Climate Change in Sudbury and Districts: Assessing Health Risks and Planning Adaptations Together

Resource for Municipalities and Interested Parties to conduct *Climate Change and Health Vulnerability and Adaptation Assessments*

Public Health Sudbury & Districts

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Preamble

Public Health Sudbury & Districts is committed to working collaboratively to support the public health aspirations of First Nations and urban Indigenous populations[1]. Our journey of reconciliation is important to us, and our learning is on-going.

This report encourages municipalities to engage in climate change adaptation planning. Municipalities are key partners for public health, but certainly not the only ones. We invite and encourage all communities, partners and interested parties, including First Nations and Indigenous peoples and agencies, to utilize this report as a resource for understanding the local health impacts of climate change.

Indigenous laws and legal traditions invoke a respectful relationship to the land rather than possession of it[2]. The land that we live upon is a shared responsibility, a shared virtue and for many, a part of who we are.

Executive Summary

Climate change is impacting human health through heatwaves, wildfires, vector-borne diseases, and weather-related events such as floods, storms, and freezing rain[5]. Public Health Sudbury & Districts' service area is not immune to the health impacts of climate change. Strategies are needed to protect us all and address health inequities for populations at greatest risk.

This resource is a tool for municipalities and interested parties to assess risks and engage in climate change adaptation planning. The resource can be used on its own in many ways, but it has been specifically designed to support Climate Change and Health Vulnerability and Adaptation Assessments. Climate Change and Health Vulnerability and Adaptation Assessments are a strategic approach for municipalities and interested parties to take collaborative action and increase resilience.

The *Climate Change in Sudbury and Districts: Assessing Health Risks and Planning Adaptations Together* report includes two parts.

Part 1: Climate Change and Health Vulnerability and Adaptation Assessments, describing:

- Hazards increasing with climate change
- Health outcomes of concern
- Populations at greatest risk and factors influencing vulnerability
- Additional resources and tools
- Appendices explaining climate change models, concepts, and terms

Part 2: Climate Change Modelling Study: Temperature and Precipitation Projections specific for Each Local Community/Geographic area. The projections specific to local communities are included and covers:

- Seasonal temperatures and precipitation
- Extreme hot and cold temperatures
- Frost season
- Freezing rain
- Wildfire

Assessing vulnerability to climate change

Climate change will not affect everyone equally. Vulnerability to climate change is commonly understood as a function of three key factors: exposure, sensitivity, and adaptive capacity.

Exposure - considers the probability of a climate-related hazard impacting an individual, population, or community[28–30].

Sensitivity - considers the degree to which the individual, population, or community is affected by the hazard[28–30].

Adaptive capacity - considers the ability of the individual, population, or community to adjust or respond to hazards, take advantage of opportunities, and respond to consequences[28–30].

In considering vulnerability to health impacts, we know that health is determined by more than access to health care services and lifestyle choices. Health is also determined by the social and economic factors that influence our lives.

In general, those with more resources are better able to adapt to climate change and take steps to protect their health. According to Statistics Canada, children, women, new immigrants, Indigenous people, and people with a disability are most likely to be low-income[33].

Historic and ongoing practices of racism, colonialism, sexism, heteronormativity, cisnormativity, and ableism contribute to population-level income inequalities and, in turn, affect an individual's ability to anticipate, resist, and recover from climate change induced events and hardships.

Adaptation measures should be planned so that people who are disproportionately affected can benefit from them. For adaptations to be inclusive and effective at improving equity, participation by individuals and communities that experience racism and marginalization is required.

Understanding health risks of climate change

Hazards are increasing with climate change. Key hazards and affected populations are detailed here.

Extreme heat

The number of days per year reaching 30°C+ will triple in the next 10 years. Those at greatest risk include older adults, people with chronic illnesses, pregnant people, infants and young children, people working in the heat, people in low-income situations, and those who are homeless.

Skin cancer risk

Warmer weather draws us outside. Without more rigorous sun-protective practices, the risk of skin cancer is expected to increase 8 per cent by the 2050s.

Intense rain

Intense, heavy rainfall events are already happening at greater frequency due to climate change and lead to costly impacts such as dangerous driving conditions, road washouts, and flooded homes.

Seasonal flooding

With warmer winters, spring flooding is a risk. When the frozen ground does not absorb the spring rainfall and snow melt, the water runs across the ground, flooding homes and rivers.

Freezing rain

Freezing rain will increase 60 per cent by the 2050s. Freezing rain causes hazardous road conditions and can lead to days-long power outages. Serious injuries occur from falls, motor vehicle collisions, carbon monoxide poisoning, and hypothermia. Health care services can be over-capacity or inaccessible. Older adults and people living with disabilities are especially vulnerable when care staff and family members can't safely travel to reach them.

Lyme disease

The geographic range of the tick vector for Lyme disease is expanding northward. Within the next couple of decades, the risk of Lyme disease will increase from low to moderate. Currently, the blacklegged tick does not commonly occur in Sudbury and Districts.

Wildfire

By the year 2030, wildfires caused by lightening will increase up to 50 per cent and by human carelessness by up to 50 per cent. Wildfire impacts including evacuation, road closures, and symptoms from smoke have affected thousands of people in northeastern Ontario since 2012.

Food and water-borne illnesses

Cases of food-borne diseases tend to peak in summer months[182]. With climate change induced warmer temperatures being more favourable for pathogen survival, cases of food-borne illnesses are expected to increase. Likewise, intense precipitation and flooding can lead to heavier levels of stormwater runoff that can cause contamination of water sources and lead to water-borne illnesses.

Mental Health

Periods of very warm weather put individuals living with mental illnesses at greater risk of heat-related morbidity and mortality. People with lived experience of extreme weather events can face a variety of mental health impacts, including depression, post-traumatic stress disorder, substance use, and feelings of helplessness[235].

Economic Impacts

Wildfire, drought, pest outbreaks, changes to tree composition, and changing temperatures will impact the forestry sector as well as sectors like tourism, manufacturing, and construction that rely on forest products and forest based recreation[4]. Extreme rainfall, freezing rain, unusually warm and dry conditions can impact mining building infrastructure and worker safety. The quantity and quality of food produced from agriculture, forests, and our freshwater food systems can be impacted by changes in pest populations, erosion, soil degradation, water issues, and growing conditions[188]. This in turn can lead to food insecurity challenges within our communities.

Looking ahead

The impacts of climate change are already being seen and affect us all.

The actions we take now will contribute to the safety and well-being of people today and that of generations to come. With the information synthesized in this resource, we better understand the health hazards that are expected to increase as climate change continues.

Conducting a Climate Change and Health Vulnerability and Adaptation Assessment will forge collaborations with different sectors and interested parties and improve community resiliency to climate change through health-protective adaptations. Pursuing this work is essential to building our adaptive capacity to climate change and ensuring healthier communities now and for future generations.

An unprecedented challenge

Climate change presents an unprecedented challenge for communities and individuals. The warming of the climate system is unmistakeable. Concentrations of greenhouse gases in the atmosphere, including carbon dioxide, methane, and nitrous oxide, are unparalleled[3]. Incidents of extreme weather and shifting temperatures and precipitation patterns are expected to continue over the next several decades[4].

Decades of research points clearly to human activity as the cause of climate change. The major causes of climate change are human production and emission of greenhouse gases into the Earth's atmosphere and land-use changes, especially deforestation[3].

Climate change is impacting human health through heatwaves, wildfires, vector-borne diseases, and weather-related events such as floods, storms, and freezing rain[5]. Public Health Sudbury & Districts' service area is not immune to the health impacts of climate change. Strategies are needed to protect us and reduce risk of climate related injuries, illnesses, and death. We can create change and address health inequities for populations at greatest risk.

The *Climate Change in Sudbury and Districts: Assessing Health Risks and Planning Adaptations Together* resource will help municipalities and interested parties to assess health risks of climate change and make decisions that will further protect the health of residents in their communities.

This resource includes two parts:

- *Part 1: Climate Change and Health Vulnerability and Adaptation Assessments*
- *Part 2: Climate Change Modelling Study: Temperature and Precipitation Projections specific for Each Local Community/Geographic area*

These documents are designed to be used in concert. Together, they provide knowledge for municipalities and interested parties to assess vulnerability to climate change and plan strategic adaptations.

Part 1: Climate Change and Health Vulnerability and Adaptation Assessments

Climate Change and Health Vulnerable and Adaptation Assessments are a strategic approach for municipalities and interested parties to assess vulnerability to climate change at a community level and plan health-protective adaptations. Climate Change and Health Vulnerability and Adaptation Assessments are community-oriented and efficient—they work against duplication of efforts by bringing together key players such as municipal staff, public health, provincial ministries, health and social service providers, non-profits, and interested parties to review local context, understand existing strengths, and plan adaptations that are needed and achievable. Adaptations can take the form of new policies or initiatives or modifications to existing programs. Importantly, a Climate Change and Health Vulnerability and Adaptation Assessment helps communities evaluate, prepare, and respond to current and projected health impacts, thereby ensuring healthier communities now and for future generations.

Climate Change in Sudbury and Districts: Assessing Health Risks and Planning Adaptations Together has been designed to introduce municipal leaders, staff, and interested parties to the health effects of climate change and provide the necessary information to inform the first three steps of a Climate Change and Health Vulnerability and Adaptation Assessment. The information presented includes health hazards increasing with climate change, health outcomes of concern, people at greatest risk and a description of factors that influence vulnerability to climate change.

Figure 1: Steps in a Climate Change and Health Vulnerability and Adaptation Assessment. Adapted from Ontario Climate Change Toolkit, Ministry of Health and Long-Term Care, 2016.

Climate Change and Health Vulnerability and Adaptation Assessments:

> identify current climate change health impacts and future risks

> identify realistic adaptations (programs, policies, or modifications) to increase resilience

> are focused at the local level and reflect unique community characteristics and resources

> benefit from intersectoral collaboration

Why adaptation and why now?

Strategies necessary to address climate change include mitigation and adaptation.

Mitigation refers to actions that decrease, stop, or capture emissions of greenhouse gases. Examples include efforts to manage energy, utilize green technology, and increase the capacity of carbon sinks (e.g. forests). Mitigation activities will slow the changing climate and the effects will be observed over many decades[6].

Adaptation protects us from the climate change impacts that are happening now or are almost certainly unavoidable in the near future[6]. Examples include hot weather response plans, upgrading storm water infrastructure, emergency preparedness, tick surveillance and Lyme disease awareness and shifts to farming practices.

Some climate change actions have dual mitigation and adaptation effects; for example, naturalizing or conserving vegetation at the edge of a creek can prevent erosion and flooding and will also mitigate climate change through capture of CO^2.

Today's adaptation actions are set against trends that are unfolding concurrently, including biodiversity loss, overall unsustainable consumption and management of natural resources, land and ecosystem degradation, human demographic shifts, and social and economic inequities[7].

Even with the most stringent mitigation efforts, the need for adaptation is unavoidable[8].

Impacts from recent climate-related events such as periods of extreme heat and floods reveal significant vulnerability and urgency for action. Those at highest risk of climate change impacts are those individuals and families with fewer resources to rely upon in times of need, most often as a result of interconnected systems of oppression (such as colonization, racism, sexism, heteronormativity, and ableism)[9–11].

> ***"Mitigation and adaptation are two sides of the very same coin. If we delay mitigation any further, we will never be able to adapt sufficiently to keep humanity safe. And if we delay adaptation, we will pay such a high price that we would never be able to look at ourselves in the mirror."***
> Christiana Figueres, United Nations Framework Convention on Climate Change, 2010-2016.

We all have a role to play

Climate change affects public health—that means all of us. This fact has resulted in concerted and proactive efforts by different sectors throughout our communities to enact change. Public Health Sudbury & Districts is also a climate change partner. We are a progressive public health agency committed to improving health and reducing social inequities. Under the *Ontario Public Health Standards*, Public Health Sudbury & Districts is responsible for assessing the health vulnerability status of communities related to climate change[12] and engaging in multi-sectoral collaboration with municipalities and other partners to reduce exposure to health hazards and promote healthy built and natural environments[12]. We are dedicated to working with our communities to promote and protect health and to prevent disease for everyone. Accomplishing this mission is based on our ability to build on the values of humility, trust, and respect.

Ontarians expect all levels of government (i.e. federal, provincial, municipal, and Indigenous) to identify and resource actions that will reduce risk and protect people from hazards, including those arising from climate change[13].

Municipalities are responsible for delivering programs and services to their residents. Constituents count on municipalities for good roads and bridges, efficient public transit, reliable water and waste systems, quality recreational facilities, social housing, emergency services, and so much more[14]. Municipalities own and operate most of Canada's public infrastructure and are on the frontlines in preparation for the impacts of climate change[15].

Proactive assessment of climate change vulnerability can ensure that current municipal programs, services, and infrastructure are sufficiently robust to continue to effectively produce desired results into the future[16]. Furthermore, protecting health and safety in the face of climate change is important to maintain economic and community stability. Sustained health improvements among individuals and communities stimulates economic growth[17]. Healthy people support healthy economies through their participation and spending[17]. Through adaptation, municipalities can invest wisely in preventative and resilience-building measures that protect communities and support recovery.

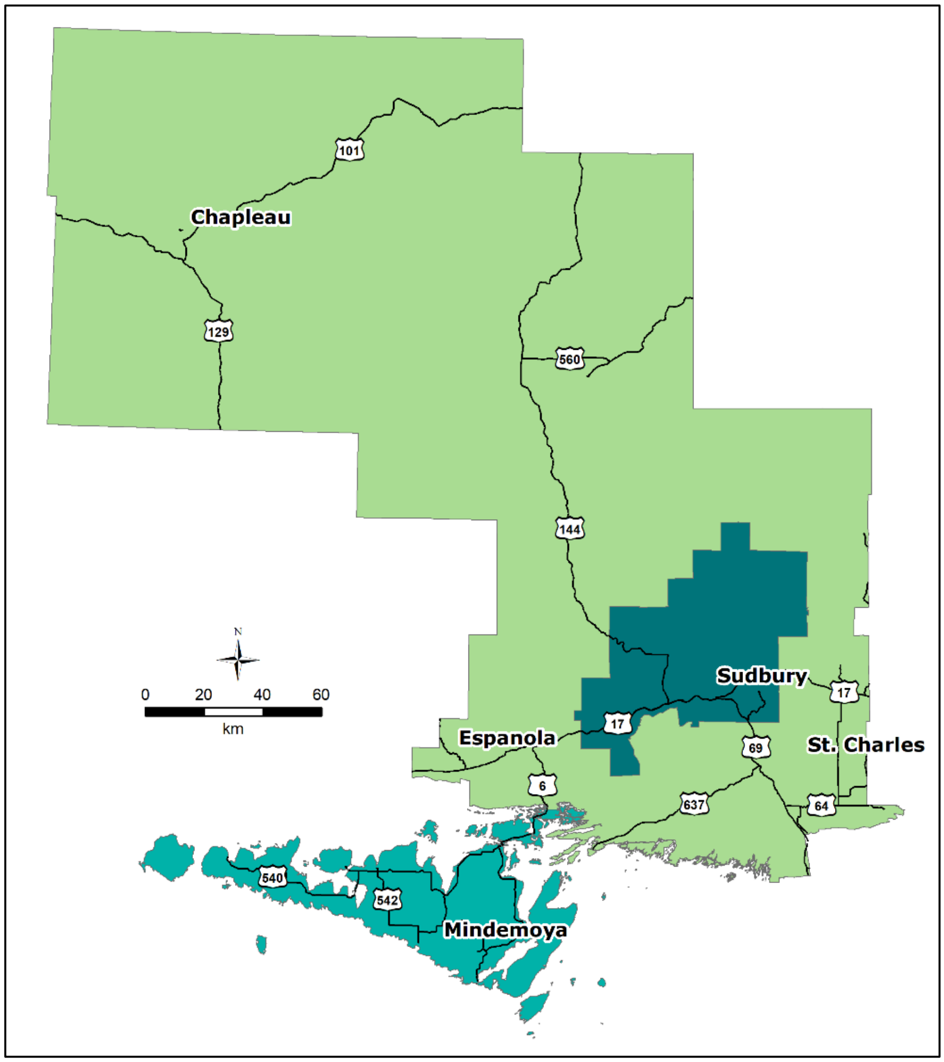

Figure 2: Map of Public Health Sudbury & Districts service area

Municipalities are well positioned to lead Climate Change and Health Vulnerability and Adaptation Assessments in their communities. They have the expertise and existing collaborations to identify risks, vulnerabilities, and opportunities within a local context.

Climate Change and Health Vulnerability and Adaptation Assessments are most effective when they incorporate multi-sectoral stakeholder input. Public health, municipal staff, and interested parties bring unique knowledge and skills to the table with respect to understanding community resources, capacity, and vulnerabilities.

The federal and provincial governments and municipal associations sometimes provide funding opportunities to support adaptation.

Local concern

Public Health Sudbury & Districts' service area covers Greater Sudbury and the districts of Sudbury and Manitoulin (Figure 2). In 2019, residents in Public Health Sudbury & Districts' service area were asked in telephone interviews about their understanding of climate change. Overwhelmingly, there is uneasiness among individuals across the service area about climate change and its impacts. Ninety-four per cent of adult respondents in the service area "somewhat agreed" or "strongly agreed" that the world's climate is changing and 92% admitted they were "somewhat concerned" or "very concerned" about climate change[18].

When asked about the likelihood of specific climate change related events in the service area, respondents reported "somewhat likely" or "very likely" to more extreme weather such as flooding, ice storms, or heavy snowstorms (83%), more frequent and severe heat waves (86%), more days with poor air quality or smog (80%), and more insects carrying diseases, such as West Nile virus and Lyme disease (72%)[19]. The responses to each of these increased climate change events was significantly higher in 2019 than in either the 2010 or 2011 reporting periods.

Similar research was conducted with residents of the City of Greater Sudbury through the efforts of the municipal program EarthCare Sudbury. Telephone interviews were initiated as part of a citizen survey. Provided a list of environmental issues, 48% of survey respondents named climate change as the most important local environmental issue [followed by water quality (18%), and the need to recycle/compost/use less waste (7%)]. Younger individuals (aged 18-34) were most likely to name climate change as the most important environmental concern[20].

The same survey found that in the City of Greater Sudbury, there is very good support (79%) for municipal initiatives that address climate change through reducing emissions of greenhouse gases. Respondents believe that local municipalities can have an impact on climate change (38%) and that individuals can make an impact, too (73%). The majority of respondents (56%) believed that their municipality should be doing more to address climate change[20].

Indigenous ways of knowing and climate action

Indigenous ways of knowing identify a special relationship with the Earth and living things in it[21]. The health of the environment and the health of people are intimately connected[21]. Practices of reverence, humility, and reciprocity are valued in relation to being caretakers of Mother Earth and realizing and respecting her gifts.

In 2016, a workshop conducted by Four Rivers, First Nations Management Environmental Services sought to understand Indigenous people's perspectives on climate change in First Nations in Northern Ontario. The workshop participants identified a need to increase capacity of First Nations leaders to understand and address climate impacts, and an opportunity to collaborate with municipalities[22].

Indigenous climate leaders connect Canada's slow pace on climate action with worldviews and policy that prioritize the economy over the survival of all living things[23]. The conversation needs to radically shift to drive change. Eriel Tchekwie Deranger from Athabasca Chipewyan First Nation and Executive Director of Indigenous Climate Action made comments in 2018 in reaction to the grim findings of a report by the Intergovernmental Panel on Climate Change (IPCC) and the Government of Canada's response. She said, "There is eminent threat coming towards us, and we have the capacity to reallocate resources, to redistribute the way that we do things, to effectively do this…to protect people and lives. And we're not doing it."[23]

It is important to acknowledge that privilege influences capability to participate in environmental policy and action[13]. Legacies of colonization have resulted in discriminatory attitudes on the part of non-Indigenous Canadians, poor decisions in the sphere of public policy, civic distrust and dire challenges for Indigenous peoples[24]. Indigenous people's voices have historically been excluded from decision-making[13]. Mi'kmaw Elder Albert Marshall's concept of Two-Eyed Seeing values Indigenous and Western knowledge through learning "to see from one eye with the strengths of Indigenous knowledges and ways of knowing, and from the other eye with the strengths of Western knowledges and ways of knowing, and to use both these eyes together, for the benefit of all".

The IPCC acknowledges that its 2022 report recognizes the interdependence of climate, ecosystems, biodiversity and human societies more than earlier IPCC assessments[7]. The report echoes the urgency that Indigenous climate leaders have voiced.

For municipalities embarking on a Climate Change and Health Vulnerability and Adaptation Assessment, appropriate and respectful engagement is essential to build relationships, mobilize the valuable perspectives of Indigenous peoples, and strengthen adaptation plans.

Indigenous Peoples in Public Health Sudbury & Districts catchment area

Public Health Sudbury & Districts' catchment area is home to over 24 000 Indigenous Peoples (including First Nations and Métis Peoples), living in urban settings and in the area's 13 First Nation Communities (Figure 3)[25]. A total of 6 379 individuals are living on-reserve in the catchment area[25]. Each First Nation community is unique, with different hopes, resources, assets, and needs. The Indigenous language most spoken in the area is Anishinaabemowin (Ojibwe language)[25]. First Nations in this region are signatory to Treaties 9 and Robinson Huron. Wiikwemkoong First Nation is an unceded territory[25].

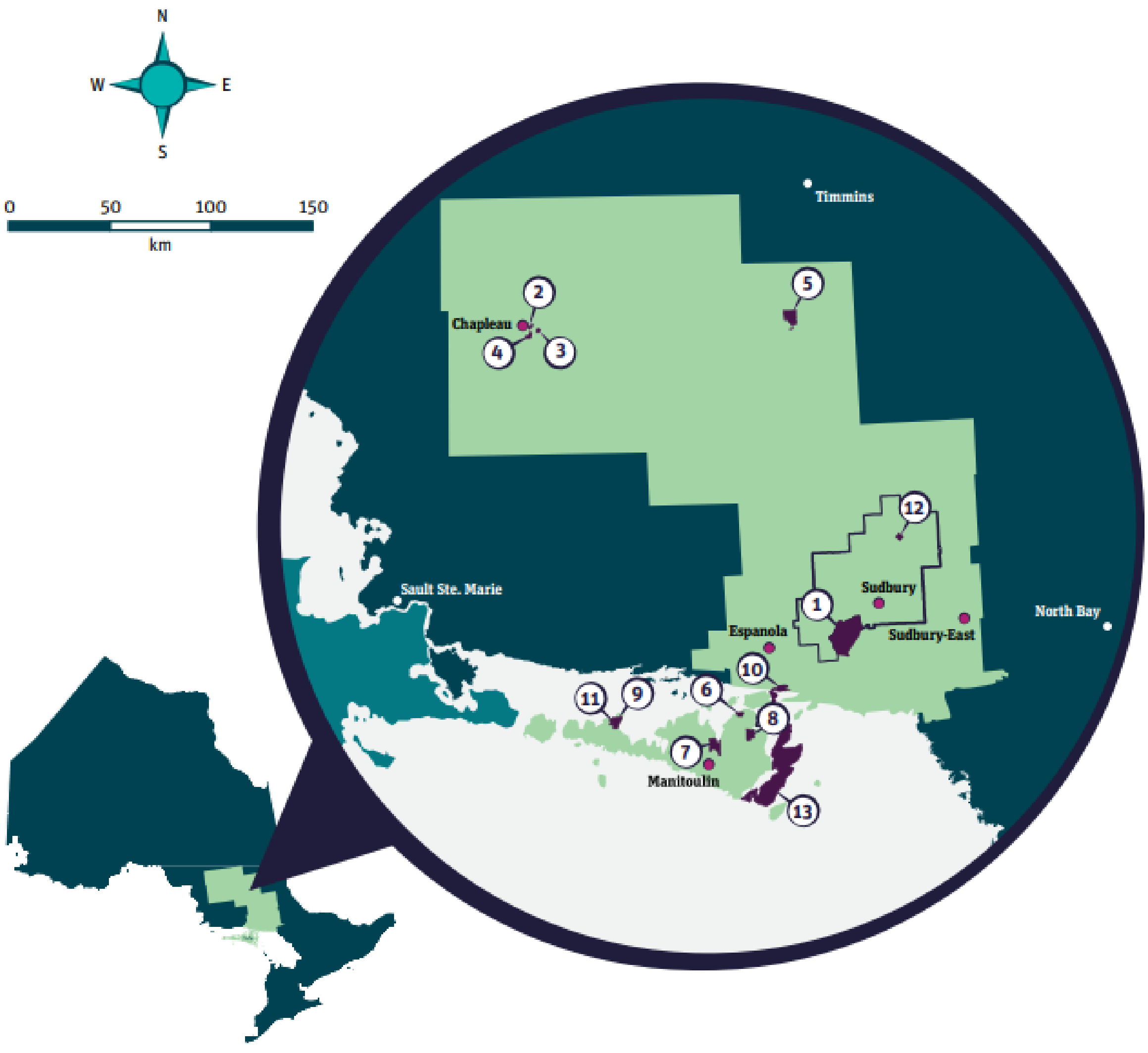

Figure 3: First Nations located in Public Health Sudbury & Districts' catchment area.

Assessing vulnerability to climate change

Actions of people and governments around the globe influence the acceleration or mitigation of climate change. Factors beyond our control can create uncertainty about the future and can lead to delays in decision-making. This psychological hurdle has impacted climate change action in the past. Today, there are ample data and resources to guide community strategies (see section 'Resources and tools'). Municipalities and interested parties will use the best available information to understand what health impacts are expected and importantly, who in the community is most at risk and why.

Climate change will not affect everyone equally. Health is dependent upon more than health care services and lifestyle choices. Health is also determined by social and economic factors that influence our lives[26]. Climate Change and Health Vulnerability and Adaptation Assessments represent an opportunity to reduce health disparities. Individual circumstances, resources and pre-existing health status should be taken into account when considering vulnerability and planning for action[10]. People with lived/living experience with low-income, poverty, colonization and unfair marginalization and oppression should be included in the development of adaptations that affect their lives[27].

Exposure, sensitivity, and adaptive capacity

At the community level, vulnerability to climate change depends largely on the completion of vulnerability assessments and the implementation of timely and effective adaptation measures.

Within a vulnerability assessment, vulnerability to climate change is commonly understood as a function of three key factors: exposure, sensitivity, and adaptive capacity[28].

Exposure refers to the probability of a climate-related hazard impacting an individual, population, or community[28–30].

Sensitivity refers to the degree to which the individual, population, or community is affected by the hazard[28–30].

Adaptive capacity is the ability of the individual, population, or community to adjust or respond to hazards, take advantage of opportunities, and respond to consequences[28–30].

Assessing exposure, sensitivity and adaptive capacity is context specific.

Factors that influence exposure

Location–Is the individual or the community in a place that is affected by the hazard? Time spent in risk-prone locations or performing risk-prone activities increases exposure[28]. For instance, rising ocean levels is not a concern for communities in Public Health Sudbury & Districts' service area, nor is smog. However, with proximity of many communities to boreal forests, exposure to forest fires and wildfire smoke is a concern. Similarly, some individuals are at increased risk of heat illness due to spending more time outdoors for recreation or work (as a matter of choice, obligation, or circumstances).

Infrastructure condition and access–The condition of community infrastructure and ease of access to services can moderate exposure to harm. For example, community infrastructure such as roads, storm sewers, and buildings can be upgraded to be more resilient to extreme weather. Disruption to utilities, medical or communication infrastructure, and transportation routes can hamper emergency response and put individuals at greater risk[28].

Socioeconomic status–Individuals living in poverty or low-income can be more at risk of exposure to hazards. For example, in cases where housing is of poor quality and not well protected from flooding or water entry, damage to belongings and exposure to mould can be a concern. Likewise, lack of access to personal or public transportation, limited mobility, and social isolation can hamper an individual's ability to evacuate or access care, putting them at greater risk[28]. Racism, colonialism, sexism, heteronormativity, cisnormativity and ableism contribute to population-level income inequalities.

Factors that influence sensitivity

Biological traits and health status–Sensitivity is determined, at least in part, by biological traits and general health status[28]. Individuals have varying sensitivity to hazards at different stages of life (infant, child, youth, adult, older adult). For example, with respect to extreme heat, babies and young children and people over the age of 65 years have decreased ability to regulate body temperature compared to healthy adults, and are more at risk of heat stroke[31]. With respect to air quality, people with respiratory conditions, such as asthma, are more sensitive to exposure to aeroallergens and other forms of air pollution[28].

Factors that influence adaptive capacity

Individual resources, abilities, and knowledge–Individuals have differing awareness of health threats and differing abilities to avoid risks[28]. Varying levels of ability, mobility, cognitive function, barriers due to racism, sexism, cisnormativity, heteronormativity, and financial and social resources can hinder individuals to adapt to hazards through planning, or in the moment[28]. Climate change compounds existing inequities. For example, individuals living on low income may be more vulnerable to a heat wave because there is no relief from the heat—their home, transportation and workplace may not have air-conditioning. Or, after an apartment floods, a person with less financial means and social support systems may experience more hardship on a variety of fronts. Costs and hardships after a flood may include replacing damaged belongings and furniture, cleaning the space, losing hours at work, keeping up with on-going expenses such as student loans, childcare, rent and groceries, and experiencing compounded stress. At the community level, knowledge and awareness of climate change among community leaders is key to the health and resiliency of the community as a whole. Community leaders should be able to perceive threatening circumstances, make assessments and utilise due diligence in managing risks[32].

Community services and supports–Variables that strengthen adaptive capacity at the community level include: political will, emergency preparedness activities, utilities infrastructure, communication strategies, and availability of health and social services[32].

Racism, colonialism, sexism, heteronormativity, cisnormativity, and ableism

Historic and ongoing oppression due to racism, colonialism, sexism, heteronormativity, cisnormativity, and ableism causes exclusion and harm[11]. The result is unfair distribution of power and resources, and experiences of harassment and violence[11]. Experiences of systemic oppression influence an individual's opportunities for economic stability and overall health, which leads to increased risk from climate change hazards[11].

Those with more resources are better able to adapt to climate change and take steps to protect their health. According to Statistics Canada, children, women, new immigrants, Indigenous people and people with a disability are most likely to be low-income[33]. Black and Indigenous populations experience disproportionate burdens of ill health linked to processes of racism and discrimination[11].

Historically disenfranchised communities are challenged to have their perspectives and needs awarded value and must work to deconstruct discriminative norms and systems[34]. Until these challenges are met, power imbalances will allow the perpetuation of health inequities and exacerbate climate vulnerability[34].

Adaptation measures should be planned so that people who are disproportionately affected can benefit from them[11]. For adaptations to be inclusive and effective at improving equity, participation by individuals and communities that experience racism and marginalization is required[11]. Going a step further, communities who experience racism and marginalization should be given the appropriate resources to lead adaptation initiatives.

Adaptation approaches to improve equity include[11]:

- resilience and asset mapping
- vulnerability mapping
- equity impact assessments
- meaningful and inclusive community engagement and communications
- funding and resource opportunities for communities to lead their own initiatives

Resources for inclusion of equity in climate change initiatives can be found in 'Resources and tools'.

Urban vs. rural communities

Assessing vulnerability is place and context specific. Variables affecting vulnerability and community adaptive capacity can differ in rural and urban locations (Table 1). Public Health Sudbury & Districts' service area includes eighteen municipalities (17 rural and one urban) and two unorganized areas.

Urban communities

Urban communities tend to have populations with higher education, skill sets, and greater income[35]. They also tend to enjoy easier access to public services and technology[35]. At the same time, adaptive capacity in urban places can be limited by significant reliance on energy, transportation and water infrastructure, and greater overall numbers of vulnerable individuals, including older adults and people living on low-income or in poverty[35]. Urban areas also experience more severe air pollution, heat island effects, less greenspace, and more high-density buildings and impervious surfaces (decreasing natural drainage and increasing potential vulnerability to run-off and flood impacts)[4].

Rural communities

Rural communities are often more vulnerable to climate change impacts than urban ones, in part due to economic dependence on renewable natural resources such as agriculture, fisheries, forestry, and outdoor tourism and recreation[35]. Sometimes called 'single industry towns', rural economies and individual livelihoods are less diversified and can be less resilient. In terms of climate-related events, being smaller and more isolated can represent a challenge for rural communities during emergency responses; there can be less capacity to accommodate patients or evacuees locally, and fewer outlets to distribute health and emergency communication to residents[4]. In terms of climate change planning, rural communities may also be challenged by limited economic resources and fewer individuals with the skills and training necessary to proactively address climate change vulnerability and adaptation[35].

Community leaders and institutions in smaller municipalities should be encouraged to embark on adaptation strategies like Climate Change and Health Vulnerability and Adaptation Assessments. The capacity of individual community members to act productively and effectively can be supported by local governments engaging in climate change planning and risk management[32]. In addition, people in rural communities have strong social capital and community attachment, which brings about resilience through 'neighbours helping neighbours' in the face of challenges[32,35].

Table 1: Urban and rural characteristics that affect vulnerability to climate change and climate-related impacts

Key Vulnerability Factors	Examples of Urban Characteristics	Examples of Rural Characteristics
Exposure • Geography • Land use • Climate	• Complex infrastructure, high density buildings and landscape dominated by impervious surfaces • Higher population density • Higher air pollutant levels	• Increased health risks from water contamination due to a high reliance on small drinking water systems • More people employed in outdoor occupations • Higher risk of exposure to land-shifts, wildfires, vector borne diseases and floods
Individual Sensitivity • Age and Gender • Health status	• Ageing population • Cardiovascular and respiratory conditions in large urban centers from air pollution and extreme heat	• High elderly population and high incidence of chronic illnesses, smoking and obesity
Key Adaptive Capacity Factors • Socio-economic status • Public services and risk communication programs • Employment	• Greater prevalence of high risk population groups, with limited adaptive capacity (e.g. low socio-economic status) • Higher prevalence of social isolation and limited access to services (e.g. immigrants, First Nations, homeless or persons of low income or with mental illnesses) • High reliance on critical infrastructure for health care and emergency service provision that are vulnerable to extreme weather	• Limited access to services during extreme events (e.g. power, water, food, medical) • Limited availability and accessibility of public services and programs and communication venues to deliver health and emergency messages • High dependency on natural resources that are vulnerable to disruption from extreme weather • Lower proportion of population highly educated • Limited livelihood and economic diversification • Limited resources and services to respond to extreme weather events and associated health burdens • Limited service access in remote communities

Source: Canada in a Changing Climate: Sector Perspectives on Impacts and Adaptation, Government of Canada, p.214.

Understanding health risks of climate change

Authorities working in medicine, public health, epidemiology, and other fields have identified a range of health hazards expected to increase with climate change.

Major risks of injury, illness, and death related to climate change will be attributable to hazards including extreme heat, extreme weather events (ice storms, floods, drought), wildfire, poor air quality, ultraviolet radiation, food safety and sustainability of food systems, and vector-borne disease (e.g. Lyme disease and West Nile virus). In addition, climate change is expected to have mental health impacts.

A key step in conducting a Climate Change and Health Vulnerability and Adaptation Assessment is being able to scope the assessment by deciding which hazards and health outcomes to include. This section describes the major health hazards related to climate change, health outcomes of concern, populations who are most vulnerable, and where possible, a discussion of health protective adaptations.

To inform a Climate Change and Health Vulnerability and Adaptation Assessment, the information in this section can be used to:

- prioritize health hazards and outcomes for inclusion based on local context and concern
- describe current health risks, including who is most at risk and why
- assess future risk using information in the technical report *Climate Change Modelling Study: Temperature and Precipitation Projections for Local Communities.*

Without adaptation, climate change is expected to increase morbidity and mortality related to:

extreme heat
freezing rain
floods
water quality
drought
wildfire
ultraviolet radiation
poor air quality
food poisoning
vector-borne disease
mental health impacts

Health facilities readiness

The healthcare sector has a specific responsibility to act on health threats and prepare for future demands on the health service. Health facilities can expect increasing injuries and illnesses and will have to provide services during climate-induced disasters and emergencies such as floods, ice storms, and heat waves. To improve outcomes all around, healthcare facilities need to incorporate both mitigation and adaptation strategies including smarter use of energy, minimizing waste, workforce training and enhancing disaster preparedness[36]. In the preparation of a community-wide Climate Change and Health Vulnerability and Adaptation Assessment, health facilities should certainly be included.

Extreme temperature

With climate change, temperatures are expected to rise throughout the year. Summer heatwaves pose a particularly dangerous threat.

Health hazards in hot weather

Hot weather events are becoming more common due to climate change[37–41].

With climate change in Public Health Sudbury & Districts' service area, the average summer temperature will be about 2°C higher in 2021-2050 compared to what it was in 1976-2005. The average number of very hot days (+30°C) will be three times higher. The average number of very hot days in 2051-2080 will be four times higher than in 1976-2005[37–41].

The technical report *Climate Change Modelling Study: Temperature and Precipitation Projections for Local Communities* contains specific data on seasonal temperatures and the number of very hot days (30°C+) experienced at present and expected with climate change for local communities.

Morbidity and mortality related to the heat are largely preventable. Heat illness and mortality is mainly caused by over-exposure to the heat or over-exertion for a person's age and or physical condition[42]. Individuals at greatest risk of heat illness include older adults, those who are chronically ill, pregnant women, infants and young children, and people who are living in situations of social or economic disadvantage[42]. Being active in hot weather for work or recreation is related to increased risk of heatstroke[43]. Spending significant amounts of time indoors in sweltering housing without relief through air-conditioning is also a risk factor. This risk is especially significant when social contact is missing as a protective factor[43].

Related to pregnant people, several complications are associated with heat, such as premature birth and early delivery, miscarriage and congenital complications like heart or neural tube defects[11].

