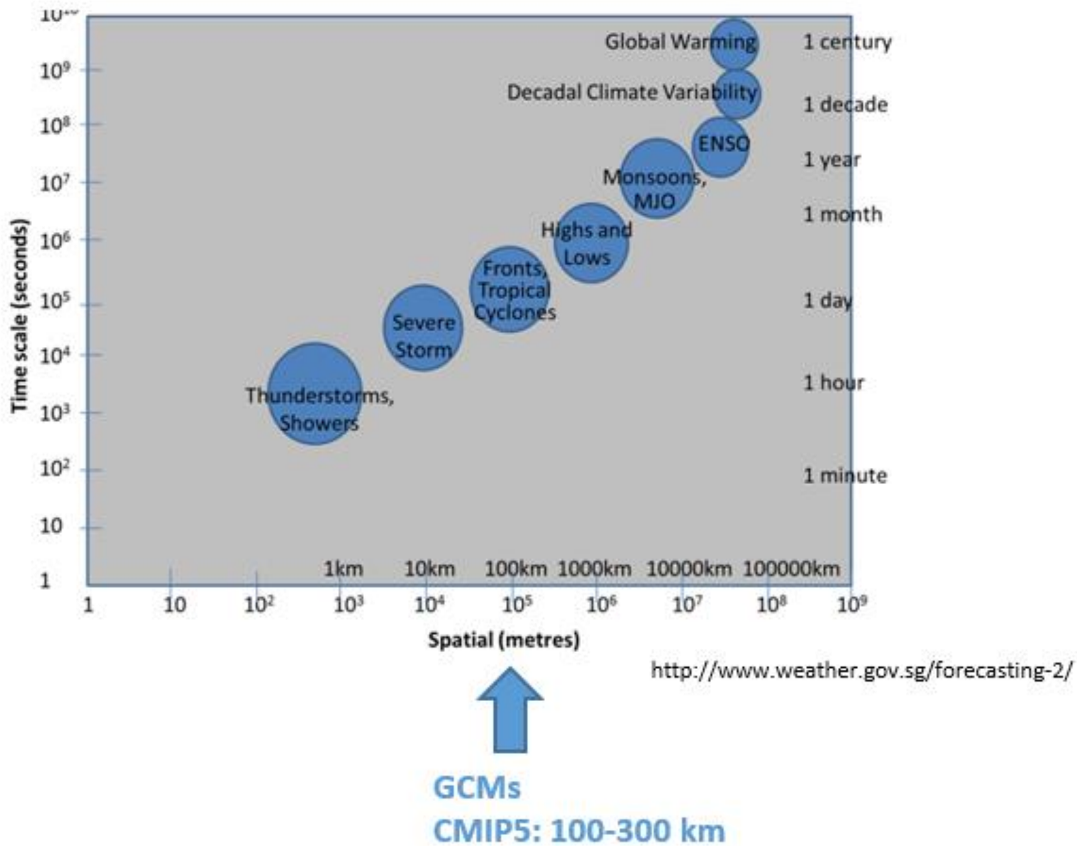


Figure Error! No text of specified style in document.**.2: Illustration of the spatial and temporal scales of selected weather systems and climactic phenomena. The typical spatial resolution of global climate models (GCMs) is indicated for reference. This figure illustrates that some models have resolutions that are too coarse for certain atmospheric phenomena to be modelled.**

