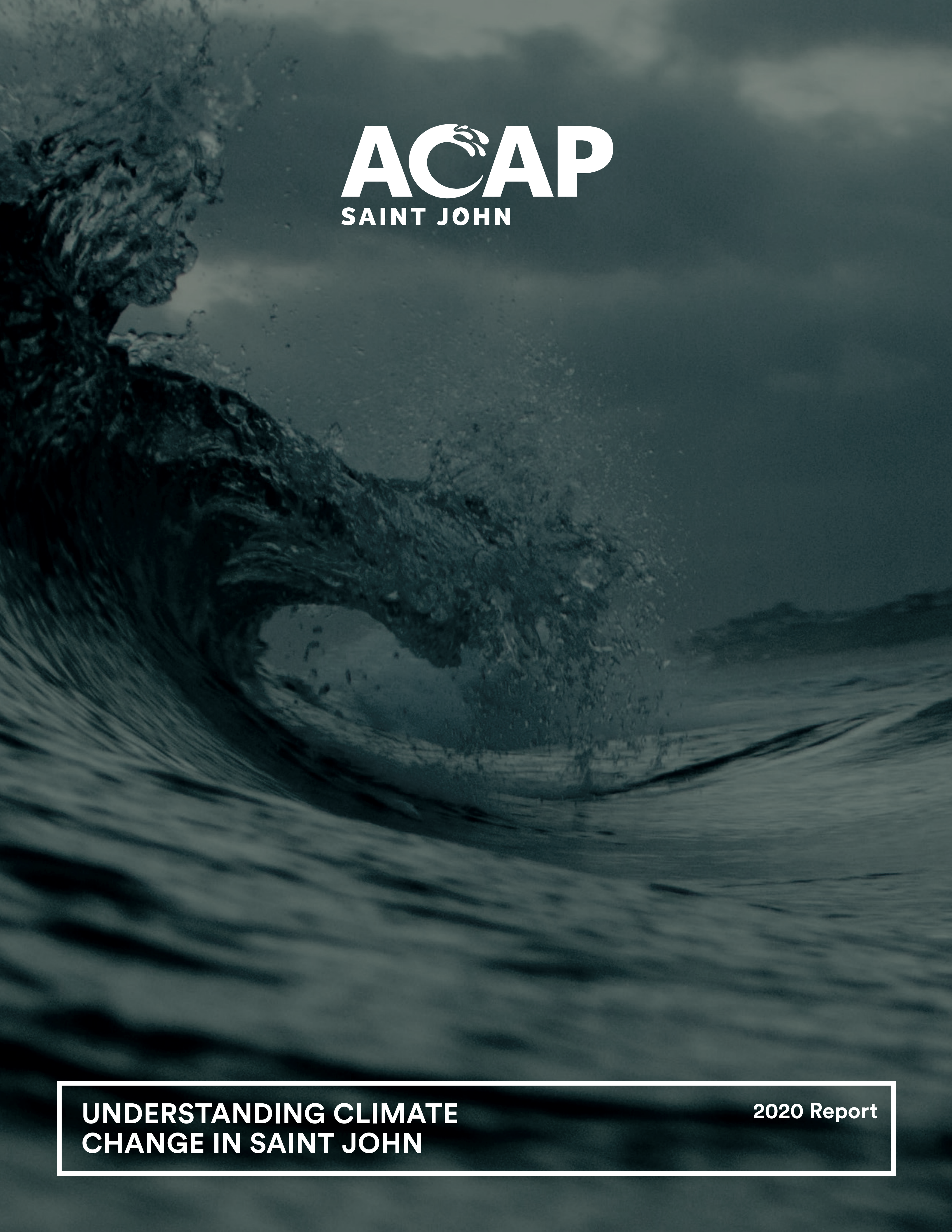
ACAP SAINT JOHN



UNDERSTANDING CLIMATE CHANGE IN SAINT JOHN

2020 Report

ACAP
SAINT JOHN

2020 Report

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INTRODUCTION

Climate Change is one of the greatest challenges facing human civilization today. It directly affects fundamental needs like food, water, and shelter. In Canada, the rate of warming is nearly twice the global average and impacts are already being felt. This report is intended to be a resource for residents, businesses, developers and Council members who are eager to learn more about the changing environment in Saint John, New Brunswick, Canada.

The primary challenges posed to Saint John as a result of Climate Change include increasing temperature, sea level rise, and higher intensity precipitation events. These result in severe inland and coastal flooding, accelerated rates of coastal erosion, and loss of land. This report introduces Climate Change science and describes the predicted weather changes for Saint John. These changes include warmer annual temperatures, warmer winters, increases in rainfall events, rising sea levels, and changes to storm frequency and intensity.

Inland flooding, a historical climate-related challenge for Saint John, is discussed as the result of changing seasonal temperature and precipitation patterns. The benefits of green infrastructure or low impact development strategies are investigated as a solution to reduce the risk of property damage from flooding. The impacts of extreme weather events, including post-tropical storms, ice storms, and wildfires in Saint John are also discussed. Understanding how Climate Change will affect the community is critical for developing effective strategies and reducing negative outcomes.

As a coastal city, sea level rise is of great concern for Saint John. Predictions suggest that a Higher High Water Large Tide (HHWLT) can be expected to be 6.2 m by 2100 for a 100 year return period. Sea level rise projection data for various flooding scenarios are provided in this report and social and environmental impacts are discussed. The largest challenge for areas impacted by sea level rise is the high economic cost associated with damage, relocation, or long-term monitoring. Strong partnerships between multiple stakeholders will be required to protect public and industrial spaces against rising sea level.

Climate Change compounds reoccurring challenges experienced in Saint John around water: changes in seasonal riverine flooding, overflow from precipitation events, and sea level rise. This report discusses challenges around freshwater availability and quality. Supporting healthy communities requires actions to ensure a safe water supply is available.

The City of Saint John must develop adaptation strategies to reduce the negative impacts associated with Climate Change. In Spring 2020, ACAP Saint John will release the Climate Change Adaptation Plan for Saint John, which will provide recommendations to reduce risks and increase the resilience of the community.

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GLOSSARY

Adaptation
Initiatives and measures that reduce the vulnerability of human and natural systems to actual or anticipated Climate Change effects.

Aquifer
A subsurface layer of rock that holds water. The pores and cracks in the rock allow water to be stored until it is pumped to the surface for use.

Blue Infrastructure
Landscape elements linked to water bodies, such as pools, ponds, artificial buffer basins or water courses.

Climate
The average weather measured by the statistical description of mean variability of wind, precipitation, temperatures etc. over time ranging from months to thousands or millions of years.

Climate Change
The long-term changes in climate variables, such as precipitation, temperature, sea level, lake levels, and changes in the frequency and intensity of extreme weather events.

Coastal Erosion
The process of removal and transport of soil and/or rock from shorelines as a result of weathering by streams, glaciers, waves, or high winds.

Coastal Squeeze
A form of coastal habitat loss, where intertidal habitats such as salt marshes, mudflats or sand dunes are lost or deteriorated due to high water levels. In response to sea level rise, defence structures (i.e. a sea wall) can prevent the inward migration of land.

Ecosystem
A system of living organisms interacting with each other and their physical environment ranging from very small spatial scales to entire regions, i.e. coastlines and watersheds.

Flood
A significant rise of water level in a stream, lake, reservoir or a coastal region from excessive rain, severe storms, rapid snow or ice melt, blocked watercourses, failure of dams, land subsidence or storm surges that inundates natural or built landscapes within city boundaries.

Flood Risk
The combination of hazards and vulnerability to floods that have a high probability to occur and/or have significant impact on property, health, or livelihoods.

Global Warming Potential (GWP)
A ratio of how much heat a gas traps in a specific time frame relative to CO_2 (IPCC, 2014). For instance, where CO_2 is estimated to have a GWP of 1 over a 100-year time period, methane is estimated to have a GWP of 28-36 over 100 years and nitrous oxide is estimated to have a GWP of 298 (United States Environmental Protection Agency, 2017).

Greenhouse Gas (GHG)
Compounds that can absorb infrared radiation and trap heat in the atmosphere, contributing to The Greenhouse Effect.

Green Infrastructure
Development that utilizes and promotes the benefits of ecosystem services including stormwater management, water filtration, carbon storage, enhanced biodiversity, and community well-being.

Grey Infrastructure
Engineering and building projects that are made from concrete and/or steel and are typically impervious in urban settings.

Harmful Algal Blooms (HABs)
Occur when colonies of algae grow to produce toxic or harmful effects on people, fish, shellfish, marine mammals, and birds.

Higher High Water Large Tide (HHWLT)
A representation of the storm surge impacts associated with the moon cycle on the high tide. It is determined by taking the average of highest predicted water levels over a 19 year period.

Inland Flooding
Flooding experienced as a result of heavy precipitation events or high river flows occurring in natural and built environments.

Low Impact Development (LID)
Urban infrastructure installed with an emphasis on conservation of natural features with the intention to reduce urban challenges around stormwater management.

Mitigation
Any policy, regulation, or project-based measure that contributes to the stabilization or reduction of greenhouse gas concentrations including renewable energy programs, and energy efficiency plans.

Resilience
The capacity of a system, community or society exposed to hazards to adapt, by resisting or changing in order to reach and maintain an acceptable level of functioning and structure.

Saltwater-Freshwater Interface
The boundary beneath the Earth's surface where saltwater and freshwater meet as a gradual transition zone where water becomes more saline as it moves seawards.

Saltwater Intrusion
The process of seawater infiltrating coastal groundwater systems, mixing with a local freshwater supply.

Storm Surge
A localized, temporary rise in water occurring during specific weather conditions.

Stormwater Runoff
Water from precipitation or snowmelt that flows across the landscape and is not stored or taken up by plants. This can be rain, melting snow or ice that washes off hard surfaces.

Stakeholders
A party, including residents, businesses, developers, First Nations, NGOs, academics, and City staff and Councillors who have an interest in a specific issue.

Vulnerability
The likelihood of a system suffering an adverse impact of Climate Change when exposed to extreme weather.

Water Security
The capacity of a city to protect urban water quality and availability to sustain livelihoods, well-being and socio-economic development.

Watershed
An area delineated topographically were all precipitation drains to one point or outlet.

Urban Heat Island (UHI)
The warming effect of built urban spaces on air temperature in comparison to surrounding rural areas.

LIST OF ACRONYMS

AR5 .... IPCC Fifth Assessment Report

AR6 .... IPCC Sixth Assessment Report

DFAA .... Disaster Financial Assistance Arrangements

ECCC .... Environment and Climate Change Canada

FTC .... Freeze-Thaw Cycles

GCMs .... General Circulation Models

GHG .... Greenhouse Gas

GNB .... Government of New Brunswick

GWP .... Global Warming Potential

HABs .... Harmful Algal Blooms

HHWLT .... Higher High Water Large Tide

IPCC .... Intergovernmental Panel on Climate Change

LID .... Low Impact Development

NBDELG .... New Brunswick Department of Environment and Local Government

NB EMO .... New Brunswick Emergency Measures Organization

RCP .... Representative Concentration Pathway

UHI .... Urban Heat Island


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1. CLIMATE CHANGE IN SAINT JOHN

Climate Change has become a regular focus of media across the world and more so than ever there is positive action being taken by local communities, nations, and municipalities to prepare and adapt to changing conditions. The City of Saint John has an opportunity to adapt to the changing climate and continue to develop as a thriving community. This chapter is intended to introduce Climate Change science including greenhouse gases (GHGs), climate modelling terminology and the changes projected for Saint John.

1.1 Introduction to Climate Change Science

The Intergovernmental Panel on Climate Change (IPCC), established in 1988, is a United Nations scientific body and the foremost authority on Climate Change science. In 2014, the Fifth Scientific Assessment Report (AR5) was released emphasizing the severity of our warming climate system. The Sixth Assessment Report (AR6), scheduled to be released in 2021, will provide stakeholders with modern solutions and updates about successful strategies to reduce Climate Change impacts.

1.1.1 The Greenhouse Effect

The global climate system is maintained by The Greenhouse Effect, which acts to regulate temperature by trapping greenhouse gases (Figure 1). This natural process controls the Earth's temperature and has allowed for ecosystems to develop and diversify. GHG emissions come from both natural and man-made sources and include carbon dioxide (CO_2), methane, water vapour, nitrous oxides, ozone, hydrofluorocarbons, perfluorocarbons and sulphur hexafluoride. Each of these gases has a specific capacity for warming the atmosphere called the global warming potential (IPCC, 2001). While CO_2 is often the focus of Climate Change conversations, each of these gases play a significant role in The Greenhouse Effect.

In the atmosphere, GHGs can be transformed by chemical processes and released beyond the atmosphere, but most are trapped, left to absorb incoming solar energy and keep the planet's surface warm. The dramatic increase in GHG emissions by humans, or anthropogenic sources, has enhanced The Greenhouse Effect, trapping heat in the atmosphere and resulting in warmer temperatures that alter atmospheric and hydrologic processes. Higher concentrations of GHGs in the atmosphere have led to 2016 being the world's hottest year on record (World Meteorological Organization, 2020). This aligns with a trend in global warming that has

What is the difference between adaptation & mitigation?

Adaptation:
Process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate harm or exploit beneficial opportunities. In natural systems, human intervention may facilitate adjustment to expected climate and its effects.

Mitigation:
Human intervention to reduce the sources or enhance the sinks of GHGs. (IPCC, n.d.)

