Risk Assessments in Newfoundland and Labrador Resource-Based Industries and Municipalities

NL Environment, Climate Change, and Municipalities

Final Report

Natural Resources Canada / Ressources naturelles Canada

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March 31, 2021

Joshua Barrett
Manager of Planning and Accountability
Department of Environment, Climate Change, and Municipalities
West Block, 4th Floor
Confederation Building
St. John's, NL, A1B 4J6

Dear Mr. Barrett:

RE: Climate Change Risk Assessment for Newfoundland and Labrador Resource Based Industries and Municipalities – Final Report

In this report, recommendations for building climate resilience of Newfoundland and Labrador's Municipalities and Resource-Based Industries are presented. A summary of the methodology and key findings associated with each step of the climate change risk and vulnerability assessment, including literature review, climate change analysis, and stakeholder engagement is summarized herein. Recommendations for further advancing adaptation are based on key impacts and opportunities identified through the climate change risk and vulnerability assessment.

Should you have any questions please feel free to contact the undersigned.

Yours very truly,

CBCL Limited

Prepared by:
Lindsay Allen, P.Eng.
Environmental Engineer
Direct: 709-364-8623
E-Mail: lallen@cbcl.ca

Reviewed by:
Lindsay Bolton, P.Eng.
Group Lead, Water Resources and Climate Change

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Executive Summary

Canada's climate will continue to warm, driven by global greenhouse gas emissions from human activity. This poses risks to all sectors of the economy and Canadian's quality of life. Action on climate change mitigation and adaptation is critically required to limit impacts on people, economy and natural ecosystems.

The Government of Newfoundland and Labrador (GovNL) has recognized that in order for industry and municipalities to remain resilient to the impacts of climate change over time, potential vulnerabilities and impacts must be recognized to support proactive adaptation planning. To achieve this, CBCL Limited was contracted by GovNL to conduct a cross-cutting risk assessment focused on identifying climate change related vulnerabilities, impacts, and potential opportunities to the provinces' municipalities and natural-resource based industries. The industries involved in the study include provincial forestry, fisheries, aquaculture, and agriculture sectors.

Climate change projections, literature soruces, and stakeholder feedback were used to identify key risks to each of the sectors. Stakeholders involved in the consultation process include representatives from municipalities (rural and urban), indigenous Governments and communities, private industry, environmental groups and Non-Governmental Organizations, relevant provincial and federal government departments, academia, electrical utilities, and local unions, among others.

The risk assessment process revealed the following cross cutting risks that are likely to impact more than one, if not all, of the target sectors:

- Increased damage to infrastructure and utilities (particularly coastal)
- Disruption to transportation networks, including roads and ferry services, which are relied upon for import and export of product as well as access to basic amenities
- Increasing emergency response requirements, exposure to extreme weather, and pests
- Shortfalls in longer-term financial planning for climate change resilience

Top priority impacts and opportunities related to each sector were identified as follows:

Municipalities

Impacts

- Lack of capacity and/or available resources to incorporate climate change to asset management plans, "build back better" design initiatives, and land use planning
- Data and guidance requirements for design of new infrastructure
- Vulnerabilities of coastal infrastructure, including ferries, roads, and sewer infrastructure
- Need for floodline mapping to inform risk

- Increasing vulnerability of coastal assets, sewer and stormwater management systems, and source water

Opportunities

- Potential new rural economic growth
- Reduced requirements for snow maintenance

Fisheries

Impacts

- Changing ocean conditions leading to increased stress on aquatic marine species
- Exposure to invasive species
- Ability of harvesters to adapt to shifting species
- Integrity of coastal infrastructure
- Insufficient access to climate monitoring data

Opportunities:

- Industry expansion in North
- Developments in research and innovation

Aquaculture (Finfish and Shellfish Farming)

Impacts

- Lack of climate monitoring systems
- Increased infrastructure damage
- Reduced water quality from increased runoff
- Increased environmental stress (e.g. susceptibility to disease)
- Potential decreasing water quality, formation of algae blooms, and decreased food availability, and the overall impact on species health

Opportunities:

- Proactive adaptation based on lessons learned from other jurisdictions
- Creating room for research and innovation

Forestry

Impacts

- Potential increased susceptibility to forest fires, freeze-thaw damage, blow downs/ windthrow, precipitation damage, invasive species, and drought
- Forest migration
- Increased disturbance and susceptibility to pests and disease
- Limited climate data resolution and high uncertainty
- Increasing requirement to update forest management plans

Opportunities:

- Creating room for research and innovation and development of the "green economy"
- Potential improved growing conditions and longer growing season
- Product and market diversification

Agriculture

Impacts

- Increased stress from drought, high temperatures, excess precipitation, and potential introduction of invasive species and pests
- Supply chain disruption
- Need for more robust stormwater management and irrigation systems to deal with high precipitation periods in shoulder seasons and drought in summer
- Potential increased frequency of winter kill events and increased wind damage
- Institutional barriers limiting holistic farm management and training

Opportunities:

- Room for improvements to food security
- Potential increased plant productivity
- Product and market diversification/expansion

Adaptation recommendations developed for top priority risks and opportunities include:

Cross Cutting

1.1 Conduct a transportation and food security risk assessment
1.2 Conduct a province-wide critical coastal infrastructure assessment
1.3 Develop a Climate Change Adaptation Plan for natural resources management
1.4 Assessing the Impacts of Climate Change on Wildlife
1.5 Incorporating Forest Fire Risk into Municipal Climate Change Adaptation Plans

Municipalities

2.1 Create a province-wide adaptation planning guidance document
2.2 Leverage a regional approach to adaptation planning
2.3 Applying a “Climate Lens” to all funded projects
2.4 Develop province-wide coastal flood risk mapping
2.5 Implement “No Net Increase in Runoff” policies
2.6 Develop a provincial stormwater design, construction, and operation guideline
2.7 Implement Build Back Better guidelines
2.8 Promote investing in adaptation
2.9 Create a centralized data portal for deploying climate related resources

Fisheries and Aquaculture

3.1 Implement a proactive approach for climate resilient infrastructure planning
3.2 Advance ocean and climate monitoring data collection programs
3.3 Improve communication of complex science topics to industry stakeholders
3.4 Establish a climate change working group to strengthen communication
3.5 Advance workforce development strategies

Forestry
4.1 Apply a Climate Lens to Forestry Management Plans
4.2 Enhanced sector collaboration on climate change adaptation
4.3 Explore opportunities for industry expansion into Labrador
4.4 Consider wildlife risks to forestry sector in feasibility of adaptation solutions

Agriculture
5.1 Conduct regional Climate Change Risk Assessments and Impact Analysis
5.2 Apply a climate lens to farm planning
5.3 Investigate and implement sustainable water management practices
5.4 Conduct a water resources study to identify solutions for drought risk
5.5 Create a business case for adaptation
5.6 Explore opportunities in Labrador
5.7 Implement pilot programs for new design alternatives against wind and snow loading

It is recommended that each adaptation measure is considered as part of the overall provincial climate change adaptation strategy.

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Chapter 1 Introduction

Newfoundland and Labrador has an abundance of natural resources that have been used for centuries to drive the provincial economy forward. Fisheries, Forestry, and Agriculture are three primary industries that provide thousands of local jobs, important provincial exports, and billions of dollars in annual revenue for the province (GovNL, 2017). **Climate change** has and will continue to impact the ecosystems and infrastructure on which natural resource-based industries rely.

Along with these natural resource-based industries, municipalities must also be prepared to adapt to the impacts of climate change. Municipalities must work to ensure that infrastructure, operations, and policy are properly updated and managed to support resiliency and long-term sustainability. For this project, municipal infrastructure refers to municipally owned and operated physical infrastructure, utility owned electricity infrastructure within the municipal boundary, and municipally owned building infrastructure.

The Government of Newfoundland and Labrador (GovNL) has recognized that in order for these industries and municipalities to remain resilient to the impacts of climate change, potential risks, vulnerabilities, and impacts must be recognized, and adaptation measures put into place in order to mitigate risks.

1.1 Project Objectives

The overall goal of the project is to use available climate change projections, and other relevant resources, to complete a cross-cutting risk assessment for the provincial agriculture, fisheries, and forestry industries, as well as municipal government sectors. This work involves using best practices and risk assessment guidelines, such as the new Canadian Council of Ministers of the Environment (CCME) **Guidance Document on Good Practices in Climate Risk Assessment** to complete a scenario planning exercise for the province, taking into account projected climate change impacts at both mid- and late-century.

The project objectives are as follows:

- Review provincial climate change projections to identify risks and vulnerabilities to target industries and municipalities.
- Review available risk assessment frameworks to develop a preferred methodology for this climate change risk assessment.
- Conduct a cross-cutting risk and vulnerability assessment for the provincial agriculture, fisheries and aquaculture, forestry, and municipal government sectors.
- Engage relevant stakeholders for the purpose of knowledge sharing, capacity building, and incorporating local experience and expertise into the risk assessment focus areas.
- Identify adaptation strategies for mitigating top priority risks.
- Support adaptation strategies with examples of work in other jurisdictions with similar socio-economic characteristics and risk profiles.
- Develop a comprehensive report outlining recommendations for enhancing provincial adaptation for key focus areas.

1.2 Scope and Methodology

The focus of this study is on slow-onset risks associated with gradually changing **climate variables**, such as temperature, precipitation, and sea level rise (SLR), which will have long-term or permanent impacts on the target sectors . The risk assessment presented in this study incorporates broad potential **climate risks**, along with their **impacts** and associated **vulnerabilities**, in order to provide insights into which aspects of industry and municipalities require **adaptation** to a changing climate.

The risk assessment was conducted through literature review as well as stakeholder engagement and consultation. Existing climate change projections were used along with literature review findings to identify key risks to the relevant sectors within the study. The focus areas determined in the preliminary risk assessment were confirmed through stakeholder consultation, where CBCL sought to gain insight from industry professionals in order to identify perceived risks and opportunities from those who work directly in each sector. Engagement was furthered through discussions with relevant environmental groups, local climate and geoscience academics, industry associations, and others.

In this report, the risk assessment methodology, key findings, and priority recommendations for adaptation are presented. Adaptation solutions for each sector, as well as cross-cutting solutions that benefit more than one industry, are recommended for each top priority impact identified in the risk assessment process.

Further descriptions of bolded text can be found in the glossary following this report.

Although climate change mitigation is a key consideration in agriculture and forestry management, it is not the focus of this report. Any adaptation measures presented in this report should be considered through a mitigation lens to determine if actions align with sectoral GHG mitigation targets.

1.3 Background

Background information on each of the target sectors included in this risk assessment are summarized blow.

1.3.1 Municipalities

In Newfoundland and Labrador today, there are 276 incorporated municipalities with great diversity in size and population. There are three cities (provincial capital of St. John's, Corner Brook, and Mount Pearl), 269 towns, and five Inuit governments, representing 89% of the provincial population (MNL, 2020). Municipalities are responsible for the coordination of local governance programs, which at times includes the operation and maintenance of core public infrastructure, community services, capital programs, planning, bylaw enforcement, and emergency services, among others. Infrastructure and services within a community may be delivered by the municipality, the province, or through a regionally shared service agreement.

Municipalities Newfoundland and Labrador (MNL), a non-profit association advocating on behalf of municipalities, lists climate change adaptation amongst as one of the key issues facing local municipal governments.

1.3.2 Fisheries and Aquaculture

The harvesting, processing and aquaculture industries in Newfoundland and Labrador are a staple to the province's economy and the livelihood of thousands of people, particularly in rural communities. The industry accounts for over 1.4 billion dollars in annual market value and employs 15,000 people in 400 different communities in the province. The current provincial wild fishery focuses on the harvesting of groundfish (such as cod and halibut), pelagics (such as capelin and mackerel), shellfish (such as lobster and crab), and emerging fisheries (such as sea cucumber). Aquaculture accounts for approximately twelve percent of the industry's total market value and has been consistently growing over the past several decades. The primary species harvested via aquaculture practices in the province include Atlantic salmon, blue mussels, steelhead trout, and Atlantic cod (GovNL, 2020).

Ocean environments are changing as a result of both climate change and other anthropogenic influences. Over the past century, Newfoundland and Labrador's wild fishery has been impacted by unsustainable practices and management. This, combined with the effects of climate change (i.e. ecosystem changes), has led to a decrease in the population size of some stock resulting in reduced quotas for harvesters. Climate change will continue to impact the health of the marine ecosystem in the future, creating new challenges for fisheries management (DFO, 2021).

The development of a **blue economy strategy** is currently under way by Fisheries and Oceans Canada (DFO). The strategy is focused on addressing climate change through "build back better" initiatives, recognizing that ocean-based employment contributes significantly to each province's gross domestic product and to employment in small coastal communities. Among others, the ocean-economy includes jobs in commercial fisheries and aquaculture operations, as well as fish and seafood processing across Canada.

Throughout the 21st century, it will be of utmost importance for the federal and provincial governments to consider the effects of climate change in fisheries and aquaculture management planning in order to ensure current practices are sustainable and will support the industry for years to come.

1.3.3 Forestry

The forestry industry has been an important component of Newfoundland and Labrador's economy for hundreds of years, providing thousands of jobs in both rural communities and larger centres, and producing products such as firewood, building materials, and newsprint. Forests also have enormous cultural and recreational value for communities, as well as spiritual value for First Nations. Respect for traditional ecological values of First Nations during the planning of climate change adaptation initiatives cannot be understated (GovNL, 2019).

The province has over 23 million hectares (ha) of boreal forest, which supports key industries including Pulp and Paper, Sawmilling, **Value-added Manufacturing**, and Wood Energy. Commercial forestry has been primarily concentrated in Central and Western Newfoundland and has focused on the harvest of the conifer species such as black spruce, balsam fir, and birch (GovNL, 2014).

Forest Management in the province is largely based on ecoregions, each of which is characterized by the plant and animal species that inhabit them as a result of the local geology and climate (GovNL, 2014). Today, forest management activities are aimed at controlling some of the highest risk-factors to commercially productive forests such as forest protection (i.e. wildfire management) and sustainability (i.e. harvesting).

The Canadian Council of Forest Ministers (CCFM) has identified action on climate change adaptation as a priority for the forestry sector. As the province continues to experience the impacts of climate change, the distribution of native species found in forest ecoregions will begin to shift with the changing climate (NRCan, 2009). Forest managers must be aware of and consider these changes in the implementation of adaptation plans and research priorities. Knowledge exchange is essential for Canada's forest industry as it adapts to a changing climate.

1.3.4 Agriculture

Newfoundland and Labrador's agriculture industry consists of a variety of agricultural practices including:

- **Horticulture** (vegetable/fruit production), feed for animals, and ornamental purposes;
- Livestock and dairy production; and
- **Secondary processing** such as processed meat, dairy products, wool and other fibres.

The province is currently self-sufficient in poultry, dairy, and eggs, meaning that the current demand for these fresh products is being met through in-province, local production. Feed for livestock, however, is largely imported.

The province has placed a significant emphasis on growing the provincial agriculture industry over the coming years, with goals including large-scale agricultural land development, doubling the province's food self-sufficiency, and updating legislation related to the agriculture sector. Additionally, the province plans to advance research in northern agriculture and climate change adaptation, which will be crucial for creating a sustainable industry with a high economic value with climate change (GovNL, 2017).

Newfoundland and Labrador is the only province in Canada that is creating significant new farm land through zoning (GovNL, 2014), which is presenting opportunities to use smart and sustainable landscape design in the planning phase. Proactive planning to incorporate climate resiliency at the onset of new development can avoid costly redesign and replacement of infrastructure that was not designed with a changing climate in mind.

Chapter 2 Climate Change in Newfoundland and Labrador

This chapter summarizes expected changes in temperature, precipitation, coastal parameters, and other projections for Newfoundland and Labrador for mid- (approximately 2050s) to late- century (approximately 2100s).
Canada's climate will continue to warm, driven by global greenhouse gas (GHG) emissions from human activity. Past warming has occurred in Canada at about double the rate of global warming, and future warming is predicted to follow the same trend (Bush and Lemmen, 2019). This poses risks to all sectors of the economy and to Canadians' quality of life. Action on climate change **adaptation** (and **mitigation**) is critically required to limit impacts on people and ecosystems.