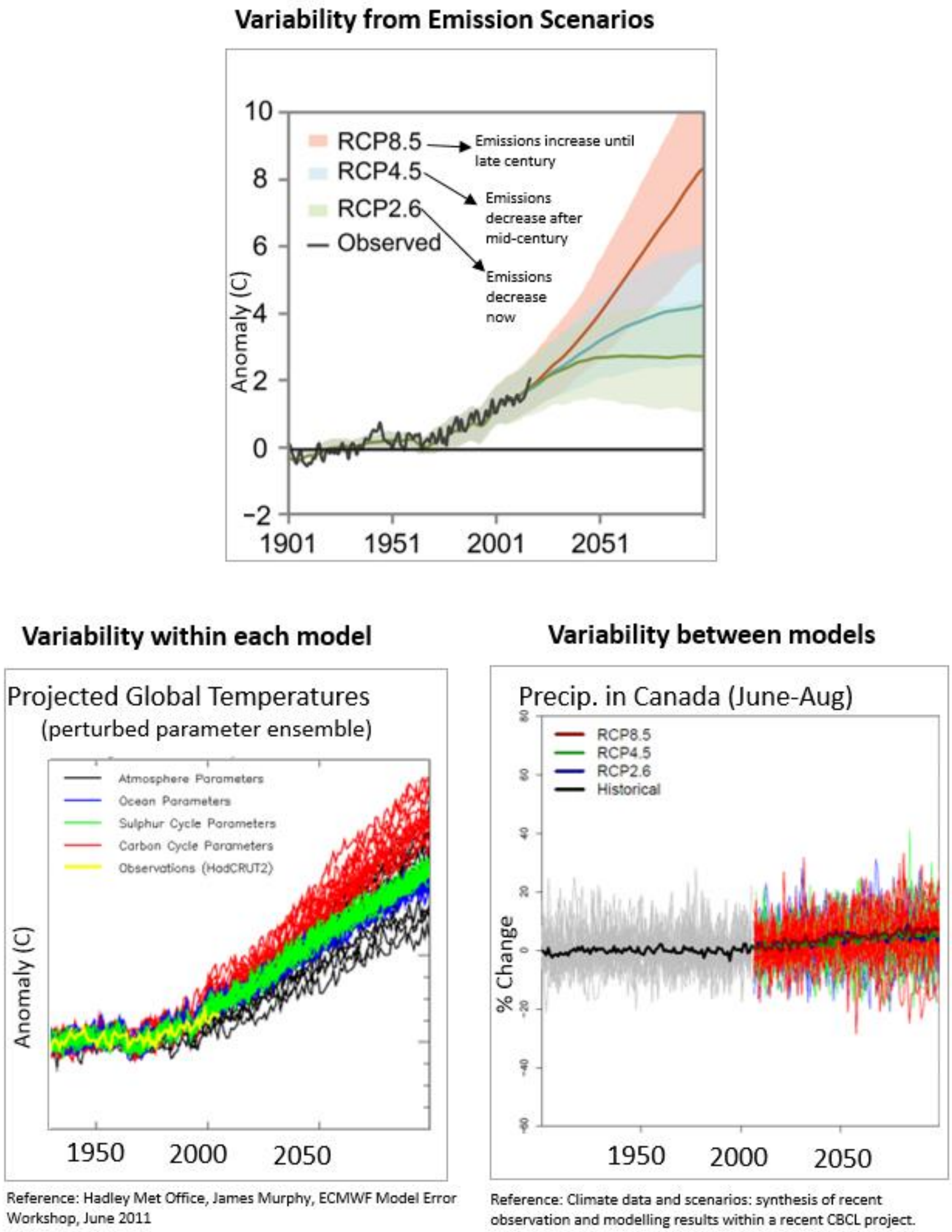


Figure Error! No text of specified style in document..**3: There are several sources of uncertainty involved in climate modeling, including natural variability, emission scenarios, and uncertainty in modelling approaches. The range of projections shown in each of these figures was obtained by running a large number of models and obtaining a range of results. In this way, running a greater number of emission scenarios, models, or model runs helps provide a measure of uncertainty.**

Data Sources

The sources of climate information used for future projections include:

- **CMIP5** –30 GCMs from the 5th phase of the CMPI5. Raw data from 22 GCM outputs obtained from the Canadian Center for Climate Modelling and Analysis was used to generate annual and monthly GCM and ensemble plots. GCM results from CMIP5 include the most up to date and best available climate data in the world. It is common practice in Canada to apply the results of these models to assess regional climate change.
- **CLIMDEX** – Some CMIP5 GCM output plots were obtained as a suite of indices called "CLIMDEX". These are defined by the Expert Team on Climate Change Detection and Indices (ETCCDI), a joint international effort, aimed at creating a standardizes list of indices for characterizing climate change.
- **IDF-CC Tool** – University of Western Ontario Intensity-Duration-Frequency Climate Change (IDF-CC) Tool. This tool provides IDF data and curves projected under multiple different representative concentration pathways (RCP) of greenhouse gas scenarios (GHG) in the future. The IDF-CC Tool stores data associated with 700 Environment and Climate Change Canada (ECCC) operated rain stations across Canada. This data is used in order to 'update' IDFs under future climate conditions in order to assess the impacts of Climate Change on IDF curves. This is done by statistically downscaling the results of 24 Global Climate Models (GCMs) and 9 downscaled GCMs to reflect the conditions of local rainfall patterns. The Environment Canada climate station located in the Town of Sussex did not have sufficient data to generate future IDF curves within the IDF-CC Tool. Therefore the site was treated as 'ungauged' in which case the tool interpolates data from the nearest climate stations to produce the updated curve for the specified location.
- **Literature** (from peer-reviewed sources, governmental and intergovernmental reports), including:
  - Box-plot figures were obtained from the '*Future Climate Scenarios – Province of New-Brunswick'* report published in 2016 by Roy and Huard. The figures were derived from simulations from the CMIP5 ensemble GCM projections statistically downscaled using observed records from selected meteorological stations. The simulations were used to generate monthly changes for specific climate parameters in order to depict the differences between the future and reference periods. This monthly change was then applied to the daily time series of the selected climate stations to generate future projections. The location used to interpret projected trends for this assessment is the Moncton station due to its proximity to the Town of Sussex (approximately 70 km to the east). Moncton was determined to be a climatically representative site not only due to its general proximity but also due to its similar latitude and location further inland than that of other surrounding station locations along the coast. A variety of climate parameters recorded on land are known to be impacted by the interactions with large bodies of water, therefore the Moncton station was determined to be the best representative station of the climatology within the Sussex region.
  - Provincial Maps were obtained through the New Brunswick Government website 'New Brunswick's Future Climate Projections: AR5 Data and Maps' From the Atlantic Climate Adaptation Solutions Association. The provincial maps were derived from information from the Roy, P. and Huard D. (2016). *Future Climate Scenarios – Province of New-Brunswick*, as described above.