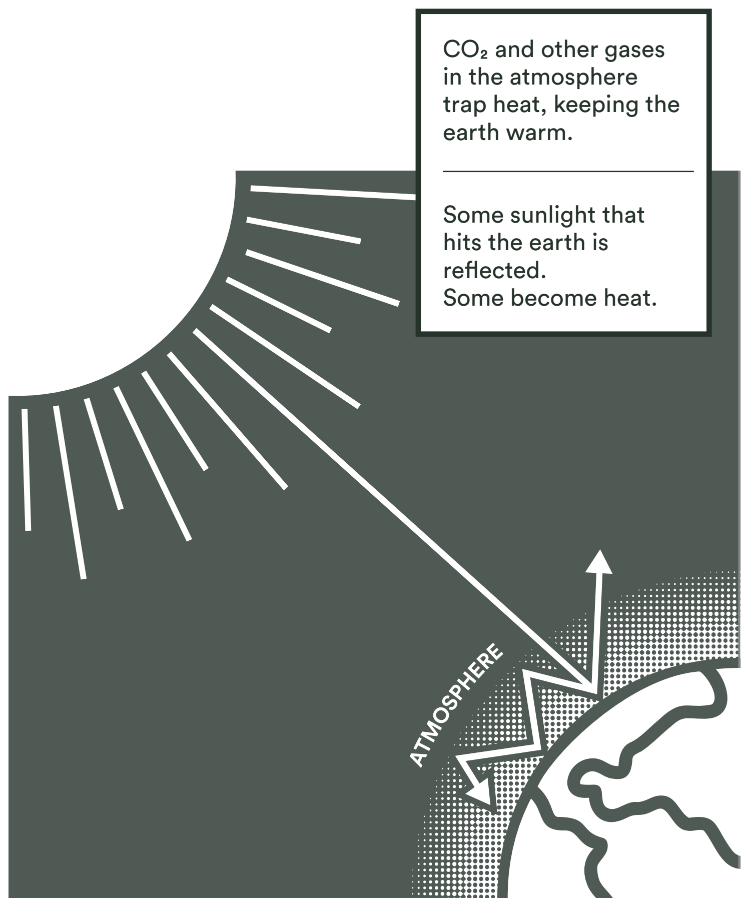

Figure 1: The Greenhouse Effect, where the sun's heat is trapped in the atmosphere by higher quantities of greenhouse gas emissions (Mathematics of Planet Earth, 2012).

been observed over the last 60 years confirming athat our climate is changing with abnormal rapidity (Figure 2).

1.1.2 Climate Modelling

The components and interactions of the climate system can be studied and simulated using climate models. The General Circulation Model (GCM) is the starting point for scientists who will use numerous models to generate accurate data (IPCC, 2001). For this report, the climate data was generated using outputs from 24 climate models by national weather services and research organizations from nine countries (Roy and Huard, 2016). To generate realistic projections, an emission scenario is applied during climate modelling to represent the concentration of GHGs that will be involved in the system. The data in this report is based on the highest emission scenario (RCP 8.5), which is closest to current trends.

Weather is defined as the fluctuating state of the atmosphere characterized by temperature, wind, precipitation, and clouds, and can only predictable over hours, days, or weeks. Climate is the average variability of these elements (or weather) over time. Climate can be observed over different scales, ranging from months to thousands or millions of years.

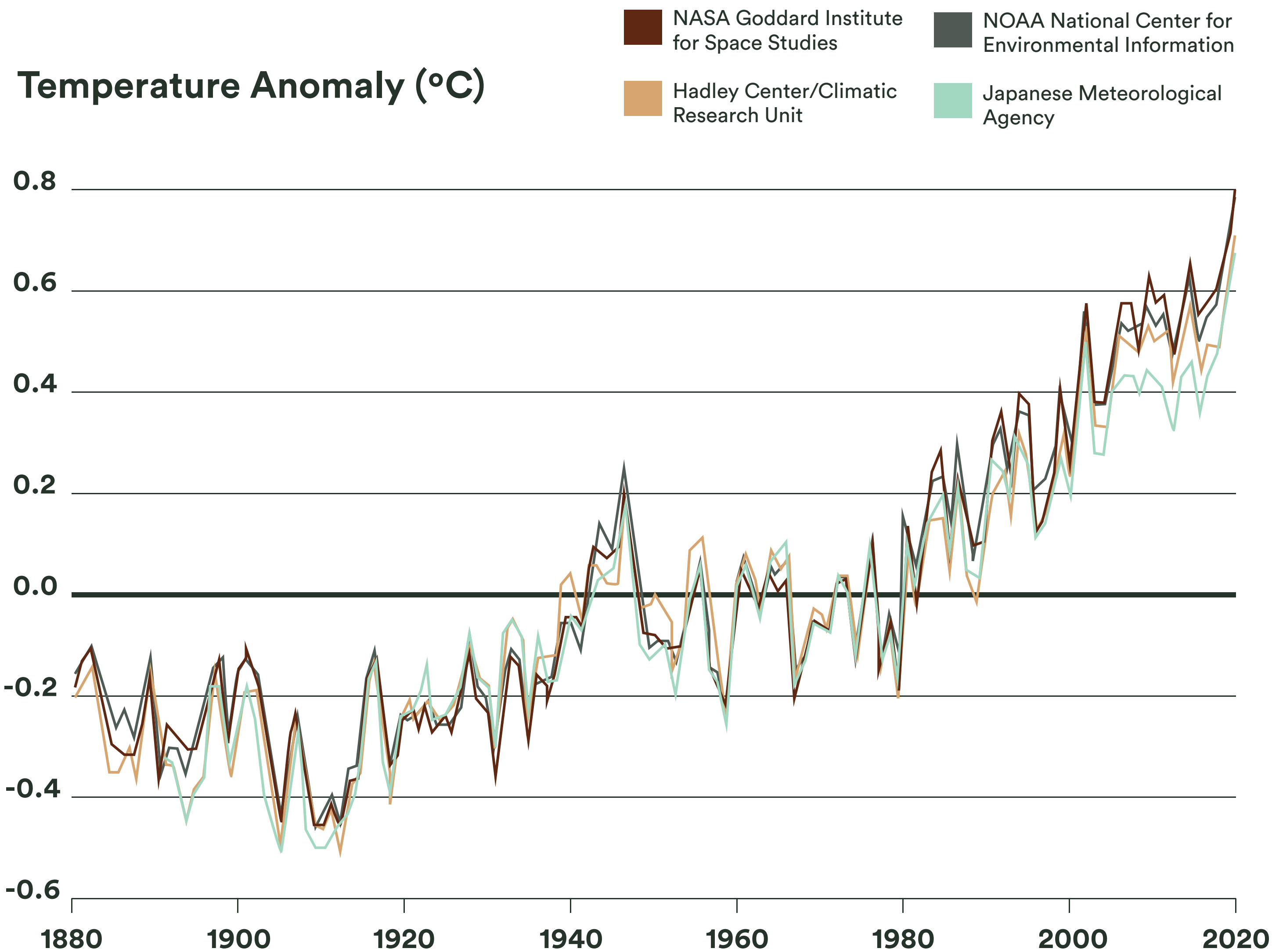

Figure 2: Temperature trends from 1880-2020 (National Aeronautics Space Agency, 2017).

What is a Baseline?

To generate future climate, a baseline of historical data is required. Reports will refer to this baseline when discussing the anticipated changes. For example: 1.5 degrees Celsius of warming compared to 2005 levels, where 2005 levels represent the historical data. The baseline period should be the same length of time as the projected term and is most often a 30 year period.

1.2 Conclusion

Chapter One has provided a brief overview of Climate Change science and modelling. The subsequent chapters will describe the climate projections for Saint John and discuss the associated impacts.


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2. TEMPERATURE

The average annual temperature in New Brunswick, relative to 1990 levels has increased by 1.1°C over the last 30 years (NBDELG, 2018a). Compared to the same 1990 baseline, annual temperatures in the province are expected to increase 3.5°C by 2080 (Roy and Huard, 2016). In the Greater Saint John Area, hotter summers and shorter, warmer winters can be expected in the future decades. Temperature projections are displayed in Figures 3 and 4 and climate data is available in Appendix A (Table 1). The annual temperature in the Greater Saint John Area is expected to rise from 5.7°C up to 9.1°C by 2071-2100 (Figure 3). Mean summer temperature could rise 3.4°C by 2071-2100 with an increase in the number of hot days (above 25°C) from 9.5 in 1971-2005 to 70 days in 2071-2100 (Figure 4 A & B). Average winter temperatures will increase from -5.4°C up to -1°C by 2071-2100 resulting in more freeze-thaw days (Figure 4 C & D). The projection data shows the annual number of freeze-thaw days will peak mid-century (2011-2040) and then decline as mean winter temperatures approach zero in the late century (Roy and Huard, 2016). Winter temperatures hovering around zero degrees can be dangerous due to the threat of freezing-rain events which are challenging to predict. Weather alerts provided by Environment and Climate Change Canada (ECCC) are critical for ensuring communities are prepared and safe during periods of unpredictable weather conditions.

Average Annual Temperature Change For Saint John

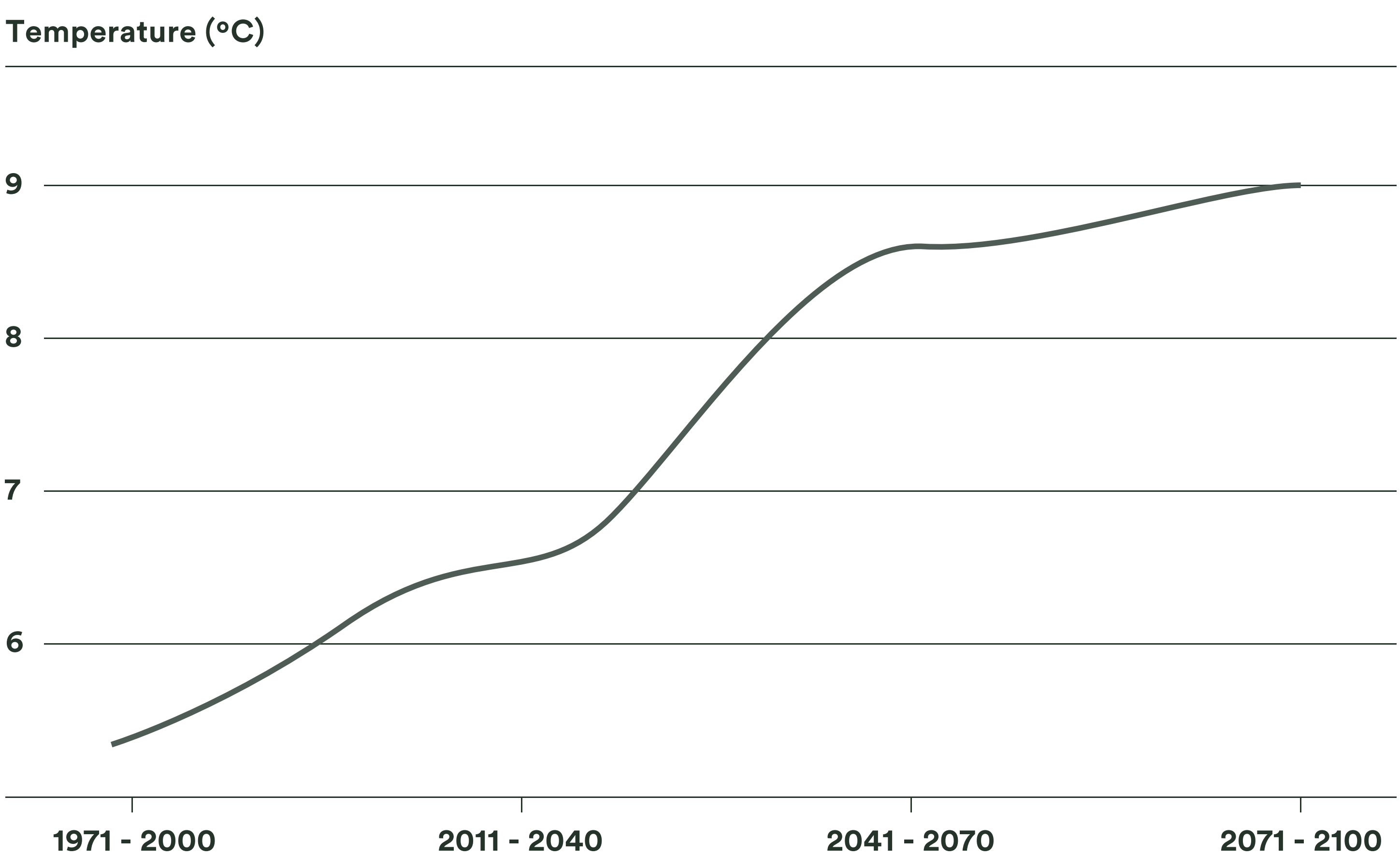
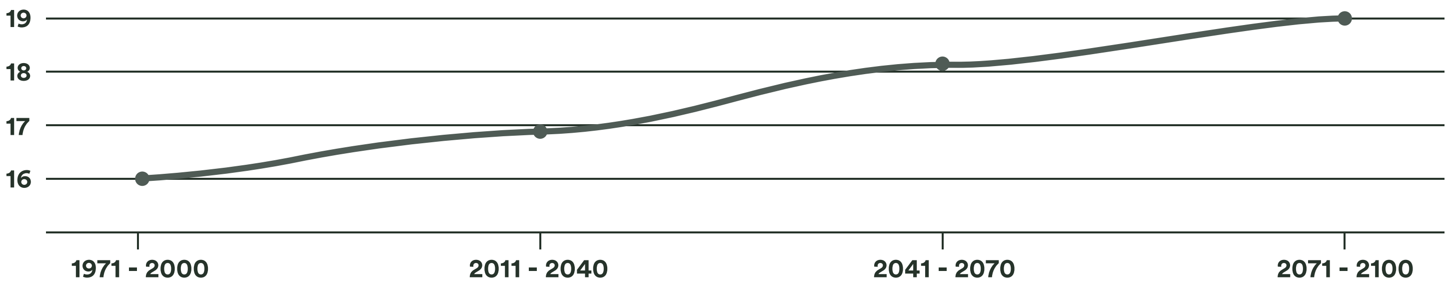


Figure 3: Average annual temperature change for Saint John up to the year 2100 by the Atlantic Climate Adaptation Solutions Association (ACASA) New Brunswick Climate Futures Projections (Roy and Huard, 2016).

