Climate Risk and Resilience Assessment

Louis Bull Tribe

60697636

April 2024

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April 8, 2024

Project #
60697636

Subject: Climate Risk and Resilience Assessment

Dear Ms. Selin:

Attached please find the final report for the Climate Risk and Resilience Assessment of the Louis Bull Tribe lands and community.

Sincerely,
AECOM Canada Ltd.

Randy Rudolph, M.Sc.
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Encl.

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Executive Summary

Louis Bull Tribe (LBT) retained AECOM to conduct a Climate Risk and Resilience Assessment (CRRA) to identify and evaluate the risk that climate-related hazards may have on its infrastructure, its people, and the natural environment. Over the course of the CRRA, the historical and future climate portraits for the were established. Based on the identified climate hazards, the climate-change-related risks were assessed before recommendations to increase the resilience of LBT were developed.

Key Messages

1	With climate change, the weather at LBT will be warmer with less snow in winter, more frequent heavy rainfall events, prolonged droughts, and a higher likelihood of wildfires.

2	Periods of high temperatures can lead to poor air and water quality. Heat exhaustion, heat stroke, dehydration, and heat stress are common health risks when adequate cooling is not available. These ailments affect the vulnerable population such as elderly people, children, pregnant women disproportionately. An increased mortality rate is often observed during periods of extreme heat.

3	In warmer and drier environments, wildfires will burn hotter and faster and consume a greater area, causing potentially significant damage to buildings and agricultural fields. Distant wildfires that do not directly threaten LBT infrastructure can reduce the air quality and lead to major health problems.

4	The structural integrity of buildings is threatened by accelerated degradation, deterioration, corrosion, and weathering of materials and foundations due to more frequent and heavier precipitation events. Degraded windows and doors can lead to the infiltration of water and the development of mold, potentially affecting people’s health.

5	Heavier precipitation can lead to flooding due to runoff or flash floods. Property damage or capacity exceedance of the wastewater and sewage system can result in the release of untreated water into nearby water bodies, posing a contamination risk to the surrounding ecosystem.

6	The local vegetation of native grassland with islands of aspen, willow shrubs, balsam will transition to an ecosystem dominated by porcupine grass, wheatgrasses, and fescue. These changes threaten Indigenous cultural maintenance, traditional activities, and land uses, such as hunting, fishing, and gathering of berries and other plants. Medicinal plants, their availability, abundance, accessibility, and pharmaceutical properties are potentially impacted by climate change.

7	Develop a FireSmart Community Plan, including a wildfire preparedness guide, removing dead vegetation, increasing community awareness, wildfire fighting training, etc. will increase the resilience of the community (FRIAA FireSmart Program).

8	The introduction of effective water management practices, including establishment of rainwater retention ponds and wetland restoration will reduce the impacts of heavy rainfall events and flooding. These practices could also reduce the stress on groundwater resources and ensure reliable access to clean water sources for agriculture and livestock, especially during heat waves.

9	Climate change will contribute to the decline in groundwater availability. Decreased recharge due to longer and more frequent droughts, reduced snowfall and diminished snowmelt in the larger watershed will likely result in groundwater shortages over the next 10 to 30 years at current withdrawal rates.

10	Develop an Emergency Preparedness and Management Plan which includes climatic or extreme weather events provides crucial guidance to the community. The expansion of existing plans by including extreme weather and climatic events is recommended.

Climate Change at the Louis Bull Tribe

With global climate change, the local climatic conditions at the LBT are changing. Climate models that provide projections of future climatic conditions show an increase in daily mean temperature and heat waves, a noticeable increase in rainfall events, the potential of prolonged droughts, and more wildfires, among other changes to the local climate.

Increasing the mean temperature makes winters milder with shorter snow cover duration and less snow accumulation. The influence of heat waves during summer can extend into the transition periods of spring and fall and potentially increase the length and intensity of dry periods or droughts (but also increase the length of the growing season). Consequently, an increased wildfire risk is likely. Extended periods of dry and hot weather make it easier for fires to ignite and spread rapidly. Fires can have a wide range of significant impacts on the LBT, affecting various aspects of the health of community members, infrastructure, air and water quality, increased risk of post-fire flooding and landslide, and the ecosystem.

In addition to a potential increase in drought frequency, the change in precipitation pattern will also lead to heavier and more frequent rainfall events. Extreme rainfall amounts over short periods, such as rain- or thunderstorms, can lead to flooding due to runoff. Climate change also impacts winter precipitation with an increase in freezing rain events which can pose a risk to infrastructure and power lines, leading to icy and hazardous conditions for community members.

Climate Change Impact on Ecosystems and Traditional Way of Life

The ecosystem surrounding LBT is characterized by the Central Parkland subregion, which is heavily cultivated and therefore highly fragmented by cropland, with isolated islands of aspen, willow shrubs and balsam. Climate change with its different aspects will push the vegetation towards a transition to an ecosystem dominated by porcupine grass, wheatgrasses, and fescue. This shift is a challenge to Indigenous cultural maintenance, as culturally important species shift their range beyond the tribal land area. Traditional land uses and cultural activities of LBT, such as hunting, fishing, and gathering berries and other plants will subsequently be impacted.

Similarly, agricultural land and practices will be affected by climate change. Some changes such as increased drought frequency or invasive species increase the risk to LBT. Reduced water availability can lead to reduced crop and grass yield as well as to reduced animal health or weight of cattle and bison. Groundwater depletion can cause, among other things, the drying of wells, the spread of underground contaminants, and ground subsidence. The plant and animal health can further be threatened by invasive species such as striped fleas beetle, deer ticks, and biting midge whose range and prevalence will continue to expand. Other aspects of climate change such as a lengthening of the growing season will bring new opportunities.

Climate Risk and Resilience Assessment

In addition to the impacts of climate change on the natural environment and the ecosystem at LBT, climate change has the potential to affect the built infrastructure and the residents, workers, and visitors of LBT. The impacts can affect the health and safety of people, compromise the structural integrity of buildings, impact the operations (e.g., services rendered), and lead to increased financial costs due to either direct damages or increases in operational costs. For each asset or operation of LBT and each aspect of climate change, the effects will be different, and for some aspects, such as winter heating costs, climate change may be beneficial.

LBT's infrastructure and people are likely to interact with or be influenced by climate risks. Hence, the CRRA focuses on the impacts of climate change on the primary needs and high-priority issues of the LBT which include:

- Regenerative Agriculture and Food Sovereignty, including:
  - Poultry production on a family scale
  - Bee keeping
  - Cattle and pasture improvement
  - Bison herd management
  - Fishing on a stocked lake
  - Local crops feed LBT livestock
- Reclamation of oil and gas sites, including reduction of fragmentation.
- Impact on Land 4 Prosperity (L4P) programs including a Culture Camp, youth education opportunities, composting and waste management and the Healing Forest Campground
- LBT infrastructure and impacts on people - residences, school, Admin Building, community centre, wastewater treatment plant.

Based on the material and information provided by the LBT, AECOM generated a list that is comprised of ten asset groups that combine assets of similar type, risk profile, or adaptation strategy. The list covers the primary needs and high-priority issues and reflects the top economic development opportunities in no particular order:

- Community buildings
- Roads and bridges
- Wastewater and sewage system
- Potable water system
- Culture camp and Healing Forest campground
- Agriculture and pasture
- Livestock
- Waste management
- Residential buildings
- People

For each of the asset groups, the effects of climate change were determined. As climate change is an ongoing transition and depends on the human behaviour over the next decades, the impacts were determined using three time-horizons (2030s, 2050s and 2080s), assuming continued and unabated emissions of greenhouse gases. This approach allows for the assessment of the vulnerabilities of the LBT infrastructure in the worst-case scenario without adequate international efforts to reduce the emissions.

Climate change takes multiple forms and can be expressed in different ways. Not all of them pose a threat to LBT. By focusing on a small but representative number of indicators for which the risk increases, a description of the vulnerabilities and risks to the built infrastructure and people of LBT was developed. The indicators include:

- Mean temperature
- Maximum temperature
- Heat wave
- Drought
- Daily rainfall (a once in 10-year event)
- Freezing Rain
- Wildfire
- Thunderstorm

Each combination of asset group and climate indicator has been evaluated individually, and a risk assessment was conducted. For example, high temperatures or heat waves lengthen the wildfire season, and in combination with low precipitation amounts, increase the potential of wildfires due to low soil moisture and drier vegetation. In warmer environments, wildfires tend to burn hotter and faster and consume a greater area. These fires can cause major damage to buildings and agriculture fields. Even in the case of wildfires that do not directly threaten the infrastructure, the reduced air quality can lead to significant health problems.

People's health can also be impacted by hot periods that can lead to a degradation in potable water quality as well as a degradation in air quality. Furthermore, extreme temperature events will directly affect people's wellbeing and productivity. During high temperature regimes, heat exhaustion, heat stroke, dehydration, and heat stress are common health risks when adequate cooling is not available. These ailments affect the vulnerable population such as elderly people, children, pregnant women disproportionately and in extreme cases could lead to death.

The increased likelihood of extreme precipitation can pose a threat to the structural integrity of buildings by accelerated degradation, deterioration, corrosion, and weathering of materials and foundations. Degraded windows and doors can lead to the infiltration of water and the development of mold that can affect health. This can equally affect community buildings, residential buildings, or the water treatment plant.

In addition, heavy precipitation has the potential to increase the occurrence of flooding due to runoff or flash floods. These events may lead to property damage or exceed the capacity of wastewater and sewage system, which could result in the release of untreated water into nearby water bodies, posing a contamination risk to the surrounding ecosystem.

In summary, climate change alters the risk to LBT. The increased risk of higher average temperature and heat waves poses an increased risk to the community, its infrastructure, and its natural environment due to wildfires and health implications. Additionally, heavy rainfall and associated flooding will increase the risk level of LBT. Other risks include the threat of freezing rain to the infrastructure integrity and community health and safety.

To reduce the vulnerability of LBT, recommended adaptation measures include:

Wildfires:

- Proceed with prescribed or cultural burning, tree thinning, pruning, understorey vegetation and litter management to minimize wildfire risk at the wildland/urban interface (prevention of wildfires).
- To limit damage and disruption from wildfire events, prune trees in the proximity to buildings to create a 2 m clearance from the ground to the lowest tree branches; remove all combustible ground cover (mulch and plants) within 1.5 m of the building's perimeter; remove needles, leaves and other debris from gutters, roof surfaces, decks, and balconies.
- Designate at least one emergency shelter per community; ensure minimum water supply for firefighting efforts.
- Develop a wildfire preparedness guide, increase community awareness, etc. to increase the resilience of the community (FRIAA FireSmart Program).

Heat and High Temperature:

- To reduce the risk of extreme heat exposure, install blinds, heat-resistant curtains, or films on windows; Shade windows with outdoor shutters and awnings.
- To reduce indoor heat gain and provide a comfortable environment for workers and visitors of community buildings and residents at home and reduce energy consumption, consider adding shades and awnings to building windows, especially along south, east, and west facing walls.
- For new-builds and renovations, use materials that are resistant to or limit the accumulation of heat, such as light-coloured materials such as white (high albedo); paint roofs with light reflective colours or use materials with high thermal resistance to reduce heat gain. In general, take into account the effects of climate change in the choice of materials, refer to the standards established by the Canadian Standards Association (CSA) and the updated National Building Code (2020).
- As an interim measure, community buildings can be used as a cooling and heating centre until residential building are upgraded or adapted.

Heavy Rainfall:

- Building water retention ponds or restoring wetlands will lessen the impacts of heavy rainfall and resulting flooding by capturing the water.

Drought:

- To mitigate agricultural vulnerability to drought, extreme temperatures, and heat waves, choose resistant crop varieties, diversify crop types. Heat-tolerant and climate adapted crop varieties are more likely to withstand extreme temperature periods and drought.
- A water retention pond can provide additional fresh water used in agriculture.

All Risks:

- Develop and implement an Emergency Preparedness and Management Plan in the case of climate or extreme weather events.
- To increase safety in case of fires, floods and other extreme event that might require evacuation, provide two or more access and egress routes to critical buildings and culture camp.

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1. Introduction

1.1 Background Information

Louis Bull Tribe (LBT) is one of the Cree Nations in Alberta. As part of the Four Nations of Maskwacis, the tribal land, located in central Alberta about 90 km south of Edmonton, encompasses 3,127 hectares (7,727 acres). While parts of the land are used for agriculture, forested areas spread throughout. The main community centre for the approximately 2,380 General Tribal members is located towards the south neighbouring the Ermineskin Cree Nation. However, individual houses and home can be found across the community (**Figure 1-1**).

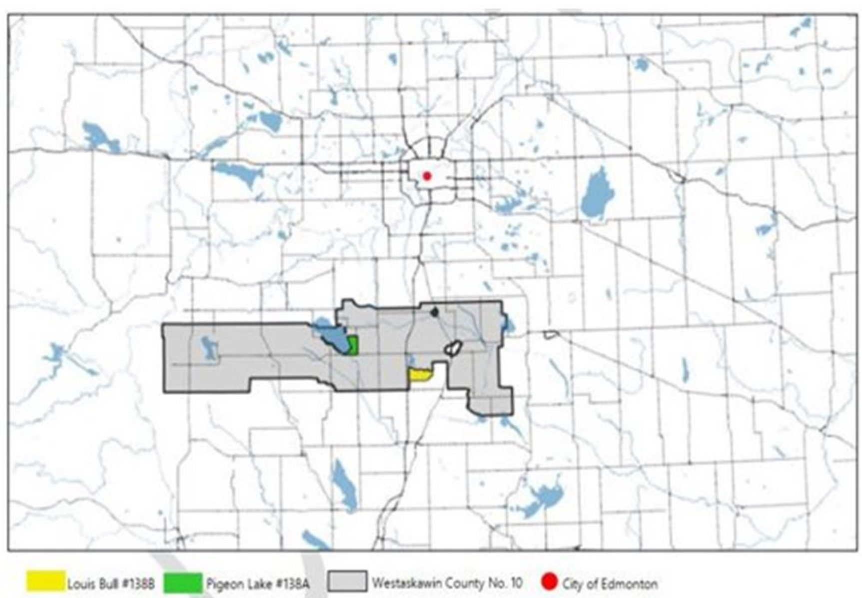
In addition to owning several businesses, LBT has developed the Land for Prosperity (L4P) Program to further improve the economic prospects while at the same time connecting the community with the land. The combination of regenerative land management and agricultural production with Indigenous knowledge and cultural and traditional education will maximize economic opportunities and ensures a continuation of traditions and Indigenous culture (**Figure 1-1**).

Having identified climate change as a risk factor to their community and the L4P Program, LBT is working to identify and evaluate the risk that climate-related hazards may have on LBT infrastructure, its people, and the natural environment. To this end, it is taking action to adapt to a changing climate and its anticipated impacts. A Climate Change Risk and Resilience Assessment (CRRA) is an important step for the LBT to evaluate of the community's vulnerabilities and exposure to different climate-related hazards. Consequently, it offers guidance for the management and the prioritisation of investments in adaptation measures.

L4P

Summary of LBT off-reserve land use

Current Us age	%	Acres
Crop	24%	2,681
Hay	1%	142
Pasture	30%	3,421
Forest	36%	4,014
Other	9%	974
Total Acres		11,232



Source: Louis Bull Tribe

Figure 1-1: Location and Boundaries of Louis Bull Tribe

1.2 Objectives

The objectives of this CRRA are to identify and evaluate the risks that climate-related hazards may have on the LBT infrastructure, its people, and the natural environment, and to recommend resilience measures to decrease the impact of these hazards. This assessment was completed following the Public Infrastructure Engineering Vulnerability Committee (PIEVC) High Level Screening Guide (HLSG) in alignment with the ISO 31000 Risk Management Standard.

1.3 Study Scope

The scope and boundaries of the assessment encompass time periods and areas during and within which the LBT, its infrastructure and people are likely to interact with or be influenced by climate risks. Hence, the CRRA focuses on the impacts of climate change on the primary needs and high-priority issues of the LBT which include:

- Regenerative Agriculture and Food Sovereignty, include:
  - Poultry production on a family scale
  - Bee keeping
  - Cattle and pasture improvement
  - Bison herd management
  - Fishing on a stocked lake
  - Local crops feed LBT livestock
- Reclamation of oil and gas sites, including reduction of fragmentation.
- Impact on L4P programs including a Culture Camp, youth education opportunities, composting and waste management and the Healing Forest Campground
- LBT infrastructure and impacts on people - residences, school, Admin Building, community centre, wastewater treatment plant.

The casino (opening planned for 2024) is outside the scope of this CRRA.

To build resilience and adaptive capacity in the community in the medium and long term, the CRRA for three time-horizons (2031-2040 or 2030s, 2046-2055 or 2050s and 2076-2085 or 2080s) has been provided. In addition, a high-level assessment also considers potential impacts of climate change to the traditional way of life of the community.

1.4 Work Plan

The CRRA was undertaken following the four key steps described in the Public Infrastructure Engineering Vulnerability Committee High Level Screening Guide (PIEVC HLSG), in alignment with the ISO 31000 Risk Management Standard (PIEVC, 2021). These steps are described below:

Scope	This step established the objectives and the context (e.g., location, setting, and time horizons) of the CRRA, and AECOM closely collaborated with LBT during this and subsequent steps. Discussed in **Section 1.3**.
Assets and Climate	During this step, the data for the CRRA and include assets, systems, and surrounding environment were collected to be assessed along with past experiences of extreme weather and climate impacts and other relevant traditional knowledge that LBT shared with AECOM. Other climate information was extracted from publicly available sources for both historical data and future climate projections for the area. Discussed in **Section 2**.
Risk Identification and Assessment	This step completed the main portion of the CRRA. The risk assessment was undertaken by determining if the assets have been affected or will experience any impacts from historic and future climate and to assess the consequences of these impacts by developing associated and applicable risk scoring. High level feedback was sought to ensure a relevant and useful CRRA. Discussed in **Section 3**.
Risk Treatment and Adaption Measures	For the final step in the CRRA, the identified risks were evaluated and assessed and recommendations for LBT were developed. These adaptation measure, together with the results of the previous three steps are laid out in this Climate Resiliency Plan. Discussed in **Section 4**.

2. Louis Bull Tribe Assets and Climate

The objective of this CRRA is to identify and evaluate the risk that climate-related hazards may have on LBT infrastructure, its people, and the natural environment, and to recommend resilience measures to decrease the impact of these hazards.

2.1 Louis Bull Tribe Assets, Elements, and Operations

Based on the material and information provided by LBT, AECOM proposed ten (10) groups of assets that include further elements, their operations, and services. These assets were determined to be relevant to the CRRA for their potential sensitivity to certain climate conditions (**Table 2-1**). They were developed in alignment with the priorities and the top economic development opportunities of LBT. The assets in **Table 2-1** are not listed in any particular order.

Table 2-1: List of Assets

#	Assets	Description and Information	
1	**Community buildings**	■ Fire hall ■ Trade shops / workshops ■ Warehouse ■ Daycare centre	■ Recreation/hall/cultural centre ■ Youth/senior centre ■ Kisipatnahk school
2	**Roads and bridges**	■ Earth road ■ Gravel roads	■ Paved roads ■ Vehicular bridges
3	**Wastewater and sewage system**	■ Vacuum truck ■ Sanitary main ■ Sewage lagoon	■ Septic tank and field ■ Jet pump disposal ■ Disposal system
4	**Potable water system**	■ Well control building ■ Emergency hand pump ■ 3 Pumphouses ■ Water treatment plant/distribution building ■ Water main	■ Water storage reservoirs ■ Wells ■ Truck fill station ■ High level lift station (pumps) ■ Water truck ■ Distribution pumphouse
5	**Culture camp and Healing Forest campground**	■ South of Battle Lake (planned according to the business plan)	■ For youth, locals, and visitors
6	**Agriculture land (field and pasture) and fisheries**	■ Agricultural land (the actual land – soil, etc.) - For growing crops - For pasture	■ Crops/grass/hay ■ Lake for fishing
7	**Livestock**	■ Poultry and turkey ■ Bees ■ Bison	■ Cattle ■ Fish
8	**Waste management**	■ Transfer station	■ Solid waste trucks
9	**Residential buildings**	■ No A/C ■ Natural gas heating	■ Central electrical service
10	**People**	■ Residents ■ Visitors	■ Employees

Note: Descriptions and detailed information added where available

2.2 Climate and Climate Change

The local climate and its changes were analyzed using observations collected by Environment and Climate Change Canada (ECCC) at Brightview, AB about 15 km away. Due to the proximity, the climate data measured in Brightview are representative for LBT. However, as the dataset is incomplete and misses hourly observations of wind, freezing rain, relative humidity, etc., supplementary data obtained at the Edmonton International Airport about 50 km distant have been used.

The local climate profile was established by averaging meteorological data of 30 years to eliminate high-frequency natural variability. The timeframe between 1981 and 2010 was chosen as the climate reference period as it reflects the baseline of the climate change projections and is currently used by ECCC. Using the temperature and precipitation data, the climate at LBT can be characterized as a continental humid climate, wet all year with mild summers.

For the climate reference period, the monthly averages of daily mean, maximum, and minimum temperature (Tmean, Tmax, and Tmin, respectively) and total monthly rainfall and snowfall, measured in mm and cm, respectively, show a distinct annual cycle (**Figure 2-1**). The daily mean temperature ranges from -9.9°C to 16.4°C. Over the same period, the daily maximum temperature has reached 35.5°C, while the lowest minimum temperature was -42.0°C.

The annual cycle of precipitation shows a pronounced maximum for the summer months, indicating the frequent occurrence of convective precipitation events in the form of rain showers, thunderstorms, etc. Over the late spring, summer, and early fall months, snowfall is rare and does not occur at all in June and July. Conversely, rainfall occurs infrequently between November and February. The maximum daily precipitation measured between 1981 and 2010 was about 96 mm.