The definitions for the climate parameters listed are taken from the data sources presented above and include:

Climdex Parameter Definitions:

- *Monthly Maximum of Daily Maximum Temperature*: the maximum temperature recorded of all daily maximum temperatures within each month.
- *Warm Spell Duration Index (WSDI)*: the annual count of days with at least 6 consecutive days when the daily maximum temperature is within the 90th percentile. The 90th percentile was evaluated as the calendar day 90th percentile centered on a 5-day window for the base period 1961-1990.
- *Number of frost days*: the annual count of days when the daily minimum temperature is less than 0°C.
- *Number of icing days*: the annual count of days when the daily maximum temperature is less than 0°C.
- *Monthly minimum of daily minimum temperature*: the minimum temperature recorded of all daily minimum temperatures.
- *Annual total precipitation in wet days*: sum of annual precipitation on days where precipitation is at least 1mm.
- *Monthly maximum 1-day precipitation*: the maximum 1-day value of daily precipitation within each month.
- *Monthly maximum consecutive 5-day precipitation*: the maximum precipitation amount within a 5-day interval within each month.
- *Annual total precipitation when daily precipitation is greater than the 95th percentile*: the annual sum of precipitation amount on wet days (when precipitation is greater than 1mm)
- *Annual total precipitation when daily precipitation is greater than the 99th percentile*: the annual sum of precipitation amount on wet days (when precipitation is greater than 1mm)
- *Maximum* Length of Dry *Spell*: maximum number of consecutive days with rainfall less than 1 mm.

New Brunswick Future Climate Predictions Parameter Definitions:

- *Annual Number of Days with Maximum Temperature greater than 30°C*: the average number of days per year when the temperature exceeds this threshold. Also known as “hot days.”
- *Annual Number of Days with Maximum Temperature greater than 35°C:* the average number of days per year when the temperature exceeds this threshold. Also known as “very hot days.”
- *Annual Cooling Degree Days (CDD)*: Cooling degree days are calculated by checking the daily mean temperature against a baseline of 18°C. Days with mean temperature below 18°C have zero cooling degree days. A day with a mean temperature of 20°C would represent 2 cooling degree days. Annual cooling degree days is the average total for the whole year.
- *Annual Heating Degree Days (HDD)*: Heating degree days are calculated by checking the daily mean temperature against a baseline of 18°C. Days with mean temperature above 18°C have zero heating degree days. A day with a mean temperature of 5°C would represent 13 heating degree days. Annual heating degree days is the average total for the whole year.
- *Growing Season Length*: the number of days between the dates when the mean daily temperature exceeds 5 degrees Celsius. The days do not need to be consecutive.

- *Mean Winter Temperature*: average temperature for the months of December, January and February.
- *Annual Freeze Thaw*: the average number of days per year when the daily maximum temperature equals or exceeds 0°C AND the daily minimum temperature is less than 0°C.
- *Winter Freeze Thaw*: the average number of days in the months of December, January and February when the daily maximum temperature equals or exceeds 0°C AND the daily minimum temperature is less than 0°C.
- *Spring Freeze Thaw*: the average number of days in the months of March, April and May when the daily maximum temperature equals or exceeds 0°C AND the daily minimum temperature is less than 0°C.
- *Annual Total Snow Days*: the average number of days per year with at least 0.2 cm of snowfall.
- *Annual Precipitation*: the average total rainfall and snowfall for the calendar year.
- *Annual Rain Days*: the average number of days per year with at least 0.2 mm of rainfall.
- *Winter Precipitation*: the average total rainfall and snowfall for the months of December, January and February.
- *Spring Precipitation*: the average total rainfall and snowfall for the months of March, April and May.
- *Summer Precipitation*: the average total rainfall and snowfall for the month of June, July and August.

Future Projection Horizons

The probability of climate parameters exceeding infrastructure thresholds were evaluated within projected time horizons. Time horizons were characterized as “baseline”, “near-term”, “mid-term”, and “long-term” and correspond to the reference period of historically recorded data and subsequent projected time frames in the future to depict climate change impacts over the 21st century. The likelihood score determined within each time period can be applied when within the risk matrix based on specific requirements for planning or asset life span.

- The **baseline** is defined by the historical period 1981-2010 and is used as a reference period of change to subsequent projected time horizons.
- The **near-term, mid-term, and long-term** correspond the general time periods of the 2030’s, 2050’s, and 2080’s, respectively. When projections for a given parameter were not available for these exact time frames, adjustments were made so that projections could be standardized for the PIEVC risk matrix.

Climate Change Emission Scenarios and Uncertainty Characterization

Climate projection data is converted to a PEIVC probability scoring (1 through 7) to be used in a risk-assessment decision making process. The PIEVC scoring is reflective of the median estimate obtained by several models or methods, and where this was ambiguous, the climate change that would result in the greater impact (opt for conservative scoring). When many sources of climate information are considered, the spread in the results must be considered in the assignment of probability scoring. This spread is referred to in climate impact assessment as uncertainty.