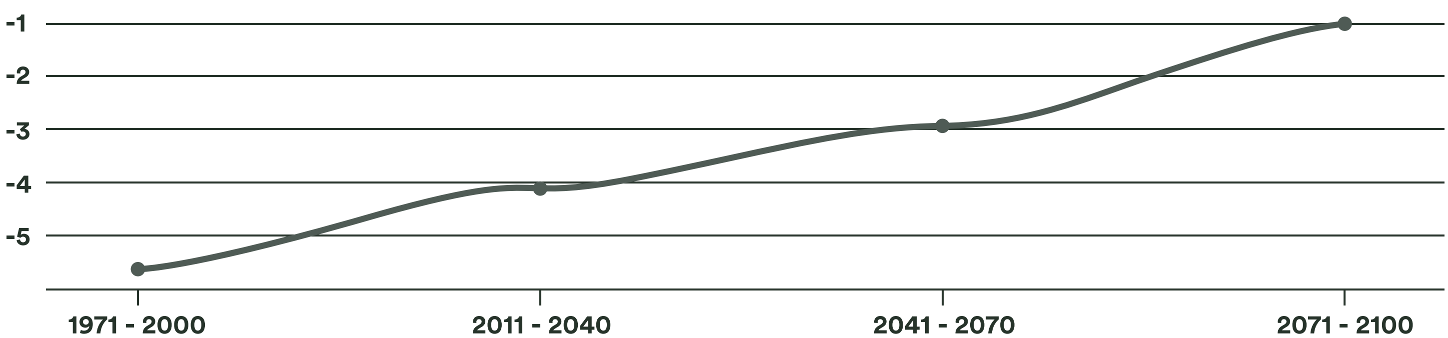
Temperature Changes For Saint John Up To The Year 2100

A Average summer temperature projections.



B The number of hot days where temperatures exceed 25°C.

C Average winter temperature projections.



D The number of freeze-thaw days where temperatures hover around zero degrees.

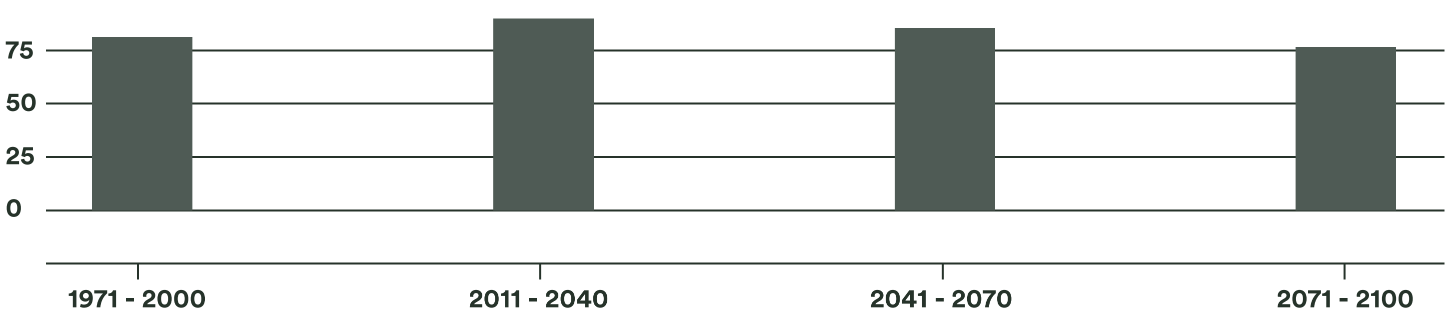


Figure 4: Temperature changes for Saint John up to the year 2100. (A) Average summer temperature projections. (B) The number of hot days where temperatures exceed 25°C. (C) Average winter temperature projections. (D) The number of freeze-thaw days where temperatures hover around zero degrees.

Did you know?

Freeze-thaw days occur when the daily maximum temperature is greater than 0°Cand the daily minimum temperature is less than 0°C. These freeze-thaw cycles (FTCs) are associated with ice and slush conditions which can directly result in damage to built infrastructure. Indirect impacts are challenging to predict and include increased use of road salt and changes to ecological cycles. FTCs are significant for plants or animal species that require stable temperatures for dormancy or are sensitive to cold spells. The production of maple syrup is an example of an industry that relies on FTCs and will need to adapt to these changing climate conditions (Roy and Huard, 2016).

In urban spaces, concrete infrastructure and dark surfaces absorb heat resulting in higher air temperatures when compared to the surrounding rural areas. In climate science, this is known as the Urban Heat Island (UHI) effect (Figure 5). Residential and commercial heating and cooling systems, vehicles and other appliances generate heat and contribute to the UHI. In combination with increasing annual temperatures, many large cities are experiencing dangerous extreme heat events. In Saint John, the UHI effect is moderated by the coastal setting. As temperatures increase, monitoring and education around heat related illness will be necessary to avoid hazards associated with heat and the UHI effect.

As the average annual temperature increases, Saint John will experience earlier snowmelt, mid-winter thaws, and ice breakups which can lead to significant

The Urban Heat Island Effect

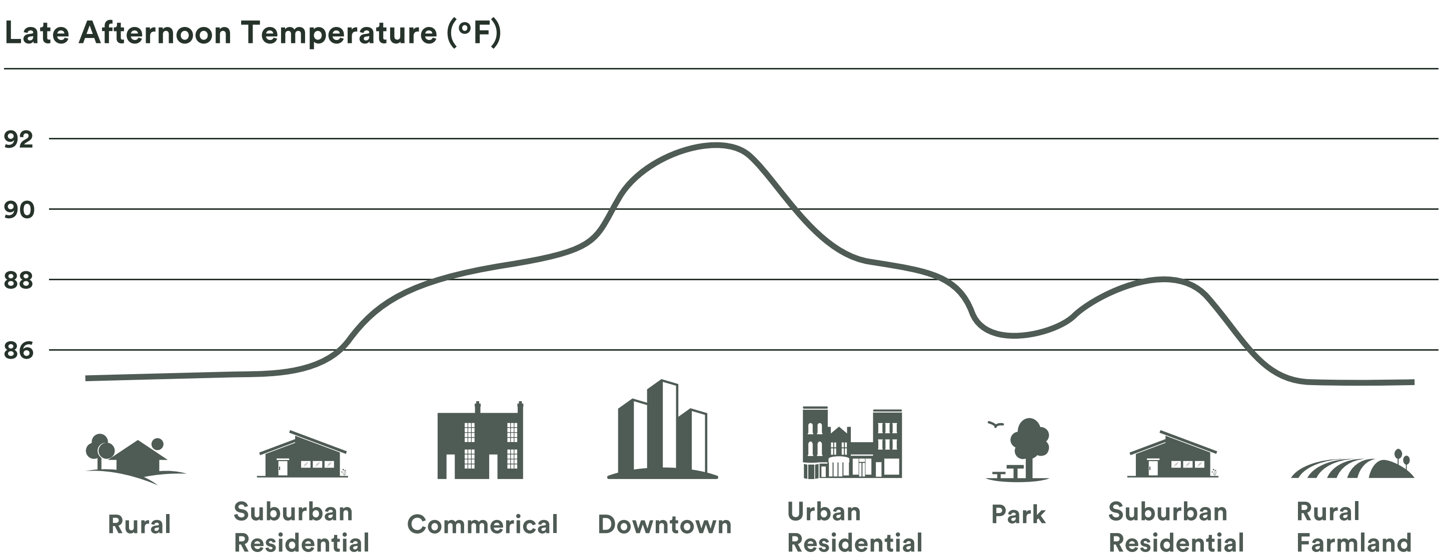
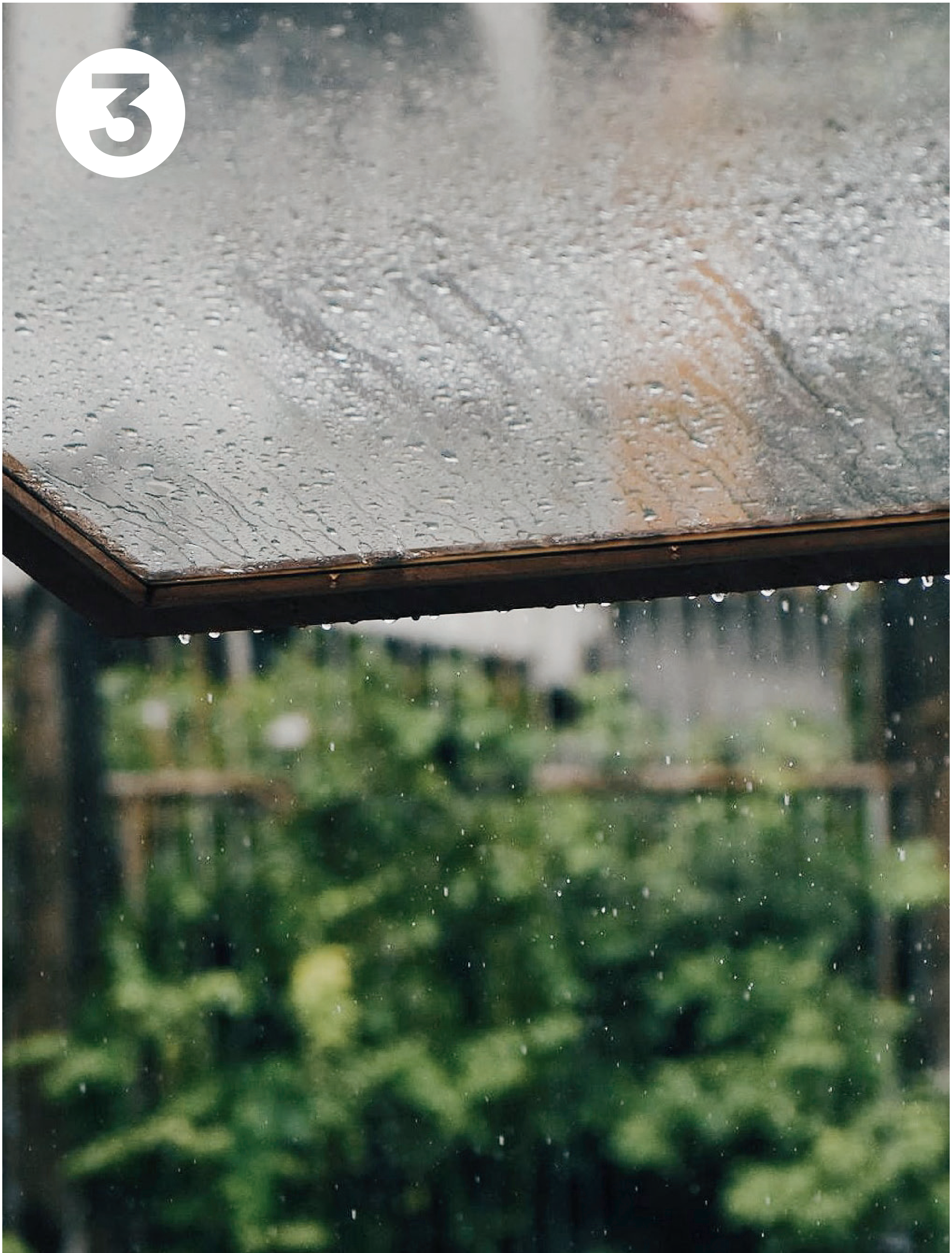


Figure 5: The Urban Heat Island effect: heat is absorbed and held by concrete and asphalt in cities. Tall buildings and lack of vegetation prevent heat from dissipating and diminish natural shade and evaporative cooling (Warren and Lemmen, 2004).

infrastructure damage when combined with intense rainfall (NBDELG, 2014). In 2018 and 2019, Saint John experienced extensive inland flooding due to the combination of spring freshet and extreme rainfall. New Brunswick communities are beginning to adjust to the impacts of warmer temperatures, however education and awareness about adaptation will be needed to reduce the health risks of warmer temperatures in Saint John.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3. PRECIPITATION

Precipitation trends tend to vary more than temperature, making patterns of rainfall in the Greater Saint John area difficult to predict. Climate models project that New Brunswick will experience an extension of dry periods and an increase in heavy precipitation events resulting in a net increase in mean annual precipitation (Figure 6; NBDELG, 2018a, Roy & Huard, 2016). This means that more precipitation will be falling during shorter periods, increasing the amount of stormwater that will be running through sewer infrastructure and into nearby waterways.

The type of seasonal precipitation (rain, snow, sleet, hail, etc.) in the Greater Saint John area is expected to change. As temperatures rise, the annual number of snow days will decrease which correlates to an increase in rain days and may result in more flooding than historically observed (Roy and Huard, 2016). River flows will become more variable as spring peak flow will occur earlier and summer minimal flows will be lower. During summer months, rivers may experience an increase in periods of very low or zero flow that can have significant ecological impact (NBDELG, n.d.). Climate data is available in Appendix A (Table 2).