Climate projections for Newfoundland and Labrador are different in several ways than projections for other provinces in Canada (Banfield and Jacobs, 1998). The climate in this region is closely tied to several coastal currents and it is highly dominated by **natural variability** (Way and Viau 2015). Although natural variability may cause the local climate to temporarily fluctuate from the projected long-term trends, this does not diminish the need to plan for climate change. Natural variability is an important distinguishing factor for climate change adaptation when comparing to solutions applied in other jurisdictions. In addition, the province experiences more freezing rain than anywhere else on the continent, and may be the Canadian province that is the most affected by **Atlantic tropical storms** (in addition to the **extra-tropical storms** which also affect the region) (Robichaud and Mullock, 2000; Lambert and Hansen, 2011).

2.1 Future Climate Scenarios

Greenhouse gases (GHGs), such as carbon dioxide and methane, trap the sun's heat within the atmosphere, causing the climate to warm. Human activities related to the generation of GHGs have exponentially increased since the industrial revolution and have been a major driver of climate change. These climate changes will be exacerbated in the future due to the inertia of the natural system and continued anthropogenic GHG emissions. Emission scenarios represent different potential pathways for the amount of GHGs that have been and continue to be emitted globally. Global GHG emissions will be affected by future population growth, future technology and alternative energy, policies, and conflict.

There are currently four industry-standard scenarios, called **Representative Concentration Pathways** (RCPs), which have been standardized by the Intergovernmental Panel on Climate Change (IPCC). These four scenarios are summarized in Table 2.1. Unless otherwise indicated, temperature and precipitation projections for this study are drawn from a 2018 report by Finnis et al. (commissioned by the NL Department of Environment, Climate Change and Municipalities), for the RCP 8.5 emission scenario. RCP 8.5 is currently the worst-case standard scenario and its use is the current standard in impact assessments and adaptation. Based on current trends and behaviours, this scenario is often considered realistic.

Table 2.1: IPCC Emission Scenarios

Emission Scenario	Global GHG Emissions	Global Warming 2081-2100*	Meets 2015 Paris Agreement for 2100 Global Warming <2°C?
Low Emissions RCP 2.6	Steep cut starting now to zero by 2070s	1.0°C (0.3 to 1.7)	Yes
Moderate Emissions RCP 4.5	Slight rise to 2040s, then drastic cut	1.8°C (1.1 to 2.6)	Possibly
Moderate-High Emissions RCP 6.0	Moderate rise to 2070s, then cut	2.2°C (1.4 to 3.1)	Unlikely
High Emissions RCP 8.5	Continuous and significant rise	3.7°C (2.6 to 4.8)	No

*Mean (and Likely Range)

2.2 Temperature

Averages and Extremes

Daily average temperatures**, daytime high** temperatures, and **nighttime low** temperatures are projected to increase, with a steady rate of change through mid- to late-century. In general, the coldest temperatures are projected to increase fastest. The greatest change is expected in winter and projected changes show the largest increases in the Labrador interior and at high latitudes. **Cold extremes** are expected to decrease in intensity and frequency, whereas **warm extremes** will increase in intensity and frequency.

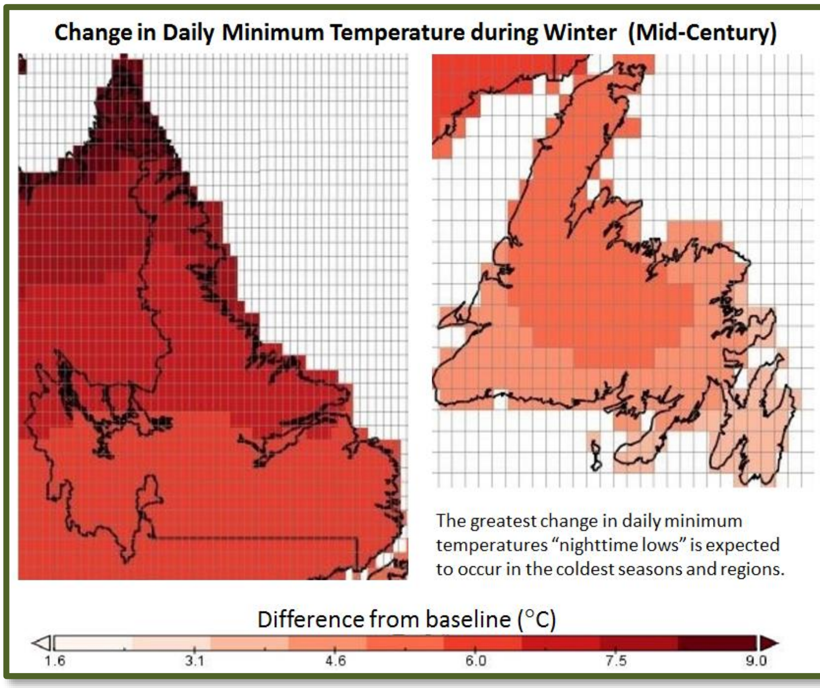


Figure 2.1 – Projections for winter (Dec-Feb) daily minimum temperature (nighttime low), for a high emission scenario (modified from Finnis et al. 2018).

Growing Season

As temperatures change, so will average characteristics and the timing of seasons. Newfoundland and Southern Labrador are expected to undergo a substantial increase in **growing degree days** during summer, with smaller increases in autumn. The greatest rates of change are expected by mid-century, on the south coast, west coast, and interior of the island.

Frost and Freeze-Thaw

The **number of days with frost** is expected to decrease, with the greatest change in regions and seasons with daytime temperatures projected to rise above near-freezing. Changes in Labrador will be less drastic, as cold winter conditions will persist for longer. Changes in **winter thaw events** and **freeze-thaw cycles** are likely to follow a similar pattern.

2.3 Precipitation

Average Precipitation

Mean daily precipitation is expected to increase throughout the province. In Newfoundland, widespread increases are expected by late century. Changes in Labrador are typically smaller, but also tend towards an increase. Despite uncertainty in the projections, precipitation is expected to increase in most locations and seasons by mid-century, and larger (nearly universal) changes are expected by the end of the century.

Precipitation Intensity

Precipitation intensity is expected to increase, as shown by several indices, such as: mean intensity of precipitation events; maximum 3-, 5- and 10-day precipitation; and number of days with 10 mm or more of precipitation. Models predict intensity increases for all of Newfoundland in all seasons, with the greatest increases in winter and on the south coast. Changes in Labrador are generally smaller. There is notable uncertainty in mid-century projections, but by late century strong increasing trends emerge.

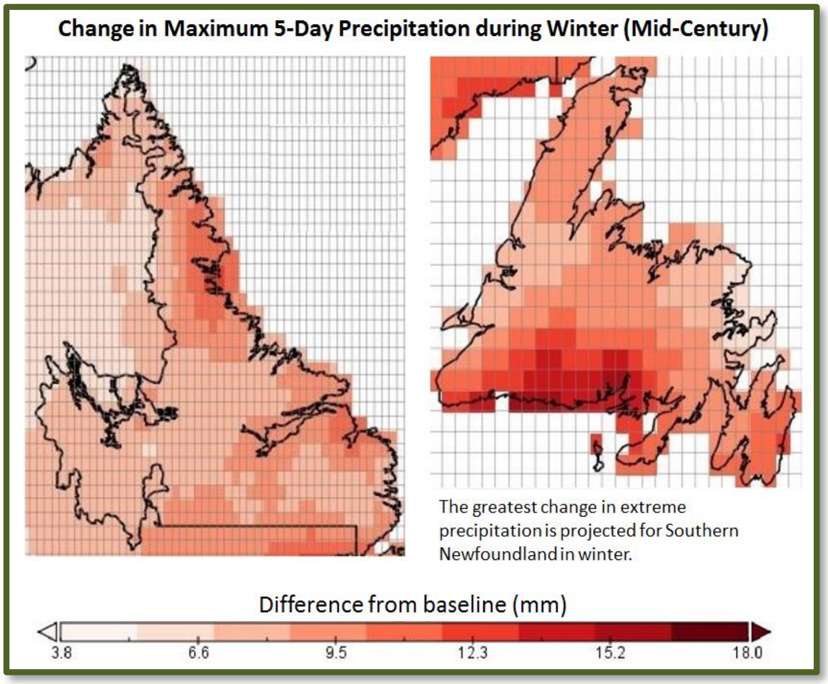


Figure 2.2 – Projections for winter (Dec-Feb) precipitation intensity, for a high-emission scenario (modified from Finnis et al. 2018).

Drought

Projections of consecutive dry days suggest that droughts are not likely to be a concern for the province (Finnis et al. 2018). However, the consecutive dry days index is only based on changes in precipitation, and it is calculated annually.

Projections for the standard precipitation evapotranspiration index (SPEI) also consider the impact of future warming on potential evapotranspiration. Although annual SPEI is expected to increase (wetter) due to wetter winter/spring conditions, an investigation of seasonal SPEI reveals slight projected decreases (drying) in parts of NL in the summer and fall (Tam et al. 2018).

Consecutive dry days and SPEI are both indicators of meteorological drought. Zhao et al. (2020) looked instead at hydrological drought (which includes watershed processes) and found that NL is projected to become dryer, even when this is not reflected by meteorological indices.

An assessment of future drought in NL would require a systematic investigation of different indices, timescales, and historical/modelled datasets (outside the scope of this assessment). For the purpose of this report, a future increase in drought in NL is considered possible.

Freezing Rain

Quantitative projections for **freezing rain** are more uncertain (and projections from Finnis et al. 2018 are not available). Increases are anticipated based on the northern movement of the 0°C temperature boundary and of freezing rain-related weather systems. The greatest changes will occur in regions and seasons with near-freezing temperatures, that is during winter months in the south of the province, and during shoulder seasons in northern regions (Cheng et al., 2011). The greatest increase in terms of hours per year will be during the second half the century in eastern Newfoundland, which already experiences the most total freezing rain hours per year in Canada. The greatest relative increase is expected in Labrador (Cheng et al., 2011). Extreme ice accretion loads, a layer of ice buildup on surfaces, will also increase (Jeong and Sushama, 2018).

Snow, Winter Rain, and Rain-on-Snow

Historically, some datasets show that some locations in NL have experienced increasing trends in **snow cover fraction** and snow amount (Mudryk et al., 2018). In terms of future changes, an increase in total annual snowfall is projected for the Torngat Mountain region (Allard and Lemay, 2012). High latitudes are expected to have an increase in snowpack density (Brown et al., 2019). In locations/seasons with mean temperatures close to zero, there is likely to be less snow and more rain, but snow cover duration or **snowfall extremes** may continue to occur even as average conditions decrease (Finnis et al., 2019; Janoski et al., 2018). These changes also mean more rain falling in winter on frozen ground, as well as rain-on-snow days, in particular in southern regions (Allard and Lemay, 2012; Jeong and Sushama, 2018).

2.4 Sea Level

Sea-Level Rise and Flooding

The IPCC projects a global **mean sea-level rise** of 40 centimeters by 2050 and 1.0 m by year 2100 for a high-emissions scenario (IPCC, 2013). **Relative sea-level change** will significantly vary across the province in part due to vertical land motion, as shown in Figure 2.3 (James et al., 2014). Land subsidence in the south will increase local relative sea level rise, while land rebound in the north will buffer it. Contributors to **extreme sea levels** include sea-level rise, an overall increase in storminess (**storm surge**), and increased wave action due to reduced ice cover (Bernier et al., 2006). In the south of Newfoundland, sea-level rise is likely to be the primary contribution to extreme sea levels, whereas in the north, storm surges and waves would continue to dominate. The projected increase in extreme water levels across the province will cause increased **coastal flooding** in low-lying areas.

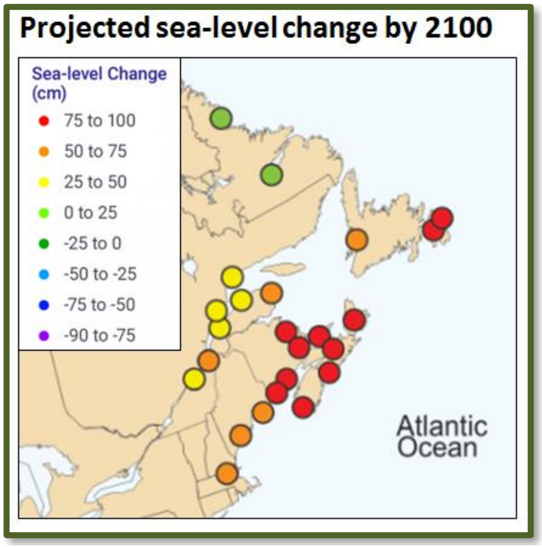


Figure 2.3 - Projected relative sea-level rise for a high emission scenario, compared to 1986–2005 (modified from Bush et al. 2019).

Coastal Erosion/Deposition

Existing rates of **coastal erosion** are highly variable across the province, with the most change occurring in unconsolidated cliffs and beaches (Irvine, 2015; Catto, 2011). Increases in erosion rates are anticipated in these areas due to changes in the processes that drive erosion (wind, waves, groundwater, and surface water). For example, the rise of extreme water levels will allow waves to get closer to cliffs, and projected increases in precipitation intensity will accelerate erosion from runoff (Irvine, 2015).

2.5 Terrestrial and Marine Environments

- **Ice Jams and River Flooding -** Flooding from ice jams has become more frequent and unpredictable in Atlantic Canada (Turcotte et al., 2019). Although increasing air temperatures will decrease river ice cover thicknesses, increased flows during freeze-up could allow for thicker ice and more severe **ice-jam flooding** (Belatos and Prowse, 200; Turcotte et al. 2019)**.** Other projected changes that are likely to exacerbate flooding include **higher intensity precipitation**, more **winter rainfall**, and **sea-level rise** combined with changes to storms. Changes to snow accumulation and **mid-winter thaw events** may also have an impact in the province (Hickman, 2006).
- **Permafrost -** Southern Labrador is at the lower end of the **permafrost** distribution (with isolated, sporadic, and discontinuous permafrost), and Northern Labrador is within the zone of continuous permafrost. Climate change over the next century is

expected to have the greatest effect on the more vulnerable permafrost at the southern boundary (Zhang et al., 2008; Way and Lewkowicz 2018).

- **Water Temperature and Quality -** Increase in wash-off events from runoff caused by extreme precipitation are likely to negatively impact water quality. Water temperature in streams and rivers is likely to increase (DFO, 2013).
- **Invasive Species, Pathogens, and Pests -** Changing climate conditions will alter suitable habitats and competition dynamics. Among other factors, modified disturbance regimes have been shown to be conducive to **invasive species** (Dyderski and Jagodzinski 2018), pathogens, and pests (Hellmann et al., 2008). Changes to sea temperatures may allow for marine invasive species to expand their range northward and deeper into the water column. In addition, changes to ocean currents may affect distribution patterns (DFO, 2013).
- **Vegetation assemblages –** Vegetation assemblages will be impacted as precipitation regimes shift and temperature isotherms move northward (Searls et al. 2021). Species composition also responds to disturbance from wildfire and invasive species (Dyderski and Jagodzinski 2018).
- **Wildfire -** Drier conditions elsewhere in Canada are projected to contribute to increased number and extent of wildfires (Wotton et al., 2010). Even if dry conditions were to remain unchanged in Newfoundland (Finnis et al., 2018), changes to vegetation assemblages and disturbances may affect fire regimes.
- **Sea-Water Temperature, Salinity, and Stratification -** With climate change, sea temperatures are expected to increase throughout the region, in all seasons, and both on the surface and the bottom (DFO, 2013; Han et al., 2015; Han et al, 2019). Due to increases in precipitation over the ocean and ice melt, coastal salinity is expected to decrease in all seasons (except some deep-ocean areas in the south where it may increase) (Han et al., 2019). Vertical mixing will be reduced due to the warmer and fresher conditions at the surface (DFO, 2013).
- **Sea Ice –** Sea ice is very likely to decline in area, thickness, volume, concentration, and duration by mid-century (DFO, 2013, and Han et al., 2019), with the greatest decreases likely in the southern part of the province (DFO, 2013), and local effects at river mouths and fjords (Allard and Lemay, 2012). See Figure 2.4.
- **Chemical Oceanographic Variables –** Reduced vertical mixing is likely to reduce the nutrient supply from deeper waters (Han et al., 2015). Dissolved oxygen will also be reduced, although this may be more localized (e.g., coastal), and acidity is projected to increase (DFO, 2013). These projected trends are a continuation of the recently observed trends in the area (Lavoie et al., 2017).