There are several sources of uncertainty, which depend on the parameter and source of climate information, listed below:

- **Emission Scenario.** Climate models are driven by different emission scenarios, or “Representative Concentration Pathways” (RCP). The emission scenario RCP8.5 represents one of the core concentration pathways used for the CMIP5 project, in which radiative forcing due to anthropogenic factors reaches 8.5 W/m^2 by 2100 and continues to grow thereafter. The pathway RCP 8.5 represents the upper margin projection of estimates, whereas RCP 4.5 is a more moderate mitigation pathway in which the increasing rate of radiative forcing decreases at approximately 2050 and stabilizes at 4.5 W/m^2 in the year 2100 (Thomson, 2011).
- **Range of results from model ensemble.** For example, the spread of results from CMIP5 model ensemble.
- **Range of results from different sources of projections**. For example, boxplots provided with in the IDF-CC Tool from IDF curves obtained using statistical downscaling, CMPI5 projections presented as box plots for specific time horizons, and the spread of individual GCM projections within the ensemble plots.
- **Time series variability.** For example, high inter-annual variability of the projection reduces the goodness of fit of a linear trend.
- **Uncertainty in the model’s ability to constrain the result**. For example, winds are poorly predicted by current climate models due to the complexity of the processes involved; therefore, the absence of a significant trend in the data should be interpreted with caution, and the “high” scenario was used to reflect this.
- **Increase in uncertainty with projection time**. Most climate parameters are better constrained in the near-term, with projection uncertainty larger in the long-term. This is due to, for example, impacts of small scale dynamics and radiative forcing becoming more uncertain over time.

A conservative scoring approach was used when considering projections from RCP 4.5 and RCP 8.5. The RCP scenario resulting in the worst impacts (in some cases, this means less climate change, e.g., for snow) was used. RCP 8.5 is the Intergovernmental Panel on Climate Change (2013) “worst case scenario” for emission increases in which radiative forcing reaches greater than 8.5 W/m^2 by 2100 and continues to rise for some time. RCP 4.5 is an intermediate concentration pathway in which the increasing trend of radiative forcing slows at approximately 2050 and is stabilized at approximately 4.5 W/m^2 after 2100.

Due to the qualitative nature of the analysis, the determined PIEVC score was rounded up in cases where projections may fall in between scores to reflect a more conservative approach. The binned nature of the PIEVC scoring system is designed to emphasize relative risk among different possible climate-infrastructure and municipal asset interactions.

The climate change projection analysis and PIEVC scoring can be found in Appendix A.