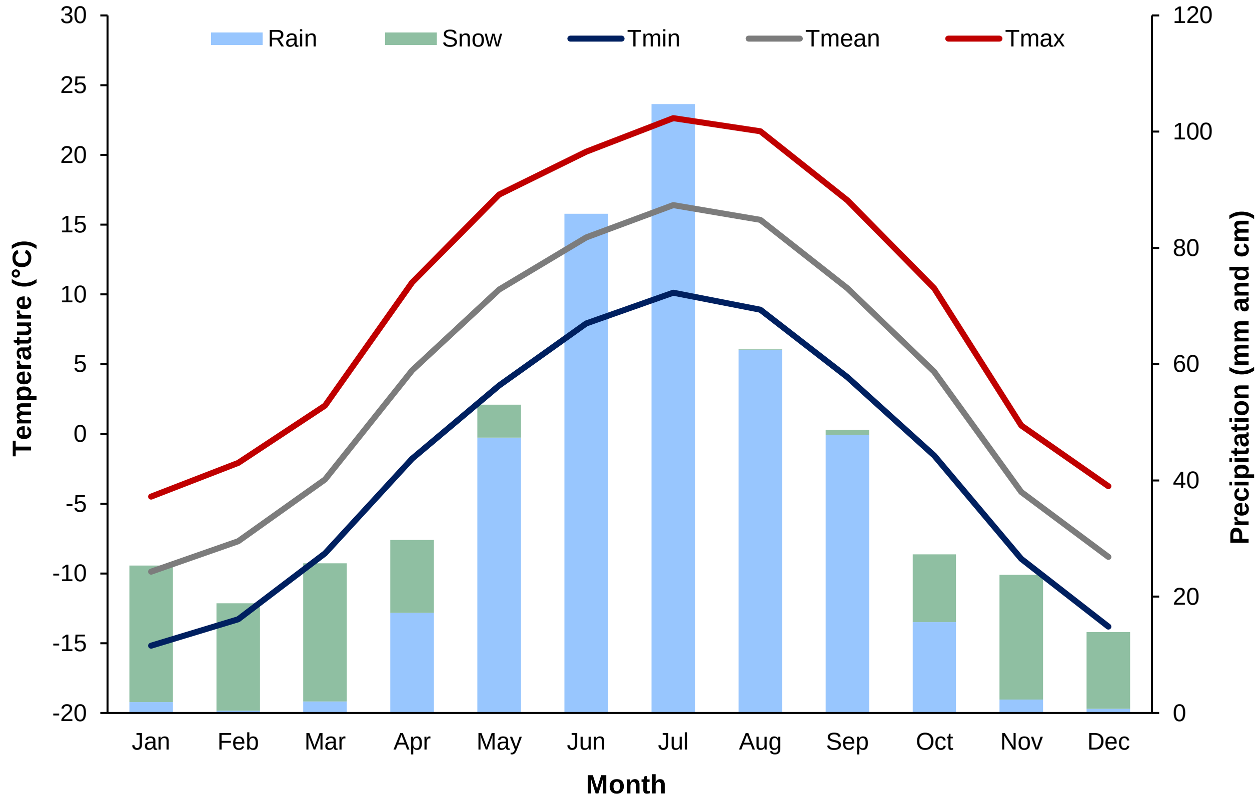


Figure 2-1: Historical Climate at Louis Bull Tribe (1981-2010)

The climate at LBT is changing due to human activities in the form of the extensive burning of fossil fuels and the large-scale transformation of land use which have led to significant increases in concentrations of greenhouse gases (GHGs) in the atmosphere. At LBT, the changes take the form of increasing temperatures with more frequent occurrences of hot days or heat waves. For example, the daily mean temperature at LBT has increased from 2.0°C to 4.3°C between the early 1970s and the early 21st century and additional increase of 4.5°C until the end of the century is projected using a high-emission scenario (RCP8.5[1]; **Figure 2-2**A). The colored shading ranging from 6.7 to 10.8°C indicate the range of the different climate models and can be viewed as a measure of uncertainty inherent to the climate projections.

With the increase in annual mean temperature, the temperature extremes are also projected to increase. The high temperature record towards the end of the century is likely to exceed 40°C and the probability of high temperatures (daily maximum temperature ≥ 30°C) increases from 73% for the climate reference period to 92% in the 2050s. For the 2080s, the probability of high temperatures reaches close to 100%. Furthermore, the probability of heat waves (defined as 3 consecutive days with daily maximum temperature above 30°C) is projected to increase from 8% for the historical reference period to 90% towards the end of the century. At the same time, the duration of heat waves and their intensity will increase over the course of the century.

At the same time, both snow- and rainfall amounts have increased over the last few decades. Despite this recent increase in snowfall, a slight decrease of the annual snowfall is projected with climate change throughout the century as winter temperatures are increasing (**Figure 2-2**B). On the other hand, the annual rainfall sum is projected to increase by 17% in the high-emission RCP8.5 scenario. Beyond the changes in annual precipitation amounts, their distribution pattern will change with extreme precipitation events such as 10-year rainfall events which currently bring 70 mm of rain seeing an increase in intensity by 80%. This increase is partly due to the likely transition to more convective precipitation events in the form of thunderstorm etc. Other inherent features of thunderstorms such as lightning, high wind speeds also have the potential to increase with climate change. However, the uncertainty regarding these features is very high.

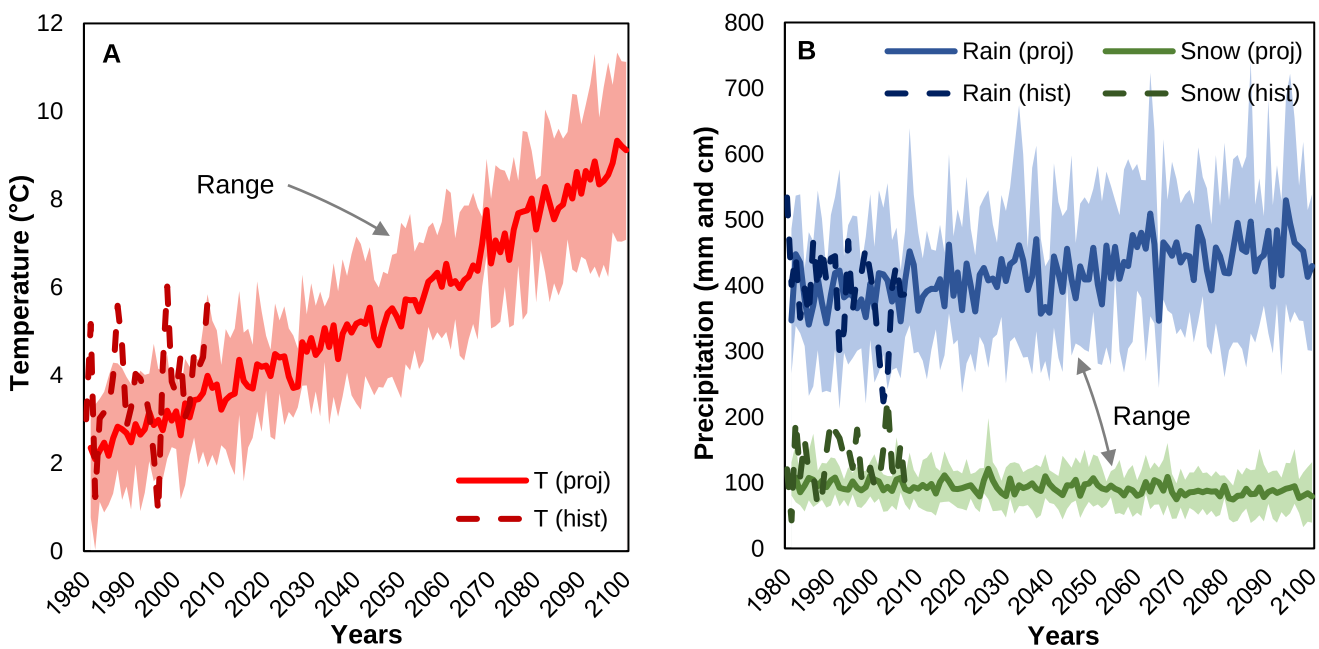


Figure 2-2: A) Projected Daily Mean Temperature Annually Averaged and B) Projected Rainfall and Snowfall Sum at Louis Bull Tribe Using the High-Emission RCP8.5 Scenario

A detailed discussion of the historical climate at LBT and the climate projections is included in **Appendix A**.

1. *The high-emission RCP8.5 scenario was used throughout the CRRA as a conservative assessment of future climatic changes. Current emission reduction policies will potentially lead to somewhat lower GHG concentrations.*

2.2.1 Climate Change Impact on Ecosystem

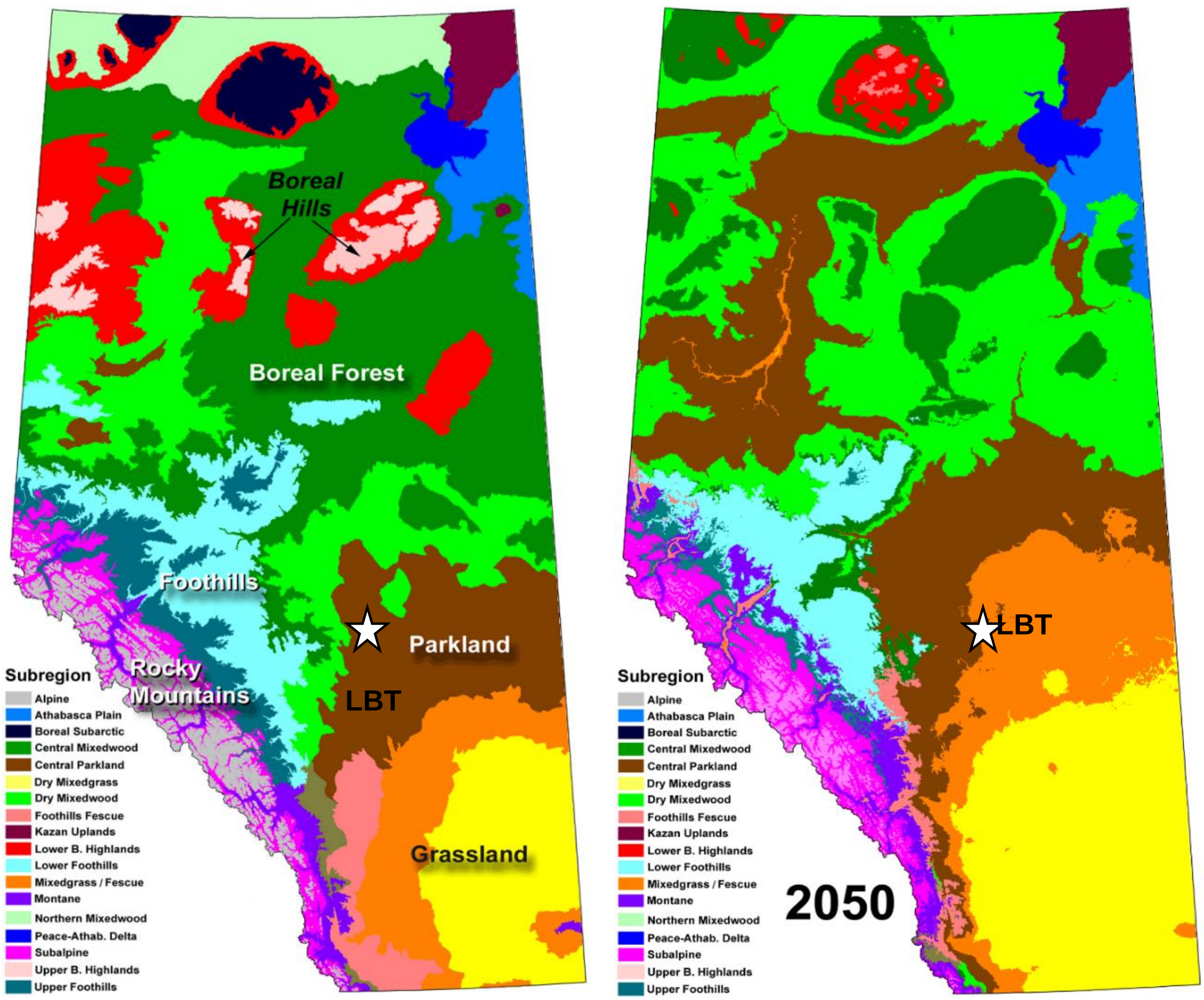
Climate change has a direct impact on the integrity and stability of ecosystems by altering biodiversity, habitats, and ecosystem processes, services, and resilience (NOAA, 2020). It poses a threat to many plants and animals, mainly due to increased temperatures, changes in precipitation patterns, disturbances in inter-species relationships, increases in pests and pathogens, in addition to anthropogenic pressure on natural habitats (Applequist et al., 2020). Social, cultural, and economic activities that revolve around land, such as hunting, trapping, gathering, fishing, and agriculture, are, therefore, deeply impacted by the changing climate.

Climate change also manifests its impacts on ecosystems through key drivers such as changes extreme events like extensive and/or recurring droughts and wildfires, which have long-lasting impacts on ecosystem resilience (Whitman et al., 2019). For instance, in forested ecosystems, tree defenses are weakened by these perturbations and become more vulnerable to insects, diseases, and invasive species. The invasion of non-local, invasive species can be linked to the decline of biodiversity by the alteration of community composition and the extinction of the more vulnerable species (Weiskopf et al., 2020). As a result, we are witnessing a regional and global reorganization of terrestrial and aquatic ecosystems driven by large-scale shifts in species distribution and abundance (**Figure 2-3**). These shifts are mainly towards higher latitudes and altitudes and will take place over decades. The speed with which the transition will happen is different from the rate of climate change as plants have greater inertia and follow the climatic changes more slowly. Furthermore, the ecosystem transition will happen heterogeneously, depending greatly on seed dispersal ability, the deterioration of soil moisture and warming, as well as disturbances like diseases, pests, wildfire, drought, and windthrow that will advantage new species to shift in the disturbed ecosystem (Sauchyn et al., 2020).

Historically, LBT is located in the Central Parkland subregion, which is heavily populated and cultivated (Alberta Parks, 2015; Sauchyn et al., 2020). The original ecosystem is therefore highly fragmented by cropland, with isolated islands of aspen, willow shrubs and balsam (Downing & Pettapiece, 2006). By 2050, it is likely that the Central Parkland vegetation will transition or will have transitioned to the conditions of a Mixedgrass/Fescue. Ecosystem and range shifts constitute a threat to Indigenous cultural maintenance, as culturally important species shift their range further than tribal land area (Weiskopf et al., 2020). This will impact most activities and traditional land use of LBT, such as hunting, fishing, and gathering berries and other plants. Regarding medicinal plants, their availability, abundance, and accessibility, inducing extinction for the more vulnerable species, and altering the phytochemical content and pharmaceutical properties of these plants (Applequist et al., 2020).

Adaptation and resilience to the impacts of climate change on ecosystems is possible through some pro-active and conservation measures. Maintaining habitat integrity and connectivity can help in limiting the non-climate stressors like pollution, invasive species, and habitat fragmentation. One avenue to ensure habitat cohesion and to prevent uncontrollable wildfires is the continuation of prescribed and/or cultural burning, tree thinning, pruning of understorey vegetation and litter. Prescribed and cultural burning has other positive effects, mainly on berry production/quality and for hunting/trapping activities (Christianson et al., 2022). Finally, restoring and protecting zones that provide valued resources are important to maintain ecosystem resilience and cultural needs.

Further details regarding the current ecosystem and the impact of climate change can be found in **Appendix B**.



Source: (Schneider & Bayne, 2015)

Figure 2-3: Current Distribution (left; 2005) and Projection (right; 2050) of Alberta's Major Eco-system Types (high-emission RCP8.5 scenario)

2.2.2 Climate Change Impacts on Agriculture

Similar to the impact of climate change on the ecosystem, agriculture is affected by the changing atmospheric and environmental conditions. Hence, the impacts of climate change on the agricultural lands, livestock, and overall agricultural practices must be considered to ensure its sustainability and resiliency. Considering the significance of agriculture to both the traditions and culture as well as the economic prosperity of LBT, including of regenerative land management, integrating of indigenous knowledge, culture, and education, and addressing food sovereignty are important factors. The main agricultural activities of LBT include poultry production, beekeeping, cattle and pasture improvement, bison heard management, fishing on a stocked lake. LBT envisions a closed loop system within which local crops feed livestock. The impacts of climate change on these specific activities are discussed below.

2.2.2.1 Agricultural and Pasture Lands

Whether natural environment or cultivated fields and pastures, the optimal growing conditions are limited to specific climatic ranges and environmental conditions. When these conditions change due to direct human interventions in the environment or due to climate change, plant growth can be delayed, slowed down or even fail (Heino et al., 2023). The LBT agricultural and pastural lands are impacted in multiple ways. While many changes will pose risk to the obtainable yields, other aspects of climate change might bring benefits.

The threats to the agricultural and pastural lands include drought conditions resulting in a decline in availability of groundwater and/or surface water. Spatiotemporal changes in precipitation and temperature (i.e., precipitation amounts and forms, timing of precipitations and snowmelt) affect groundwater recharge timing and rate (Environment Canada, 2004; Zaremehrjardy et al., 2022; Weber, 2024). Furthermore, extreme events, such as droughts and extreme precipitation, can alter groundwater recharge through reduced ground infiltration, increased evaporation and increased runoff (Environment Canada, 2004). Groundwater depletion can cause several socio-economic and environmental problems, such as the drying of wells, the increase in the costs related to operating wells, spread of pollutions from surrounding contaminated soils or aquifers, ground subsidence, and reduced discharge to surface waters and wetlands (Aeschbach-Hertig & Gleeson, 2012).

Furthermore, dry conditions in combination with increased evaporation and transpiration due to higher temperatures during the growing seasons can lead to a decrease in soil moisture and subsequent soil erosion. Subsequently, the productions and obtainable yield of, for example, corn and wheat decreases significantly (Lesk et al., 2016). Warmer and drier weather conditions lead also to longer the wildfire season and more intense fires by increasing the availability of combustible materials.

Increased precipitation in terms of higher seasonal rainfall amounts, especially during the growing season, can lead to root rotting, the development of mold, or fungal infection of plants. Shorter-term high-intensity rainfall can also pose risk by flooding the agricultural lands. This can lead to the immediate destruction harvests or can have longer-term effects such as worsened water quality resulting from runoff, soil erosion and long-term negative effects on soil fertility. All factors can limit production and yields over years.

On the other hand, climate change also presents opportunities for agriculture (Sauchyn et al., 2020), as the warming in the Prairies can lead to longer growing seasons resulting in a northward increase in arable land space (Laforge et al., 2021). Warming is generally associated with fewer cold days in the winter, higher maximum temperatures throughout the year, and with increases in both the daytime and the nighttime temperatures. Consequently, frost damage to plants will likely decrease in frequency. Overall, it is projected that across the Prairies, the yield of spring wheat will increase by 26-37% mid-century, while the harvest of Timothy grass in the Edmonton area will increase by 24% for the first cut and decrease by 31% for the second cut (Sauchyn et al., 2020).

To ensure plant health, high yields, and increase food security, different adaptation measures are available. These recommendations include the practice of zero-tillage farming to decrease evaporation and increase water conservation, reduce soil erosion, and increase soil fertility. Furthermore, yields can be stabilized or increased by planting native crop varieties and traditional foods that are heat and drought tolerant and by changing the seeding dates and cropping regimes.

2.2.2.2 Cattle and Bison Herd Management

Dry conditions and droughts pose not only a risk to the yield of agricultural and pastoral land but also affect the cattle and bison herd management. Slower or reduced growth of grasses and other feed for the animals might require supplementary feeding to ensure animal health and to achieve targeted weight. Livestock production will be negatively impacted from a decrease in water availability, and an increase in heat events, leading in lower weight gains. Warmer summers can also bring an increase in heat stress, livestock death, decreased milk production and fertility. Furthermore, shifts in biodiversity can lead to an increase in pests, diseases, and invasive species, such as weeds and insects that can negatively impact both crop and livestock productions and health. These include cereal rusts, striped fleas beetle, crucifer flea beetle, deer ticks, and biting midges (Canola Watch, 2012; Lysyk & Dergousoff, 2014; Alberta Animal Health Source, 2020).

Good herd management practices including monitoring of livestock during extreme weather conditions such as heat waves can ensure good animal health. Alternatively, raising more heat- or drought-adapted breeds or species might be necessary for LBT to achieve its goal of food security. Continuation of traditional or Indigenous practices such as grazing cattle with cover crops are beneficial to the animals as well as the biodiversity and returns nutrients to the soil (BCRC, 2023).

2.2.2.3 Poultry

Similarly, climate change threatens the feed quality for poultry (chicken and turkey) due to increased temperature, changes in rainfall, increased numbers and intensity of heat waves, droughts, and flooding events, emergence of new pests and diseases and invasive weeds negatively impacting feed crop yields. This reduces growth, and egg and meat yields. Warmer temperatures also lead to heat stress, reduced reproductivity and even mortality in poultry (especially if confined) (Laforge et al., 2021). Furthermore, water availability affects both chicken and turkey water intake and overall health (The Poultry Site, 2023).

Options for adaptation include:

- Diversify feed crops to allow poultry to be less reliant climate-sensitive feed crops.
- Select poultry breeds that are more heat tolerant.
- Use rainwater harvesting and other water management strategies to increase water storage and availability for poultry farming (The Poultry Site, 2023).

2.2.2.4 Beekeeping

Climate change poses a threat to bees due to the warmer temperatures, droughts, flooding and other extreme weather events, according to the Food and Agriculture Organisation (FAO, 2018). Additionally, the resulting shifts in flowering periods delay pollination due to change in abundance of flowers in bloom and the availability of pollinators such as, bees (FAO, 2020). By creating and maintaining great diversity of bee habitats among the agriculturally used land, the health and number of bees can be increased.