Projected changes to precipitation in Saint John

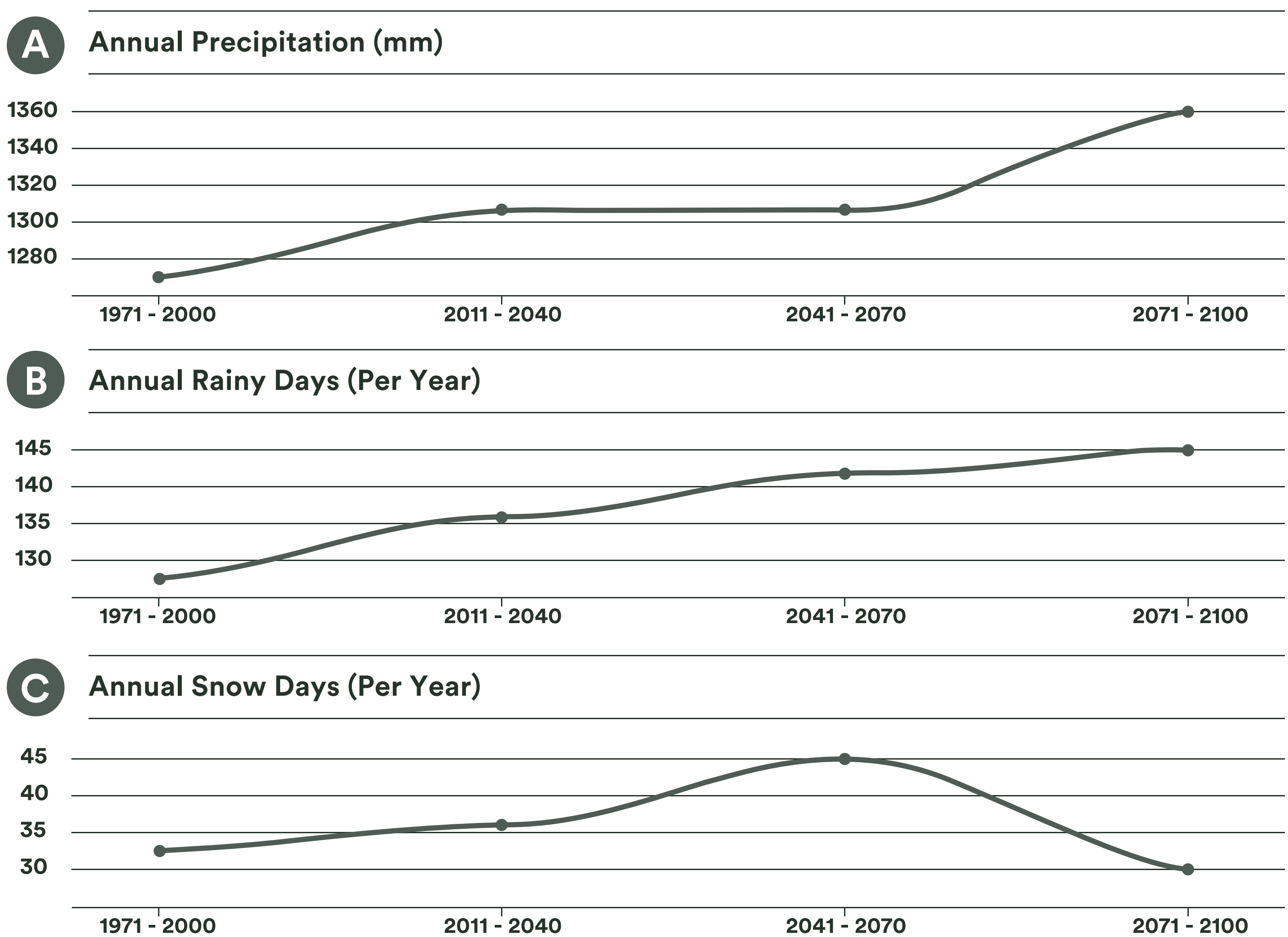

Figure 6: Projected changes to precipitation in Saint John. An increase in annual precipitation is anticipated (A) and changes in the annual number of rain days and snow days are shown (B) and (C). Precipitation projections up to the year 2100 by the Atlantic Climate Adaptation Solutions Association (ACASA) New Brunswick Climate Futures Projections (Roy and Huard, 2016).


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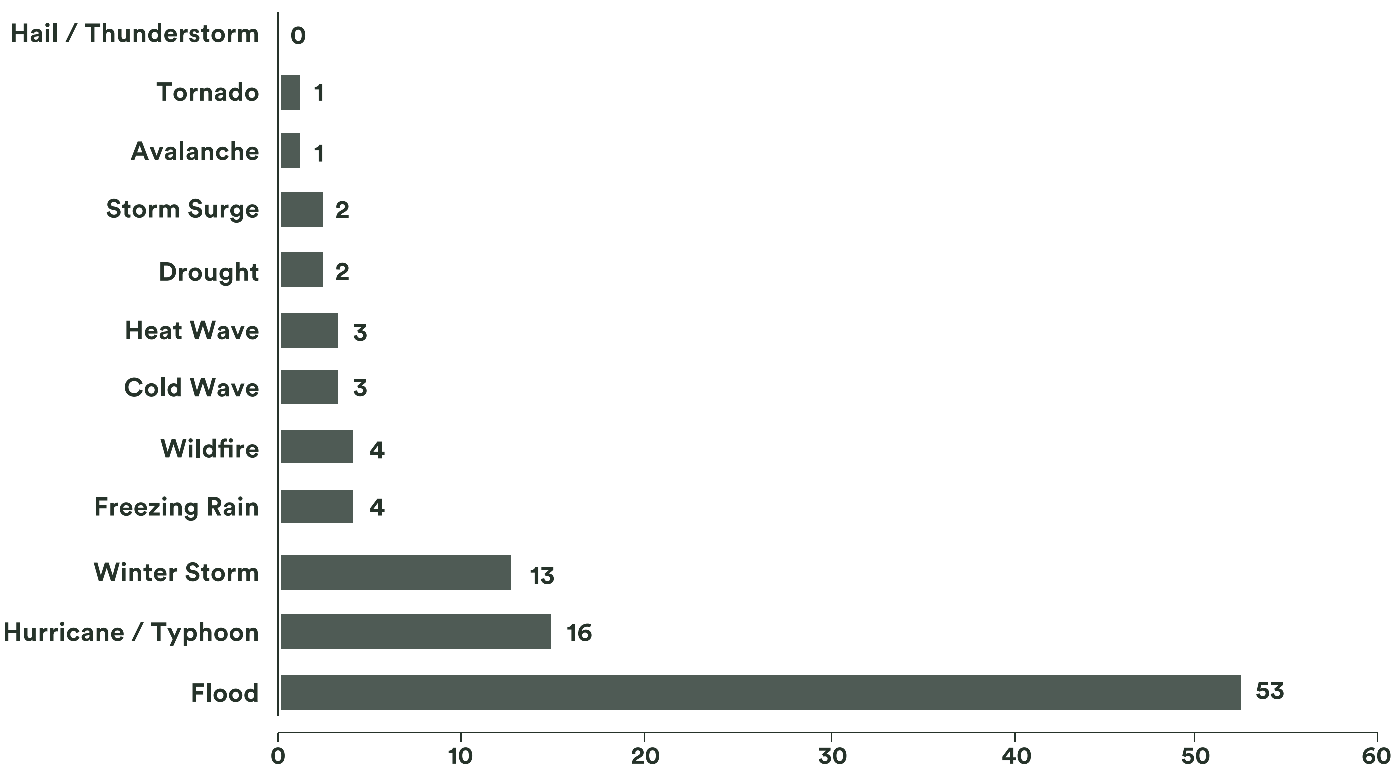
4. EXTREME WEATHER

Extreme weather events are controlled by changes in atmospheric temperature, pressure and moisture. They are expected to become more frequent and intense as a result of changing climate. For every 1°C rise in temperature the amount of moisture in the atmosphere increases by 7% or more (Daigle, 2012). In response to increased moisture, New Brunswick can expect 10 to 20% more extreme rainfall events per year (Canadian Center for Climate Modeling and Analysis, 2017). Historically, extreme rainfall events (50 millimetres or more over a 24-hour period) have caused millions of dollars in flood damage in Saint John, as well as within outlying communities. Most notable were damages in 2008, 2018, and 2019 when heavy rain events coincided with the melting of record-breaking snowfall (NBDELG, n.d.).

Projection trends show an increase in the annual temperature and precipitation in Saint John, however emphasis must be placed on the extremes of each variable, for example days of extreme heat or heavy precipitation events. The impacts of extreme wind, including power outages and fallen trees are already experienced throughout the City. Preparedness is essential to avoid injury and respond quickly as extreme wind events will continue to be experienced.

Natural disasters recorded in Atlantic Canada from 1900-2005

Figure 7: Natural disasters recorded in Atlantic Canada from 1900-2005, retrieved from Atlantic Climate Adaptation Solutions Association (2011).



From 1900-2005, Atlantic Canada experienced approximately 53 flooding events, 16 hurricanes, and 13 winter storms (Figure 7). With shifting hydrological conditions and warming temperatures, Saint John can expect an increase in the intensity and frequency of heavy precipitation, high winds, storm surges, summer convective storms (thunderstorms, hail storms, hurricanes), and severe winter storms. These events are often associated with high damage and recovery costs, emphasizing the importance of preparedness and adaptation. Learning from past extreme weather events can provide insights necessary to lessen future impacts.

In 2017, a survey was conducted by the Conservation Council of New Brunswick after post-tropical storm Arthur, which hit the Maritimes in July 2014. The responses highlighted gaps in emergency preparedness that should be addressed in all New Brunswick municipalities (Comeau, 2017). The biggest concerns for the citizens who participated were power loss, food, water, downed trees, and blocked roads. Municipal staffing and a lack of qualified contractors to conduct cleanup was also recognized as a significant issue.

4.1 Frequency and Economic Costs

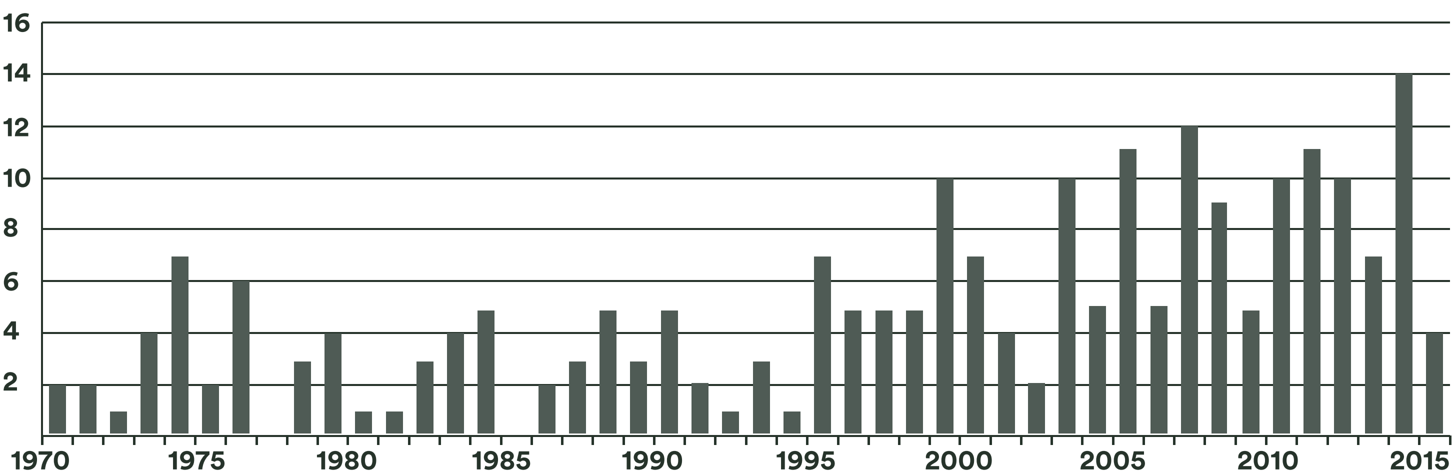
Canadian municipalities have experienced significant increases in the costs associated with property damage and emergency response caused by more frequent extreme weather events (Moudrak and Feltmate, 2017). Public Safety Canada has found that the number of incidences where provinces and territories have required or obtained Disaster Financial Assistance Arrangements (DFAA) significantly increased between 1970 and 2015, well in excess of population growth (Figure 8).

Despite a general trend of increased frequency, anticipating extreme weather events continues to be a challenge. Unlike overall temperature and precipitation trends, windstorms, heavy precipitation, heat waves, forest fires, drought, and ice storms are not accurately represented through climate models, especially on a regional scale (Université Virtuelle Environnement et Développement Durable, 2016). Without an accurate model, the statistics from DFAA and the Insurance Bureau of Canada highlight the need for municipalities to prepare for an increasing trend in more severe weather events. Over six years (2009-2015) the total of DFAA costs associated with extreme weather was greater than the previous 39 fiscal years combined. In those years, flooding accounted for 75% of all expenditures (Moudrak and Feltmate, 2017).

4.2 Post-tropical Storms, Hurricanes and Ice Storms

The City of Saint John is at risk to damages from post-tropical storms and hurricanes which bring strong winds and heavy precipitation. When compounded by higher sea levels these events can lead to power outages, flooding, and isolation which can result in significant economic and public health risks (NBDELG, n.d.). During the winter, ice storms create hazardous conditions for citizens travelling throughout the City. As the winter temperature increases closer to zero degrees Celcius more freezing rain and ice accumulation is anticipated.