Appendix C

Risk Assessment Matrix

Climate Paramter:		Warm Temperature					Cold Termperature					Freeze Thaw Cycles					Snow Accumulation				
Time Horizon			Baseline	Near-term	Mid-term	Long-term		Baseline	Near-term	Mid-term	Long-term		Baseline	Near-term	Mid-term	Long-term		Baseline	Near-term	Mid-term	Long-term
		P	4	5	6	7	P	4	4	3	2	P	4	4	3	3	P	4	4	3	2
Municipal System	Infrastructure																				
Water System	Distribution System	S	1				S	5				S	5				S	1			
		Risk	4	5	6	7	Risk	20	20	15	10	Risk	20	20	15	15	Risk	4	4	3	2
	Wellfield	S	3				S	1				S	1				S	1			
		Risk	12	15	18	21	Risk	4	4	3	2	Risk	4	4	3	3	Risk	4	4	3	2
	Well Houses (2)	S	1				S	1				S	1				S	1			
		Risk	4	5	6	7	Risk	4	4	3	2	Risk	4	4	3	3	Risk	4	4	3	2
	Fire Hydrants	S	0				S	2				S	2				S	2			
		Risk	0	0	0	0	Risk	8	8	6	4	Risk	8	8	6	6	Risk	8	8	6	4
	Water Storage Reservoirs (Tanks)	S	2				S	2				S	1				S	1			
		Risk	8	10	12	14	Risk	8	8	6	4	Risk	4	4	3	3	Risk	4	4	3	2
Sanitary System	Collection/ Pipe	S	1				S	2				S	3				S	0			
		Risk	4	5	6	7	Risk	8	8	6	4	Risk	12	12	9	9	Risk	0	0	0	0
	Lift Stations (6)	S	1				S	2				S	2				S	1			
		Risk	4	5	6	7	Risk	8	8	6	4	Risk	8	8	6	6	Risk	4	4	3	2
	Lagoon	S	4				S	3				S	2				S	1			
		Risk	16	20	24	28	Risk	12	12	9	6	Risk	8	8	6	6	Risk	4	4	3	2
Storm System	Collection/ Pipe	S	1				S	2				S	3				S	0			
		Risk	4	5	6	7	Risk	8	8	6	4	Risk	12	12	9	9	Risk	0	0	0	0
	Culverts	S	1				S	1				S	3				S	2			
		Risk	4	5	6	7	Risk	4	4	3	2	Risk	12	12	9	9	Risk	8	8	6	4
	Stormater Storage	S	0				S	2				S	0				S	1			
		Risk	0	0	0	0	Risk	8	8	6	4	Risk	0	0	0	0	Risk	4	4	3	2
Transportation	Roads	S	1				S	1				S	5				S	3			
		Risk	4	5	6	7	Risk	4	4	3	2	Risk	20	20	15	15	Risk	12	12	9	6
	Bridges	S	1				S	2				S	5				S	2			
		Risk	4	5	6	7	Risk	8	8	6	4	Risk	20	20	15	15	Risk	8	8	6	4
	Sidewalk	S	1				S	1				S	4				S	4			
		Risk	4	5	6	7	Risk	4	4	3	2	Risk	16	16	12	12	Risk	16	16	12	8
	Walking Trail	S	1				S	0				S	2				S	0			
		Risk	4	5	6	7	Risk	0	0	0	0	Risk	8	8	6	6	Risk	0	0	0	0
Buildings	Town Hall	S	1				S	1				S	0				S	1			
		Risk	4	5	6	7	Risk	4	4	3	2	Risk	0	0	0	0	Risk	4	4	3	2
	Fire Hall	S	1				S	1				S	0				S	1			
		Risk	4	5	6	7	Risk	4	4	3	2	Risk	0	0	0	0	Risk	4	4	3	2
	Public Works Department	S	1				S	1				S	0				S	1			
		Risk	4	5	6	7	Risk	4	4	3	2	Risk	0	0	0	0	Risk	4	4	3	2
	8th Hussars Sports Centre	S	1				S	1				S	0				S	1			
		Risk	4	5	6	7	Risk	4	4	3	2	Risk	0	0	0	0	Risk	4	4	3	2
	Golden Jubliee Hall	S	1				S	1				S	0				S	1			
		Risk	4	5	6	7	Risk	4	4	3	2	Risk	0	0	0	0	Risk	4	4	3	2
	Art and Culture Centre	S	1				S	1				S	0				S	1			
		Risk	4	5	6	7	Risk	4	4	3	2	Risk	0	0	0	0	Risk	4	4	3	2
	Tourist Centre (Train Station)	S	1				S	1				S	0				S	1			
		Risk	4	5	6	7	Risk	4	4	3	2	Risk	0	0	0	0	Risk	4	4	3	2
	Public Library	S	1				S	1				S	0				S	1			
		Risk	4	5	6	7	Risk	4	4	3	2	Risk	0	0	0	0	Risk	4	4	3	2
	Rotary Amphitheatre	S	1				S	1				S	0				S	1			
		Risk	4	5	6	7	Risk	4	4	3	2	Risk	0	0	0	0	Risk	4	4	3	2
	Leonard's Gate	S	1				S	1				S	0				S	1			
		Risk	4	5	6	7	Risk	4	4	3	2	Risk	0	0	0	0	Risk	4	4	3	2
Recreation and Landscaping	Parks	S	1				S	0				S	1				S	0			
		Risk	4	5	6	7	Risk	0	0	0	0	Risk	4	4	3	3	Risk	0	0	0	0
	Trees and Plants	S	1				S	0				S	0				S	0			
		Risk	4	5	6	7	Risk	0	0	0	0	Risk	0	0	0	0	Risk	0	0	0	0
Economic Development and Tourism	Indoor Events	S	0				S	0				S	0				S	0			
		Risk	0	0	0	0	Risk	0	0	0	0	Risk	0	0	0	0	Risk	0	0	0	0
	Atlantic Balloon Fiesta	S	0				S	0				S	0				S	0			
		Risk	0	0	0	0	Risk	0	0	0	0	Risk	0	0	0	0	Risk	0	0	0	0
	Sussex Flea Market	S	3				S	0				S	0				S	0			
		Risk	12	15	18	21	Risk	0	0	0	0	Risk	0	0	0	0	Risk	0	0	0	0
	Winter Recreation (Poley Mountain)	S	0				S	0				S	4				S	0			
		Risk	0	0	0	0	Risk	0	0	0	0	Risk	16	16	12	12	Risk	0	0	0	0
Maintenance	Snow and Ice Clearing	S	0				S	2				S	2				S	2			
		Risk	0	0	0	0	Risk	8	8	6	4	Risk	8	8	6	6	Risk	8	8	6	4
	Asphalt Re-surfacing	S	1				S	1				S	5				S	2			
		Risk	4	5	6	7	Risk	4	4	3	2	Risk	20	20	15	15	Risk	8	8	6	4
	Flushing (storm/sanitary)	S	0				S	1				S	2				S	2			
		Risk	0	0	0	0	Risk	4	4	3	2	Risk	8	8	6	6	Risk	8	8	6	4
Environment	Erosion protection (RipRap)	S	0				S	0				S	3				S	1			
		Risk	0	0	0	0	Risk	0	0	0	0	Risk	12	12	9	9	Risk	4	4	3	2
	Tree and Plant Health	S	0				S	1				S	1				S	1			
		Risk	0	0	0	0	Risk	4	4	3	2	Risk	4	4	3	3	Risk	4	4	3	2
	Water/Air Quality	S	1				S	0				S	0				S	0			
		Risk	4	5	6	7	Risk	0	0	0	0	Risk	0	0	0	0	Risk	0	0	0	0
Land Use and Policies	Stormwater Management Policies	S	0				S	3				S	5				S	5			
		Risk	0	0	0	0	Risk	12	12	9	6	Risk	20	20	15	15	Risk	20	20	15	10
	Design Guidelines	S	0				S	0				S	0				S	0			
		Risk	0	0	0	0	Risk	0	0	0	0	Risk	0	0	0	0	Risk	0	0	0	0
	Development Policies	S	0				S	0				S	0				S	0			
		Risk	0	0	0	0	Risk	0	0	0	0	Risk	0	0	0	0	Risk	0	0	0	0
Emergency Services and Public Safety	Fire	S	3				S	0				S	0				S	0			
		Risk	12	15	18	21	Risk	0	0	0	0	Risk	0	0	0	0	Risk	0	0	0	0
	Police	S	1				S	1				S	0				S	0			
		Risk	4	5	6	7	Risk	4	4	3	2	Risk	0	0	0	0	Risk	0	0	0	0
	EMO	S	1				S	1				S	1				S	1			
		Risk	4	5	6	7	Risk	4	4	3	2	Risk	4	4	3	3	Risk	4	4	3	2