Taking common medications can decrease the body's ability to effectively regulate heat and increase risk of heat illness. Medications having this effect include some anti-depressants, drugs for Parkinson's disease, psychiatric drugs, antihistamines, and diuretics. Drugs like this can interfere with the effectiveness of a variety of normal thermoregulatory functions, including perception of being hot and the ability to cool the body through sweating[44].

Unfortunately, many people who are most vulnerable to the heat do not take protective actions[42]. They may not believe that their health is at risk, may not recognise heat illness when it is happening, or may think it best to 'tough it out'[42,45].

Data shows that cities like Montreal, Toronto, and Windsor experience about 40-120 excess deaths per year associated with hot weather[42]. Statistically, in smaller communities the impact of extreme heat is more difficult to measure due to lower population densities[42].

An extreme heat event occurred in British Columbia from June 25 to July 1, 2021. The scorching heat led to multiple days of record-breaking temperatures. The village of Lytton, British Columbia recorded the hottest national temperatures in history on June 27 (46.6°C), June 28 (47.5°C), and June 29 (49.6°C)[46].

Sadly, the heat event was associated with 595 heat-related deaths in the province[47].

A heat-related death is defined as a death where[47]:

- The localized environment or body temperature is keeping with hyperthermia; or
- There is no direct temperature at the time of death but there is evidence (circumstantial, scene environment, medical history) to support that heat played a significant causal effect on the death.

Sixty-nine per cent of the deaths occurred in people aged 70 years and over, and nearly all of the heat injuries (96%) occurred inside a residence (decedent's own or another's residence, hotels/motels, rooming houses, SRO (single room occupancy), shelters, social/supportive housing, seniors' homes, long term care facilities, nursing homes, etc.)[47]. In the Greater Vancouver area, more deaths occurred among people living in neighbourhoods with material and social deprivation. In fact, for those living in neighbourhoods with material and social privilege, the death rate was lower than normal during the heat wave, indicating that those at risk may have taken **extra** health precautions and protected themselves effectively[46].

Deadly heat wave in Quebec in the summer of 2018

To illustrate the danger of extreme heat, consider the heat event that occurred in Montreal, Quebec, from June 30 to July 5, 2018[34]. During this time, maximum daily temperatures ranged from 31.7 °C to 35.3 °C with lows between 20.1 °C and 22.8 °C overnight[35]. A total of 66 deaths were counted in the community for which the heat was a contributing factor[34] . Characteristics noted among those that died included being older adult males, living alone, having no air-conditioning, and having pre-existing medical conditions (including respiratory or cardiovascular conditions, mental health conditions, or drug or alcohol dependence)[35]. The City of Montreal activated heat response interventions, including managing an increased need for ambulances, initiating door-to-door visits to vulnerable individuals, and extending open-hours at public places with air-conditioning (‘cooling centers’)[35].

Heat and mental health

Over the past decade, studies have identified individuals with mental and behavioural illnesses as being at increased risk of adverse health outcomes during heat waves[48–50]. Individuals living with schizophrenia, mood and neurotic disorders, and dementia and people who use drugs are at increased risk of hospitalization during heat waves[48]. An Australian study found that compared with non-heat-wave periods, hospital admissions for mental and behavioural disorders increased by 7.3%[50]. A Toronto study found a 29% increase in mental health emergency room visits over 7 days after exposure to mean daily temperatures of 28°C[49]. As noted earlier, some medications including antidepressants, antihistamines, and antipsychotics, whether prescribed, over-the-counter, or recreational, and illicit drugs such as cocaine and ecstasy, can interfere with the body’s ability to thermoregulate and predispose users to heat-related illnesses[44].

Heat warnings and temperature triggers

Heat warnings are issued by Environment and Climate Change Canada when very high temperatures are expected to pose an elevated risk of heat illness. Heat warning temperature triggers were developed by Health Canada and Public Health Ontario for 3 distinct regions in Ontario based on mortality and population data, humidex, local climate, and air pollution characteristics[51].

In Northern Ontario, heat warnings are issued when the temperature is forecast ≥29°C or humidex ≥36°C for at least 2 consecutive days, with overnight lows falling to ≥18°C[51] (Table 2). An extended heat warning is issued when the heat forecast is maintained for at least 3 consecutive days[51]. In 2020, the communities of Greater Sudbury, Markstay, French River, Killarney, Espanola, Massey and Manitoulin Island were under heat warning for 11 consecutive days, from June 30-July 10 (*Figure 4*).

Figure 4: **Communities of Greater Sudbury, were under heat warning for 11 consecutive days, June 30-July 10, 2020.** Photo: John Lappa, Sudbury Star.

Table 2: Heat warning region and associated intensity and duration trigger

Region	Heat warning temperature trigger	Duration requirement
Northern Ontario	Tmax ≥ 29°C and Tmin ≥ 18°C OR Humidex ≥ 36	2+ days

Public health units (PHUs) play a role in the Ontario-wide hot weather communication and notification process known as the Harmonized Heat Warning and Information System (HWIS). Since 2017, the HWIS has been utilized to streamline heat warnings for communities in different regions in Ontario[51]. Before HWIS, there were conflicting messages between neighbouring communities because they set their own temperature triggers for heat warnings or had none at all.

Under the HWIS, PHUs receive heat warnings provided by Environment and Climate Change Canada and disseminate the warning along with appropriate health protective information[51].

Where communities have a hot weather response plan, PHUs may have other responsibilities, as well.

To receive an email when a heat alert is issued, sign up through the EC Alert Me program at https://ecalertme.weather.gc.ca/createaccount_en.php.

Hot weather response plans

Municipalities and interested parties can work together to form a hot weather response plan. Various community or municipal departments may be involved (recreation, social services, emergency services), as well as partners such as health service providers, long-term care providers, public health, safety committees, schools, childcare providers, landlords, faith-based organizations, the Red Cross, and others[51].

Coordinated activities may include[51]:

- local partner notification processes
- public communication of the heat warning and health protective information
- making cooling spaces and hydration accessible to the public
- proactively protecting higher-risk populations, for instance through responses designed for shelters, childcare settings, schools, apartments, and long-term care homes
- ‘check on your neighbour’ programs
- occupational health and safety for workers in hot weather
- preparing for and responding to impacts on health services

Health hazards of cold weather

Very cold weather is expected to decrease with climate change in Public Health Sudbury & Districts' service area. The average number of winter days reaching -30°C in 2021-2050 will decrease by about 50 percent compared to 1976-2005[37–41]. Across the service area, the first fall frost will occur about 10 days later and the last spring frost will occur about 10 days earlier in 2021-2050 compared to 1976-2005[37–41].

With climate change, annual total winter precipitation in the service area will increase a small amount[37–41]. Across Canada, accumulation of snow will be offset by warmer temperatures[52]. During the period 1981-2015, the portion of the year with snow cover decreased across Canada at a rate of 5%-10% per decade, and similarly, snow accumulation declined by 5%-10% per decade[52]. Climate change models predict that snow accumulation will continue to decline at a rate of 5-10% per decade in southern regions of Canada through to 2050[52].

The technical report, *Climate Change Modelling Study: Temperature and Precipitation Projections for Local Communities* contains information for local communities outlining current and projected winter precipitation and frequency of very cold days (-30°C).

Figure 5*: A man exposed to the cold without shelter in Sudbury, Ontario.* Photo: Larson Heinonen.

Winter storms and heavy snowfall are well-known hazards in Northern Ontario. Heavy snowfall can reduce visibility, create treacherous driving conditions, and knock down trees and utility lines[53]. Blowing snow can cause drifts that make it difficult for people to leave their homes or get out of their driveways[53].

In Canada, there are more deaths during the winter months than the summer months[54]. During the winter season, increased seasonal mortality is understood to be influenced by the spread of influenza, accidents and injuries, and the stress of cold weather on the cardiovascular system[54,55].

Direct health hazards of cold exposure include frostbite, windburn, and hypothermia. Frost bite is characterised by the skin and possibly underlying tissue freezing[56,57]. Frostbite is more likely to occur to skin exposed to the cold and wind (nose, ears, cheeks), or to extremities (fingers, toes)[57]. Signs and symptoms of frostbite can include change in skin colour, skin that feels cold, and tingling, numbness, burning, pain, or swelling sensation at the affected area[57]. Windburn is a milder condition where exposed skin becomes dry, red, and sore, but does not freeze[56]. Hypothermia occurs when the body gets cold and loses more heat than it can generate[58]. Signs and symptoms of hypothermia include confusion, slowed thinking, slurred speech, stiff movements, lack of energy, and drowsiness[58]. Shivering is an early stage of hypothermia but can disappear as the condition persists[58].

Canadian statistics report that deaths associated with exposure to the cold are most common among males, aged 44-65 years[59]. Those most vulnerable to health hazards related to the cold include people who work or recreate outdoors, people with pre-existing medical conditions, older adults, infants, young children, and people experiencing homelessness[60].

People experiencing homelessness are at greater risk from the cold because they may spend long periods of time outdoors and often face challenges such as inadequate shelter, clothing and nutrition, and having a number of underlying health concerns (Figure 5) [56,61].

Individuals and communities can take precautions to prevent cold weather morbidity and mortality (Table 3).

Table 3: Individual and community preparedness for cold weather

Individual preparedness for cold weather[62,63]:	Community preparedness for cold weather[64]:
• Check the weather forecast before going outside. • Be alert to winter storm warnings and avoid unnecessary travel. • Dress in layers, with a wind resistant outer layer. • Wear a hat, mitts or gloves, and warm, waterproof footwear. • Protect extremities from the cold (ears, nose, fingers, and toes), they lose heat the fastest. • Seek shelter from the wind and limit time spent outdoors. • Watch for signs of frostbite and hypothermia. • Be careful when clearing snow; take your time to avoid overexertion.	• Issue extreme cold weather alerts accompanied by health protective information. • Encourage citizens to check in on neighbours and loved ones. • Appeal to the public when donations to shelters are urgently needed. • Open an emergency telephone hotline to take calls from concerned citizens and direct callers to appropriate services (e.g. Emergency warming centres). • Operate daytime and over-night warming centres, • Prepare for higher demand at existing shelter programs. • Provide outreach services to make contact with people on the street and support them to keep safe.

Extreme weather

Climate change is expected to increase hazards related to extreme weather. In this section, ice storms, flood, water quality, drought and tornado, downburst and microburst are discussed.

Ice storms

Freezing rain can cause significant harm to people and communities[65] and with climate change it is expected to increase considerably in Ontario[66]. Studies identifying risk of freezing rain for individual communities were limited; they were found at the regional level. In the region of Canada including Montreal, North Bay, Ottawa, Sudbury and Trenton, climate change is expected to increase freezing rain 60% by the 2050s and 95% by the 2080s[66]. Farther north, the impacts are expected to be even greater. In the region of Ontario including Timmins, Kapuskasing, Thunder Bay and Kenora, freezing rain is expected to increase 85% by the 2050s and 135% in the 2080s[66].

The technical report *Climate Change Modelling Study: Temperature and Precipitation Projections for Local Communities* contains more details on the frequency of freezing rain experienced at present and expected with climate change.

Ice storms and freezing rain can have significant impacts on communities, especially related to hydro services, transportation, and safety. Freezing rain that occurs during the cold months of the year can cause hazardous, slippery road conditions, and power outages. Trees covered with ice can fall, disrupting power lines or blocking roadways. Individuals may find themselves stranded or injured on roads or at home, in the cold and dark without power. Emergency responders are not immune to the hazards caused by freezing rain. It may take hours for help to arrive to a person in need, and days for hydro to be restored.

Health hazards of ice storms

Major health impacts of ice storms include[67]:

- falls, motor vehicle collisions, injuries from clean up of debris, fractures, musculoskeletal injuries
- carbon monoxide poisoning
- cold-related injuries or hypothermia due to absence of heating in homes
- acute cardiovascular events

- stress, mental health impacts, psychiatric illnesses

Although anyone can be affected by hazards of freezing rain and ice storms, some people are more at risk. People with existing medical conditions (especially involving the heart or respiratory system), people with reduced mobility and people with fewer financial and social resources to rely upon are at greater risk[68]. A report commissioned after the 1998 ice storm in Eastern Ontario and Quebec identified that emergency shelters were primarily used by the "economically and socially disadvantaged members of society, as well as the most physically and psychologically vulnerable" (Figure 6).[69] As well, many older adults and individuals living with disabilities who remained in their homes were in harms way without their regular care and services, and older adults living in private and public care homes were also identified as being particularly vulnerable to physical and psychological harm[69].

Figure 6: A nurse attends to an older woman at a shelter during a severe ice storm in 1998. Photo: Canapress.

Severe ice storms in Ontario

Two serious events in Ontario are described here to illustrate the range of adverse health impacts and severe challenges that can occur with freezing rain.

1998 ice storm in Eastern Ontario and Quebec

Many Ontarians have heard reference to or personally recall the ice storm that hit Eastern Ontario and Quebec in the early days of January 1998. Five million people were without power in Ontario, Quebec, and parts of the United States[59]. In Ontario, 11 000 hydro poles were destroyed or damaged and close to 600 000 homes were without power[59]. There were 26 deaths in Quebec and Ontario by causes including fire, hypothermia, falling ice, and carbon-monoxide poisoning[59].

There were at least 700 cases of carbon-monoxide poisoning reported to the provincial poison control centre, and the hyperbaric chamber at a Montreal hospital was used to treat 45 victims in less than 10 days[60]. Carbon monoxide poisonings occurred after people ran barbeques, vehicles, or gas-powered heaters or generators indoors, often in garages or basements[60].

Health care services were disrupted, over capacity, or unavailable[60]. Many hospitals and clinics ran services off generators and some had to use alternate sources of water or boil water[60]. One hospital set up a shelter for its employees' families, providing nourishment and places to sleep, to ease the effect on employees and facilitate their ability to continue work[60]. Scheduled surgeries and appointments were cancelled, ambulances were too busy to provide routine transfers, and many patients who would have been discharged from hospital could not be due to homes without power, blocked roads, and other issues[60].

2013 ice storm in Toronto

A more recent ice storm in Toronto occurred on December 22, 2013, impacting the Christmas holiday season[61]. Between 10-30 mm of freezing rain fell during the storm[62]. About 250 000 people were without power, and of those, thousands were cut off for 3 days or more[61]. Twenty public housing apartment buildings were without power, affecting heating, lights, food storage and food preparation for thousands of people[62]. Flights were cancelled or delayed, streetcar service was suspended due to icy power lines, and hospitals and water treatment plants were operating on generators[61,62]. Calls to emergency medical services increased 63% and emergency department visits for physical injuries, exposure to cold temperatures, and carbon monoxide poisoning were increased[56].

Communities that engage in emergency response exercises would find value in choosing a severe ice storm as a focus scenario.

References:

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Individuals and communities can take precautions to prevent illness and injuries (Table 4).

Table 4: Individual and community preparedness for ice storms

Individual preparedness for ice storms[70]:	Community preparedness for ice storms:
• Monitor the weather forecast. • Limit travel unless it is necessary. • Make a family emergency plan. • Build an emergency survival kit. • For more details online, search: Emergency Management Ontario, Be Prepared.	• Distribute weather warnings and precautions to the public. • Distribute emergency survival kits to lower-income families. • Provide public information about the risk of carbon monoxide poisoning. • Develop emergency plans with regards to ice storms. • Ensure secondary heat and power sources for critical facilities. • Establish community survival/evacuation areas that have secondary heat and power sources and can accommodate individuals in emergency situations.

Flood

Increases in extreme storms with climate change, particularly intense precipitation, can impact flood risk. Rainfall is one of the factors that contribute to flood. Analyses of disastrous flood events often point to multiple mechanisms of causation, including land-use, urbanisation, existing flood management, and weather systems[71]. With climate change, floods can become more pronounced and hazardous. Of particular concern is a dangerous pattern of warm, dry weather followed by unusually heavy rainfall[72].

A "100-year storm" is a severe storm that has a 1 in 100 chance of occurring in any given year.

Research shows that climate change has intensified incidents of extreme precipitation in North America since pre-industrial times and at the current level of warming, the "100-year storm" will occur more often than before[73]. A 100-year storm is an atypical, powerful storm that has a 1 in 100 chance of occurring in any given year[74] (Table 5).

Table 5: Recurrence intervals and probabilities of occurrences

Recurrence interval (years)	Probability of occurrence in any given year	% chance of occurrence in any given year
100	1 in 100	1
50	1 in 50	2
20	1 in 20	5
10	1 in 10	10
5	1 in 5	20
2	1 in 2	50

The power of a 100-year storm is described by the duration and intensity of the rainfall[75]. A report produced for the City of Greater Sudbury showed that based on 30+ years of data from the weather station at the Greater Sudbury Airport, a 100-year storm for Greater Sudbury releases a total of 43.1 mm of rainfall in 30 minutes[76]. Comparatively, a 50-year storm releases 38.8 mm in 30 minutes and a 25-year storm releases 34.5 mm[76]. A 2-year storm releases 17.2 mm in 30 minutes[76]. Without accounting for duration and intensity, a typical rainy day in Greater Sudbury would release between 0.2-25 mm of rain in a 24-hour period[77]. Data like this is typically used by engineers in design decisions for municipal infrastructure.

At our current level of climate change, 100-year storms are already more common. In the south and northeast region of the province of Ontario, including Public Health Sudbury & Districts' service area, a 100-year precipitation event is expected to occur every 20 years[73]. Similarly, what was a 50-year precipitation event will also occur every 20 years and a 20-year event will occur every 10 years[73]. If municipal infrastructure design does not account for increased frequency of unusually heavy rainfall, we can expect to experience more severe floods that overwhelm the infrastructure.

Flooding is the leading cause of public emergency in the province of Ontario[78]. Between 1900 and 2018, 62 disaster-level floods have occurred in the province[79]. Disaster-level events are defined as inflicting one or more serious adverse impacts, including 10 or more people killed, 100 or more people affected/injured/evacuated, or significant damage such that the community affected cannot recover on its own[80].

Causes of flood

There are several causes of flooding, two common ones being rainfall and snow melt. In Ontario, floods most frequently occur during the spring snow-melt season[81,82]. In winter and spring, rapid snow melt can release large quantities of water. Flooding can occur when the frozen ground does not absorb the melt water[83](Figure 7), or when rain falls on snow. Snow melt or rainfall can flood areas adjacent to rivers and other water bodies. Surface runoff occurs when rain or snow melt exceeds the soils maximum saturation level and water floods the surface of the ground[83].

Figure 7: An unusually warm January causes major flooding and closes the highway at Pointe au Baril, Ontario, 2008. Source: Sudbury.com. Photo: Kevin Shanahan.

Urban stormwater runoff is another type of flood that primarily affects developed areas with impermeable ground cover (e.g., cement and pavement)[84]. Water moves swiftly over impermeable surfaces and may flood low lying areas. Older municipal stormwater drainage systems and wastewater treatment plants can become overloaded which can cause back-up flooding onto streets and into residential basements[84].

Flooding of homes by sewage back-up can occur during heavy precipitation in older urban areas where homes are connected to a single municipal pipe[84]. Older urban areas typically had stormwater and sewage pipes combined in a single pipe[84]. If the stormwater/sewage pipe became overloaded during heavy rain, mixed rain and sewage water could back up into people's homes, spilling out of toilets or drains into living areas[84]. The sewage-contaminated water may cause disease. Affected walls, floors, fixtures, and belongings must be remediated carefully (cleaned and sanitized, or replaced)[85].

Physical impacts of floods

The physical impact of a flood depends on the level and speed of the flood water, duration of the event, terrain, soil conditions, and the elements of the built environment that are affected (homes, roads, buildings, bridges, etc.)[86].

Flood impacts can be very serious, and include fatalities, injuries, disruption of transportation routes and disruption of hydro, water, and gas lines[86]. The disruption of a flood can cause commercial supplies such as food, fuel and equipment to become unavailable, drinking-water supplies to become polluted or unsafe, and health and social services that people rely to become unavailable[86]. Flood waters can bring about erosion, unstable soil, and landslide. Roads, buildings, and structures can become unsafe or may collapse due to damage from fast-flowing water and erosion (Figure 8). For individuals, even a few inches of floodwater in a home can cause tens of thousands of dollars in damage[86].

Health impacts of floods

In addition to physical impacts, floods can have significant health and safety impacts, including[87]:

Drowning[87]

- Misjudging how deep the water is, or how quickly and strongly the current is moving, can lead to drowning.
- Attempting to drive, boat, or swim through floodwater is a risky activity.

Figure 8: Torrential rains cause wash outs of Highway 17 at Wawa, Ontario, in October 2012; the township declares a state of emergency. Source: CBC.ca. Photo: Martine Laberge/Radio-Canada.

Injuries[87]

- During a flood, heavy objects move quickly through the floodwater and impact people.

- Exposure to cold floodwater can lead to hypothermia.
- Electrocution can occur in flood-affected buildings with damaged wiring, and when an individual comes in contact with electrical sources or appliances that are turned on.

Diseases spread through contaminated water [87] (See also, 'Water quality')

- Flood water can overwhelm storm sewers, and water treatment and sewage treatment systems, leading to contaminated municipal water and contaminated rivers, lakes, and streams.
- Sewer systems can back up into homes, exposing people to water contaminated with bacteria from raw sewage.
- Individuals may drink tap or well water that has mixed with flood water, unaware of the danger of bacteria or chemical contamination.

Diseases spread through food contamination[87] (See also, 'Health hazards of food poisoning')

- Food can come in contact with contaminated flood water, or contaminated drinking water (municipal or private water systems).
- Power outages can disable refrigeration, leading to food spoilage and food poisoning. Power outages may occur due to downed power lines in a storm or if power is turned off in a home due to flooding.

Mould exposure/indoor air quality[87]

- Flooded buildings are difficult to dry, creating a hospitable environment for bacteria and mould growth.
- Mould exposure can cause allergic reactions, breathing difficulties, and asthma attacks, and is a major health concern related to floods.

Mental health[87]

- Floods cause personal property damage, personal loss, physical health problems and financial strains that contribute to stress, anxiety, and depression.
- The long-term effects of floods (e.g., re-locating, re-building, community disarray, uncertainty, loss, injury) contribute to continued mental health concerns and post-traumatic stress disorder.

Major flooding events are often intensely distressing and traumatic and can have significant effects on mental health. Recovery of wellbeing after a life-altering flood often follows a non-linear trajectory, with ups and downs as time passes[88]. Feelings of lack of control and powerlessness around one's circumstances during and after the flood have negative consequences for well-being[88]. Major sources of stress related to floods include the material and economic consequences of the disaster and the perception of a ruptured future for the individual and the family[88]. Protective factors related to flood events include having community communication systems and government intervention supports which lessen feelings of isolation, uncertainty, and lack of control[88]. As well, having rich personal support networks can improve individuals' material and emotional resiliency in the face of loss[88].

Monitoring and predicting floods

Currently, monitoring and predicting flood flows and water levels falls under the responsibility of Conservation Authorities where they exist. Alternatively, the responsibility is held by the Ministry of Natural Resources and Forestry[78]. Working together, the Ministry of Natural Resources and Forestry, Environment and Climate Change Canada, and Conservation Authorities advise municipalities on flood contingency plans and during responses to flood events[78].

Conservation Authorities utilise floodplain mapping to inform their work[89]. Floodplain mapping involves inputting background data such as land-use, topography, and precipitation into a computer model that predicts watercourse flows[89]. The floodplain map considers a 1 in 100 year flood event and can identify areas most at risk of a flood of this severity[89]. Floodplain mapping should be updated when modelling and software is improved and as topography changes[89]. Topography changes can include natural and man-made developments (such as roads, culverts, wetland infilling, and buildings)[89].

Communities that are not serviced by a Conservation Authority receive flood information from the nearest Ministry of Natural Resources and Forestry office[90].

Flood forecasting and warning program for Ontario

Up-to-date flood information is issued by Conservation Authorities and the Ministry of Natural Resources and Forestry under the Flood Forecasting and Warning Program for Ontario[90]. Information contained on the site includes updates with respect to current conditions (e.g., early notice of the potential for flooding based on precipitation or snow melt, and water safety messages), as well as flood watch and flood warnings[90].

Individuals and communities can take precautions against flood hazards (Table 6).

Table 6: Individual and community preparedness for floods

Individual preparedness for floods[91]:	Community preparedness for floods:
• Put weather protection sealant around basement windows and the base of ground-level doors. • Install the drainage for downspouts a sufficient distance from your residence to ensure water moves away from the building. • Consider installing a sump pump and zero reverse flow valves in basement floor drains. • Do not store your important documents in the basement. Keep them at a higher level, protected from flood damage. • Advise children to never play around high water, storm drains or flooded areas.	• Distribute flood warnings to the public accompanied by health protective information. • Update flood plain mapping as needed. • Include impacts of climate change in public works infrastructure planning. • Increase natural drainage through porous pavement and landscaping techniques. • Increase and conserve vegetative cover to prevent erosion. • Increase and conserve vegetative cover, natural landscapes, ponds, and wetlands to alleviate flooding.

Climate Change Modelling Study: Temperature and Precipitation Projections for Local Communities provides specific information on precipitation experienced at present and expected with climate change.

Water quality

Water quality refers to the suitability of water for a particular purpose, often drinking or recreation, based on selected physical, chemical, and biological characteristics. Water containing physical, chemical, or biological contaminants can be unsafe for drinking, brushing teeth, washing fruit and vegetables, bathing, and recreational activities like swimming. With climate change, increases in intense precipitation are expected, which can lead to heavier levels of stormwater runoff and contamination of well water and surface water. Exposure to unsafe water can lead to water-borne illness.

Stormwater runoff and contamination of water sources

Stormwater runoff is a major contributor to water contamination. During a rainstorm, stormwater moves quickly across the ground, picking up potentially dangerous contaminants and transferring them to surface water (such as creeks, streams, rivers, and lakes) and groundwater. In urban and rural developed areas, contaminants in stormwater runoff can include sediment, oils and grease, bacteria, pesticides and herbicides, metals and nitrogen and phosphorus[92,93] (Table 7).

Table 7: Stormwater runoff contaminants and their sources

Stormwater contaminant	Source
Suspended Solids/Sediment	Construction sites, roads, winter sanding
Nutrients (nitrogen and phosphorus)	Fertilizers, fecal matter (pets), human sewage
Metals	Cars
Oil and grease	Cars, leaks, spills
Bacteria	Fecal matter (pets, animals, agriculture), human sewage
Pesticides and Herbicides	Yard and garden care

Sources of water that we use for drinking and recreation can be degraded by stormwater runoff[94], and rain and floods have been linked to waterborne illness outbreaks[93]. Importantly, heavy rainfall and floods can carry harmful fecal contaminants from agriculture, pets, wildlife or human septic systems into water sources[93]. Surface water and well water are affected by runoff in different ways and require different precautions related to health. Municipal water users should be alert to water quality advisories.

Surface water quality

During a precipitation event, the level of contamination in surface waters can increase temporarily and wash off or diffuse afterward[95]. Many factors influence the contamination of surface water by stormwater runoff, including intensity and duration of rainfall, sources of contamination, characteristics of the ground (e.g. natural or impervious), and impacts of stormwater management, if applicable[95]. Surface water quality is important for human and environmental health. Surface water may contain harmful levels of bacteria, parasites, viruses, and other contaminants, and should not be considered safe to drink without effective filter or treatment[96]. Some surface waters commonly utilized by the public are tested for suitability for recreational use[97]. Public Health Sudbury & Districts tests water at designated public beaches throughout the summer to protect swimmers from potential illnesses that could be picked up from unacceptably high levels of pathogenic organisms[97]. A designated beach is one that is owned and operated by the municipality which the general public has access to[97]. Users of designated beaches can check the results of the sampling on Public Health Sudbury & Districts' *Check Before You Go!* website[97].

Well water quality

Depending on the age, condition and construction of a well, contamination can enter from the surface or groundwater[98]. Wells can be improperly sited or sealed or may deteriorate over time[99]. In the event that a well might be contaminated by heavy rains or flood water, the water should not be considered safe to drink or use. In the short-term, water should be boiled for at least one minute before being used for drinking, bathing, washing fruit or vegetables, or preparing infant formula. Once the rain has passed or flood recedes, wells should be disinfected by adding bleach to them, and water should be tested for safety[85].

Residents living in private dwellings that are not connected to municipal water should test their drinking water at least three times per year[96]. Well water samples from private citizens are accepted and tested by Public Health Ontario labs[100].

Water quality advisories for municipal water users

Users of municipal water can reliably count on their water being safe for drinking and bathing. Regulations are in place to protect water users from exposure to contaminated water. The *Safe Drinking Water Act* is in place to protect municipal water users from exposure to contaminated water. The Act regulates municipal and regulated non-municipal water systems and requires that water is tested to be safe[101]. Municipal water users are notified if drinking water is unsafe for use; Boil Water Advisories and Drinking Water Advisories are issued by the Medical Officer of Health when a condition exists with a drinking water supply that may result in a health risk for users. The advisory is lifted after the situation is remedied and testing confirms that the water is safe to use[102].

Drinking water treatment plants typically utilize multiple barriers in their treatment[103]. Surface water sources are known to be more susceptible to contamination and thus surface water plants often utilize more advanced treatment techniques[103]. Intense precipitation or flood can impact both surface water and groundwater sources[103]. Water treatment systems can be stressed by increased water contamination and flow as a result of heavy precipitation and flood[103]. This effect could become even greater with climate change[103].

Water-borne illness

Exposure to contaminated water can cause water-borne illness, often from unsafe levels of bacteria, viruses, parasites, toxins or other contaminants[96]. Fecal bacteria implicated in waterborne illness include *E. coli*, *Salmonella*, *Shigella*, *Campylobacter* and *Yersinia*[94].

Water-borne illness can occur after drinking contaminated water or contacting contaminated water during recreational activities like swimming[104].

Symptoms of waterborne illness include stomach pain, nausea, diarrhea, vomiting, fever, and malaise. Depending on the pathogen, symptoms can appear anywhere from hours to days after exposure[105]. Not everyone exposed to a waterborne pathogen will become sick. Many will have mild symptoms, or no symptoms at all. Some individuals are at greater risk of serious symptoms and even death, these people include the very young, the elderly, pregnant women, and those with weakened immune systems[105].

Tornadoes, downbursts, and microbursts

When the term 'extreme weather' is used in relation to climate change, phenomenon like tornado and hurricane come to mind. The appearance of weather alerts on cell phones and the rapid spread of sensational news may partly explain the false impression that tornados are on the rise.

With climate change, it is known that extreme storms with intense rain will increase[73]. While tornadoes form from thunderstorms[106], the relationship between formation of tornadoes and climate change is not clear. Currently, there is low confidence in projections of tornado and extreme winds (with the exception of tropical cyclones) related to climate change. To date, studies of extreme winds are limited and shortcomings exist in the simulation of the complex phenomena that influence tornado formation during storms[107].

Figure 9: A downburst causes damage to property in Sudbury, Ontario, in July 2018. Thousands of residents and businesses were left without power. Source: Sudbury.com. File photo not attributed.

Like tornadoes, downbursts and microbursts are weather events characterized by high-speed winds. Downburst and microburst are much more common than tornadoes[108]; however, no statistics were found describing the frequency or severity of downbursts or microbursts in Public Health Sudbury & Districts' service area.

A downburst is a non-rotating mass of air that moves extremely fast from the cloud level to the ground, spreading out as it impacts the ground. Downbursts are powerful and damaging (Figure

9) and have been observed to strengthen after impact with the ground. Downbursts can be dry or accompanied by rain[109]. A microburst is a shorter less-intense variety of a downburst.

Being prepared for weather events is a valuable strategy to increase resilience to climate change. Details on tornado risk and, importantly, advance notice of severe weather through weather alerts, is provided in this section.

Tornado hazards

Tornadoes are rotating columns of high-speed wind that can cause major destruction, including uprooting trees, demolishing homes, and picking up cars[110]. Tornadoes often (but not always) appear with a funnel cloud, and are often associated with storm clouds, thunder, lightning, rain, hail, or an extremely dark sky[110]. A rumbling or whistling sound is a warning sign of a potential tornado[110].

Tornado intensity is classified by the Fujita Scale, based on wind speeds. The wind speeds associated with each scale range from 60-110 km/hour (F0), 120-170 km/h (F1), 180-240 km/h (F2) to over 420 km/hr (F5). In Northern Ontario, probable and confirmed tornadoes are most often F0 to F2, with one occurrence of an F3 in the last 200 years[111] (Figure 10). Since 2013, Environment and Climate Change Canada has utilized the Enhanced Fujita scale, which includes more detailed damage indicators (e.g. linking wind speeds to levels of damage to trees, office towers, residential housing, and other structures)[112].

Tornado risk and occurrence in Canada

Tornado occurrence in Canada is classified under 4 levels of probability: very low, low, medium and high[113]. An area of high probability could expect 2 or more tornadoes per 10 000 km^2 per year, medium probability could expect 1-2 per 10 000 km^2 per year, and low and very low could expect 0.05-0.10 and 0-0.05 tornadoes per 10 000 km^2 per year, respectively[113](Figure 10). Public Health Sudbury & Districts' service area is characterized as low probability (Figure 11).

Between 1946 and 2021, 20 weather disasters involving tornadoes have occurred in the province of Ontario, including only 1 in Northern Ontario[114], impacting Greater Sudbury, Ontario. On August 20, 1970, an F3 tornado struck Lively and Sudbury. The storm appeared suddenly and in the course of a few minutes, killed 6 people, injured 200, and left hundreds homeless. The damage left by the tornado amounted to more than $100 million in today's dollars[115] .

Figure 10: Confirmed tornado occurrences by the Fujita scale (1980-2009), with shaded areas denoting levels of probability. In the light grey zone ("rare"), 0.05-0.10 tornado would be expected per 10 000 km per year. In the medium grey zone, ("Prone to F0-F1"), 0.10-0.50 tornado would be expected per 10 000 km per year. In the dark grey zone, ("Prone to F2-F5"), 0.5-1.0 tornado would be expected per 10 000 km per year. Source: Sills, D., et al. *Using tornado, lightning and population data to identify tornado prone areas in Canada*, Environment Canada.