2.2.2.5 Fishing on a Stocked Lake

Alberta’s native cold-water fish are negatively impacted by climate change due to warmer winters and summers, change in precipitation and snowpack which leads to warmer and lower water levels. Depending on the species, increases of water temperatures above 17°C will lead to reduced feeding and growth (e.g., adult grayling), while temperature above 22°C is life threatening for the Athabasca rainbow trout (Alberta Wilderness Association, 2023). To ensure good fish health and high numbers, it is recommended to include the changing water temperatures as a decision factor when the lakes are stocked.

Further details including additional adaptation recommendation are included in **Appendix B**.

2.2.3 Climate Indicators and their Likelihood

Climate conditions or events that can cause loss of productivity, damage to the infrastructure, harm to citizens, employees, or visitors, etc. can be represented by climate indicators. Describing the fundamental aspects of the regional climate and its change, annual averages of daily mean temperature or annual sums of rainfall amounts were used directly as climate indicators. These local indicators were calculated for the historical reference period (1981-2010) as well as for the future time horizons. For other aspects of climate change such as extreme temperature or extreme rainfall, the annual maxima have been selected. A third group of climate indicators is defined by thresholds (e.g., a heat wave can be defined as instances of at least three days with minimum temperatures greater than 20°C and maximum temperatures above 30°C).

To analyze the climate change at LBT, historical observations data, extracted from ECCC's website for the weather station in Brightview, AB, supplemented by data from the stations at Edmonton International Airport were systematically analyzed. For the future projections, local climate information obtained from numerical models were utilized in combination with numerous publications discussing climatic changes to variables such as freezing rain, fog, relative humidity, thunderstorms with their different aspects such as lightning, heavy rainfall, tornados, etc.

In total, 47 climate indicators were reviewed at a high-level to assess the risk to the project due to climate change for the 2030s-, 2050s- and 2080s-time horizons relative to the baseline (1981-2010) (**Appendix A**). According to the PIEVC HLSG guide, the historical climate is assigned a probability score of 3. If climate event becomes less frequent or less intense, the probability score decreases, and if event becomes more frequent or more intense, the score increases (**Table 2-2**).

Table 2-2: Likelihood Scoring Description

Likelihood	Baseline	Method	Relative Change
1	↑	Likely to occur less frequently than current climate	50-100% reduction in frequency or intensity with reference to baseline mean
2			10-50% reduction in frequency or intensity with reference to baseline mean
3	Baseline	Likely to occur as frequently as current climate	Baseline mean conditions or a change in frequency or intensity of ±10% with reference to baseline mean
4	↓		10-50% increase in frequency or intensity with reference to baseline mean
5		Likely to occur more frequently than current climate	50-100%+ increase in frequency or intensity with reference to baseline mean

Source: (PIEVC, 2021)

The relative change to the historical reference period has been calculated for all climate indicators. Subsequently, the respective likelihood score was assigned for all time horizons. For example, the daily mean temperature is projected to have increased by 73% in the 2050s and by 139% in 2080s compared to the historical reference periods of 1981-2010. Consequently, a likelihood score of 5 has been assigned for both time horizon. Similarly, the frequency of heavy rainfall (i.e., historical 10-year return event of daily rainfall) is projected to increase by 51% in the 2050s and 67% in the 2080s, warranting a likelihood score of 5 for both time horizons. The full list of all indicators, their absolute and relative change, and the decisions on the inclusion of the climate indicators in the assessment and, in case of an exclusion, a corresponding justification is provided in **Appendix A**.

As a result of this initial review, a large number of climate indicators were removed from the analysis as their probabilities were low, their impacts on LBT are deemed low or nonexistent or are assessed in combination with other indicators (**Appendix A**). The remaining eight indicators are selected as:

- the climate indicators identified past extreme weather conditions (past extreme weather events were researched as they provide insights into the potential relevance of certain climate indicators for the future infrastructure),
- historical and future annual and seasonal variation of both temperature and precipitation provide insights on future trends,
- applicable climate indicators show significant increases in probability during the project's timeframe,
- the local reality mandates the inclusion of the climate indicator,
- potential interactions of a certain climate condition with a project component carries non-negligible risks.

The selected climate indicators are summarized in **Table 2-3**.

Table 2-3: Climate Indicator Likelihood Scoring for the Selected Indicators Using the High-Emission RCP8.5 Scenario

Climate Indicators	Definitions	Hist.	2030s	2050s	2080s
Mean temperature	Annual average of daily mean temperature	3	5	5	5
Maximum temperature	Annual average of daily max temperature	3	4	4	4
Heat wave	Daily maximum temperature greater than 30°C for at least 3 consecutive days	3	5	5	5
Drought	Monthly precipitation is less than the 1st decile[2] of the historical precipitation for the corresponding month	3	3	4	4
Daily rainfall (10-year event)	10-year return values for daily rainfall	3	4	5	5
Freezing Rain	Annual number of hours with freezing rain	3	5	5	5
Wildfire	Wildfire threat	3	4	5	5
Thunderstorm	Convective storms that can include lightning, hail, downburst, derechos, tornados, and heavy precipitation	3	4	4	4

2. *The first tenth of ten equal part of a whole.*

3. Risk Identification and Assessment

3.1 Estimates of Consequences

Before risk analysis was conducted, the level of consequences for each interaction of the ten LBT assets and operations and the eight climate indicators was estimated. To this end, four impact categories were identified based on the most relevant aspects regarding the risk management for LBT. These four impact categories are defined as

1. **Impact on health and safety**, including occupational illness and injury to staff, residents, or visitors because of incidents for which LBT may be liable,
2. **Infrastructure integrity**, including damages or deterioration of essential assets,
3. **Operational impact**, including operational delays, process slowdowns, or interruption of services,
4. **Financial impact**, including losses due to additional cost/expense directly attributed to the event, damages to asset to be repaired immediately to maintain operations, or failure to maintain operations.

The severity rating (1- very low to 5 - very high) and impact categories which were used to guide the risk analysis are detailed in **Table 3-1**.

Table 3-1: Impact Severity Rating and Impact Categories

Impact Categories					
Impact Severity Rating	**Consequences**	**Health & Safety**	**Infrastructure Integrity**	**Operational Impact**	**Financial Impact**
1	**Very low**	First Aid Injury	Very low damage; repairable immediately	Operation impacted for a few hours but/or no service interruption to the public, requiring additional time (4 to 6 hours)	Less than $2.5k – additional cost/expense directly attributed to the event, or minor damage to asset to be fixed in next routine service. Claim against LBT of <$500
2	**Low**	Medical treatment for a minor injury	Minor damage to component materials; Reduction of the service life of the material	Operation impacted for a day but/or no service interruption to the public/Work operations slow down, requiring additional time (1 day)	$2.5k - $5k – additional cost/expense directly attributed to the event, or damage to asset to be fixed in advance of next routine service. Claim against LBT of >$500 but <$1k
3	**Moderate**	Bodily injury / Illness with work restrictions	Moderate damage to component materials; Slow deterioration of the materials of certain essential components	Operation impacted for a week and/or limited-service interruption to the public/Work operations slow down, requiring additional time (1 to 3 days)	$5k - $10k – additional cost/expense directly attributed to the event, or damage to asset to be fixed in advance of next routine service. Claim against LBT of >$1k but <$2.5k
4	**High**	Permanent disabling injury or multiple people injured	Accelerated deterioration of the materials of certain essential components	Operation impacted for a month and/or service interruption to the public up to a week/Work operations slow down, requiring additional time (3 to 5 days)	$10k - $15k – additional cost/expense directly attributed to the event, or damage to asset to be fixed immediately to maintain operations. Claim against LBT of >$2.5k but <$5k
5	**Very high**	Fatality or significant irreversible disability	Deterioration of materials causing the failure of several elements essential to the functionality of the network	Operation impacted for > month and/or service interruption to the public up to > week/ Work operations slow down, requiring additional time (>5 days)	More than $15k – additional cost/expense directly attributed to the event, or damage to asset to be fixed immediately to maintain operations, or operations cannot be maintained, and alternatives arranged. Claim against LBT of >$5k

Based on the impact severity rating in **Table 3-1**, the potential consequences of interactions of climate change and assets were evaluated. The consequence levels were established using expert judgement and relevant literature (Marlon et al., 2009; Baziene et al., 2013; Snyder, 2017; Hughes et al., 2021). A two-level risk analysis exercise was completed by the AECOM project team, with two risk evaluators and a discussion to review differences in opinion and come to a consensus. If a consensus could not be reached, or if there was a lack of information and knowledge, other experts were consulted to further refine the analysis.

The assessment revealed high-impact consequences for all impact categories with two very high-impact consequences in terms of financial impact (**Figure 3-1**). This ranking can be used to help prioritize adaptation measures that will minimize impacts related to health and safety of residents, staff and visitors, the infrastructure integrity, the operation, and the finances of the LBT and the building owners.

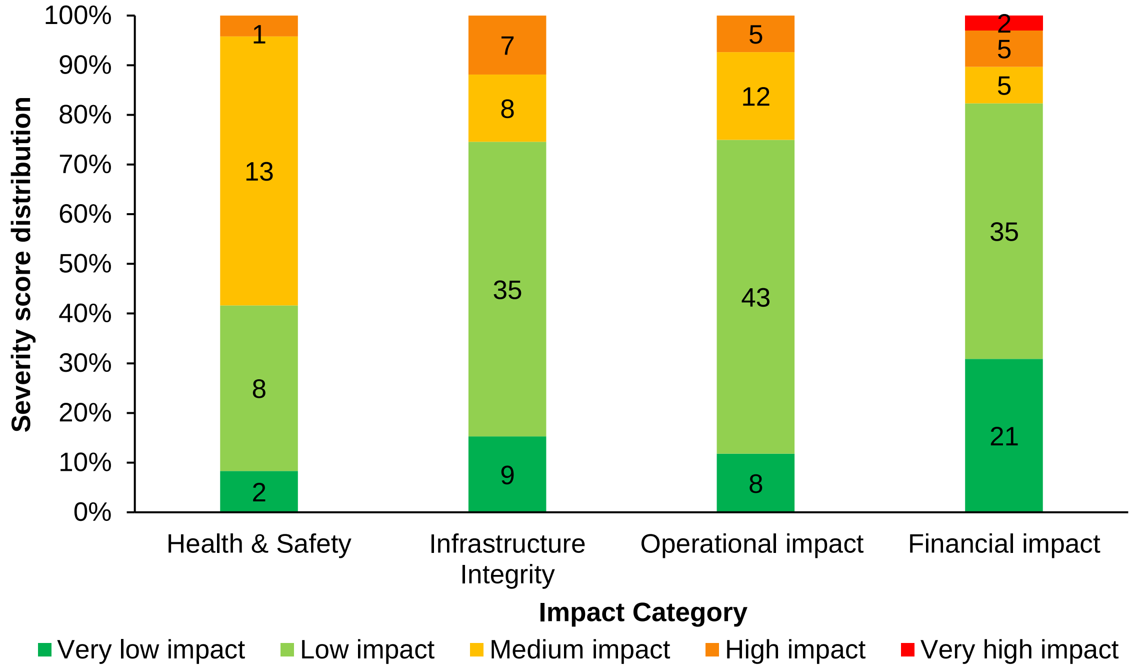


Figure 3-1: Number of Interactions per Level of Severity for Each Impact Category

Further details discussing the assessment process and additional results are included in **Appendix C**.

3.2 Risk Evaluation

The risk score is obtained by multiplying the likelihood (of the weather/climate event) by the severity/consequence score and exposure where the binary exposure term is either 0 for no exposure or 1 if the asset is exposed to the weather/climate event (PIEVC, 2021).

$$Risk = Likelihood \times Consequence \times Exposure$$

Using the equation above, the risk level for all 80 interactions between the eight climate indicators (**Table 2-3**) and the ten asset groups (**Table 2-1**) have been calculated. Four (4) interactions were assessed as not impacted by the selected climate indicators and hence were excluded from the risk analysis. The remaining 76 interactions show a low to high risk (**Figure 3-2**). While the risk assessment shows for many interactions the same results across all time horizons, the risk level increases for some interactions such as heavy rainfall (e.g., historical 10-year event) or wildfire. Over the course of this century, the level of risks of some interactions increases further from low to medium and high (**Figure 3-2**). Detailed discussion of Risk Assessment, including estimates of consequences and risk evaluation is presented in **Appendix C**.

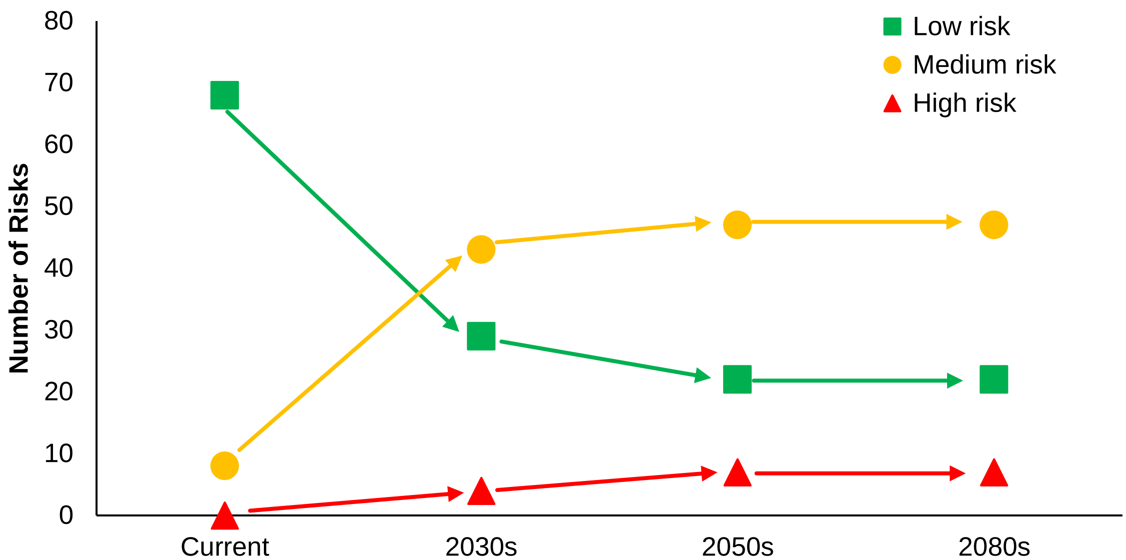


Figure 3-2: Level of Risks of Interactions between Weather Events and Assets Current and Future Time Horizons Using the High-Emission RCP8.5 Scenario

A summary of the highest risk scores for the individual interactions of weather/climate events and assets using the high-emission RCP8.5 scenario is provided in **Table 3-2**. The risk analysis process helped to qualitatively make decisions on which climate hazards should become priorities. The table below is organized by systems, project infrastructure elements and highlights the risk interaction with highest scores. Increased severity of heat waves, daily rainfall (10-year event), freezing rain and wildfire events are projected to have the biggest shift in risk between today and the future timeframes. The LBT infrastructure elements likely to be at greatest risk in the future (2080s) include agriculture land (field and pasture) and fisheries, residential and community buildings, and people well-being.

Table 3-2: Summary of Highest Risk Scores Using the High-Emission RCP8.5 Scenario

Assets	Climate Indicators	Timeframe			
		Hist	2030s	2050s	2080s
Community Buildings	Wildfire	15	20	25	25
Residential Buildings	Wildfire	15	20	25	25
Agriculture land (field and pasture) and fisheries	Heat wave	12	20	20	20
	Daily Rainfall (10-year events)	12	16	20	20
	Freezing Rain	12	20	20	20
	Wildfire	12	16	20	20
People	Wildfire	12	16	20	20

4. Risk Treatment and Adaptation Measures

The project team identified risk treatment and adaptation measures for reducing medium and high risks to lower, more acceptable levels. For future timeframes, these measures are summarized in **Table 4-1**. Climate indicators that resulted in similar risk assessments and adaptation measure are combined (i.e., Tmean, Tmax and heat waves) by using the higher risk scoring in case they differ.

A detailed version of **Table 4-1** is also included in **Appendix D**, with additional information on the effectiveness of the adaptation measures as well as the recommended timeframe for their implementing. One important way to adapt to climate change and increase resilience is by implementing pro-active and conservation measures such as the continuation of prescribed and cultural burnings to reduce the risks of uncontrollable wildfires. Furthermore, maintaining habitat integrity and connectivity can help the conservation of the current ecosystem by limiting the non-climate stressors like pollution, invasive species, and habitat fragmentation. A highlight of some recommended adaptation measures addressing the high-risk interactions identified in **Table 3-2** as well as some additional medium-risk interactions is presented here and in **Table 4-1.**

Table 4-1: Summary of Risk Treatment and Adaptation Measures

	Risk Reduction
Adaptation Measures	**Prescribed or cultural burning, tree thinning and pruning**
	Benefits and Comments: (Cultural Burning & Prescribed Fire, 2024) ■ Prevention or curtailment of wildfire by consumption of fuel. ■ Increased habitat health by increased food sources and balance to food chains ■ Refreshed soil nutrients and increased resilience of forests ■ Increased adaptation to changing climate
	Develop a wildfire preparedness guide, increase community awareness (FRIAA FireSmart Program)
	Benefits and Comments: ■ Increased preparedness in case of wildfire (vegetation and fuel management, public education, emergency planning, etc.)
	Establish clear access roads to and within campgrounds for emergency vehicles; maintain these roads and keep them clear of debris during fire season.
	Benefits and comments ■ It enables emergency vehicles to reach the campground quickly, reducing response times during critical situations. ■ Improved access minimizes the risk of blocked or impassable roads due to congestion, fallen trees, or debris, which can hinder emergency efforts.
	Ensure reliable access to water sources in campgrounds, community, and residential buildings for firefighting efforts, including water tanks, hydrants, and hoses.
	Benefits and Comments: ■ With hydrants in place, firefighters can protect homes and structures by ensuring a sufficient water supply to create firebreaks. ■ Implement controlled burns or vegetation management practice help to reduce fuel loads.
Adaptation Measures	**Implementing early warning and detection systems for heat waves, thunderstorms, freezing rain, wildfires etc.; Develop an Emergency Preparedness and Management Plan** (Public Safety Canada, 2018)[3]
	Benefits and comments ■ Allows for proactive responses to address issues promptly. ■ Ensures timely communication of severe weather warnings with community members during outdoors activities such as hunting or trapping
	Use community buildings as an interim cooling and heating centre until residential building are upgraded or adapted (e.g., installation of AC in residential houses, use of highly reflective material).
	Benefits and comments ■ Community buildings can provide immediate relief to residents during extreme weather events, offering a place to escape from extreme heat or cold. ■ Community buildings often have the infrastructure for heating and cooling systems in place, making it easier to regulate indoor temperatures efficiently.
	Choose crop varieties that are more tolerant of climate extreme events (extreme heat, drought, etc.)
	Benefits and Comments: ■ Heat-tolerant and climate adapted crop varieties are more likely to withstand extreme temperature events, extend periods of drought. ■ These varieties help ensure a stable food supply, even in the face of unpredictable weather, contributing to food security in the region.
	Implement effective water management practices, including rainwater retention ponds and wetland restoration to contain floodwaters
	Benefits and Comments: ■ It ensures reliable access to clean water sources for agriculture and livestock, especially during heat waves. ■ It helps reduce the risks and severity of the consequences of pluvial and fluvial flooding. ■ Increases biodiversity
	Consider climate change (e.g., increased water consumption during periods of high temperature and drought) during renovations/new build
	Benefits and comments ■ Invest in resilient infrastructure can help to maintain essential services during extreme heat when replaced/upgraded pumps, lift station and other asset components are appropriately sized. ■ Invest in water conservation efforts in residential buildings (e.g., low flush toilets)
	Build a shelter structure for culture camp and healing forest campground users to use in case of heavy precipitation and thunderstorm
	Benefits and Comments: ■ Shelters offer a dry and warm space, shielding individuals from the heavy rainfall and lightning during thunderstorms. ■ Shelter helps prevent exposure to cold and wet conditions, reducing the risk of illnesses and injuries associated with extreme weather.

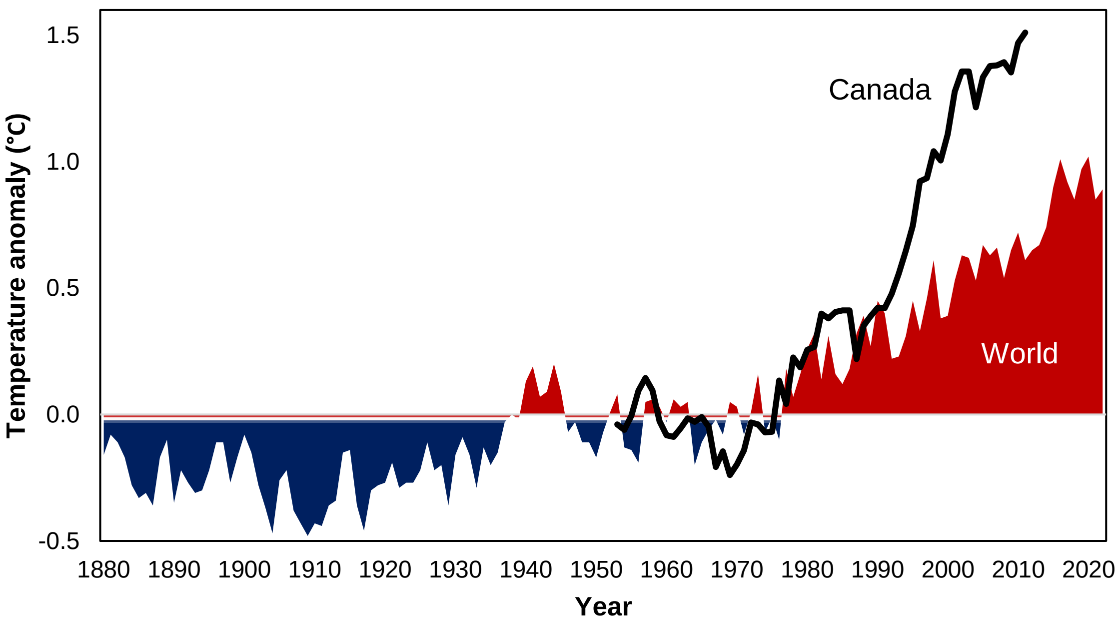
3. *Identify Emergency Management team; Identify critical assets and services; Identify vulnerabilities; Develop mitigation and adaptation strategies; Develop timelines and priority actions; Communicate strategies and plans; Train and exercise.*

Appendix A

Detailed Discussion of Climate Change

Earth's climate has always been changing due to natural phenomena such as the variability in solar and orbital forcing and volcanic activity. Although these processes continue to act, over the last 250 years, changes to these natural causes of climate change have been negligible compared to anthropogenic (i.e., man-made) climate-change drivers. Human activities in the form of the extensive burning of fossil fuels and the large-scale transformation of land use have led to significant increases in concentrations of greenhouse gases (GHGs) such as carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O), which have resulted in observed and projected changes to Earth's climate (IPCC, 2021).