Total Annual and Seasonal Precipitation

	Baseline	Near-term	Mid-term	Long-term
P	4	4	5	5
S	0			
Risk	0	0	0	0
S	2			
Risk	8	8	10	10
S	1			
Risk	4	4	5	5
S	0			
Risk	0	0	0	0
S	0			
Risk	0	0	0	0
S	3			
Risk	12	12	15	15
S	3			
Risk	12	12	15	15
S	3			
Risk	12	12	15	15
S	3			
Risk	12	12	15	15
S	1			
Risk	4	4	5	5
S	1			
Risk	4	4	5	5
S	1			
Risk	4	4	5	5
S	2			
Risk	8	8	10	10
S	0			
Risk	0	0	0	0
S	0			
Risk	0	0	0	0
S	2			
Risk	8	8	10	10
S	2			
Risk	8	8	10	10
S	2			
Risk	8	8	10	10
S	2			
Risk	8	8	10	10
S	2			
Risk	8	8	10	10
S	2			
Risk	8	8	10	10
S	2			
Risk	8	8	10	10
S	2			
Risk	8	8	10	10
S	2			
Risk	8	8	10	10
S	2			
Risk	8	8	10	10
S	0			
Risk	0	0	0	0
S	2			
Risk	8	8	10	10
S	0			
Risk	0	0	0	0
S	1			
Risk	4	4	5	5
S	0			
Risk	0	0	0	0
S	1			
Risk	4	4	5	5
S	1			
Risk	4	4	5	5
S	0			
Risk	0	0	0	0
S	1			
Risk	4	4	5	5
S	0			
Risk	0	0	0	0
S	1			
Risk	4	4	5	5
S	0			
Risk	0	0	0	0
S	5			
Risk	20	20	25	25
S	1			
Risk	4	4	5	5
S	1			
Risk	4	4	5	5
S	4			
Risk	16	16	20	20
S	1			
Risk	4	4	5	5
S	1			
Risk	4	4	5	5

Precipitation Intensity (Flooding proxy)

	Baseline	Near-term	Mid-term	Long-term
P	4	5	6	7
S	0			
Risk	0	0	0	0
S	3			
Risk	12	15	18	21
S	4			
Risk	16	20	24	28
S	0			
Risk	0	0	0	0
S	0			
Risk	0	0	0	0
S	4			
Risk	16	20	24	28
S	4			
Risk	16	20	24	28
S	4			
Risk	16	20	24	28
S	5			
Risk	20	25	30	35
S	4			
Risk	16	20	24	28
S	3			
Risk	12	15	18	21
S	4			
Risk	16	20	24	28
S	2			
Risk	8	10	12	14
S	2			
Risk	8	10	12	14
S	4			
Risk	16	20	24	28
S	2			
Risk	8	10	12	14
S	2			
Risk	8	10	12	14
S	2			
Risk	8	10	12	14
S	2			
Risk	8	10	12	14
S	2			
Risk	8	10	12	14
S	2			
Risk	8	10	12	14
S	2			
Risk	8	10	12	14
S	2			
Risk	8	10	12	14
S	2			
Risk	8	10	12	14
S	2			
Risk	8	10	12	14
S	2			
Risk	8	10	12	14
S	1			
Risk	4	5	6	7
S	1			
Risk	4	5	6	7
S	5			
Risk	20	25	30	35
S	3			
Risk	12	15	18	21
S	1			
Risk	4	5	6	7
S	3			
Risk	12	15	18	21
S	1			
Risk	4	5	6	7
S	0			
Risk	0	0	0	0
S	4			
Risk	16	20	24	28
S	1			
Risk	4	5	6	7
S	4			
Risk	16	20	24	28
S	6			
Risk	24	30	36	42
S	6			
Risk	24	30	36	42
S	6			
Risk	24	30	36	42
S	1			
Risk	4	5	6	7
S	2			
Risk	8	10	12	14
S	6			
Risk	24	30	36	42