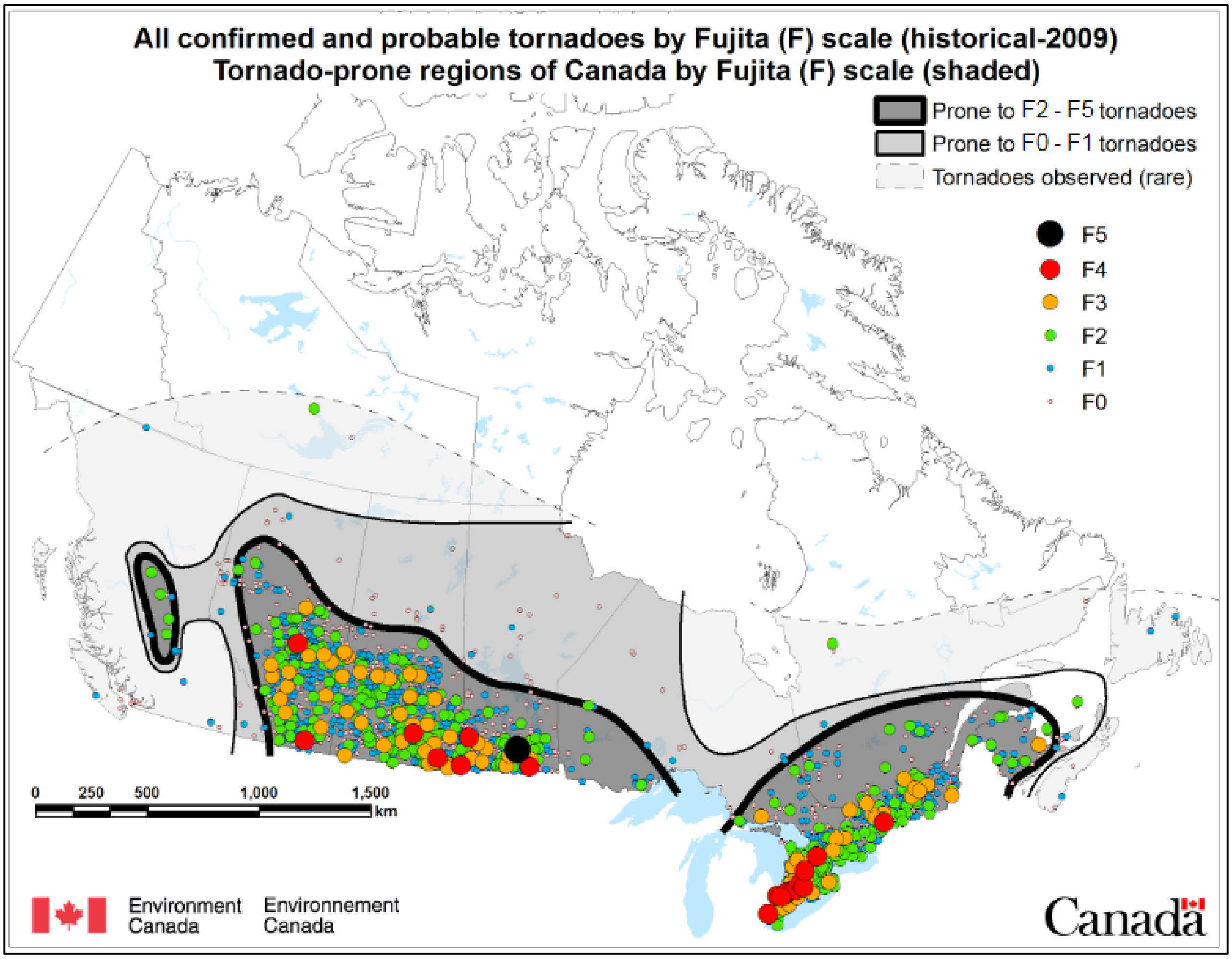
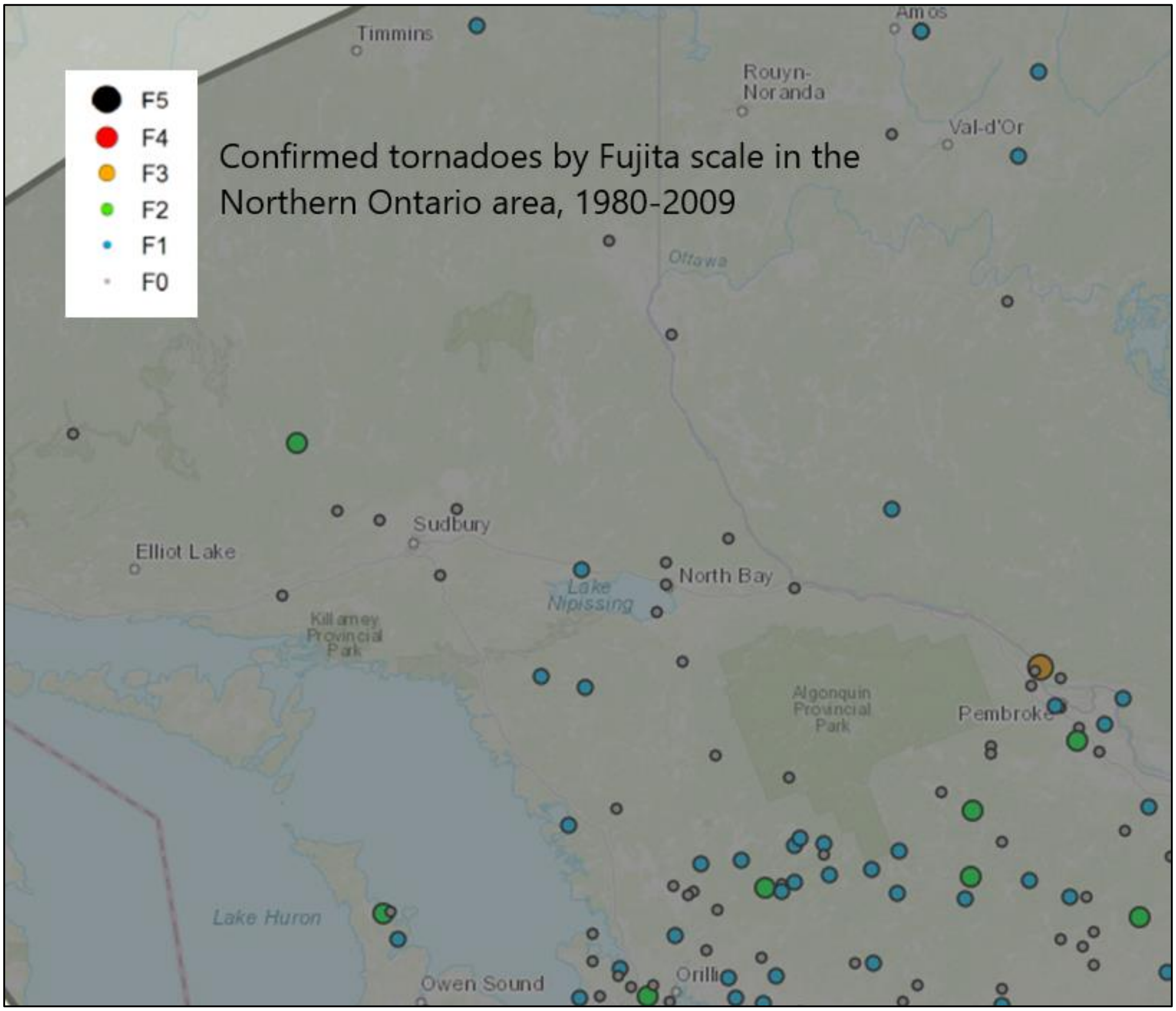


Figure 11: Confirmed tornadoes by Fujita scale in the Northern Ontario area, 1980-2009.
Taken from A Story Map: Tornadoes in Canada[116]



Weather alerts for tornado and severe thunderstorms

Weather alerts can provide advance notice of a possible or impending weather hazard. Environment and Climate Change Canada issues public weather alerts for many weather hazards, including severe thunderstorms and tornadoes. There are two types of alerts, 'Watch' and 'Warning'. A weather 'Watch' is issued when conditions are favourable for the development of the weather hazard. A weather 'Warning' is issued when there is evidence based on radar, satellite pictures. or from a reliable spotter that the weather condition is imminent or occurring[117]. In addition, to alert the public of not so common, inconvenient, or unusual weather conditions, a 'weather statement' may be issued[118].

To receive weather alerts from Environment and Climate Change Canada by email or SMS text messaging, visit https://ecalertme.weather.gc.ca/createaccount_en.php.

Ontario Alert Ready emergency alert system

The Ontario Alert Ready emergency alert system delivers alerts to Canadians through television, radio, and LTE-connected and compatible wireless devices. When considered a threat to life, a tornado alert can be issued by the Alert Ready program[119].

Drought

Climate models project with medium confidence that droughts in Canada will be slightly more frequent and longer in duration by the end of the 21st century as compared to present day. Detailed local projections of drought risk are limited because Canadian research has tended to focus on the prairie provinces[120]. Drought can adversely affect water quality and quantity[120].

A drought is a prolonged interval of unusually dry conditions that depletes water resources[121]. The characteristics of droughts are not consistent, with different causes, durations, and impacts[121]. Droughts do not require a complete absence of precipitation and can last for short periods, or several years[121].

Water quality

Drought can negatively impact water quality and affect health in a variety of ways. Compacted soil as a result of drought can lead to increased runoff and likelihood of water contamination[120]. Lower than normal water levels and slower water flow is linked to higher concentrations of contaminants including sediment, nitrate, phosphates, chlorides, and sulphates[120]. These factors contribute to nutrient loading (mainly nitrogen and phosphorus), which contributes to growth of cyanobacteria blooms. Also known as blue green algae, some cyanobacteria produce toxins that are hazardous if ingested by humans and animals[120].

Warmer water temperatures and decreases in water volume and flow are conditions that promote the survival and growth of water-borne pathogens[120]. The effects of climate change could increase numbers of water-borne pathogens of concern in Ontario, such as Campylobacter, Salmonella and Giardia[120].

Drought can impact municipal water treatment, as well. During drought, there can be a decrease of pressure at water treatment plants, increasing turbidity and creating a greater need for water treatment[120]. Municipalities may appeal to residents to reduce water use, for example when seasonal rainfall is lower than normal[122].

Water quantity

Dry conditions can lead to low water levels and overall reduction of water quantity at surface water sources and in the aquifer. Rain or melting snow slowly moves down through the ground to the aquifer–this is called recharge[123]. Prolonged dry conditions, especially over multiple seasons, can affect the potential of the groundwater in the aquifer to recharge.

Low water quantity can impact health in a variety of ways. In the agriculture sector, dry conditions can lead to crop losses, impacting farming income, food availability and food cost[120]. As well, dry conditions followed by intense rain can increase transference of bacteria in livestock manure to crops, farm facilities or water sources, increasing risk of food and water-borne illness[120]. Drought has been associated with wildfires in Canada and is expected to contribute to increases in the number of wildfires in prairie provinces[120]. In the United States, low-water conditions have been associated with incidence of spinal cord injuries from diving into shallow water bodies[120]. Low-water conditions can impact capacity to generate hydroelectricity, resulting in power being purchased from other jurisdictions to meet electricity needs, sometimes at higher cost or from higher-emission sources[120].

Monitoring and responding to low-water conditions

In Ontario, the Ministry of Natural Resources and Forestry is responsible to monitor surface water and provide information about low water risks[124]. The Ministry of Natural Resources and Forestry's Surface Water Monitoring Centre monitors and collects data, analyzes, and forecasts water levels, and disseminates early messages to Conservation Authorities. Low water conditions can be caused by lack of rain, high temperatures, and increased demand for water[124]. Conservation Authorities and/or municipalities will issue a public notification if low water conditions exist and actions to be taken by water users, for example, water users may be asked to voluntarily reduce their water consumption by 10%, 20% or greater[125].

Current low water status is commonly found on local Conservation Authority websites or can be accessed on the Ministry of Natural Resources and Forestry webpage for the Surface Water Monitoring Centre.

Local water source protection

The Clean Water Act requires that communities develop collaborative watershed-based source protection plans[126]. The plans identify existing and future threats to municipal residential water sources and prescribe policies, actions, and programs to reduce or eliminate the threats. Threats to water **quality** include the presence of chemicals or pathogens. For example, solvents, fuels, fertilizers, pesticides, or micro-organisms capable of causing disease. Threats to water **quantity** are activities that impair the ability of water to recharge, and activities that contribute to the over-use of water[127]. Two watershed-based source protection regions are located within the Public Health Sudbury and Districts service area: Sudbury and, further north, Mattagami.

At the time of this report, the threat to water quantity in Northern Ontario was low; less than 10% of available water was being used, assessed as low-water stress[128]. By comparison, the threat to water quantity in the southwest part of the province is high; more than 40% of available water is used, assessed as severe water stress. This is caused by large industrial and municipal water demands and low inland surface water supply[128].

Ontario manages water taken from lakes, rivers, streams, ponds, and groundwater through the Ontario Water Resources Act and the Water Taking and Transfer Regulation. Permits to take water are issued by the Ministry of the Environment, Conservation and Parks. The approval of a permit to take water takes into consideration the impact on the watershed[129]. Source water protection plans compare the water available in the natural environment with the amount being used by municipal, commercial and industrial users. This assessment is called a 'water budget' and identifies where water demand could pose a threat to the watershed[129].

Continued attention to water conservation and protection of wetlands and water sources is required to safeguard this fundamental natural resource.

Water resources and sustainable development

Sustainable development is meant to ensure availability and sustainable management of natural resources for the benefit of all. Canada adopted the United Nations Sustainable Development Agenda for 2030[130], which defines goals to protect and restore clean water resources. Sustainable development pillars for water are symbiotic with effective climate change adaptation. They include[131]:

- Universal and equitable access to safe and affordable drinking water for all.
- Adequate and equitable sanitation and hygiene for all.
- Improved water quality by reducing pollution, eliminating dumping, and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse.
- Increased water-use efficiency across all sectors and sustainable withdrawals and supply of freshwater.
- Water-related ecosystems are protected and restored, including mountains, forests, wetlands, rivers, aquifers, and lakes.

Water-saving strategies for individuals

Individuals can engage in water-saving behaviours at any time. Conservation Authorities recommend strategies to "reduce, repair and retrofit" to help households reduce water consumption[132].

Reduce—Be aware of your water use, and consider ways to use less[132].

- Turn off the tap when brushing your teeth or washing your hands.
- Keep a jug of water in the fridge instead of running the tap to get cold water.
- Don't use running water to thaw food. For water efficiency and food safety, defrost food in the refrigerator.
- Shorten your shower by a minute or two and you'll save up 550 litres per week.
- Cut grass to a higher level (5-8 cm). Taller grass shades roots and holds soil moisture better than short grass.
- Avoid children's recreational water toys that requires a constant flow of water; consider a small kiddy pool instead.
- Water vegetable gardens in the morning or evening, near the roots, and by hand.

Repair—Locate and repair leaks to save water, money, and to prevent potentially costly property damage[132].

- Check for toilet leaks; add a few drops of food colouring into the toilet tanks and wait a few minutes. If, without flushing, the colour appears in the bowl, you have a leak.
- Check for leaks in pipes and fittings; a leak of only one drop per second wastes up to 10 000 litres of water annually.

Retrofit—Install water saving devices on existing fixtures and select water efficient devices when replacing older, water guzzling fixtures and appliances[132].

- Low flow shower head can save up to 7.5 litres of water per minute.
- Faucet aerator can reduce water use by 25%.
- Older toilets use about 20 litres per flush. Consider installing a low-flow toilet which uses only 6 litres.

Ultraviolet radiation

With climate change, people may be drawn more frequently outside taking advantage of warmer temperatures for work and recreation. In the absence of more rigorous sun-protective practices and adaptations, the risk of skin cancer due to ultraviolet radiation (UVR) exposure is significant. Research shows that incidence of non-melanoma skin cancer correlated significantly with ambient UVR dose and average temperature in the summer in ten regions in the United States[133]. A study conducted in Ontario utilized this relationship between cancer and temperature as a basis for assessment of future risk[134]. The study projected that with climate change, rates of basal cell carcinoma in Public Health Sudbury & Districts' service area may increase by 8% in the 2050s and 13.5% in the 2080s[134].

Ultraviolet radiation comes from natural sources, like the sun, and artificial sources, such as tanning equipment, welding equipment, black lights, and lasers. The most important source of UVR exposure is the sun[135].

Health impacts of UVR exposure

Exposure to UVR interferes with the skin's normal processes, growth and appearance, and can result in sunburn and skin cancer[136].

There are three different types of skin cancer linked to UVR exposure: basal cell cancer, squamous cell cancer, and malignant melanoma[136]. Basal cell and squamous cell cancers make up the majority of skin cancers (77% and 23%, respectively[137]); melanoma is much less common. Most basal cell and squamous cell cancers grow slowly, are found early, and do not metastasize to other parts of the body[138]. About 1 in 8 Canadians will develop basal cell cancer in their lifetime and 1 in 20 for squamous cell cancer[137].

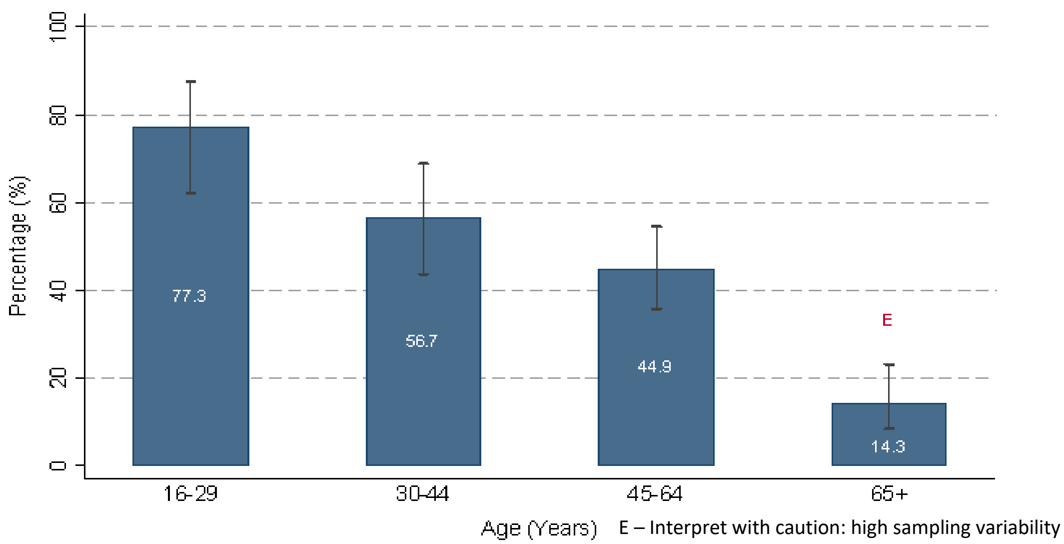
Anyone can get skin cancer, but factors that increase the risk of developing non melanoma skin cancer include[137,139]:

- personal or family history of skin cancer
- exposure to UVR from the sun or artificial tanning equipment
- sun sensitive skin that burns or freckles easily, rather than tans
- having many moles
- light-coloured skin, eyes, and hair
- having been exposed to radiation treatment (e.g. for cancer)

Sunburn is a risk factor for skin cancer[139].

Sunburn is more common in younger adults than older adults. In Public Health Sudbury & Districts' service area, 77% of people aged 16-29 report at least one sunburn in the last 12 months[140] (Figure 12). According to an Ontario survey, taking part in outdoor recreational activities without adequate sun protection accounts for 64% sunburns[141]. Children in Ontario are less likely to get a sunburn than adults even though they spend more time in the sun[141]. The majority of children are protected from the sun in one or more ways, including wearing sunscreen, wearing protective clothing and seeking shade[141].

Figure 12: Per cent of adults in Public Health Sudbury & Districts' service area who report a sunburn in the last 12 months



The UV Index

The UV Index was created by scientists at Environment and Climate Change Canada in 1992. In 1994, the World Health Organization and the United Nations Environment Program recognized the value of the UV Index and adopted it as an international program[142]. The purpose of the UV Index is to inform Canadians about the strength of the sun's rays and protective measure to take. The higher the UV Index number, the stronger the sun's rays and the greater the need to take precautions[143]. The UV Index is forecast daily and is updated hourly if cloud cover changes[144].

Environment and Climate Change Canada's UV Index

UV Index	Description	Sun Protection Actions
0–2	Low	• **Minimal sun protection required** for normal activity. • Wear sunglasses on bright days. If outside for more than one hour, cover up and use sunscreen. • Reflection off snow can nearly double UV strength. Wear sunglasses and apply sunscreen.
3–5	Moderate	• **Take precautions** – cover up, wear a hat, sunglasses and sunscreen – especially if you will be outside for 30 minutes or more. • Look for shade near midday when the sun is strongest.
6–7	High	• **Protection required** – UV damages the skin and can cause sunburn. • Reduce time in the sun between 11 a.m. and 3 p.m., and take full precautions – seek shade, cover up, wear a hat, sunglasses and sunscreen.
8–10	Very High	• **Extra precautions required** – unprotected skin will be damaged and can burn quickly. • Avoid the sun between 11 a.m. and 3 p.m., and take full precautions – seek shade, cover up, wear a hat, sunglasses and sunscreen.
11+	Extreme	• **Take full precautions.** Unprotected skin will be damaged and can burn in minutes. Avoid the sun between 11 a.m. and 3 p.m., cover up, wear a hat, sunglasses and sunscreen. • White sand and other bright surfaces reflect UV and increase UV exposure. • Values of 11 or more are very rare in Canada. However, the UV Index can reach 14 or more in the tropics and southern U.S.

Source: Government of Canada

Sun safety for individual and communities

Spending time outdoors should be enjoyable and safe. Individuals and communities can take precautions to reduce risk of ultraviolet radiation from the sun (Table 8).

Table 8: Sun safety for individuals and communities

Individual sun safety[145,146]	Community sun safety[145]
• Check the UV index and protect yourself and those in your care when it is 3 or higher. • Reduce sun exposure between 11 a.m. and 3 p.m. • Seek out shade when possible or bring your own (e.g. an umbrella or canopy). • Cover up with clothing, a wide-brimmed hat, sunglasses and apply sunscreen with SPF 30 or higher. Look for 'broad spectrum' and 'water-resistant' on the label and re-apply when needed. • Be a positive role model for children and friends by practicing sun safe behaviours.	• Create shade at public facilities, such as playgrounds, parks, sports fields, and community gathering spaces. • Incorporate shade policies into official plans and municipal documents. • Conduct a shade audit for a specific municipal location to inform decisions regarding the need for more trees or shade structures and where to most effectively place them. Plant native tree species for shade. • Encourage sun safety and shade policies at schools, daycares, and workplaces. • Engage in public messaging around sun safety.

Wildfire

Wildfires can be a normal occurrence in the forest ecosystem, helping to maintain forest health and diversity; they also have the potential to threaten communities and gravely impact health and safety. With climate change, the length of the fire season across Public Health Sudbury & Districts' service area is expected to extend 30-50 days by 2041-2070 compared to the reference period, 1981-2010[147]. In addition, the number of wildfires caused by lightening will increase 25-50%, and the number caused by human carelessness will increase 10-50% by the year 2030[148].

Climate Change Modelling Study: Temperature and Precipitation Projections for Local Communities provides details on projected changes to fire season length and wildfire risk for local communities.

In any given year, the number of wildfires in Ontario varies widely but generally reaches hundreds or more. For example, for the period 1976-2000, the number of fires in Ontario ranged from 601 to 3970 per year[149]. Over the last decade, there was an average of 559 wildfires per year in Ontario[150] and in recent years, the number of wildfires in Ontario has ranged from 307 to 1325 per year (Table 9). Wildfires typically start by lightening or human carelessness[151].

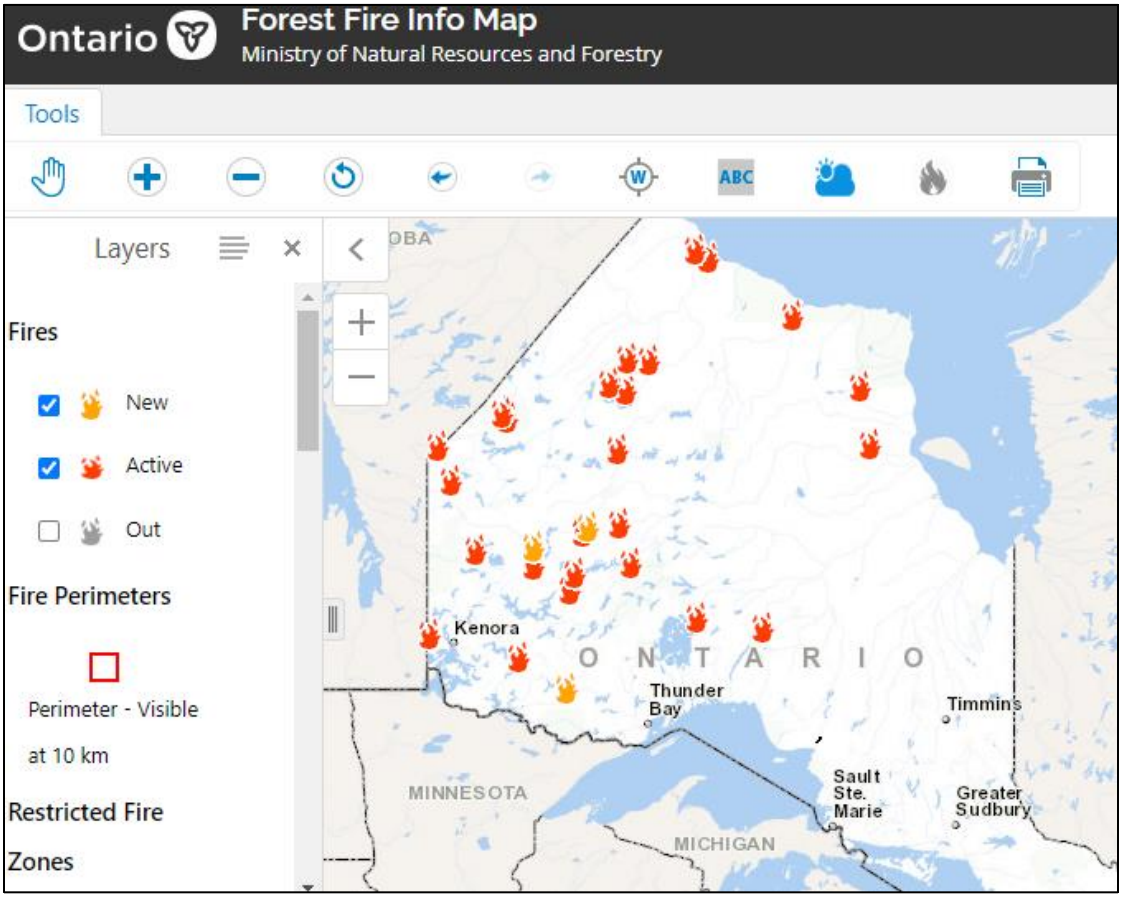
Table 9: Number of confirmed wildfires per year in Ontario by year

Year	Number of confirmed wildfires in Ontario
2017	776[152]
2018	1,325[152]
2019	537[150]
2020	607[150]
2021	1,198[153]

The fire season is defined as the period of the year when wildfires are likely to start, spread, and cause damage[147]. The fire season in Public Health Sudbury & Districts' service area runs from approximately April 1 to October 15[147].

The Ministry of Natural Resources and Forestry is responsible for wildfire management on Crown Land in Ontario[154]. Up-to-date information about current forest fire risk, forest fire activity and fire restrictions can be found at the Ministry of Natural Resources and Forestry webpage dedicated to Forest Fires (https://www.ontario.ca/page/forest-fires). The information is presented on an interactive map with real time updates. The map visually shows locations of fires, fire status (new, active or out), restricted fire zones, and other information as chosen by the user (Figure 13).

Figure 13: Example view of Ministry of Natural Resources and Forestry interactive Forest Fire Info Map. Source: Ministry of Natural Resources and Forestry, Forest Fire Info Map online platform.



Health impacts from wildfire

Smoke from wildfires can affect air quality great distances away from where fires are actively burning. Evacuations (Figure 14) and road closures (Figure 15) can occur due to fires and smoke.

Local air quality impacts due to wildfire smoke are not typically reflected by the provincial air quality monitoring and rating system, Air Quality Health Index (AQHI). This is because wildfire smoke conditions change rapidly and the AQHI is calculated using an average of the past three hours pollutant data[155]. Instead, Environment and Climate Change Canada may issue an air quality advisory when smoke from wildfires is expected to impact the public[156].

The dense smoke produced by wildfires contains particulate matter and toxic pollutants that can be inhaled deep into the lungs. Wildfire smoke is a mixture of water vapour, carbon monoxide, carbon dioxide, nitrogen oxides, hydrocarbons, other chemicals containing carbon, particulate matter and traces of minerals[157].

It is estimated that there are more than 2500 premature deaths per year in Canada attributed to exposure to wildfire smoke[158].

Although some people are at greater risk, anyone can be affected by wildfire smoke[159]. Those at greater risk of the effects of wildfire smoke are small children, pregnant women, older adults, people with lung or heart conditions and people involved in strenuous outdoor work or activities[159].

Figure 14: The 'Parry Sound 33' forest fire causes heavy smoke over Highway 69 and forces community evacuations, August 2018. Source: Muskoka 411. Photo: Ontario Provincial Police

Milder and more common symptoms of smoke exposure include[159]:

> sore and watery eyes

> runny nose and sinus irritation

> scratchy throat and mild coughing

> headache

The following symptoms are less common, but are more serious[159]:

> shortness of breath

> wheezing (including asthma attacks)

> severe cough

> dizziness

> chest pains

> heart palpitations

When wildfire smoke is in the air, individuals can take precautions to protect their health[159]:

> Cancel or reschedule strenuous outdoor activity.

- Keep apprised of the local fire and smoke situation through traditional and social media.
- In the home, keep windows and doors closed. Use a clean, good quality air filter (such as HEPA) in your ventilation system and use the recirculation setting to prevent smoke from entering your home.
- In vehicles, keep windows closed and set the fans to recirculate interior air.
- If you are vulnerable to the effects of smoke, and the levels are high where you live, evaluate whether it is possible to temporarily re-locate to a place with clearer air and follow the advice of your healthcare provider.

Figure 15: A forest fire sparks a 2-hour voluntary evacuation notice for Gogama in June 2019. Highway 144 is closed to the south due to smoke, limiting travel. Sudbury.com. Photo: Supplied.

FireSmart program for resilient homes and communities

Natural Resources Canada recommends the FireSmart program for homeowners and communities to mitigate wildfire risk and improve resilience. FireSmart approaches include wildfire mitigation, preparedness, response, and recovery[160] (Table 10).

Table 10: FireSmart approaches for wildfire resilience

Homeowner preparedness for wildfires	Community preparedness for wildfires
• Prepare a 72-hour emergency kit. • Prepare and discuss a family emergency plan. • Check for, and remove, fire hazards in and around your home, such as dried out branches, leaves, and debris. • Utilize non-combustible materials for home siding and roof. • Implement landscaping solutions such as tree pruning and tree placement away from the home.	• Evaluate wildland/urban interface hazards [where forests meet developed areas (residential, recreational or industrial)]. • Identify and implement wildfire mitigation strategies. • Engage in wildfire emergency response scenario training. • Develop community education programs. • Utilize land-use planning solutions.
More details can be found in *FireSmart: Protecting your Community from Wildfire*, 2003.	

Air quality

Climate change is expected to impact air quality in a variety of ways, including[161]:

Increases in particulate matter

> Increases in wildfires will produce more particulate matter air pollution.

Increases in ground level ozone

> Ground level ozone is formed when gases in the environment react in the presence of heat and sunlight. With climate change, warmer temperatures and longer summers may cause higher ozone concentrations.

Increases in aeroallergen levels, such as pollen and spores

> With climate change, warmer weather may result in increased pollen production in plants and a longer allergy season.

Outdoor air pollution is a complex mixture of gases and particles, entering the air from natural and human sources. Natural sources of air pollution include wildfires, dust storms, and pollen[162]. Human activities that produce air pollution include fossil fuel combustion (e.g. for motor vehicles, space and water heating for buildings, and industrial processes) and emissions from industry (e.g. mining, foundries, forest products, pulp and paper, petroleum refining, chemical production)[163,164].

Common pollutants in outdoor air include[165]:

- Carbon monoxide (CO)
- Nitrogen oxides (NO_x)
- Sulfur dioxide (SO_2)
- Ground level ozone
- Particulate matter (PM)*
- Volatile organic compounds (VOCs)

*Particulate matter in Ontario is largely made up of sulphates, nitrates, organic carbon compounds, elemental carbon and soil[165]. Particles less than 2.5 micrometers in diameter are inhalable deep into the lungs and pose the greatest risk to health[166]. These particles, known as $PM_{2.5}$, are measured at Ontario's air monitoring stations.

Health impacts of poor air quality

Clean air is imperative for human health at all stages of life. Each person reacts to poor air quality differently.

People most at risk for health effects are[167]:

- older adults
    - Older adults may have weaker lungs and heart or may have an undiagnosed lung or heart condition.
- young children
    - Young children breathe in more air in relation to their body weight, thereby breathing in more contaminants.
- those who are active outdoors
    - More contaminants enter the lungs if breathing faster and deeper while active (working, exercising, or recreating).
- those who live near industries or busy roadways
- those who have existing heart conditions such as heart failure, angina, and arrhythmia
- those who have existing breathing or lung problems and illnesses such as asthma, allergies, lung cancer and chronic obstructive pulmonary disease

Air pollution can cause symptoms such as tiredness, headache or dizziness, coughing and sneezing, wheezing or difficulty breathing, mucous in the nose or throat and dry or irritated eyes, nose, throat, and skin[167]. People with heart problems may experience chest or arm pain, irregular heart beats, swelling in ankles and feet, or increased shortness of breath[167].

Air Quality Health Index

The Air Quality Health Index (AQHI) is a tool that helps people understand the health risk of the current air quality and take appropriate actions to protect themselves[168]. Due to the tool's reliance on provincial air quality monitoring stations, within Public Health Sudbury & Districts' service area the AQHI is only available for Sudbury, Ontario.

***Air quality health index** readings for Sudbury in 2017 were low risk 97% of the time, and moderate risk 3% of the time.*

Forecast daily and updated every hour, the AQHI measures the air quality in relation to health risk on a scale from 1 to 10. The lower the AQHI rating, the lower the health risk. Health messages customized to the risk levels are provided for the general population and 'at risk' population[168] (Table 11).

The 'at risk' population includes individuals at higher risk of symptoms due to poor air quality, for example, people with heart, or breathing problems[168].

Table 11: Air Quality Health Index - health risk scale and health messages

Health Risk	Air Quality Health Index	Health Messages	
		At Risk Population*	General Population
Low	1 - 3	**Enjoy** your usual outdoor activities.	**Ideal** air quality for outdoor activities.
Moderate	4 - 6	**Consider reducing** or rescheduling strenuous activities outdoors if you are experiencing symptoms.	**No need to modify** your usual outdoor activities unless you experience symptoms such as coughing and throat irritation.
High	7 - 10	**Reduce** or reschedule strenuous activities outdoors. Children and the elderly should also take it easy.	**Consider reducing** or rescheduling strenuous activities outdoors if you experience symptoms such as coughing and throat irritation.
Very High	Above 10	**Avoid** strenuous activities outdoors. Children and the elderly should also avoid outdoor physical exertion.	**Reduce** or reschedule strenuous activities outdoors, especially if you experience symptoms such as coughing and throat irritation.

In 2017, the AQHI readings for Sudbury in 2017 were low risk 97% of the time, and moderate risk 3% of the time[169].

Special air quality alerts and smog and air health advisories

Special Air Quality Alerts and Smog and Air Health Advisories are issued jointly by Environment and Climate Change Canada and the Ontario Ministry of Environment, Conservation and Parks[170]. Air quality alerts are issued for weather forecast regions, including Chapleau-Gogama, Greater Sudbury and Vicinity, and Manitoulin-Northshore-Killarney, among others[171]. In 2018, Special Air Quality Alerts were issued to alert the public to wildfire smoke impacts in Sudbury and vicinity, Espanola, and Manitoulin[172,173].

Special Air Quality Statement[170]

- Issued when there is an air quality concern for a particular area that is expected to last for at least three hours, or when the Air Quality Health Index is forecast to reach, or has reached, the high-risk category for one to two hours.

In 2018, Special Air Quality Alerts were issued to warn the public of wildfire smoke impacts in Sudbury and vicinity, Espanola, and Manitoulin.

Smog and Air Health Advisory[170]

- Issued when the Air Quality Health Index is forecast to reach, or has reached, the high-risk category, and is expected to last for at least three hours.

To receive an email when an air quality alert is issued, visit http://www.airqualityontario.com/alerts/signup.php.

Assessment of local air quality

Air quality in Ontario is monitored by the Ministry of the Environment, Conservation and Parks through a network of 39 outdoor air monitoring stations[174]. Within Public Health Sudbury & Districts' service area there is only one station that is part of this network, located at 155 Elm Street, in Sudbury. The station measures ozone, particulate matter ($PM_{2.5}$), NO_2 and SO_2[175].

Air quality in Public Health Sudbury & Districts' service area is very good. According to the most recent Ontario Air Quality Report (2017), air quality assessed at the Sudbury monitoring station met the Canadian Ambient Air Quality Standards for particulate matter ($PM_{2.5}$), NO_2, SO_2 and ozone. In addition, Air Quality Health Index readings for Sudbury in 2017 were low risk 97% of the time, and moderate risk 3% of the time. In 2017, there were no special air quality alerts or smog and air health advisories issued in the Environment and Climate Change Canada weather forecasting regions of Chapleau-Gogama, Greater Sudbury and Vicinity, and Manitoulin-Northshore-Killarney[169].

Health protective behaviours

When air quality is poor, even otherwise healthy people can experience adverse symptoms. Everyone should take precautions, for example:

- Check the AQHI and follow the recommendations around cancelling or rescheduling strenuous activities if appropriate.
- Understand your risk and the risk of those in your care.
- Pay attention to Special Air Quality Alerts, when issued. Sign up to receive alerts at http://www.airqualityontario.com/alerts/signup.php.

There are innumerable ways to improve air quality and reduce greenhouse gas emissions. Individuals can help reduce air pollution by choosing greener transportation options (walking, biking, public transit, fuel-efficient, hybrid or electric vehicles), turning down heating and air conditioning at home, completing energy-efficient home retrofits, wasting less, eating less meat, planting trees and native species and being an advocate for the protection of natural lands and greenspaces. Municipalities can improve air quality and reduce greenhouse gas emissions by supporting low-carbon and zero-emission transportation options, utilizing green building standards and retrofits, and implementing land-use planning policies to conserve and increase greenspace[176].

Regulation of air quality

Air quality in Ontario is regulated by the Ministry of the Environment, Conservation and Parks. In Ontario, there are standards for general air quality and for facilities that emit contaminants into the air.

Ontario's Ambient Air Quality Criteria (AAQC) are air standards for general air quality and represent the maximum desirable concentration of a contaminant from all sources. The AAQC intend to protect against adverse effects including health, odour, visibility, corrosion, vegetation effects, soiling, or other impacts. The AAQC are commonly used in assessment of general air quality in communities and annual reporting on air quality across the province[177].

Facilities and businesses that emit pollutants into the air must comply with regulations designed to limit exposure to substances that can affect human health and the environment. Facilities must comply with air standards, which are legal limits for contaminants in air[178]. Air standards are updated based on science and set at concentrations that are protective against adverse effects to health and the environment[179].

If a facility faces challenges in meeting a required air standard, achieving regulatory compliance may be possible by requesting a Site-Specific Standard or Technical Standard. The site-specific standard is an air concentration approved for an individual facility[178]. A technical standard is a technology-based solution designed for two or more facilities in a sector that may not be able to meet an air standard for technical or economic reasons[178]. Technical standards exist for sectors such as forest products, petrochemical, pulp and paper, mining, petroleum refining, foundries and metal finishers[163].

Facilities are required to notify the Ministry of the Environment, Conservation and Parks if an emission exceeds any applicable air standard. In addition, regulated facilities are required to prepare and submit an emission summary report to the Ministry annually[178].

Air standards for specific contaminants, site-specific and technical standards are found within Ontario Regulation 419/05.

Food safety and sustainable food systems

Changes in temperature, precipitation and weather-related emergencies are expected to affect the growth and survival of foodborne pathogens and risk of food poisoning.

Food poisoning is expected to increase with climate change due to warmer, more favourable temperatures for pathogen survival combined with human behaviours that impact food safety practices, especially BBQ cooking, camping, and outdoor picnics[180]. Outdoor cooking and storing food for lengths of times outdoors can lead to improper temperature control and increase the risk of proliferation of pathogens in food.

In Canada, cases of foodborne diseases including salmonellosis and campylobacteriosis increase as environmental temperature increases (within limits), and tend to peak in summer months[181].