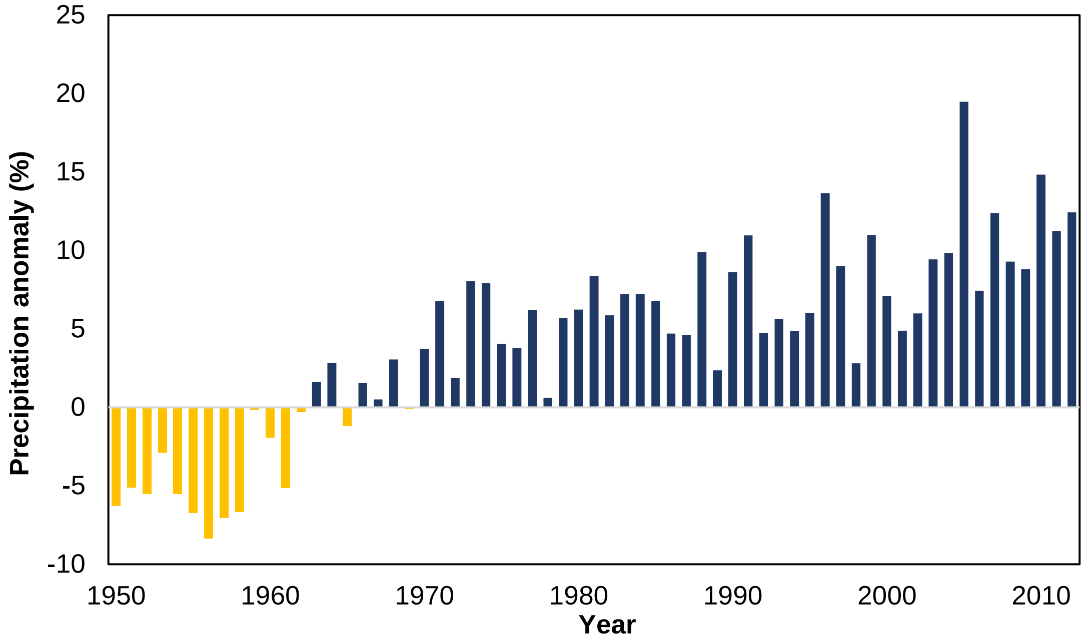
These changes are measurable and visible through a range of indicators pertaining to the air, lakes and oceans, ice, plants and animals, and land across the globe. For example, global mean temperature has been about 0.8°C higher in 2011-2020 than in 1951-1980 (color contours in **Figure A1**) (NASA, 2023). In Canada, the temperature increase over the second half of the 20th and into the 21st century was even more pronounced with the temperature being 1.3°C higher in 2001-2010 than in 1951-1980 (Government of Canada, 2019).



Source: (NASA, 2023) and (Bush & Lemmen, 2019)

Figure A1: Temperature Anomaly Relative to 1951-1980

Over the same period, the average precipitation in Canada has increase by about 12% relative to 1951-1980 (**Figure A2**) Moreover, the distribution of precipitation has shifted towards more extreme events with heavy precipitation occurring more frequently. At the same time, the frequency and intensity of droughts or extended dry periods has increased (Hartmann et al., 2013). These new precipitation patters result in more frequent flooding events and in an increased risk of wildfires. Other impacts of climate change include the poleward and upslope movement flora and fauna, global sea-level rise, and the melting of glacier, ice sheets, and the Arctic Sea ice.



Source: (Bush & Lemmen, 2019)

Figure A2: Precipitation Anomaly for the Annual Precipitation Sum in Canada Relative to 1951-1980

A-1 Historical Climate at Louis Bull Tribe

Representative for LBT, the local climate was analyzed using observations of the historical weather and climate collected by Environment and Climate Change Canada (ECCC) at Brightview, AB about 15 km away. In addition, observations of wind, freezing rain, relative humidity, etc., supplementary data were obtained from the Edmonton International Airport at about 50 km distance to complete the dataset. Despite the greater distance to LBT, these data are assumed to representative for LBT and can be used to describe the historical local climate.

The daily mean temperature at LBT has increased from 2.0°C in the early 1970s to 4.3°C in the early 21st century (**Figure A3A**). This constitutes an increase of 0.66°C per decade. For the daily minimum and maximum, a similar increase of 0.70 and 0.61°C/decade has been observed. In addition to the annually averaged temperature increase, the extreme temperature events have also become more frequent. The number of days with temperatures above 30°C has increased by 1.8 per year since the 1970s and reached a maximum of 10 days in 2002 (**Figure A3B**).

Similarly, the historical precipitation trends at LBT indicate an increase. The trend is driven by the increases in both annual rainfall and snowfall (**Figure A3C**). On average, the annual snowfall amount has increased by 1.2 cm per decade, while the annual rainfall sum has increased more significantly by 5 mm/decade from 1961 to 2007. Despite this overall increase in precipitation, the risk of droughts and flooding events have also increased as precipitation pattern have shifted to more extreme events with longer dry periods. Consequently, climate change has increased the wildfire risk with wildfire season becoming longer, the area burned getting larger and the severity of the fires increasing. The recent wildfire in Alberta and in the vicinity of Edmonton impacted LBT due to the extensive smoke development. A small fire that recently broke out on tribal land was quickly extinguished by the local four band fire department.

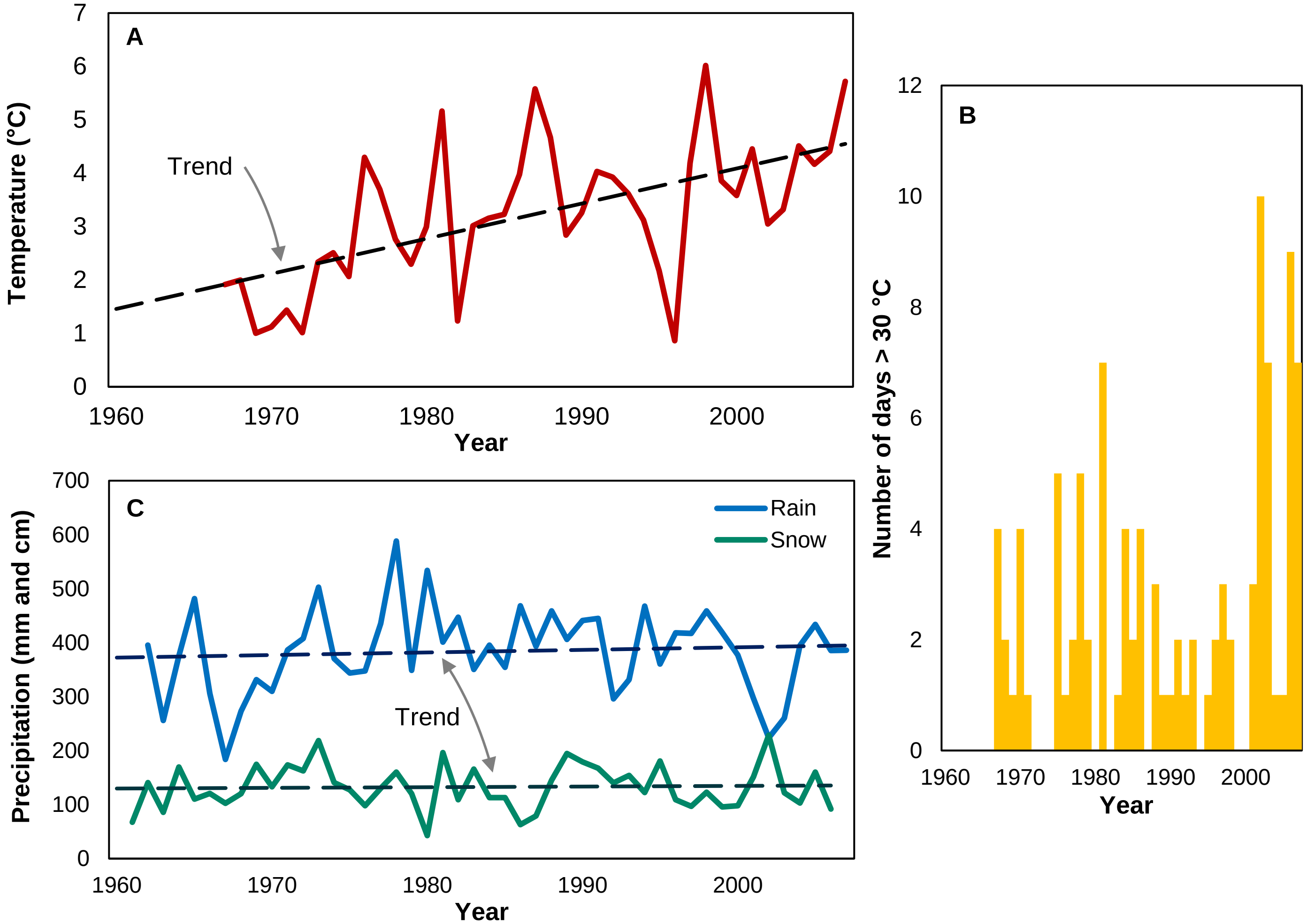


Figure A3: A) Annually Averaged Daily Mean Temperature, B) Number of Days above 30 °C, and C) Annual Precipitation Sum (Rain and Snow) at LBT, AB

A-2 Climate Projections

To understand the exposure of the humans as well as built and natural infrastructure to climate change and assess the associated risks, it is essential to establish potential climatic changes at the location and over the lifespan of humans and the infrastructures. This CRRA is based on the regional climate projections obtained from statistically downscaled multi-model ensembles constructed from twenty-four (24) Coupled Model Intercomparison Project

Phase 5 (CMIP5) global climate models (GCM) (ECCC, 2018). The CMIP5 simulations build the bases of the Fifth Assessment Report (AR5) of the Intergovernmental Panel of Climate change (IPCC).

As future global emissions of greenhouse gases (GHGs) and other pollutants are uncertain, four realisations with different GHG concentration trajectories have been conducted. These Representative Concentration Pathways (RCPs) are named after their associated level of radiative forcing (i.e., the change in the atmosphere's energy balance) in 2100. Hence, as an example, the RCP2.6 corresponds to 2.6 W/m² of radiative forcing and a surplus of energy of 2.6 W/m² in Earth's atmosphere. Projected GHG concentration levels (including carbon dioxide (CO_2) and methane (CH_4)) are depended on the anticipated population growth, changes in economics activity and energy consumption, shifts in land use, and climate policies (IPCC, 2014). A high-level description of the RCPs can be found in **Table A1**.

Table A1: Representative Concentration Pathways (RCPs)

RCP	Description
RCP 2.6	Stringent mitigation scenario: representative of a scenario that aims to keep global warming likely below a 2°C increase above preindustrial temperatures. Ambitious reduction of GHG emissions required for this scenario for emissions to peak around 2020, then decline, and become net negative before 2100.
RCP 4.5	Intermediate mitigation scenario consistent with relatively ambitious emissions reductions. The GHG emissions increase before starting to decline between 2040 and 2050. This scenario will likely fall short of the 2°C limit agreed upon in the Paris Agreement.
RCP 6.0	Intermediate to high emissions scenario with emissions peaking in 2080 and declining for the rest of the century.
RCP 8.5	Very high GHG emissions: consistent with no policy changes to reduce emissions (sometimes called the current policies or business as usual scenario).

Source: (IPCC, 2014)

While the global temperature increase is likely to exceed the limit of 2°C set in the Paris Climate Agreement (UNFCCC, 2015) for all RCP scenarios but the RCP2.6 scenario (IPCC, 2014), the corresponding levels of decarbonization necessary to achieve the RCP2.6 scenario are beyond most ambitious decarbonization plans. On the other hand, the RCP8.5 represents the high end of possible GHG emissions over the course of this century. Although countries have outlined various climate actions in their Intended Nationally Determined Contributions (INDCs), the GHG emissions keep increasing (Hook, 2020; UNFCCC, 2022), and exceed the emission for the intermediate scenarios. Consequently, the RCP8.5 scenario was chosen for his CRRA to allow for a conservative assessment of the risks due to climate change.

From the available climate models, 12 representative models for the high-emission scenario (RCP8.5) were selected for the CRRA (**Table A2**). These simulations represent the full range and uncertainty of the simulations at LBT. All simulations have a spatial resolution of 300 arc seconds (about 10 km) and a temporal resolution of 24 h. The available variables are daily minimum temperature, daily maximum temperature, and daily precipitation rate (PCIC, 2019).

Table A2: Selected Global Climate Models (GCMs)

Global Climate Models		
ACCESS1-0	CSIRO-mk3-6-0	IPSL-CM5A-MR
CanESM2	GFDL-CM3	MIROC5
CCSM4	GFDL-EMSM2G	MPI-ESM-LR
CNRM-CM5	inmcm4	MRI-CGCM3

The historical observation and future projections for LBT were analyzed using a climate data analysis program developed by AECOM. This tool extracts average values, trends, extreme values, and other climate indicators and calculates their return periods and probabilities for the climate reference period and future time horizons. Over fifty climate indicators with thresholds pertinent to the site location are determined from which the most relevant to LBT were selected. These climate variables passed through vigorous quality control.

A-3 Identification of Climate Indicators

To determine the climate-related risks to LBT, numerous climate indicators were used, each of them describing different aspects of the climatic changes. Overall, 47 climate indicators were reviewed at a high-level to assess the risk to LBT due to climate change. Their definitions and thresholds are listed in **Table A3**.

Table A3: Climate Indicators and Additional Information

Climate Indicator	Definition and Thresholds	Justification
Mean temperature	Annual average of daily mean temperature	
Maximum temperature	Annual average of daily maximum temperature	
Minimum temperature	Annual average of daily minimum temperature	
Abs. Tmax	Absolute maximum of daily temperature	
Abs. Tmin	Absolute minimum of daily temperature	
Heat wave	Daily maximum temperature greater than 30°C for at least 3 consecutive days	Professional judgement based on climate information at location (ECCC)
Cold spell	Daily minimum temperature lower than -25°C for at least 3 consecutive days	Professional judgement based on climate information at location (ECCC)
Freeze-thaw cycles	Number of days with Tmax > 0°C and Tmin < 0°C	Melting point
HDD	Heating degree days	Canadian standard
CDD	Cooling degree days	Canadian standard
FDD	Freezing degree days	Melting point
MDD	Winter melting degree days, where winter is defined as Nov-March	Melting point
Frost-free season	Number of days without Tmin <0°C	
Last day of spring frost	Last day in spring with Tmin <0°C	
First day of fall frost	First day in fall with Tmin < 0°C	
Growing degree days	Annual degree days with basis 5°C	(Climate Atlas of Canada, 2019)
CHU	Corn heat units	(Climate Atlas of Canada, 2019)
R	Annual rainfall sum	
S	Annual snowfall sum	
P	Annual precipitation sum	
Rmax	Maximum of daily rainfall	
Smax	Maximum of daily snowfall	
Pmax	Maximum of daily precipitation	
Dry Period	Period of at least 14 consecutive days without precipitation	Professional judgement based on climate information at location (ECCC)
Drought	Monthly precipitation is less than the 1st decile of the historical precipitation for the corresponding month	Handbook of Drought Indicators and Indices (WMO, 2016)
SPEI	Standardized Precipitation Evapotranspiration Index – severity and duration of drought	Literature review (Masud et al., 2017)
Return periods for heavy rainfall	10-/50-/ and 100-year return values for daily rainfall	
Multi-day heavy precipitation	Maximum 5-day precipitation	
Return periods for heavy snowfall	10-/100-/ and 200-year return values for daily snowfall	
Snow depth	Snow depth (snow on the ground)	
Snow depth max	Max snow depth (accumulated snow on the ground)	
Heavy wind	Maximum sustained wind (10 min)	

Climate Indicator	Definition and Thresholds	Justification
Wind (gusts)	Wind gusts (maximum wind speed over 10 seconds)	
RH	Annually averaged relative humidity	
Humidex	Maximum of daily humidex	
Windchill	Maximum of daily windchill	
Fog	Annual hours with fog	
Rfreeze	Average of annual hours with freezing rain	
Wildfire	Combination of FWI, FSL, FSI (fire severity index), burned area, including wildfire smoke	
Lightning	Lightning strikes per year (within 25 km)	
Tornados	Number of tornados per year	
Hail		

For each climate indicator, the historical values for the reference period (1981-2010) as well as the projected values for the three time-horizons (2030s, 2050s, and 2080s) were calculated. From these values, the relative change to the reference period was determined and scored (**Table A4**). Also included in **Table A4** are statements on their inclusion in the assessment as well as a commentary on the exclusion.

Table A4: Climate Indicators and their Change and Likelihood Scores for All Time Horizons

Climate Indicator	Hist	2030s			2050s			2080s			Included in Assessment (Y/N)	Exclusion Comments
		Value	Change (%)	Likelihood Score	Value	Change (%)	Likelihood scores	Value	Change (%)	Likelihood Scores		
Mean T (°C)	3.5	5.4	54.7	5	6.0	72.8	5	8.3	138.7	5	Y	-
Max T (°C)	9.3	11.2	19.7	4	11.7	25.3	4	14.0	49.3	4	Y	-
Min T (°C)	-2.4	-0.4	-83.0	1	0.3	-113.6	1	2.7	-212.5	1	N	Reduced likelihood
Abs. Tmax (°C)	35.5	36.2	2.0	3	37.0	4.2	3	39.1	10.1	4	N	Similar to max T
Abs. Tmin (°C)	-42.0	-35.5	-15.4	2	-33.4	-20.5	2	-28.4	-32.3	2	N	Reduced likelihood
Heat wave											Y	-
Number	0.3	1.2	361.4	5	2.0	660.6	5	3.8	1368.7	5	-	-
Length (days)	3.3	3.9	19.1	4	4.1	24.6	4	5.6	73.5	5	-	-
Intensity (°C)	31.9	32.5	2.1	3	32.6	1.9	3	33.2	4.3	3	-	-
Cold spell											N	Reduced likelihood
Number	2.2	1.1	-50.3	1	0.7	-66.6	1	0.0	-100.0	1	-	-
Length (days)	4.9	4.6	-5.3	3	4.4	-10.2	2	0.0	-100.0	1	-	-
Intensity (°C)	-30.2	-29.2	-3.4	3	-29.0	-3.9	3	0.0	-100.0	1	-	-
Daily maximum T											N	Similar to max T
10-year Tmax (°C)	34.8	36.9	5.9	3	38.1	9.3	3	40.4	16.1	4	-	-
100-year Tmax (°C)	38.6	40.7	5.3	3	41.7	8.1	3	43.8	13.5	4	-	-
200-year Tmax (°C)	39.7	41.8	5.2	3	42.8	7.8	3	44.8	12.8	4	-	-
Daily minimum T											N	Reduced likelihood
10-year Tmin (°C)	-43.3	-38.5	-11.2	2	-38.1	-12.1	2	-32.0	-26.2	2	-	-
100-year Tmin (°C)	-54.3	-48.6	-10.6	2	-47.8	-12.0	2	-40.4	-25.7	2	-	-
200-year Tmin (°C)	-57.6	-51.9	-9.8	3	-51.1	-11.4	2	-43.3	-24.9	2	-	-
Freeze-thaw cycles	105.5	102.2	-3.2	3	94.0	-11.0	2	87.2	-17.3	2	N	Reduced likelihood
HDD	5113.5	4484.5	-12.3	2	4301.3	-15.9	2	3631.5	-29.0	2	N	Reduced likelihood
CDD	37.0	104.2	181.9	5	151.8	310.4	5	320.6	766.8	5	N	No risk potential
FDD	1105.2	795.7	-28.0	2	749.1	-32.2	2	444.6	-59.77	1	N	Reduced likelihood
MDD	7.2	10.9	53.1	5	10.8	51.0	5	20.1	181.1	5	N	No risk potential
Frost-free season	118.0	133.0	12.7	4	146.0	23.7	4	162.0	37.3	4	N	No risk potential
Last day of spring frost	137.0	129.0	-5.8	3	122.0	-11.0	2	114.0	-16.8	2	N	Reduced likelihood
First day of fall frost	256.0	264.0	3.1	3	270.0	5.5	3	278.0	8.6	3	N	No risk potential
Growing degree days	1396.0	1699.1	21.7	4	1859.8	33.2	4	2296.6	64.5	5	N	No risk potential
CHU	2105.1	2517.2	19.6	4	2817.5	33.8	4	3314.6	57.5	5	N	No risk potential
R (mm)	388.4	411.3	5.9	3	417.0	7.4	3	439.4	13.1	4	N	Similar to daily rainfall
S (cm)	131.3	129.5	-1.4	3	129.0	-1.8	3	117.7	-10.4	2	N	Reduced likelihood
P (mm)	519.7	540.8	4.1	3	546.0	5.1	3	557.1	7.2	3	N	Similar to daily rainfall
Max R (mm)	96.0	109.2	13.8	4	114.0	18.7	4	133.2	38.7	4	N	Similar to daily rainfall
Max S (cm)	32.0	25.5	-20.4	2	29.0	-9.4	3	27.8	-13.3	2	N	Reduced likelihood
Max P (mm)	96.0	109.2	13.8	4	114.0	18.7	4	133.2	38.7	4	N	Similar to daily rainfall
Dry Period											N	Similar to drought (SPEI)
Number	2.0	1.7	-12.4	2	1.9	-5.2	3	2.0	1.2	3	-	-
Length (days)	17.8	17.3	-2.8	3	17.6	-1.1	3	17.8	-0.4	3	-	-
Drought (decile)	1.5	1.5	1.7	3	1.4	-7.1	3	1.6	2.7	3	N	Similar to drought (SPEI)
Severity (SPEI)^						30.0	4				Y	-
Duration (SPEI)^						10.0	4				-	-
Daily Rainfall											-	-
10-year rain (mm)	70.2	79.8	13.8	4	83.3	18.7	4	110.7	57.8	5	-	-
50-year rain (mm)	93.1	105.9	13.8	4	110.5	18.7	4	146.9	57.8	5	-	-
100-year rain (mm)	102.8	116.9	13.8	4	122.0	18.7	4	162.1	57.8	5	-	-
10-year Rain (70.2 mm)	10.0	6.0	40.4	4	4.9	51.0	5	3.3	66.9	5	Y	-
50-year Rain (93.1 mm)	50.0	23.3	53.5	5	19.4	61.3	5	8.5	82.9	5	-	-
100-year Rain (102.8 mm)	100.0	42.9	57.1	5	33.3	66.8	5	14.5	85.5	5	-	-
Multi-day heavy precipitation (mm)	70.4	74.6	6.0	3	71.3	1.2	3	77.1	9.6	3	N	Similar to max R
Daily snowfall											N	Unchanged likelihood
10-year snow (cm)	26.0	26.3	1.1	3	27.2	4.6	3	27.3	5.1	3	-	-
100-year snow (cm)	38.9	39.1	0.6	3	40.2	3.5	3	41.0	5.4	3	-	-
200-year snow (cm)	42.7	42.9	0.5	3	44.1	3.2	3	45.1	5.5	3	-	-
Snow depth (cm)	7.8	-20.7	-365.71	1	-20.4	-362.42	1	-21.2	-371.93	1	N	Reduced likelihood
Snow depth max (cm)	64.0	47.1	-26.4	2	54.7	-14.5	2	48.5	-24.3	2	N	Reduced likelihood