Low Precipitation

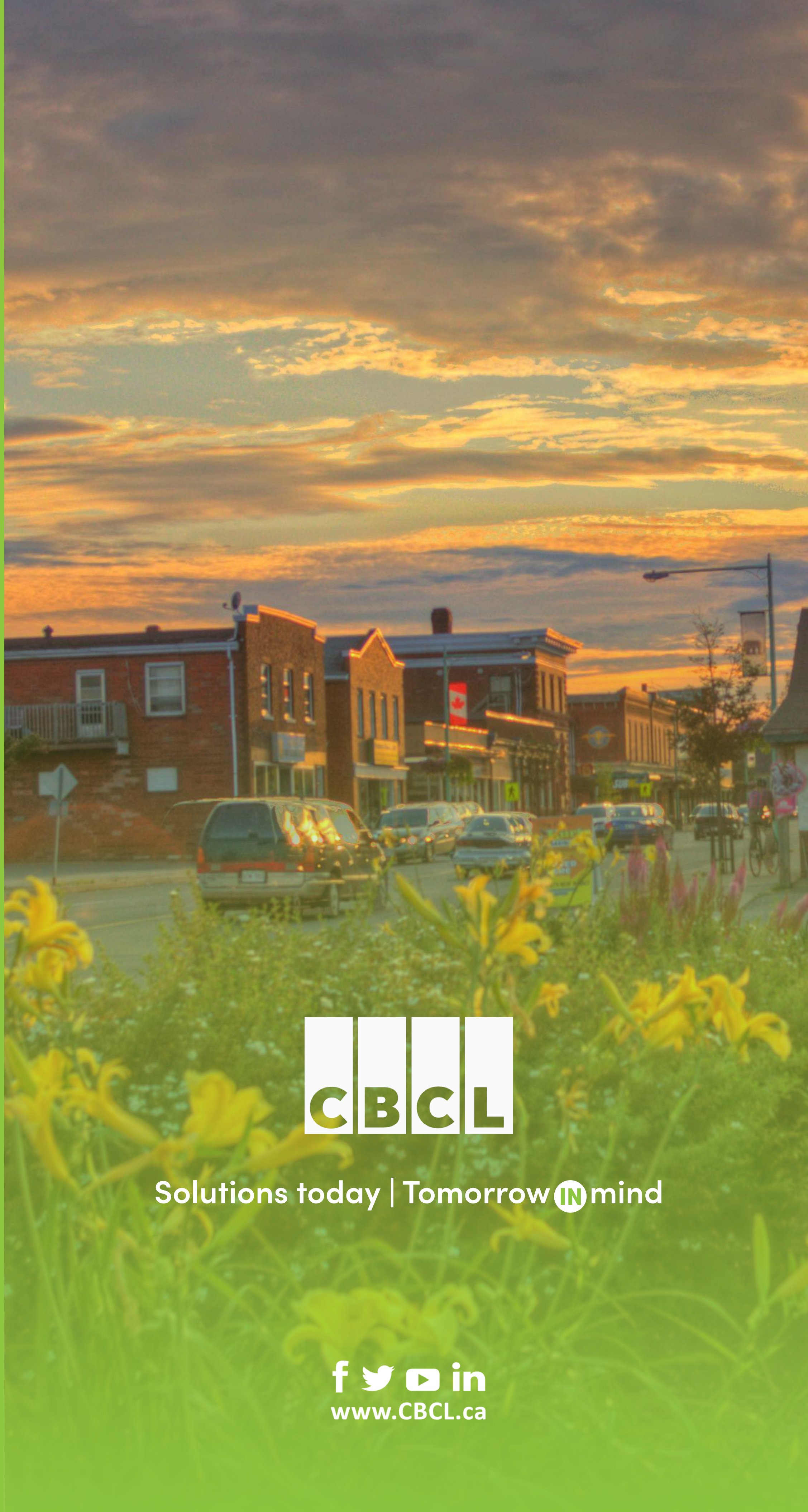
	Baseline	Near-term	Mid-term	Long-term
P	4	4	5	5
S	3			
Risk	12	12	15	15
S	3			
Risk	12	12	15	15
S	3			
Risk	12	12	15	15
S	3			
Risk	12	12	15	15
S	3			
Risk	12	12	15	15
S	0			
Risk	0	0	0	0
S	0			
Risk	0	0	0	0
S	1			
Risk	4	4	5	5
S	0			
Risk	0	0	0	0
S	0			
Risk	0	0	0	0
S	0			
Risk	0	0	0	0
S	0			
Risk	0	0	0	0
S	0			
Risk	0	0	0	0
S	0			
Risk	0	0	0	0
S	0			
Risk	0	0	0	0
S	0			
Risk	0	0	0	0
S	0			
Risk	0	0	0	0
S	0			
Risk	0	0	0	0
S	0			
Risk	0	0	0	0
S	0			
Risk	0	0	0	0
S	0			
Risk	0	0	0	0
S	0			
Risk	0	0	0	0
S	0			
Risk	0	0	0	0
S	0			
Risk	0	0	0	0
S	0			
Risk	0	0	0	0
S	1			
Risk	4	4	5	5
S	2			
Risk	8	8	10	10
S	0			
Risk	0	0	0	0
S	0			
Risk	0	0	0	0
S	0			
Risk	0	0	0	0
S	6			
Risk	24	24	30	30
S	0			
Risk	0	0	0	0
S	0			
Risk	0	0	0	0
S	1			
Risk	4	4	5	5
S	0			
Risk	0	0	0	0
S	3			
Risk	12	12	15	15
S	0			
Risk	0	0	0	0
S	0			
Risk	0	0	0	0
S	0			
Risk	0	0	0	0
S	0			
Risk	0	0	0	0
S	4			
Risk	16	16	20	20
S	0			
Risk	0	0	0	0
S	1			
Risk	4	4	5	5