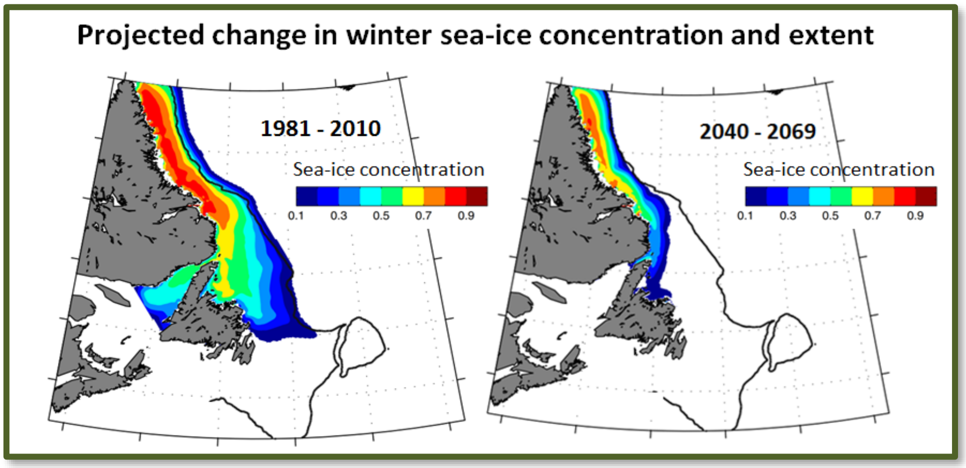


Figure 2.4 - Winter (Jan-Mar) sea-ice projections (modified from Han et al. 2017). Gulf of St. Lawrence is shown as blank as it is outside the model area.

2.6 Winds, Storms, and Changing Atmospheric Conditions

- **Hurricanes, nor'easters, and winter storms -** A possible increase in the intensities of tropical (e.g., hurricanes) and extra-tropical (e.g., nor'easters) storms is anticipated, resulting primarily in increased precipitation rates (Knutson et al., 2019; Liu et al., 2019; Colle et al., 2015). It is possible that winds and surge may increase, which would have more effect as sea levels rise along the south coast and would be particularly damaging for longer duration storms which can span several tidal cycles (Greenan et al. 2018), such as Nor'easters.
- **Atmospheric Conditions -** Changes to atmospheric conditions will include increased concentration of GHGs, the potential for changes to pollution and air quality, and uncertain trends in shortwave radiation (due predominantly to uncertainties in cloud cover) (Lucas et al. 2019, Fu and Tian 2019).

2.7 Summary

The following table summarizes mid- and late- century changes.

Table 2.2: Mid- and Late-Century Changes Projected for Newfoundland and Labrador

	Temperature	Precipitation	Sea Level
Summary of Climate Change Projections	Daily average, daytime high, and nighttime low temperatures are projected to increase, with a steady rate of change through mid- to late- century.	Mean daily precipitation is expected to increase throughout most of the province by 2050 and nearly the whole province by 2100, for all seasons.	Increases of up to 0.4 m by 2050 and up to 1.0 m by 2100. Relative sea-level change will vary significantly across the province.
Spatial Variability	The largest increases are expected in the Labrador interior and at high latitudes.	Widespread increases are expected in Newfoundland. Changes in Labrador are typically smaller.	Sea level rise is the primary contributor to extreme sea levels in the South. In the North, storm surges and waves will dominate due to sea-ice loss

Chapter 3 Risk and Vulnerability Assessment Methodology

The risk and vulnerability assessment was conducted using relevant risk assessment guidelines and best practices including the following:

- **ISO 31000** for Risk Management;
- **ISO 14090** for Adaptation to Climate Change; and,
- **CCME Guidance for Best Practices when Conducting Risk Assessments**

The following subsections outline the methodology and project stages that contributed to conducting the overall risk and vulnerability assessment for the relevant sectors. Findings from each of these sections are compiled in Chapter 4, which outlines the key risks and opportunities identified throughout the course of the project. Risks and vulnerabilities assessed as part of this analysis are both a combination of perceived risks based on reported stakeholder concerns, as well as risks identified in literature.

3.1 Literature Review

Based on the climate projections outlined in Chapter 2, a literature review was conducted to identify relevant assets within each sector, and risks to those assets that may result from the changing climate.

Literature review focused on industries and municipalities with respect to best management practices, infrastructure and service requirements, legislation, and ecosystem reliability, among others. The review aimed to identify primary assets, commercially harvested species and crops, infrastructure requirements, and existing policies to be analyzed as part of the climate change risk assessment. Once sector assets were identified, further research was conducted to determine how each asset could be impacted by relevant climate parameters in both the mid- and long- term. Potential opportunities were also identified. Lastly, a review of historical and ongoing climate change projects, initiatives, and programmes related to each industry within the province was conducted to understand current adaptation priorities.

The literature review phase formed the basis of the preliminary risk assessment, which was then validated and expanded upon during the stakeholder engagement phase of the project.

3.2 Stakeholder Engagement

In the fall of 2020, CBCL held a series of stakeholder engagement workshops in order to obtain feedback on the risk assessment directly from professionals in each target sector. Individual virtual workshops were held for each sector which facilitated discussion on past experiences and perceived future risks affecting each industry. Opportunities resulting from climate change were also discussed.

The overall goal of the stakeholder engagement workshops included:

- Ground truthing findings from the initial literature review;
- Identifying cross-sectoral issues faced by different industries in the province (i.e., similar climate change related issues throughout different industries); and,
- Disseminating information about climate change impacts and risks to relevant parties.

3.2.1 Stakeholder Mapping

Stakeholders were identified with the assistance of the project steering committee, and with input from the following groups:

1. Municipalities Newfoundland and Labrador (MNL);
2. Various Government of Newfoundland and Labrador divisions (ex. Indigenous Affairs and Reconciliation); and
3. Industry Association Groups.

Substantial effort was made to ensure that diverse stakeholders were engaged in this process, including representatives from the following groups:

- Municipalities (rural and urban), including engineers, planners, and council members;
- Indigenous Governments and community representatives;
- Industry consultants;
- Environmental groups and Non-governmental Organizations;
- Relevant provincial and federal government departments;
- Academia;
- Private sector;
- Industry associations;
- Electrical utilities; and
- Local Unions, among others.

3.2.2 Workshops

Workshops were held in virtual meeting and webinar platforms. Sessions generally consisted of a brief upfront presentation on relevant climate projections for the province, followed by open discussion with workshop participants on the following main themes:

- Key climate parameters and projections of interest to each group.
- Perceived risks and vulnerabilities to each group.
- Barriers to action on adaptation.

- Potential opportunities resulting from climate change.

To engage workshop participants and spark conversation, interactive anonymous polls were used throughout each of the sessions where participants were asked to provide feedback on several key topics, such as:

1. What climate change risks they have experienced to date.
2. How each group perceives risks or opportunities to their sector as a result of climate change.
3. Perceived barriers to acting on risks or implementing relevant adaptation measures.

Participants were able to select from a series of answers, and CBCL facilitators asked follow-up questions to the group based on the results of the polls.

Each workshop consisted of open discussion among all participants, with the exception of the Municipalities Workshop which was split up due to the higher number of stakeholder groups. In this session, participants were separated into breakout rooms within the virtual meeting platform, consisting of approximately 25 participants per group. Each breakout room focused on a different topic, including:

- Transportation and Planning
- Asset Management and Design
- Flooding and Erosion
- Economics, Environment, and Health and Safety

Stakeholder engagement sessions with Indigenous community representatives were conducted using virtual meeting platforms with follow up calls and emails.

Following the formal stakeholder engagement phase of the project, additional virtual discussions were held between project team members and key provincial government departments. The purpose of this dialogue was to follow up on any risks identified in literature that warranted additional discussion or clarification.

3.2.3 Notes of Engagement

The feedback received as part of this study was more heavily weighted toward inshore fisheries then offshore. Indigenous community feedback on the impacts of climate change to the forest sector was sought, although limited feedback was received. It is recommended that future iterations of this report consider strategically targeted engagement with representatives of the offshore fishing industry and indigenous community stakeholders in industry.

Chapter 4 Risk and Vulnerability Assessment Findings

The following sections outline the climate change related risks, opportunities, and barriers to adaptation for each sector based on information obtained in literature review and stakeholder consultation sessions. Each perceived risk or opportunity heard in consultation was further assessed, either through literature review or discussions with various government departments, to better understand relative impacts and prioritize recommended actions for adaptation.

4.1 Municipalities

Through stakeholder engagement and literature review, climate change risks and opportunities to key municipal sectors were identified and are summarized below.

Transportation and Planning

- **Increasing Requirements for Maintenance of Rural Roads:** A likely increase in maintenance requirements and public safety risks were identified due to increasing snow accumulation, freezing rain, and freeze-thaw cycles, as well as increased flood risk and washout of culverts.
- **Increased Need for Communication and Knowledge Sharing:** Community representatives noted that managing climate change risks presents added complications for municipalities with intersecting provincially owned roads and associated culverts. Without property communication and collaboration between the involved parties there may be inefficiencies in addressing risks, or risks may not get addressed at all.
- **Insufficient Capacity for Land Use Planning:** Not all municipalities report having sufficient in-house capacity to develop appropriate land-use planning materials and flood plain maps without regional collaboration or provincial assistance and/or support.

Asset Management and Design

- **Lack of Available Resources:** Smaller municipalities lack the expertise and resources to incorporate climate change into their procurement processes. While a provincial toolkit is available, this kit reportedly does not address climate change sufficiently to support risk-based decisions and adaptation plans at the infrastructure level. Some municipalities also lack the GIS capabilities required to sufficiently assess risk.

- **Funding Accessibility Limitations:** Increasing storm frequency and intensity has placed pressure on end-of-life assets, while operations and maintenance costs are beyond the financial capabilities of many municipalities. Municipalities often recognize that there are funding opportunities to bridge this gap but note that it can be difficult to leverage these opportunities effectively due to capacity limitations, tight funding timelines, or high minimum thresholds for project cost.
- **Data Requirements for Design of New Infrastructure:** Up-to-date and readily available data is required to design and maintain climate resilient infrastructure, which is not always straightforward or readily available for municipalities. Additional levels of complexity will have to be considered in future infrastructure design as floodplains change, limits are placed on geographic extent and type of allowable development, and regulations such as flood-proofing for new buildings come into effect. There is, however, an opportunity to improve designs as aging infrastructure gets replaced.

Flooding and Erosion

- **Complexity of Floodline Mapping:** Communication and accessibility of flood maps for decision makers, engineers, and residents is considered essential for building climate resilience at the municipal level. Smaller municipalities feel that provincial assistance with executing flood mapping is required and that lessons learned from larger municipalities can help smaller communities execute similar projects.
- **Impact of Uncertainty on Insurance:** Many stakeholders expressed concern around the use of climate change adjusted flood plain maps for community planning. Concerns involved the use of delineating floodlines based on a rainfall projection, which has perceived larger uncertainty as compared to a historically measured flooding events and data. There is a perception that flood maps may impact insurance and resale value for residents, therefore that maps must be defendable.
- **Cost of Incorporating Climate Change Projections into Design:** Costs associated with building for large return period or annual exceedance probability events, such as the 100-year or 500-year projections with climate change, can be significant when compared to traditional design approaches that do not consider climate change. This additional cost can deter investment in climate resilient infrastructure. A cost-benefit approach where a “do nothing” cost is calculated against an estimation of the potential loss is required to present the value of investing in resilience through a loss avoided lens. The best way forward is ultimately dependent on the asset owner’s risk tolerance.
- **Increasing Vulnerability of Coastal Assets:** Coastal communities often rely on coastal infrastructure for transportation and economic activity. Coastal assets such as ferries, roads, wastewater treatment plants, residential septic systems, electrical and communications infrastructure, landfills, and wharves are becoming increasingly vulnerable with sea level rise.
- **Increasing Vulnerability of Sewer and Stormwater Management Systems:** Managing storm water and flood risk in overland and piped systems is a growing concern for many municipalities as structural damage, debris blockages, ice buildup,

and other climate related factors affect operations. Inflow and infiltration management in wet sanitary and combined sewers is becoming more difficult. Reservoirs and dam failure management concerns, such as dam breach and washout, are growing with climate change.

- **Increasing Vulnerability of Source Water:** Impacts of temperatures and saltwater intrusion on groundwater sources was noted as a key risk for municipalities who rely on groundwater for drinking water. Although rare, some municipalities are also at risk of surface water contamination by salt water during storm surge events, as occurred in the town of Ramea in 2016. Drought and water quality concerns (e.g., algae) are a result of treatment facilities that are not currently capable of treating these issues.

Economics, Environment, and Health and Safety

- **Wellbeing of Emergency Responders and Utility Providers:** Increased stress and long working hours from more accidents and disaster response calls may lead to an increase in fatigue, accidents, and injury for emergency responders, municipal service providers, and utility providers. Access for these service providers may also become increasingly difficult during extreme weather events due to downed trees, blocked access, or flooding on critical transportation routes.
- **Disrupted Access to Rural Communities:** Factors such as food insecurity and accessibility, as well as reliability of communications and electrical infrastructure, is a concern for rural communities and industry that rely on highways and ferry services that are vulnerable to extreme weather.
- **Access to Potable Water:** Continued delivery of safe and clean drinking water may be challenged by power outages and changes to raw water quality and quantity.
- **Increased Exposure to Wildfire and Extreme Weather:** Communities are concerned that wildfire will increase with climate change, putting residents at the forest-urban interface at greater risk. There is a concern that residential insurance rates in rural communities may increase as a result. Extreme weather such as windstorms can lead to extended power outages and damage to linear infrastructure such as power lines.
- **Disruption to Health and Wellbeing:** Community services and traditional recreational activities may be impacted by climate change and extreme weather.
- **Damage to Key Community and Social Infrastructure:** Important community facilities and features such as sports fields, walking and hiking trails, historic sites, among others, will become more susceptible to flooding and structural damage due to extreme weather. Risks to electrical and communications infrastructure, traffic lights, signage, and bus shelters, among others, were discussed.
- **Hindered Economic Development:** Economic development in rural and coastal communities may be significantly impacted by climate change. Provincial and federal ferry service delays and crossing cancellations can have noteworthy impacts on local economy.

Opportunities

- **Rural Economic Growth:** Opportunities resulting from climate change in the agriculture and forestry industries, such as crop diversification or longer growing season, may be beneficial for rural economy in terms of creating jobs and new opportunities for residential growth.
- **Reduced Requirements for Snow Maintenance:** On average, snow maintenance and plowing costs may decline with climate change is the longer term.

4.2 Fisheries

Climate change risks and opportunities for the commercial fishery (excluding aquaculture, see Section 4.3), as identified through research and stakeholder feedback, are summarized below. National and international references related to risks and/or advantages to commercial fisheries are summarized throughout this section. While such risks and/or advantages have been presented in other jurisdictions, detailed studies regarding Newfoundland ecosystems and invasive species have not been conducted to the same extent. Environmental processes that have and will continue to drive certain species to flourish and others to diminish, are complex and occur at vastly different scales within the **marine food web**. This includes changes from the microscopic organism level up to habitat loss, all of which will have an impact on commercially harvested species.

Ecosystem Changes

- **Increased Stress:** It is possible that temperature will impact the growth rate, migration patterns, and reproductive cycles of key harvested species. In addition, prey availability could also be impacted by climate change.
- **Formation of Harmful Algal Blooms:** Uncontrolled nutrient runoff from land-based sources may contribute to the formation of harmful algal blooms.
- **Exposure to Invasive Species:** Increases in new exotic species, such as sunfish and sharks, as well as changing dominant species, are early signs of a changing climate. Lessons learned from the past invasive species outbreaks, such as the green crab, have presented opportunities to improve risk assessment methodologies and include climate change in ecosystem management approaches.
- **Changing Ocean Conditions:** Potential increased ocean acidity will affect shellfish exoskeleton formation, and potential lower levels of dissolved oxygen may lead to decreased fish productivity (DFO, 2013). Increased wave action may lead to coastal habitat degradation and increased turbidity in coastal waters, which may result in reduced light attenuation, impacts to the productivity of marine plants, and an overall disruption to the marine food chain. (DFO, 2013; Liddon, 2017).