In addition, increases in food poisoning in the summer can be related to bacterial pathogen levels in the meat of animals raised for food at different points along the food system. A Canadian study found that the odds of detecting *Campylobacter* bacteria in pig and chicken products was highest in June through November in abattoir and retail settings. This corresponds to the period of peak average air temperatures and an approximate two-to-three-month period afterward. The finding illustrates that at warmer times of the year, pathogens are more prevalent in the animals before slaughter, and further, pathogens continue to survive in the retail environment[182].

Emergency situations caused by extreme weather events represent a concern for food safety, as well. Risks are mainly linked to unsafe food storage and cross-contamination from the environment or from people[181]. In emergency situations, lack of electricity can make refrigeration of food impossible. Perishable foods can quickly become unsafe to eat. Pathogens can begin to multiply on perishable food after two hours at room temperature—after this, the food is no longer considered safe to eat[183]. Poor sanitation can compound the risk of illness. Hands and surfaces cannot be properly cleaned if there is a lack of clean water, and unsanitary toilet facilities, close personal contact or over-crowding can allow pathogens to proliferate and spread person to person[181].

Health hazards of food poisoning

Food poisoning, also called foodborne illness, is brought about by ingesting food that contains large amounts of harmful microorganisms (pathogens), or from consuming foods in which bacteria have produced toxins[184]. The most common pathogens associated with food poisoning are bacteria (e.g., *E. coli*, *Salmonella*, *Campylobacter*, *Listeria*, and *Cholera*), viruses (e.g., hepatitis A and norovirus), and parasites (e.g., *Cyclospora*). The Government of Canada estimates that there are approximately 11 million cases of foodborne illnesses every year[184].

Symptoms of food poisoning can occur hours to days after consumption and individuals may not even realize they have acquired a foodborne illness. Symptoms of food poisoning include nausea, vomiting, diarrhea, stomach pains or cramps, and fever[184].

Certain groups of people are more likely to experience food poisoning and to have a more serious illness[185].

Those at greater risk of food poisoning include[185]:

- older adults (+65 years)
    - Older adults are at greater risk because as the body ages, the immune system and organs do not function as efficiently. Nearly half of people aged 65 and older who have a lab-confirmed foodborne illness from *Salmonella*, *Campylobacter*, *Listeria* or *E. coli* are hospitalized[185].
- children younger than 5 years
    - Young children have immune systems that are still developing and have a lower ability to combat pathogens. Food poisoning can be particularly dangerous for young children because illness can lead to diarrhea and dehydration. Hospitalization and organ failure are also risks for young children with serious food illness[185].
- pregnant people
    - During pregnancy, the immune system is weakened. Food poisoning in a pregnant person can cause miscarriage, stillbirth, and premature birth[186].
- people with weakened immune systems due to diabetes, alcoholism, liver or kidney disease, and HIV/AIDS; or due to receiving chemotherapy or radiation therapy[185]

Safe food handling

At certain temperatures, pathogens in food can multiply very quickly to harmful levels. Foods that are most often implicated in food poisoning include milk and milk products, eggs, cooked rice, meat and poultry, fish and shellfish, and raw sprouts[184].

Follow these safe food handling practices to reduce the risk of food poisoning[184]:

- Clean—If hands, food, work surfaces, and utensils are not cleaned and sanitized, harmful pathogens can easily spread.

- Separate—Raw food such as meat can contain harmful bacteria. These bacteria can be transferred from raw food to cooked and ready-to-eat food.
- Cook—Cooking food to the right internal temperature will kill off harmful pathogens. Verify cooking temperatures using a probe thermometer. Once cooked, keep hot foods above 60°C (140°F).
- Chill—Bacteria can grow in the temperature danger zone, between 4°C and 60°C (40°F to 140°F). Keep cold foods at or below 4°C (40°F).

Food systems and climate change

Food systems are complex and non-linear[187]. According to the High Level Panel of Experts on Food Security and Nutrition, food systems are explained as "[including] all the elements…and activities that relate to the production, processing, distribution and marketing, preparation and consumption of food and the outputs of these activities, including socioeconomic and environmental outcomes"[188]. Food system outputs (e.g. foods or ingredients) may originate from agriculture, forestry, or fisheries[189].

Figure 16: A hearty and nourishing salad including healthy fats and protein made with leftover potatoes and steamed snap peas. Photo: Kate Comeau.

The current food systems offer, for many people, easy access to a variety of affordable food throughout the year. However, they are also among the greatest drivers of poor human health, environmental degradation and climate change[190].

Current agricultural practices contribute to about 12% of total Canadian emissions[191]. Greenhouse gas emissions produced by farms are the result of activities such as combustion of fuels (using gasoline and diesel, and for heating and electricity), application of nitrogen fertilizer, and methane released by manure and cows as they digest grass[191]. Other ways in which the current food systems contribute to the production of greenhouse gases include the transportation of food and release of methane from food waste in landfills[192,193].

The health impacts of food systems are interconnected, self-reinforcing, and complex[194]. Five key ways in which current food systems negatively impact health are the exacerbation of food insecurity and unhealthy dietary patterns, and exposure to occupational hazards, environmental contaminants, and contaminated foods[194]. These negative impacts are made worse by climate change and most severely impact populations living on low incomes[187].

The quantity, and quality of food from agriculture, forests and freshwater food systems are impacted by climate change due a variety of factors such as changes in pest populations, erosion, nutrient depletion of soils, and growing conditions[187]. Although initial increases in crop production may occur, particularly in temperate regions, it is anticipated that crop production will fall almost everywhere in the world by 2050 due to rising temperatures[187].

Sustainable food systems

Sustainable food systems are fundamental to addressing climate change. In addition, sustainable food systems are those that ensure food security. Food security refers to the ability to acquire or consume food that is adequate in quality and quantity. Expressed another way, food security means being able to access and afford food that can keep you and your family healthy and full. Food insecurity is often linked with a household's financial ability to access adequate food[195].

Sustainable food systems "deliver food and nutrition security for all in such a way that the economic, social and environmental [structures] for food security and nutrition for future generations are not compromised"[188]. Sustainable diets are those diets with low environmental impact [e.g. carbon emissions, land use, and water use] which contribute to food and nutrition security and to healthy life for present and future generations (Figure 16)[196]. Sustainable diets are[196]:

- protective and respectful of biodiversity and ecosystems
- culturally acceptable, accessible, economically fair and affordable
- nutritionally adequate, safe, and healthy while optimizing natural and human resources

Sustainable food systems contribute to and are supported by sustainable diets; the two are inseparable[187]. Sustainable food systems and sustainable diets can be supported by individuals and communities in a variety of ways[187] (Table 12).

Table 12: Actions to support sustainable food systems and sustainable diets[187]

Supporting sustainable food systems and sustainable diets
• Consume a primarily plant-based diet [foods derived from plants, including fruits, vegetables, nuts, seeds, and legumes (lentils, dried beans, and peas)]. • Reduce meat consumption (especially ruminant meat, e.g., beef, bison, and lamb).

- Consume seasonal, field grown vegetables and fruits (greenhouses are energy intensive).
- Reduce food loss and waste.
- Choose certified sustainable fish.
- Breastfeed
- Limit consumption of highly processed foods.
- Develop local/regional food production systems that eliminate environmental contamination and greenhouse gas emissions and guarantee safe, fair work in the agriculture sector.
- Incorporate protection of water quality and quantity in food system planning.
- Encourage urban and rural food production that is climate resilient.

Adaptations for food safety and sustainable food systems

Immediate health risks can be moderated by incorporating food safety and food security actions into local emergency preparedness planning[197]. Food security actions may include planning for emergency provision of food and water for those experiencing greatest need. Food safety responses may include public education bulletins and coordination of food safety response activities by public health inspectors. To become more resilient to climate change over the long-term, adaptations related to food systems must be approached in ways that do not exacerbate inequalities and which recognize local situations and diversity of food systems[187]. Fundamental changes must occur in areas of food production, processing, transportation, packaging, and disposal practices. It is recommended that a food systems approach be taken to create sustainable food systems[189].

Disruptions to the food supply chains and volatile food prices caused by the COVID-19 pandemic and other factors have demonstrated the risk that is faced when the majority of our food is sourced from faraway locations. Creating local/regional food production systems can protect communities from future supply chain disruptions. Ideally, regional food production should be developed in such a way that it eliminates environmental contamination and greenhouse gas emissions, incorporates protection of water quality and quantity, and guarantees safe, fair work in the agriculture sector. Both urban and rural food production should be considered in supplying food for local population.

Vector-borne diseases

Vector-borne diseases are caused by viruses, bacteria, or parasites that are transmitted to humans through the bite of insects (‘vectors’) such as ticks, fleas, or mosquitoes[198,199]. Vector-borne diseases of significance in Ontario include Lyme disease (caused by the bacteria *Borrelia burgdorferi* and transmitted to humans by ticks), and West Nile Virus and eastern equine encephalitis virus, transmitted to humans by mosquitoes[200–202].

Climate change is expected to increase the risk of tick and mosquito borne diseases. With warmer temperatures, the geographic range of the local tick vector for Lyme disease is expected to expand northward. Risk of tick exposure in Public Health Sudbury & Districts' service area will increase from the current low risk designation to moderate risk by 2020-2049[203]. Mosquito-borne diseases are expected to increase as well. Warmer temperatures with above average precipitation are supportive of mosquito breeding cycles and virus incubation[204], and the geographic range of the mosquito vector for West Nile virus is expected to move northward from 2020s through to the 2080s[205]. Climate warming and other environmental changes may contribute to the expansion of uncommon or exotic tick and mosquito species into Canada[206,207]. New vector species can carry and transmit pathogenic bacteria and viruses to humans, increasing risk of disease[206,207]. More details are found in this section under the titles 'Tick-borne disease and Climate Change' and 'Mosquito-borne disease and Climate Change'.

Health hazards of tick-borne disease

Lyme disease is an infection caused by the bacteria *Borrelia burgdorferi* and is transmitted to humans through the bite of an infected blacklegged tick, *Ixodes scapularis.* Lyme disease is the most common vector-borne disease in North America and incidence has been increasing in Ontario since the early 2000s[208]. The observed increase in incidence may be due to a number of factors, including increasing numbers of individuals exposed to Lyme disease, expanding risk areas in Ontario and increased public and physician awareness of the disease[209].

The black-legged tick prefers a forested habitat with brush and tall grasses[201,210] (Figure 17). Individuals at greatest risk of exposure to infected ticks include those who spend significant amounts of time outdoors, such as campers, hikers, and hunters, especially in areas where black-legged ticks are known to occur[209].

Figure 17: Black-legged ticks prefer forested places with brush and tall grasses. People spending time outdoors should take precautions against ticks.

In Ontario, black-legged ticks are known to occur in southwestern areas of the province, and pockets of northern Ontario, near Thunder Bay, Rainy River, and Kenora. Black-legged ticks do not commonly occur in Public Health Sudbury & Districts' service area (Figure 18).

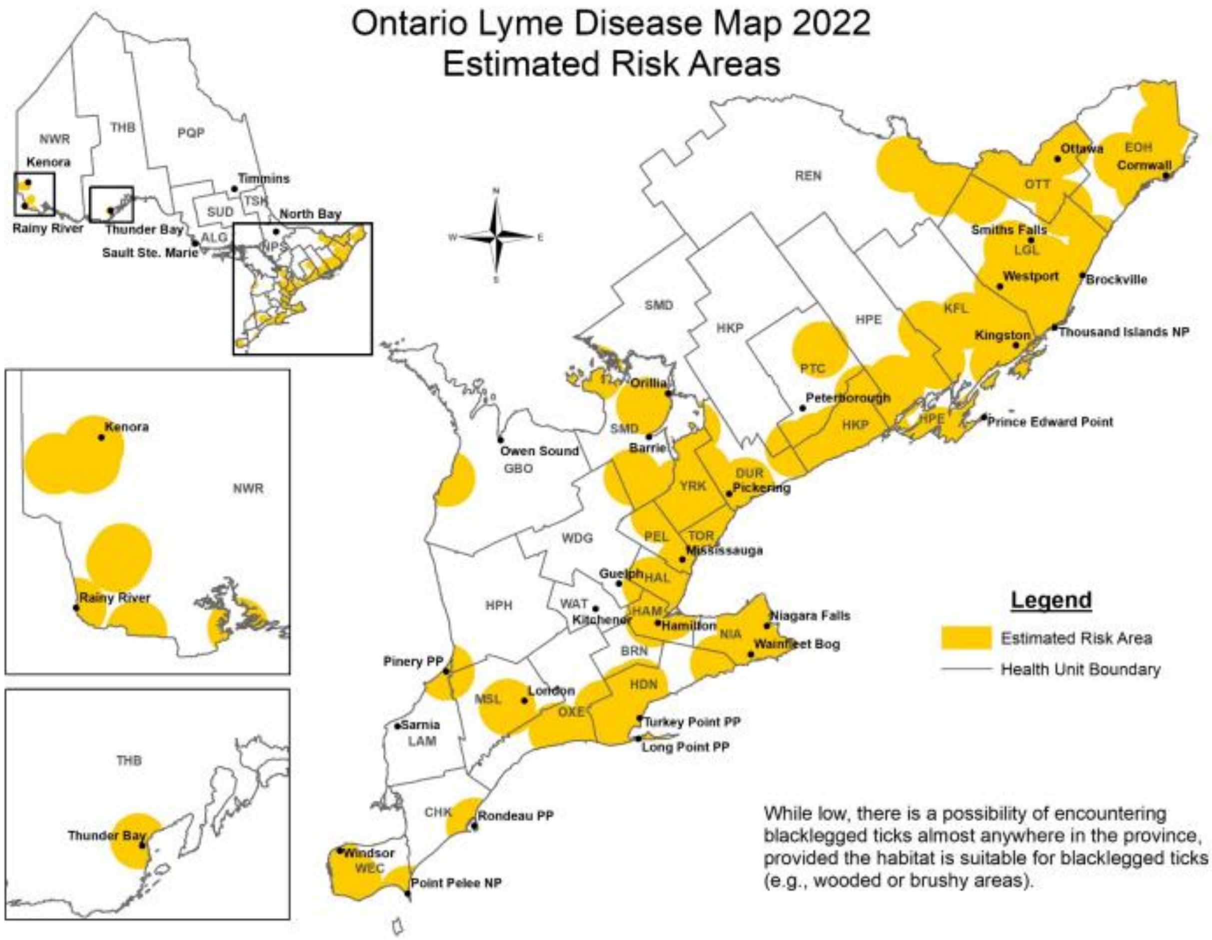


Figure 18: Lyme disease estimated risk areas in Ontario. Yellow colour indicates areas where blacklegged ticks have been identified or are known to occur, and where people have the potential to come into contact with infective ticks. Source: Public Health Ontario.

The incidence of Lyme disease in Public Health Sudbury & Districts' service area is low. Between 2011 and 2021, there were 9 confirmed cases of Lyme disease originating from local ticks[211]. Because tick bites are painless and ticks can be very small (1-3 mm[212]), some victims of Lyme disease are unaware that they were ever in contact with a tick[201].

The most common symptom of Lyme disease is a skin rash that occurs at the location of the bite of the tick within 2-30 days. The rash often takes on a characteristic bull's eye appearance (Figure 19). Other symptoms include headache, chills, pains in the joints, loss of appetite, nausea, fatigue, fever, aching muscles, stiff neck, sore throat, and vomiting[201]. Later stages of Lyme disease can involve arthritic, cardiac, and neurological complications[201]. Mental health impacts can be experienced by patients whose cases have developed neurologic involvement. Reactions can include paranoia, dementia, schizophrenia, bipolar disorder, major depression, and other issues[213].

Figure 19: A bull's eye rash at the site of a tick bite.
Source: Health Canada

Lyme disease can be prevented by taking precautions against black-legged ticks[201]:

- Wear light coloured clothing outdoors. It makes ticks easier to spot.
- Wear long pants and a long-sleeved shirt.
- Wear closed footwear and socks, never sandals, when walking through fields or woods.
- Tuck your pants into your socks.
- Use a tick repellent containing DEET. Apply it to your skin and outer clothing.
- Put a tick and flea collar on your pets and check them periodically.
- Search your body well for ticks after walking through fields or woods. Pay special attention to areas such as the groin, scalp, and armpits.

Tick-borne disease and climate change

Climate change is expected to enhance the climatic suitability for the blacklegged tick and expand its current geographic range into new areas. Ticks can be dispersed northward by migratory land birds. Carried a distance by birds, ticks may drop off in new areas, infect wildlife and be able to establish reproducing populations where they have landed (provided the temperature and habitat are favourable). A 2008 study produced risk maps predicting range expansion of black-legged ticks (*Ixodes scapularis*) with climate change[203]. The maps showed that Public Health Sudbury & Districts' service area will move from low risk of having established tick populations in 2000-2019 to moderate risk in 2020-2049 under a moderate climate change scenario[203] (Figure 20).

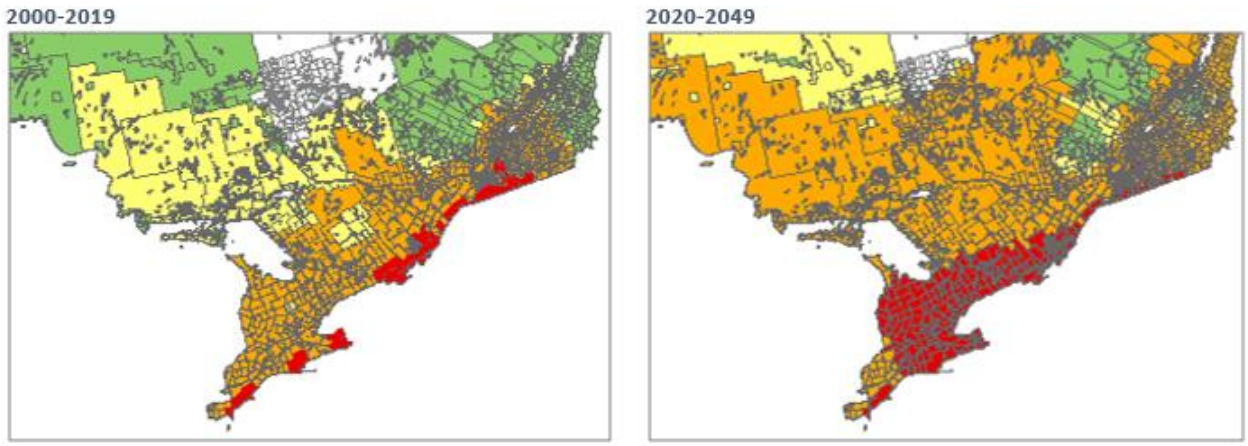


Figure 20: Risk maps for the occurrence of the Lyme disease vector Ixodes scapularis showing current (2000-2019) and projected risk (2020-2049) under climate change, in southern and central parts of the province of Ontario. The 'high' risk regions for *I. scapularis* population establishment are indicated in red, the 'moderate' risk regions are in orange, the 'low' risk regions are in yellow, regions with no risk of established populations but some risk from bird-borne 'adventitious' ticks are in green, and regions with no predicted risk of either are colourless. Adapted from Ogden et al, 2008.

In addition to Lyme disease, four other tick-borne diseases are of concern in Canada and are likely to increase with climate change: Anaplasmosis; Babesiosis; Powassan virus; and *Borrelia miyamotoi* disease[206]. These diseases can be transmitted by a number of different tick species. The ticks and pathogens have been identified in Canada, although exposure and human cases of disease are rare[206]. Detection of ticks through surveillance, reporting of human cases, and maintenance of accurate risk information is needed to inform medical care and public health action[206].

Tick surveillance

Tick surveillance is conducted to determine the level of establishment of black-legged tick populations within an area and assess the possible risk of human *B. burgdorferi* infection. Tick surveillance may be passive (accepting and examining ticks submitted from the public), or it may be active (collecting ticks from their natural habitat through an activity called 'tick dragging'). Incidence rates of Lyme disease correlate with areas reporting larger numbers of blacklegged ticks through passive surveillance. Passive surveillance offers important information in regions with newly established and/or expanding black-legged tick populations[214].

Public Health Sudbury & Districts conducts tick surveillance in accordance with guidance developed by Public Health Ontario for the Ministry of Health[214]. Passive surveillance is conducted, with tick dragging if indicated by passive surveillance (for example, if a cluster of black-legged ticks positive for *B. burgdorferi* are recovered through passive surveillance)[214].

Health hazards of mosquito-borne disease

Two mosquito-borne diseases are of concern in Ontario: West Nile virus and eastern equine encephalitis virus.

West Nile virus

West Nile virus was first isolated in Uganda, Africa in 1937, and was introduced into North America in 1999. In the summer of 1999, an outbreak of West Nile virus occurred in New York City resulting in 62 cases of encephalitis and 7 deaths. Since then, it has spread mainly west and south through the United States and Canada. The first human case in Canada occurred in 2002[215]. There are very few cases of West Nile virus in Public Health Sudbury & Districts' service area. Between 2005 and 2018 there have been 5 cases (one in 2006, 2011 and 2015 and two in 2017)[211].

West Nile virus is spread to humans through the bite of an infected mosquito (Figure 21). Mosquitoes become infected from feeding on the blood of an infected bird (primarily crows, ravens, blue jays, and magpies)[215]. In Ontario, mosquitoes of the *Culex* species are primarily responsible for West Nile virus transmission to humans[216]. Interestingly, the *Culex* mosquito is an urban-dwelling species with a preference for lifecycle development in water catch basins in urban settings (the mosquitoes lay their eggs and hatch larvae in standing water)[200,209]. As a consequence, the majority of human cases in Ontario are reported in the Greater Toronto Area[211].

Figure 21: West Nile virus is spread to humans through the bite of an infected mosquito.

Infections in humans are typically mild and symptoms include fever, headache, body aches, nausea and/or vomiting, and occasionally skin rash and swollen lymph glands. Some patients can experience mental health effects such as cognitive impairments to learning and memory[217], personality changes, and periods of depression[218]. Symptoms of more severe infection may include neck stiffness, disorientation, coma, tremors, convulsions, paralysis and, rarely, death[215].

Eastern equine encephalitis virus

Eastern equine encephalitis virus (EEEv) is a mosquito-borne virus found throughout the Western Hemisphere. It is considered the most severe mosquito-borne virus in North America, due to it’s high fatality rate in severe cases (30-75%) and potential for permanent neurological conditions in survivors[219]. As of 2017, only a single human case of EEEv has been recorded in Ontario (occurring 2016)[220]. In the United States, an average of 11 cases of EEEv are reported annually. Most cases occur in the States of Massachusetts, Michigan, Florida, Georgia, New York, and North Carolina[221].

The virus is known to be found in birds and is transmitted by mosquito to horses and humans. The virus is not transmitted directly between horses and humans. The main mosquito vector for EEEv in Ontario is *Culiseta melanura*. *Culiseta melanura* prefers a habitat of flooded forests or swamps. The majority of cases in horses occur adjacent to flooded forests or swamps in rural areas. Cases of EEEv in horses occur annually in rural areas of southern Ontario[220]. The first ever case of EEEv in horses in Public Health Sudbury and Districts’ service area was reported in Greater Sudbury in 2019[222].

Most people who become infected with EEEv will be asymptomatic or have mild symptoms such as fever, chills, muscle, or joint pain. Severe cases of EEEv can progress into encephalitis or meningitis, resulting in disorientation, seizure, coma, and sometimes death[202,223].

Prevention of mosquito-borne disease

Exposure to West Nile virus and eastern equine encephalitis virus can be prevented by[200]:

- Preventing mosquito bites:
    - Use an insect repellent according to product directions.
    - Stay indoors or take precautions from dusk to dawn when mosquitoes are most active.
    - Wear light-coloured clothing, including long sleeves, long pants, socks and a hat whenever you are outdoors.
    - Check window and door screens in your home to ensure that there are no tears or holes for mosquitoes to get through.

- Eliminating mosquito breeding sites:
    - Remove or change standing water once a week from areas that can hold water, including bird baths, old tires, unused containers, barrels, flowerpot saucers, clogged gutters, and eaves troughs and catch basins.

Mosquito-borne disease and climate change

Ontario's endemic mosquito borne diseases have complex transmission cycles involving animal hosts (birds and mammals) and multiple mosquito species—all of which may be sensitive to climate and environmental changes. As a result, forecasting potential outcomes to mosquito borne diseases related to climate change is challenging[204].

In general, it is expected that climate change will increase the risk of endemic mosquito borne diseases due to changes in temperature and rainfall patterns. An increase in precipitation supports the potential breeding habitat for mosquitoes in the environment. The relationship is non-linear, as above average rainfall is related to increased abundance of mosquitoes, while excessive, violent precipitation can destroy eggs and larvae. Warmer temperatures are known to increase rates of development of immature mosquitoes, leading to higher reproductive rates and population increases. In addition, elevated temperatures shorten the incubation period in mosquitoes that have become infected, so that their bite can become infectious to humans sooner[204].

Climate change has the potential to expand the range of mosquito vectors in Ontario. There is a predicted possible northward expansion of *Culex pipiens*, the mosquito species associated with West Nile virus in Ontario, from the 2020s through to the 2080s[205]. Being an urban species, this finding may have significant implications for more urbanized areas compared to rural ones. Climate change could impact reservoir host populations (e.g. birds) influencing their abundance or distribution. Other factors may also influence risk of mosquito borne disease in the future, including land-use changes resulting in habitat loss and gain for mosquitos and reservoir hosts, and mosquito surveillance and control activities[204].

With climate change, there is also the potential for exotic mosquito species to become established in Canada[204]. The *Aedes* species of mosquito is not endemic to Canada[224]. *Aedes* mosquito species are capable of carrying viruses such as chikungunya virus, dengue virus, West Nile virus, yellow fever virus and Zika virus[224]. Rarely detected in Ontario, *Aedes* species were not known to survive the cold winters and have established populations[224]. In the last few years, this has changed with respect to one species, *Aedes albopicus*. Recently detected in Windsor, Ontario, *Aedes albopicus* has been collected at all life stages for three consecutive years. *Aedes albopicus* is surviving all seasons, breeding successfully, and is now considered established in Windsor, Ontario[224]. It is believed that the arrival of *Aedes albopicus* in Windsor was aided by humans–possibly transported from the northern United States by vehicle or train[224]. The discovery of this species occurred through mosquito surveillance programs[224].

Monitoring of mosquito populations through surveillance activities will continue to inform risk, especially as mosquito species range expand northward.

Other mosquito-borne diseases of concern include St. Louis encephalitis virus and La Crosse encephalitis virus, which cause uncommon but severe and sometimes fatal disease in humans and are endemic to American states bordering Canada[11].

Mosquito surveillance

Public health units in Ontario conduct mosquito surveillance. Mosquito surveillance serves as an early warning system for West Nile virus and eastern equine encephalitis virus, alerting the public health community to the presence of mosquito vector species, and facilitating the assessment of risk. Mosquito surveillance is conducted by placing specialized mosquito traps at different locations throughout the health unit area and leaving them overnight. The traps are collected, and the mosquitos are identified to species. Those species that are thought to be vectors of West Nile virus or EEEv are tested for the virus[225]. Mosquito surveillance allows public health officials to understand which species of mosquitoes are present, how abundant the mosquitoes are, and if viruses of concern have entered the mosquito population[226].

In 2018, the majority of mosquitoes testing positive for West Nile virus or EEEv were trapped in the Greater Toronto area, as well as urban areas of southwestern and southeastern Ontario[225]. Within Public Health Sudbury & Districts' service area, mosquitoes testing positive for West Nile virus were identified in the municipality of Greater Sudbury in 2006 (community of Copper Cliff) and in 2013 (New Sudbury community area)[227–229].

Mental health

Mental health refers to a state of social, emotional and psychological well-being whereby the individual can cope with life stresses and challenges, and is able to contribute productively in their work and in their community[230]. Mental health is influenced by many factors, including life experiences, relationships with others, physical health status, and home, work, and school environments[231]. Being mentally healthy can increase feelings of self-worth, improve resilience (the ability to successfully move on after a negative event), and can reduce the risk of developing mental illness[230,231].

Mental health is different from mental illness. Mental illness affects a person over a prolonged period of time and can include a wide scope of conditions. Challenges faced relating to mental illness may include significant levels of distress, changes in thinking, mood or behaviour, or feelings of loneliness, sadness, and disconnection. Mental illness usually begins during adolescence and young adulthood; however, it can be experienced by people of all ages and backgrounds. Examples of mental illnesses include mood disorders (depression, bipolar disorder), anxiety disorders, schizophrenia, eating disorders, and personality disorders[232].

To achieve the best possible mental health state, the *Mental Health Strategy for Canada* highlights the need to promote mental health across the lifespan, foster recovery and well-being, and reduce disparities in mental health risk factors[230]. Mental health risk factors include poverty, family or partner conflict or violence, neglect in early childhood, having a parent with a substance-use problem, and living inadequate or unsafe housing[233].

Mental health hazards

While the physical health impacts of climate change are well-known, the mental health impacts are sometimes overlooked. Mental and physical health should have 'parity of esteem' or should be valued equally. In considering health impacts of climate change, mental health should be an explicit goal.[234]

Direct mental health hazards

Climate change can directly impact mental health through extreme heat, extreme weather events and wildfire, and vector-borne disease.

Extreme heat—Periods of very warm weather put individuals living with mental illnesses at greater risk of heat-related morbidity and mortality (See 'Heat and Mental Health').

Wildfire, severe flood, and ice storms—People that have lived through significant events such as wildfire, floods and ice storms can experience a variety of mental health impacts, including depression, anxiety, post-traumatic stress disorder, substance use, relationship strain, and feelings of helplessness and compounded stress[235].

After the wildfire affecting Fort McMurray, Alberta, in 2016, surveys of young people affected showed that 37% met the criteria for probable post-traumatic stress disorder, 31% met the criteria for probable depression, 27% for probable anxiety and 15% for probable alcohol/substance use disorder[236].

Public health surveillance after flooding in southern Alberta in 2013 revealed 1-2 fold increases in new prescriptions for anti-anxiety medications and sleep aids, and significant increases in sexual assaults presenting to emergency departments[237]. Local women's shelters reported doubling numbers of women and children accessing services and increased level of trauma in their experiences[238].

During and after the ice storm impacting Ontario and Quebec in 1998, the number of mental health concerns increased as the crisis progressed[239]. People experienced irritability, insomnia, conflict with family, isolation, and symptoms characterized as related to post-traumatic stress[239]. Among others, volunteers, first responders, medical personnel and their families, and individuals utilizing emergency shelters were documented as experiencing strain[239]. In response to the identified need, the Quebec Order of Psychologists set up a telephone hotline to help members of the public cope[239].

Vector-borne disease—Vector-borne diseases can produce mental health concerns and cognitive impairments. For example, in Lyme disease patients whose cases develop neurologic involvement, a broad range of symptoms and illnesses are possible, including paranoia, dementia, schizophrenia, bipolar disorder, panic attacks, anorexia, obsessive compulsive disorder, and major depression. In addition, up to 66% of patients with late Lyme disease experience significant symptoms of depression[213].

Patients with West Nile virus can experience cognitive impairments in verbal learning and memory, visual learning and memory, information processing speed, and visual-spatial ability[217]. In addition, it is not uncommon to observe personality changes and depression in West Nile virus patients[218].

Indirect mental health hazards

Climate change can indirectly impact people's mental health through changes to land and water-based activities and occupations. Stress and anxiety resulting from knowledge of the impending threat of climate change has also been recognized in the mental health field and is sometimes termed 'eco-anxiety'.

Adverse impacts to sectors such as tourism, agriculture, fisheries, forestry, and others can lead to economic instability, physical displacement, and a disrupted sense of security and belonging[235]. Unwanted change in one's situation can produce a sense of loss of control of one's life and sadness for the way that things used to be[240]. Loss of occupation has been associated with increased risk of depression following a natural disaster[240].

Figure 22: More than 700 people participated in Fridays for Future climate rally in Sudbury, Ontario on September 26, 2019. Photo: John Lappa, Sudbury Star.

While adverse impacts to mental health have been described, there is also the potential for growth following disasters related to climate change. Especially among individuals with access to physical and psychological support after an adverse event, post-traumatic growth can give rise to feelings of gratitude, compassion, generosity, and optimism[241].

Recently, an increase in public awareness of the grave consequences of climate change has been at the centre of mass public demonstrations[242]. A rally in Sudbury, Ontario, on September 26, 2019, drew more than 700 people demanding urgent action to combat climate change[243] (Figure 22). Recently, the term eco-anxiety has been used to describe an overarching sense of dread about the threat of climate change to our well-being and survival[235,244]. Eco-anxiety can manifest as anger that the climate crisis has advanced this far, frustration tied to inability to make a difference to stop it, and feelings of loss and guilt for future generations (Figure 23)[240]. Eco-anxiety can also feel like a spiritual loss. For those that experience their spirit as being innately connected to nature and the natural environment, the degradation and destruction of the environment can bring about a heavy sense of helplessness and despair[245]

Interventions supporting mental health

Each community has unique assets and vulnerabilities related to mental health. Community interventions that can support mental wellness in the face of climate change include[241]:

- Specific practices and behavioral interventions, such as inpatient or outpatient mental health care or counselling, and alternative mental health therapies such as mindfulness
- Community-based interventions, such as self-help groups, faith-based care, or civic action groups
- Mental health care training, such as Mental Health First Aid
- Awareness-raising of the mental health implications of climate change
- Integration of mental health care into vulnerability assessments and disaster risk management plans

Figure 23: A University of British Columbia student conveys emotion through face paint during a climate march in Vancouver in 2019. Photo: Ben Nelms, CBC..

Mental health consequences of climate change are expected to be unevenly distributed in the population, impacting those with fewer resources to a greater degree[241].

Uptake of mental health interventions by individuals and support for mental health interventions by decision makers is influenced by factors such as mental health literacy, access (financial and physical), communication and outreach, government assistance, intersectoral collaboration, sense of community, social capital, community preparedness, and cultural relevancy[241]. Through taking a proactive approach and paying attention to these factors, decision makers engaging in Climate Change and Health Vulnerability and Adaptation Assessments can maximize the benefits of existing resources. Furthermore, Climate Change and Health Vulnerability and Adaptation Assessments benefit from multi-stakeholder knowledge and perspectives. Relevant stakeholders related to mental health include people living with mental health problems and illnesses and their families and mental health service providers[230].

Protective factors that lead to positive mental health

Mental health policies and programs should address the individual, their connections and the broader environment in which they live[246]. The 3 most important determinants of mental health include social inclusion, freedom from discrimination and violence, and access to economic resources[246].

Social inclusion

Social ties promote feelings of attachment and companionship and enhance an individual's sense of purpose and self-esteem. A social network provides support to someone in need and helps them to cope in times of difficulty[246]. Participation in the community is associated with better self-reported mental health[246].

Freedom from discrimination and violence

Discrimination and violence are risk factors for poor mental health. In fact, they are often linked. Violence is commonly a vehicle through which discrimination based around race, gender, sexual orientation and/or disability is acted out. Forms of violence include child abuse, neglect by parents, intimate partner violence, sexual violence, bullying, youth violence, elder abuse, and self-directed violence[246]. Substance abuse and mental health problems are strongly linked to experiences of violence[246].

Access to economic resources

Having resources such as housing, education, work, and income protect and promote mental health. Lack of economic resources can lead to sustained hardship, material deprivation, poverty and poorer mental health[246]. Strategies that improve access to economic resources and work to redress inequalities experienced by oppressed or marginalized populations can promote positive mental health[246].

Economic impacts

Climate change will have economic impacts on a multitude of levels. Global and local economies will be impacted by the transition to a lower-carbon economy[247]. Economic sectors like forestry, mining, agriculture, fisheries, tourism, and others will be impacted differently by the effects of climate change[4]. Extreme weather events can have direct economic impacts in communities—damaging property, interrupting business, and bringing about financial distress for individuals and families. The impacts of extreme weather emergencies and disasters do not affect everyone equally. People living on low-income and in poverty are often more harshly affected by serious adverse events and disasters and may have a more difficult time recovering. This hardship can exacerbate existing inequities, including opportunities for health. This section will discuss possible economic impacts related to climate change for important sectors within Public Health Sudbury & Districts' service area, describe economic impacts of extreme weather on communities, and examine how emergencies and disasters affect people unequally.

Impacts to key economic sectors

In assessing health vulnerability to climate change and prioritizing community adaptations, it is important to understand how key economic sectors in local communities will be impacted. Hundreds and even thousands of people in a municipality can be affected if a significant employer suffers losses. For long term stability all companies and industries need to prepare for climate risks and adapt. Interested parties and municipalities can reach out to major employers and include them in Climate Change and Health Vulnerability and Adaptation Assessments.

Research shows that with climate change, economic sectors will face risks and possible opportunities[4]. This section identifies some key sectors and discusses climate impacts relevant to operations in the Public Health Sudbury & Districts service area.

Forestry

Healthy, abundant forests provide ecosystem benefits for living things, as well as benefits of clean air, water, carbon storage, and soil nutrients[4]. Forests provide economic benefits from the harvest of timber and non-timber forest products such as berries. In addition, forests have recreational and cultural value[4]. Forest-based communities can be dependent upon forest resources for jobs and outdoor recreation, including tourism[4].

Key risks of climate change to forests are explained in Table 13 and include wildfire, drought, pest outbreaks, changes to tree composition, and changing temperatures[4]. Economic impacts to the forestry sector will extend to other sectors that rely on forest products including manufacturing and construction[4].