Freezing Rain

	Baseline	Near-term	Mid-term	Long-term
P	4	4	5	5
S	1			
Risk	4	4	5	5
S	1			
Risk	4	4	5	5
S	1			
Risk	4	4	5	5
S	3			
Risk	12	12	15	15
S	1			
Risk	4	4	5	5
S	1			
Risk	4	4	5	5
S	2			
Risk	8	8	10	10
S	1			
Risk	4	4	5	5
S	4			
Risk	16	16	20	20
S	1			
Risk	4	4	5	5
S	1			
Risk	4	4	5	5
S	5			
Risk	20	20	25	25
S	4			
Risk	16	16	20	20
S	4			
Risk	16	16	20	20
S	2			
Risk	8	8	10	10
S	1			
Risk	4	4	5	5
S	1			
Risk	4	4	5	5
S	1			
Risk	4	4	5	5
S	1			
Risk	4	4	5	5
S	1			
Risk	4	4	5	5
S	1			
Risk	4	4	5	5
S	1			
Risk	4	4	5	5
S	1			
Risk	4	4	5	5
S	1			
Risk	4	4	5	5
S	1			
Risk	4	4	5	5
S	2			
Risk	8	8	10	10
S	2			
Risk	8	8	10	10
S	1			
Risk	4	4	5	5
S	0			
Risk	0	0	0	0
S	0			
Risk	0	0	0	0
S	4			
Risk	16	16	20	20
S	3			
Risk	12	12	15	15
S	0			
Risk	0	0	0	0
S	2			
Risk	8	8	10	10
S	0			
Risk	0	0	0	0
S	3			
Risk	12	12	15	15
S	0			
Risk	0	0	0	0
S	1			
Risk	4	4	5	5
S	3			
Risk	12	12	15	15
S	3			
Risk	12	12	15	15
S	0			
Risk	0	0	0	0
S	3			
Risk	12	12	15	15
S	3			
Risk	12	12	15	15

Wind

	Baseline	Near-term	Mid-term	Long-term
P	4	4	5	5
S	0			
Risk	0	0	0	0
S	0			
Risk	0	0	0	0
S	1			
Risk	4	4	5	5
S	0			
Risk	0	0	0	0
S	1			
Risk	4	4	5	5
S	0			
Risk	0	0	0	0
S	1			
Risk	4	4	5	5
S	1			
Risk	4	4	5	5
S	0			
Risk	0	0	0	0
S	0			
Risk	0	0	0	0
S	0			
Risk	0	0	0	0
S	1			
Risk	4	4	5	5
S	2			
Risk	8	8	10	10
S	1			
Risk	4	4	5	5
S	2			
Risk	8	8	10	10
S	2			
Risk	8	8	10	10
S	2			
Risk	8	8	10	10
S	2			
Risk	8	8	10	10
S	2			
Risk	8	8	10	10
S	2			
Risk	8	8	10	10
S	2			
Risk	8	8	10	10
S	2			
Risk	8	8	10	10
S	2			
Risk	8	8	10	10
S	2			
Risk	8	8	10	10
S	2			
Risk	8	8	10	10
S	1			
Risk	4	4	5	5
S	3			
Risk	12	12	15	15
S	0			
Risk	0	0	0	0
S	5			
Risk	20	20	25	25
S	1			
Risk	4	4	5	5
S	1			
Risk	4	4	5	5
S	1			
Risk	4	4	5	5
S	0			
Risk	0	0	0	0
S	0			
Risk	0	0	0	0
S	0			
Risk	0	0	0	0
S	5			
Risk	20	20	25	25
S	2			
Risk	8	8	10	10
S	1			
Risk	4	4	5	5
S	1			
Risk	4	4	5	5
S	1			
Risk	4	4	5	5
S	5			
Risk	20	20	25	25
S	0			
Risk	0	0	0	0
S	0			
Risk	0	0	0	0



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