Figure 8: Number of natural disasters in Canada requiring DFAA from 1970-2015 (Moudrak and Feltmate, 2017).



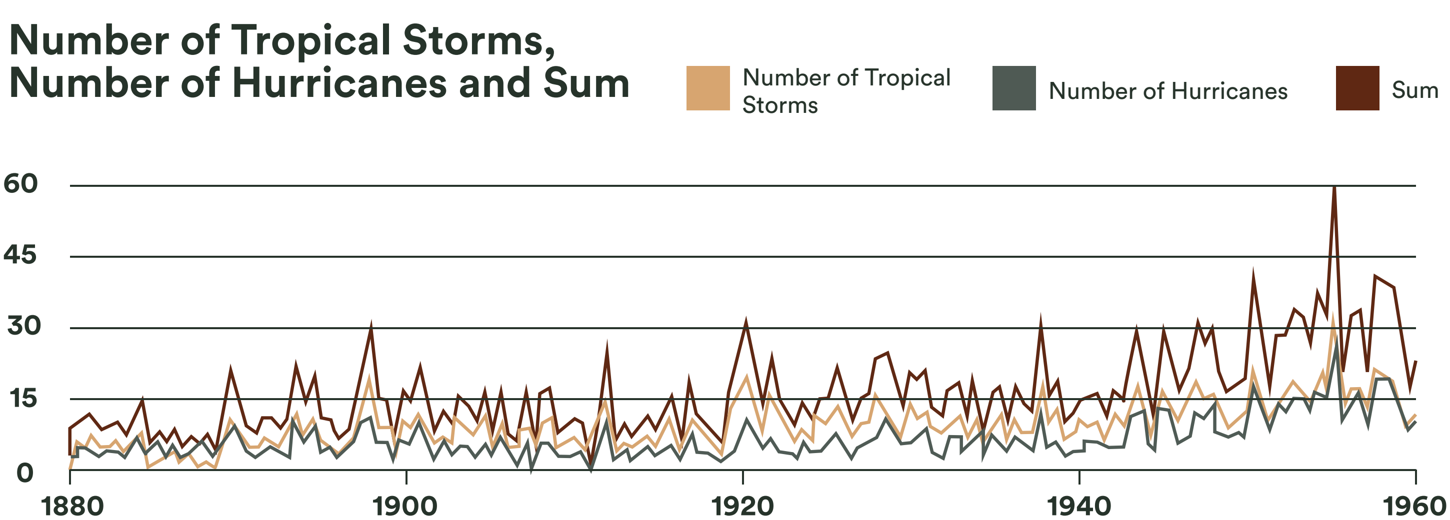


Figure 9: Frequency of tropical storms and hurricanes in the North Atlantic region since 1850 displaying cyclic variations but an overall increase (ACAP Saint John, 2016).

4.2.1 Tropical storms, hurricanes and post-tropical storms

A tropical storm describes a storm system with a low-pressure centre that develops over tropical or subtropical waters in the Atlantic Ocean. If temperature conditions are suitable, a tropical storm can develop into a tropical cyclone, commonly known as a hurricane. A post-tropical describes a storm that maintains strong winds and heavy precipitation but does not qualify as a tropical storm as it no longer exists in tropical regions.

This type of storm system develops when sea surface temperatures are above 25°C (NOAA, 2019). As a result of increases in both annual surface temperatures and sea surface temperatures, more frequent and severe storms are predicted around the world. Trends in the North Atlantic support this prediction showing an increase in the number of tropical storms and hurricanes compared to historical events a(Figure 9). This trend emphasizes the need for adaptation and preparedness in the Greater Saint John area.

4.2.2 Ice Storms

As a result of increased temperature and precipitation, freezing rain, and ice storm events will create new challenges for municipalities. During January of 2017, a multi-day ice storm along the coast of New Brunswick led to road closures, downed trees and powerlines, resulting in power outages for over 300,000 residents. Extended power outages from ice accumulation on power lines and fallen trees are especially dangerous during cold temperatures. Following this event, the Government of New Brunswick developed a series of recommendations to reduce vulnerability during these types of storms (GNB, 2017).
In Saint John, winter temperatures will increase creating ideal conditions for freezing rain events and ice storms. When combined with poor visibility, low temperatures and high winds, the presence of ice can be extremely hazardous for residents (NOAA, n.d.-a). Adaptation strategies to reduce the hazards associated with ice storms include tree trimming around power lines and education around emergency preparedness.

Figure 10: The conditions after an ice storm can be extremely hazardous for pedestrians and motorists (Photo: ACAP Saint John).

4.3 Drought and Wildfires

Climate Change is expected to impact temperature and precipitation extremes in the Greater Saint John area. This means that warmer temperatures may be experienced in combination with periods of heavy precipitation or with periods of minimal precipitation. These changes will have severe impacts such as increased drought stress on crops and shortages of drinking water (NBDELG, n.d.). The City of Saint John is at low risk to these impacts due to the availability of drinking water from surface reservoirs.

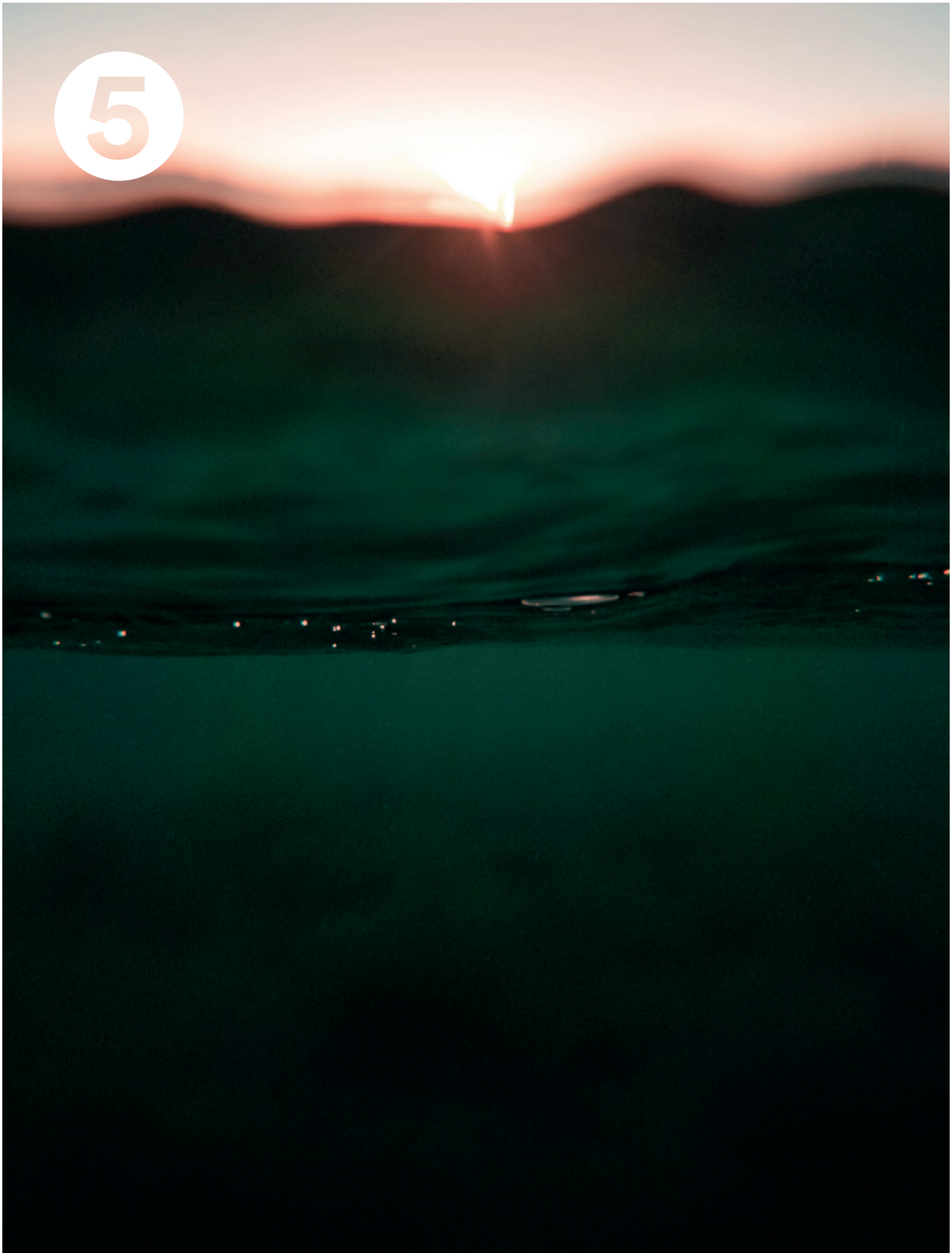
The IPCC defines drought as a period of dry weather that leads to an abnormal balance of water in the system (IPCC, n.d).

Drought conditions create dry and warm forested regions, providing fuel for wildfires to break out. Occurrence of wildfires in Canada's boreal forest is the highest observed in human history, resulting in evacuations and stress on remote communities (WMO, 2019). Recent studies suggest that the number of forest fires in Canada will increase by 25% by 2030 and by 75 to 140% by the end of the century (Wotton, Nock, & Flannigan, 2010). By the year 2040, wildfires in Canada may last an average of 30 days and burn 1.5 times more forest area compared to the late 1990's (Government of Canada, 2018).

Increased fire hazard in New Brunswick will threaten infrastructure and ecosystems and reduce air quality. To adapt, the Government of New Brunswick recommends maintaining air quality tracking and advisory programs, increasing the number of health studies to better understand the risks of forest fire smoke, and to promote appropriate forest fire risk prevention or mitigation behavior on a municipal level (NBDELG, n.d.). In Saint John, similar wildfire adaptation is necessary for properties with large woodlots and park spaces.

4.4 Conclusion

As the frequency and severity of extreme weather events increases, adaptation strategies must be taken to reduce negative impacts on municipalities. Results from the public survey conducted by the Conservation Council of New Brunswick provides several recommendations for municipalities to reduce vulnerability to extreme weather. Some adaptations include: cyclical tree trimming around power lines to reduce potential power outages; backup power options with the capacity to sustain residents for 3 to 7 days; and training for emergency officials to handle mental health impacts that may require additional support (Comeau, 2017). Exploring response and recovery from more recent storm events including post-tropical storm Dorian (September 2019) can help identify where support is required to build resilience to these types of extreme weather.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5. SEA LEVEL RISE (SLR)

Global sea level is predicted to rise by a maximum of 0.98 metres by 2100 (Daigle, 2012; IPCC, 2014). Between 1911 to 2000, sea level increased by approximately 30 centimetres (International Council for Local Environmental Initiatives Canada, n.d.). Research suggests the levels will continue to rise by approximately 86 centimetres (+/- 38 centimetres) by the end of the century (Daigle, 2014). As a result, New Brunswick will face more frequent and permanent coastal flooding.

5.0.1 Why is the sea level rising?

The rising sea level in Saint John can be attributed to a combination of melting polar ice, warming ocean temperatures and vertical crustal movement. The addition of freshwater from melting ice caps has a direct effect on sea level. An increase in ocean temperatures results in the thermal expansion of water, meaning water molecules will take up more space and contribute to rising water levels. Lastly, the geologic setting of Saint John has a large role in understanding sea level rise. During the last ice-age, the weight of glaciers located over Quebec and the St. Lawrence River put pressure on Earth's crust. This resulted in crustal uplift throughout Nova Scotia and southeastern New Brunswick (Koohzare et al., 2007). When the pressure of the ice was removed, the crust began to subside to its original position.