Table 13: Climate impacts and risks to forestry sector

Climate impact	Risks to forestry sector
Wildfire	• Wildfire can destroy vast amounts of forest and occurrence is expected to increase with climate change.
Dry conditions or drought	• Drought and decreased moisture can impact tree mortality, radial growth, and productivity (often measured by tree height). • Drought is a risk factor for wildfire.
Expanding range of pests	• Several pests that impact forests are currently limited by winter temperatures, but the range and severity of outbreaks are likely to increase as winter temperatures rise. • The mountain pine beetle outbreaks in western Canada have been widely attributed to higher winter temperatures along with other contributing factors.
Tree species composition	• With changing temperatures, changes in tree species composition will impact the forest sector on a longer time scale. • There is high uncertainty in range-shift projections for North American forests. • As temperatures warms, species may not naturally migrate 'fast enough' to keep up with their climate niche.
Warmer temperatures	• A longer growing season may benefit tree populations in the northern portion of the species range. • More southerly populations may show neutral or adverse effects to growth; enhanced growth could be possible when trees are young and other growing conditions are ideal.

Mining

The mining sector is a major employer and contributor to national and local economies. This sector employs 80 000 people in Ontario directly and indirectly, including processing, refining, and the mine equipment and services sector[248]. Economic impacts to the mining sector will extend to the mining services sector. Climate risks to the mining sector are explained in Table 14 and include extreme rainfall and flood, increased freezing rain and extreme winter snow, and unusually warm, dry conditions[4].

Table 14: Climate impacts and risks to mining sector

Climate impact	Risks to mining sector
Extreme rainfall and flood	• Extreme precipitation can impact built infrastructure, for example affecting the integrity of berms, tailings dams and conditions of roads. • Flood and high river flows can exceed the capacity of water management structures.
Increased freezing rain and extreme winter snow	• Freezing rain and snowstorms can impact worker safety and productivity. • Built assets and equipment can be impacted, reducing safety and productivity, and increasing maintenance activities needed to restore conditions for work.
Warm, dry conditions	• Warm, dry conditions can exacerbate dust emissions and increase the need for abatement activities. • Extreme heat can impact the health of outdoor workers, reduce productivity, and increase the need for hot-weather safety activities.

Agriculture and fisheries

Food is sourced and produced through industry-based production of agriculture and fisheries products and also non-commercial elements including fishing, hunting, gardening, and gathering. Climate change could have some benefits to agriculture. Warmer temperatures could lead to a longer growing season, more variety and range of crops, longer outdoor feeding seasons for livestock, and the northward expansion of the maple syrup industry[4]. With respect to risks, the agriculture sector could be impacted adversely by warmer temperatures and water issues (availability and contamination). The fisheries sector could experience multiple impacts of warmer temperatures, as well. Table 15 outlines the climate impacts and risks to agriculture and fisheries sectors.

Table 15: Climate impacts and risks to agriculture and fisheries sectors

Climate impact	Risks to agriculture sector
Warmer temperatures	• With warmer temperatures, there is possibility of increased growth of weeds, risk of new pests and diseases and more severe outbreaks of currents ones.
Water issues	• Drought and dry conditions could lead to problems with water availability and need for more strict water management and conservation. • Extreme precipitation can lead to risk of water contamination related to runoff of livestock manure.

Climate impact	Risks to fisheries sector
Warmer temperatures	• At a regional level, warmer temperatures may drive impacts from invading species, physical habitat changes and shifts in availability and access to fish stocks (or other aquatic food resources). These factors will influence economic implications at the local level. • Changes to aquatic thermal conditions are expected to have negative consequences for cold and cool-water species (e.g. varieties of trout, walleye, perch, bass, pike, whitefish, salmon, smelt[249]).

Tourism

The tourism sector employs over 400 000 people in the province of Ontario[250]; many of these jobs are within small businesses and in smaller communities and rural areas[4]. Sixty per cent of tourist spending in Ontario is generated by Ontarians travelling within the province. Overseas visitors generate 19% of Ontario tourism spending, followed by visitors from the United States (13%) and other Canadian provinces (8%)[250]. With climate change, the tourism sector in the Public Health Sudbury & Districts service area may be positively impacted by warmer temperatures. Summer tourism could benefit from longer seasons (e.g. golf, hiking, camping, park visits, swimming, boating) and extreme heat may drive some tourists northward in Ontario for summer activities. At the same time, the sector could see some negative impacts of warmer temperatures, as well as adverse impacts from wildfire and drought[4,251]. Climate risks to the tourism sector are explained in Table 16.

Table 16: Climate impacts and risks to tourism sector

Climate impact	Risks to tourism sector
Warmer temperatures	• Skiing and snowmobiling can be negatively affected by warmer winter temperatures leading to a shorter season and less snow accumulation. • Ice-fishing season may be shorter due to warmer winter temperatures, with a potential for later-freeze-up and earlier thaw. • Warmer water temperatures could negatively affect fish stocks, impacting cold and cool-water sports fishing. • Warmer water temperatures, low-water levels and nutrient loading may support blue green algae blooms[120]. Some blue green algae species are capable of releasing toxins that are hazardous if ingested by humans and animals[251].
Wildfire	• Wildfire could impact camping and cottaging.
Dry conditions or drought	• Drought is a risk factor for wildfire. • Low-water conditions could negatively impact summer recreational water activities.

Extreme weather impacts on communities

Extreme weather is expected to increase with climate change and can cause significant, widespread economic impacts to communities[252]. Two major categories of economic impact include damage to fixed assets and business interruption[252]. Different types of weather can bring about these impacts; intense rain, floods, severe ice storms, freezing rain, and unusually heavy snowfall can be implicated. Businesses, homes, and powerlines can be damaged, and roads and transportation routes can be affected. Impacts can range from small to severe and life changing. Furthermore, economic impacts can have ripple effects. Damage to assets or business interruption can lead to financial difficulties, stress, and health implications.

To illustrate the impacts that can occur with extreme weather, consider a severe ice storm. Trees or branches burdened with ice can fall onto powerlines, causing power outages. Lack of power can necessitate businesses to close temporarily, sending employees home. A business interruption means there is a loss of provision of goods and services, impacting the company, the employees who lose wages, and the broader community. Businesses not affected by a power outage could be impacted by icy, hazardous roads. People and goods cannot safely arrive at the places they need to go. Different forms of travel can be impacted–airlines, commercial vehicles, private vehicles, and public transportation. Travellers on roads may become stranded by downed trees or may be involved in motor vehicle accidents. Slips and falls can cause injuries which can impact people's ability to work. Freezing rain is expected to become more frequent with climate change[66], and with intense precipitation increasing[73], it is possible that a severe ice storm like the one in Eastern Ontario and Quebec (See "1998 ice storm in Eastern Ontario and Quebec") or in the Toronto area (See "2013 ice storm in Toronto") will occur here.

Other extreme weather events that can cause serious economic impacts in communities include extreme rain, flood, and snowfall. Fierce winds, rain, and lightning can cause extensive tree damage that leads to power outages. Heavy rain can cause flooding, hazardous road conditions, and roads to be closed. Homes and commercial properties can be damaged by flood water. Even a few inches of water in a basement can cause significant damage to walls, flooring, furniture, important documents, and irreplaceable items. Municipal stormwater systems can become overloaded, causing sewage backup into homes. An intense snowfall can also cause power outages and road hazards. In addition, build-up of snow on roofs can contribute to water infiltration into buildings and homes, and to roof collapse.

Some businesses, such as insurance providers, construction and repair services may experience increased demand for their services following an extreme weather event[252].

Unequal impacts

Extreme weather events and disasters do not impact everyone equally. Some individuals and families are better resourced and prepared for disasters. Within the Public Health Sudbury & Districts' service area, about 52% of households have taken steps to prepare for an emergency or disaster. Of those households with an emergency plan, the majority have a supply of food and bottled water to last at least three days, and money in small bills[253]. Two thirds of Canadians (64%) have an emergency fund sufficient to cover 3 months' worth of expenses. A similar proportion (65%) are confident that they could come up with $2,000 if needed in the next month[254].

Some people experience more financial hardship than others. About 17% of Canadians say that their monthly expenses exceed their income. Persons under the age of 65 and those with household incomes under $40,000 are more likely to have difficulty keeping up with bill payments and other financial commitments. Lone parents and people who are separated or divorced are more likely to report falling behind financially[254].

Income is a significant socioeconomic factor linked to increased vulnerability in emergency and disaster situations[255]. Although the greatest magnitude of economic damage is often born by wealthier people due to possessions of higher financial value, the relative impact is greater for low income groups[256]. Socioeconomic factors play a role in all areas of life and often determine a person's life experiences, relationships, opportunities, and overall life chances[257]. In times of emergency or disaster, people's capacities to "anticipate, cope, resist and recover" are influenced by socioeconomic factors, including income[258].

People living in poverty or with low incomes are often less prepared for weather emergencies and disasters[259]. When a person's income is not enough to cover their basic needs, more urgent priorities probably outweigh saving for emergencies or purchasing insurance or costly emergency supplies. To this point, research on the effects of Hurricane Katrina on residents in New Orleans, Louisiana, found that parts of the city with high proportions of people living in poverty also had low percentages of people with flood insurance[256].

Furthermore, after a disaster, people in straitened circumstances may not be able to afford costs to replace belongings, repair homes, or relocate[256]. People in these circumstances are more likely to become homeless following an adverse event[257]. For people lacking resources to recover, the effects of a disaster can persist into the next generation[256].

Access to financial aid can be problematic for some individuals, as well. Recovery from disaster can be bolstered when people can negotiate bureaucratic systems and acquire financial aid. People with higher-income and literacy have been shown to have more knowledge of sources of aid to which they are entitled and better ability to progress through the system to acquire it[257].

Disasters and emergencies often reveal larger societal inequities. Everyone suffers, but those higher on the income ladder possess a cushion against adverse economic impacts, and usually can access the supports and services that they need to recover more easily. As a result of this disparity in opportunity, the struggles of those close to the margins can become more visible[257]. Existing inequities in health are also exacerbated by emergencies and disasters. Prioritizing health when living moment-by-moment in circumstances of extreme material deprivation is simply impossible[260]. Living on low-income and poverty increases the risk of poor health (mental and physical) across the life course[260].

Communities can take steps to mitigate socioeconomic conditions that make some people more vulnerable and address inequities related to disasters and emergencies[257,257,261] (Table 17).

Table 17: Actions to reduce inequities in emergency and disaster situations

Actions to reduce inequities in emergency and disaster situations[257,257,261]
• Promote policies that raise people out of poverty, for example, living wages or guaranteed basic income[261]. • Promote safe, affordable housing. • Improve access to government disaster recovery assistance. • Consider access to transportation in emergency response plans. Evacuation plans should not rely upon personal vehicles. • Through education, increase awareness of the diversity of various communities and inequities among emergency preparedness and response officials, and review and update emergency plans accordingly. • Include people from all income levels in emergency planning.

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Part 2: Climate Change Modelling Study: Temperature and Precipitation Projections specific for Each Local Community/Geographic area.

Climate Change Modelling Study

Temperature and precipitation projections for Chapleau and area

Public Health Sudbury & Districts
2022

Public Health
Santé publique
SUDBURY & DISTRICTS

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Climate change in Chapleau

Climate change has impacts everywhere. Although many communities in Northern Ontario contain abundant carbon sinks in the form of forests and are making efforts to reduce greenhouse gas emissions, they are not immune to impacts. Information on carbon sinks, greenhouse gases, the greenhouse effect, and global warming is found in Appendix A.

*Climate change modelling **and** emission scenarios **are explained in*** **Appendix B.**

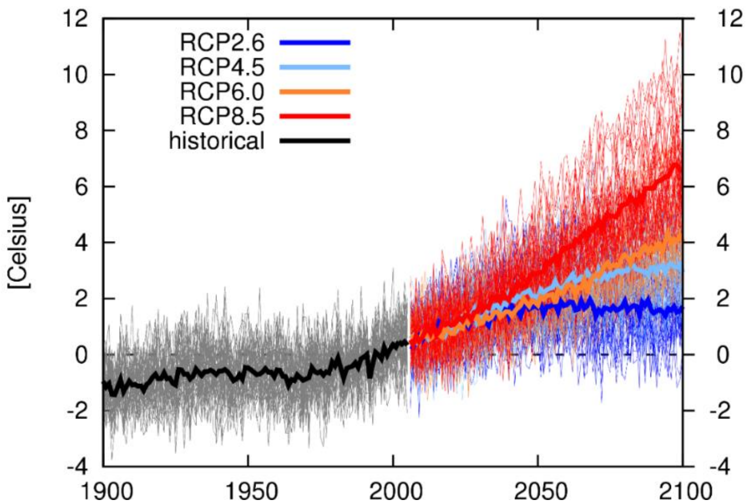
This section refers to climate change modelling and emission scenarios. Explanations of these concepts are found in Appendix B.

Briefly, climate change models are computer simulations that predict future states based on levels of greenhouse gas emissions and the resultant global warming effects. The emission scenarios range from low emission to high emission. A low emission scenario is a future where global greenhouse gas emissions are significantly curtailed, and global warming is slowed. A high emission scenario is a future where global greenhouse gas emissions continue to rise and global warming does, too. The low emission scenario is called RCP2.6. Moderate emission scenarios include RCP 4.5 and RCP6, and a high emission scenario is called RCP8.5.

Evidence of a warming trend

In an effort to establish a national weather service, some of the first weather stations were positioned along the Canadian Pacific Railroad in the early 1880s[2]. Therefore, in many places it is possible to assess weather trends dating back 100 years or more. Relative to today, a warming trend has been observed; Figure 1 is a time series graph depicting temperature change in degrees Celsius in Chapleau relative to 1986-2005, beginning with recorded temperatures in 1900 (black line) and moving to projected temperatures after 2005 (coloured lines). The recorded warming trend is particularly steep heading into the 2000s and beyond (black line). After 2005, the coloured lines depict temperature changes expected under different climate change scenarios, RCP2.6 (dark blue line), RCP4.5 (light blue line), RCP6.0 (orange line) and RCP8.5 (red line). Depending on the climate scenario, climate change models predict that temperatures will rise between 2 and 7 degrees Celsius relative to baseline (1986-2005) (Figure 1).

Figure 1 : Historical temperature change in degrees Celsius in Chapleau, Ontario, relative to 1986-2005, and projected temperature increase under climate change



With increasingly warm temperatures, record-breaking hot weather has been experienced recently in Ontario, North America, and around the world[3–5].

Globally, the decade 2001-2010 was the warmest in recorded history, followed by the previous decade, 1991-2000, which held the earlier record[6]. These conditions are consistent with a long-term warming trend[6]. Northern latitudes tend to warm at a higher rate, with the Arctic warming at about twice the rate of lower latitudes[6].

Climate change projections for Chapleau and area

While understanding the general impacts of climate change is informative, in order to properly prepare, it is important that communities understand the specific impacts that are expected locally under moderate and high emission climate change scenarios. This section describes current and projected temperature (hot and cold), precipitation (rain and freezing rain), and wildfire.

Temperature

Increases in seasonal temperatures drive many of the climate impacts that put health at risk. Warmer summer temperatures contribute to heatwaves, wildfire, drought, ultraviolet radiation exposure, worsening air quality, and risks to food safety. Warmer seasonal temperatures also drive the northward expansion of ticks and mosquitoes capable of transmitting diseases such as Lyme disease and West Nile virus. Warmer winter temperatures are implicated in increasing risk of freezing rain, particularly in the colder winter months, and flooding due to rainfall over snow.

The danger of these increasing hazards and populations most at risk are explored in detail in Part 1 of this resource.

The following sections present the projected seasonal temperatures under the RCP4.5 (moderate emission) and RCP8.5 (high emission) scenarios. The projections were generated by Climate Atlas of Canada for the municipality of Chapleau.

The projections are presented as 30-year blocks, which is a common practice in the field of meteorology. The average of weather values over a 30-year period helps in describing the climate in a particular location and is a useful base for comparison to other locations or time periods[7].

Seasonal temperatures under moderate emissions

Under a moderate emission scenario, RCP4.5, the annual and seasonal average temperatures in Chapleau are expected to increase (Table 1). The average annual temperature at baseline is 1.8°C (1975-2005). The average annual temperature is expected to increase from 3.8°C in 2021-2050 to 4.9°C in 2051-2080 (172% increase from baseline). The average winter temperature at baseline is -13.7 °C (1975-2005). The average winter temperature is expected to increase from -11.4°C in 2021-2050 to -9.9°C in 2051-2080 (28% increase from baseline). The average summer temperature at baseline is 15.7°C (1975-2005). With climate change, average summer temperatures will be similar to present day Sudbury, Ontario (17.8°C). The average summer temperature is expected to increase from 17.4°C in 2021-2050 to 18.5°C in 2051-2080[8] (18% increase from baseline).

Table 1: Projected mean seasonal temperatures for Chapleau, under RCP4.5 scenario

Projected mean seasonal temperatures (°C) under RCP4.5, in the township of Chapleau, Ontario			
	1976-2005	2021-2050	2051-2080
Annual	1.8	3.8	4.9
Spring	0.9	2.8	3.7
Summer	15.7	17.4	18.5
Fall	4.2	6.2	7.0
Winter	-13.7	-11.4	-9.9

Seasonal temperatures under high emissions

Under a high emission scenario, RCP8.5, the annual and seasonal average temperatures in Chapleau are expected to increase (Table 2). The average annual temperature at baseline is 1.8°C (1975-2005). The average annual temperature is expected to increase from 4.1°C in 2021-2050 to 6.5°C in 2051-2080 (261% increase from baseline). The average winter temperature at baseline is -13.7 °C (1975-2005). The average winter temperature is expected to increase from -11.1°C in 2021-2050 to -8.1°C in 2051-2080 (159% increase from baseline). The average summer temperature at baseline is 15.7°C (1975-2005). The average summer temperature is expected to increase from 17.8°C in 2021-2050 to 20°C in 2051-2080[8] (27% increase from baseline).

Table 2: Projected mean seasonal temperatures for Chapleau, under RCP8.5 scenario

Projected mean seasonal temperatures (°C) under RCP8.5, in the township of Chapleau, Ontario			
	1976-2005	2021-2050	2051-2080
Annual	1.8	4.1	6.5
Spring	0.9	2.9	5.1
Summer	15.7	17.8	20
Fall	4.2	6.4	8.5
Winter	-13.7	-11.1	-8.1

Extreme hot temperatures

This section describes the current situation and projected frequency of very hot weather (30+°C) under climate change. Extreme heat is of great concern locally and around the country—communities have been under heat warning, hot temperatures records have been broken, and heat waves have been implicated in illnesses and deaths[9–14]. Very hot weather is expected to double or triple with climate change, placing many people at increased risk of heat illness. The health implications of hot weather and populations most at risk are explored in detail in 'Health hazards in hot weather' in Part 1 of this resource.

Very hot days (+30°C) at present and with climate change

Climate change is expected to increase the number of hot days experienced in the summer months. In the township of Chapleau, there was an average of 6 very hot days (30+°C) per year in 1976-2005. With climate change under RCP4.5, that number is expected to reach an average of 15 very hot days per year in 2021-2050 and 23 in 2051-2080. Under RCP8.5, there is projected to be 17 very hot days per year in 2021-2050 and 39 in 2051-2080[8] (Table 3).

Table 3 : Current and projected average number of very hot days (+30°C) per year in the township of Chapleau[8]

	Average number of +30°C days per year				
Region	Baseline	RCP4.5 moderate emission scenario		RCP8.5 high emission scenario	
Time span	1976-2005	2021-2050	2051-2080	2021-2050	2051-2080
Township of Chapleau	3	9	15	11	26

Heat warnings and temperature triggers

Hot weather is monitored by Environment and Climate Change Canada. Heat warnings are issued when temperatures reach specific temperature triggers. Heat warning temperature triggers were developed by Health Canada and Public Health Ontario for 3 distinct regions in Ontario based on mortality and population data, humidex, local climate, and air pollution characteristics[15].

In Northern Ontario, a Heat Warning is issued by Environment and Climate Change Canada when the temperature is forecast ≥29°C or humidex ≥36°C for at least 2 consecutive days, with overnight lows falling to ≥18°C[15] (Table 4). An extended heat warning is issued when the heat forecast is maintained for at least 3 consecutive days[15].

Table 4: Criteria for the issuing of a heat warning in Northern Ontario

Region	Heat warning temperature trigger	Duration requirement
Northern Ontario	Tmax ≥ 29°C and Tmin ≥ 18°C OR Humidex ≥ 36	2+ days

Public Health Sudbury & Districts publicly communicates heat warnings and extended heat warnings issued by Environment and Climate Change Canada. Chapleau, Missinaibi Lake, Gogama and Foleyet were under heat warning for 1 day in 2022, 9 days in 2021 and 16 days in 2020 (Table 5).

Table 5 : Total days under heat warning in Chapleau, Missinaibi Lake, Gogama and Foleyet (2019-2022)

Year	Total number of days under heat warning
2022	1
2021	9
2020	16
2019	10

To receive an email when a heat warning is issued, sign up through the EC Alert Me program at https://ecalertme.weather.gc.ca/createaccount_en.php.

Extreme cold temperatures and frost season

This section describes the current situation and projected frequency of cold weather (-30°C) under climate change. While very cold weather will decrease, winter hazards in the north do not disappear. The region will continue to experience months of cold weather and people without adequate protection will be at risk of cold weather injuries such as frostbite and hypothermia. Especially in the colder winter months, incidence of freezing rain is expected to increase with climate change[16], and incidence of extreme precipitation (including heavy snow) is expected to occur more frequently than before[17]. The serious health implications of cold weather and freezing rain are explored in detail in 'Health hazards in cold weather' and 'Ice storms' in Part 1 of this resource.

This section also describes the current situation and expected changes to the frost-free season. A longer frost-free season could have positive implications for the agriculture sector and home gardeners.

Very cold temperatures and frost-free season

In general, the frequency and severity of cold weather is expected to decrease under climate change. In the township of Chapleau, there was an average of 17 very cold days (-30°C) per year in 1976-2005. With climate change under RCP4.5, that number is expected to decrease to 9 very cold day per year in 2021-2050 and 6 in 2051-2080. Under RCP8.5, there is projected to be 8 very cold day per year in 2021-2050 and 3 in 2051-2080[8] (Table 6).

Table 6 : Current and projected average number of very cold days (-30 ° C) per year in the township of Chapleau[8]

	Average number of -30 ° C days per year				
	Baseline	RCP4.5 moderate emission scenario		RCP8.5 high emission scenario	
Time span	1976-2005	2021-2050	2051-2080	2021-2050	2051-2080
Average number of -30 ° C days per year	17	9	6	8	3

Currently, the first fall frost occurs on average on September 16. Under RCP4.5, by 2021-2050, the first fall frost is expected to occur about 12 days later, by September 28 on average. Under RCP8.5, by 2021-2050, the first fall frost is expected to occur by September 29[8] (Table 7).

Table 7: Current and projected average date of first fall frost and frost-free days per year in the township of Chapleau[8]

	Date of first fall frost and length of frost-free season in days				
	Baseline	RCP4.5 moderate emission scenario		RCP8.5 high emission scenario	
Time span	1976-2005	2021-2050	2051-2080	2021-2050	2051-2080
Average date of first fall frost	September 16	September 28	October 2	September 29	October 12
Length of frost-free season (days)	106	127	138	130	153

Precipitation

This section describes precipitation at present and with climate change.

With climate change, seasonal precipitation is expected to increase a small amount from baseline. The largest increases in seasonal precipitation will be seen in the fall. This change could impact the agriculture sector by affecting fall harvest. Rain can degrade the quality of important crops like wheat, and heavy farming equipment required for harvest can become stuck and inoperable in waterlogged fields[18].

As the climate warms, the type of precipitation we can expect will change. In the winter months when we typically experience snow, the occurrence of freezing rain will increase. Projections show that incidence of freezing rain will double or triple in some parts of Ontario[16]. With intense precipitation increasing, it is possible that a severe ice storm like the one in Eastern Ontario and Quebec or in the Toronto area will occur here (see "Ice storms" in Part 1 of this resource).

Increased incidence of extreme precipitation during spring, summer and fall is also expected. An extreme rain event that would be expected to occur once every 50 years is expected to occur more often under climate change[19]. Extreme rainfall can lead to impacts such as floods and degradation of water quality. Significant health impacts caused by flood and water quality are explored in detail in Part 1 of this resource.

At the current time, average annual precipitation recorded at the Chapleau weather station amounts to 809 mm total, with 545.1 mm falling as rain and 281.5 mm falling as snow[20] (Table 8).

Table 8: Average annual precipitation in Chapleau

Average annual precipitation in Chapleau, 1981 to 2010	
Precipitation type	Measurement (mm)
Rainfall	545.1 mm
Snowfall	281.5 cm (281 mm water equivalent)
Precipitation Total	809 mm

Seasonal precipitation under moderate emissions

With climate change, studies of general trends point to wetter weather on a national and provincial scale[6,21]. Projected changes in precipitation under a moderate emission scenario, RCP4.5, are outlined in Table 9. Compared to baseline (1976-2005), annual mean precipitation is expected to increase by 46 mm in 2021-2050, and 71 mm by 2051-2080. The wettest season is the fall. Mean precipitation in the fall is expected to increase by 15 mm in 2021-2050, and 23 mm by 2051-2080[8].

Table 9: Projected mean seasonal precipitation for Chapleau, under RCP4.5 scenario

Projected mean seasonal precipitation (mm) under RCP4.5, in Chapleau, Ontario			
Time span	1976-2005	2021-2050	2051-2080
Annual	851	897	922
Spring	180	192	202
Summer	239	244	245
Fall	256	271	277
Winter	175	191	198

Seasonal precipitation under high emissions

Projected changes to precipitation do not vary greatly between moderate and high emission scenarios. Precipitation changes under a high emission scenario, RCP8.5, are outlined in Table 10. Compared to baseline (1976-2005), annual mean precipitation is expected to increase by 53 mm in 2021-2050, and 92 mm by 2051-2080. Mean precipitation in the fall is expected to increase by 18 mm in 2021-2050, and 24 mm by 2051-2080[8].

Table 10: Projected mean seasonal precipitation for Chapleau, under RCP8.5 scenario

Projected mean seasonal precipitation (mm) under RCP8.5, in Chapleau, Ontario			
Time span	1976-2005	2021-2050	2051-2080
Annual	851	904	943
Spring	180	195	214
Summer	239	242	237
Fall	256	274	280
Winter	175	193	211

Current and projected freezing rain

Freezing rain can cause considerable adverse impacts to communities, including power outages, hazardous roads and disruption of services[22], and with climate change, is expected to increase in frequency[23]. In communities with formal emergency preparedness plans and where emergency preparedness exercises are performed, organisers would very likely find value in choosing a severe ice storm as a focus scenario.

An Ontario study investigated freezing rain occurrence in select cities. Over a typical winter, November to April, freezing rain was found to occur more frequently in communities located geographically in the centre of the province than those farther north or south. Although Chapleau was not included in the study, for comparison, there has historically been about 7.7 days of freezing rain in Sudbury compared to 3.1 in Kapuskasing and 5.2 in Toronto[23] (Table 11).

Table 11: Historical incidence of freezing rain in select Ontario cities, 1953-2001

Historical incidence of freezing rain in select Ontario cities, 1953-2001[23]		
Weather station	Winter seasonal (Nov-Apr) average # of days with freezing rain	Winter seasonal (Nov-Apr) average # of hours with freezing rain
Kapuskasing	3.1	8.2
Kenora	2.6	6.2
Sioux Lookout	2.3	4.8
Thunder Bay	2.1	6.2
Timmins	4.2	11.5
Sault St. Marie	3.7	10.3
Sudbury	7.7	24.4
North Bay	7.5	22.4
Ottawa	9.7	36.6
Montreal	7.8	27.4
Toronto	5.2	17.1
Windsor	4.9	14.3

Another study investigated historical incidence of freezing rain and projected increases with climate change[16]. This study differentiated between colder winter months (December, January, and February) and warmer ones (November, March, and April), and looked at a few cities and two regions in the province of Ontario (‘eastern’ and ‘northern’). The results showed that freezing rain was expected to increase more dramatically during the colder winter months than the warmer ones[16]. With climate change bringing about warmer winter temperatures during the colder months, it becomes more likely for precipitation to fall as rain (rather than snow) than before. Although Chapleau was not specifically included in the study, for comparison, the study found that in Sudbury, during the baseline period 1961-2000, there was an average of about 4 total freezing-rain days in colder winter months (Table 12)[16]. Under climate change, the number of days with freezing rain increased by 1.5 days in the 2050s, and 3 days in the 2080s (Table 12)[16].

Table 12: Historical and projected number of days with freezing rain during colder winter months in Sudbury and Timmins, Ontario

Number of days with freezing rain during colder winter months – historical and projected with climate change			
City	Historical average # days with freezing rain (Dec-Feb), 1961- 2000	2050s projected # days with freezing rain (Dec-Feb) in 2050s	2080s projected # days with freezing rain (Dec-Feb) in 2080s
Sudbury	4	5.5	7
Timmins	1.5	2.5	3.5

Furthermore, from a regional perspective, freezing rain during colder months is expected to increase more in the northern region of Ontario than the eastern region. Freezing rain in cities in the northern region will increase 85% by the 2050s and 135% by the 2080s (Table 13)[16]. In comparison, freezing rain in the eastern region will increase 60% by the 2050s and 95% by the 2080s[16].

Freezing rain events in the warmer winter months are expected to increase a small amount in the northern region of Ontario and not at all in the eastern region[16].

Table 13: Projected increases in freezing rain during colder months (Dec, Jan, Feb) vs. warmer months (Nov, Mar, Apr) in different regions of Ontario

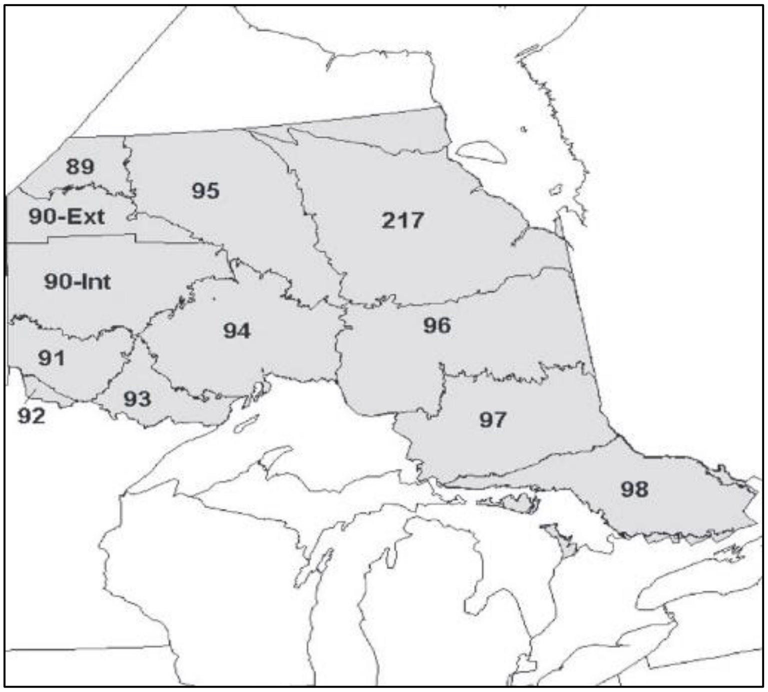
Projected increases in freezing rain in winter season during colder months (Dec, Jan, Feb) vs. warmer months (Nov, Mar, Apr)		
	Colder winter months 2050s	Colder winter months 2080s
Eastern Ontario (Montreal, Quebec, North Bay, Ottawa, Sudbury and Trenton)	+60%	+95%
Northern Ontario (Kapuskasing, Kenora, Sioux Lookout, Thunder Bay and Timmins)	+85%	+135%
	Warmer winter months 2050s	Warmer winter months 2080s
Eastern Ontario (Montreal, Quebec, North Bay, Ottawa, Sudbury and Trenton)	Not significant	Not significant
Northern Ontario (Kapuskasing, Kenora, Sioux Lookout, Thunder Bay and Timmins)	+10%	+20%

Wildfire

Wildfire activity is controlled by a number of factors including fuel, ignition, and weather. Climate change is expected to worsen all three factors, raising wildfire risk levels[24]. Periods of warm, dry weather reduce moisture content in wildfire fuel (e.g. biomass such as brush, leaves, and trees)[24], making it more receptive to catch fire[24]. Cloud-to-ground lightning is expected to increase with climate change, and fires caused by lightning and by human error are more likely to catch and continue to burn in dry conditions[24]. Wildfires have the potential to threaten communities and gravely impact health and safety (see 'Health impacts from wildfire' in Part 1 of this resource). This section describes increases in wildfire risk with climate change.

With climate change, the wildfire season is expected to become longer, and wildfires caused by lightning and humans are expected to increase (Table 14). Two forestry ecoregions exist in the Public Health Sudbury & Districts' service area. The ecoregion that covers the Chapleau area is referred to as ecoregion 97 (Figure 2).

Figure 2: The Ontario fire management zone (shaded) and national ecoregion designations within the zone. Public Health Sudbury & Districts service area is covered by ecoregions 97 and 98. The Chapleau office is located in ecoregion 97 and the offices in Sudbury East, Greater Sudbury, Manitoulin Island, and Espanola are located in ecozone 98.



The length of the fire season across Public Health Sudbury & District service area is projected to become longer under climate change (Table 14). Under the RCP2.6 (low emission) scenario the wildfire season in the Chapleau area is expected to lengthen by 10-20 days by 2041-2070[25]. Under the RCP8.5 (high emission) scenario, the wildfire season is expected to lengthen by 40-50 days by 2041-2070[25].

In addition, wildfires are expected to increase under climate change. Under a middle-ground emission scenario (RCP4.5), lightning caused wildfires in the Chapleau area are expected to increase by 25-50% by the year 2030[26]. Similarly, human caused wildfires are expected to increase by 25-50% by the year 2030[26].

Table 14: Changes in fire season length and number of wildfires under climate change

		Expected increase in fire season length by 2041-2070 (days)		Expected increase in lightning caused fires by year 2030	Expected increase in human caused fires by year 2030
Ecoregion	Public Health Sudbury & Districts service area office location	RCP2.6	RCP8.5	RCP4.5	RCP4.5
97	Chapleau	10 to 20 days	40 to 50 days	25-50%	25-50%
98	Sudbury East, Manitoulin Island, Greater Sudbury, and Espanola	10 to 20 days	30 to 40 days	25-50%	10-25%

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Climate Change Modelling Study

Temperature and precipitation projections for Espanola and area

Public Health Sudbury & Districts
2022

Public Health
Santé publique
SUDBURY & DISTRICTS

Author

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Climate change in Espanola

Climate change has impacts everywhere. Although many communities in Northern Ontario contain abundant carbon sinks in the form of forests and are making efforts to reduce greenhouse gas emissions, they are not immune to impacts. Information on carbon sinks, greenhouse gases, the greenhouse effect, and global warming is found in Appendix A.

*Climate change modelling **and** emission scenarios **are explained in*** **Appendix B.**

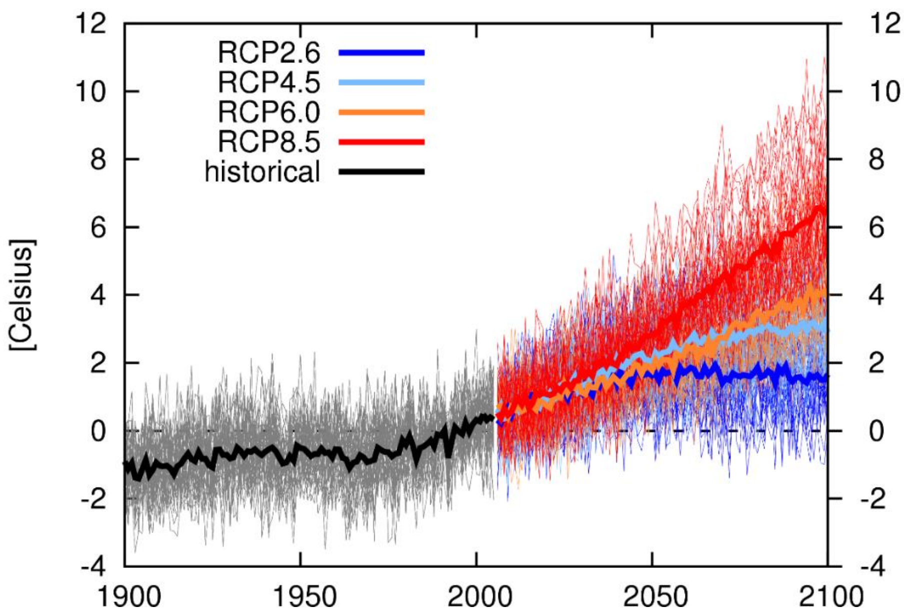
This section refers to climate change modelling and emission scenarios. Explanations of these concepts are found in Appendix B.

Briefly, climate change models are computer simulations that predict future states based on levels of greenhouse gas emissions and the resultant global warming effects. The emission scenarios range from low emission to high emission. A low emission scenario is a future where global greenhouse gas emissions are significantly curtailed, and global warming is slowed. A high emission scenario is a future where global greenhouse gas emissions continue to rise and global warming does, too. The low emission scenario is called RCP2.6. Moderate emission scenarios include RCP 4.5 and RCP6, and a high emission scenario is called RCP8.5.

Evidence of a warming trend

In an effort to establish a national weather service, some of the first weather stations were positioned along the Canadian Pacific Railroad in the early 1880s[2]. Therefore, in many places it is possible to assess weather trends dating back 100 years or more. Relative to today, a warming trend has been observed; Figure 1 is a time series graph depicting temperature change in degrees Celsius in Espanola relative to 1986-2005, beginning with recorded temperatures in 1900 (black line) and moving to projected temperatures after 2005 (coloured lines). The recorded warming trend is particularly steep heading into the 2000s and beyond (black line). After 2005, the coloured lines depict temperature changes expected under different climate change scenarios RCP2.6 (dark blue line), RCP4.5 (light blue line), RCP6.0 (orange line) and RCP8.5 (red line). Depending on the climate scenario, climate change models predict that temperatures will rise between 2 and 7 degrees Celsius relative to baseline (1986-2005) (Figure 1).