Commercially Harvested Species

- **Ability to Adapt to Shifting Species:** Environmental changes such as increasing ocean temperature are driving fluctuations in the dominant harvested species (DFO, 2019b). Typical commercial harvested species by region may change with climate change, which may impact stocks and harvesting quotas. The introduction of new species could be an opportunity for harvesters, if invasive species continue to be monitored and controlled effectively, although this is challenging. Adaptation via changes in dominant harvested species may need to occur more quickly in the future with climate change. Flexibility to adapt harvesting approaches, and subsequent downstream value chain responses, to rapid changes is beneficial.

- **Potential Decline in Seal Populations:** Higher risk of population declines due to changing ice regimes, ocean acidification, and invasive species potentially affecting some species that seals rely on for food (DFO, 2019b). Population declines may have an impact on sustainable seal hunts, as well as seal harvesting and processing industries.

Infrastructure and Data

- **Integrity of Wharves and Piers:** Older infrastructure in small craft harbours (SCHs) was typically not designed with sea level rise projections in mind and more dredging may be required in the future due to changes in sediment transport as a result of increased wave action. Infrastructure funding is available for climate change adaptation projects, although many small municipalities do not have the resources or knowledge to take advantage of these opportunities.
- **Inefficient Access to Climate Data:** Data is difficult to find and not presented in a user-friendly way.
- **Increasing Weather Variability:** Weather is becoming increasingly variable and therefore harder to predict; this is creating potential risks for an industry that depends largely on historical knowledge.
- **Increased Operation and Maintenance Requirements for Roads and Buildings:** Potential increases in weathering and decreased life expectancy of roads due to freeze-thaw. Potential structural damages to coastal buildings, wharves, slipways, and breakwaters from extreme weather, as well as increases in operating costs for cooling requirements at processing plants and supporting facilities.

Health and Safety

- **Decreased Reliability of Forecast with more Extreme Weather:** Increasing and more sporadic winds, waves, and ice regimes are creating health and safety concerns for harvesters. Forecast reliability could result in further safety challenges.
- **Potential Need to Increase Emergency Response Coverage:** Search and rescue coverage in the Labrador Sea may need to expand should fisheries move further north with shifting species.

Opportunities

- **Industry Expansion in North:** Further expansion of fishing industry into Labrador and the Arctic region is possible (such as for shrimp and Greenland halibut). Enhanced collection of ecosystem data in the North is required to support studies on the migration, spawning habits and distribution of these species.
- **Developments in Research and Innovation:** There is abundant room for research and innovation within the industry. Particular topics noted by stakeholders include

research into evolving pests and pathogens with climate change. There are specific climate-related impacts to commercially harvested species that involve complex processes which are not yet fully understood with climate change. For example, specific impacts on fish migration patterns, food chain disruptions, fish stress due to warmer ocean temperatures, susceptibility of each species to pests and disease, food competition among species, impacts of sea ice reduction on algal blooms, and other species-specific factors. Some of these challenging topics are being researched by various provincial and federal government departments, academia, and/or private industry.

4.3 Aquaculture

Climate change risks and opportunities specific to the aquaculture industry, as identified through research and stakeholder feedback, are summarized below. Through stakeholder feedback, it was reported that finfish and shellfish aquaculture operations have unique challenges as a result of climate change and therefore these subsectors have been organized separately in this section.

Finfish Farming

- **Restrictions in Accessibility:** Imports and exports are vulnerable to extreme weather (e.g., due to a ferry service delay), and food sourcing is currently imported from outside of the province. Imports and exports are vulnerable to extreme weather (e.g., ferry service) for the delivery of fish, food and necessary supplies.
- **Lack of Monitoring Systems:** Climate monitoring station data is used to inform historical and current events (recreate and analyze past events) and for design. For example, climate monitoring is used for return period statistics to inform cage and mooring standards, design, and placement. Monitoring station data coverage is limited in some regions, meaning that the data required for informing decision making and design may not be sufficient for future development.
- **Impacts to Salmon Growth:** Small changes in the biophysical environment, such as water temperature, can have significant impacts on salmon growth and performance. Environmental stress may cause increased susceptibility of certain species to disease.
- **Potential Decreasing Water Quality:** Warmer, more buoyant waters are expected to result in increased stratification at local scales. This is a concern as warmer layers of water are related to water quality parameters (e.g. dissolved oxygen) and the transmission of pathogens and parasites (Karvonen et al., 2010), which have a direct impact on the health of species.
- **Potential Formation of Algal Blooms:** It is possible that algal blooms, which can have a toxic effect on fish, will become more common with increasing temperatures. Improved data related to the impacts and growth of marine algae could improve response in terms of preventative actions.

Shellfish Farming

- **Potential for Decreased Food Availability:** Warmer temperatures may negatively impact natural food sources for muscles as these animals are passive filter feeders. Fluctuations in temperature, salinity, and Chlorophyll-A in the water column may impact shellfish food availability and overall quality of water in and around production areas.
- **Potential for Decreased Water Quality:** Warmer, more buoyant waters are expected to result in increased stratification at local scales. This is a concern as warmer layers of water can influence food availability which have a direct impact on the health of the species. Ocean acidity, for example, is increasing due to carbon emissions from human activity and these same emissions are a key driver of climate change (Burger et al, 2020). Ocean acidification affects the shells of marine mollusc like the blue mussel. Human influenced changes to our marine ecosystems includes nutrient loading and increased pathogens, which are influenced by land-use practices in the watershed.
- **Improving Coverage of Climate Monitoring Systems:** Minimal coverage of climate monitoring systems are limiting the industry's ability respond and adapt to climate change. Shellfish harvesting closures are based on a combination of rainfall predictions, measured rainfall (closest regional station), and other times water quality sampling. Improved rainfall monitoring (including representative locations within the watershed) may help to better understand local water quality dynamics, including the impacts of stormwater runoff and untreated wastewater discharges on local water quality. An improved understanding of water quality challenges within each watershed through better monitoring programs can provide insight into valuable opportunities to reduce the length and timing of closures.

General

- **Increasing Infrastructure Damage:** Increased exposure to wave action and storm surge from extreme weather resulting in potential structural damage to infrastructure and power outages.

Opportunities

- **Proactive Adaptation Based on Lessons Learned from Other Jurisdictions:** There is potential to learn from more southern locations that will potentially see similar impacts to their fishing and aquaculture industry before these impacts reach Newfoundland and Labrador. This provides the provincial industry with an opportunity to be proactive in their management and adaptation strategies.
- **Creating Room for Research and Innovation:** There is abundant room for research and innovation within the industry. Particular topics noted by stakeholders include: (1) Research into how pests and pathogens evolve with climate change; (2) Potential dietary changes that can help fish adapt and become more climate resilient; (3) Genetic research for more robust species.

4.4 Forestry

Climate change risks and opportunities to the forestry industry, as identified through research and stakeholder feedback, are summarized below. National and international references related to risks and/or advantages to commercial harvested tree species are summarized throughout this section. While such risks and/or advantages have been presented in other jurisdictions, detailed studies regarding Newfoundland boreal forests and invasive species have not been conducted to the same extent.

Wood Supply

- **Potential Increased Susceptibility to Forest Fires:** Risk to wood supply may possibly increase with climate change due to increased fire weather (warmer and drier conditions). A potential increase in drought frequency or intensity could also have an impact on fire susceptibility. Forest fires have been managed well in the province historically due in part to successful wildfire prevention and reporting programs.
- **Potential Increase in Freeze-Thaw Damage:** Potential increases to freeze-thaw cycles in the shoulder seasons may lead to amplified damage to trees, cracked tree roots and bark, and heaving of small trees and shrubs out of soil.
- **Potential Increase in Windthrow:** Intensifying storms and wind events may lead to an increase in the number of excessive or large-scale blow downs/wind throw in the future, especially in coastal regions (NRCan, 2009). However, the commercial impact of this will be dependent on the industry's ability to respond and harvest following an event.
- **Susceptibility to Invasive Species, Pests, Disease:** Insects are a primary cause of forest disturbance in the boreal forests of Newfoundland and Labrador; and forests are expected to become increasingly vulnerable to insects with climate change (NRCan, 2009). Increased reproduction, diversity, and a northern migration of forest insects, pests, and pathogens as well as increased exposure to already present invasive species will also increase climate risks (Kirilenko and Sedjo, 2007). Although not particularly prevalent today, ticks and Lyme disease (among others) may become a concern for the forestry industry in the future (GovNL, 2016). Drought can further result in reduced ability for trees to produce sap, which protects them from some invasive species (Karl et al., 2009).
- **Potential Increase in Precipitation Damage:** Increases in the amount and intensity of precipitation may lead to trees becoming suffocated due to standing water in poorly draining soils, deposited mud and sediment (Kirilenko and Sedjo, 2007); however, these impacts will be very site specific and depend on topography and soil characteristics. Increased precipitation may also cause undermining of root systems and damage from fast moving flood water. Damage to trees from increased freezing rain is also possible.
- **Forest Migration:** Climate change is causing unprecedented environmental shifts that are outpacing the natural migration of forests species (NRCan, 2020a). With climate change, it is possible that growth rate and distribution of commercially important tree species will be affected by changing temperatures, timing of seasons, moisture levels,

and **disturbance regimes**. All of these changes may cause stress to maladapted species, decrease productivity, and increase susceptibility of forests to disease and insect attack. In the medium-term, radical changes in forest composition are not expected; however, tree species migration is a slow process and precise data on past tree species distribution is limited (NRCan, 2020c). Balsam fir, for example, may have difficulty persisting in the Maritimes under a changing climate (Williamson et al, 2009). Modelling of forest growth and yield between 2020 and 2100 indicate that modest increase in black spruce and balsam fir productivity in northerly growing environments within NL are possible; however, trends are highly dependent on the climate scenario analyzed (Searls et al, 2021).

- **Increased Temperature and Drought Stress:** Under drought conditions, some tree species become weakened, stressed, and increasingly susceptible to disturbance.
- **Increased Tree Mortality:** Projected increases in drought, fire, windstorms, insects, and disease outbreaks are expected to result in greater tree mortality across Canada (NRCan, 2020c). The management of insects like the hemlock looper, are currently being studied through a climate change lens (NRCan, 2020c). Snow accumulation provides essential insulation for shallow root system species and if roots freeze, die-offs can occur.

Infrastructure and Operations

- **Increased Maintenance Requirements for Supporting Infrastructure:** Increased maintenance requirements (due to freeze-thaw event) as well as recovery of assets (such as bridges, culverts, access roads, and trails) following larger and more frequent rainfall events or storms that result in washouts or severe erosion is possible in the future. Ferry services, such as Marine Atlantic, are likely to become more unreliable with extreme winds and increased storm frequency. This service is essential for import of supplies and export of products. Further, the ability to use winter roads to access environmentally sensitive areas may be impacted by changing seasonal temperatures.
- **More Frequent Power Outages:** Increased vulnerability to power outages due to extreme weather events. Vulnerability is variable across the industry, where larger facilities are often equipped with backup power supplies while smaller sawmills typically are not.
- **High Uncertainty and Low-Resolution Data Challenges:** Stakeholders noted that climate data lacks the resolution required to make decisions around regional operational changes, such as infrastructure sizing. A lack of knowledge on how to deal with the uncertainty in climate projections data was presented as challenge in longer term planning.

Health and Safety

- **Worker Exposure to Extreme Weather and Invasive Species:** Increased exposure of industry workers to wildfire, extreme heat, and disease-borne invasive species such as ticks (Bouchard et al, 2019). There is potential for increased strain on fire and emergency services.
- **Increased Susceptibility to Wildfire**: The fire season in some regions of eastern Canada may continue to lengthen with climate change. The total number of, and the total area burned by, large fires may also increase in the future (NRCan, 2020c).

Policy and Programmes

- **More Frequent Updates to Forest Management Plans:** Plans will need to be updated to account for changes in tree growth, ecoregions, harvesting seasons, species harvested, and protections against invasive species. These plans can be further supported by associated modeling work and progressive policies that support adaptation to a wide range of projected changes.

Opportunities for Growth

- **Creating Room for Resources and Innovation:** Some industry groups are interested in genetic testing and other innovative strategies to assess the long-term viability of various species under tree improvement programs; although, climate change was not a major factor noted in this testing.
- **Development of Green Economy:** The green economy and bioeconomy is an opportunity to advance the forestry sector and improve efficiencies in an evolving social and economic landscape. This may include proactive forest harvesting approaches before trees die and release carbon following a major forest disturbance event.
- **Potential Improved Growing Conditions:** Increased CO_2 in the atmosphere, and increased number of growing degree days, which are favourable for growth (Pan et al., 2015). Increased water use efficiency in tree species may also result in opportunities (Price et al., 2013). Generally moister conditions have the potential to create opportunities for the forest sector (NRCan, 2020c).
- **Potentially Longer Growing Season:** A shift in seasonal availability of water from earlier snowmelt may lead to an earlier growing season (Ryan et al., 2008) A longer growing season length (by 20-40 days by 2100) is a potential opportunity for the sector; however, related changes in pests, fire weather, and storms may outweigh any perceived benefit.
- **Product and Market Diversification:** Economic and species diversification is a method available for adapting to climate change. Switching from a volume-based to value-based manufacturing, as well as product diversification (such as pharmaceuticals and biomass) may create new economic opportunities for this industry. Expansion of forestry into Labrador may become more viable with climate change; however, access to the mainland may become a concern with increasing risk of sea level rise and storm surge distribution for ferry services and container ship. Labrador may also have a higher risk of drought and wildfire with climate change.

4.5 Agriculture

Climate change risks and opportunities to the agriculture industry, as identified through research and stakeholder feedback, are summarized below. Studies that are referenced below are reflective of research completed in other jurisdictions that identify additional risks or advantages to specific crops based on relevant climatic factors. There are many other factors that can contribute to each of these risks or opportunities, such as changes to soil pH, moisture content, and nutrient availability. At this time, detailed regional studies have not been conducted that analyze the impact that such factors may have on crops within the provincial landscape.

Productivity and Health

- **Potentially Increased Frequency of Winter Kill Events:** Issues with winter kill may be exacerbated as warm spells in late winter triggering earlier growth of crops, which are subsequent harmed by returning cold winter temperatures.
- **Increased Water Stress from Excess Precipitation:** Increases in precipitation amount and intensity can lead to excess water during seeding season, washout of top nutrient-dense soil and loss of fertilizers/ nutrients, damage to plants from intense rainfall, water stress making plants vulnerable to pests and disease, undermining of root systems, and plant suffocation.
- **Potential Degradation of Soil Quality:** Decrease in soil carbon affecting soil functions including structure, stability, topsoil water holding capacity, and nutrient availability (Hatfield et al., 2008). Increased evapotranspiration leading to loss of water form soil (Hatfield et al., 2008). Nutrient immobilization in soils exacerbated by drought conditions (Arora, 2019).
- **Potential Increased Wind Damage:** Increased winds may cause wind erosion of soil, damage to crops, saltwater spray impacting coastal crops and water supplies (for both irrigation and livestock).
- **Increased Stress from Warmer Temperature:** Warmer temperatures may lead to increased stress and decreased production in livestock and certain crops. Risks related to more complex changes such as shifting productivity, invasive species, pests, and disease management are certainly a concern for the industry with a warming climate, but these expected changes are currently not well understood. Plants and livestock have tolerable ranges of heat and humidity for healthy, productive growth. Conditions experienced outside of these windows, has the potential to cause stress, reducing productivity and even potentially causing mortality (Climate Atlas of Canada, n.d.). This risk may be higher for **intensive operations**.
- **Potential Introduction of Invasive Species and Pests:** It is expected that invasive species and pests will become a more prominent issue as diversity of crops in the province grows, global travel expands, and new host plants are introduced. This may have an impact on effectiveness of pesticides currently used. The anticipated increase in vector-borne pests (e.g. ticks) as well as the spreading of disease may become more prominent due to accelerated growth of pathogens and/or parasites that live part of

their life cycle outside of their host (Rojas-Downing et al., 2015). This will affect the health of livestock and plants.