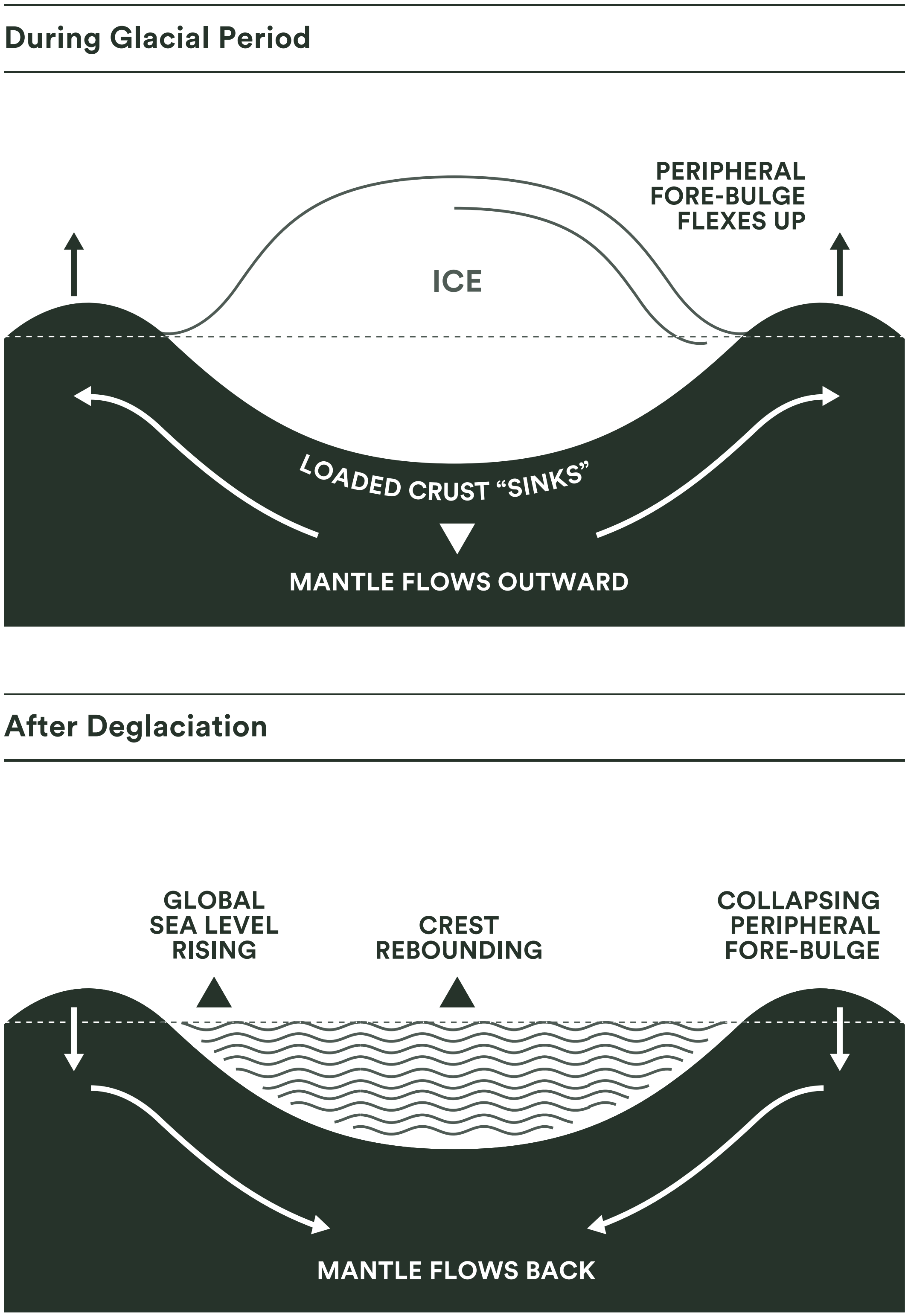


Figure 11: The process of crustal subsidence being experienced in Saint John due to the pressure from glaciers during the most recent ice age (Henton et al, 2006).

Saint John experiences a gradual subsidence of approximately 0.4 millimetres per year (Daigle, 2014) (Figure 11).

5.0.2 SLR Predictions for Saint John

Flooding scenarios up to the year 2100 have been projected for coastal communities in southeast New Brunswick (Daigle, 2017). This research provides values for total sea level over different return periods (Figure 12). Total sea level is the sum of Higher High Water Large Tide (HHWLT), anticipated regional sea level rise, and highest storm surge amplitude. Using different return periods provides a range of severity that can be anticipated depending on the intensity of storm events. The flooding scenarios also include the glacial collapse of the West Antarctic ice sheet, which could result in further sea level rise of approximately 65 cm (Figure 12B; Daigle, 2017). Sea level rise data can be found in Appendix A (Table 3).

Sea level rise has many impacts including coastal erosion, coastal squeeze, changing tidal amplitude, and increased storm surge. Ultimately, these can result in significant flooding events and the permanent loss of land and habitat. The costs of coastal flooding are higher in New Brunswick than any other Atlantic province and five times higher than the Canadian average. The cost of damages to homes in New Brunswick are expected to reach $730 to $1,830 per resident per year by the year 2050 (NBDELG, 2014). To adapt to Climate Change, the City of Saint John must take action to protect coastlines and reduce the hazardous impacts of sea level rise.

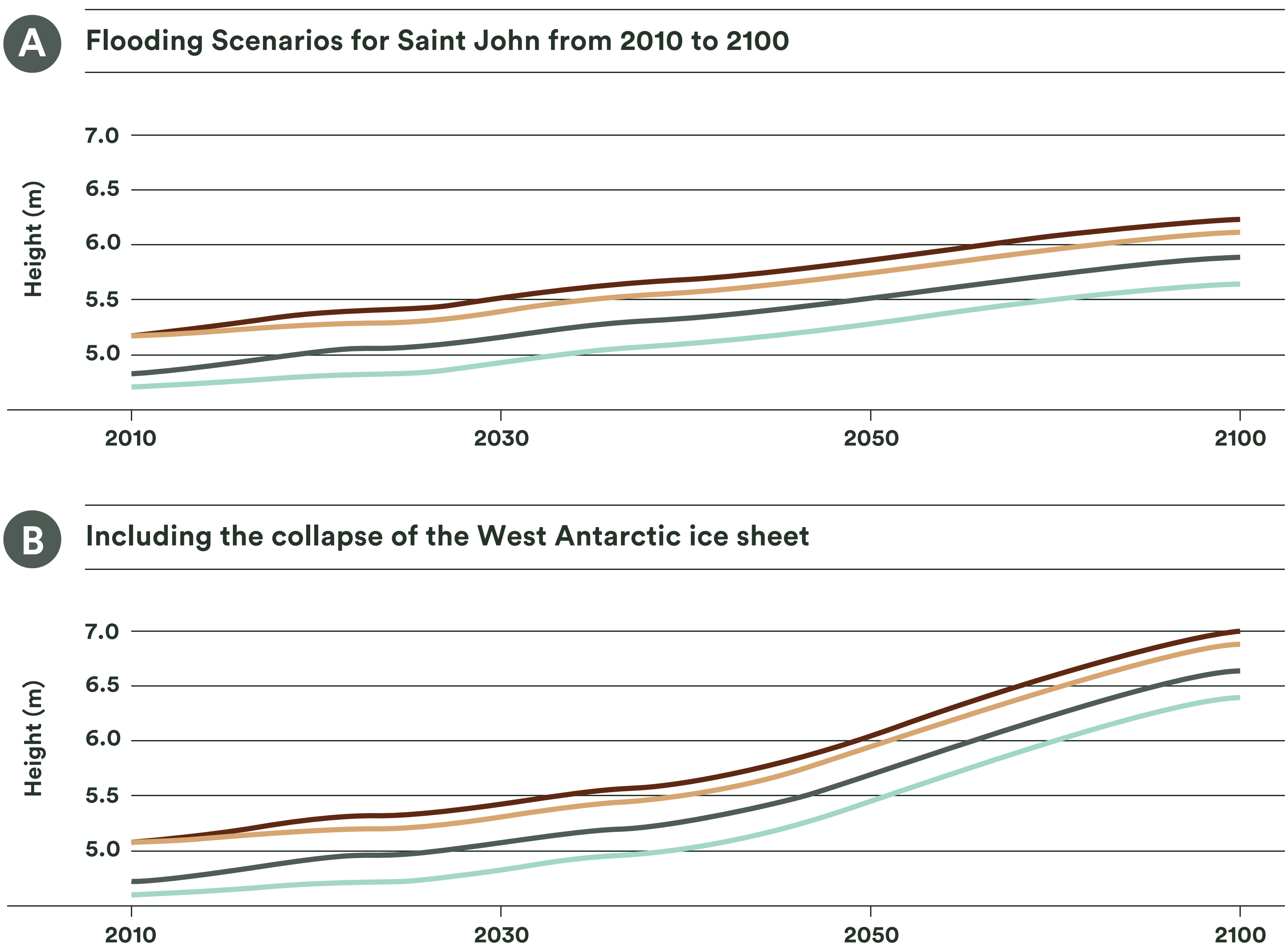


Figure 12: (A) Flooding Scenarios for Saint John from 2010 to 2100, expressed as the total sea level for various return periods. (B) Flooding scenarios include the collapse of the West Antarctic ice sheet which by the year 2100, would cause sea levels to rise substantially more than projections suggest (Daigle, 2017). In both (A) and (B), an increase in sea level is observed.

Return periods express the probability of a flood or storm event. For example, a 1 in 100-year event has a 1% chance of occurring in any given year; a 1 in 5-year event has a 20% chance of occurring; and a 1-year or annual event is likely to occur every year. Return periods are calculated based on current weather patterns and do not include changes in future climate. A 1 in 100-year event could become a 1 in 50-year event as the climate changes.

Figure 13: Shoreline erosion at Sand Cove Road in West Saint John (Photo: ACAP Saint John).

5.1 Coastal Erosion

Sea level rise will not only lead to more severe flooding but will also increase erosion of coastline areas. Coastal erosion can threaten homes, businesses, bridges, roads, and historic sites in coastal zones. Roads and railways built near shorelines are now recognized to be vulnerable to coastal erosion and flooding. Repairs and consolidation of embankments, bridges, abandoning old roads, and relocating routes are expensive adaptation responses (Université Virtuelle Environnement et Développement Durable, 2016). Aside from the high costs of damage, coastal erosion can cut off essential supply chains, limit opportunities in tourism, curb new development, and increase ecological sensitivity of an area. Red Head Road, Sand Cove Road, Bayshore Beach, Sheldon Point Road and Lorneville Cove have already been identified as experiencing coastal erosion in Saint John (Figure 13). New Brunswick coastlines are eroding at 0.59 to 0.88 metres per year due to sea level rise and sensitivity to storm surges (O'Carroll and Bérubé, n.d.). In areas that experience instability, slope movement can be hazardous depending on the amount of material being shifted. Monitoring of areas experiencing high erosion is of significant importance, in order to warn residents about high risk areas that may pose danger to commuters, residents, or recreationists.

In critical areas, the City has the option to protect, accommodate or retreat and accept the loss of land (Figure 14). Each strategy will have different risks and costs specific to the rate of erosion. The expense of accommodation and protection strategies may also deter property owners, leaving retreat as the only option.

Grey infrastructure in Saint John was designed to accommodate a 0.7 metre rise in sea level. However, with sea level rise projected to reach 0.86 metres rise by the year 2100, the City needs to recognize the increased risk of coastal erosion, flooding and infrastructure damage (NBDELG, n.d.). Properties in high risk erosion zones are vulnerable to seawater contamination in drinking wells and permanent loss of land. Ultimately, coastal erosion, exacerbated by sea level rise and increased storm surge, leads to negative impacts on harbours, native species, and nearby homes and businesses (NBDELG, 2014; Lemmen et al., 2016).

Hard protection infrastructure includes dykes, seawalls, rock armouring, or geosystems that consolidate retreating coastal zones. Soft infrastructure can be measures such as heightened conservation efforts or reinstating vegetation (bioengineering) that will buffer shoreline protection for beaches and wetlands (i.e. planting willows, maintaining mangroves, or beach renourishment).

Flood Mitigation Strategies For Sea Level Rise

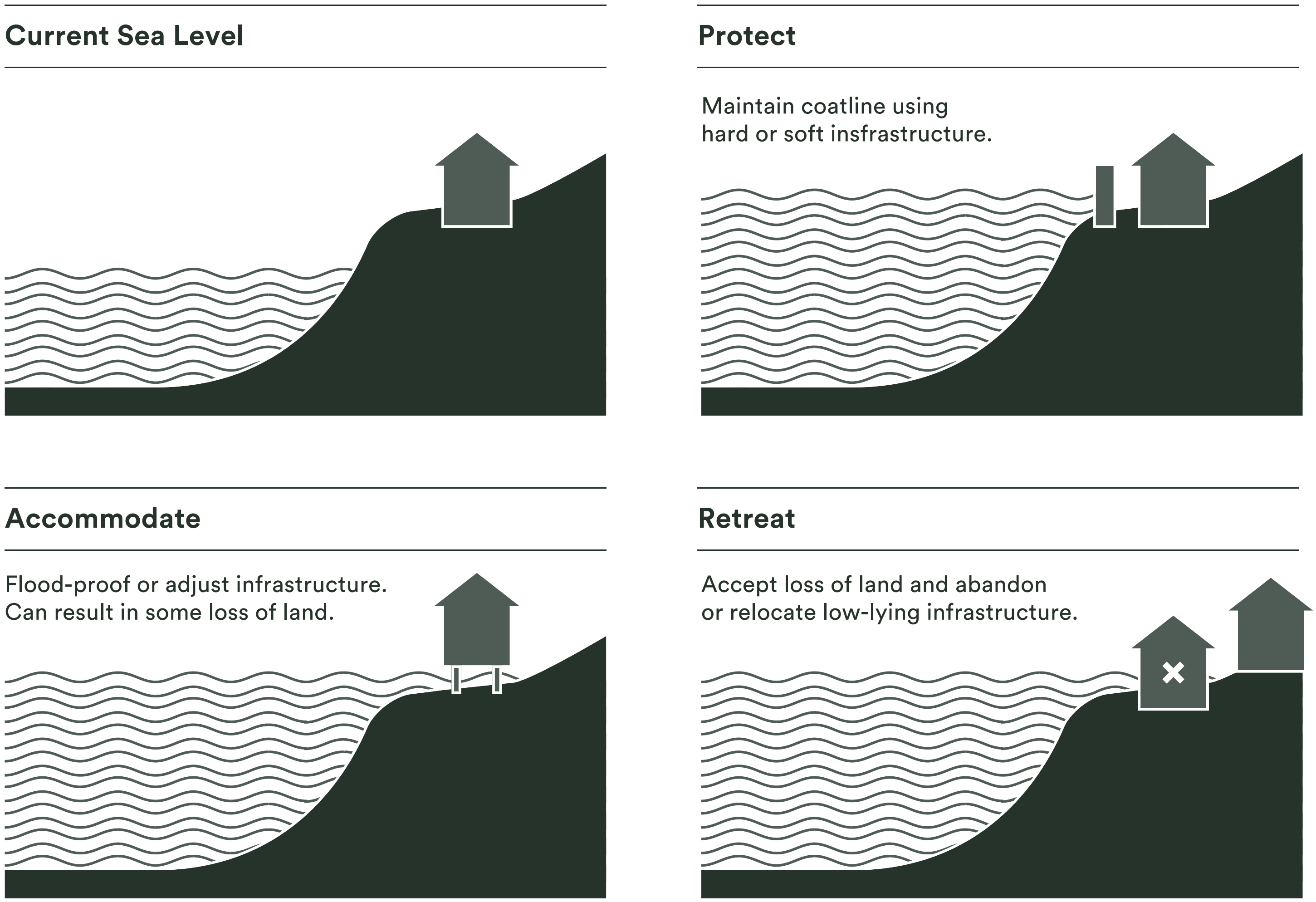


Figure 14: Flood mitigation strategies for sea level rise (Lemmen et al., 2016).