Figure 1: Historical temperature change in degrees Celsius in Espanola, Ontario, relative to 1986-2005, and projected temperature increase under climate change



With increasingly warm temperatures, record-breaking hot weather has been experienced recently in Ontario, North America, and around the world[3–5].

Globally, the decade 2001-2010 was the warmest in recorded history, followed by the previous decade, 1991-2000, which held the earlier record[6]. These conditions are consistent with a long-term warming trend[6]. Northern latitudes tend to warm at a higher rate, with the Arctic warming at about twice the rate of lower latitudes[6].

Climate change projections for Espanola and area

While understanding the general impacts of climate change is informative, in order to properly prepare, it is important that communities understand the specific impacts that are expected locally under moderate and high emission climate change scenarios. This section describes current and projected temperature (hot and cold), precipitation (rain and freezing rain), and wildfire.

Temperature

Increases in seasonal temperatures drive many of the climate impacts that put health at risk. Warmer summer temperatures contribute to heatwaves, wildfire, drought, ultraviolet radiation exposure, worsening air quality, and risks to food safety. Warmer seasonal temperatures also drive the northward expansion of ticks and mosquitoes capable of transmitting diseases such as Lyme disease and West Nile virus. Warmer winter temperatures are implicated in increasing risk of freezing rain, particularly in the colder winter months, and flooding due to rainfall over snow.

The danger of these increasing hazards and populations most at risk are explored in detail in Part 1 of this resource.

The following sections present the projected seasonal temperatures under the RCP4.5 (moderate emission) and RCP8.5 (high emission) scenarios. The projections were generated by Climate Atlas of Canada for the municipality of Espanola.

The projections are presented as 30-year blocks, which is a common practice in the field of meteorology. The average of weather values over a 30-year period helps in describing the climate in a particular location and is a useful base for comparison to other locations or time periods[7].

Seasonal temperatures under moderate emissions

Under a moderate emission scenario, RCP4.5, the annual and seasonal average temperatures in Espanola are expected to increase (Table 1).

The average annual temperature at baseline is 4.7°C (1975-2005). The average annual temperature is expected to increase from 6.7°C in 2021-2050 to 7.8°C in 2051-2080 (66% increase from baseline). The average winter temperature at baseline is -9.6 °C (1975-2005). The average winter temperature is expected to increase from -7.3°C in 2021-2050 to -5.9°C in 2051-2080 (39% increase from baseline). The average summer temperature at baseline is 17.7°C (1975-2005). With climate change, average summer temperatures will be similar to present day Toronto, Ontario (20.3°C). The average summer temperature is expected to increase from 19.5°C in 2021-2050 to 20.5°C in 2051-2080[8] (16% increase from baseline).

Table 1: Projected mean seasonal temperatures for Espanola, under RCP4.5 scenario

Projected mean seasonal temperatures (°C) under RCP4.5, in the municipality of Espanola, Ontario			
	1976-2005	2021-2050	2051-2080
Annual	4.7	6.7	7.8
Spring	3.5	5.4	6.4
Summer	17.7	19.5	20.5
Fall	7	8.9	9.7
Winter	-9.6	-7.3	-5.9

Seasonal temperatures under high emissions

Under a high emission scenario, RCP8.5, the annual and seasonal average temperatures in Espanola are expected to increase (Table 2). The average annual temperature at baseline is 4.7°C (1975-2005). The average annual temperature is expected to increase from 6.9°C in 2021-2050 to 9.3°C in 2051-2080 (98% increase from baseline). The average winter temperature at baseline is -9.6 °C (1975-2005). The average winter temperature is expected to increase from -7.1°C in 2021-2050 to -4.2°C in 2051-2080 (56% increase from baseline). The average summer temperature at baseline is 17.7°C (1975-2005). The average summer temperature is expected to increase from 19.8°C in 2021-2050 to 22.1°C in 2051-2080[8] (25% increase from baseline).

Table 2 : Projected mean seasonal temperatures for Espanola, under RCP8.5 scenario

Projected mean seasonal temperatures (°C) under RCP8.5, in the municipality of Espanola, Ontario			
	1976-2005	2021-2050	2051-2080
Annual	4.7	6.9	9.3
Spring	3.5	5.5	7.7
Summer	17.7	19.8	22.1
Fall	7	9.2	11.2
Winter	-9.6	-7.1	-4.2

Extreme hot temperatures

This section describes the current situation and projected frequency of very hot weather (30+°C) under climate change. Extreme heat is of great concern locally and around the country—communities have been under heat warning, hot temperatures records have been broken, and heat waves have been implicated in illnesses and deaths[9–14]. Very hot weather is expected to double or triple with climate change, placing many people at increased risk of heat illness. The health implications of hot weather and populations most at risk are explored in detail in 'Health hazards in hot weather' in Part 1 of this resource.

Very hot days (+30 °C) at present and with climate change

Climate change is expected to increase the number of hot days experienced in the summer months. In the municipality of Espanola, there was an average of 6 very hot days (30+°C) per year in 1976-2005. With climate change under RCP4.5, that number is expected to reach an average of 15 very hot days per year in 2021-2050 and 23 in 2051-2080. Under RCP8.5, there is projected to be 17 very hot days per year in 2021-2050 and 39 in 2051-2080[8] (Table 3).

Table 3 : Current and projected average number of very hot days (+30 °C) per year in the municipality of Espanola[8]

	Average number of +30°C days per year				
Region	Baseline	RCP4.5 Moderate emission scenario		RCP8.5 High emission scenario	
Time span	1976-2005	2021-2050	2051-2080	2021-2050	2051-2080
Municipality of Espanola	6	15	23	17	39

Heat warnings and temperature triggers

Currently, hot weather is monitored by Environment and Climate Change Canada. Heat warnings are issued when temperatures reach specific temperature triggers. Heat warning temperature triggers were developed by Health Canada and Public Health Ontario for 3 distinct regions in Ontario based on mortality and population data, humidex, local climate, and air pollution characteristics[15].

In Northern Ontario, a Heat Warning is issued by Environment and Climate Change Canada when the temperature is forecast ≥29°C or humidex ≥36°C for at least 2 consecutive days, with overnight lows falling to ≥18°C[15] (Table 4). An extended heat warning is issued when the heat forecast is maintained for at least 3 consecutive days[15].

Table 4: Criteria for the issuing of a heat warning in Northern Ontario

Region	Heat warning temperature trigger	Duration requirement
Northern Ontario	Tmax ≥ 29°C and Tmin ≥ 18°C OR Humidex ≥ 36	2+ days

Public Health Sudbury & Districts publicly communicates heat warnings and extended heat warnings issued by Environment and Climate Change Canada. Espanola, Massey and Killarney were under heat warning for 0 days in 2022, 5 days in 2021 and 9 days in 2020 (Table 5).

Table 5: Total days under heat warning in Espanola, Massey and Killarney (2019-2022)

Year	Total number of days under heat warning
2022	0
2021	5
2020	9
2019	0

To receive an email when a heat warning is issued, sign up through the EC Alert Me program at https://ecalertme.weather.gc.ca/createaccount_en.php.

Extreme cold temperatures and frost season

This section describes the current situation and projected frequency of cold weather (-30°C) under climate change. While very cold weather will decrease, winter hazards in the north do not disappear. The region will continue to experience months of cold weather and people without adequate protection will be at risk of cold weather injuries such as frostbite and hypothermia. Especially in the colder winter months, incidence of freezing rain is expected to increase with climate change[16], and incidence of extreme precipitation (including heavy snow) is expected to occur more frequently than before[17]. The serious health implications of cold weather and freezing rain are explored in detail in 'Health hazards in cold weather' and 'Ice storms' in Part 1 of this resource.

This section also describes the current situation and expected changes to the frost-free season. A longer frost-free season could have positive implications for the agriculture sector and home gardeners.

Very cold temperatures and frost-free season

In general, the frequency and severity of extreme cold weather is expected to decrease under climate change. In the municipality of Espanola, there was an average of 4 very cold days (-30°C) per year in 1976-2005. With climate change under RCP4.5, that number is expected to decrease to 1 very cold day per year in 2021-2050 and 1 in 2051-2080. Under RCP8.5, there is projected to be 1 very cold day per year in 2021-2050 and 0 in 2051-2080[8] (Table 6).

Table 6: Current and projected average number of very cold days (-30°C) per year in the municipality of Espanola[8]

	Average number of -30°C days per year				
	Baseline	RCP4.5 moderate emission scenario		RCP8.5 high emission scenario	
Time span	1976-2005	2021-2050	2051-2080	2021-2050	2051-2080
Average number of -30°C days per year	4	1	1	1	0

Currently, the first fall frost occurs on average on September 30. Under RCP4.5, by 2021-2050, the first fall frost is expected to occur about 11 days later, by October 11 on average. Under RCP8.5, by 2021-2050, the first fall frost is expected to occur by October 15 (Table 7).

Table 7: Current and projected average date of first fall frost and frost-free days per year in the municipality of Espanola[8]

	Date of first fall frost and length of frost-free season in days				
	Baseline	RCP4.5 Moderate emission scenario		RCP8.5 High emission scenario	
Time span	1976-2005	2021-2050	2051-2080	2021-2050	2051-2080
Average date of first fall frost	September 30	October 11	October 18	October 15	October 27
Length of frost-free season (days)	137	158	169	163	186

Precipitation

This section describes precipitation at present and with climate change.

With climate change, seasonal precipitation is expected to increase a small amount from baseline. The largest increases in seasonal precipitation will be seen in the fall. This change could impact the agriculture sector by affecting fall harvest. Rain can degrade the quality of important crops like wheat, and heavy farming equipment required for harvest can become stuck and inoperable in waterlogged fields[18].

As the climate warms, the type of precipitation we can expect will change. In the winter months when we typically experience snow, the occurrence of freezing rain will increase. Projections show that incidence of freezing rain will double or triple in some parts of Ontario[16]. With intense precipitation increasing, it is possible that a severe ice storm like the one in Eastern Ontario and Quebec or in the Toronto area will occur here (see “Ice storms” in Part 1 of this resource).

Increased incidence of extreme precipitation during spring, summer and fall is also expected. An extreme rain event that would be expected to occur once every 50 years is expected to occur more often under climate change[19]. Extreme rainfall can lead to impacts such as floods and degradation of water quality. Significant health impacts caused by flood and water quality are explored in detail in Part 1 of this resource.

At the current time, average annual precipitation recorded at the Massey weather station amounts to 890.1 mm total, with 689.2 mm falling as rain and 200.9 cm falling as snow[20] (Table 8).

Table 8: Average annual precipitation in Massey, Ontario

Average annual precipitation in Massey, Ontario (township of Sables-Spanish Rivers), 1981 to 2010	
Precipitation type	Measurement
Rainfall	689.2 mm
Snowfall	200.9 cm (200.9 mm water equivalent)
Precipitation total	890.1 mm

Seasonal precipitation under moderate emissions

With climate change, studies of general trends point to wetter weather on a national and provincial scale[6,21]. Projected changes in precipitation under a moderate emission scenario, RCP4.5, are outlined in Table 9. Compared to baseline (1976-2005), annual mean precipitation is expected to increase by 40 mm in 2021-2050, and 74 mm by 2051-2080. The wettest season is the fall. Mean precipitation in the fall is expected to increase by 10 mm in 2021-2050, and 22 mm by 2051-2080[8].

Table 9: Projected mean seasonal precipitation for Espanola, under RCP4.5 scenario

Projected mean seasonal precipitation (mm) under RCP4.5, in the municipality of Espanola, Ontario			
Time span	1976-2005	2021-2050	2051-2080
Annual	841	881	915
Spring	190	201	212
Summer	208	212	215
Fall	263	273	285
Winter	181	195	202

Seasonal precipitation under high emissions

Projected changes to precipitation do not vary greatly between moderate and high emission scenarios. Precipitation changes under a high emission scenario, RCP8.5, are outlined in Table 10. Compared to baseline (1976-2005), annual mean precipitation is expected to increase by 55 mm in 2021-2050, and 87 mm by 2051-2080. Mean precipitation in the fall is expected to increase by 17 mm in 2021-2050, and 21 mm by 2051-2080[8].

Table 10: Projected mean seasonal precipitation for Espanola, under RCP8.5 scenario

Projected mean seasonal precipitation (mm) under RCP8.5, in the municipality of Espanola, Ontario			
Time span	1976-2005	2021-2050	2051-2080
Annual	841	896	928
Spring	190	208	224
Summer	209	210	205
Fall	263	280	284
Winter	181	198	215

Current and projected freezing rain

Freezing rain can cause considerable adverse impacts to communities, including power outages, hazardous roads and disruption of services[22], and with climate change, is expected to increase in frequency[23]. In communities with formal emergency preparedness plans and where emergency preparedness exercises are performed, organisers would very likely find value in choosing a severe ice storm as a focus scenario.

An Ontario study investigated freezing rain occurrence in select cities. Over a typical winter, November to April, freezing rain was found to occur more frequently in communities located geographically in the centre of the province than those farther north or south. Although Espanola was not included in the study, for comparison, there has historically been about 7.7 days of freezing rain in Sudbury compared to 3.1 in Kapuskasing and 5.2 in Toronto[23] (Table 11).

Table 11: Historical incidence of freezing rain in select Ontario cities, 1953-2001

Historical incidence of freezing rain in select Ontario cities, 1953-2001[23]		
Weather station	Winter seasonal (Nov-Apr) average # of days with freezing rain	Winter seasonal (Nov-Apr) average # of hours with freezing rain
Kapuskasing	3.1	8.2
Kenora	2.6	6.2
Sioux Lookout	2.3	4.8
Thunder Bay	2.1	6.2
Timmins	4.2	11.5
Sault St. Marie	3.7	10.3
Sudbury	7.7	24.4
North Bay	7.5	22.4
Ottawa	9.7	36.6
Montreal	7.8	27.4
Toronto	5.2	17.1
Windsor	4.9	14.3

Another study investigated historical incidence of freezing rain and projected increases with climate change[16]. This study differentiated between colder winter months (December, January, and February) and warmer ones (November, March, and April), and looked at a few cities and two regions in the province of Ontario ('eastern' and 'northern'). The results showed that freezing rain was expected to increase more dramatically during the colder winter months than the warmer ones[16]. With climate change bringing about warmer winter temperatures during the colder months, it becomes more likely for precipitation to fall as rain (rather than snow) than before. Although Espanola was not specifically included in the study, for comparison, the study found that in Sudbury, during the baseline period 1961-2000, there was an average of about 4 total freezing-rain days in colder winter months (Table 12)[16]. Under climate change, the number of days with freezing rain increased by 1.5 days in the 2050s, and 3 days in the 2080s (Table 12)[16].

Table 12: Historical and projected number of days with freezing rain during colder winter months in Sudbury and Timmins, Ontario

Number of days with freezing rain during colder winter months – Historical and projected with climate change			
City	Historical average # days with freezing rain (Dec-Feb), 1961- 2000	2050s Projected # days with freezing rain (Dec-Feb) in 2050s	2080s Projected # days with freezing rain (Dec-Feb) in 2080s
Sudbury	4	5.5	7
Timmins	1.5	2.5	3.5

Furthermore, from a regional perspective, freezing rain during colder months is expected to increase more in the northern region of Ontario than the eastern region. Freezing rain in cities in the northern region will increase 85% by the 2050s and 135% by the 2080s (Table 13)[16]. In comparison, freezing rain in the eastern region will increase 60% by the 2050s and 95% by the 2080s[16].

Freezing rain events in the warmer winter months are expected to increase a small amount in the northern region of Ontario and not at all in the eastern region[16].

Table 13: Projected increases in freezing rain during colder months (Dec, Jan, Feb) vs. warmer months (Nov, Mar, Apr) in different regions of Ontario

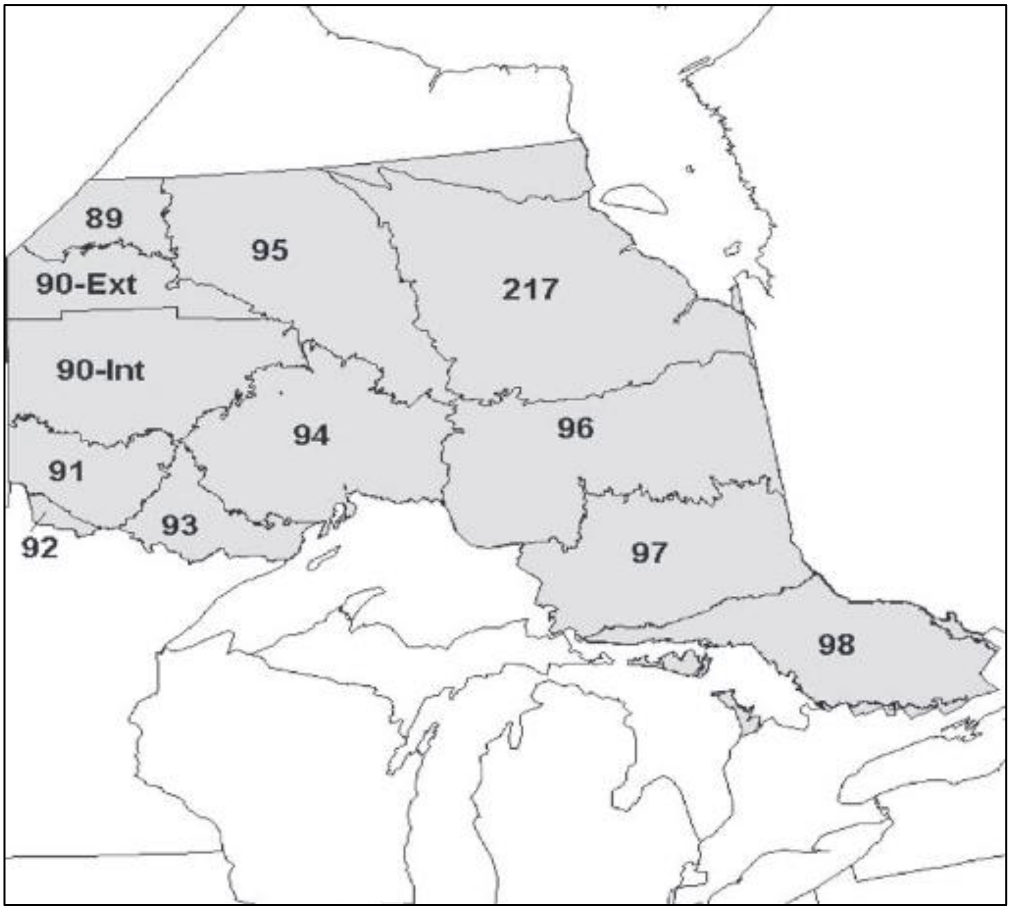
Projected increases in freezing rain in winter season during colder months (Dec, Jan, Feb) vs. warmer months (Nov, Mar, Apr)		
	Colder winter months 2050s	Colder winter months 2080s
Eastern Ontario (Montreal, Quebec, North Bay, Ottawa, Sudbury and Trenton)	+60%	+95%
Northern Ontario (Kapuskasing, Kenora, Sioux Lookout, Thunder Bay and Timmins)	+85%	+135%
	Warmer winter months 2050s	Warmer winter months 2080s
Eastern Ontario (Montreal, Quebec, North Bay, Ottawa, Sudbury and Trenton)	Not significant	Not significant
Northern Ontario (Kapuskasing, Kenora, Sioux Lookout, Thunder Bay and Timmins)	+10%	+20%

Wildfire

Wildfire activity is controlled by a number of factors including fuel, ignition, and weather. Climate change is expected to worsen all three factors, raising wildfire risk levels[24]. Periods of warm, dry weather reduce moisture content in wildfire fuel (e.g. biomass such as brush, leaves, and trees)[24], making it more receptive to catch fire[24]. Cloud-to-ground lightning is expected to increase with climate change, and fires caused lightning and by human error are more likely to catch and continue to burn in dry conditions[24]. Wildfires have the potential to threaten communities and gravely impact health and safety (see 'Health impacts from wildfire' in Part 1 of this resource). This section describes increases in wildfire risk with climate change.

With climate change, the wildfire season is expected to become longer, and wildfires caused by lightning and humans are expected to increase (Table 14). Two forestry ecoregions exist in the Public Health Sudbury & Districts' service area. Ecoregion 98 covers Sudbury East, Manitoulin Island, Greater Sudbury, and Espanola areas, and ecoregion 97 covers the Chapleau area (Figure 2).

Figure 2: The Ontario fire management zone (shaded) and national ecoregion designations within the zone. Public Health Sudbury & Districts' service area is covered by ecoregions 97 and 98. The Chapleau office is located in ecoregion 97 and the offices in Sudbury East, Greater Sudbury, Manitoulin Island, and Espanola are located in ecozone 98.



The length of the wildfire season across Public Health Sudbury & Districts' service area is projected to become longer under climate change (Table 14). Under the RCP2.6 (low emission) scenario the wildfire season in ecoregion 98 is expected to lengthen by 10-20 days by 2041-2070[25]. Under the RCP8.5 (high emission) scenario, the wildfire season in ecoregion 98 is expected to lengthen by 30-40 days by 2041-2070[25].

Under a middle-ground emission scenario (RCP4.5), lightning caused wildfires in ecoregion 98 are expected to increase by 25-50% by 2030[26]. Human caused wildfires in ecoregion 98 are expected to increase by 10-25% by 2030[26].

Table 14: Changes in fire season length and number of wildfires under climate change

		Expected increase in fire season length by 2041-2070 (days)		Expected increase in lightning caused fires by year 2030	Expected increase in human caused fires by year 2030
Ecoregion	Public Health Sudbury & Districts' service area office location	RCP2.6	RCP8.5	RCP4.5	RCP4.5
98	Sudbury East, Manitoulin Island, Greater Sudbury, and Espanola	10 to 20 days	30 to 40 days	25-50%	10-25%
97	Chapleau	10 to 20 days	40 to 50 days	25-50%	25-50%

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Climate Change Modelling Study

Temperature and precipitation projections for Greater Sudbury

Public Health Sudbury & Districts
2022

Public Health
Santé publique
SUDBURY & DISTRICTS

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Climate change in Greater Sudbury

Climate change has impacts everywhere. Although many communities in Northern Ontario contain abundant carbon sinks in the form of forests and are making efforts to reduce greenhouse gas emissions, they are not immune to impacts. Information on carbon sinks, greenhouse gases, the greenhouse effect, and global warming is found in Appendix A.

Climate change modelling and emission scenarios are explained in Appendix B.

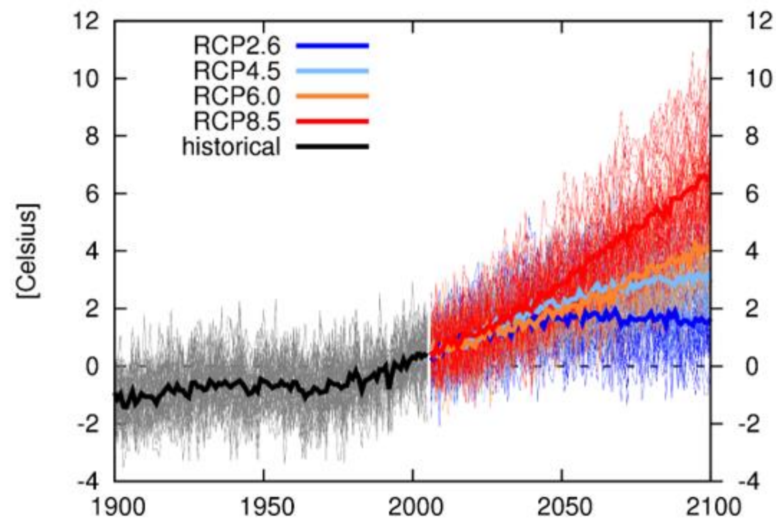
This section refers to climate change modelling and emission scenarios. Explanations of these concepts are found in Appendix B.

Briefly, climate change models are computer simulations that predict future states based on levels of greenhouse gas emissions and the resultant global warming effects. The emission scenarios range from low emission to high emission. A low emission scenario is a future where global greenhouse gas emissions are significantly curtailed, and global warming is slowed. A high emission scenario is a future where global greenhouse gas emissions continue to rise and global warming does, too. The low emission scenario is called RCP2.6. Moderate emission scenarios include RCP4.5 and RCP6, and a high emission scenario is called RCP8.5.

Evidence of a warming trend

In an effort to establish a national weather service, some of the first weather stations were positioned along the Canadian Pacific Railroad in the early 1880s[3]. Therefore, in many places it is possible to assess weather trends dating back 100 years or more. Relative to today, a warming trend has been observed; Figure 1is a time series graph depicting temperature change in degrees Celsius in relative to 1986-2005, beginning with recorded temperatures in 1900 (black line) and moving to projected temperatures after 2005 (coloured lines). The recorded warming trend is particularly steep heading into the 2000s and beyond (black line). After 2005, the coloured lines depict temperature changes expected under different climate change scenarios RCP2.6 (dark blue line), RCP4.5 (light blue line), RCP6.0 (orange line) and RCP8.5 (red line). Depending on the climate scenario, climate change models predict that temperatures will rise between 2 and 7 degrees Celsius relative to baseline (1986-2005) (Figure 1).

Figure1: Historical temperature change in degrees Celsius in Sudbury, Ontario, relative to 1986-2005, and projected temperature increase under climate change.



With increasingly warm temperatures, record-breaking hot weather has been experienced recently in Ontario, North America, and around the world[4–6].

Globally, the decade 2001-2010 was the warmest in recorded history, followed by the previous decade, 1991-2000, which held the earlier record[7]. These conditions are consistent with a long-term warming trend[7]. Northern latitudes tend to warm at a higher rate, with the Arctic warming at about twice the rate of lower latitudes[7].

Climate change projections for Greater Sudbury

While understanding the general impacts of climate change is informative, in order to properly prepare, it is important that communities understand the specific impacts that are expected locally. under moderate and high emission climate change scenarios. This section describes current and projected temperature (hot and cold), precipitation (rain and freezing rain), and wildfire.

Temperature

Increases in seasonal temperatures drive many of the climate impacts that put health at risk. Warmer summer temperatures contribute to heatwaves, wildfire, drought, ultraviolet radiation exposure, worsening air quality, and risks to food safety. Warmer seasonal temperatures also drive the northward expansion of ticks and mosquitoes capable of transmitting diseases such as Lyme disease and West Nile virus. Warmer winter temperatures are implicated in increasing risk of freezing rain, particularly in the colder winter months, and flooding due to rainfall over snow.

The danger of these increasing hazards and populations most at risk are explored in detail in Part 1 of this resource.

The following sections present the projected seasonal temperatures under the RCP4.5 (moderate emission) and RCP8.5 (high emission) scenarios. The projections were generated by Climate Atlas of Canada for the municipality of Greater Sudbury.

The projections are presented as 30-year blocks, which is a common practice in the field of meteorology. The average of weather values over a 30-year period helps in describing the climate in a particular location and is a useful base for comparison to other locations or time periods[8].

Seasonal temperatures under moderate emissions

Under a moderate emission scenario, RCP4.5, the annual and seasonal average temperatures in Greater Sudbury are expected to increase (Table 1).

The average annual temperature at baseline is 4.3°C (1975-2005). The average annual temperature is expected to increase from 6.3°C in 2021-2050 to 7.3°C in 2051-2080 (70% increase from baseline). The average winter temperature at baseline is -10.8 °C (1975-2005). The average winter temperature is expected to increase from -7.3°C in 2021-2050 to -7.1°C in 2051-2080 (39% increase from baseline). The average summer temperature at baseline is 17.8°C (1975-2005). With climate change, average summer temperatures will be similar to present day Toronto, Ontario (20.3°C). The average summer temperature is expected to increase from 19.6°C in 2021-2050 to 20.7°C in 2051-2080[9] (16% increase from baseline).

Table 1: Projected mean seasonal temperatures for Greater Sudbury, under RCP4.5 scenario

Projected mean seasonal temperatures (°C) under RCP4.5, in the municipality of Greater Sudbury, Ontario			
	1976-2005	2021-2050	2051-2080
Annual	4.3	6.3	7.3
Spring	3.3	5.2	6.1
Summer	17.8	19.6	20.7
Fall	6.5	8.4	9.3
Winter	-10.8	-7.3	-7.1

Seasonal temperatures under high emissions

Under a high emission scenario, RCP8.5, the annual and seasonal average temperatures in Greater Sudbury are expected to increase (Table 2). The average annual temperature at baseline is 4.3°C (1975-2005). The average annual temperature is expected to increase from 6.5°C in 2021-2050 to 8.8°C in 2051-2080 (105% increase from baseline). The average winter temperature at baseline is -10.8 °C (1975-2005). The average winter temperature is expected to increase from -8.2°C in 2021-2050 to -5.4°C in 2051-2080 (50% increase from baseline). The average summer temperature at baseline is 17.8°C (1975-2005). The average summer temperature is expected to increase from 20.0°C in 2021-2050 to 22.2°C in 2051-2080[9] (25% increase from baseline).

Table 2: Projected mean seasonal temperatures for Greater Sudbury, under RCP8.5 scenario

Projected mean seasonal temperatures (°C) under RCP8.5, in the municipality of Greater Sudbury, Ontario			
	1976-2005	2021-2050	2051-2080
Annual	4.3	6.5	8.8
Spring	3.3	5.3	7.5
Summer	17.8	20.0	22.2
Fall	6.5	8.7	10.7
Winter	-10.8	-8.2	-5.4

Extreme hot temperatures

This section describes the current situation and projected frequency of very hot weather (30+°C) under climate change. Extreme heat is of great concern locally and around the country—communities have been under heat warning, hot temperatures records have been broken, and heat waves have been implicated in illnesses and deaths[10–15]. Very hot weather is expected to double or triple with climate change, placing many people at increased risk of heat illness. The health implications of hot weather and populations most at risk are explored in detail in 'Health hazards in hot weather' in Part 1 of this resource.

Very hot days (+30 °C) at present and with climate change

Climate change is expected to increase the number of hot days experienced in the summer months. In the municipality of Greater Sudbury, there was an average of 6 very hot days (30+°C) per year in 1976-2005. With climate change under RCP4.5, that number is expected to reach an average of 15 very hot days per year in 2021-2050 and 23 in 2051-2080. Under RCP8.5, there is projected to be 17 very hot days per year in 2021-2050 and 39 in 2051-2080[9] (Table 3).

Table 3: Current and projected average number of very hot days (+30 °C) per year in the municipality of Greater Sudbury[9]

	Average number of +30 °C days per year				
Region	Baseline	RCP4.5 Moderate emission scenario		RCP8.5 High emission scenario	
Time span	1976-2005	2021-2050	2051-2080	2021-2050	2051-2080
Municipality of Greater Sudbury	6	16	24	18	39

Heat warnings and temperature triggers

Currently, hot weather is monitored by Environment and Climate Change Canada. Heat warnings are issued when temperatures reach specific temperature triggers. Heat warning temperature triggers were developed by Health Canada and Public Health Ontario for 3 distinct regions in Ontario based on mortality and population data, humidex, local climate, and air pollution characteristics[16].

In Northern Ontario, a Heat Warning is issued by Environment and Climate Change Canada when the temperature is forecast ≥29°C or humidex ≥36°C for at least 2 consecutive days, with overnight lows falling to ≥18°C[16] (Table 4). An extended heat warning is issued when the heat forecast is maintained for at least 3 consecutive days[16].

Table 4: Criteria for the issuing of a heat warning in Northern Ontario

Region	Heat warning temperature trigger	Duration requirement
Northern Ontario	Tmax ≥ 29°C and Tmin ≥ 18°C OR Humidex ≥ 36	2+ days

Public Health Sudbury & Districts publicly communicates heat warnings and extended heat warnings issued by Environment and Climate Change Canada. Greater Sudbury was under heat warning for 6 days in 2022, 21 days in 2021, and 22 days in 2020 (Table 5).

Table 5: Total days under heat warning in Greater Sudbury (2019-2022)

Year	Total number of days under heat warning
2022	6
2021	21
2020	22
2019	8

To receive an email when a heat warning is issued, sign up through the EC Alert Me program at https://ecalertme.weather.gc.ca/createaccount_en.php.

Extreme cold temperatures and frost season

This section describes the current situation and projected frequency of cold weather (-30°C) under climate change. While very cold weather will decrease, winter hazards in the north do not disappear. The region will continue to experience months of cold weather and people without adequate protection will be at risk of cold weather injuries such as frostbite and hypothermia. Especially in the colder winter months, incidence of freezing rain is expected to increase with climate change[17], and incidence of extreme precipitation (including heavy snow) is expected to occur more frequently than before[18]. The serious health implications of cold weather and freezing rain are explored in detail in 'Health hazards in cold weather' and 'Ice storms' in Part 1 of this resource.

This section also describes the current situation and expected changes to the frost-free season. A longer frost-free season could have positive implications for the agriculture sector and home gardeners.

Very cold temperatures and frost-free season

In general, the frequency and severity of extreme cold weather is expected to decrease under climate change. In the municipality of Greater Sudbury, there was an average of 5 very cold days (-30°C) per year in 1976-2005. With climate change under RCP4.5, that number is expected to decrease to 2 very cold days per year in 2021-2050 and 1 in 2051-2080. Under RCP8.5, there is projected to be 1 very cold day per year in 2021-2050 and 0 in 2051-2080[9] (Table 6).

Table 6: Current and projected average number of very cold days (-30°C) per year in the municipality of Greater Sudbury[9]

	Average number of -30°C days per year				
	Baseline	RCP4.5 moderate emission scenario		RCP8.5 high emission scenario	
Time span	1976-2005	2021-2050	2051-2080	2021-2050	2051-2080
Average number of -30°C days per year	5	2	1	1	0

Currently, the first fall frost occurs on average on September 30. Under RCP4.5, by 2021-2050, the first fall frost is expected to occur about 11 days later, by October 11 on average. Under RCP8.5, by 2021-2050, the first fall frost is expected to occur by October 14 (Table 7).

Table7: Current and projected average date of first fall frost and frost-free days per year in the municipality of Greater Sudbury[9]

	Date of first fall frost and length of frost-free season in days				
	Baseline	RCP4.5 moderate emission scenario		RCP8.5 high emission scenario	
Time span	1976-2005	2021-2050	2051-2080	2021-2050	2051-2080
Average date of first fall frost	September 30	October 11	October 17	October 14	October 26
Length of frost-free season (days)	137	157	168	163	184

Precipitation

This section describes precipitation at present and with climate change.

With climate change, seasonal precipitation is expected to increase a small amount from baseline. The largest increases in seasonal precipitation will be seen in the fall. This change could impact the agriculture sector by affecting fall harvest. Rain can degrade the quality of important crops like wheat, and heavy farming equipment required for harvest can become stuck and inoperable in waterlogged fields[19].

As the climate warms, the type of precipitation we can expect will change. In the winter months when we typically experience snow, the occurrence of freezing rain will increase. Projections show that incidence of freezing rain will double or triple in some parts of Ontario[17]. With intense precipitation increasing, it is possible that a severe ice storm like the one in Eastern Ontario and Quebec or in the Toronto area will occur here (see "Ice storms" in Part 1 of this resource).

Increased incidence of extreme precipitation during spring, summer and fall is also expected. An extreme rain event that would be expected to occur once every 50 years is expected to occur more often under climate change[20]. Extreme rainfall can lead to impacts such as floods and degradation of water quality. Significant health impacts caused by flood and water quality are explored in detail in Part 1 of this resource.

At the current time, average annual precipitation recorded at the 'Sudbury A' weather station amounts to 903.3 mm total, with 675.7 mm falling as rain and 263.4 cm falling as snow[21] (Table 8).

Table 8: Average annual precipitation in Massey, Ontario

Average annual precipitation in Sudbury, Ontario, 1981 to 2010	
Precipitation type	Measurement
Rainfall	675.7 mm
Snowfall	263.4 cm (263.4 mm water equivalent)
Precipitation total	903.3 mm

Seasonal precipitation under moderate emissions

With climate change, studies of general trends point to wetter weather on a national and provincial scale[7,22]. Projected changes in precipitation under a moderate emission scenario, RCP4.5, are outlined in Table 9. Compared to baseline (1976-2005), annual mean precipitation is expected to increase by 42 mm in 2021-2050, and 76 mm by 2051-2080. The wettest season is the fall. Mean precipitation in the fall is expected to increase by 11 mm in 2021-2050, and 23 mm by 2051-2080[9].

Table 9: Projected mean seasonal precipitation for Greater Sudbury, under RCP4.5 scenario

Projected mean seasonal precipitation (mm) under RCP4.5, in the municipality of Greater Sudbury, Ontario			
Time span	1976-2005	2021-2050	2051-2080
Annual	848	890	924
Spring	191	203	215
Summer	217	223	225
Fall	257	268	280
Winter	183	197	205

Seasonal precipitation under high emissions

Projected changes to precipitation do not vary greatly between moderate and high emission scenarios. Precipitation changes under a high emission scenario, RCP8.5, are outlined in Table 10. Compared to baseline (1976-2005), annual mean precipitation is expected to increase by 56 mm in 2021-2050, and 90 mm by 2051-2080. Mean precipitation in the fall is expected to increase by 17 mm in 2021-2050, and 22 mm by 2051-2080[9].