- **Potential Increased Weather Variability:** Industry professionals indicated that because the growing season "climate" tends to vary on an inter-annual basis, it is difficult to rely on a longer growing season or warmer temperatures, despite trends presented in climate projections. The industry needs to have flexible adaptation measures and back-up plans in place for unexpected shifts in weather, such as a late spring or early fall frost.

Infrastructure

- **Changing Requirements for Stormwater Management:** Increased precipitation will lead to stormwater management issues including the management of drainage and storage features. Poor draining and flooded fields are unsuitable for farming equipment to work on. Extreme rainfall during the seeding or harvesting period, as well as flooding of pastures, is creating stormwater management and soil erosion challenges for farmers. With climate change, farmers who are already dealing with these challenges may be at highest risk as the frequency and intensity of extreme events increases.
- **Potential Increased Damage to Infrastructure:** Heavy loading from snow and winds was discussed as a major risk to farm buildings, greenhouses, and other supporting infrastructure. Excessive wind and snow loading can lead to complete loss of buildings if improperly monitored and managed. Snow, rain-on-snow, and wind loads are all possible triggers for a building collapse. Newfoundland and Labrador Federation of Agriculture (NLFA) is planning to complete a study of the on-farm infrastructure needs of the agriculture sector. The results of the NLFA study should be aligned with the current report.
- **Potential Disruptions in Supply Chain:** The timing for planting and harvesting crops may change overtime as shoulder seasons are warming, and the risk of a late frost lessens (AAFC, 2020). The viability of extending the **growing season** may be crop specific and dependent on the supply chain. The sector is reliant on timely access to amendments, fertilizers, and seeds. A narrow window for product exports and supply chain capacity (storage and transportation) must also be considered in assessing the feasibility of extending the growing season or changing planting or harvest timing.
- **Increased Damage to Public Roads:** Weathering of roads and supporting transportation infrastructure due to freeze-thaw, as well as road closures (washouts and flooding) because of extreme precipitation, may also increase.
- **Changing Requirements for Irrigation Systems:** Drought has impacted some crops in the past; however, there are no clear crop-specific drought indices available for NL crops, making the identification of risk as well as planning for adaptation difficult. Potatoes, for example, were identified as a drought-sensitive crop during consultation. Crops with high water requirements, such as cranberry for example, were also discussed in consultation. These crops may be highly impacted by metrological and hydrological drought and may contribute to the depletion of water resources if sustainable land use practices are not employed.

Policy and Planning

- **Disruption to Required Services:** Strong winds often lead to disruptions in both the ferry service and power outages that can have detrimental effects on farmers, including delays in seed imports and exports of farmed products. During extreme weather, communities may become isolated or ferry services to the island may be interrupted. The province relies on key transportation networks, including ferries and rural road networks, for access to remote regions. Beyond food production, other essential items such as fertilizers, amendments, and seeds are also imported.
- **Institutional Barriers:** Farmers noted that it is of particular importance that the correct policies are in place to support the implementation of holistic farm management solutions that incorporate water and infrastructure management through natural adaptation solutions such as effective landscape design (e.g., tree planting to combat erosion and as a wind break). Additionally, training should be in place for agriculture industry professionals at various levels (management all the way to frontline workers) in order to understand and properly address barriers to implementation. A lack of communication, networking, and sharing of lessons learned across the industry was discussed as opportunities for advancing adaptation. Platforms are required to enhance communication and improve knowledge sharing.

Opportunities for Growth

- **Product Diversification:** As public perception shifts towards healthier and local food options; this may create a market for new crops. Similarly, warmer temperatures may allow for a longer growing season and new crops to be grown. A warmer summer season may further expand the biodiversity of crops in the provincial agriculture industry if heat tolerant species can be identified.
- **Market Expansion:** Expansion into new markets for pharmaceuticals and other non-food crops may emerge.
- **New Agricultural Lands**: With climate change, as well as other anthropogenic factors such as increased food demand, the conversion of boreal forest into agricultural land is possible (Altdorff et al, 2017). Over the long term, agricultural land conversion may impact soil hydrology. With climate change, this may lead to increasing erosion risk and nutrient loss by runoff, contributing to potential flood risk, as well as limiting groundwater recharge, hence contributing to hydrological drought (Altdorff et al, 2017).
- **Room for Improvements to Food Security:** With growing concerns over food security, as well as more public awareness around healthy eating, sustainability, and wellness related to food, there may be an opportunity for local farmers to fill an industry gap. A local approach may allow niche crop farmers to emerge, creating additional agriculture jobs and help to improve food security.
- **Reduced Energy Costs in Winter:** During stakeholder engagement, the impacts of cold winters on winter greenhouse heating costs were discussed. With climate change, warmer average winters may reduce energy computation for heating.
- **Potential Increase Plant Productivity:** Increased plant productivity due to carbon fertilization is possible (Hatfield et al., 2008). Increased water-use efficiency in crops

(plants take in more carbon while minimizing water loss through transpiration, i.e., less water required to be drawn out of soil by plants for photosynthesis) (Hatfield et al., 2008). Increased CO_2 in the atmosphere and an increase in number of growing degree days are both favourable for growth (Climate Atlas of Canada, n.d.). Although benefits of climate change resulting from extended growing seasons and warmer average temperatures are routinely highlighted for this sector, there is a perception that the risks of climate change may outweigh these benefits. However, adaptation involves building strategies for both maximizing benefits and mitigating risks.

4.6 Cross-Cutting

There were several climate related risks identified in literature and during stakeholder consultation that were noted to have a potential impact within all or most studied sectors. While each sector experiences the effects of these impacts differently based on relative vulnerability, the following risks were identified as cross-cutting:

- **Potential Increased Damage to Infrastructure:** Commercial, residential, and industrial infrastructure may be impacted by climate change to varying degrees. Extreme precipitation and flooding may cause basement and main floor flooding or undermining of foundations. Wind, snow, and ice loading may cause structural damage to roofs and exteriors, including farms and greenhouses. Industries relying on coastal infrastructure may be exposed to increasing damage to wharves, piers, and other coastal structures due to sea level rise and coastal flooding. These risks are relevant to all sectors.
- **Potential Disruption to Transportation Network:** Increased winds and storm intensity will potentially lead to increased disruptions in ferry services and impacts to critical road networks such as provincial highways. Both affect import and export of products, as well as food security, particularly in rural communities.
- **Emergency Response Requirements and Increased Worker Exposure:** Both industry and municipalities are concerned that extreme heat, increased storm intensity causing flooding, road washouts, downed trees, and power outages, among others, may result in increased stress on emergency responders. Increased exposure of workers to floodwater, extreme heat, severe weather, and disease borne pests (such as ticks) may occur.
- **Limitations in Accessing Funding:** There was a consensus among most stakeholder groups that there are limited resources and knowledge available to fully capitalize on climate change-related funding opportunities.

Chapter 5 Recommendations for Adaptation

The following sections outline the recommendations for adaptation within each sector. The focus areas highlighted reflect the highest ranked risks.

5.1 Cross-Cutting

The following cross-cutting risks and opportunities impact more than one industry or government sector. Identifying synergies between sectors may provide collaborative opportunities for adaptation. It is recommended that the following are considered as part of the overall provincial climate change adaptation strategy:

Transportation and Food Security Risk Assessment

Newfoundland and Labrador rely heavily on imported food through ferry service and highway operations. Import, exports, and local transportation through handling facilities are being challenged by flooding, sea level rise, and high winds resulting in closures. Ferry service or road closures impact import/ export of essential goods for aquaculture, agriculture, and fisheries operations, as well as access to basic amenities (food, goods, services) in rural communities. It is recommended that the province consider completing a comprehensive risk and vulnerability assessment on the reliability of key transportation network points for both industry and isolated remote communities. The outcomes of this analysis would shortlist the highest risk transportation network points to key economic sectors and communities. Transportation risks resulting from climate change extend into three key categories and may require unique risk assessments:

- **Provincial Imports and Exports via Ferry**: Poultry and dairy farming rely on imported seeds, fertilizers, and amendments in their operations. Timing is important as seeds and fertilizers must arrive within a small planting window. Aquaculture also relies on access to imported feed, such as dairy farmers who import grain for feed. Exports related to industrial milk production and live shellfish (mussels and lobster) have limited shelf-life and can suffer loss if access to market is restricted due to ferry crossing delays.
- **Provincial Road and Ferry Access**: Food insecurity and accessibility is a concern for rural communities that rely on provincial highway and local ferry services that are vulnerable to extreme weather. Road washouts, flooding, or snow/ice accumulation can block emergency responders who may not have an alternate route available. A road closure could result in complete isolation for some rural communities. The aquaculture industry also relies on public utilities and assets. Road washouts have resulted in loss of

deliveries of essential food supplies for fish. Communities require emergency response planning to prioritize upgrades on high-risk roads and provincial highways.

- **Northern Indigenous Communities**: Changing sea ice conditions and permafrost stability are impacting traditional transportation routes in Labrador. These changes are contributing to food insecurity in some remote communities, which are also impacted by ferry service interruptions. The stress of food insecurity, compounded by climate related threats to traditional cultural and hunting practices, may be working against initiatives to strengthen the mental health of Northern Indigenous peoples.

Case Study: Isolated Communities

In January of 2015, sections of the Trans-Canada Highway near Corner Brook washed out due to heavy rainfall and flooding. Several communities across Western Newfoundland declared a state of emergency as a result of the flooding. During this flooding event, highway washouts outside of Corner Brook contributed to communities being isolated. Other communities and farmland experienced substantial flood damage (CBC, 2018).

Province-Wide Critical Coastal Infrastructure Assessment

The fisheries and aquaculture industry often rely on private, provincially, or federally owned coastal infrastructure. This infrastructure was typically not designed historically with sea level rise and storm surge flood risk in mind. At-risk coastal infrastructure (such as wharves, buildings, and breakwaters) will impact fisheries, municipalities/Indigenous governments, communities, and tourism. Vulnerable local ferry services also place towns at risk who are reliant for access. Prioritization of coastal infrastructure upgrades should be based on a province wide risk-assessment with input from key industry stakeholders. It is recommended that a risk-based prioritization study be accompanied by a cost-benefit analysis to inform an overall province-wide action plan. As there are over 350 small craft harbours across the province, a preliminary shortlist of focus areas may be required, noting that sea level is not rising along all coastlines. Existing infrastructure needs assessments will provide valuable insight into industry growth projections which may inform the focus areas for this study.

Case Study: Wave Mitigation in Cow Head Small Craft Harbour

The Harbour of Cow Head was at significant risk of basin wave agitation due to high wind and wave exposure. A coastal computer model was used to analyze local wave conditions and test breakwater design options to protect moored vessels and coastal infrastructure in the harbour. The design incorporated the option to incrementally raise the breakwater in response to rising sea levels.

Adaptation strategies included:

- **Protect for wave agitation**
- **Adapt design to local armour stone size limits**
- **Raise structures and design to allow for further raising with future sea level rise**

Designing a wide structure, that could be incrementally raised over time, also offered ease of construction using long-reach excavators that are less costly compared to a marine barge. This project also included considerations for protecting the core structure from storm exposure during construction.

Climate Change Adaptation Plan for Natural Resources Management

It is recommended that a climate change impact study for natural resource-based industries is completed to apply findings of national climate impact modelling programs examining projected future changes in resource availability for Newfoundland and Labrador. Impact modelling can inform specific adaptation measures for provincial ecosystem management and adaptive supply chain approaches. These recommendations are further developed in report sections 5.2 – 5.5.

Assessing the Impacts of Climate Change on Wildlife

Newfoundland and Labrador's wildlife resources contribute significantly to the provincial economy, natural heritage, and culture. Research on the impacts of climate change on wildlife species and critical habitat management in the province remains an import aspect of provincial climate change adaptation planning. The Wildlife Division is part of the provincial Department of Fisheries, Forestry and Agriculture and is responsible for the assessment and listing of species at risk as well as related conservation activities, among many other duties. Adaptation strategies recommended for both municipalities and natural resource-based sectors should also consider the impacts to wildlife.

Incorporating Forest Fire Risk into Municipal Climate Change Adaptation Plans

Resources available for mitigating fire risk include: **Fire Smart Canada** tools for communities to assess wildfire risk and a risk reduction program for forestry companies (NRCan, 2020e); and **The Forest Change Toolkit** which is a list of tools and resources for understanding and managing forest fire risk. According to the 2020 The State of Canada's Forests Annual Report, the Government of Canada will be launching a satellite built specifically to monitor wildfires in the coming years. NLFIA advocates for the use of intensive silviculture as a means of managing fuel build up to reduce forest fire risk, in response to climate change. It is recommended that these wildfire risk management tools are considered in municipal climate change adaptation plans in consultation with emergency services and the forestry department, where required.

5.2 Municipalities

The management of municipal infrastructure is becoming increasingly challenging in a changing climate. There are many ways in which climate change may impact communities in Newfoundland and Labrador, from increases in wind loading to stormwater management challenges. Through consultations with communities across the province, the following focus areas were highlighted for building municipal capacity to adapt to climate change.

It is recommended that the following be considered as part of the overall provincial climate change adaptation strategy for municipalities:

Creating a Province-Wide Adaptation Planning Guidance Document

Create a guide ("how to" document) with best practices for executing an engineering and/or policy-driven climate change adaptation plan at the municipal or regional level. This document is intended to be more advanced than the existing **"7-step method"** for municipalities who want to further develop their infrastructure planning. The 7-step toolkit is an excellent qualitative risk assessment framework and would contribute as a pre-screening tool to this new guidance document. The guide would include:

- A risk management framework for prioritizing projects in a holistic way that considers climate risk to all areas of a municipality and rank them consistently across the region using a quantitative approach.
- A consistent table of contents and layout for all plans provided as part of the guide. Further, stakeholders provided direct feedback that having a provincial representative assigned to a project of this nature would help with consistency in the layout, content, and execution of plans.
- Guidance on an approach for incorporation into or alignment with the new provincial asset management planning framework and emergency management plans.

- Best practices for engagement with local industry, including natural resources-based industries and tourism sectors, as well as service providers such as NL Power.

Consider including a legislative requirement to have adaptation plans completed for high risk communities and aid with project scoping, drafting of request for proposals (RFPs), as well as funding program applications (if applicable). Determining what communities are at "high risk" could involve a combination of inland flood risk, coastal flood risk, and coastal erosion risk, as performed in New Brunswick, for example. References to the 2012 *Flood Risk Vulnerability Analysis Project* completed through ACASA as well as the provincial *Flood Events Inventory Database* (recording flooding events from 1900 forward) are two excellent sources of information to inform this process.

Leveraging a Regional Approach to Adaptation Planning

The province began implementing programs that enable communities to pursue regional infrastructure improvements in 2020 through the launch of regional governance pilots. Opportunities for the incorporation and testing of regional climate change adaptation initiatives could serve as valuable case studies for the use of a regional approach to adaptation. A regional approach may also help municipalities who are struggling with internal GIS capabilities. During stakeholder consultation, it was noted that flood risk related challenges often cross municipal boundaries and involve provincial assets. In this circumstance, a regional approach to flood risk analysis and stormwater management may be preferred. Specific climate related challenges also differ regionally and therefore shared data collection and analysis programs would offer smaller communities additional support, reduce redundancy, and promote consistency.