Climate Indicator	Hist	2030s			2050s			2080s			Included in Assessment (Y/N)	Exclusion Comments
		Value	Change (%)	Likelihood Score	Value	Change (%)	Likelihood scores	Value	Change (%)	Likelihood Scores		
Heavy wind* (km/h)	76.0	75.4	-0.8	3	73.5	-3.3	3	73.8	-2.9	3	N	Unchanged likelihood
10-year wind (gusts)* (km/h)	101.3	100.5	-0.8	3	98.0	-3.3	3	98.4	-2.9	3	N	Unchanged likelihood
100-year wind (gusts)* (km/h)	120.5	119.5	-0.8	3	116.5	-3.3	3	117.0	-2.9	3	N	Unchanged likelihood
200-year wind (gusts)* (km/h)	126.12	125.2	-0.8	3	122.0	-3.3	3	122.5	-2.9	3	N	Unchanged likelihood
RH (%)	69.5			3			3			3	N	Unchanged likelihood
Fog	376.7			3			3			3	N	Unchanged likelihood
Rfreeze	13.9	31.4	126.2	5	36.4	162.3	5	22.5	62.3	5	Y	-
Wildfire				4			5			5	Y	-
FWI max	133.6	Projected to increase									-	-
FSL	212.5				237.5	11.8	4	257.5	21.2	4	-	-
Thunderstorm				4			4			4	Y	-
Heavy precipitation (mm)	22.1	25.1	13.8	4	26.2	18.7	4	30.7	38.7	4	-	-
Tornados	0.1	Projections highly uncertain – potential for increase in tornado activity									-	-
Lightning	1641.0	Projected to increase with climate change									-	-
Hail		Projected to increase with climate change									-	-

Appendix B

Climate Change Impacts on Ecosystems and Agriculture

B-1 Ecosystems

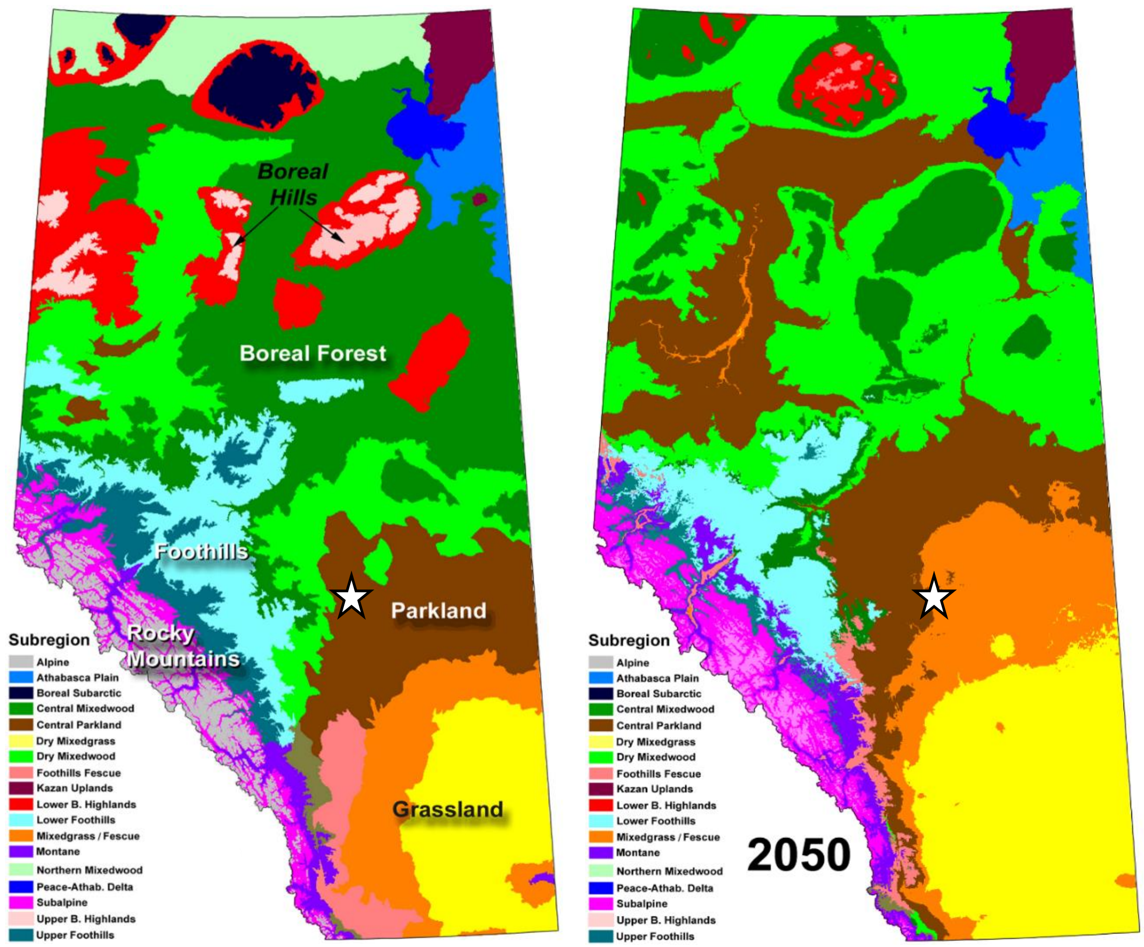
A community of organisms living and interacting within a physical environment is described as an ecosystem. Climate change has a direct impact on the integrity and stability of ecosystems by altering biodiversity, habitats, and ecosystem processes and services (NOAA, 2020). It poses a threat to many species, mainly due to increased temperatures, changes in precipitation patterns, disturbances in inter-species relationships, increases in pests and pathogens, in addition to anthropogenic pressure on natural habitats (Applequist et al., 2020). Social, cultural, and economic activities that revolve around land, such as hunting, trapping, gathering, fishing, and agriculture, are, therefore, deeply impacted by the changing climate.

The impacts of climate change on ecosystems are complex and operate at multiple scales, from individuals to populations, communities, and species. These impacts include changes in morphology, phenology, behaviour, and range (Weiskopf et al., 2020). Morphological changes which are often related to body size are hard and complex to understand and predict. It is hence difficult to attribute observed changes to climate change. On the other hand, changes in phenology, or the recurrence and seasonal timing of biological events, are some of the first signs of species responding to climate change.

Although a wide range of species across most of the world’s biomes have exhibited changes in phenology, the magnitude of these changes varies greatly. Thereby, the phenological shifts are often asynchronous, resulting in the disruption of inter-species relationships as well as in the functioning, persistence, and resilience of ecosystems. For plants, these changes can influence the beginning of the growing season or the timing of budding and flowering. For terrestrial and aquatic animals, phenological changes can result in an earlier migration and breeding periods. As an example, scientists have observed that brown bears from Kodiak Island, Alaska, are switching their primary food source from sockeye salmon to red elderberry following anomalously warm springs, when elderberry fruits ripe earlier. This change in the prey-predator relationship disrupts the ecological balance in the population of sockeye salmon and in the food web (Deacy et al., 2017). Other behavioural changes include seeking refuge or shade, altered feeding times, and shifts in the circadian and circannual rhythms (e.g., hibernation and migration).

On a larger scale, climate change manifests its impacts on ecosystems through key drivers such as changes in extreme events and biological invasions. Extreme events like extensive and/or recurring droughts and wildfires have long-lasting and synergistical impacts on ecosystem resilience (Whitman et al., 2019). In forested ecosystems, tree defenses are weakened by these perturbations and are more vulnerable to insects, diseases, and invasive species. Indeed, climate change is facilitating the introduction and proliferation of exotic, invasive species. Many of these species are opportunistic generalists that can take advantage of changing environmental conditions, spread to new areas and out-compete local species (Weiskopf et al., 2020).The invasion of non-local, invasive species can be linked to the decline of biodiversity by the alteration of community composition and the extinction of the more vulnerable species.

These described pressures, mainly driven by changes in temperature and precipitations, result in large-scale shifts in species distribution, abundance, and reorganization of terrestrial and aquatic ecosystems. In reaction to the increase in temperature and changes in precipitations, the suitable range of many plant and animal species is expected to shift mainly to higher latitudes and/or altitude. It has been found that already 55% of plant and animal species across North America have expanded their range to cooler zones and retreated from the warmer front of their range (i.e., local extinctions) (Wiens, 2016; Wang et al., 2023). While temperature and precipitations are typically the two key abiotic drivers of ecosystem shifts, other parameters, such as topography, land use, and microclimates, can influence the shifts as well.

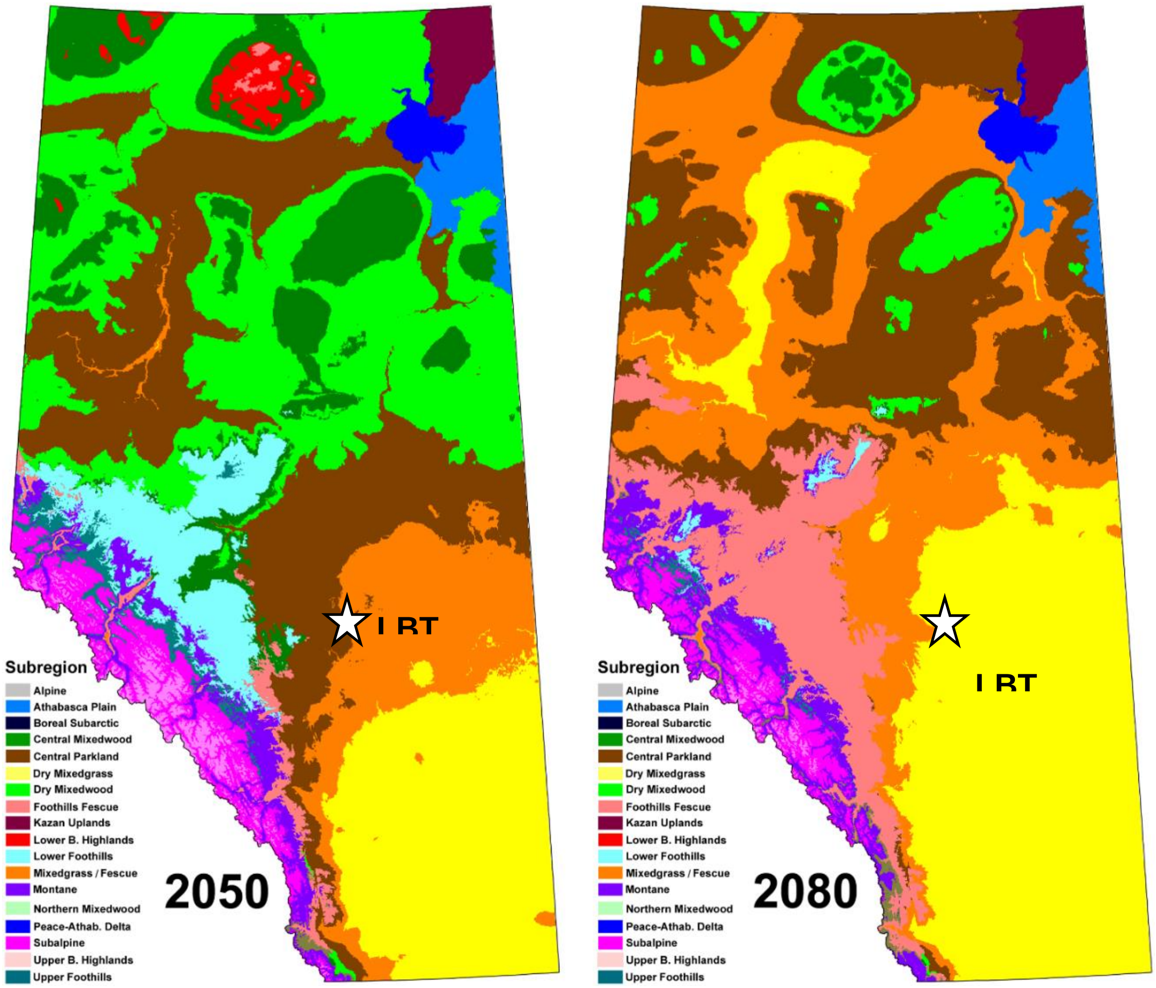


Source: (Schneider & Bayne, 2015)

Figure B1: Current Distribution (left; 2005) and Projection (right; 2050) of Alberta's Major Ecosystem Types (RCP8.5)

Historically, LBT is located in the Central Parkland subregion (**Figure B1**) (Sauchyn et al., 2020). The Central Parkland subregion is heavily populated and about 80% of its area is cultivated (Alberta Parks, 2015). The original ecosystem is therefore highly fragmented by cropland, with isolated islands of aspen, willow shrubs and balsam (Downing & Pettapiece, 2006). In 2050, these forested islands will likely be stressed due to warmer and dryer conditions and will transition to a Mixedgrass/Fescue.

Further into the future, it is expected for the ecosystems at LBT to transition to a dry Mixedgrass environment, which is the warmest and driest subregion of Alberta (**Figure B2**). The dominant vegetation of this subregion, which is expanding from the south of the province, is short and mid-height grasses (Downing & Pettapiece, 2006). Most activities and traditional land use, such as hunting, fishing, and gathering berries and other plants, would be greatly impacted for the next generations as forested islands make place for open, grass plains.



Source: (Schneider & Bayne, 2015)

Figure B2: Projected Distribution (2050 and 2080) of Alberta's Major ecosystem types (RCP8.5)

The shift of ecosystems will take place over decades and is projected to continue in the next century. The speed with which the transition will happen is different from the rate of climate change as plants have greater inertia and follow the climatic changes more slowly. Furthermore, the ecosystem transition will happen heterogeneously, depending greatly on seed dispersal ability, the deterioration of soil moisture and warming, as well as disturbances like diseases, pests, wildfire, drought, and windthrow that will advantage new species to shift in the disturbed ecosystem (Sauchyn et al., 2020). Human activities that cause habitat destruction and fragmentation, such as massive agriculture, deforestation, and mining exploitation, can also affect the ability of plants and animals to migrate. For example, the fragmentation of watercourses can compromise the ability of certain fish species, which are very sensitive to biotic and abiotic changes, to migrate to suitable habitats. Even though animals are more mobile than plants, some species that are more sensitive to habitat suitability (e.g., presence of specific plants or prey) will be limited by the rate of their habitat transition.

Climate change also impacts the capacity of ecosystems to provide for human communities and societies (i.e., ecosystem services). The alterations to ecosystem services may include impairment of water supply and quality, increase of food insecurity, loss of medicinal plants, and threat to the maintenance of culture and traditions. Indeed, drier years can lead to surface water shortage, while the increase of stream water temperature alters water quality and promotes harmful algae blooms. Moreover, climate change can have detrimental effects on medicinal plants by decreasing their availability, abundance, and accessibility, inducing extinction for the more vulnerable species, and altering the phytochemical content and pharmaceutical properties of these plants (Applequist et al., 2020). The potential loss of the wild growth of these medicinal plants might necessitate the cultivation of these valued plants. Ecosystem and range shifts constitute a threat to Indigenous cultural maintenance: culturally important species shift their range further than tribal land area (Weiskopf et al., 2020).

Adaptation and resilience to the impacts of climate change on ecosystems is possible through some pro-active and conservation measures. On one hand, identifying, through a climate change vulnerability assessment, the exposure, sensitivity and adaptative capacity of important, traditionally used species can help focus the attention on specific threats to the community. On the other hand, maintaining habitat integrity and connectivity can help in limiting the non-climate stressors like pollution, invasive species, and habitat fragmentation. One avenue to prevent uncontrollable wildfires and ensure habitat cohesion is the continuation of prescribed and/or cultural burning, tree thinning, pruning of understorey vegetation and litter. Prescribed and cultural burning has other positive effects, mainly on berry production/quality and for hunting/trapping activities (Christianson et al., 2022). Finally, restoring and protecting zones that provide valued resources are important to maintain ecosystem resilience and cultural needs.

B-2 Agriculture

Considering the significance of maintaining a strong connection to the land to the Louis Bull Tribe community, then agricultural activities must incorporate practices that promote regenerative land management, integration of indigenous knowledge, culture, and education, and addressing food sovereignty. Further to this, the impacts of climate change on these activities must also be considered to ensure its sustainability and resiliency to climate change. The agricultural activities include poultry production, beekeeping, cattle and pasture improvement, bison heard management, fishing on a stocked lake, a closed loop system within which local crops feed livestock.

B-2.1 Agricultural and Pasture Lands

The optimal growing conditions for plants occur within a specific climatic range and environmental conditions. When these conditions change due to direct human interventions in the environment or due to climate change, plant growth can be delayed, slowed down or even fail (Heino et al., 2023). Climate change impacts agriculture in multiple ways. Some of the direct impacts include changes to the length of the growing season, the quantity and expected timing of precipitation, frequency of extreme events such as heatwave, windstorms, flooding, and drought. Warming is generally associated with fewer cold days in the winter, higher maximum temperatures throughout the year, and with increases in both the daytime and the nighttime temperatures. Warming can also increase mid-winter thaws which can increase the likelihood of flooding. The changes in the length of the growing season can result in the need to change farming practices to accommodate the shifts in seeding dates and harvest times. However, climate change also presents opportunities for agriculture, as the warming in the Prairies can lead to longer growing seasons resulting in a northward increase in arable land space (Laforge et al., 2021; The Poultry Site, 2023).

Changes in the intensity, frequency, and duration of precipitation, combined with increased evaporation and transpiration due to higher temperatures during the growing seasons, can lead to a decrease in soil moisture and subsequent soil erosion. Extreme precipitations following an extended period of dry, or drought conditions can also lead to soil erosion. Increased precipitation, especially extreme rainfalls, and snow events can result in flooding, which can negatively impact water quality resulting from runoff, and lead to soil erosion and long-term effects on soil fertility.

Most of Alberta's groundwater recharge comes from the infiltration of surface water and snowmelt (North Saskatchewan Watershed Alliance, 2012). In multiple watersheds in the province, groundwater resources are put under stress, resulting in a decline in availability of the resource (Bhatti et al., 2021). Although the effects of climate change on groundwater levels and dynamics are complex and not fully understood, it is expected that spatiotemporal changes in precipitation and temperature (i.e., precipitation amounts and form, timing of precipitations and snowmelt) affect groundwater recharge timing and rate (Environment Canada, 2004; Aeschbach-Hertig & Gleeson, 2012; Zaremehrjardy et al., 2022; Weber, 2024). Furthermore, extreme events, such as droughts and extreme precipitation, can alter groundwater recharge through reduced ground infiltration, increased evaporation and increased runoff (Environment Canada, 2004). Groundwater depletion can cause several socio-economic and environmental problems, such as the drying of wells, the increase in the costs related to operating wells, spread of pollutions from surrounding contaminated soils or aquifers, ground subsidence, and reduced discharge to surface waters and wetlands (Aeschbach-Hertig & Gleeson, 2012).

The frequency of other extreme weather events including wildfires, and severe thunderstorm will increase. The increase in wildfires is fuelled by more favourable conditions due to warmer and drier weather making the wildfire season longer and leading to more intense fires. Dry conditions and the increased availability of combustible materials further increases the likelihood of spread (IPCC, 2014). In addition to lightening, thunderstorms produce very heavy rainfall that can also lead to water runoff, soil erosion and issues with soil fertility. These indirect impacts of climate change negatively affect the productivity of the agricultural land.

Given the above-mentioned expected changes in climate and impacts on the agricultural land the projections in crop yields are presented for the prairie provinces as a whole and not Alberta nor LBT. They are therefore considered as representative of crop production for the purpose of this report. Some crop yields are expected to increase e.g., Spring wheat, while others are expected to decrease e.g., canola (**TableB1**).