5.2 Coastal Squeeze

Coastal squeeze is a term that describes the inland movement of coastal wetlands as sea level rises. As environmental factors, such as wind or waves, alter the landscape, coastal habitat will naturally reestablish further inland as an extension of the existing habitat. The progression of coastal squeeze depends on the presence of hard infrastructure or natural barriers can prevent salt marshes, mudflats, and sand dunes from migrating inward (Pontee, 2013). Figure 15 shows three coastal squeeze situations including (a) where there is no obstruction, (b) where a barrier to migration is in place, and (c) where a natural obstruction to landward migration exists.

Available conservation techniques to protect ecosystems include coastal restoration and development of migration corridors (Borchert et al., 2018). These corridors control the migration of displaced species, reducing the risk of wildlife in urban spaces. Educating homeowners and developers about coastal squeeze can help prevent habitat loss by transitioning commercial and residential lawns into natural coastal plantings (Powell, 2018). By monitoring species movements and coastal erosion, the negative impacts of coastal squeeze can be reduced.

Sea level rise describes the average increase in water due to melting glaciers, increasing water temperature and geologic setting. Storm surge is a temporary rise in water occurring during specific weather conditions. Problematic situations arise when these two are combined.

5.3 Storm Surge

Storm surge describes the temporary rise of water levels instigated by severe weather conditions. Often, a strong onshore wind combined with a low atmospheric pressure system will intensify wave amplitudes resulting in shoreline flooding (Natural Resources Canada, 2007). Storm surge events pose a significant financial risk to the City due to flood damage, road closures, loss of property, habitat loss, landslides, and debris flow.

There are several well documented storm surges that have caused severe damage to communities around the Bay of Fundy, such as the Saxby Gale of 1869 and the Groundhog Day Storm of 1976 where tides rose up to 2.5 metres above predicted levels (Desplanque and Mossman, 1999). When high water is experienced in combination with heavier annual precipitation the likelihood of a 1 in 100-year flooding event from storm surge increases (Public Health Agency of Canada, 2018).

Conservation of coastal habitats is a Climate Change adaptation strategy that can provide flood water storage, storm surge buffering and coastal erosion control. Research indicates that storm surge amplitude can be reduced by approximately one foot for every 1.6 kilometres of vegetated wetland that exists between a coast and urban development (NOAA, n.d.-b). In situations where natural conservation will not accommodate projected storm surge levels, the City can use hard infrastructure (i.e. dykes and sea walls) to prepare for the coastal impacts.

5.4 Conclusion

Adaptations to protect urban areas or relocate infrastructure due to sea level rise are often expensive and involve collaboration between multiple stakeholders. The challenges created by coastal erosion, coastal squeeze, and storm surge are site specific and require long term monitoring. As the water levels rise, the City will have to evaluate and prioritize the options for maintaining the coastline and relocating at-risk infrastructure.

Predicting storm surge levels can be difficult, but there are tools available for early warning. For instance, the Smart Atlantic Saint John Inshore Weather buoy has collected meteorological and oceanographic data since 2015. The buoy enhances public safety and operational efficiency of harbour activity by providing online access to real-time weather and directional wave data.

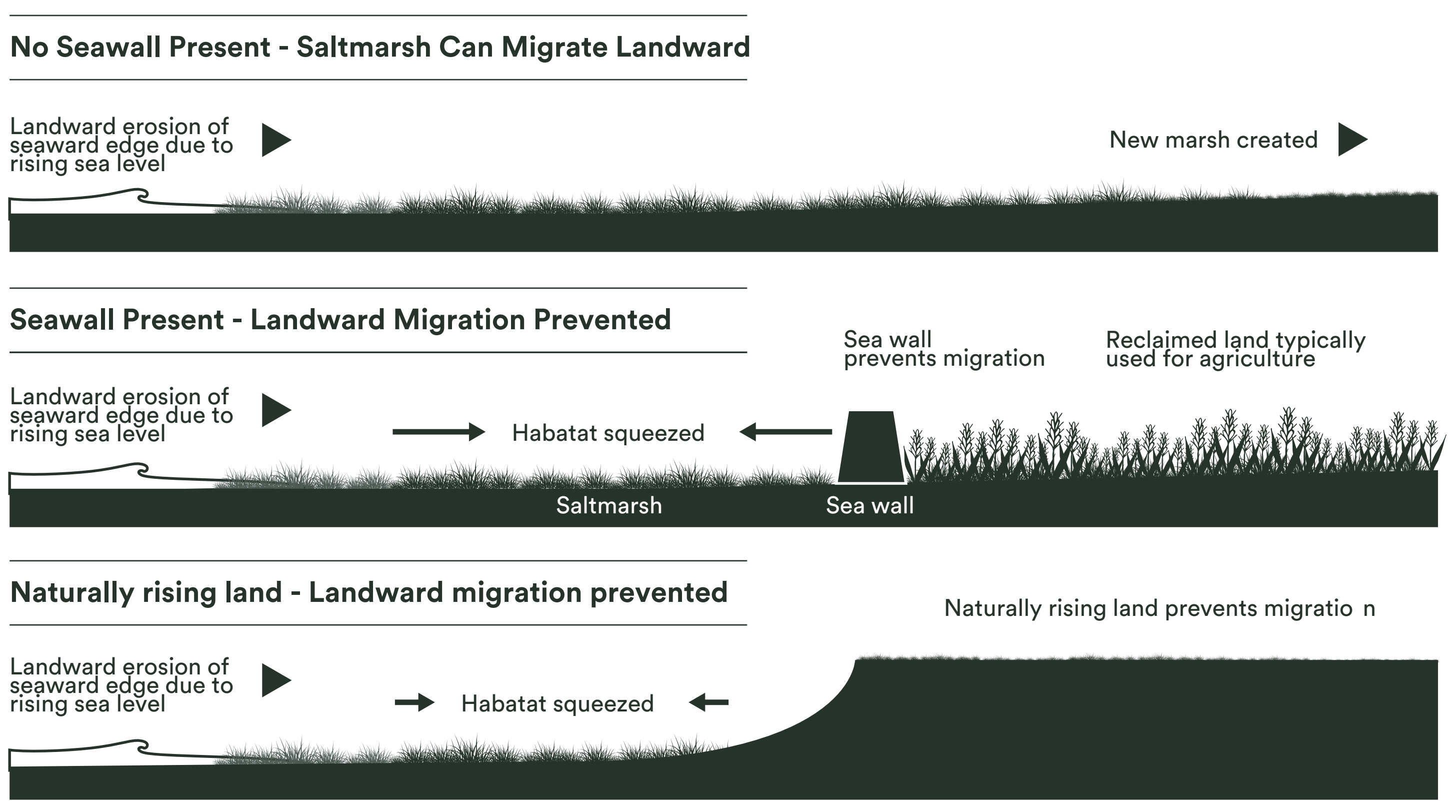
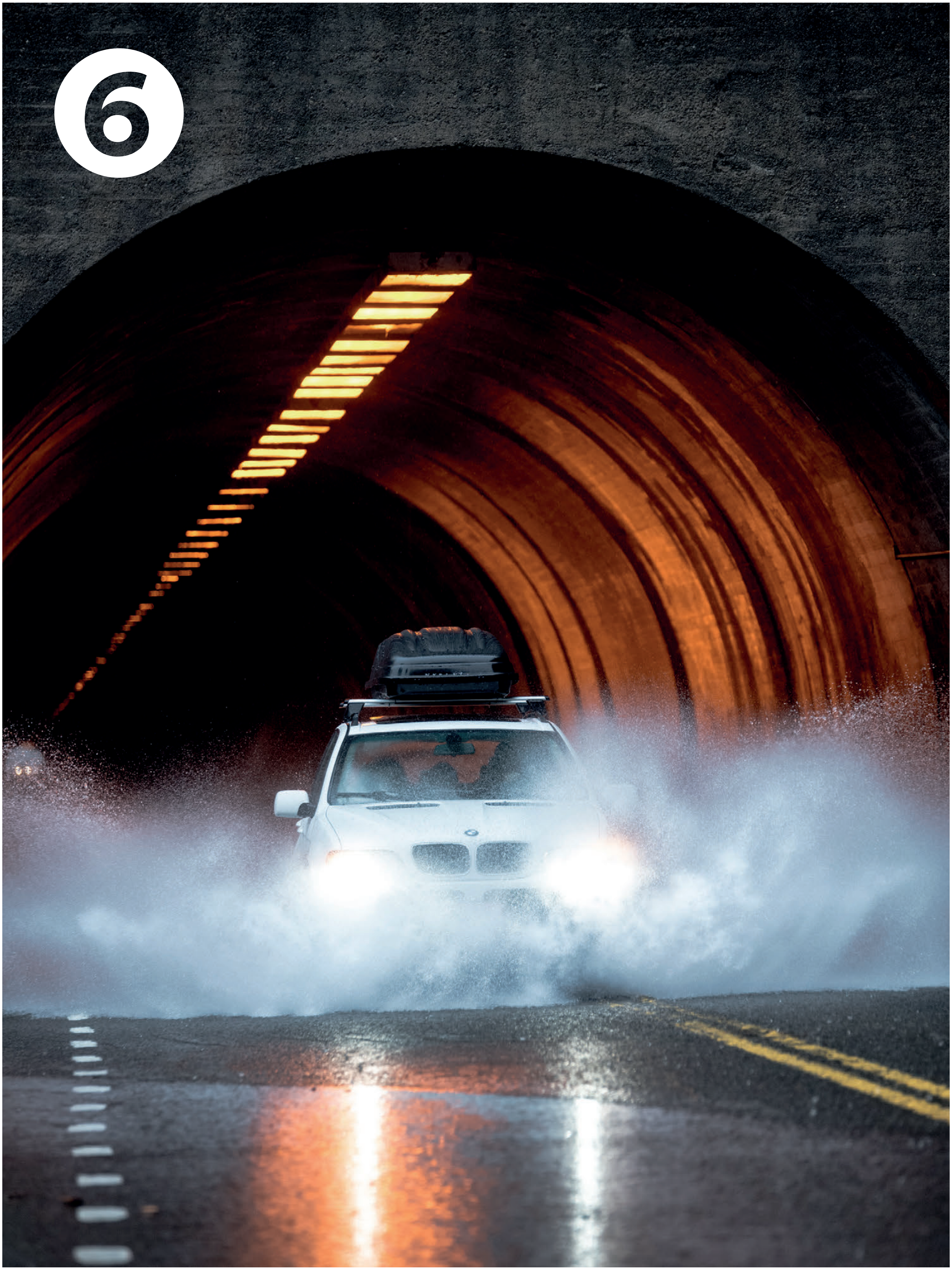


Figure 15: Habitat migration scenarios under sea level rise: (a) No seawall is present and new marsh land is created, (b) A seawall prevents migration and habitat is lost, (c) Naturally rising land prevents migration and habitat is lost (Savard et al, 2016).


6

6. FLOODING

Flooding is the most frequent natural disaster in Atlantic Canada. Between 2007 and 2017 the Government of New Brunswick spent $185 million on disaster recovery primarily from flooding events. The Flood Risk Reduction Strategy for New Brunswick aims to build resilience through accurate hazard identification, old infrastructure retrofits, new infrastructure regulations, and informed mitigation practices (GNB, 2014b). In Saint John, there are two types of flooding that can be expected: inland flooding from heavy precipitation and high river flows; and coastal flooding due to sea level rise or storm surge. This chapter will discuss inland flooding in Saint John.

6.1 Damage to Urban Built Environment

As discussed in Chapter 3, Climate Change is expected to increase precipitation resulting in more frequent and severe flooding in Saint John. Adaptive approaches to planning, development and infrastructure management can reduce the damage associated with flood events.

6.1.1 Grey Infrastructure

The term grey infrastructure is used to describe infrastructure that has low infiltration capacity and easily becomes flooded during periods of high runoff (Depietri and McPhearson, 2017). Municipal infrastructure is mostly impermeable, meaning water does not naturally soak back into the surface. This makes urban environments especially vulnerable to flooding and puts pressure on stormwater systems to transport the water elsewhere. In Saint John, facilities vulnerable to flooding include residential and commercial buildings, sewage treatment, water services, power generation, industrial activity, communications, and healthcare services.

The City of Saint John can plan to reduce flooding risks by adjusting building standards to account for 1 in 100-year storm water levels. The Intact Center on Climate Adaptation provides recommendations for municipalities and homeowners to reduce flooding in urban spaces. A few of their suggestions include: designing roads to be at least 30 cm below the lowest building openings, ensuring backup power is available for wastewater pumping stations, building driveways to slope away from homes and garages, installing backwater valves in basements, and having heating, ventilation, and air conditioning (HVAC) systems installed above grade to avoid destruction or damage to property (Moudrak and Feltmate, 2017).

Figure 16: Road closure during the 2019 spring freshet flooding of the St. John River (Photo: ACAP Saint John).