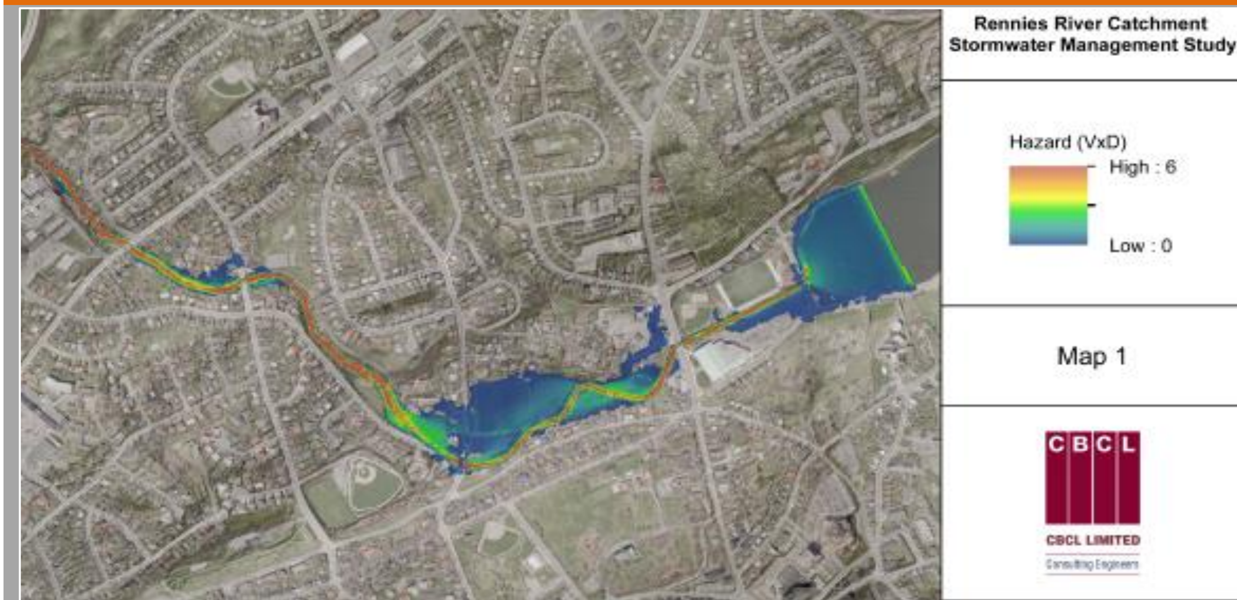
Applying a "Climate Lens" to all Funded Projects

For projects awarded through the province, such as Gas Tax or Stimulus Funding, add a condition that climate change resilience is required in the award letter. This process is currently being initiated through all provincial infrastructure funding programs, and should further include reporting on loss avoided and cost-benefit calculations (i.e., the cost of doing nothing, the risk associated with loss, and the cost of mitigating that risk). Criteria for triggering the engineering and climate lens should consider minimum thresholds and other provisions to avoid unnecessary additional administration for projects where the climate lens is not practical or necessary.

Developing Province-Wide Coastal Flood Risk Mapping

Developing sea level rise and storm surge flood maps for coastal areas (map each coastline) will complement newly available coastal erosion maps. Local projections for sea level in small craft harbours is available through DFO. Storm surge data is largely missing for many coastlines, creating challenges. A lack of LiDAR data is a barrier to plotting flood line mapping for communities and industry. Municipalities want LiDAR for creating flood risk maps or graphics that show sea level rise and coastal flood risk projections relative to a known landmark in their community. Consider surveying a structure in each community and then producing a graphic to show expected SLR and storm surge flood lines relative to this landmark where flood mapping isn't possible.

Case Study: Rennies River Catchment Stormwater Management Plan



In 2014, the City of St. John's completed the Rennies River Catchment Stormwater Management Plan (RRCSWMP). This plan included modelling for the Rennies River system to produce floodplain and flood hazard maps for existing and future conditions with climate change.

Using the results of floodplain and flood hazard mapping, preliminary cost opinions and designs for the optimum flood and erosion control methods were developed. Proposed improvements included bridge upgrades, berms, and increased stormwater storage through the use of a flow control structure. Since the completion of the RRCSWMP, the bridge on O'Leary Avenue has been upgraded and flood protection berms have been constructed along Leary's Brook adjacent to the Health Sciences Centre. Additional analyses on the proposed flow control structure and flood protection berms between Long Pond and Quidi Vidi Lake.

Consider the Implementation of “No Net Increase in Runoff” Policies

Improved stormwater management techniques are required to limit flood risk through development and infilling. A shift to more proactive approaches is needed to prevent loss and improve public safety. Some municipalities could benefit from “net-zero runoff” style policies for new development. These policies aim to limit the flow of a proposed development site to pre-development levels through improved site-level stormwater management. Provincial assistance in drafting a policy and sharing of lessons learned on this topic would be valuable. Stormwater management policies that limit increased runoff could benefit shellfish aquaculture sites downstream of new development.

Creating a Provincial Stormwater Design, Construction and Operation Guideline

Create a standalone Stormwater Design, Construction and Operation Guideline for the province or incorporate stormwater infrastructure into the existing provincial design, construction and operation guideline for water and sewerage infrastructure. Incorporating climate change into the planning of new infrastructure requires a longer term understanding of risk and an appreciation of the importance of proactive planning. The guideline would address best practices for the inclusion of climate change considerations in infrastructure planning and align with the provincial flood line mapping guideline.

Implement Build Back Better Guidelines

Include a set of ‘build back better’ guidelines that considers a cost-benefit investment approach to planning for the future in consideration of both climate change and growth projections. Proactive planning through relatively small additional front-end engineering scopes (climate change and coastal analysis) during preliminary engineering can provide significant risk reduction for replacements/ renewal.

It is recommended that the province work with the DFO coastal engineer on practical procurement document language and evaluation procedures for NL that can be used on local or provincial coastal infrastructure projects at the planning stage to ensure that the climate lens is applied consistently to new infrastructure projects.

Regional engineers with the provincial Department of Transportation and Infrastructure’s Municipal Infrastructure Division often assist local municipalities with administering and scoping projects. This includes identifying data gaps, finding relevant provincial climate data sets and flood mapping, as well as including appropriate language in procurement documents that consider climate change impacts to an infrastructure project or study. Regional engineers are working on the ground with municipalities to advance these important infrastructure projects. To ensure ongoing projects are arrived at with consistency, and that the most recent data sources are being applied, it is recommended that regional engineers are provided with training and tools to help municipalities with project scoping and practical procurement document language for the inclusion of climate change in infrastructure projects.

Promoting Investment in Adaptation

An increase in storm frequency and intensity has placed pressure on end of life assets while at the same time, operations and maintenance costs are currently beyond the financial capabilities of many municipalities. This has led to a strain on capital investment needs for infrastructure upgrades, which makes investment in climate resilience challenging. Municipalities recognize that there are funding opportunities to bridge this gap; however, have noted that it can be difficult to leverage some federal funding opportunities effectively based on the application process, eligibility criteria, and/or spending timelines. In other examples, long-term financial planning was insufficient to prepare communities for the cost-sharing component of funding. This is particularly true for small communities with limited resources and capacity to find and respond to funding opportunities. Knowledge mobilization on the costs associated with a "do-nothing approach" is an important aspect in gaining community buy-in for investing in adaptation. Promoting flexible or extended funding timelines, as well as a regional approach to project execution (where appropriate), will help communities leverage available funding for adaptation projects.

Creating a Centralized Data Portal

The provincial method for deploying resources was noted as a key consideration in communicating climate change risks. Sometimes the data that communities need exists, it is simply difficult to track down. The Turn Back the Tide climate data portal was created to provide a single point of entry for provincial climate change data, tools and resources. Ongoing initiatives to create a centralized and up to date data portal for all key climate related data needs is essential.

5.3 Fisheries and Aquaculture

In this chapter, recommendations have focused on top priority local infrastructure and data needs. It is recommended that the following are considered as part of the overall provincial climate change adaptation strategy for Fisheries and Aquaculture:

Proactive Approach for Climate Resilient Infrastructure Planning

Infrastructure in SCHs was historically not designed to account for SLR, coastal erosion, or a decline in the sea ice extent and season. During the stakeholder engagement sessions, more recent examples of inconsistent incorporation of SLR and coastal flood risk, as well as examples of short-term and insufficient growth planning were provided. As a result, the coastal infrastructure that both municipalities and industry rely upon may be exposed to evolving risks and operational challenges associated with climate change. The cost of upgrading at-risk coastal infrastructure can be significant. It is essential that a future focused lens be applied in the design, operation, and maintenance planning stages for all new infrastructure proactively to ensure longevity and reliability.

A multi-part solution for consideration includes:
(1) Assist inshore fisheries and small municipalities with funding programs targeted for climate resilient upgrades of at-risk existing infrastructure;
(2) Work with current and future lease-holders as well as the provincial government to understand industry growth projections and account for these projections in the planning stage;
(3) Use proactive planning approaches through relatively low cost additional front-end engineering scopes (climate change and coastal analysis) during conceptual design to provide significant risk reduction for replacements or renewal; and
(4) Work with Fisheries and Oceans Canada Coastal Engineers on practical Request for Proposal (RFP) language and evaluation procedures that can be used on local or provincial infrastructure projects at the planning stage to ensure that the climate lens is meaningfully applied with consistency.

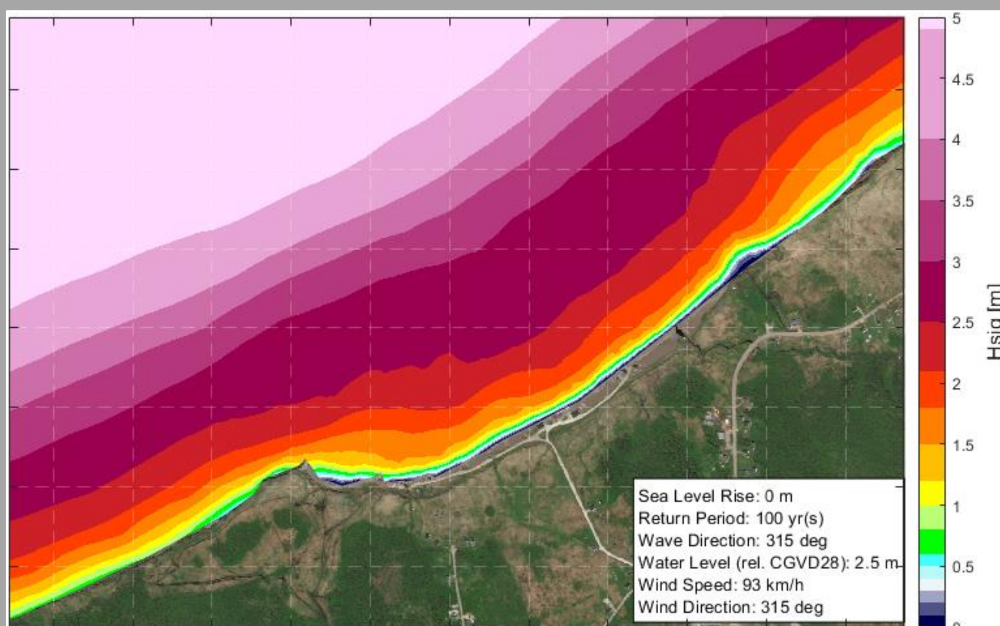
Advancing Ocean and Climate Monitoring Data Collection Programs

According to feedback received during stakeholder consultation, the success of aquaculture operations is closely tied to effective environmental monitoring programs. An improved understanding of risk through enhanced monitoring programs will feed into pilot programs of new technologies to support adaptation. Currently, two major Fisheries and Oceans Canada programs collect data on ocean conditions (**AZMP** and **AZOMP**). For shellfish operations, the Canadian Shellfish Sanitation Program (CSSP) is responsible for environmental monitoring; however, improvements to this program to better align with national climate change adaptation objectives were brought forward in stakeholder consultation. Water quality challenges associated with changing ocean conditions and increased land-based runoff, compounded by other anthropogenic factors such as land use, are a perceived risk to shellfish harvesters in addition to climate change. A strong CSSP, that leverages the best available climate projections and marine science research, as well as traditional knowledge, is required to make informed decisions around the development of new operations, as well as the management of existing shellfish harvesting operations. Continued engagement with municipalities, landowners, and First Nations around sustainable land use practices and management of both wastewater and stormwater are also continuing to improve water quality along Newfoundland and Labrador's coasts. The availability of sufficient communications infrastructure was identified as a potential barrier in rural communities to implementation of enhanced monitoring. NAIA is currently completing a study on the existing and future infrastructure and telecommunications needs of the finfish and shellfish sectors to inform a multi-year investment plan. Further, based on findings presented in the Fisheries and Oceans Canada Outlook to 2027 for Canadian Fish and Seafood report, the high cost of feed products is expected to drive diversification of feed formulations and support increased production of species, such as bivalves, that do not require imported feed such as bivalves, further emphasizing the importance of a strong CSSP program (DFO, 2018b).

Case Study: Damaged Fishing Slipways in Lourdes

Beach erosion at Lourdes, NL as a result of wave exposure resulted in recurring damage to fixed concrete slipways in the Lourdes Small Craft Harbour. In order to replace the slipways with a more resilient design, the local sediment transport and wave regime was analyzed.

Based on modelling results, a preferred slipway location and design was proposed with beach control structures to mitigate beach erosion. Site selection included a site with low sediment transport (downdrift) to reduce dredging requirements and a piled construction that allows beach movement under and through the structure.



The adaptation strategy developed for the Lourdes Fishing Slipway was designed to accommodate the local dynamic beach processes, expecting that the beach will continue to change.

Communicating Complex Climate Science Topics

Understanding the links between climate projections and changing marine ecosystems can be complex and challenging to communicate. Effective engagement of inshore fisheries harvesters and plant workers, as well as processors, requires tailored and practical outreach activities. Active participation from the federal and provincial governments, with industry associations, is required to translate these complex changes to the local content.

Establish a Climate Change Working Group

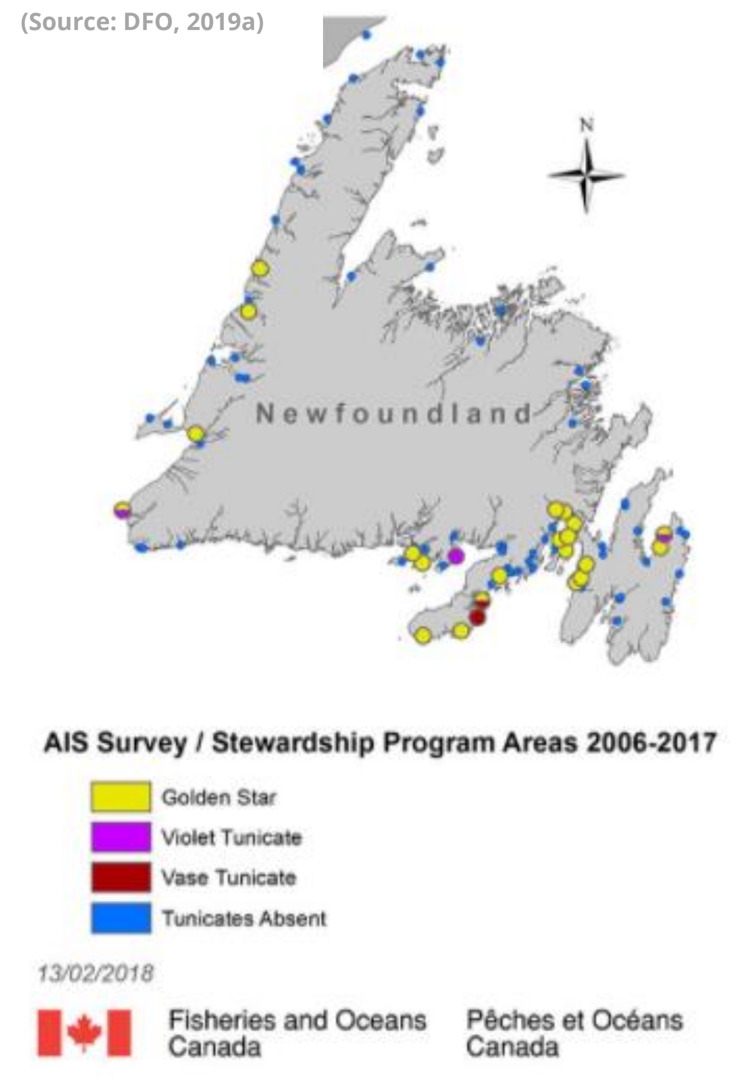
A climate change working group, hosted by the Marine Institute Centre for Fisheries Ecosystem research (CFER), for example, could serve to strengthen communication and knowledge throughout the province on climate change risks and vulnerabilities affecting the industry. Wide ranging stakeholder representation from associations, industry, academia, government, indigenous communities, and coastal municipalities may be recommended.