TableB1: Simulations of Changes in Future Crop Yields in Canadian Prairie Provinces Using Various Climate Scenarios.

Locations	Crops	Yield change and the time period
Swift Current, SK	Spring wheat	8-11% (2041-2070) and 8-15% (2071-2100)
Brandon, MB	Canola	-21% to -44% (2041-2070) and -23% to -74% (2071-2100)
13 locations across the Prairies	Spring wheat	15-25% (2041-2070)
11 locations across the Prairies	Spring wheat	26-37% (2041-2070)
Dauphin, MB; Melfort, SK; Edmonton, AB; Fort Vermilion, AB	Timothy	>24% for first cut and <-31% for second cut (2040-2069)
Swift Current, SK	Spring wheat (Biofuel cultivar)	41-74% (2040-2069)
Swift Current, SK; Melfort, SK; Lethbridge, AB	Spring wheat	~37% (2040-2069)

Source: Adapted from (Sauchyn et al., 2020)

B-2.2 Local Crops feed Livestock

Considering the above-mentioned climate impacts on the productivity of agricultural land and crop production, the resulting decrease in good quality forage crops and grazing lands can pose a threat to livestock nutrition and subsequently its health. The indigenous practice of feeding local crops and the remains (waste) from harvested crops to livestock can also negatively impact livestock health if the quality of the crops is compromised (FoodPrint, 2023).

During intense or prolonged, multi-year drought events, communities may struggle to feed livestock with locally grown crops, resulting in the need to downsize their herd or have the feed delivered by truck, which can be expensive (Stephenson, 2023).

B-2.3 Cattle and Bison Herd Management

Climate change and shifts in biodiversity lead to an increase in pests, diseases, and invasive species, such as weeds and insects that can negatively impact both crop and livestock productions and health. These include cereal rusts, striped fleas beetle, crucifer flea beetle, deer ticks, and biting midge. Additionally, livestock production will be negatively impacted from a decrease in water availability, and an increase in heat events, leading in lower weight gains. Warmer summers can also bring an increase in heat stress, livestock death, decreased milk production and fertility.

B-2.4 Poultry

Similarly, climate change threatens the feed quality for poultry (chicken and turkey) due to increased temperature, changes in rainfall, increase in heat wave, droughts and flooding event, emergence of new pests and diseases and invasive weeds negatively impacting feed crop yields. This reduces the growth, and egg and meat yields. Warmer temperatures also lead to heat stress, reduced reproductivity and even mortality in poultry (especially if confined) (Laforge et al., 2021). Furthermore, water availability affects both chicken and turkey water intake and overall health (The Poultry Site, 2023).

B-2.5 Beekeeping

According to the Food and Agriculture Organisation, climate change poses a threat to bees due to the warmer temperatures, droughts, flooding and other extreme weather events. Additionally, the resulting shifts in flowering periods delay pollination due to change in abundance of flowers in bloom and the availability of pollinators such as, bees (FAO, 2020).

B-2.6 Fishing on a Stocked Lake

Alberta's native cold-water fish are negatively impacted by climate change due to warmer winters and summers, change in precipitation and snowpack which leads to warmer and lower water levels. **Table B2** shows the water temperature related typical behaviours of cold-water fish in Alberta.

Table B2: Typical Cold-Water Fish Behaviours in Alberta and Potential Climate Change Induced Temperature Threats

Cold-water Fish	Changes in Abiotic Conditions	Consequences
Adult grayling	Water temperature above 17 °C	Reduced feeding & growth
	Water temperature above 24 °C	Life threatening
Athabasca rainbow trout	Water temperature above 22 °C	Life threatening
Bull trout	Water temperature above 16 °C	Reduced occurrence
Westslope cutthroat trout	Drying of small tributaries (preferred habitat)	Life threatening
	Higher water temperature	Increased mortality

Source: (Alberta Wilderness Association, 2023)

B-2.7 Regenerative Agriculture as an Adaptation measure for Agriculture

The Central Parkland subregion is mainly used for agricultural land with approximately 5% being native vegetation. The mains crops are wheat, barley, canola, flax, among others. Additionally, 2% of the subregion is covered with waterbodies and 10% of wetlands cover. With the projected environmental shift to Mixedgrass/Fescue, the conditions will be more conducive to mainly wheat production with some continued barley and canola production. The increases in drought length and frequency and warmer summer will potentially results in reduced yields. In these climatic conditions, there may be less open water bodies and wetlands compared to the original Central Parkland subregion.

The shift to Dry Mixedgrass in the long-term future (2080s) could mean an even drier region, which is conducive for growing mainly wheat/fallow, with smaller grazing areas. The conditions are the results of higher temperatures, intense mid-summer sunshine, low precipitation, and drying winds, leading to moisture deficits in plants. Trees tend to grow close to rivers and other surface waters. There is also high evaporation and cold, long winters with low snow cover, leading to changes in soil fertility.

These means that the adaptation measures used to build resilience of the agricultural practises used in the LBT community must be appropriate for crops, poultry, livestock, (mainly cattle and bison), beekeeping, and fisheries production, and considering the impacts of climate change, the projected shifts in ecosystem, while using their traditional practices and knowledge. This is done to achieve food sovereignty which *'… is a specific policy approach to address the underlying issues impacting Indigenous peoples and their ability to respond to their own needs for healthy, culturally adapted Indigenous food.'*(Indigenous Food Systems Network, s. d.) In this context, *'Regenerative Agriculture a way of farming that nurtures and restores soil health, and therefore reduces water use, prevents land degradation, and promotes biodiversity. By minimizing land ploughing, practicing rotating crops, and using animal manure and compost, regenerative agriculture ensures that the soil stores more carbon, conserves more moisture, and is healthier due to thriving fungal communities… Regenerative agriculture helps lower greenhouse gas emissions, conserves water, and restores land. Moreover, healthy soil produces more food and better nutrition and has other positive impacts on ecosystems and biodiversity*' (UNDP, 2023). Many regenerative agricultural practices have been traditionally used by Indigenous People and have supported the regeneration of natural resources such as soil, water, and forests (FoodPrint, 2023).

Regenerative agricultural practices for crops and land management include (Sauchyn et al., 2020; Laforge et al., 2021):

- Practice zero-tillage methods.
- Change seeding dates and cropping regimes or types.
- Adopt mixed farming systems with crops, livestock, beekeeping, and waste management strategies (including composting) to implement a closed-loop system.
- Use native crop varieties and traditional foods that are more resilient, heat and drought tolerant.
- Intercrop plants that will benefit each other by adding essential nutrients to the soil as natural fertilizer (FoodPrint, 2023).
- Use agroforestry methods for land management (FoodPrint, 2023).
- Incorporate good grazing practices for land management to boost biodiversity (FoodPrint, 2023).
- Use precision agriculture to facilitate adaptive actions.
- Use crop insurance and climate data for farm planning and risk assessments.

Additionally, there is already a trend to increase farm size to accommodate the new infrastructure and practices.

Regenerative Agricultural practices for livestock include (Sauchyn et al., 2020; Laforge et al., 2021):

- Monitoring livestock during heat events and using heat-abatement strategies.
- Improve livestock practices (e.g., breeding, feeding, feed stockpiling).
- Adopt mixed farming systems with crops, livestock, beekeeping, poultry, and waste management strategies (including composting) to implement a closed-loop system.
- Adopt good herd management practices.
- Raise alternative breeds and species and preserve the genetic diversity that are stress and heat tolerant (FoodPrint, 2023).
- Use and integrated pest management system.
- Use traditional strategies such as grazing cattle with cover crops which have added benefits such as returning nutrients to the soil (BCRC, 2023).
- Develop enterprises that are appropriate for the LBT geographic locations.

Regenerative Agricultural practices for poultry include (The Poultry Site, 2023):

- Diversify feed crops to allow poultry to be less reliant climate-sensitive feed crops. Select poultry breeds that are more heat tolerant.
- Use rainwater harvesting and other water management strategies to increase water storage and availability for poultry farming.

Regenerative Agricultural practices for beekeeping include (FoodPrint, 2023):

- Create and maintain greater diversity that attracts more pollinators such as bees and create more bee habitats in agriculture.
- Use biological pest control and management practices.
- Integrate local and scientific knowledge and experience to diversify the farms, improve food resources and provide suitable shelter for bees.

Regenerative Agricultural practices for fisheries include (MacPherson et al., 2019):

- Use an integrated approach of close seasons for fishing.
- Improve water habitat quality using the regenerative agriculture practices mentioned above for improved land and livestock management.
- Stock the lake with fish for fishing.

Finally, it is important to farm on agricultural land and other natural resources such as forests and lakes, using an approach that incorporates the ecosystems' ability to maintain biodiversity, and be climate resilient, all while using traditional Indigenous cultural knowledge to achieve food sovereignty and creating agricultural enterprises.

Appendix C

Risk Assessment

C-1 Detailed Discussion of Risk Assessment

C-1.1 Estimate of Consequence

The assessment revealed that of 80 potential interactions between eight climate indicators and ten assets, four (4) combinations resulted in a no-impact assessment due to no exposure of the assets to weather/climate events and were therefore excluded from the subsequent analysis. For the remaining interactions, the impact severity was assessed for each impact category (**Figure C1**). The majority of interactions received a *very low* or *low* severity assessment. The category "Financial impact" is most severely impacted by climate and weather-related events with five *medium*-severity assessments and five *high*-severity assessments and two *very high*-severity assessments. This ranking can be used to help prioritize adaptation measures that will minimize impacts related to health and safety of residents, staff and visitors, the infrastructure integrity, the operation, and the finances of the LBT and the building owners.

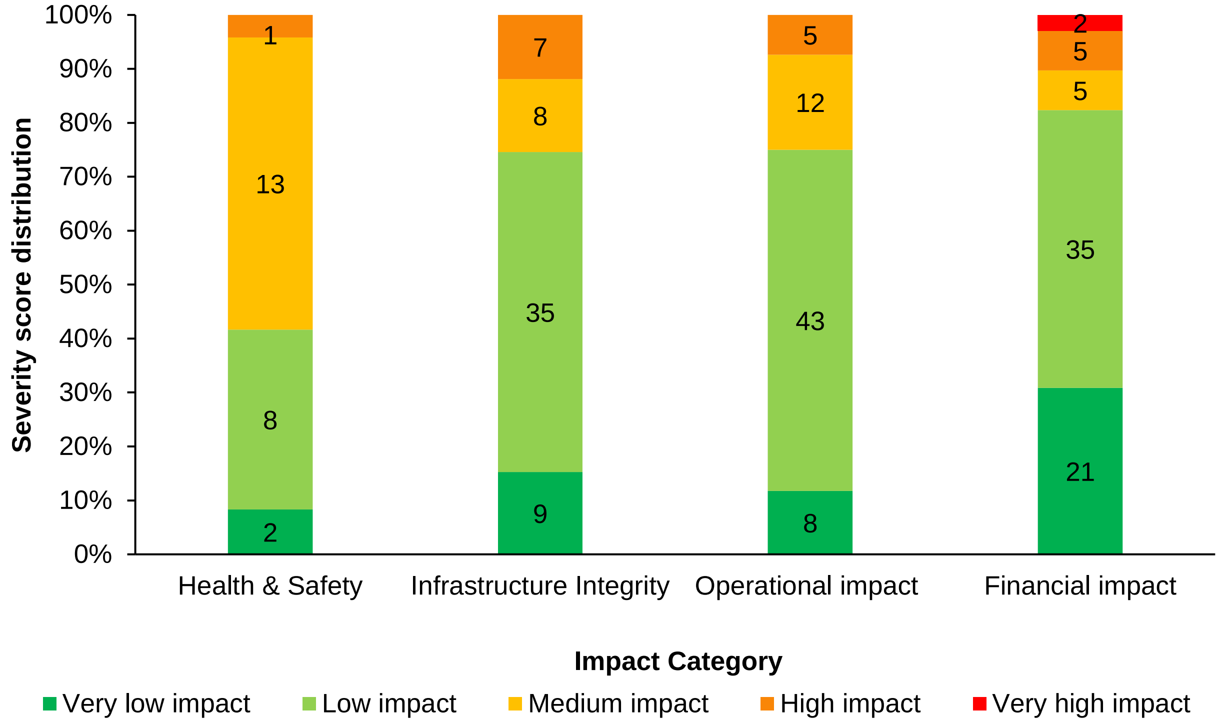


Figure C1: Number of Interactions per Level of Severity for Each Impact Category

Zooming in on one specific weather event (using heat wave as an example; **Figure C2**), for each asset and impact category, the consequence/severity score can further guide and focus the mitigation and adaptation measures in response to the projected changes in weather and climate (Table 2-4). Heat wave, freezing rain, and wildfire have a large number of *moderate* and *high*-severity assessments, while other climate indicators such as drought or heavy thunderstorms have mostly *low*-severity assessments. An interactive Pivot table, which allows for the selection and visualization of the severity for each climate indicator and each infrastructure component, is provided under a separate cover.

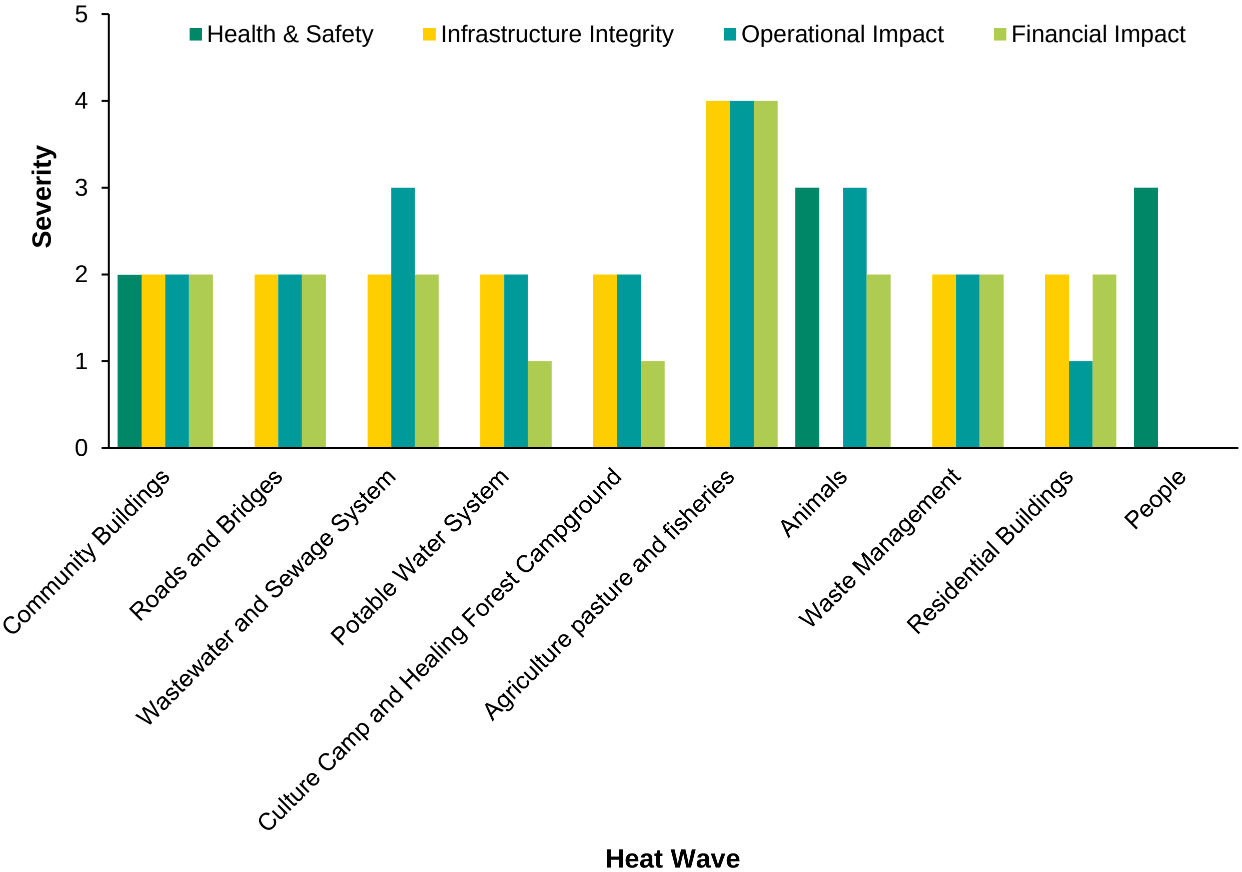


Figure C2: Level of Severity of Consequences of Heat Waves on the Individual Assets/ Operations for Each Impact Category

C-2 Detailed Discussion of Risk Evaluation

The risk score is obtained by multiplying the likelihood (of the weather/climate event) by the severity/consequence score and exposure where the binary exposure term is either 0 for no exposure or 1 if the asset is exposed to the weather/climate event (PIEVC, 2021)

$$Risk = Likelihood \times Consequence \times Exposure$$

Using the equation above, the risk level for all 80 interactions between the eight climate indicators and the ten asset groups have been calculated. Four (4) interactions were assessed to not be impacted by the selected climate indicators and hence were excluded from the risk analysis. The remaining 76 interactions show a low to high risk (Figure C3). While the risk assessment shows for many interactions the same results across all time horizons, the risk level increases for some interactions such as heavy rainfall (e.g., historical 10-year event or wildfire).

For the climate reference period (Current),

- 68 interactions result in a *low*-risk;
- 8 interactions result in a *moderate*-risk;
- 0 interaction result in a *high*-risk.

For the near-term future (2030s), the assessment indicated

- 29 interactions with a *low*-risk;
- 43 interactions with a *moderate*-risk, of which
  - 39 interactions changed from *low*-risk to *moderate*-risk;
- 4 interactions with a *high*-risk, of which
  - All interactions changed from a *moderate*-risk to a *high*-risk

For the medium-term future (2050s), the assessment indicated

- 22 interactions with a low-risk;
- 47 interactions with a moderate-risk, of which
  - 7 interactions changed from *low*-risk to *moderate*-risk;
- 7 interactions with a *high*-risk, of which
  - 3 interactions changed from a *moderate*-risk to a *high*-risk

For the long-term future timeframes (2080s), the assessment indicated

- 22 interactions with a *low*-risk;
- 47 interactions with a *moderate*-risk, of which
- 7 interactions with a *high*-risk.

A break-down of the risk scoring for the individual interactions of weather/climate events and assets is provided in **Table C1**. The risk assessment for both the climate references period (1981-2010) and the future time horizons of 2030s, 2050s and 2080s highlight the increased risk due to heat waves, freezing rain and wildfire.

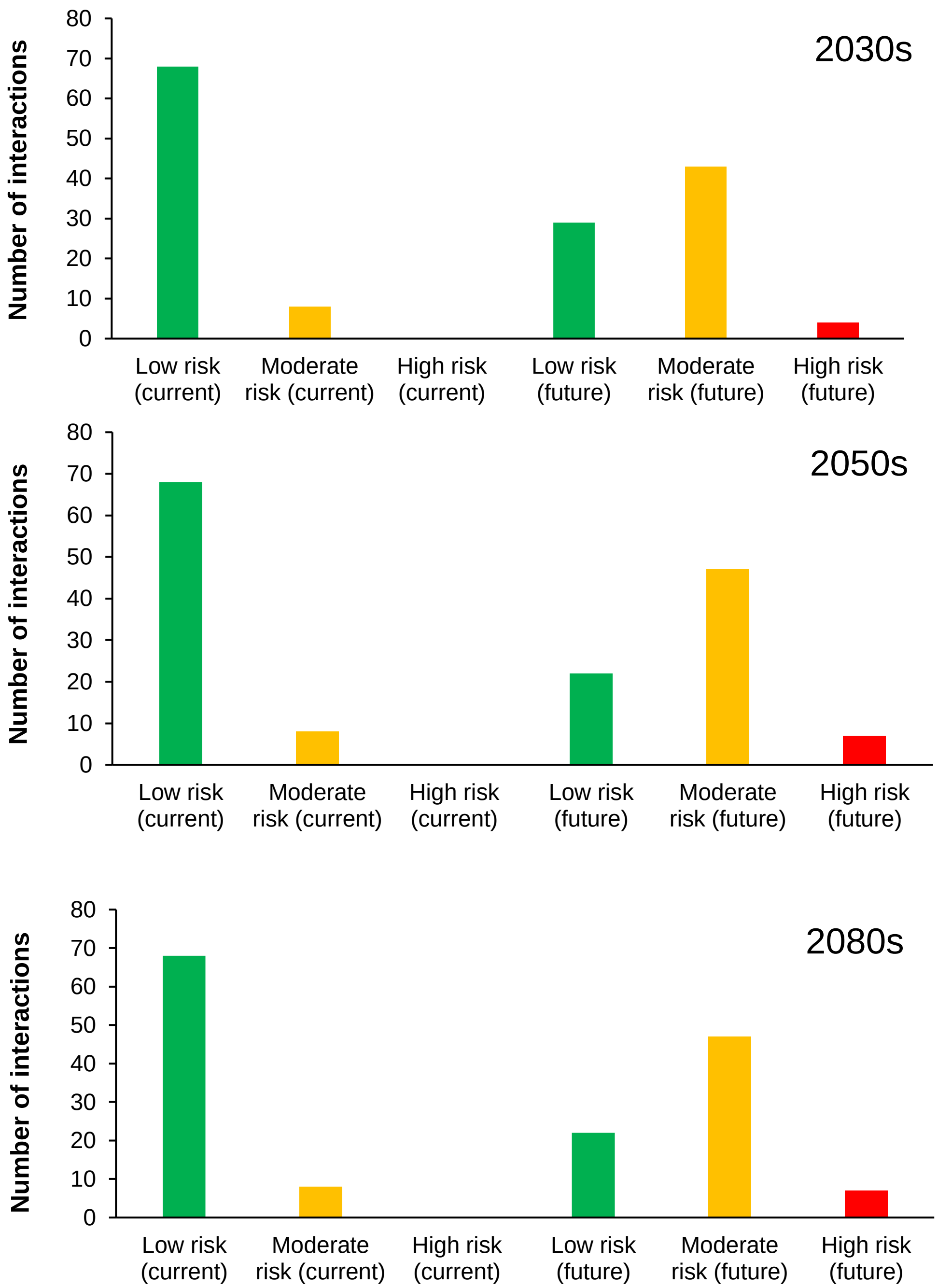


Figure C3: Level of Risks of Interactions between Weather Events and Assets Current and Future Time Horizons Using the High-Emission RCP8.5 Scenario