Figure 17: Grey infrastructure in Saint John includes roads, bridges, railways, buildings, stormwater drainage, and sewers. These images depict the low infiltration capacity in urban areas (Photo: ACAP Saint John).

6.1.2 Green Infrastructure

Green infrastructure, also known as Low Impact Development (LID), refers to stormwater management methods that promote infiltration and retention rather than methods that focus on directing surface runoff into water treatment facilities, storage ponds, or natural systems (Buckland-Nicks, 2016). Studies have shown that green infrastructure significantly mitigates flooding risk in urban spaces (Depietri and McPhearson, 2017). In watersheds with greater than 25% impermeable surfaces, the likelihood of a 1 in 100-year flood is increased to a likelihood of 1 in 5 (Trice, 2017).

For municipalities, green infrastructure and natural asset restoration can be more cost effective to maintain then engineered structures (Depietri and McPhearson, 2017). Besides the cost, the co-benefits of natural assets include a range of ecosystem services that provide flood and erosion control, heat moderation, pollination, carbon dioxide storage, and enhancement of community well-being.

Figure 18: In 2019, ACAP Saint John installed a rain garden on Queen Square West as a pilot project for the City. Green infrastructure can include implementing rainfall capture systems, permeable pavement, green roofs, bioswales, and rain gardens (Photo: ACAP Saint John).

6.1.3 Hybrid Approach

The value of grey and green climate adaptation solutions has been assessed by researchers Depietri and McPhearson (2007), who highlight the dependence of cities on natural ecosystems for urban disaster risk reduction. The findings suggest a hybrid approach (green infrastructure integrated with grey infrastructure) to be the most effective at reducing risk in complex urban systems. An example of this hybrid approach is a wetland restoration coupled with engineering measures (i.e. a small levee, bioswales, rain gardens, green roofs, or street trees) to enhance flood protection while taking advantage of low impact development (Table 1).

Grey	Hybrid or mixed approaches	Green and Blue
Hard, engineering structures	Blend of biological-physical and engineering structures	Biophysical, Ecosystems and their services
Very limited role of ecosystem functions	Allows for some ecosystem functions mediated by technological solutions	Mainly relying on existing or restored ecosystem fuctions and water bodies
e.g. canals, pipes and tunnels of the drainage system; dikes; wastewater treatment plants; water filtration plants	e.g. biowales; porous pavement; green roofs; rain gardens; constructed wetlands; Sustainable Urban Drainage Systems (SUDS)	e.g. wetlands restoration; installation of grass and riparian buffers; urban trees; stream restoration; rivers, lakes, ponds, oceans and seas

Table 1: Grey, hybrid, or green and blue infrastructure adaptation options (Depietri and McPhearson, 2017).

6.2 Planning for Flooding

Flood risk mapping technologies can be used to estimate the extent of potential flooding under different scenarios. These resources are extremely useful for emergency preparedness and adaptation planning. The Climate Change Adaptation Plan for Saint John by ACAP Saint John will use flood risk mapping to identify roadways, residential and commercial lots, industrial sites, and other areas at risk for flooding. These maps can be used by the City to limit development in at-risk areas.

Aside from development restrictions in flood-prone areas, early warning systems play an increasingly important role in flood risk preparedness. The New Brunswick Emergency Measures Organization (NB EMO) has developed a River Watch program to alert residents to potential flooding events and provide a flood forecasting system to predict high water levels on the Wəlastəkw (St. John River) up to two days in advance.

6.3 Conclusion

In the coming century, Saint John will experience higher river flows and heavier precipitation creating flooding challenges that we are not currently prepared for. Flood risk mapping will play a significant role in restricting development and building awareness for homeowners living in floodplains. Adaptation is required to reduce the negative impacts that can result including property damage or contamination from combined sewer overflows. Green or hybrid infrastructure approaches are recommended as proactive adaptation practices.


7

7. URBAN WATER QUALITY AND SECURITY

The quality and availability of drinking water is of primary concern for municipalities who rely on local aquifers and surface ponds to sustain residential needs. In Saint John, drinking water is sourced privately from wells or through Saint John Water, which is sourced from surface reservoirs in Spruce Lake and Loch Lomond.

According to the United Nations, water security is the capacity of a population to ensure sustainable access, availability and quality of water necessary to "sustaining livelihoods, human well-being, and socio-economic development, for ensuring protection against water-borne pollution and water-related disasters, and for preserving ecosystems" (United Nations Water, 2013).

7.1 Saltwater Intrusion

Saltwater intrusion occurs when seawater enters into the coastal groundwater system and is a recognized hazard to coastal communities around the world (Giudice & Broster, 2006). This has a direct effect on human health and industrial sectors (including agriculture, forestry, and fisheries) resulting in increased demand on freshwater resources. In Saint John, surface reservoirs for drinking water are monitored for saltwater intrusion.

Various strategies can be employed by local governments in areas impacted by saltwater intrusion. Desalination plants are facilities where salt and minerals are removed from saline water. City planners may favour relocation and changes to zoning laws over desalination because of its costliness which is estimated to $0.25 to $0.50 per resident per day in Canada (Université Virtuelle Environnement et Développement Durable, 2016). Saltwater intrusion is a growing concern in Saint John, specifically the West Side drinking water supply. By observing invasive species, groundwater quality, and changes in coastal habitats and species, City officials could be alerted about changes in the saltwater-freshwater interface before the most severe impacts are felt.

7.2 Water Quality and Availability

Other than saltwater intrusion, changing climate conditions pose significant risk to urban water quality and availability. Changes in precipitation patterns can diminish freshwater supplies (Government of New Brunswick, n.d.). Warmer annual temperatures and lower summer river levels can alter water quality, creating more favourable conditions for bacterial growth and harmful algal blooms (HABs). As well, increased stormwater runoff can introduce pollutants, viruses, and sewage backup into drinking water reservoirs (Fann et al., 2016).

In Saint John, flooding of stormwater systems can cause combined sanitary and stormwater systems to backup and contaminate waterways. After a heavy rainfall, faecal coliform levels are commonly observed above recommended guidelines (ACAP Saint John, 2017). Increased effort to separate combined sewer infrastructure and monitoring of waterways are actions required to improve water quality in Saint John. Processing water through a treatment facility can reduce hazards in municipal drinking water sources. However, when detected, toxins can be costly to remove (United States Environmental Protection Agency, 2018). Routine monitoring is undertaken by Saint John Water to reduce health hazards that can result from exposure or consumption.

7.2.1 Cyanobacteria

Cyanobacteria, sometimes referred to as blue-green algae, has been observed in New Brunswick waterways, and can release cyanotoxins which are toxic to both humans and animals. Exposure can result in itchy eyes and skin, rashes, blisters, nausea, fever, vomiting, gastrointestinal issues, headaches, and/or dizziness (NBDELG, 2018b). If drinking water reservoirs are contaminated by cyanobacteria, the water is unsafe for consumption until the bloom has subsided. Using water contaminated with cyanobacteria to bathe, wash clothes, or clean is not recommended. In addition, fish from contaminated waters should not be consumed. Monitoring and education around cyanobacteria is necessary to ensure the safety of residents in Saint John.

7.3 Ocean Warming and Acidification

Similar to the atmosphere, Earth's oceans absorb CO_2 from the atmosphere. As a result of increased GHG emissions, excess CO_2 dissolves in oceans where it breaks down to carbonic acid, carbonates and bicarbonate. Higher CO_2 quantities have caused ocean acidity to rise by 30% since the beginning of the industrial revolution (Université Virtuelle Environnement et

Développement Durable, 2016). Warmer, and more acidic waters significantly affect already fragile ecosystems and intertidal zones.

Ocean warming and acidification is a severe threat for ecosystems along the Bay of Fundy including sponges, anemones, sea squirts, crustaceans, and mollusks. These species have a significant role in the economic and recreational prosperity of coastal communities in New Brunswick (Université Virtuelle Environnement et Développement Durable, 2016). Important species like haddock, winter flounder, lobster and herring fisheries will be threatened by changes in the coastal ecosystem (CPAWS, n.d.).

7.4 Tourism and Fisheries

As a coastal city, Saint John has a long history of tourism and fishing industries. Climate Change has indirect impacts on these sectors and how they are managed.

7.4.1 Sustainable Tourism in Saint John

Coastal tourism in the Greater Saint John Area is dependent on the maintenance of natural landscapes that are vulnerable to Climate Change. Many ecologically sensitive tourist attractions in the area such as wetlands and beaches will require protection from coastal erosion. More extreme weather can dissuade tourists and cruise ships from visiting attractions in the Bay of Fundy. The United Nations Environment Programme and the World Tourism Organization (2005) have presented a range of measures to adapt coastal tourism to changing climate conditions including soft protection of coastlines to fight erosion and drainage management to reduce the risk of flooding. Adaptations intended to enhance and protect natural tourism attractions will also increase climate resiliency along the coastline. The tourism sector in Saint John has a unique opportunity to share the natural beauty of New Brunswick while also demonstrating the need for Climate Change adaptation.

Figure 19: A large cruise ship bringing in thousands of tourists is seen docked at the Marco Polo Terminal in Saint John's Central Peninsula (Photo: ACAP Saint John).

7.4.2 Fisheries

Fishing is an important economic and recreational activity in Saint John. The City promotes fishing as a recreational activity and tourist attraction, offering licenses for stocked lakes like those in Rockwood Park. As the climate changes, habitat for numerous fish species are threatened which has significant impacts on both commercial and recreational fisheries. For example, fisherpeople will need to adjust to the disappearance of some species and the emergence of others (Université Virtuelle Environnement et Développement Durable, 2016).

7.5 Conclusion

The major threats to the drinking water supply in Greater Saint John include saltwater intrusion, and the growth of bacteria or HABs as a result of increasing temperatures and precipitation. These changes, as well as ocean acidification, will have a large impact on ecosystem function. Monitoring water quality and species populations is important as it helps to address hazards associated with urban water quality. Alteration of water resources in Saint John will significantly alter the tourism and fishing sectors. Sustainable and restorative practices and monitoring programs are strategies that can be taken to reduce negative impacts associated with changing water quality and availability.

Figure 20: While aquaculture plays a significant role in reducing the overharvesting of wild stocks, the industry has significant impacts to the natural environment and is vulnerable to climate changes. Species under stress from aquaculture practices have an increased sensitivity to changes in environmental conditions. (Photo: ACAP Saint John).

8

NEXT STEPS

This report will serve to inform residents, businesses, and policy makers in the City of Saint John of the social, economic and environmental impacts of Climate Change. To follow this report, a Climate Change Adaptation Plan for Saint John will be completed that will measure the impacts of Climate Change in Saint John through a risk and vulnerability assessment, and adaptation practices will be recommended. This report, along with the Adaptation Plan will work synergistically to provide the City of Saint John with the tools to prepare for the impacts of Climate Change.

ACAP SAINT JOHN

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APPENDIX A: CLIMATE DATA

Table 1: Temperature projections for the Greater Saint John Area up to the year 2100 by the Atlantic Climate Adaptation Solutions Association (ACASA) New Brunswick Climate Futures Projections (Roy and Huard, 2016).

Temperature Projections for the Greater Saint John Area

	1971 - 2000	2011 - 2040	2041 - 2070	2071 - 2100
Summer Temperature (°C)	16	17	18.4	19.4
Winter Temperature (°C)	-5.4	-3.9	-2.8	-1
Annual Temperature (°C)	5.7	6.8	8.7	9.1
Annual Number of Freeze-Thaw Days[1]	83	91	87	78
Annual Hot Days (T>25°C)	9.5	12	54.5	70

Table 2: Precipitation projections up to the year 2100 by the Atlantic Climate Adaptation Solutions Association (ACASA) New Brunswick Climate Futures Projections (Roy and Huard, 2016).

Precipitation Projections for the Greater Saint John Area

	1971 - 2000	2011 - 2040	2041 - 2070	2071 - 2100
Precipitation (mm)	1274	1308	1308	1359
Annual Total Rain Days[2]	127	137	144	148
Annual Total Snow Days[3]	32.5	36	45	30

[1] Annual Freeze-thaw days is the average number of days per year when the daily maximum temperature equals or exceeds 0 degrees Celsius AND the daily minimum temperature is less than 0 degrees Celsius.
[2] Annual Total Rain Days is the average number of days per year with at least 0.2 mm of rainfall.
[3] Annual Total Snow Days is the average number of days per year with at least 0.2 cm of snowfall.

Table 3: Flooding Scenarios for Saint John, New Brunswick from 2010 to 2100. Scenarios are expressed as the total sea level (sum of HHWLT, regional sea level rise and storm surge; Daigle, 2017).

Zone 12: Saint John County - County Line to Cape Spencer, HHWLT 4.4 m ± 0.2 (CGVD28)[4]

Return Period	Level 2010	Level 2030	Level 2050	Level 2100	Level 2100 + 65m
1-Year	4.9 ± 0.2	5.0 ± 0.3	5.2 ± 0.3	5.7 ± 0.6	6.4 ± 0.6
5-Year	5.0 ± 0.2	5.2 ± 0.3	5.4 ± 0.3	5.9 ± 0.6	6.6 ± 0.6
50-Year	5.3 ± 0.2	5.4 ± 0.3	5.6 ± 0.3	6.1 ± 0.6	6.8 ± 0.6
100-Year	5.3 ± 0.2	5.5 ± 0.3	5.7 ± 0.3	6.2 ± 0.6	6.9 ± 0.6

[4] Range of uncertainty represents the difference between the selected HHWLT value for Zone and the range of HHWLT values for Zone.

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