Table 10: Projected mean seasonal precipitation for Greater Sudbury, under RCP8.5 scenario

Projected mean seasonal precipitation (mm) under RCP8.5, in the municipality of Greater Sudbury, Ontario			
Time span	1976-2005	2021-2050	2051-2080
Annual	848	904	938
Spring	191	209	226
Summer	217	219	216
Fall	257	274	279
Winter	183	201	218

Current and projected freezing rain

Freezing rain can cause considerable adverse impacts to communities, including power outages, hazardous roads and disruption of services[23], and with climate change, is expected to increase in frequency[24]. In communities with formal emergency preparedness plans and where emergency preparedness exercises are performed, organisers would very likely find value in choosing a severe ice storm as a focus scenario.

An Ontario study investigated freezing rain occurrence in select cities. Over a typical winter, November to April, freezing rain was found to occur more frequently in communities located geographically in the centre of the province than those farther north or south. For example, over a winter season in Sudbury, historically, there have been about 7.7 days of freezing rain, compared to 3.1 in Kapuskasing and 5.2 in Toronto[24] (Table 11).

Table 11: Historical incidence of freezing rain in select Ontario cities, 1953-2001

Historical incidence of freezing rain in select Ontario cities, 1953-2001[24]		
Weather station	Winter seasonal (Nov-Apr) average # of days with freezing rain	Winter Seasonal (Nov-Apr) average # of hours with freezing rain
Kapuskasing	3.1	8.2
Kenora	2.6	6.2
Sioux Lookout	2.3	4.8
Thunder Bay	2.1	6.2
Timmins	4.2	11.5
Sault St. Marie	3.7	10.3
Sudbury	7.7	24.4
North Bay	7.5	22.4
Ottawa	9.7	36.6
Montreal	7.8	27.4
Toronto	5.2	17.1
Windsor	4.9	14.3

Another study investigated historical incidence of freezing rain and projected increases with climate change[17]. This study differentiated between colder winter months (December, January, and February) and warmer ones (November, March, and April), and looked at a few cities and two regions in the province of Ontario (‘eastern’ and ‘northern’). The results showed that freezing rain was expected to increase more dramatically during the colder winter months than the warmer ones[17]. With climate change bringing about warmer winter temperatures during the colder months, it becomes more likely for precipitation to fall as rain (rather than snow) than before. The study found that in Sudbury, during the baseline period 1961-2000, there was an average of about 4 total freezing-rain days in colder winter months (Table12)[17]. Under climate change, the number of days with freezing rain increased by 1.5 days in the 2050s, and 3 days in the 2080s (Table 12)[17].

Table 12: Historical and projected number of days with freezing rain during colder winter months in Sudbury and Timmins, Ontario

Number of days with freezing rain during colder winter months – historical and projected with climate change			
City	Historical average # days with freezing rain (Dec-Feb), 1961- 2000	2050s projected # days with freezing rain (Dec-Feb) in 2050s	2080s projected # days with freezing rain (Dec-Feb) in 2080s
Sudbury	4	5.5	7
Timmins	1.5	2.5	3.5

Furthermore, from a regional perspective, freezing rain during colder months is expected to increase more in the northern region of Ontario than the eastern region. Freezing rain in cities in the northern region will increase 85% by the 2050s and 135% by the 2080s (Table 13)[17]. In comparison, freezing rain in the eastern region will increase 60% by the 2050s and 95% by the 2080s[17].

Freezing rain events in the warmer winter months are expected to increase by a small amount in the northern region of Ontario and not at all in the eastern region[17].

Table 13: Projected increases in freezing rain during colder months (Dec, Jan, Feb) vs. warmer months (Nov, Mar, Apr) in different regions of Ontario

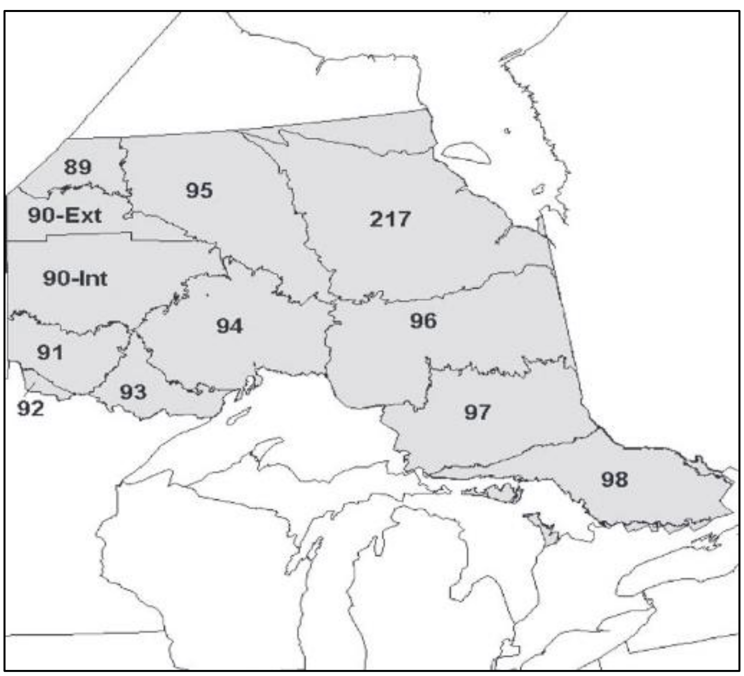
Projected increases in freezing rain in winter season during colder months (Dec, Jan, Feb) vs. warmer months (Nov, Mar, Apr)		
	Colder winter months 2050s	Colder winter months 2080s
Eastern Ontario (Montreal, Quebec, North Bay, Ottawa, Sudbury and Trenton)	+60%	+95%
Northern Ontario (Kapuskasing, Kenora, Sioux Lookout, Thunder Bay and Timmins)	+85%	+135%
	Warmer winter months 2050s	Warmer winter months 2080s
Eastern Ontario (Montreal, Quebec, North Bay, Ottawa, Sudbury and Trenton)	Not significant	Not significant
Northern Ontario (Kapuskasing, Kenora, Sioux Lookout, Thunder Bay and Timmins)	+10%	+20%

Wildfire

Wildfire activity is controlled by a number of factors including fuel, ignition, and weather. Climate change is expected to worsen all three factors, raising wildfire risk levels[25]. Periods of warm, dry weather reduce moisture content in wildfire fuel (e.g. biomass such as brush, leaves, and trees)[25], making it more receptive to catch fire[25]. Cloud-to-ground lightning is expected to increase with climate change, and fires caused by lightning and by human error are more likely to catch and continue to burn in dry conditions[25]. Wildfires have the potential to threaten communities and gravely impact health and safety (see 'Health impacts from wildfire' in Part 1 of this resource). This section describes increases in wildfire risk with climate change.

With climate change, the wildfire season is expected to become longer, and wildfires caused by lightning and humans are expected to increase (Table 14). Two forestry ecoregions exist in the Public Health Sudbury & Districts' service area. Ecoregion 98 covers Sudbury East, Manitoulin Island, Greater Sudbury, and Espanola areas, and ecoregion 97 covers the Chapleau area (Figure 2).

Figure 2: The Ontario fire management zone (shaded) and national ecoregion designations within the zone. Public Health Sudbury & Districts service area is covered by ecoregions 97 and 98. The Chapleau office is located in ecoregion 97 and the offices in Sudbury East, Greater Sudbury, Manitoulin Island and Espanola are located in ecozone 98.



The length of the wildfire season across Public Health Sudbury & Districts service area is projected to become longer under climate change (Table 14). Under the RCP2.6 (low emission) scenario the wildfire season in ecoregion 98 is expected to lengthen by 10-20 days by 2041-2070[26]. Under the RCP8.5 (high emission) scenario, the wildfire season in ecoregion 98 is expected to lengthen by 30-40 days by 2041-2070[26].

Under a middle-ground emission scenario (RCP4.5), lightning caused wildfires in ecoregion 98 are expected to increase by 25-50% by 2030[27]. Human-caused wildfires in ecoregion 98 are expected to increase by 10-25% by 2030[27].

Table 14: Changes in fire season length and number of wildfires under climate change

		Expected increase in fire season length by 2041-2070 (days)		Expected increase in lightning caused fires by year 2030	Expected increase in human caused fires by year 2030
Ecoregion	Public Health Sudbury & Districts service area office location	RCP2.6	RCP8.5	RCP4.5	RCP4.5
98	Sudbury East, Manitoulin Island, Greater Sudbury, and Espanola	10 to 20 days	30 to 40 days	25-50%	10-25%
97	Chapleau	10 to 20 days	40 to 50 days	25-50%	25-50%

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Climate Change Modelling Study

Temperature and precipitation projections for Manitoulin Island and area

Public Health Sudbury & Districts
2022

Public Health
Santé publique
SUDBURY & DISTRICTS

Author

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Climate change in the Manitoulin Island area

Climate change has impacts everywhere. Although many communities in Northern Ontario contain abundant carbon sinks in the form of forests and are making efforts to reduce greenhouse gas emissions, they are not immune to impacts. Information on carbon sinks, greenhouse gases, the greenhouse effect, and global warming is found in Appendix A.

Climate change modelling ***and*** *emission scenarios* ***are explained in*** **Appendix B.**

This section refers to climate change modelling and emission scenarios. Explanations of these concepts are found in Appendix B.

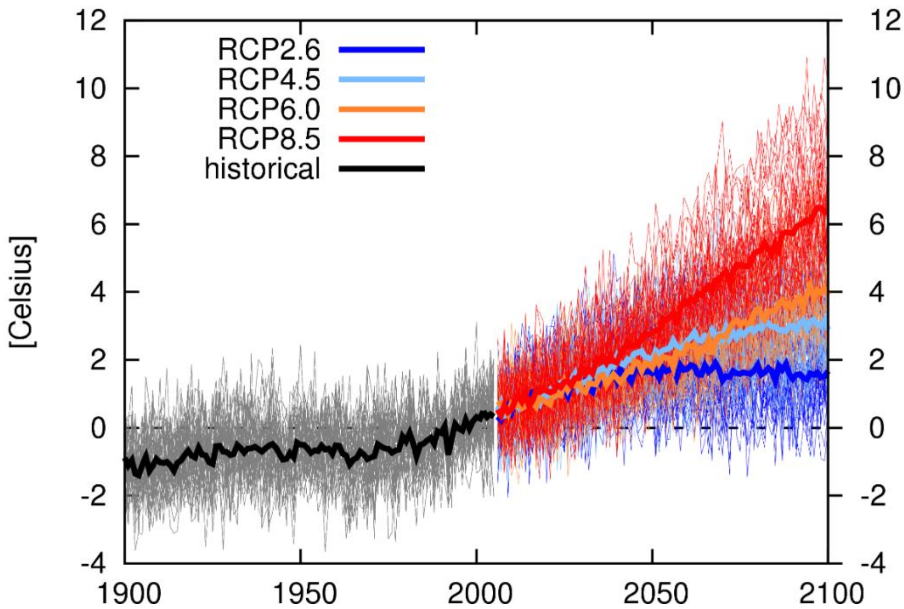
Briefly, climate change models are computer simulations that predict future states based on levels of greenhouse gas emissions and the resultant global warming effects. The emission scenarios range from low emission to high emission. A low emission scenario is a future where global greenhouse gas emissions are significantly curtailed, and global warming is slowed. A high emission scenario is a future where global greenhouse gas emissions continue to rise and global warming does, too. The low emission scenario is called RCP2.6. Moderate emission scenarios include RCP 4.5 and RCP6, and a high emission scenario is called RCP8.5.

Evidence of a warming trend

In an effort to establish a national weather service, some of the first weather stations were positioned along the Canadian Pacific Railroad in the early 1880's[3]. Therefore, in many places it is possible to assess weather trends dating back 100 years or more. Relative to today, a warming trend has been observed; Figure 1is a time series graph depicting temperature change in degrees Celsius in Gore Bay relative to 1986-2005, beginning with recorded temperatures in 1900 (black line) and moving to projected temperatures after 2005 (coloured lines). The recorded warming trend is particularly steep heading into the 2000's and beyond (black line). After 2005, the coloured lines depict temperature changes expected under different climate change scenarios, RCP2.6 (dark blue line), RCP4.5 (light blue line), RCP6.0 (orange line) and RCP8.5 (red line).

Depending on the climate scenario, climate change models predict that temperatures will rise between 2 and 7 degrees Celsius relative to baseline (1986-2005) (Figure 1).

Figure1: Historical temperature change in degrees Celsius in Gore Bay, Ontario, relative to 1986-2005, and projected temperature increase under climate change



With increasingly warm temperatures, record-breaking hot weather has been experienced recently in Ontario, North America, and around the world[4–6].

Globally, the decade 2001-2010 was the warmest in recorded history, followed by the previous decade, 1991-2000, which held the earlier record[7]. These conditions are consistent with a long-term warming trend[7]. Northern latitudes tend to warm at a higher rate, with the Arctic warming at about twice the rate of lower latitudes[7].

Climate change projections for the Manitoulin Island area

While understanding the general impacts of climate change is informative, in order to properly prepare, it is important that communities understand the specific impacts that are expected locally, under moderate and high emission climate change scenarios. This section describes current and projected temperature (hot and cold), precipitation (rain and freezing rain), and wildfire.

Current and projected temperatures

Increases in seasonal temperatures drive many of the climate impacts that put health at risk. Warmer summer temperatures contribute to heatwaves, wildfire, drought, ultraviolet radiation exposure, worsening air quality, and risks to food safety. Warmer seasonal temperatures also drive the northward expansion of ticks and mosquitoes capable of transmitting diseases such as Lyme disease and West Nile virus. Warmer winter temperatures are implicated in increasing risk of freezing rain, particularly in the colder winter months, and flooding due to rainfall over snow.

The danger of these increasing hazards and populations most at risk are explored in detail in Part 1 of this resource.

The following sections present the projected seasonal temperatures under the RCP4.5 (moderate emission) and RCP8.5 (high emission) scenarios. The projections were generated by Climate Atlas of Canada for Kagawong, Ontario, as a representation for the Manitoulin area.

Climate change projections for Kagawong, Ontario, were chosen to represent the Manitoulin area.

The projections are presented as 30-year blocks, which is a common practice in the field of meteorology. The average of weather values over a 30 year period helps in describing the climate in a particular location and is a useful base for comparison to other locations or time periods[8].

Seasonal temperatures under moderate emissions

Under a moderate emission scenario, RCP4.5, the annual and seasonal average temperatures in Kagawong, Ontario, are expected to increase (Table 1). The average annual temperature at baseline is 5.3°C (1975-2005). The average annual temperature is expected to increase from 7.3°C in 2021-2050 to 8.4°C in 2051-2080 (59% increase from baseline). The average winter temperature at baseline is -7.8 °C (1975-2005). The average winter temperature is expected to increase from -5.5°C in 2021-2050 to -4.1°C in 2051-2080 (47% increase from baseline). The average summer temperature at baseline is 17.5°C (1975-2005). With climate change, average summer temperatures will be similar to present day Toronto, Ontario (20.3°C). The average summer temperature is expected to increase from 19.3°C in 2021-2050 to 20.4°C in 2051-2080[9] (17% increase from baseline).

Table 1: Projected mean seasonal temperatures for Kagawong, Ontario, under RCP4.5 scenario

Projected Mean Seasonal Temperatures (°C) under RCP4.5, in the region of Kagawong, Ontario			
	1976-2005	2021-2050	2051-2080
Annual	5.3	7.3	8.4
Spring	3.5	5.4	6.4
Summer	17.5	19.3	20.4
Fall	7.9	9.9	10.7
Winter	-7.8	-5.5	-4.1

Seasonal temperatures under high emissions

Under a high emission scenario, RCP8.5, the annual and seasonal average temperatures in Kagawong are expected to increase (Table 2). The average annual temperature at baseline is 5.3°C (1975-2005). The average annual temperature is expected to increase from 7.6°C in 2021-2050 to 9.9°C in 2051-2080 (87% increase from baseline). The average winter temperature at baseline is -7.8 °C (1975-2005). The average winter temperature is expected to increase from -5.3°C in 2021-2050 to -2.4°C in 2051-2080 (69% increase from baseline). The average summer temperature at baseline is 17.5°C (1975-2005). The average summer temperature is expected to increase from 19.6°C in 2021-2050 to 21.9°C in 2051-2080[9] (25% increase from baseline).

Table 2: Projected mean seasonal temperatures for Kagawong, Ontario, under RCP8.5 scenario

Projected Mean Seasonal Temperatures (°C) under RCP8.5, in the region of Kagawong, Ontario			
	1976-2005	2021-2050	2051-2080
Annual	5.3	7.6	9.9
Spring	3.5	5.5	7.7
Summer	17.5	19.6	21.9
Fall	7.9	10.1	12.1
Winter	-7.8	-5.3	-2.4

Extreme hot temperatures

This section describes the current situation and projected frequency of very hot weather (30+°C) under climate change. Extreme heat is of great concern locally and around the country—communities have been under heat warning, hot temperatures records have been broken, and heat waves have been implicated in illnesses and deaths[10–15]. Very hot weather is expected to double or triple with climate change, placing many people at increased risk of heat illness. The health implications of hot weather and populations most at risk are explored in detail in 'Health hazards in hot weather' in Part 1 of this resource.

Very hot days (+30°C) at present and with climate change

Climate change is expected to increase the number of hot days experienced in the summer months. In Kagawong, Ontario, there was an average of 2 very hot days (30+°C) per year in 1976-2005. With climate change under RCP4.5, that number is expected to reach an average of 7 very hot days per year in 2021-2050 and 13 in 2051-2080. Under RCP8.5, there is projected to be 8 very hot days per year in 2021-2050 and 25 in 2051-2080[9] (Table 3).

Table 3: Current and projected average number of very hot days (+30°C) per year in Kagawong, Ontario[9]

	Average number of +30°C days per year				
Region	Baseline	RCP4.5 moderate emission scenario		RCP8.5 high emission scenario	
Time span	1976-2005	2021-2050	2051-2080	2021-2050	2051-2080
Kagawong, Ontario	2	7	13	8	25

Heat warnings and temperature triggers

Hot weather is monitored by Environment and Climate Change Canada. Heat warnings are issued when temperatures reach specific temperature triggers. Heat warning temperature triggers were developed by Health Canada and Public Health Ontario for 3 distinct regions in Ontario based on mortality and population data, humidex, local climate, and air pollution characteristics[16].

In Northern Ontario, a Heat Warning is issued by Environment and Climate Change Canada when the temperature is forecast ≥29°C or humidex ≥36°C for at least 2 consecutive days, with overnight lows falling to ≥18°C[16] (Table 4). An extended heat warning is issued when the heat forecast is maintained for at least 3 consecutive days[16].

Table 4: Criteria for the issuing of a heat warning in Northern Ontario

Region	Heat warning temperature trigger	Duration requirement
Northern Ontario	Tmax ≥ 29°C and Tmin ≥ 18°C OR Humidex ≥ 36	2+ days

Public Health Sudbury & Districts publicly communicates heat warnings and extended heat warnings issued by Environment and Climate Change Canada. The Manitoulin Island area was under heat warning for 0 days in 2022, 4 days in 2021 and 8 days in 2020(Table 5).

Table 5: Total days under heat warning in the Manitoulin Island area (2019-2022)

Year	Total number of days under heat warning
2022	0
2021	4
2020	8
2019	0

To receive an email when a heat warning is issued, sign up through the EC Alert Me program at https://ecalertme.weather.gc.ca/createaccount_en.php.

Extreme cold temperatures and frost season

This section describes the current situation and projected frequency of cold weather (-30°C) under climate change. While very cold weather will decrease, winter hazards in the north do not disappear. The region will continue to experience months of cold weather and people without adequate protection will be at risk of cold weather injuries such as frostbite and hypothermia. Especially in the colder winter months, incidence of freezing rain is expected to increase with climate change[17], and incidence of extreme precipitation (including heavy snow) is expected to occur more frequently than before[18]. The serious health implications of cold weather and freezing rain are explored in detail in ‘Health hazards in cold weather’ and ‘Ice storms’ in Part 1 of this resource.

This section also describes the current situation and expected changes to the frost-free season. A longer frost-free season could have positive implications for the agriculture sector and home gardeners.

Very cold temperatures and frost-free season

In general, the frequency and severity of cold weather is expected to decrease under climate change. In Kagawong, Ontario, there was an average of 1 very cold day (-30°C) per year in 1976-2005. With climate change under both RCP4.5 and RCP8.5, that number is expected to decrease to 0 very cold day per year in 2021-2050 and in 2051-2080 (Table 6).

Table 6: Current and projected average number of very cold days (-30°C) per year in Kagawong, Ontario[9]

	Average number of -30°C days per year				
	Baseline	RCP4.5 moderate emission scenario		RCP8.5 high emission scenario	
Time span	1976-2005	2021-2050	2051-2080	2021-2050	2051-2080
Average number of -30°C days per year	1	0	0	0	0

Currently, the first fall frost occurs on average on October 13. Under RCP4.5, by 2021-2050, the first fall frost is expected to occur about 12 days later, by October 25 on average. Under RCP8.5, by 2021-2050, the first fall frost is expected to occur by October 27[9] (Table 7).

Table 7: Current and projected average date of first fall frost and frost-free days per year in Kagawong, Ontario[9]

	Date of first fall frost and length of frost-free season in days				
	Baseline	RCP4.5 moderate emission scenario		RCP8.5 high emission scenario	
Time span	1976-2005	2021-2050	2051-2080	2021-2050	2051-2080
Average date of first fall frost	October 13	October 25	October 30	October 27	November 9
Length of frost-free season (days)	156	177	188	182	205

Precipitation

This section describes precipitation at present and with climate change.

With climate change, seasonal precipitation is expected to increase a small amount from baseline. The largest increases in seasonal precipitation will be seen in the fall. This change could impact the agriculture sector by affecting fall harvest. Rain can degrade the quality of important crops like wheat, and heavy farming equipment required for harvest can become stuck and inoperable in waterlogged fields[19].

As the climate warms, the type of precipitation we can expect will change. In the winter months when we typically experience snow, the occurrence of freezing rain will increase. Projections show that incidence of freezing rain will double or triple in some parts of Ontario[17]. With intense precipitation increasing, it is possible that a severe ice storm like the one in Eastern Ontario and Quebec or in the Toronto area will occur here (see "Ice storms" in Part 1 of this resource).

Increased incidence of extreme precipitation during spring, summer and fall is also expected. An extreme rain event that would be expected to occur once every 50 years is expected to occur more often under climate change[20]. Extreme rainfall can lead to impacts such as floods and degradation of water quality. Significant health impacts caused by flood and water quality are explored in detail in Part 1 of this resource.

At the current time, average annual precipitation recorded at the Gore Bay weather station amounts to 808.9 mm total, with 625.0 mm falling as rain and 267.3 cm falling as snow[21] (Table 8).

Table 8: Average annual precipitation in Gore Bay, Ontario

Average annual precipitation in Gore Bay, Ontario, 1971 to 2000	
Precipitation type	Measurement
Rainfall	625.0 mm
Snowfall	267.3 cm (267.3 mm water equivalent)
Precipitation total	808.9 mm

Seasonal precipitation under moderate emissions

With climate change, studies of general trends point to wetter weather on a national and provincial scale[7,22]. Projected changes in precipitation under a moderate emission scenario, RCP4.5, are outlined in Table 9. Compared to baseline (1976-2005), annual mean precipitation is expected to increase by 38 mm in 2021-2050, and 73 mm by 2051-2080. The wettest season is the fall. Mean precipitation in the fall is expected to increase by 10 mm in 2021-2050, and 23 mm by 2051-2080[9].

Table 9: Projected mean seasonal precipitation for Kagawong, Ontario, under RCP4.5 scenario

Projected mean seasonal precipitation (mm) under RCP4.5, in the region of Kagawong, Ontario			
Time span	1976-2005	2021-2050	2051-2080
Annual	837	875	910
Spring	189	199	210
Summer	196	199	203
Fall	263	273	286
Winter	189	204	211

Seasonal precipitation under high emissions

Projected changes to precipitation do not vary greatly between moderate and high emission scenarios. Precipitation changes under a high emission scenario, RCP8.5, are outlined in Table 10. Compared to baseline (1976-2005), annual mean precipitation is expected to increase by 56 mm in 2021-2050, and 87 mm by 2051-2080. Mean precipitation in the fall is expected to increase by 16 mm in 2021-2050, and 21 mm by 2051-2080[9].

Table 10: Projected mean seasonal precipitation for Kagawong, Ontario, under RCP8.5 scenario

Projected mean seasonal precipitation (mm) under RCP8.5, in the region of Kagawong, Ontario			
Time span	1976-2005	2021-2050	2051-2080
Annual	837	893	924
Spring	189	208	223
Summer	196	198	193
Fall	263	279	284
Winter	189	207	224

Current and projected freezing rain

Freezing rain can cause considerable adverse impacts to communities, including power outages, hazardous roads and disruption of services[23], and with climate change, is expected to increase in frequency[24]. In communities with formal emergency preparedness plans and where emergency preparedness exercises are performed, organisers would very likely find value in choosing a severe ice storm as a focus scenario.

An Ontario study investigated freezing rain occurrence in select cities. Over a typical winter, November to April, freezing rain was found to occur more frequently in communities located geographically in the centre of the province than those farther north or south. Although Manitoulin Island was not included in the study, for comparison, there has historically been about 7.7 days of freezing rain in Sudbury compared to 3.1 in Kapuskasing and 5.2 in Toronto[24] (Table 11).

Table 11: Historical incidence of freezing rain in select Ontario cities, 1953-2001

Historical incidence of freezing rain in select Ontario cities, 1953-2001[24]		
Weather station	Winter seasonal (Nov-Apr) average # of days with freezing rain	Winter seasonal (Nov-Apr) average # of hours with freezing rain
Kapuskasing	3.1	8.2
Kenora	2.6	6.2
Sioux Lookout	2.3	4.8
Thunder Bay	2.1	6.2
Timmins	4.2	11.5
Sault St. Marie	3.7	10.3
Sudbury	7.7	24.4
North Bay	7.5	22.4
Ottawa	9.7	36.6
Montreal	7.8	27.4
Toronto	5.2	17.1
Windsor	4.9	14.3

Another study investigated historical incidence of freezing rain and projected increases with climate change[17]. This study differentiated between colder winter months (December, January, and February) and warmer ones (November, March, and April), and looked at a few cities and two regions in the province of Ontario ('eastern' and 'northern'). The results showed that freezing rain was expected to increase more dramatically during the colder winter months than the warmer ones[17]. With climate change bringing about warmer winter temperatures during the colder months, it becomes more likely for precipitation to fall as rain (rather than snow) than before. Although the Manitoulin Island area was not specifically included in the study, for comparison, the study found that in Sudbury, during the baseline period 1961-2000, there was an average of about 4 total freezing-rain days in colder winter months (Table 12)[17]. Under climate change, the number of days with freezing rain increased by 1.5 days in the 2050s, and 3 days in the 2080s (Table 12)[17].

Table 12: Historical and projected number of days with freezing rain during colder winter months in Sudbury and Timmins, Ontario

Number of days with freezing rain during colder winter months – historical and projected with climate change			
City	Historical average # days with freezing rain (Dec-Feb), 1961- 2000	2050s projected # days with freezing rain (Dec-Feb) in 2050s	2080s projected # days with freezing rain (Dec-Feb) in 2080s
Sudbury	4	5.5	7
Timmins	1.5	2.5	3.5

Furthermore, from a regional perspective, freezing rain during colder months is expected to increase more in the northern region of Ontario than the eastern region. Freezing rain in cities in the northern region will increase 85% by the 2050s and 135% by the 2080's (Table 13)[17]. In comparison, freezing rain in the eastern region will increase 60% by the 2050s and 95% by the 2080s[17].

Freezing rain events in the warmer winter months are expected to increase a small amount in the northern region of Ontario and not at all in the eastern region[17].

Table 13: Projected increases in freezing rain during colder months (Dec, Jan, Feb) vs. warmer months (Nov, Mar, Apr) in different regions of Ontario

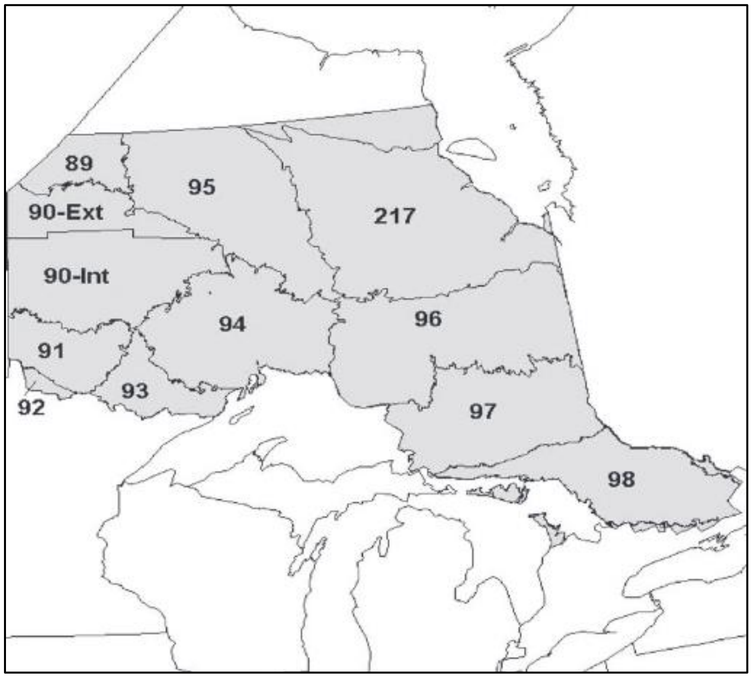
Projected increases in freezing rain in winter season during colder months (Dec, Jan, Feb) vs. warmer months (Nov, Mar, Apr)		
	Colder winter months 2050s	Colder winter months 2080s
Eastern Ontario (Montreal, Quebec, North Bay, Ottawa, Sudbury and Trenton)	+60%	+95%
Northern Ontario (Kapuskasing, Kenora, Sioux Lookout, Thunder Bay and Timmins)	+85%	+135%
	Warmer winter months 2050s	Warmer winter months 2080s
Eastern Ontario (Montreal, Quebec, North Bay, Ottawa, Sudbury and Trenton)	Not significant	Not significant
Northern Ontario (Kapuskasing, Kenora, Sioux Lookout, Thunder Bay and Timmins)	+10%	+20%

Wildfire

Wildfire activity is controlled by a number of factors including fuel, ignition, and weather. Climate change is expected to worsen all three factors, raising wildfire risk levels[25]. Periods of warm, dry weather reduce moisture content in wildfire fuel (e.g. biomass such as brush, leaves, and trees)[25], making it more receptive to catch fire[25]. Cloud-to-ground lightning is expected to increase with climate change, and fires caused by lightning and by human error are more likely to catch and continue to burn in dry conditions[25]. Wildfires have the potential to threaten communities and gravely impact health and safety (see 'Health impacts from wildfire' in Part 1 of this resource). This section describes increases in wildfire risk with climate change.

With climate change, the wildfire season is expected to become longer, and wildfires caused by lightning and humans are expected to increase (Table 14). Two forestry ecoregions exist in the Public Health Sudbury & Districts' service area. Ecoregion 98 covers Sudbury East, Manitoulin Island, Greater Sudbury, and Espanola areas, and ecoregion 97 covers the Chapleau area (Figure 2).

Figure 2: The Ontario fire management zone (shaded) and national ecoregion designations within the zone. Public Health Sudbury & Districts service area is covered by ecoregions 97 and 98. The Chapleau office is located in ecoregion 97 and the offices in Sudbury East, Greater Sudbury, Manitoulin Island, and Espanola are located in ecozone 98.



The length of the wildfire season across Public Health Sudbury & Districts service area is projected to become longer under climate change (Table 14). Under the RCP2.6 (low emission) scenario the wildfire season in ecoregion 98 is expected to lengthen by 10-20 days by 2041-2070[26]. Under the RCP8.5 (high emission) scenario, the wildfire season in ecoregion 98 is expected to lengthen by 30-40 days by 2041-2070[26].

Under a middle-ground emission scenario (RCP4.5), lightning caused wildfires in ecoregion 98 are expected to increase by 25-50% by 2030[27]. Human caused wildfires in ecoregion 98 are expected to increase by 10-25% by 2030[27].

Table 14: Changes in fire season length and number of wildfires under climate change

		Expected increase in fire season length by 2041-2070 (days)		Expected increase in lightning caused fires by year 2030	Expected increase in human caused fires by year 2030
Ecoregion	Public Health Sudbury & Districts' service area office location	RCP2.6	RCP8.5	RCP4.5	RCP4.5
98	Sudbury East, Manitoulin Island, Greater Sudbury, and Espanola	10 to 20 days	30 to 40 days	25-50%	10-25%
97	Chapleau	10 to 20 days	40 to 50 days	25-50%	25-50%

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Climate Change Modelling Study

Temperature and precipitation projections for Sudbury East and area

Public Health Sudbury & Districts
2022

Public Health
Santé publique
SUDBURY & DISTRICTS

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Climate change in Sudbury East

Climate change has impacts everywhere. Although many communities in Northern Ontario contain abundant carbon sinks in the form of forests and are making efforts to reduce greenhouse gas emissions, they are not immune to impacts. Information on carbon sinks, greenhouse gases, the greenhouse effect, and global warming is found in Appendix A.

Climate change modelling ***and*** *emission scenarios* ***are explained in*** **Appendix B.**

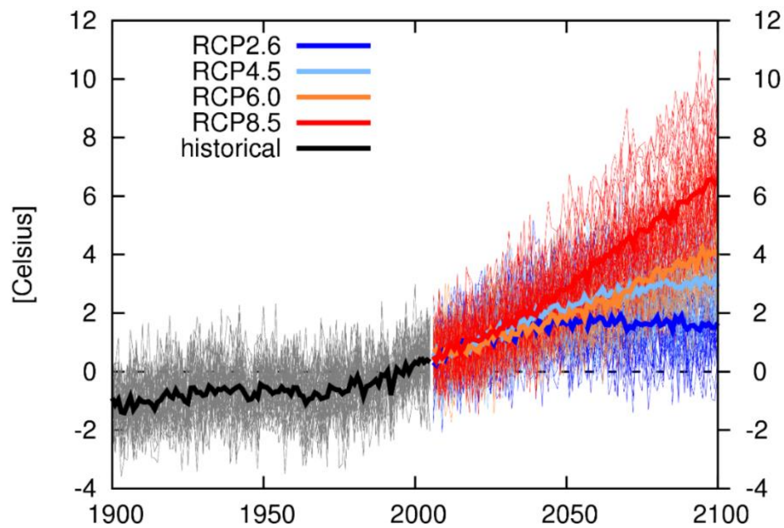
This section refers to climate change modelling and emission scenarios. Explanations of these concepts are found in Appendix B.

Briefly, climate change models are computer simulations that predict future states based on levels of greenhouse gas emissions and the resultant global warming effects. The emission scenarios range from low emission to high emission. A low emission scenario is a future where global greenhouse gas emissions are significantly curtailed, and global warming is slowed. A high emission scenario is a future where global greenhouse gas emissions continue to rise and global warming does, too. The low emission scenario is called RCP2.6. Moderate emission scenarios include RCP 4.5 and RCP6, and a high emission scenario is called RCP8.5.

Evidence of a warming trend

In an effort to establish a national weather service, some of the first weather stations were positioned along the Canadian Pacific Railroad in the early 1880s[2]. Therefore, in many places it is possible to assess weather trends dating back 100 years or more. Relative to today, a warming trend has been observed near Sudbury East; Figure 1is a time series graph depicting temperature change in degrees Celsius in Sturgeon Falls relative to 1986-2005, beginning with recorded temperatures in 1900 (black line) and moving to projected temperatures after 2005 (coloured lines). The recorded warming trend is particularly steep heading into the 2000s and beyond (black line). After 2005, the coloured lines depict temperature changes expected under different climate change scenarios, RCP2.6 (dark blue line), RCP4.5 (light blue line), RCP6.0 (orange line) and RCP8.5 (red line). Depending on the climate scenario, climate change models predict that temperatures will rise between 2 and 7 degrees Celsius relative to baseline (1986-2005) Figure 1.

Figure 1: Historical temperature change in degrees Celsius in Sturgeon Falls, Ontario relative to 1986-2005, and projected increase under climate change



With increasingly warm temperatures, record-breaking hot weather has been experienced recently in Ontario, North America, and around the world[3–5].

Globally, the decade 2001-2010 was the warmest in recorded history, followed by the previous decade, 1991-2000, which held the earlier record[6]. These conditions are consistent with a long-term warming trend[6]. Northern latitudes tend to warm at a higher rate, with the Arctic warming at about twice the rate of lower latitudes[6].

Climate change projections for Sudbury East and area

While understanding the general impacts of climate change is informative, in order to properly prepare, it is important that communities understand the specific impacts that are expected locally, under moderate and high emission climate change scenarios. This section describes current and projected temperature (hot and cold), precipitation (rain and freezing rain), and wildfire.

Temperature

Increases in seasonal temperatures drive many of the climate impacts that put health at risk. Warmer summer temperatures contribute to heatwaves, wildfire, drought, ultraviolet radiation exposure, worsening air quality, and risks to food safety. Warmer seasonal temperatures also drive the northward expansion of ticks and mosquitoes capable of transmitting diseases such as Lyme disease and West Nile virus. Warmer winter temperatures are implicated in increasing risk of freezing rain, particularly in the colder winter months, and flooding due to rainfall over snow.

The danger of these increasing hazards and populations most at risk are explored in detail in Part 1 of this resource.

The following sections present the projected seasonal temperatures under the RCP4.5 (moderate emission) and RCP8.5 (high emission) scenarios. The projections were generated by Climate Atlas of Canada for the Noelville area as a representation for the Sudbury East area.

The projections are presented as 30-year blocks, which is a common practice in the field of meteorology. The average of weather values over a 30-year period helps in describing the climate in a particular location and is a useful base for comparison to other locations or time periods[7].