Table C1: Risk Evaluation Matrix Using the High-Emission RCP8.5 Scenario

	Tmean				Tmax				Heat wave				Drought				Daily rainfall (10-year event)				Freezing rain				Wildfire				Thunderstorms				Total number of future moderate and high risks per infrastructure element
Infrastructure elements	Hist	2030s	2050s	2080s	Hist	2030s	2050s	2080s	Hist	2030s	2050s	2080s	Hist	2030s	2050s	2080s	Hist	2030s	2050s	2080s	Hist	2030s	2050s	2080s	Hist	2030s	2050s	2080s	Hist	2030s	2050s	2080s	(Future)
Community Buildings	6	10	10	10	6	8	8	8	6	10	10	10	3	3	4	4	9	12	15	15	9	15	15	15	15	20	25	25	9	12	12	12	6
Roads and Bridges	6	10	10	10	6	8	8	8	6	10	10	10	6	6	8	8	9	12	15	15	6	10	10	10	9	12	15	15	6	8	8	8	5
Wastewater and Sewage System	6	10	10	10	6	8	8	8	9	15	15	15	3	3	4	4	6	8	10	10									6	8	8	8	3
Potable Water System	3	5	5	5	6	8	8	8	6	10	10	10	6	6	8	8	6	8	10	10	6	10	10	10	9	12	15	15	6	8	8	8	4
Culture Camp and Healing Forest Campground	6	10	10	10	6	8	8	8	6	10	10	10	6	6	8	8	6	8	10	10	9	15	15	15	9	12	15	15	9	12	12	12	6
Agriculture land (field and pasture) and fisheries	9	15	15	15	9	12	12	12	12	20	20	20	12	12	16	16	12	16	20	20	12	20	20	20	12	16	20	20	9	12	12	12	7
Livestock	9	15	15	15	9	12	12	12	9	15	15	15	9	9	12	12	6	8	10	10	6	10	10	10	9	12	15	15	6	8	8	8	7
Waste Management	3	5	5	5	6	8	8	8	6	10	10	10					6	8	10	10	6	10	10	10					6	8	8	8	3
Residential Buildings	6	10	10	10	6	8	8	8	6	10	10	10	3	3	4	4	9	12	15	15	6	10	10	10	15	20	25	25	6	8	8	8	5
People	9	15	15	15	9	12	12	12	9	15	15	15	6	6	8	8	6	8	10	10	9	15	15	15	12	16	20	20	9	12	12	12	7
Total number of risks per climate parameter and horizon	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**9**	**9**	**9**	**9**	**10**	**10**	**10**	**10**	**9**	**9**	**9**	**9**	**8**	**8**	**8**	**8**	**10**	**10**	**10**	**10**	

Risk Evaluation Matrix Scoring

Severity of Consequences	Very High	5	5	10	15	20	25
	High	4	4	8	12	16	20
	Moderate	3	3	6	9	12	15
	Low	2	2	4	6	8	10
	Very Low	1	1	2	3	4	5
			1	2	3	4	5
			Very Low	Low	Moderate	High	Very High
			Probability (Likelihood)				

Risk Rating (according to PIEVC HLSG)

Risk (R) = Likelihood (L) x Consequence (C)		
Low Risk:	R ≤ 9	Controls likely not required
Moderate Risk:	10 ≤ R ≤ 16	Some controls required to reduce risks to lower levels
High Risk:	R ≥ 20	High priority control measures required

Appendix D

Risk Treatment and Adaptation Measures

Risk Event	Project Components	Risk	Adaptation Measure or Risk Treatment	Comments	Implementation Timeframe	Effectiveness
Tmean	Community Buildings	10	■ High temperatures and heat waves can accelerate building envelope deterioration (roof, windows, exterior doors), resulting in increase inspection and maintenance costs. Hotter summers and heat waves can increase indoor air temperature and therefore the need for cooling/ventilation systems.	**Design:** ■ Install blinds, heat-resistant curtains, or films on windows. ■ Shade windows with outdoor shutters and awnings. ■ Use materials that are resistant to or limit the accumulation of heat, such as light-colored materials such as white (high albedo); ■ Paint roofs with light reflective colors or use materials with high thermal resistance to reduce heat gain; ■ Consider nature-based approaches, such as green roofs or green walls, to reduce building temperature during heat waves and extremely hot days. **O&M:** ■ Conduct regular inspection and maintenance of community buildings to ensure they remain resilient to extreme heat and events and higher temperatures. **Policy:** ■ As an interim measure, community buildings can be used as a cooling and heating centre until residential building are upgraded or adapted.	**Design, O&M, Policy**	**Very effective**
	Roads and Bridges	10	■ Higher temperatures may cause premature deterioration of paved surfaces over time (e.g., potholes, rutting, cracking), resulting in more maintenance costs, particularly in high-traffic areas.	**Design:** ■ Use light colored materials for pavement surfaces on sidewalks. ■ Use heat resistant paving materials with higher solar reflectance to reduce damages (e.g., potholes and cracks) and UHI effect. Also consider use of additives in asphalt mix to reduce shoving/rutting. ■ Use technologies such as soil stabilization with additives to enhance the road’s resistant to extreme temperatures and moisture changes. **O&M:** ■ Track impacts of extreme heat to identify "hot spots" that may require an increased rate of inspection. ■ Conduct frequent inspections of pavement surfaces to ensure cracks are properly sealed. ■ Conduct regular inspection of vehicular bridges for structural integrity and heat-induced stress.	**Design, O&M**	**Very effective**
	Wastewater and Sewage System	10	■ High temperature can promote the growth of algae leading to issues such as oxygen depletion and foul odours. ■ ‘Higher temperature may result in accelerated deterioration of wastewater collection system elements, resulting in increased inspections and maintenance costs.	**Design:** ■ Consider climate change (e.g., increased water consumption during periods of high temperature) when replacing/upgrading pumps/lift station. **O&M:** ■ Increase circulation and mixing of the lagoon waters to prevent stratification and sludge build up in the bottom of the lagoon, which can be a source of odours. Install monitoring system to monitor odours and additional off-gassing during hot temperatures.	**Design, O&M**	**Very effective**
	Culture Camp and Healing Forest Campground	10	■ Warmer temperature can promote the spread of pests like mosquitos and ticks, as well as invasive exotic plants. Surface water quality can also be impacted by high temperature through bacteria and algae proliferation. As high temperature and heat waves are favourable to wildfire propagation, fire bans may be in place. Hot temperatures and heat waves can increase vegetation mortality.	**Design:** ■ Visitors and camp users should have access to sufficiently shaded areas (e.g., planting trees). **Policy:** ■ Develop and implement an Emergency Preparedness and Management Plan in the case of a heat wave. ■ Communicate the health risks and individual prevention measures concerning insects and pests. ■ Communicate the health risks and individual prevention measures concerning heat-related illnesses	**Design, Policy**	**Very effective**
	Agriculture land (field and pasture) and fisheries	15	■ A higher air temperature changes the capacity of air to hold water vapour, or moisture, and enhances evaporation. These atmospheric changes can affect crop growth, productivity, mortality, water usage and produce quality. ■ Higher temperature and heat waves can create favourable conditions for pests and disease, leading to increased infestations in crops and pastures. ■ Extended periods of high temperatures and heat waves can lead to reduced water availability.	**Design:** ■ Choose heat-resistant crop varieties and diversify crop types to reduce vulnerability to heat stress. ■ Practice rational grazing to prevent overgrazing and allow pastures to recover during hot periods. ■ Ensure reliable access to clean water sources for livestock, especially during heat waves. **O&M:** ■ Monitor and maintain water quality to ensure suitable conditions for fish populations during heat waves.	**Design, O&M**	**Very effective**
	Livestock	15	■ Heat stress can lead to reduced egg production, poor meat quality, and increased mortality rates among poultry, such as chickens and turkeys. Heat waves can make poultry more vulnerable to diseases, leading to higher healthcare costs. It can affect bees, decrease honey production and lower pollination rates for crops.	**Design:** ■ Provide shade and adequate ventilation in animal House to reduce heat stress. ■ Ensure a continuous supply of clean, cool water for animals, as they may drink more during hot weather. **O&M:** ■ Monitor animal health for signs of heat stress and implement appropriate measures. ■ Minimize the movement of livestock during the hottest parts of the day. **Policy:** ■ Develop and implement emergency response plan for extreme heat events.	**Design, O&M, Policy**	**Very effective**

Risk Event	Project Components	Risk	Adaptation Measure or Risk Treatment	Comments	Implementation Timeframe	Effectiveness
	Residential Buildings	10	■ High temperatures and heat waves can accelerate building envelope deterioration (roof, windows, exterior doors), resulting in increase inspection and maintenance costs. Hotter summers and heat waves can increase indoor air temperature and therefore the need for cooling/ventilation systems.	**Design:** ■ Paint building roofs with light reflective colours or use materials with high thermal resistance to minimize solar heat gain. ■ Install overhangs on south-facing windows to minimize solar heat. ■ Install or upgrade ventilation and cooling systems to increase people's wellbeing. ■ Install green roofs to reduce heat gain and energy consumption linked to cooling.	**Design**	**Very effective**
	People	15	■ Higher temperatures and heat waves could impact people's wellbeing and productivity (e.g., heat exhaustion and heat stroke, dehydration, heat stress). High temperatures and heat waves can cause delays in work. People will be affected by high temperatures/heat wave if not sufficient shade (e.g., trees) is provided. People's health can also be impacted since hot periods can lead to a degradation in potable water quality as well as a degradation in air quality. Heat waves can affect vulnerable people in greater proportions and intensity (Health Canada, 2011; US EPA, 2022).	**O&M:** ■ For workers, shift maintenance work to cooler parts of the day. **Policy:** ■ As an interim measure, community buildings can be used as a cooling and heating centre until residential building are upgraded or adapted. ■ Implement an alert protocol designed to identify and communicate hot weather and heat wave conditions that could impact the wellbeing of residents, visitors, and workers. ■ Communicate the health risks of extreme heat events with the public, as recommended by (Health Canada, 2011)For example, share heat wave warnings and health safety tips on display signs in community buildings (e.g., school, administration building, community hall)	**O&M, Policy**	**Very effective**
Tmax	Agriculture land (field and pasture) and fisheries	12	■ A higher air temperature changes the capacity of air to hold water vapour, or moisture, and enhances evaporation. These atmospheric changes can affect crop growth, productivity, mortality, water usage and produce quality. ■ Higher temperature and heat waves can create favourable conditions for pests and disease, leading to increased infestations in crops and pastures. ■ Extended periods of high temperatures and heat waves can lead to reduced water availability.	**Design:** ■ Choose heat-resistant crop varieties and diversify crop types to reduce vulnerability to heat stress. ■ Practice rational grazing to prevent overgrazing and allow pastures to recover during hot periods. ■ Ensure reliable access to clean water sources for livestock, especially during heat waves. **O&M:** ■ Monitor and maintain water quality to ensure suitable conditions for fish populations during heat waves.	**Design, O&M**	**Very effective**
	Livestock	12	■ Heat stress can lead to reduced egg production, poor meat quality, and increased mortality rates among poultry, such as chickens and turkeys. Heat waves can make poultry more vulnerable to diseases, leading to higher healthcare costs. It can affect bees, decrease honey production, and lower pollination rates for crops.	**Design:** ■ Provide shade and adequate ventilation in animal House to reduce heat stress. ■ Ensure a continuous supply of clean, cool water for animals, as they may drink more during hot weather. **O&M:** ■ Monitor animal health for signs of heat stress and implement appropriate measures. ■ Minimize the movement of livestock during the hottest parts of the day. **Policy:** ■ Develop and implement emergency response plan for extreme heat events.	**Design, O&M, Policy**	**Very effective**
	People	12	■ Higher temperatures and heat waves could impact people's wellbeing and productivity (e.g., heat exhaustion and heat stroke, dehydration, heat stress). High temperatures and heat waves can cause delays in work. People will be affected by high temperatures/heat wave if not sufficient shade (e.g., trees) is provided. People's health can also be impacted since hot periods can lead to a degradation in potable water quality as well as a degradation in air quality. Heat waves can affect vulnerable people in greater proportions and intensity (Health Canada, 2011; US EPA, 2022).	**O&M:** ■ For workers, shift maintenance work to cooler parts of the day. **Policy:** ■ As an interim measure, community buildings can be used as a cooling and heating centre until residential building are upgraded or adapted. ■ Implement an alert protocol designed to identify and communicate hot weather and heat wave conditions that could impact the wellbeing of residents, visitors, and workers. ■ Communicate the health risks of extreme heat events with the public, as recommended by (Health Canada, 2011). For example, share heat wave warnings and health safety tips on display signs in community buildings (e.g., school, administration building, community hall).	**O&M, Policy**	**Very effective**
Heat wave	Community Buildings	10	■ High temperatures and heat waves can accelerate building envelope deterioration (roof, windows, exterior doors), resulting in increase inspection and maintenance costs. Hotter summers and heat waves can increase indoor air temperature and therefore the need for cooling/ventilation systems.	**Design:** ■ Install shaders and awnings on windows, especially along south, east and west facing walls. ■ Install blinds, heat-resistant curtains, or films on windows. ■ Use materials that are resistant to or limit the accumulation of heat, such as light-colored materials such as white (high albedo); ■ Paint roofs with light reflective colors or use materials with high thermal resistance to reduce heat gain; ■ Consider nature-based approaches, such as green roofs or green walls, to reduce building temperature during heat waves and extremely hot days. **O&M:** ■ Conduct regular inspection and maintenance of community buildings to ensure they remain resilient to extreme heat and events and higher temperatures. **Policy:** ■ As an interim measure, community buildings can be used as a cooling and heating centre until residential building are upgraded or adapted.	**Design, O&M, Policy**	**Very effective**

Risk Event	Project Components	Risk	Adaptation Measure or Risk Treatment	Comments	Implementation Timeframe	Effectiveness
	Roads and Bridges	10	■ Higher temperatures may cause premature deterioration of paved surfaces over time (e.g., potholes, rutting, cracking), resulting in more maintenance costs, particularly in high-traffic areas.	**Design:** ■ Use light colored materials for pavement surfaces on sidewalks. ■ Use heat resistant paving materials with higher solar reflectance to reduce damages (e.g., potholes and cracks) and UHI effect. Also consider use of additives in asphalt mix to reduce shoving/rutting. **O&M:** ■ Track impacts of extreme heat to identify "hot spots" that may require an increased rate of inspection. ■ Conduct frequent inspections of pavement surfaces to ensure cracks are properly sealed. ■ Conduct regular inspection of vehicular bridges for structural integrity and heat-induced stress.	**Design, O&M**	**Very effective**
	Wastewater and Sewage System	15	■ High temperature can promote the growth of algae leading to issues such as oxygen depletion and foul odours. ■ 'Higher temperature may result in accelerated deterioration of wastewater collection system elements, resulting in increased inspections and maintenance costs.	**Design:** ■ Consider climate change (e.g., increased water consumption during periods of high temperature) when replacing/upgrading pumps/lift station. **O&M:** ■ Increase circulation and mixing of the lagoon waters to prevent stratification and sludge build up in the bottom of the lagoon, which can be a source of odours. ■ Install monitoring system to monitor odours and additional off-gassing during hot temperatures.	**Design, O&M**	**Very effective**
	Potable Water System	10	■ High temperatures and heat waves can accelerate building envelope deterioration (roof, windows, exterior doors); may result in accelerated deterioration of potable water system elements, resulting in increased inspections and maintenance costs. ■ The demand for water may increase during periods of high temperature and heat waves.	**Design:** ■ Use materials that have a high heat resistance for potable water system elements. ■ Install wellhead covers to shield wellheads from direct sunlight and prevent overheating. ■ Implement backup power sources to maintain continuous water distribution during power outages. **O&M:** ■ Track impacts of extreme heat to identify "hot spots" that may require an increased rate of inspection. ■ Conduct frequent inspections of water distribution elements and pipes to ensure the efficiency of elements.	**Design, O&M**	**Very effective**
	Culture Camp and Healing Forest Campground	10	■ Warmer temperature can promote the spread of pests like mosquitos and ticks, as well as invasive exotic plants. Surface water quality can also be impacted by high temperature through bacteria and algae proliferation. As high temperature and heat waves are favourable to wildfire propagation, fire bans may be in place. Hot temperatures and heat waves can increase vegetation mortality.	**Design:** ■ Visitors and camp users should have access to sufficiently shaded areas (e.g., planting trees). **Policy:** ■ Develop and implement an Emergency Preparedness and Management Plan in the case of a heat wave. ■ Communicate the health risks and individual prevention measures concerning insects and pests. ■ Communicate the health risks and individual prevention measures concerning heat-related illnesses	**Design, Policy**	**Very effective**
	Agriculture land (field and pasture) and fisheries	20	■ A higher air temperature changes the capacity of air to hold water vapour, or moisture, and enhances evaporation. These atmospheric changes can affect crop growth, productivity, mortality, water usage and produce quality. ■ Higher temperature and heat waves can create favourable conditions for pests and disease, leading to increased infestations in crops and pastures. ■ Extended periods of high temperatures and heat waves can lead to reduced water availability.	**Design:** ■ Choose heat-resistant crop varieties and diversify crop types to reduce vulnerability to heat stress. ■ Practice rational grazing to prevent overgrazing and allow pastures to recover during hot periods. ■ Ensure reliable access to clean water sources for livestock, especially during heat waves. **O&M:** ■ Monitor and maintain water quality to ensure suitable conditions for fish populations during heat waves.	**Design, O&M**	**Very effective**
	Livestock	15	■ Heat stress can lead to reduced egg production, poor meat quality, and increased mortality rates among poultry, such as chickens and turkeys. Heat waves can make poultry more vulnerable to diseases, leading to higher healthcare costs. It can affect bees, decrease honey production and lower pollination rates for crops.	**Design:** ■ Provide shade and adequate ventilation in animal house to reduce heat stress. ■ Ensure a continuous supply of clean, cool water for animals, as they may drink more during hot weather. **O&M:** ■ Monitor animal health for signs of heat stress and implement appropriate measures. ■ Minimize the movement of livestock during the hottest parts of the day. **Policy:** ■ Develop and implement emergency response plan for extreme heat events.	**Design, O&M, Policy**	**Very effective**
	Waste Management	10	■ Heat waves can accelerate the decomposition of organic waste in composting facilities and leading to odour issues and increase the cost of monitoring and maintenance. Higher temperature and heat waves can increase the risk of equipment overheating, leading to service disruptions and operational challenges.	**Design:** ■ Implement leachate management systems to handle increased leachate volumes due to higher temperatures. ■ Cover compost piles and provide shading to prevent excessive drying and heat buildup, which can hamper the composting process. **O&M:** ■ Conduct regular monitoring and inspection of waste management components to maintain optimal conditions.	**Design, O&M**	**Very effective**
	Residential Buildings	10	■ High temperatures and heat waves can accelerate building envelope deterioration (roof, windows, exterior doors), resulting in increase inspection and maintenance costs. Hotter summers and heat waves can increase indoor air temperature and therefore the need for cooling/ventilation systems.	**Design:** ■ Paint building roofs with light reflective colours or use materials with high thermal resistance to minimize solar heat gain. ■ Install overhangs on south-facing windows to minimize solar heat. ■ Install or upgrade ventilation and cooling systems to increase people's wellbeing. ■ Install green roofs to reduce heat gain and energy consumption linked to cooling.	**Design**	**Very effective**