Case Study: Aquatic Invasive Species Monitoring

The Qalipu Natural Resources department has ongoing research and monitoring programs for species at risk, invasive species (since 2005), and climate change. Throughout 2019, QNR deployed climate and aquatic monitoring stations to collect valuable data that will be used to inform future climate change adaptation strategies (Qalipu First Nation, 2020). Since 2015, QNR have been working on research to better understand the golden star tunicate (an Aquatic Invasive Species in Newfoundland and Labrador). These filter feeders are a potential threat to mussel farmers and shellfish harvesters.

Memorial University of Newfoundland and DFO are also studying the reproduction cycle of the golden star tunicate at Arnold's Cove (DFO, 2019a). The adjacent figure represents the distribution of invasive tunicate in NL waters.

(Source: DFO, 2019a)



Case Study: A Spotlight on Fisheries and Oceans Science

DFO delivers two programs in the Atlantic Zone that collect and report data on changing ocean conditions. Through these programs, changes to both the physical (e.g., loss of sea ice), biological (e.g., species abundance), and chemical (e.g. acidification) marine environment are being observed. These observed changes are well documented and summarized in The State of the Atlantic Ocean report series, the most recent of which was released in 2018.

In the future, sea surface temperatures and sea levels may continue to rise along certain coastlines, while sea ice cover declines. These factors, along with shifting ocean currents and water quality changes, are all interconnected and contribute to physiological stress on marine species which may result in changing regional ocean productivity. Sea level rise and coastal erosion, which contribute to flood risk, is creating challenges for coastal communities, fisheries, and aquaculture. It is important to note, however, that not all coastlines are experiencing a proportional rise in sea levels and in some locations sea level is falling relative to the ground elevation, due to ground subsidence.

The shifting distribution of key species, including movement and abundance, is a concern for the commercial fishery. One important climate change impact is a result of shifting seasons and the timing of spring blooms that are essential food for forage fish. Studies by Fisheries and Oceans Canada on capelin population on the Newfoundland and Labrador Shelves, for example, found that a key factor for growth and spawning is the timing of melting sea ice in spring. Species that favour warmer water temperatures, such as the silver hake, may have an increasing advantage in Atlantic Canadian waters due to climate change (DFO, 2018a). This may also be true for new warm water adapted aquatic invasive species.

Important questions for commercial fisheries on the status of fish stocks now and into the future, include: (1) Will projected changes support or diminish the abundance of currently valuable commercial species off the coast of Newfoundland and Labrador?; and (2) Will projected changes create favourable conditions for new, exotic commercially valuable species off the coast of Newfoundland and Labrador?

Information on the status and trends of fish and invertebrate species through the Fisheries and Oceans Stock Assessments are critical pieces of scientific research that are building the foundational elements required to answer these challenging questions. The mussel sector relies on seed supply from the natural environment, the availability of which may change in the future. The long-term sustainability of the industry relies on continued research on fisheries sciences and resulting proactive resource management. It is recommended that the Government of Newfoundland and Labrador continue to work closely with the Department of Fisheries and Oceans to disseminate valuable findings of these ongoing studies to support mobilization and engagement on adaptation, and continue to advocate for enhanced data collection and research in Labrador bioregions.

Workforce Development

Changing labour force demographics are creating challenges for many natural resource-based industries in Newfoundland and Labrador. Sharing of lessons learned from historical and traditional knowledge and experience with past climate and resource shifts, to safety practices in extreme weather are all tools available for building resilience in a changing workforce. NAIA has developed a Recruitment and Retention Strategy for the Aquaculture industry that was informed though a Labour Market Analysis and Training Capacity Review completed in 2018. In relation to the wild fishery, the Professional Fish Harvesters Certification Board is currently working on a strategy to encourage younger people to participate in industry. It is recommended that through this program, a space for sharing lessons learned and best practices with harvesters who are new to the industry is established.

5.4 Forestry

In this chapter, recommendations have focused on top priority local infrastructure and data needs presented during stakeholder consultation. It is recommended that the following are considered as part of the overall provincial climate change adaptation strategy for the forestry sector:

Applying a Climate Lens to Forestry Management Plans

Currently, each Forest Management District must have a five-year operating plan released from the Environmental Assessment (EA). Consider incorporating climate change adaption during the preparation of the 5 year forest management plans and long-term strategic forest management plans, similar to requirements in Ontario, such as: (i) development of a predictive model for the growth and yield of under varying climatic growing conditions; (ii) testing tolerance to climate change by planting tree species outside of their natural range; (iii) developing a predictive model for the growth and yield of trees under varying climatic conditions; (iv) examining the genetic capacity of specific tree species to respond to increasing temperature and carbon dioxide levels.

Predictive models of forest growth and yield are typically calculated based on the assumption of stationary future climate (i.e. no climate change). This is problematic and may result in unreliable long-term growth forecasts with climate change (Searls et al, 2021). It is recommended that forest growth and yield projections with climate change are developed and incorporated into long-term forest management planning.

Foresters in Canada have already begun replanting harvested sites with trees better adapted to future climate conditions (NRCan, 2020d). Models can predict how future climate conditions are anticipated to change to better inform adaptation plans. However, there is high uncertainty in several of the processes that drive complex ecosystem changes with climate change and therefore the results of modelling should be interpreted through this lens. For this reason, adaptation strategies should take into consideration a range of potential future outcomes and take advantage of opportunities for diverse and **inherently flexible** approaches (Climate Atlas of Canada, n.d.).

Case Study: Forest Impact Modelling and Research

Impact modelling is being used to inform species risk assessments and forest productivity with climate change. Impact studies can be used to determine changes in forest growth at local and regional scales under future climate scenarios. Researchers are also using climate projections to develop an online mapping tool to visually depict how more than 3000 species may respond regionally to climate change (NRCan, 2021). Other initiatives include improved forest monitoring using remote sensing approaches and studying the sensitivity of forests to ecosystem changes and disturbance regimes (NRCan, 2021).

Innovative applied genetic research to help restore white pine populations in Newfoundland is being completed with climate change in mind. An interesting preliminary finding of this research is the potential to mix local seed with more southern sources to provide increased genetic diversity and climate resilience (NRCan, 2021). Ongoing monitoring and research related to invasive pests is encouraged. These initiatives may align with agriculture sector priorities (GovNL, n.d.).

Image: white pine tree species in Newfoundland (GovNL, n.d.).

Enhancing Sector Collaboration on Climate Change Adaptation

Create a working group to enhance sector collaboration, engagement, and foster partnerships with an aim to advance knowledge of the importance of climate change adaptation. Stakeholder representation could include: NFIA, province, Canadian Forestry Service, academia, Parks Canada, Indigenous governments and organizations, associations, research groups, NGOs, and industry. Create a clear vision, mandate, and expectations of the committee to facilitate and improve knowledge of projections, impacts, risks, and adaptation. The committee can aim to strategically leverage federal supports to ensure funding opportunities are not being missed.

Explore Opportunities for Expansion into Labrador

Improved access to Labrador (through changing ice and new highways) may create opportunities to expand industry operations further North; however, more study into the viability of forestry operations in Northern climates requires further research. A closer look at impact modeling related to future forest fire, drought, pests, and invasive species risk with climate change is recommended to be incorporated into feasibility assessment. There may be opportunities to partner with Quebec on research in the Labrador region.

Case Study: Labrador Climate and Weather Monitoring and Arctic Sea Ice Training

In 2017, through Queen's University, the community of Nain began a climate and weather monitoring network along existing traditional trail and travel routes in coastal Labrador with a focus on northern Labrador and Nunatsiavut communities (Government of Canada, 2015). An independent initiative began in 2018 to develop knowledge on the impacts of climate change on transportation throughout the sea ice season in Iqaluit, Arviat and Qikiqtarjuaq. The Artic Sea Ice Training initiative included the testing of larger scale training opportunities and challenges related to climate change on northern transportation (Transport Canada, 2019). Important data collected through these programs may be of use in assessing risk to the forestry sector in considering expansion into Labrador.


(Source: SmartICE, 2018)

Consider Wildlife Risks to Forestry Sector

Boreal woodland caribou populations have declined in Labrador due in part to climate change according to research completed by the Government of Newfoundland and Labrador. Notably, the relevant index for this impact analysis was increased freezing rain in fall, as ice prevents access to vegetation for feeding, placing caribou populations at risk. Snowfall is also linked to population survival through protection from predators (Schmelzer et al., 2020). The George River caribou herd is reportedly migrating into the northern Labrador boreal forest during winter (Schmelzer et al., 2020). Wildlife risks for species at risk or in decline should be considered when analyzing the feasibility of adaptation solutions. Although the risks of climate change on wildlife were not a focus of this report, future research opportunities would benefit from a focus on the impacts of climate change on wildlife, with a particular emphasis on species at risk. This is also true for the consideration of the historical and projected future ranges of wildlife species in sustainable forest management planning activities.

5.5 Agriculture

In this section, recommendations have focused on top priority local infrastructure and planning needs presented during stakeholder consultation. It is recommended that the following are considered as part of the overall provincial climate change adaptation strategy for agriculture:

Regional Climate Change Risk Assessment and Impact Analysis

It is recommended that cop specific (such as greenhouses, potatoes, and grains) climate change risk assessments are completed to identify relevant risks on a regional basis, with consideration of regional exposure, sensitivity, and adaptive capacity. This risk assessment will narrow in on priority areas by region and define the baseline conditions for these crops. Gaps in available climate monitoring station coverage and climate projections may be identified regionally. Regional climate data was identified in stakeholder consolation as a barrier to adaptation. Cross-cutting benefits of improved data may be available with other sectors.

Relevant, crop specific climate indices (used for projecting climate changes) are required based on sensitivity, exposure, and adaptive capacity for each crop. For example, drought projections for specific crops can reveal vastly different projected changes. Once regional projections become available for relevant indices, impact models can be used to assess regional impacts to key crops. Socioeconomic consequences and potential impacts to wildlife (particularly species at risk that rely on agricultural land for habitat) should be included in the analysis.

Case Study: Centre for Agriculture and Forestry Development

In 2018, the Wooddale Tree Nursery was converted into a Centre for Agriculture and Forestry Development. Today, the Centre is growing vegetable transplants for the agriculture industry and is serving as a facility for collaborative provincial research into crop diversification, among other initiatives. Genetic research into climate-resilient species was identified during stakeholder engagement as a potential priority area.

Applying a Climate Lens to Farm Planning

Studying the impacts of climate change on Newfoundland's agriculture and agri-food sector provides a basis for the development of decision support tools for policy makers and managers to further advance provincial food self-sufficiency targets. It is recommended that the province provides assistance to support farmers in the development of farm plans that incorporate climate change risk assessment and adaptation plans to address top priority risks for that region.

The first step in this process may be the inclusion of climate change risk assessment guidance and tools. One avenue to accomplish this is through the provincial Environmental Farm Plan (EFP) Workbook.

There are currently funding programs available, such as the provincial EFP program as well as the Environmental Sustainability and Climate Change Program under Canadian Agricultural Partnership (CAP), that may be leveraged to support this initiative. Access to funding may be dependent on the completion of an updated EFP that includes a climate change risk management plan.

It is recommended that the Government of Newfoundland and Labrador continue to work closely with the Agriculture and Agri-Food Canada to disseminate valuable findings of ongoing federal climate studies to support mobilization, awareness, and engagement on the need for adaptation across industry. Apply findings of these studies to farm and land development plans, as well as training, research, and innovation programs as part of a province -wide climate change strategy for forestry.

Sustainable Farm Management Practices

Stakeholders noted that it is particularly important that the correct policy be in place to implement holistic farm management solutions and practices that incorporate water resources management, nature-based solutions for adaptation (e.g., tree planting to combat erosion), and effective landscape design. Naturalized approaches may need to be tested for suitability in northern climates.

Development of a Beneficial Management Practice (BMP) guidance document for onsite water management is recommended. The BMP guidance document would cover topics such as nature-based solutions to drought management, rainwater capture and water reuse/ recycling, runoff and nutrient leaching, erosion control, protection of wetland features, as well as flood risk mitigation.

During stakeholder engagement, intensive and diversified farming and landscape practices, such as mixing crops through polyculture/ intercropping (instead of mono cropping) as well as “integrated farming” (e.g. having a mix of crops, livestock, and forest areas) was discussed as a resilience strategy to mitigate losses from an extreme weather year and may provide better landscape, water resources, and pest management. It is recommended that pilot programs are considered for measuring the success of diversified farming practices to better support the development of guidance measures that encourage these practices.

Complete a Water Resource Study

Drought was reported to be a concern for low-drought tolerant crops, such as potatoes. As a result, harvesters discussed considering the implementation of on-farm irrigation system during stakeholder consultation. Evaluating water resources in agricultural areas and the potential impacts of long-term irrigation on both surface and groundwater resources is recommended. Many stakeholders consulted as part of this projects reported having access to surface water (lake, river, stream) near the farm.

The conversion of boreal forests to agricultural lands may change soil properties, contributing to reduced groundwater recharge and increased downstream flood risk (Altdorff et al, 2017). For this reason, it is recommended that the impacts to water resources are considered within the context of relevant regional (and crop specific) drought-projections in the determination of suitable new areas for farmland. The downstream impact on fish and other aquatic species (e.g. ecological maintenance flows) should also be considered.

Creating a Business Case for Adaptation

With climate change, the province's mandate is to create knowledge around risks and opportunities and disseminate that knowledge to the industry. Industry is generally focused on shorter-term investment and climate change is typically a longer-term issue that needs the support of a strong business case. Educational material must be able to demonstrate how this risk impacts production, operation, or reduces risk on an annual basis with a strong cost-benefit. In the future, an incentive program may become the business case.

This recommendation could involve a combination of running a pilot program to establish options and measure cost-benefit and communicating the available options to industry (higher cost alternatives that increase resilience). The pilot program may include a method for analyzing risk and creating a best practice for: strategic wind break (consider the impacts on wind and snow), use of crop diversification and inter-crops (nutrient uptake and insurance against abnormal weather), as well as improved water resource management on site.

NL offers a crop insurance program under the Business Risk Management funding program to insure eligible crops against weather related perils such a drought, frost, wind and excessive rainfall. Currently, FFA is working to introduce new insurance products for other crops and help mitigate risk for farmers. There is a potential opportunity for a "building back better" approach through this program as well as the Canadian Agricultural Partnership program.

Opportunities in Labrador

This transdisciplinary research initiative would involve assessing agricultural sector opportunities in Labrador and could be a cross-cutting research effort with the forestry sector, as this aligns with advancement in northern climate research into climate related risks such as invasive species and forest fire. This research also aligns with feedback received from Northern and remote communities concerned about food security. Many stakeholders would be considered.

Case Study: Low-Input Agriculture in Cool Climate Boreal Ecosystems

The provincial government is currently collaborating with Agriculture and Agri-Food Canada, Grenfell Campus of Memorial University, and Corner Brook Pulp and Paper Ltd. on an assessment of the impacts of a warming climate on agricultural production in northern boreal growing regions such as Newfoundland and Labrador. The project involves studying soil health, as well as yield potential and quality of crop varieties to inform management practices that adapt to the local cool-climate growing conditions to reduce nitrogen fertilizer requirements and leaching. The project is expected to be cross-cutting and investigate opportunities to use the by-products of other industries such as fish sludge and paper mill waste (GovNL, 2020).

Create Pilot Programs

It is recommended that pilot programs are implemented for new design alternatives for increased wind and snow loads, including best practices for the use of wind breaks to protect commercial structures and greenhouses. Consider measuring the cost-benefit associated with more resilient construction alternatives or land use practices to present as part of the pilot program performance indicators. This data can be further used to encourage sustainable design of new farmland, including maintain tree cover and other nature based solutions to soil erosion and increasing wind loads.

Chapter 6 Closing

This study presents the impacts of climate change on multiple sectors for the purpose of guiding climate adaptation and resiliency planning focus areas for Newfoundland and Labrador.

It is projected that the province will become steadily warmer through mid- to late- century, with the largest increases in the Labrador interior and at high latitudes. Mean daily precipitation is expected to increase throughout most of the province by 2050 and nearly the whole province by 2100, for all seasons. Sea level rise is the primary contributor to extreme sea levels in the South, whereas in the North, storm surges and waves will dominate due to sea-ice loss. Although uncertainty remains high, the occurrence of extreme weather such as lightning, extreme wind, storms (e.g. nor'easters, hurricanes), and wildfires may increase.