Seasonal temperatures under moderate emissions

Under a moderate emission scenario, RCP4.5, the annual and seasonal average temperatures in Sudbury East are expected to increase (Table 1). The average annual temperature at baseline is 4.8°C (1975-2005). The average annual temperature is expected to increase from 6.8°C in 2021-2050 to 7.9°C in 2051-2080 (65% increase from baseline). The average winter temperature at baseline is -9.8 °C (1975-2005). The average winter temperature is expected to increase from -7.5°C in 2021-2050 to -6.2°C in 2051-2080 (37% increase from baseline). The average summer temperature at baseline is 18°C (1975-2005). With climate change, average summer temperatures will be similar to present day Toronto, Ontario (20.3°C). The average summer temperature is expected to increase from 19.7°C in 2021-2050 to 20.8°C in 2051-2080[8] (16% increase from baseline).

Table 1: Projected mean seasonal temperatures for Noelville, under RCP4.5 scenario

Projected Mean Seasonal Temperatures (°C) under RCP4.5 in Noelville, Ontario (municipality of French River)			
	1976-2005	2021-2050	2051-2080
Annual	4.8	6.8	7.9
Spring	3.8	5.7	6.6
Summer	18	19.7	20.8
Fall	7.2	9.1	9.9
Winter	-9.8	-7.5	-6.2

Seasonal temperatures under high emissions

Under a high emission scenario, RCP8.5, the annual and seasonal average temperatures in Sudbury East are expected to increase (Table 2). The average annual temperature at baseline is 4.8°C (1975-2005). The average annual temperature is expected to increase from 7.0°C in 2021-2050 to 9.4°C in 2051-2080 (96% increase from baseline). The average winter temperature at baseline is -9.8 °C (1975-2005). The average winter temperature is expected to increase from -7.4°C in 2021-2050 to -4.5°C in 2051-2080 (54% increase from baseline). The average summer temperature at baseline is 18°C (1975-2005). The average summer temperature is expected to increase from 20.1°C in 2021-2050 to 22.4°C in 2051-2080[8] (24% increase from baseline).

Table 2: Projected mean seasonal temperatures for Noelville, under RCP8.5 scenario

Projected Mean Seasonal Temperatures (°C) under RCP8.5 in Noelville, Ontario (municipality of French River)			
	1976-2005	2021-2050	2051-2080
Annual	4.8	7.0	9.4
Spring	3.8	5.8	7.9
Summer	18	20.1	22.4
Fall	7.2	9.4	11.4
Winter	-9.8	-7.4	-4.5

Extreme hot temperatures

This section describes the current situation and projected frequency of very hot weather (30+°C) under climate change. Extreme heat is of great concern locally and around the country—communities have been under heat warning, hot temperatures records have been broken, and heat waves have been implicated in illnesses and deaths[9–14]. Very hot weather is expected to double or triple with climate change, placing many people at increased risk of heat illness. The health implications of hot weather and populations most at risk are explored in detail in 'Health hazards in hot weather' in Part 1 of this resource.

Very hot days (+30°C) at present and with climate change

Climate change is expected to increase the number of hot days experienced in the summer months. In the municipality of French River, there was an average of 6 very hot days (30+°C) per year in 1976-2005. With climate change under RCP4.5, that number is expected to reach an average of 16 very hot days per year in 2021-2050 and 25 in 2051-2080. Under RCP8.5, there is projected to be 19 very hot days per year in 2021-2050 and 41 in 2051-2080[8] (Table 3).

Table 3: Current and projected average number of very hot days (+30°C) per year in the municipality of French River: Noelville[8]

	Average number of +30°C days per year				
Region	Baseline	RCP4.5 moderate emission scenario		RCP8.5 high emission scenario	
Time span	1976-2005	2021-2050	2051-2080	2021-2050	2051-2080
Municipality of French River: Noelville	6	16	25	19	41

It is significant to note that climate projections for Sudbury East predict an average of 16 very hot days (+30°C) per year in 2021-2050[8].

Heat warnings and temperature triggers

Hot weather is monitored by Environment and Climate Change Canada. Heat warnings are issued when temperatures reach specific temperature triggers. Heat warning temperature triggers were developed by Health Canada and Public Health Ontario for 3 distinct regions in Ontario based on mortality and population data, humidex, local climate, and air pollution characteristics[15].

In Northern Ontario, a Heat Warning is issued by Environment and Climate Change Canada when the temperature is forecast ≥29°C or humidex ≥36°C for at least 2 consecutive days, with overnight lows falling to ≥18°C[15] (Table 4). An extended heat warning is issued when the heat forecast is maintained for at least 3 consecutive days[15].

Table 4: Criteria for the issuing of a heat warning in Northern Ontario

Region	Heat warning temperature trigger	Duration requirement
Northern Ontario	Tmax ≥ 29°C and Tmin ≥ 18°C OR Humidex ≥ 36	2+ days

Public Health Sudbury & Districts publicly communicates heat warnings and extended heat warnings issued by Environment and Climate Change Canada. In Sudbury East and vicinity, there were 3 days under heat warning in 2022, 8 days in 2021 and 23 in 2020 (Table 5). Heat warnings are issued in Sudbury East under the following groupings:

- Markstay-Warren, St. Charles
- West-Nipissing, French River
- Espanola, Massey and Killarney

Table 5: Total days under heat warning in Sudbury East and vicinity (2019-2022)

Year	Total number of days under heat warning
2022	3
2021	8
2020	23
2019	6

To receive an email when a heat alert is issued, sign up through the EC Alert Me program at https://ecalertme.weather.gc.ca/createaccount_en.php.

Extreme cold temperatures and frost season

This section describes the current situation and projected frequency of cold weather (-30°C) under climate change. While very cold weather will decrease, winter hazards in the north do not disappear. The region will continue to experience months of cold weather and people without adequate protection will be at risk of cold weather injuries such as frostbite and hypothermia. Especially in the colder winter months, incidence of freezing rain is expected to increase with climate change[16], and incidence of extreme precipitation (including heavy snow) is expected to occur more frequently than before[17]. The serious health implications of cold weather and freezing rain are explored in detail in 'Health hazards in cold weather' and 'Ice storms' in Part 1 of this resource.

This section also describes the current situation and expected changes to the frost-free season. A longer frost-free season could have positive implications for the agriculture sector and home gardeners.

Very cold temperatures and frost-free season

In general, the frequency and severity of cold weather is expected to decrease under climate change. In Sudbury East, there was an average of 5 very cold days (-30°C) per year in 1976-2005. With climate change under RCP4.5, that number is expected to decrease to 2 very cold days per year in 2021-2050 and 1 in 2051-2080. Under RCP8.5, there is projected to be 2 very cold days per year in 2021-2050 and 0 in 2051-2080[8] (Table 6).

Table 6: Current and projected average number of very cold days (-30°C) per year in Noelville, Ontario (municipality of French River)[8]

	Average number of -30°C days per year				
	Baseline	RCP4.5 moderate emission scenario		RCP8.5 high emission scenario	
Time span	1976-2005	2021-2050	2051-2080	2021-2050	2051-2080
Average number of -30°C days per year	5	2	1	2	0

Currently, the first fall frost occurs on average on September 29. Under RCP4.5, by 2021-2050, the first fall frost is expected to occur about 11 days later, by October 10 on average. Under RCP8.5, by 2021-2050, the first fall frost is expected to occur by October 14[8] (Table 7).

Table 7: Current and projected average date of first fall frost and frost-free days per year in Noelville, Ontario (municipality of French River)[8]

	Date of first fall frost and length of frost-free season in days				
	Baseline	RCP4.5 moderate emission scenario		RCP8.5 high emission scenario	
Time span	1976-2005	2021-2050	2051-2080	2021-2050	2051-2080
Average date of first fall frost	September 29	October 10	October 16	October 14	October 26
Length of frost-free season (days)	137	156	168	163	185

Precipitation

This section describes precipitation at present and with climate change.

With climate change, seasonal precipitation is expected to increase a small amount from baseline. The largest increases in seasonal precipitation will be seen in the fall. This change could impact the agriculture sector by affecting fall harvest. Rain can degrade the quality of important crops like wheat, and heavy farming equipment required for harvest can become stuck and inoperable in waterlogged fields[18].

As the climate warms, the type of precipitation we can expect will change. In the winter months when we typically experience snow, the occurrence of freezing rain will increase. Projections show that incidence of freezing rain will double or triple in some parts of Ontario[16]. With intense precipitation increasing, it is possible that a severe ice storm like the one in Eastern Ontario and Quebec or in the Toronto area will occur here (see “Ice storms” in Part 1 of this resource).

Increased incidence of extreme precipitation during spring, summer and fall is also expected. An extreme rain event that would be expected to occur once every 50 years is expected to occur more often under climate change[19]. Extreme rainfall can lead to impacts such as floods and degradation of water quality. Significant health impacts caused by flood and water quality are explored in detail in Part 1 of this resource.

At the current time, average annual precipitation recorded at the Monetville weather station amounts to 1005.4 mm total, with 758.8 mm falling as rain and 246.6 cm falling as snow[20] (Table 8).

Table 8: Average annual precipitation in Monetville, Ontario

Average Annual Precipitation in Monetville, Ontario (municipality of French River), 1981 to 2010	
Precipitation type	Measurement (mm)
Rainfall	758.8 mm
Snowfall	246.6 cm (246.6 mm water equivalent)
Precipitation total	1005.4 mm

Seasonal precipitation under moderate emissions

With climate change, studies of general trends point to wetter weather on a national and provincial scale[6,21]. Projected changes in precipitation in Sudbury East under a moderate emission scenario, RCP4.5, are outlined inTable 9. Compared to baseline (1976-2005), annual mean precipitation is expected to increase by 46 mm in 2021-2050, and 80 mm by 2051-2080. The wettest season is the fall. Mean precipitation in the fall is expected to increase by 11 mm in 2021-2050, and 24 mm by 2051-2080[8].

Table 9: Projected mean seasonal precipitation for Noelville, Ontario, under RCP4.5 scenario

Projected Mean Seasonal Precipitation (mm) under RCP4.5, in Noelville, Ontario (municipality of French River)			
Time span	1976-2005	2021-2050	2051-2080
Annual	906	952	986
Spring	201	213	224
Summer	224	230	232
Fall	272	283	296
Winter	210	227	235

Seasonal precipitation under high emissions

Projected changes to precipitation do not vary greatly between moderate and high emission scenarios. Precipitation changes under a high emission scenario, RCP8.5, are outlined inTable 10. Compared to baseline (1976-2005), annual mean precipitation is expected to increase by 60 mm in 2021-2050, and 93 mm by 2051-2080. Mean precipitation in the fall is expected to increase by 18 mm in 2021-2050, and 20 mm by 2051-2080[8].

Table 10: Projected mean seasonal precipitation in Noelville, Ontario, under RCP8.5 scenario

Projected Mean Seasonal Precipitation (mm) under RCP8.5, in Noelville, Ontario (municipality of French River)			
Time span	1976-2005	2021-2050	2051-2080
Annual	906	966	999
Spring	201	220	235
Summer	224	226	222
Fall	272	290	292
Winter	210	231	249

Current and projected freezing rain

Freezing rain can cause considerable adverse impacts to communities, including power outages, hazardous roads and disruption of services[22], and with climate change, is expected to increase in frequency[23]. In communities with formal emergency preparedness plans and where emergency preparedness exercises are performed, organisers would very likely find value in choosing a severe ice storm as a focus scenario.

An Ontario study investigated freezing rain occurrence in select cities. Over a typical winter, November to April, freezing rain was found to occur more frequently in communities located geographically in the centre of the province than those farther north or south. Although Espanola was not included in the study, for comparison, there has historically been about 7.7 days of freezing rain in Sudbury compared to 3.1 in Kapuskasing and 5.2 in Toronto[23] (Table 11).

Table 11: Historical incidence of freezing rain in select Ontario cities, 1953-2001

Historical incidence of freezing rain in select Ontario Cities, 1953-2001[23]		
Weather Station	Winter seasonal (Nov-Apr) average # of days with freezing rain	Winter seasonal (Nov-Apr) average # of hours with freezing rain
Kapuskasing	3.1	8.2
Kenora	2.6	6.2
Sioux Lookout	2.3	4.8
Thunder Bay	2.1	6.2
Timmins	4.2	11.5
Sault St. Marie	3.7	10.3
Sudbury	7.7	24.4
North Bay	7.5	22.4
Ottawa	9.7	36.6
Montreal	7.8	27.4
Toronto	5.2	17.1
Windsor	4.9	14.3

Another study investigated historical incidence of freezing rain and projected increases with climate change[16]. This study differentiated between colder winter months (December, January, and February) and warmer ones (November, March, and April), and looked at a few cities and two regions in the province of Ontario ('eastern' and 'northern'). The results showed that freezing rain was expected to increase more dramatically during the colder winter months than the warmer ones[16]. With climate change bringing about warmer winter temperatures during the colder months, it becomes more likely for precipitation to fall as rain (rather than snow) than before. Although communities in Sudbury East were not specifically included in the study, for comparison, the study found that in Sudbury, during the baseline period 1961-2000, there was an average of about 4 total freezing-rain days in colder winter months (Table 12)[16]. Under climate change, the number of days with freezing rain increased by 1.5 days in the 2050s, and 3 days in the 2080s (Table 12)[16].

Table 12: Historical and projected number of days with freezing rain during colder winter months in Sudbury and Timmins, Ontario

Number of days with freezing rain during colder winter months – historical and projected with climate change			
City	Historical average # days with freezing rain (Dec-Feb), 1961- 2000	2050s projected # days with freezing rain (Dec-Feb) in 2050s	2080s projected # days with freezing rain (Dec-Feb) in 2080s
Sudbury	4	5.5	7
Timmins	1.5	2.5	3.5

Furthermore, from a regional perspective, freezing rain during colder months is expected to increase more in the northern region of Ontario than the eastern region. Freezing rain in cities in the northern region will increase 85% by the 2050s and 135% by the 2080s (Table 12)[16]. In comparison, freezing rain in the eastern region will increase 60% by the 2050s and 95% by the 2080s[16].

Freezing rain events in the warmer winter months are expected to increase a small amount in the northern region of Ontario and not at all in the eastern region[16].

Table 13: Projected increases in freezing rain during colder months (Dec, Jan, Feb) vs. warmer months (Nov, Mar, Apr) in different regions of Ontario

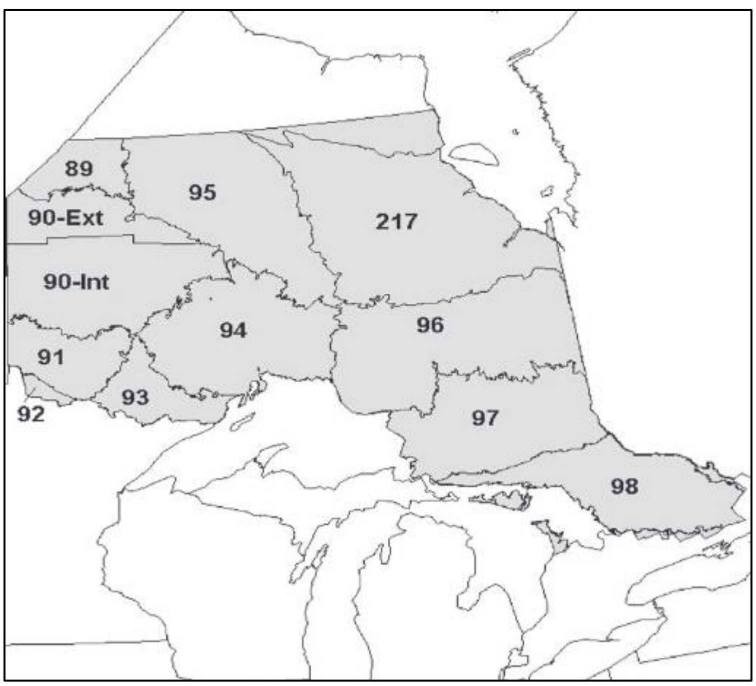
Projected increases in freezing rain in winter season during colder months (Dec, Jan, Feb) vs. warmer months (Nov, Mar, Apr)		
	Colder winter months 2050s	Colder winter months 2080s
Eastern Ontario (Montreal, Quebec, North Bay, Ottawa, Sudbury and Trenton)	+60%	+95%
Northern Ontario (Kapuskasing, Kenora, Sioux Lookout, Thunder Bay and Timmins)	+85%	+135%
	Warmer winter months 2050s	Warmer winter months 2080s
Eastern Ontario (Montreal, Quebec, North Bay, Ottawa, Sudbury and Trenton)	Not significant	Not significant
Northern Ontario (Kapuskasing, Kenora, Sioux Lookout, Thunder Bay and Timmins)	+10%	+20%

Wildfire

Wildfire activity is controlled by a number of factors including fuel, ignition, and weather. Climate change is expected to worsen all three factors, raising wildfire risk levels[24]. Periods of warm, dry weather reduce moisture content in wildfire fuel (e.g. biomass such as brush, leaves, and trees)[24], making it more receptive to catch fire[24]. Cloud-to-ground lightning is expected to increase with climate change, and fires caused by lightning and by human error are more likely to catch and continue to burn in dry conditions[24]. Wildfires have the potential to threaten communities and gravely impact health and safety (see 'Health impacts from wildfire' in Part 1 of this resource). This section describes increases in wildfire risk with climate change.

With climate change, the wildfire season is expected to become longer, and wildfires caused by lightning and humans are expected to increase (Table 14). Two forestry ecoregions exist in the Public Health Sudbury & Districts' service area. Ecoregion 98 covers Sudbury East, Manitoulin Island, Greater Sudbury, and Espanola areas, and ecoregion 97 covers the Chapleau area (Figure 2).

Figure 2: The Ontario fire management zone (shaded) and national ecoregion designations within the zone. Public Health Sudbury & Districts service area is covered by ecoregions 97 and 98. The Chapleau office is located in ecoregion 97 and the offices in Sudbury East, Greater Sudbury, Manitoulin Island, and Espanola are located in ecozone 98.



The length of the wildfire season across Public Health Sudbury & Districts service area is projected to become longer under climate change (Table 14). Under the RCP2.6 (low emission) scenario the wildfire season in ecoregion 98 is expected to lengthen by 10-20 days by 2041-2070[25]. Under the RCP8.5 (high emission) scenario, the wildfire season in ecoregion 98 is expected to lengthen by 30-40 days by 2041-2070[25].

Under a middle-ground emission scenario (RCP4.5), lightning caused wildfires in ecoregion 98 are expected to increase by 25-50% by 2030[26]. Human caused wildfires in ecoregion 98 are expected to increase by 10-25% by 2030[26].

Table 14: Changes in fire season length and number of wildfires under climate change

		Expected increase in fire season length by 2041-2070 (days)		Expected increase in lightning caused fires by year 2030	Expected increase in human caused fires by year 2030
Ecoregion	Public Health Sudbury & Districts' service area office location	RCP2.6	RCP8.5	RCP4.5	RCP4.5
98	Sudbury East, Manitoulin Island, Greater Sudbury, and Espanola	10 to 20 days	30 to 40 days	25-50%	10-25%
97	Chapleau	10 to 20 days	40 to 50 days	25-50%	25-50%

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Next steps

The impacts of climate change are already being seen and will invariably affect us all. The actions we take now will contribute to the safety and well-being of people today and that of generations to come. With the information synthesized in the present resource, *Assessing Health Risks and Planning Adaptations Together* we better understand the health hazards that are expected to increase as climate change continues. We also better understand the significant physical and mental health impacts of climate change and who in our community is most at risk.

There is a critical need to conduct Climate Change and Health Vulnerability and Adaptation Assessments to identify and implement adaptations and prevent the adverse health outcomes that loom before us. Within the framework of a Climate Change and Health Vulnerability and Adaptation Assessment, the next step is to come together to decide which health risks are of most concern locally and which adverse health outcomes we are committed to preventing. After this, adaptation options can be identified, prioritized, and implemented. Adaptations may take the form of new programs, strategies or policies, or modifications to existing ones. Finally, a plan should be developed to monitor the burden of health outcomes and the effectiveness of the adaptation plan.

This work is best completed collaboratively. A multi-sector approach is ideal, including the municipality, primary health care, public health, provincial ministries, Indigenous peoples and agencies, and community groups and interested parties. A collaborative approach like this will facilitate cross-sectoral cooperation on new and existing adaptations and ensure interdependencies are considered.

There are tools available to guide the process of a Climate Change and Health Vulnerability and Adaptation Assessment, including step-by-step instructions, worksheets and templates for each activity and phase (See 'Resources and tools'). For any municipality, the assessment scope and process chosen will vary, depending on factors such as human and fiscal resources, community buy-in, timeframes, and others. An assessment may be led by a single agency or in partnership and may be conducted using existing internal resources or external funding sources (e.g. a grant or special project funding).

Conducting a Climate Change and Health Vulnerability and Adaptation Assessment will forge collaborations with different sectors and interested parties and improve community resiliency to climate change through health-protective adaptations. Pursuing this work is essential to building our adaptive capacity to climate change and ensuring healthier communities now and for future generations.

Resources and tools

Climate change vulnerability and adaptation assessment tools:

1. **Ontario Climate Change and Health Toolkit**

Source: Ontario Ministry of Health and Long-term Care

Description: Climate change and health vulnerability and adaptation assessments are conducted at local to national scales to understand current impacts and projected future risks of climate variability and change, and to identify policies and programs to increase resilience to these risks.

Ebi, K., Anderson, V., Berry, P., Paterson J., Yusa, A. (2016) *Ontario Climate Change and Health Toolkit*.
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2. **Building Adaptive & Resilient Communities (BARC) program**

Source: ICLEI Local Governments for Sustainability

Description: Building Adaptive & Resilient Communities (BARC) is a national program focused on resilience and adaptation. BARC offers a comprehensive way to respond to the impacts of climate change, develop and implement an adaptation plan, and protect the people, property, and prosperity of your community. Our decades of experience in the field of municipal governance will give you the know-how needed to respond to the impacts of a changing climate. Cost to join the program ranges from $20,000-$30,000.

https://icleicanada.org/barc-program/

3. **Changing Climate, Changing Communities: Guide and Workbook for Municipal Climate Adaptation from ICLEI Local Governments for Sustainability**

Source: ICLEI Local Governments for Sustainability

Description: The Changing Climate, Changing Communities Guide and Workbook is a milestone-based framework to assist local governments in the creation of adaptation plans to address the relevant climate change impacts associated with their communities.

https://icleicanada.org/project/changing-climate-changing-communities-guide-and-workbook-for-municipal-climate-adaptation/

4. **The Health Care Facility Climate Change Resiliency Toolkit**

Source: The Canadian Coalition for Green Health Care

Description: The toolkit empowers healthcare facilities to assess their resiliency, identify climate change related risks, understand their current state of preparedness, and become better prepared.

5. https://greenhealthcare.ca/climate-change-resiliency-toolkit/ **Canada in a Changing Climate: Advancing our Knowledge for Action**

Source: Government of Canada

Description: A national assessment of how and why Canada's climate is changing; the impacts of these changes on our communities, environment, and economy; and how we are adapting. Includes a Regional Perspectives chapter for the Province of Ontario.

https://changingclimate.ca/

Adaptation discussion guide for local government staff:

Municipal Climate Services Collaborative. 2020. *Talking it through: A discussion guide for local government staff on climate adaptation*. Environment and Climate Change Canada and Federation of Canadian Municipalities. https://data.fcm.ca/documents/resources/MCIP/talking-it-through-discussion-guide.pdf

Description: This discussion guide assists local government staff in facilitating conversations with senior decision makers and elected officials about the impacts of climate change in their local contexts; their current level of preparedness; the measures and solutions needed to increase future resiliency; and the necessity to mainstream adaptation into local government operations and services.

Climate change reports generated with Indigenous knowledge:

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Incorporating equity into vulnerability and adaptation assessments:

1. Ontario Ministry of Health and Long-term Care's Health Equity Impact Assessment Tool https://www.health.gov.on.ca/en/pro/programs/heia/tool.aspx

2. Making Equity Real in Climate Adaptation and Community Resilience Policies and Programs: A Guidebook

   https://greenlining.org/publications/2019/making-equity-real-in-climate-adaption-and-community-resilience-policies-and-programs-a-guidebook/

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Incorporating Mental Health Indicators into Climate Change and Health Vulnerability and Adaptation Assessments

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Sector-specific climate change impacts and adaptation

Canada in a Changing Climate: Sector Perspectives on Impacts and Adaptation

Warren, F.J., Lemmen, D.S., editors (2014). Canada in a Changing Climate: Sector Perspectives on Impacts and Adaptation. Government of Canada, Ottawa, ON, 286p. https://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/earthsciences/pdf/assess/2014/pdf/Full-Report_Eng.pdf

Climate Change and Health Vulnerability and Adaptation Assessments in Ontario:

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2. *Public Health Vulnerability to Climate Change in the Region of Peel* (2017) https://cleanairpartnership.org/cac/wp-content/uploads/2017/11/L_Aubin_Health-Vulnerability-session-GTA-CAC-November-2017.pdf

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Appendix A:

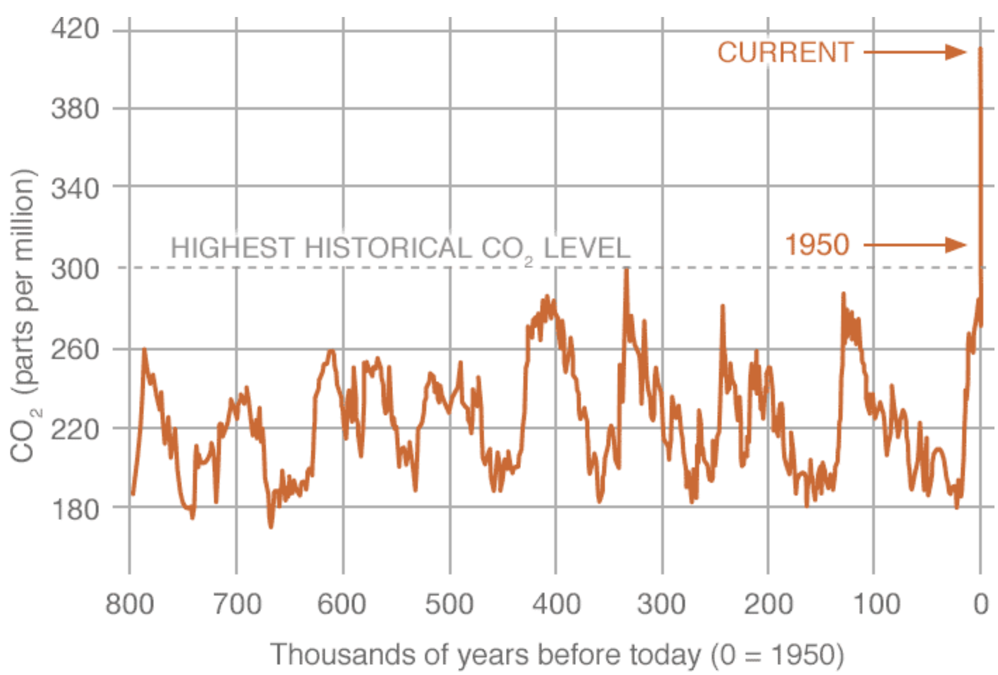
Where do greenhouse gases come from?

Greenhouse gases are gases in the Earth's atmosphere that sustain life on Earth by trapping the sun's heat. Many greenhouse gases are naturally occurring, mainly water vapour, carbon-dioxide and methane. Since the industrial revolution, human activities, such as burning fossil fuels, have rapidly added greenhouse gases to the atmosphere; in fact, human activities are responsible for almost all of the increase in greenhouse gases over the last 250 years[262]. Today, there is 42 per cent more carbon dioxide in the atmosphere than at the start of the industrial era and levels of methane and carbon dioxide are the highest they have been in 400 000 years[263].

One way that scientists determine historical levels of carbon dioxide is through collection of ice in places like Greenland and Antarctica. Researchers drill deep into the ice to obtain ice core samples that are hundreds of thousands of years old. The ice cores contain pockets of air which hold a record of what the atmosphere was like when the layer of ice formed[264].

Figure 24 illustrates carbon dioxide levels over the last 800 000 years, as reconstructed from ice cores, and shows the steep increase above highest historical levels beginning around 1950.

Figure 24: Carbon dioxide levels (parts per million) during the last 800,000 years, as reconstructed from ice cores. Source: climate.nasa.gov/vital-signs/carbon-dioxide/



The largest sources of greenhouse gas emissions in Ontario are[164]:

- Transportation, 34%: Includes emissions from passenger and commercial vehicles.
- Industry, 30%: Predominantly emissions from mining, oil and gas, construction, iron and steel, chemical, and paper and wood products.
- Buildings, 17%: Emissions from space and water heating for residential, commercial, and institutional buildings.

What is a carbon sink?

Carbon Sink is an area that removes carbon dioxide from the atmosphere[265]. The two main carbon sinks are forests and oceans[265]. Carbon sinks are important because they reduce the amount of carbon dioxide in the atmosphere, moderating global warming[265]. Trees take up carbon dioxide, and in the presence of the light of the sun, turn it into energy to build roots, stems and leaves[265,266]. This process, which emits oxygen as a by-product, is called photosynthesis[266]. Oceans absorb carbon dioxide into the water itself, and also in phytoplankton and other underwater plants[265].

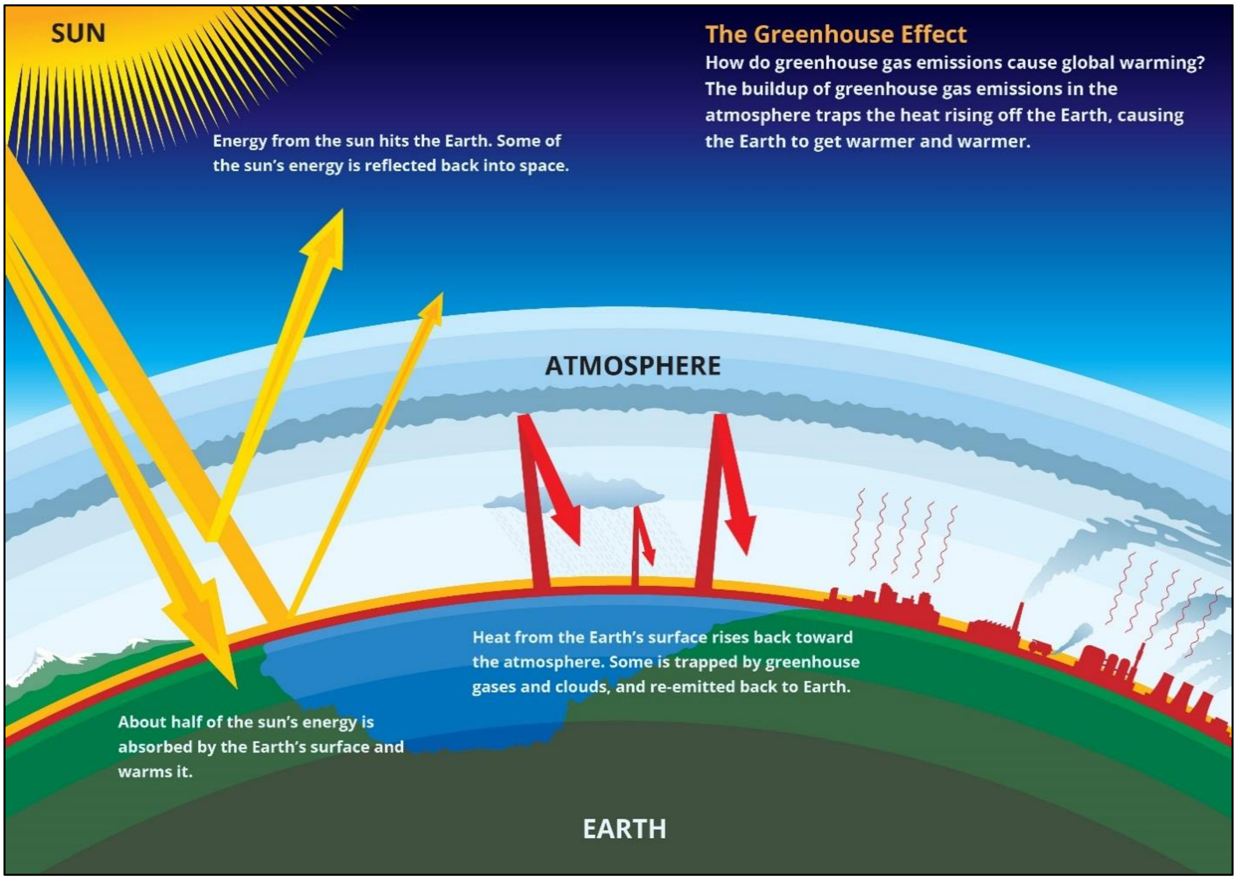
Global warming and the greenhouse effect

Global warming occurs through a process called the Greenhouse Effect (Figure 25). The greenhouse effect begins when energy from the sun warms the Earth, a normal phenomenon that makes the Earth inhabitable for living things. Some of the sun's energy is absorbed by the Earth, and some is reflected back into space.

The atmosphere acts like the glass walls and ceiling of a greenhouse, holding in the heat from the sun, and preventing some of it from disappearing into space. The atmosphere is made up of various gases, including water vapour and greenhouse gases. Greenhouse gases have the particular property that they absorb the sun's energy more than water vapour or other gases and trap the heat. The more greenhouse gases in the atmosphere, the greater the heat-trapping capacity, and the warmer the Earth will become[267].

Other moderators of climate, such water vapour/clouds, volcanoes, and fluctuations in the sun's energy, are not sufficient to explain global warming. The Intergovernmental Panel on Climate Change has studied observed temperature changes from 1860 to the 2000s, and has shown that the observed changes align with human behaviour, mainly human-produced emissions of greenhouse gases, ozone, and aerosols[268].

Figure 25: The Greenhouse Effect: how greenhouse gases cause the Earth to warm.



Appendix B:

Climate change models and emission scenarios

Climate change model is a complex computer simulation of the climate system that makes projections of the climate based on future scenarios of greenhouse gases emissions. Climate change models can simulate the climate system's response to greenhouse gas emissions but cannot predict future human activities. For example, will humanity take giant leaps to rapidly reduce emissions, or will the status quo continue to dominate for decades to come? To deal with this uncertainty, projections are made using various scenarios or pathways of future emissions, land-use change, and socioeconomic factors[269]. There are four climate change model scenarios utilised by the Intergovernmental Panel on Climate Change, known as RCP2.6, RCP4.5, RCP6, and RCP8.5[270]. See RCP, below.

RCP refers to 'Representative Concentration Pathway'. Within this name, the term 'concentration' refers to the concentration of greenhouse gases and thus, the degree of climate warming. The word 'pathway' refers to 'how to get there', meaning, what factors are included in the scenario to bring about the warming[270,271]. Each RCP scenario also includes a number (e.g., RCP2.6). The number refers to the amount of warming that will occur (specifically, radiative forcing measured in watts/m2)[270,271]. Four RCP scenarios are used by the Intergovernmental Panel on Climate Change to represent a broad range of climate outcomes, varying from a low degree of global warming, to a high degree[270]. RCP2.6 is the scenario where the climate warms the least[270]. RCP8.5 is the scenario where the climate warms the most[270]. RCP4.5 and RCP6 are 'middle-ground' scenarios[270]. The table below depicts the climate change model scenarios and the impacts they project.

Figure 26: Climate change model scenarios, global warming, and environmental and human health outlook

Climate change model scenario	Level of global warming represented	Environmental and human health outlook
RCP2.6	Low	Best case
RCP4.5	Moderate	Moderate
RCP6	Moderate	Moderate
RCP8.5	High	Worst case

Appendix C:

Glossary of terms

Some terms related to climate change are occasionally misunderstood or mis-used. For example, “Climate change” and “global warming” are often used interchangeably but have distinct meanings[272]. For clarity, a collection of climate change terms used in this report are defined here.

Weather refers to atmospheric conditions that occur locally over short periods of time—from minutes to hours or days. Familiar examples include rain, snow, clouds, winds, floods, or thunderstorms. Weather is local and short-term[272].

Climate refers to the long-term regional or even global average of temperature, humidity, and rainfall patterns over seasons, years, or decades. Climate is regional and long-term[272].

Global warming refers to the heating of the Earth’s climate system observed since the industrial revolution (~1880) due to human activities, mainly burning fossil fuel, which increases levels of heat-trapping greenhouse gases in the atmosphere[272]. Since the industrial revolution, the average surface temperature of the Earth has increased by about 1°C, relative to the mid-20th-century baseline (of 1951-1980), and is currently increasing by 0.2°C each decade[272].

Climate change refers to the change in long-term average weather patterns primarily caused by human activities (mainly burning fossil fuels and release of greenhouse gases) and the observed effects of the change. The observed effects of climate change include increased temperature trends, extreme weather events, drought, flood, glaciers melting, sea levels rising, ocean acidification, and other phenomenon[272].

Mitigation refers to actions that decrease, stop or capture emissions of greenhouse gases. Examples include efforts to manage energy, utilize green technology and increase the capacity of carbon sinks (e.g. forests). Mitigation will slow the changing climate and the effects will be observed over many decades[6].

Adaptation refers to actions that reduce the negative impact of climate change or take advantage of potential new opportunities. Adaptation is needed because even with mitigation, climate change is present today and further impacts are almost certainly unavoidable in the short or medium-term[273]. Examples of adaptations include hot weather response plans, production of local food, and tick surveillance and Lyme disease awareness.

Morbidity is being unhealthy or symptomatic related to a condition, disease or event[274].

Mortality refers to deaths related to a condition, disease or event[274].

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