Risk Event	Project Components	Risk	Adaptation Measure or Risk Treatment	Comments	Implementation Timeframe	Effectiveness
	People	15	■ Higher temperatures and heat waves could impact people's wellbeing and productivity (e.g., heat exhaustion and heat stroke, dehydration, heat stress). High temperatures and heat waves can cause delays in work. People will be affected by high temperatures/heat wave if not sufficient shade (e.g., trees) is provided. People's health can also be impacted since hot periods can lead to a degradation in potable water quality as well as a degradation in air quality. Heat waves can affect vulnerable people in greater proportions and intensity (Health Canada, 2011; US EPA, 2022).	**O&M:** ■ For workers, shift maintenance work to cooler parts of the day. **Policy:** ■ As an interim measure, community buildings can be used as a cooling and heating centre until residential building are upgraded or adapted. ■ Implement an alert protocol designed to identify and communicate hot weather and heat wave conditions that could impact the wellbeing of residents, visitors, and workers. ■ Communicate the health risks of extreme heat events with the public, as recommended by (Health Canada, 2011). For example, share heat wave warnings and health safety tips on display signs in community buildings (e.g., school, administration building, community hall).	**O&M, Policy**	**Very effective**
Drought	Agriculture land (field and pasture) and fisheries	16	■ Drought can cause water scarcity, leading to inadequate moisture for crop growth. It reduces water availability. ■ Prolonged drought can lead to soil degradation, reducing soil fertility and long-term productivity.	**Design:** ■ Building water retention ponds and restoring wetlands can increase the availability of water. ■ Choose drought-resistant crop varieties and diversify crop types to reduce vulnerability to drought. ■ Implement water management practices to optimize water use and reduce water wastage. ■ Practice rational grazing to prevent overgrazing and allow pastures to recover during dry spells. ■ Ensure reliable access to clean water sources for livestock to prevent dehydration. **O&M:** ■ Monitor and maintain water quality to ensure suitable conditions for fish populations, assess impacts and adjust fishing practices.	**Design, O&M**	**Very effective**
	Livestock	12	■ Drought can lead to reduced water availability, which is critical for animal's well-being. Insufficient water can cause dehydration, reduced egg production, and increased mortality rates of animals. ■ Lower water levels in rivers, lakes, and reservoirs that can limit the habitat and breeding areas for fish, reducing fish population.	**Design:** ■ Install efficient watering systems for poultry that minimize water wastage. ■ Implement water-saving practices to ensure a stable food and water supply during droughts. **Policy:** ■ Develop and implement emergency response plan for drought events.	**Design, Policy**	**Very effective**
Daily rainfall (10-year event)	Community Buildings	15	■ Increased precipitation can reduce structural integrity of building components by accelerated degradation, deterioration, corrosion and weathering of materials and foundations. Wetter conditions can increase mold growth. Frequent heavy rainfalls can lead to more frequent floods (from watercourses, water infiltration and storm sewers). Evacuation might be necessary due to flooding of the creek.	**Design:** ■ Provide sufficient drainage system capacity to handle high water flows during intensive rainfall. **O&M:** ■ Inspect door and window seals regularly to reduce water infiltration. ■ Provide easy access to drainage systems including roof drains to allow for frequent inspections of the drainage system. ■ Clear drainage systems of debris (e.g., objects, leaves) to prevent sewer back up.	**Design, O&M**	**Very effective**
	Roads and Bridges	15	■ Extreme/heavy rainfall could cause premature damages to the road pavement (e.g., rutting, potholes) as well as the signage. Reduced road safety. Heavy rainfall may increase need for surface drainage to prevent flooding. Earth roads loose their structural integrity during heavy rainfall events (e.g., water pooling, washouts, etc.).	**Design:** ■ Incorporate low impact development practices or green Infrastructure to manage stormwater runoff and prevent flood damages. Some examples include, bioretention planters, bioswales, etc. ■ Implement gravel compaction techniques to reduce erosion and rutting during heavy rains. ■ Design and maintain the road with a crown or camber to encourage water runoff to the sides rather than pooling in the centre. **O&M:** ■ Clear drainage systems of debris to prevent sewer back up ■ Conduct frequent grading and maintenance of gravel roads to fill potholes and maintain a smooth surface that can handle heavy rainfall more effectively.	**Design, O&M**	**Very effective**
	Wastewater and Sewage System	10	■ Frequent heavy rainfalls can lead to more frequent floods (from watercourses, water infiltration and storm sewers). This can lead to an increase in inspection and maintenance costs. Heavy and frequent rainfalls will increase the amount of runoff water to reach the drainage system. That stress can increase risk of overflow/flooding. If the lagoon reaches its capacity, wastewater may have to be released in the stream before the required time, leading to possible contamination of surrounding ecosystems. ■ Also the heavy rainfall and storm related may cause power outages, resulting in increased maintenance and inspection costs.	**Design:** ■ Consider increasing the dimensions of the lagoon to have a larger decantation capacity in the event of flooding or of overflow caused by a heavy volume of runoff water. **O&M:** ■ Inspect door and window seals regularly to reduce water infiltration (lift stations). ■ Proceed to regular inspections and maintenance to the lift stations to quickly detect material degradation and mold development.	**Design, O&M**	**Very effective**

Risk Event	Project Components	Risk	Adaptation Measure or Risk Treatment	Comments	Implementation Timeframe	Effectiveness
	Potable Water System	10	■ Increased precipitation can reduce structural integrity of building components by accelerated degradation, deterioration, corrosion and weathering of materials and foundations. Frequent heavy rainfalls can lead to more frequent floods (from watercourses, water infiltration and storm sewers). This can lead to an increase in inspection and maintenance costs.	**O&M:** ■ Proceed to inspections and maintenance after a heavy rainfall or a flooding event to quickly detect material degradation and mold development. ■ Inspect door and window seals regularly to reduce water infiltration. **Policy:** ■ Develop and implement an Emergency Preparedness and Management Plan in the case of a heavy rainfall or flood event.	**O&M, Policy**	**Very effective**
	Culture Camp and Healing Forest Campground	10	■ Heavy rainfalls may lead to the cancellation of camp activities. Heavy and frequent precipitation can cause flooding from watercourses.	**Design:** ■ Build a shelter structure for camp users to use in case of a storm (heavy rainfall event). **Policy:** ■ Establish a flood warning system that alerts visitors and camp users in advance so that they can plan their travel and their stay.	**Design, Policy**	**Very effective**
	Agriculture land (field and pasture) and fisheries	20	■ Excess humidity affects crops production and can increase risks of crops diseases, pests and mold. Heavy and frequent rainfall can lead to more frequent floods (from watercourses, water infiltration and storm sewers). This can lead to an increase in inspection and maintenance costs. Heavy rainfalls can lead to rotting of the roots and destruction of crops.	**Design:** ■ Implement improved drainage systems, including ditches, swales, and culverts, to manage excess rainwater and prevent waterlogging of fields. ■ Plant cover crops that help prevent soil erosion and improve soil structure, which can reduce the impacts of heavy rainfall. ■ Choose crop varieties that are more resilient to excessive rainfall and waterlogged conditions. **Policy:** ■ Implement weather forecasting and rainfall monitoring systems to anticipate heavy rain events and adjust planting and harvesting schedules accordingly. ■ Develop and implement an Emergency Preparedness and Management Plan in the case of a heavy rainfall or flood event.	**Design, Policy**	**Very effective**
	Livestock	10	■ Heavy rainfall can lead to flooding and pose a threat to the health and safety of animals. Excessive moisture can create conditions favourable for the growth of pathogens, increasing the risk of disease outbreaks among animals. ■ Heavy rainfall can cause soil erosion, leading to soil degradation and nutrient loss in pastures.	**Design:** ■ Implement effective drainage systems around poultry houses to prevent waterlogging. ■ Ensure animals, birds have access to dry and safe shelter during heavy rainfall events. **O&M:** ■ Monitor the health and well-being of the animals during and after heavy rainfalls. **Policy:** ■ Develop and implement emergency response plan for heavy rainfall events.	**Design, O&M, Policy**	**Very effective**
	Waste Management	10	■ Heavy rainfall can cause debris and leachate to escape from contaminated local resources and landfill. It may create challenges in waste management and transportation for solid waste trucks and transfer stations due to slippery road conditions. Heavy rainfall can lead to potential equipment damage, and increased inspection and maintenance costs.	**Design:** ■ Store collected waste in elevated or covered areas to prevent flooding and runoff during heavy rains. ■ Cover compost piles during heavy rainfall to prevent over-saturation and leaching. ■ Improve drainage systems at transfer stations to direct rainwater away from waste storage and handling areas. **Policy:** ■ Develop and implement emergency response plan for heavy rainfall events.	**Design, Policy**	**Very effective**
	Residential Buildings	15	■ Increased precipitation can reduce structural integrity of building components by accelerated degradation, deterioration, corrosion and weathering of materials and foundations. Intense rainfall and wet conditions can increase mold growth. Frequent heavy rainfalls can lead to more frequent floods (from watercourses, water infiltration and storm sewers). Evacuation might be necessary due to flooding of the creek.	**Design:** ■ Provide sufficient drainage system capacity to handle high water flows during intensive rainfall. **O&M:** ■ In case of winter precipitation, de-ice roof drains to prevent them from becoming clogged and to provide a path for snow and debris to for the flow of melted snow and ice. ■ Remove debris from nearest storm drain or ditch and culvert. ■ Proceed to inspections and maintenance after a heavy rainfall or a flooding event to quickly detect material degradation and mold development. ■ Inspect door and window seals regularly to reduce water infiltration. **Policy:** ■ Develop and implement an Emergency Preparedness and Management Plan in the case of a heavy rainfall or flood event.	**Design, O&M, Policy**	**Very effective**
	People	10	■ Heavy rainfall can cause disruption of construction or maintenance work, resulting in delays in operations. It can cause flooding, which would impede safety. Flooding can also cause property damage. Heavy rainfall may cause flash floods, which could make it difficult for people to access their residence or other buildings.	**O&M:** ■ Maintain proper ventilation to ensure good indoor air quality and to control moisture inside the buildings. **Policy:** ■ Develop and implement an Emergency Preparedness and Management Plan in the case of a heavy rainfall or flood event. ■ Provide real-time flood alerts so that commuters can plan their travel accordingly.	**Design, O&M, Policy**	**Very effective**

Risk Event	Project Components	Risk	Adaptation Measure or Risk Treatment	Comments	Implementation Timeframe	Effectiveness
Freezing Rain	Community Buildings	15	■ Freezing rainstorms can damage property, buildings, and other infrastructures. It may cause damages to rooftops and the ice weight may compromise the roof's load-bearing capacity. Power outages are frequent.	**Design:** ■ In design and retrofit projects taking into account the effects of climate change in the choice of materials, refer to the standards established by the Canadian Standards Association (CSA) and the updated National Building Code, 2020) **O&M:** ■ If no building envelope renovation is planned: ○ Upgrade insulation at building corners to reduce heat loss; Seal joints between panels to address insulation discontinuity issues as identified in the energy retrofit study (Blouin Tardif, 2017) ○ Increasing the frequency of wall condition monitoring in critical areas.	**Design, O&M**	**Very effective**
	Roads and Bridges	10	■ Freezing rain results in slippery road conditions (in particularly on paved roads). Freezing rain on damaged road (cracks, potholes, etc.) can increase the damage by widening the cracks etc. Even on gravel roads, it can create a layer of ice, making it difficult for vehicles to navigate and creating hazardous condition. Resulted in reduced road safety and increased in maintenance costs. ■ Health and Safety scores?	**O&M:** ■ Conduct ice clearing of access roads and parking lots to maintain good road conditions.	**O&M**	**Very effective**
	Potable Water System	10	■ Freezing rain can cause power outage. Debris (branches, objects) can damage infrastructures and buildings if they fall too closely.	**O&M:** ■ Proceed regular inspections and maintenance of the potable water system components after freezing rain events.	**O&M**	**Very effective**
	Culture Camp and Healing Forest Campground	15	■ Freezing rain can cause damage to trees, causing branches or trunks to fall. Freezing rain may lead to the cancellation of camp activities.	**Design:** ■ Build a shelter structure for camp users to use in case of a freezing rain. **Policy:** ■ Establish a freezing rain warning system that alerts visitors and camp users in advance so that they can plan their travel and their stay.	**Design, Policy**	**Very effective**
	Agriculture land (field and pasture) and fisheries	20	■ Freezing rain can cause damages to plant structure and foliage, leading to crop loss. Affected crops often experience reduced yields and may fail to reach their full potential. Freezing rain may disrupt access to water sources if they freeze over.	**Design:** ■ Use protective covers, such as row covers or frost blankets, to shield vulnerable crops from freezing rain and ice accumulation. ■ Choose crop varieties that are more tolerant of cold and freezing conditions. **Policy:** ■ Develop and implement emergency response plans for each sector to address immediate needs and damage assessment.	**Design, Policy**	**Very effective**
	Livestock	10	■ Freezing rain creates icy conditions, which can lead to cold stress in animals. Freezing rain can lead to power outages, which can disrupt heating systems in poultry farms, making it difficult to maintain the animal's comfort and health.	**Design:** ■ Ensure animal houses (poultry, turkey, and etc.) are well-insulated and equipped with heating systems to maintain a suitable temperature during freezing rain events. ■ Maintaining proper ventilation to prevent the buildup of moisture. ■ Use protective covers or wraps for beehives to shield them from freezing rain and wind. ■ Provide shelter or windbreaks to protect livestock from freezing rain and cold winds. **Policy:** ■ Develop and implement emergency response plan for freezing rainfall events.	**Design, Policy**	**Very effective**
	Waste Management	10	■ Freezing rain can create hazardous conditions for waste management. Icy roads and sidewalks leading to service delays and safety risk. ■ It also can affect the operation of facilities by potentially freezing waste materials and making them more challenging to process in operations and equipment.	**Design:** ■ Cover compost piles during freezing rain to prevent them from becoming encased in ice and to maintain composting conditions. ■ Ensure backup power sources are available for critical equipment and heating systems during power outages. **O&M:** ■ Conduct regular snow and ice removal for access roads and working areas to maintain safe operations. **Policy:** ■ Develop and implement emergency response plan to address potential ice-related incidents and equipment failures.	**Design, O&M, Policy**	**Very effective**
	Residential Buildings	10	■ Freezing rain can result in accelerated deterioration of exterior building elements (e.g., windows, exterior doors) and the building envelope, resulting in increased inspections and maintenance costs. Power outages are frequent.	**Design:** ■ In design and retrofit project taking into account the effects of climate change in the choice of materials, refer to the standards established by the Canadian Standards Association (CSA) and the updated National Building Code, 2020) **O&M:** ■ If no building envelope renovation is planned: ○ Upgrade insulation at building corners to reduce heat loss; Seal joints between panels to address insulation discontinuity issues as identified in the energy retrofit study (Blouin Tardif, 2017) ○ Increasing the frequency of wall condition monitoring in critical areas.	**Design, O&M**	**Very effective**

Risk Event	Project Components	Risk	Adaptation Measure or Risk Treatment	Comments	Implementation Timeframe	Effectiveness
	People	15	■ Freezing rain can cause dangerous driving conditions, power outage, the closure of buildings and damages to roads and buildings because of fallen debris. This can cause delays in the mobilization and arrival of first responders during emergency situations. Freezing rain can cause disruption of construction or maintenance work, resulting in delays in operations. Icy parking lots and pathways can be dangerous for pedestrians.	**Design:** ■ Establish an emergency heating centre for residents to visit in case of extended power outage. **O&M:** ■ Modify work schedules under conditions induced by climate-related disruption. **Policy:** ■ Implement an early warning system that alert staff in advance so that necessary resources can be deployed on site before, during and after an extreme weather event.	**Design, O&M, Policy**	**Very effective**
Wildfire	Community Buildings	25	■ Wildfires can cause major damages to buildings and decrease air quality. Evacuation may be necessary.	**Design:** ■ Ensure reliable access to water for firefighting efforts, including fire hydrants and water tanks. ■ Implement smoke and fire alarm systems with battery backup and regular maintenance. ■ Install backup power sources, like generators or battery systems, to maintain essential functions during power outages. **O&M:** ■ Remove needles, leaves and other debris from gutters, roof surfaces, decks and balconies. ■ Remove all combustible ground cover (mulch and plants) within 1.5 m of the building's perimeter. ■ Prune trees to create a 2 m clearance from the ground to the lowest tree branches. **Policy:** ■ Develop a wildfire preparedness guide and increase community awareness (FRIAA FireSmart Program) ■ Develop and implement emergency response plan for wildfire events. ■ Designate at least one emergency shelter per community.	**Design, O&M, Policy**	**Very effective**
	Roads and Bridges	15	■ Wildfire can leave the pavement more pliable, almost literally melting. ■ Wildfire can cause premature damages to the paved surfaces (e.g., rutting, rills), causing increased maintenance costs.	**O&M:** ■ Conduct pruning and tree removal, along the road corridor to reduce fuel loads. ■ Conduct regular maintenance and inspection of paved roads to prevent the accumulation of flammable debris and ensure safe travel. **Policy:** ■ Implement early warning systems to prepare for wildfire events and make informed decisions about road closures.	**Design, O&M, Policy**	**Very effective**
	Potable Water System	15	■ Wildfires can damage power lines and pumphouse facilities that affect the operation of water treatment plants and distribution systems. ■ Intense heat and flames can damage water treatment equipment, pumps, and pipelines, leading to financial damage and operation delays or shut down.	**Design:** ■ Install backup power generators to ensure continued operation of pumphouses and water treatment during power outage caused by wildfire. **O&M:** ■ Increase water storage capacity in reservoirs and tanks to provide a buffer in case of supply interruptions or firefighting efforts that may reduce water pressure. ■ Use remote monitoring systems to track the status of well control buildings, pumphouse, and other potable water system elements. **Policy:** ■ Implement advanced wildfire detection system and monitoring systems that provide early warning.	**Design, O&M, Policy**	**Very effective**
	Culture Camp and Healing Forest Campground	15	■ Wildfire pose a direct threat to the safety of camp visitors and staff. Smoke and poor air quality can endanger the health of individuals and ability to engage in outdoor camp activities.	**Design:** ■ Implement controlled burns or vegetation management practice to reduce fuel loads and create defensible spaces. ■ Ensure reliable access to water sources for firefighting efforts, including water tanks, hydrants, and hoses. **O&M:** ■ Establish clear access roads to and within campgrounds for emergency vehicles; maintain these roads and keep them clear of debris during fires seasons. ■ **Policy:** ■ Develop and implement emergency response plan for wildfire events. ■ Designate an emergency shelter for protection in case of danger.	**Design, O&M, Policy**	**Very effective**
	Agriculture land (field and pasture) and fisheries	20	■ Smoke can hinder photosynthesis and reduce plant growth, affecting crop yields and quality. Wildfire can affect soil fertility, water quality and requires recovery and risk reduction steps.	**Design:** ■ Ensure reliable access to water sources during and after wildfires. **O&M:** ■ Conduct regular water quality testing to detect any post-fire contamination and adjust fishing or agricultural practices accordingly. **Policy:** ■ Develop and implement emergency response plan for wildfire events.	**Design, O&M, Policy**	**Very effective**
	Livestock	15	■ Wildfire smoke can reduce air quality, leading to respiratory issues on poultry and turkeys. Wildfire can destroy the natural habitat and result in food scarcity and malnutrition among the animals.	**Design:** ■ Secure alternative water sources on stockpile water advanced to ensure livestock have access to drinking water during and after wildfires. ■ Stockpile emergency feed and supplies in a safe location to ensure animals have adequate nutrition during evacuation. **Policy:** ■ Implement fire detection and warning system that provide early alerts to farmers and allowing them to evacuate animals if necessary.	**Design, Policy**	**Very effective**

Risk Event	Project Components	Risk	Adaptation Measure or Risk Treatment	Comments	Implementation Timeframe	Effectiveness
	Residential Buildings	25	■ Wildfires can cause major damages to buildings and decrease indoor air quality, resulting in operational impact. Evacuations may be necessary.	**Design:** ■ Ensure reliable access to water for firefighting efforts, including fire hydrants and water tanks. ■ Implement smoke and fire alarm systems with battery backup and regular maintenance. ■ Install backup power sources, like generators or battery systems, to maintain essential functions during power outages. **O&M:** ■ Remove needles, leaves and other debris from gutters, roof surfaces, decks, and balconies. ■ Remove all combustible ground cover (mulch and plants) within 1.5 m of the building's perimeter. ■ Prune trees to create a 2 m clearance from the ground to the lowest tree branches. **Policy:** ■ Develop and implement emergency response plan for wildfire events.	**Design, O&M, Policy**	**Very effective**
	People	20	■ Wildfire may cause chronic effects on human health. Smoke from wildfire produces fine and ultrafine particles that can travel up to 1,000 kilometres and affect the health of people. Wildfires are also associated with increase greenhouse gases and affect air quality index.	**Design:** ■ Install electric or HEPA filters in the ventilation system. HEPA (high-efficiency particulate absorbing filter) filters will help with smoke management, and management of air-borne illnesses. ■ Install a dual stage filter system to minimize the replacement frequency of finer filters during wildfire smoke events. **O&M:** ■ Implementing early warning and detection systems; Improve preparedness planning for wildfire. **Policy:** ■ Develop a wildfire preparedness guide and increase community awareness (FRIAA FireSmart Program)	**Design, O&M, Policy**	**Very effective**
Thunderstorm	Community Buildings	12	■ Thunderstorms, combined with heavy wind, heavy snowfall, rain or freezing rain, can affect the integrity of the building envelope and other infrastructures. Strong winds can create pressure differences that may cause air leaks, water infiltration or even structural damage, resulting in increased inspections and maintenance costs.	**Design:** ■ Equip critical buildings like fire hall and daycare centre with backup power sources, such as generators, to ensure essential function during power outages. **O&M:** ■ Conduct regular maintenance and inspection of roofs, walls, and structural components to prevent leaks and water damage during heavy rains associated with thunderstorms. **Policy:** ■ Develop and implement emergency response plan for thunderstorms events.	**Design, O&M, Policy**	**Very effective**
	Culture Camp and Healing Forest Campground	12	■ Thunderstorms combined with high winds and heavy rain, can cause damage to trees, causing branches or trunks to fall. It may lead to the cancellation of camp activities.	**Design:** ■ Build a shelter structure for camp users to use in case of thunderstorms. **Policy:** ■ Establish a storm warning system that alerts visitors and camp users in advance so that they can plan their travel and their stay. ■ Establish and communicate guidelines on what to do in case of a thunderstorm to camp users and visitors.	**Design, Policy**	**Very Effective**
	Agriculture land (field and pasture) and fisheries	12	■ Thunderstorms combined with intense rainfall, can lead to flooding, soil erosion, and waterlogged fields, which can damage crops and pasture. Hail can severely damage crops, leading to reduced yields or even complete crop loss. ■ Stronger winds associated to thunderstorms can break or uproot crops, particularly taller crops.	**Design:** ■ Plant windbreaks or shelterbelts of trees and shrubs to protect crops from strong winds associated with thunderstorms. ■ Choose crop varieties that are more resilient to heavy rain and wind, if possible. **Policy:** ■ Develop and implement emergency response plans for each sector to address immediate needs and damage assessment.	**Design, Policy**	**Very effective**
	People	12	■ Thunderstorm especially hail can pose a damager to construction and maintenance staff. ■ Hail can cause break side windows on cars and cause severe injuries to people. ■ Thunderstorms can cause dangerous driving conditions and power outage, which can cause delays in the mobilization and arrival of first responders during emergency situations.	**O&M:** ■ Modify work schedules under conditions induced by climate-related disruptions. **Policy:** ■ Develop and implement an Emergency Preparedness and Management Plan in the case of thunderstorm event. ■ Provide real-time flood and thunderstorm alerts so that visitors can plan their travel accordingly.	**O&M, Policy**	**Very effective**

Appendix E

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