A climate change risk assessment was completed with input from stakeholders in each of the target sectors to prioritize focus areas for proactive planning and action on climate change adaptation. Communities and stakeholder groups across the province are encouraged to apply the recommendations presented in this report to better understand and prepare for future climate conditions.

As climate science evolves and new data from impact models become available, the risk assessment presented in this report should be updated. While for most parameters, new climate models are not anticipated to drastically change the priority areas presented in this report, new projections should be monitored to assess risk implications.

FINAL REPORT

Prepared by:
Lindsay Allen, P.Eng.
Environmental Engineer
Direct: 709-364-8623
E-Mail: lallen@cbcl.ca

Reviewed by:
Lindsay Bolton, P.Eng.
Group Lead, Water Resources and Climate Change

APPENDIX A

Glossary

7-Step Method: A Government of Newfoundland and Labrador initiative designed to help communities assess their vulnerability to climate change. The seven-step process involves examining coastal vulnerability, flooding, slope movement, drinking water supply, wildfires, and winter conditions.

Atlantic Tropical Storms: A tropical cyclone that forms in the Atlantic Ocean, usually between the months of June and November. Tropical storms have one-minute maximum sustained winds of at least 63 km/h, which is less severe than hurricanes which are characterized by having one-minute maximum sustained winds exceeding 119 km/h (NHC, 2020).

Atlantic Zone: Encompasses the Gulf of Saint Lawrence, Quebec, Maritimes, and Newfoundland and Labrador regions of Fisheries and Oceans Canada

Atlantic Zone Monitoring Program (AZMP): A DFO program aimed to collect and analyze the biological, chemical, and physical field data that are necessary to:

- Characterize and understand the causes of ocean variability at the seasonal, inter-annual, and decadal scales
- Provide multidisciplinary data sets that can be used to establish relationships among the biological, chemical, and physical variables
- Provide adequate data to support the sound development of ocean activities

Atlantic Zone Off-Shelf Monitoring Program (AZOMP): A DFO program to collect and analyze data from the continental slope and the deep waters of the northwestern Atlantic Ocean.

Aquatic Invasive Species: Fish, invertebrate, or plant species that have been introduced into a new aquatic environment, outside of their natural range. One introduced, aquatic invasive species populations and grow quickly because they don't have natural predators in their new environment. As a result, they can out compete and harm native species, or alter habitats to make them inhospitable for the native species.

Blue Economy Strategy: A DFO initiative to harness ocean growth potential in Canada by building back better and bluer, by creating jobs in coastal communities while ensuring our oceans remain healthy.

Climate Change: Significant changes in global temperature, precipitation, wind patterns and other measures of climate that occur over several decades or longer, resulting predominantly from burning fossil fuels, which add heat-trapping gases to Earth's atmosphere.

Climate Change Adaptation: 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).

Climate Change Mitigation: actions made to limit the magnitude and/or rate of long-term climate change, generally involving efforts to reduce human emissions of greenhouse gases.

Climate Impacts: The potential consequences of climate change of particular climate variables, to systems, processes, and sectors. A description of an impact should include an identification of the 'someone' or 'something' that will be impacted, the specific way it will be impacted, and the reason the impact may occur.

Climate Risks: Potential adverse impacts from climate change such as extreme weather, floods or droughts, and sea-level rise. Risk is quantified by assessing the overall likelihood and consequences of a particular climate impact occurring.

Climate Variables: Specific aspects of climate characterization, such as temperature, precipitation, and wind.

Climate Vulnerabilities: The degree to which systems, processes, or sectors might be affected either adversely or beneficially by climate related impacts. Vulnerability assessments generally also identify the receptors, be they people, livelihoods, species or ecosystems in places and settings that may be adversely affected, as well as the degree to which an organization has financial, human, or technical resources to adapt to identify impacts of climate change (i.e. the adaptive capacity).

Coastal Erosion: The loss or displacement of land, or the long-term removal of sediment and rocks along the coastline due to the action of waves, currents, tides, wind-driven water, waterborne ice, or other impacts of storms.

Coastal flooding is governed by the combination of:

- **Still water levels** from tide, storm surge and sea level rise as defined in the present section.
- **Wave impacts**, including runup and overtopping wave components for areas exposed to ocean swell.
- **River** contribution for estuaries.

Cold Extremes: Excessively told temperatures relative to normal climate patterns of a certain region. Generally well below zero in Canada.

Daily Average Temperature: Mean of the temperatures observed at 24 equidistant times in the course of a continuous 24-hour period.

Daytime High Temperature: Maximum temperature reached in a 24 hour day, generally between 7:00 a.m. and 7:00 p.m.

Disturbance Regimes: The characterization of the cumulative effects of all disturbance events occurring in a govern area and time period**.**

Exotic Species: those species that occur in areas outside of their natural geographic range.

Extra-Tropical Storms: Major storms formed north of the tropics that produce wind speeds equivalent to those of weak hurricanes, resulting in very large waves and storm surges along coastal environments. Often referred to as Nor'easters or Weather Fronts. Formed when cold air masses interact with warm air masses on land or at sea (PSU, 2014).

Extreme Sea Levels: Higher or lower than normal water level thresholds for a particular location.

Fire Smart Canada: A national organization that leads the development of resources and programs designed to empower the public and increase neighbourhood resilience to wildfire across Canada.

Fish Stocks: the population or total mass of a fishery resource. The term fish stock usually refers to a particular fish population that is more or less isolated from other stocks of the same species. In a particular fishery, the fish stock may be one or several species.

Forage Fish: small pelagic fish (i.e. living neither close to the bottom nor near the shore) which are preyed on by larger predators for food, including larger fish, seabirds, and marine mammals.

Forest Change Toolkit: A lots of resources for climate change adaptation maintained by Natural Resources Canada.

Freeze-thaw Cycles: occurs when the daily maximum temperature is higher than 0 °C and the daily minimum temperature is less than or equal to -1 °C.

Freezing Rain: Rain that freezes on impact with the ground or solid objects.

Growing Degree Days: A weather-based indicator for assessing crop development. A calculation used by crop producers that is a measure of heat accumulation used to predict plant and pest development rates such as the date that a crop reaches maturity (Farmwest, 2020).

Growing Season: the portion of the year in which local conditions, including rainfall, temperature, and daylight, permit normal plant growth.

Guidance Document on Good Practices in Climate Risk Assessment: A document prepared by the government of Newfoundland and Labrador which provides a comprehensive review of climate change risk assessment methodologies and standards used at various scales in Canada and internationally.

Higher Intensity Precipitation: Above average levels of precipitation over a relative period of time. High intensity of rainfall on steep slopes may lead to flash floods, while on flat areas it may lead to ponding, or urban floods when the drainage capacity is insufficient for the intensity of the falling rain.

High-Grading: In forestry, a harvesting method that removes the trees of highest commercial value, leaving small trees, as well as large ones of poor quality and of low-value species (CPF, 2012).

Horticulture: The branch of plant agriculture dealing with garden crops, generally fruits, vegetables, and ornamental plants.

Ice-Jam Flooding: Occurs when floating river ice accumulates at a natural or man-made feature that impedes the progress of the ice downstream with the river current. Ice jams can significantly reduce the flow of a river and cause upstream flooding.

Inherently Flexible: able to easily adjust and quickly decide on next steps or transition to new methodologies.

Intensive Operations: a type of agriculture, both of crop plants and of animals, with a higher use of inputs such as capital and labour, and higher crop yields relative to land area.

Invasive Species: an exotic species that threatens the native species to the ecosystem.

Marine Food Web: A system of interconnected food chains indicating what eats what in the marine environment.

Mean Daily Precipitation: A measure of the average amount of precipitation anticipated to fall each day in a particular climate region.

Mean Sea-Level Rise: The average, long-term global rise of the ocean surface measured from the centre of the earth, as derived from satellite observations.

Mid Winter Thaw Events: A thaw or rise in temperature occurring in mid-winter, generally linked to intrusion of warm air from southerly flow, and may be associated with fog, rain and/or freezing rain, and typically last for several days. This weather event is an anomalous departure from the average annual temperatures at about the same time on a calendar.

Natural Variability: the variation in climate parameters caused by nonhuman forces.

Newfoundland and Labrador Shelves: The region of the North American continental shelf situated off the coast of Newfoundland and Labrador. This area is relatively shallow which allows light to reach the seabed, therefore photosynthesis occurs throughout the water column enabling the growth of phytoplankton, the first link in the marine food chain. These conditions normally favour reproduction and help explain the abundant stock of fish and marine mammals in the region.

Nighttime Low Temperature: Minimum temperature reached in a 24 hour day, generally between 7:00 pm and 7:00 a.m.

Number of Days with Frost: total number of days with a minimum temperature below zero degrees Celsius between the first frost day in autumn and the last frost day in spring

Ocean Productivity: Primary productivity is the rate at which atmospheric or aqueous carbon dioxide is converted by autotrophs (primary producers) to organic material. In the oceans, almost all primary producers are algae, with a small fraction contributed by vascular plants and other groups. Algae encompass a diverse range of organisms, ranging from single floating cells to attached seaweeds. The total amount of productivity in a region or system is gross primary productivity. A certain amount of organic material is used to sustain the life of producers; what remains is net productivity. Net marine primary productivity is the amount of organic material available to support the consumers (herbivores and carnivores) of the sea.

Permafrost: Any ground that remains completely frozen (0°C or colder) for at least two years straight. These permanently frozen grounds are most common in regions with high mountains and in Earth's higher latitudes

Precipitation Intensity: the ratio of the total amount of rain (rainfall depth) falling during a given period to the duration of the period. It is expressed in depth units per unit time, usually as mm per hour (mm/h).

Relative Sea-Level Change: How the height of the ocean rises or falls relative to the land at a particular location.

Representative Concentration Pathways: Greenhouse gas concentration trajectory adopted by the International Panel on Climate Change. The pathways describe different climate futures, all of which are considered possible depending on the volume of greenhouse gases emitted in the years to come. The RCPs – originally RCP2.6, RCP4.5, RCP6, and RCP8.5 – are labelled after a possible range of radiative forcing values in the year 2100 (2.6, 4.5, 6, and 8.5 W/m2, respectively) (Moss et Al, 2008).

Sea-Level Rise: Increase in the level of the world's oceans due to the effects of global warming. Global Mean SLR will accelerate due to climate change, causing increased risks of coastal erosion and flooding. Relative sea level rise (RSLR) represents Global Mean SLR corrected with local factors including but not limited to vertical land motion.

Secondary Processing: Converting raw food ingredients into more useful or edible forms. Secondary food products are refined, purified, extracted or transformed from minimally processed primary food products. For example, dairy, flours, edible oils, or sugars and sweeteners.

Snow Cover Fraction: Portion of the land surface covered by snow on a monthly basis.

Snowfall Extremes: Major snowfall events characterized by a relatively higher intensity and duration longer than normally experienced in a particular climate region.

State of the Atlantic Ocean Report: A DFO report describing the status and trends in ocean science in bioregions of the Gulf of St. Lawrence, Scotian Shelf, and Newfoundland Labrador Shelves.

Storm surge: Storm surges are created by meteorological effects on sea level, such as **wind set-up** and low atmospheric pressure, and can be defined as the difference between the observed water level during a storm and the predicted astronomical tide. Regional storm surge trends can be inferred from large-scale models, and nearby tide gauge observations if available.

Value-Added Manufacturing: A process which transforms raw materials or primary commodities into much more valuable goods and services to customers downstream. For example, producing cabinets, furniture, or engineered wood products from untreated wood, lumber, or plywood.

Warm Extremes: Period of excessively hot and sometimes also humid weather relative to normal climate patterns of a certain region.

Warmer, Wetter, and Stormier: Weather conditions resulting from increased levels of atmospheric carbon, which has led to warmer oceans, increased sea-level, increased air temperatures, and the ability for the atmosphere to hold more water. These factors contribute to making storms more intense with heavier, prolonged rainfall,

Wind Set-Up: The Increase in mean water level along the coast due to shoreward wind stresses on the water surface.

Winter Rainfall: Rainfall occurring from January to April associated with higher than average temperatures for a region that would primarily see snowfall throughout the winter months. Can lead to water accumulation on streets and in parking lots due to partial or complete blockage of manholes by snow and ice. This type of event is generally followed by sudden temperatures drops that transforms the buildup of rain into ice-covered surfaces (Groleau et Al., 2007).

APPENDIX B

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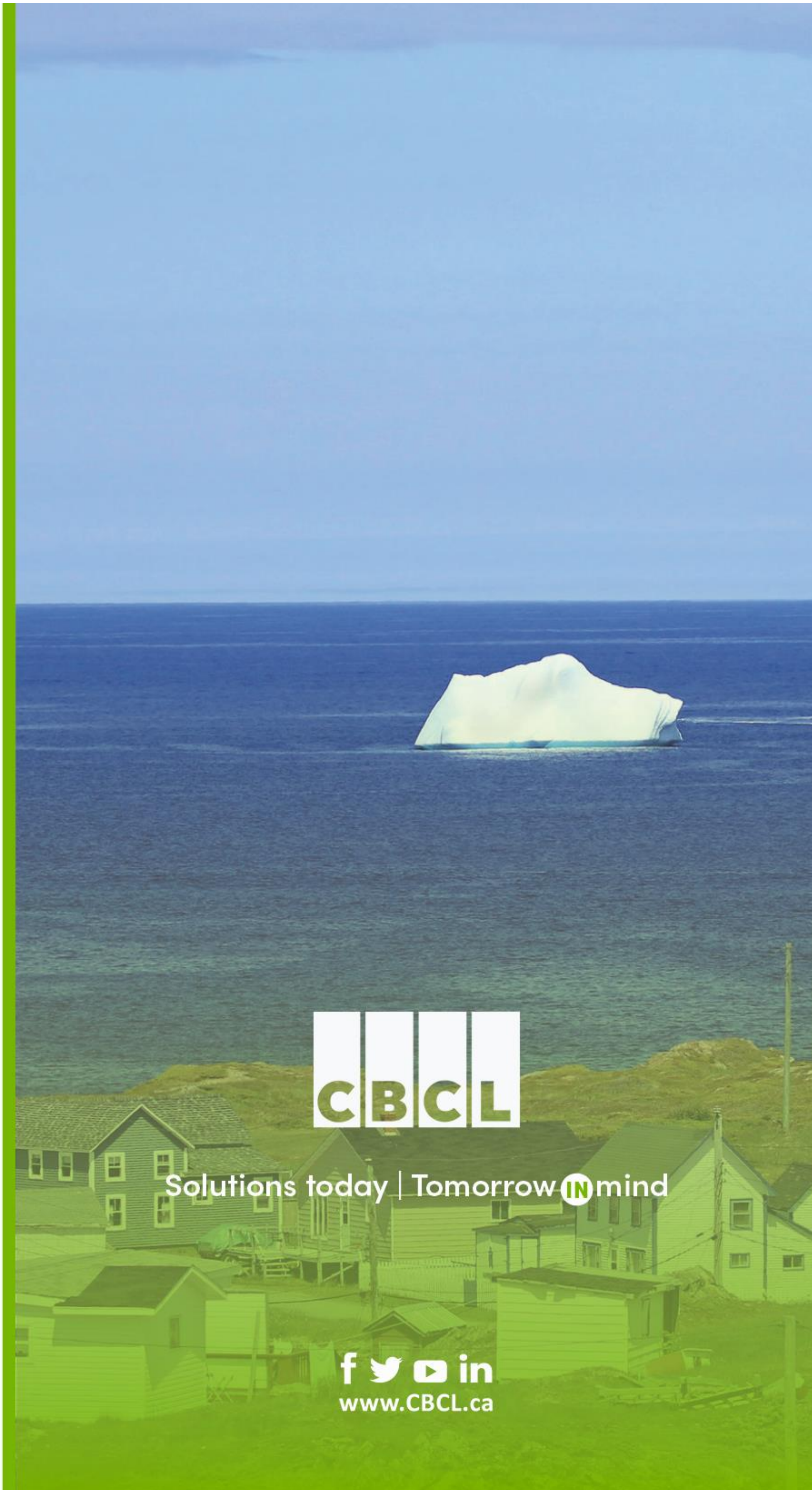
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